



# THE WORLD'S WATER

Volume 8

The Biennial Report on Freshwater Resources

**Peter H. Gleick**

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- Hydraulic Fracturing
  - Corporate Water Engagement
  - Water Footprints
  - Sustainable Water Jobs
  - Global Water Governance
  - Desalination Financing
  - Zombie Water Projects
  - Water and Conflict

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# Foreword

It is a privilege to write a foreword to volume 8 of *The World's Water*, an indispensable biennial report on the condition of the earth's water resource. Water is life. Without water, there is no life as we know it. Yet humans have abused it and misused it and polluted, wasted, and destroyed it.

In the 1990s, when I was vice president of environmentally and socially sustainable development for the World Bank, I was appalled at the lack of international engagement on the issue of water. In a speech I gave in Stockholm in August 1995, I said: "The wars of this century have been for oil, but the wars of the next century shall be for water"—a statement that echoed around the news media of the world. Many accused me of being an alarmist, but gradually, within a few years, the issue of water and water management started taking its rightful place among the national, regional, and global priorities of various actors around the planet. What was lacking was a proper global perspective on the issue of water that would go way beyond chapter 18 of Rio's Agenda 21.

And here, like a beacon unto the multitudes, the careful and meticulous scientific work of the Pacific Institute and its president, Peter Gleick, came to the fore in the form of *The World's Water* series. It provided the most thoughtful, comprehensive, and interesting coverage of the available knowledge and the insights needed to deal with the myriad problems that water represents. Sixteen years later, the eighth volume of *The World's Water* continues that distinguished tradition. Although many notable agencies of the United Nations, the World Water Council, the Global Water Partnership, the World Resources Institute, and others have been producing excellent reports on water issues, *The World's Water* continues its tradition of excellence, and I heartily recommend it to anyone interested in dispassionate and thoughtful discussion of the complex and important issues involved.

As we have come to expect, this year's report, beyond providing a host of useful data, also marshals many experts to address important themes of water and water use. Starting with global water governance, it deals with the issue that most concerned me so many years ago. Today, as I sit in Egypt and watch the unfolding debates about the management of the Nile's waters as Ethiopia proceeds to build its Grand Ethiopian Renaissance Dam (GERD), and as I watch the agonies of populations in places enduring droughts and the general mismanagement of our most precious resources in so many countries, I can think of no more important topic that should elicit an international focus on cooperation rather than conflict. We must see that nature does not recognize political boundaries and that, just as water flows in rivers shared by countries, climate change affects all countries, not only those whose economic conduct plays a major role in causing it.

Beyond global water governance (addressed in chapter 1), the importance of engaging the private sector in smart water management is addressed in chapter 2. Here, if public and private partnerships are to thrive, transparency must be the order of the day. Such collaboration will help us attain the goal of ensuring that all people have access to clean

water and proper sanitation and that water is properly managed in agriculture, still the sector accounting for the largest water withdrawals.

Economic issues are widely discussed in this report. There are great opportunities to generate employment and jobs by smart investments in water systems (discussed in chapter 3). The rapidly expanding technique of hydraulic fracturing (or “fracking”) raises problems and poses risks to water systems from inappropriately conducted fossil-fuel extraction, all of which is discussed in chapter 4. The cost and financing of seawater desalination projects are discussed in chapter 6. And recurrently revived large-scale infrastructure schemes and projects—here named “zombie water projects”—are discussed in chapter 7.

Chapter 5 of this report presents background and detail on a tool of enormous value, the “water footprint,” and discusses its application worldwide. If only the concerned parties would all listen and make use of the insights generated by this tool.

But why should I take up more of the readers’ time? Let them delve into the riches between these covers. It is time to read, learn, and reflect . . . and to enjoy.

*Ismail Serageldin*  
*Librarian of Alexandria*  
*Former Vice President, World Bank*

# Introduction

When the first volume of *The World's Water* was published, the United Nations' Millennium Development Goals had not yet been established. Today, as we finish volume 8, we are racing toward the 2015 deadline for those goals, but basic human needs for water and sanitation remain unsatisfied. Deadlines aside, if we are ever to achieve the objectives of global health and sustainability, water security is critical.

In this volume, we continue to provide data on access (by country and by urban-rural split) to water and sanitation. We also provide data on the ongoing, unchecked severe cholera outbreaks that are a direct consequence of our failure to meet basic human needs for safe water. Human-caused climate changes are also increasingly apparent, with growing evidence around the world in the form of alterations of natural hydrology and impacts on our built water infrastructure. Ecosystems that rely on freshwater continue to deteriorate in many parts of the world as human competition for water grows. And conflicts over water allocations and use are growing, not diminishing, as reflected in the Water Conflict Chronology—a regular feature of these volumes.

*The World's Water*, however, has always been about more than water “problems.” My colleagues and I believe strongly that there are successful and expandable solutions out there, and we try to describe and discuss them in every volume. New thinking about solutions and the “soft path for water” are both needed and available, if we look around. As a result, *The World's Water* has always tried to explore new ideas, successful case studies, and innovative communications efforts.

There is no shortage of topics to address, and as always it is a challenge to try to choose among them for inclusion in the books. In this latest volume we tackle some new topics and revisit and update some older ones.

Chapter 1 offers an overview of the complex institutions and ideas that constitute “global water governance” and offers some thoughts about how to improve and manage water systems at local, continental, and global scales while still protecting the critical needs of communities.

Chapter 2 revisits previous Pacific Institute efforts on how to engage the corporate sector in more sustainable water management, reporting, and use. Some innovative efforts are under way under the auspices of the United Nations Global Compact office and the United Nations' CEO Water Mandate, bringing new voices into the water discussion. The hope, still to be fully realized, is that responsible and sustainable corporate water management will play a role alongside the efforts of governments and nongovernmental organizations in moving toward more sustainable water policy.

The third chapter in this volume summarizes recent work completed at the Pacific Institute on water-related jobs. Jobs, in different sectors of the economy, are required to manage, deliver, and treat the freshwater required to satisfy our commercial, institutional, industrial, agricultural, and domestic needs for goods and services. In addition, growing attention is being given to sustainable measures such as low-impact development, water reuse, watershed restoration, water conservation and efficiency, and many

other proven and promising practices. As the country shifts to more sustainable water management, new services, occupations, and markets are emerging. Our research suggests that water is a worthy arena for exploring green jobs.

Chapter 4 expands on the work we presented in the previous volume focused on energy and water, especially the increasingly controversial issue of hydraulic fracturing, or “fracking.” This practice has been particularly controversial in the United States but is expanding globally, wherever unconventional natural gas development is under way. To better identify and understand the key issues, the Pacific Institute conducted extensive interviews with a diverse group of stakeholders, including representatives from state and federal agencies, academia, industry, environmental groups, and community-based organizations from across the United States. This chapter provides a short summary of the key issues identified in the interviews and an assessment and synthesis of existing research.

Chapter 5 digs into the useful concept of the “water footprint.” We use water for many purposes: drinking, bathing, washing our clothes, watering our gardens, and more. In addition to these direct uses, however, water is needed to produce nearly everything we use and consume, from the food we eat and the clothes we wear to the technological devices that are integral to our modern society. A full measure of the water footprint of an individual, industrial sector, or society is the combination of direct and indirect water needed to provide our basket of goods and services. This chapter discusses the tool of “footprinting,” how it is related to other footprint indicators, such as the carbon footprint and the ecological footprint, how it is calculated, and the findings from some recent research.

Chapter 6 returns to the issue of desalination. In this chapter, we provide a short summary of the economics of various major desalination projects and the spatial and temporal variability associated with these costs. We also describe project-related risks associated with desalination plants, and we provide two case studies of seawater desalination projects in the United States to highlight some of the issues around cost and financing of these projects.

The final chapter, chapter 7, tackles the issue of water “zombies.” As any consumer of popular culture today knows, a zombie is an undead creature, something that was killed but came back to “life” in some form to terrify, entertain, and gross people out. Zombie books, movies, costumes, makeup, computer games, and more are big business. But not all zombies are fictional, and some are potentially really dangerous—at least to our pocketbooks and environment. These include “zombie water projects,” which we define as large, costly water projects that are proposed, killed off for one reason or another, and brought back to life, even if the project itself is socially, politically, economically, or environmentally unjustified. In chapter 7 we offer—in an only partly tongue-in-cheek presentation—a description of some major zombie water projects from the past century: serious proposals for massive projects to use, divert, or transfer water that died only to come back to life in one form or another. In short, this chapter argues that modern civilization must learn that our ability to do something doesn’t mean that we actually should do it, especially in the field of large-scale geoengineering.

The chapters are supplemented with shorter In Brief reports on items of interest. The current volume includes an update on the Red Sea–Dead Sea proposals, the role of water in the current Syrian conflict, and a detailed update of our popular Water Conflict Chronology, with entries through the end of 2012. The chronology offers historical examples



of conflicts related to water going back millennia, and it is also available in a flexible and useful format online at <http://www.worldwater.org>, where readers can sort water conflicts by time, location, type of conflict, and more and see the results in active maps.

We provide in the back of volume 8 a complete table of contents and integrated index across all previous volumes, to help readers find information in the earlier editions that might be useful or relevant in their research or other efforts.

Finally, *The World's Water* again offers a wide variety of important, useful, and popular data on water in a series of data tables. In this volume we present updated data on water supply and use by country, the latest progress (or lack thereof) toward the Millennium Development Goals for water and sanitation, runoff data for the world's largest and most important rivers, irrigation data, estimates of funding for water from overseas development agencies, tables on water footprints of consumption, and more.

If there is any good news, it is that water is receiving more attention from policy makers, scientists, the media, and members of the public. Education and awareness are key steps in moving toward implementing smart and effective solutions. We are happy to think we are playing even a small role.

Special thanks to all of my coauthors, both within the Pacific Institute and outside with partner organizations. This project continues to benefit from the support of Island Press, including Emily Davis, my new(ish) editor. Thank you, Emily, for your help getting this latest volume out the door!

*Peter H. Gleick*  
*Oakland, California, 2013*



# Global Water Governance in the Twenty-First Century

Heather Cooley, Newsha Ajami, Mai-Lan Ha, Veena Srinivasan,  
Jason Morrison, Kristina Donnelly, and Juliet Christian-Smith

Growing pressure on the world's water resources is having major impacts on our social and economic well-being. Even as the planet's endowment of water is expected to remain constant, human appropriation of water, already at 50 percent by some measures, is expected to increase further (Postel et al. 1996). Pressures on water resources are likely to worsen in response to population growth, shifts toward more meat-based diets, climate change, and other challenges. Moreover, the world's water is increasingly becoming degraded in quality, raising the cost of treatment and threatening human and ecosystem health (Palaniappan et al. 2010). Furthermore, the physical availability of freshwater resources does not guarantee that a safe, affordable water supply is available to all. At least 780 million people do not have access to clean drinking water, some 2.5 billion people lack access to safe sanitation systems, and 2–5 million people—mainly children—die as a result of preventable water-related diseases every year (Gleick 2002; UN 2009; WHO and UNICEF 2012).

There is growing recognition that the scope and complexity of water-related challenges extend beyond national and regional boundaries and therefore cannot be adequately addressed solely by national or regional policies. In a recent report, the United Nations notes that “water has long ceased to be solely a local issue” (UN 2012a, 40). In particular, widespread water scarcity and lack of access to water supply and sanitation threaten socioeconomic development and national security for countries around the world. Additionally, people around the world share and exchange water directly and indirectly through natural hydrologic units and systems and through global trade (i.e., “virtual water,” discussed below). Furthermore, climate change and the growing presence of multinational companies within the water sector play a role in globalizing water issues (Hoekstra 2006).

Over the past sixty years, a number of efforts have sought to address the many challenges facing the water sector. Early efforts to address these challenges were almost entirely based on developing large-scale physical infrastructure, such as dams and reservoirs, to produce new water supplies. Amid a growing recognition that technology and infrastructure alone were not sufficient to address persistent water management concerns, discourse about water governance began to emerge in the early 1990s. In its first World Water Development Report, the United Nations strongly stated that the “water

crisis is essentially a crisis of governance and societies are facing a number of social, economic and political challenges on how to govern water more effectively” (UN 2003b, 370). In this chapter, we describe some of the major global water challenges and identify key deficiencies in global water governance in addressing these challenges. We conclude with several recommendations for improving global water governance in order to better address major water concerns in the twenty-first century.

## Global Water Challenges

As described below, the scope and complexity of water-related challenges extend beyond traditional national and regional boundaries. Such challenges require broader thinking and more comprehensive solutions.

### Water Scarcity

Water scarcity is a major challenge, affecting every continent around the world. Water scarcity occurs when water demand nears (or exceeds) the available water supply. Several groups, including the World Resources Institute and the International Water Management Institute (IWMI), have developed tools to promote a better understanding of where and how water risks are emerging around the world. The IWMI, for example, estimates that 1.2 billion people—nearly 20 percent of the world’s population—live in areas of physical water scarcity, where water withdrawals for agriculture, industry, and domestic purposes exceed 75 percent of river flows. An additional 500 million people live in areas approaching physical scarcity. Another 1.6 billion people live in areas of economic water scarcity, where water is available but human capacity or financial resources limit access. In these areas, adequate infrastructure may not be available or, if water is available, its distribution may be inequitable (IWMI 2007).

But water scarcity isn’t solely a natural phenomenon; it’s also a human one. Numerous human activities—such as untimely water use, pollution, insufficient or poorly maintained infrastructure, and inadequate management systems—can result in or exacerbate water scarcity. As noted by the United Nations, there are adequate water resources to meet our needs, but water “is distributed unevenly and too much of it is wasted, polluted and unsustainably managed” (UN 2012b).

Widespread declines in groundwater levels are one symptom of water scarcity. Groundwater is an important source of freshwater in many parts of the world. Some areas, however, have become overly dependent on groundwater supplies. In the past two decades, advances in well-drilling techniques have significantly reduced the cost of extracting groundwater. Driven, in part, by these technological advancements, groundwater withdrawals have tripled over the past fifty years (UN 2012a). In some areas, the rate of groundwater extraction now consistently exceeds natural recharge rates, causing widespread depletion and declining groundwater levels. A recent analysis of groundwater extraction by hydrologist Yoshihide Wada and colleagues (2010) finds that depletion rates doubled between 1960 and 2000 and are especially high in parts of China, India, and the United States. Much of the groundwater extracted supports agriculture (67 percent), although it is also used for domestic (22 percent) and industrial (11 percent) purposes.

## Water Quality

While most water assessments emphasize water quantity, water quality is also critical for satisfying basic human and environmental needs. The quality of the world's water is under increasing threat as a result of population growth, expanding industrial and agricultural activities, and climate change. Poor water quality threatens human and ecosystem health, increases water treatment costs, and reduces the availability of safe water for drinking and other uses (Palaniappan et al. 2010). It also limits economic productivity and development opportunities. Indeed, the United Nations finds that “water quality is a global concern as risks of degradation translate directly into social and economic impacts” (UN 2012a, 403).

Water quality concerns are widespread, although the true extent of the problem remains unknown. In developing countries, an estimated 90 percent of sewage and 70 percent of industrial waste is discharged into waterways without any treatment at all (UN 2003a). Asian rivers are the most polluted in the world, and bacteria levels from human waste in these rivers are three times higher than the global average. Moreover, lead levels in these rivers are twenty times more than in rivers in industrialized countries (UNESCO 2005).

### *Drinking Water and Sanitation Access*

The failure to provide safe drinking water and adequate sanitation services to all people is perhaps the greatest development failure of the twentieth century. In an attempt to remedy this failure, the United Nations established the Millennium Development Goals (MDGs), eight targets designed to tackle extreme poverty. At the direction of United Nations member countries, UN organizations and multilateral and bilateral development agencies have been working to achieve these goals by the year 2015. While many of the MDGs are widely acknowledged to be associated with water, including those related to improving gender equality and reducing child mortality, Target 7.C specifically aims to reduce by half the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015. Although not without their critics, the MDGs have served to highlight the importance of water, sanitation, and hygiene in improving health and economic opportunities (UN 2012a).

By UN measures (which are acknowledged to have important limitations), significant progress has been made in improving access to drinking water. In 1990, 76 percent of the global population had access to an “improved drinking water source”—defined as one that, by nature of its construction or through active intervention, is likely to be protected from outside contamination, in particular from contamination with fecal matter—whereas by 2010, this number had grown to 89 percent (WHO and UNICEF 2012). The global population as a whole is on track to meet the MDG drinking water target; however, global aggregates hide large regional disparities. For example, while India and China have made significant progress, sub-Saharan Africa, where only 61 percent of the population has access to an improved water source, is unlikely to achieve the MDG drinking water target. Additionally, coverage in the least developed countries is worse than in other developing countries. Finally, even within countries, there are disparities between urban and rural communities and between the rich and the poor (WHO and UNICEF 2012).

Despite this progress, access to an improved drinking water source remains out of reach for many people. An estimated 780 million people do not have access to basic

water service (WHO and UNICEF 2012). Additionally, the MDG drinking water target is based on access to an improved supply of water with little or no consideration of whether the water is affordable, whether the water is safe for consumption, or whether that access is being maintained over time. For example, naturally occurring arsenic pollution in groundwater affects nearly 140 million people in seventy countries on all continents (UN 2009). In Bangladesh alone, nearly 70 million people are exposed to groundwater contaminated with arsenic beyond the recommended limits of the World Health Organization (UN 2009).

Far less progress has been made in achieving the MDG sanitation targets. In 1990, nearly half of the global population had access to improved sanitation. By 2010, the percentage of people with access to improved sanitation had increased to 63 percent. An estimated 2.5 billion people still lack access to improved sanitation (WHO and UNICEF 2012). The global population is not on track to meet the sanitation target, and coverage is especially low in sub-Saharan Africa and in southern Asia.

## Water and Ecosystems

Freshwater ecosystems are among the most extensively altered systems on Earth. Rivers, streams, and lakes have been subjected to chemical, physical, and biological alteration as a result of large-scale water diversions, introduction of invasive species, overharvesting, pollution, and climate change (Carpenter et al. 2011). An estimated 20–35 percent of freshwater fish are vulnerable or endangered, mostly because of habitat alteration, although pollution, invasive species, and overharvesting are also to blame (Cosgrove and Rijsberman 2000). About half of the world's wetlands have been lost since 1900, and much of the remaining wetland area is degraded (Zedler and Kercher 2005). Freshwater ecosystem conditions are likely to continue to decline unless action is taken to address acute threats and better manage freshwater resources.

## Globalization and Virtual Water Flows

Globalization is characterized by the production and movement of goods and services around the world, and water is a key ingredient, either directly or indirectly, in almost every good produced. Consequently, the movement of goods effectively results in the movement of water around the world. Existing patterns of trade, however, are not necessarily water efficient. Many factors are at play when global trade decisions are made, and water is rarely one of them. The concept of “virtual water”—the water embedded in the production of food and other products—has been introduced as a way to evaluate the role of trade in distributing water resources. Some have argued that by allowing those living in water-scarce regions to meet some of their water needs through the import of water-intensive goods, international trade can provide a mechanism to improve global water-use efficiency (Allan 1993). Others, however, have posited that it simply externalizes the environmental burden of producing a particular product. In any case, the facts suggest that countries' relative water endowments are not dictating global trade patterns. Indeed, three of the world's top ten food exporters are considered water scarce, and three of the top ten food importers are water rich (World Economic Forum Water Initiative 2011). Furthermore, globalization increases dependence on others for essential goods and increases vulnerability to external water scarcity (Hoekstra and Mekonnen 2012).



## Climate Change

Rising concentrations of greenhouse gases resulting from human activities are causing large-scale changes to Earth's climate. These climatic changes will have major implications for global water resources. As temperatures rise, the flows of water in the hydrologic cycle will accelerate. In short, climate change will intensify the water cycle, altering water availability, timing, quality, and demand. Indeed, all of the major international and national assessments of climate change have concluded that freshwater systems are among the most vulnerable, presenting risk for all sectors of society (Compagnucci et al. 2001; SEG 2007; Kundzewicz et al. 2007; Bates et al. 2008; USGCRP 2013). A technical report on freshwater resources released in 2008 by the Intergovernmental Panel on Climate Change (IPCC) concludes that "water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change" (Bates et al. 2008).

A community's vulnerability to climate change will depend upon the magnitude of the impact and the community's sensitivity and adaptive capacity. As noted by Kenneth D. Frederick of Resources for the Future and Peter H. Gleick of the Pacific Institute (1999), "the socioeconomic impacts of floods, droughts, and climate and non-climate factors affecting the supply and demand for water will depend in large part on how society adapts." The poor and those living in developing countries are the most vulnerable because they have fewer social, technological, and financial resources to enable them to adapt (UNFCCC 2007).

## Water-Energy-Food Nexus

Throughout the twentieth century, the close connections between water, energy, and food were largely unknown or were ignored in policy decision making. Water, energy, and food systems, and the governance institutions set up to manage them, were often separated by well-defined silos, and managers rarely communicated with one another. Water systems were often designed and constructed with the assumption that energy would be cheap and abundant, and energy systems were designed and constructed with the assumption that water would be cheap and abundant. Likewise, food systems have been operated as though neither the cost nor the availability of water and energy would constrain production. We now understand that this is no longer true: these critical resources are closely interconnected, and a growing interest in the water-energy-food nexus highlights the need to better understand and manage these interdependencies:

- Agriculture is a major user of water, accounting for 70 percent of all freshwater withdrawals. Agriculture is also a major user of energy, and food prices are sensitive to energy prices and policies on fertilizers, pesticides, and transportation to distribute products. Meeting the food and fiber demands of a growing population that is simultaneously shifting toward a more water-intensive diet will require a rethinking of how water is used.
- Energy is a major user of water. In the United States, for example, thermo-electric power plants account for nearly 50 percent of all freshwater withdrawals (Kenny et al. 2009). Newly proposed energy sources, such as biofuels, are placing additional strains on local water resources and global food systems.

- Large amounts of energy are required to capture, treat, distribute, and use water. Population growth and climate change are prompting some to consider importing water over longer distances, accessing groundwater from greater depths, or developing more marginal, lower-quality supplies that require extensive treatment.

Failure to consider these linkages in policy and decision making can lead to unintended consequences. Biofuels, for example, have emerged as an alternative to traditional, fossil-fuel-based energy sources, and many governments have instituted mandates and incentives to promote biofuel development. The European Union has committed to converting 10 percent of its transportation fuel to biofuels by 2020 (UN 2012a). In 2009–2010, nearly 40 percent of domestic corn use in the United States was for fuel (USDA 2010). However, first-generation biofuels, which represent the vast majority of biofuels produced today, are water and chemical intensive, and their development increases pollution of and competition for limited water resources. Additionally, biofuels compete with food crops for land and water resources, contributing to increased food prices and threats to food security. The impacts of increasing biofuel production make it clear that national decision making is linked to global agricultural output, food prices, and water availability.

## The Emergence of Global Water Governance

The importance of governance as a key factor in addressing water-related challenges began to emerge in the late twentieth century amid a growing recognition that technology and infrastructure alone were not sufficient to address persistent water management concerns. Indeed, in its first World Water Development Report, the United Nations issued a strongly worded statement that the “water crisis is essentially a crisis of governance and societies are facing a number of social, economic and political challenges on how to govern water more effectively” (UN 2003b). Early water governance efforts emphasized the local and regional scales, in part because water challenges were largely perceived as local issues. But the scope and complexity of water challenges, as described above, highlight the need for a more comprehensive and coordinated global effort.

Despite the need, discussions about global water governance have been limited. One of the few definitions of global water governance comes from a 2008 study that defines it as “the development and implementation of norms, principles, rules, incentives, informative tools, and infrastructure to promote a change in the behavior of actors at the global level in the area of water governance” (Pahl-Wostl et al. 2008, 422). Thus, global water governance focuses on the processes of international cooperation and multilateralism. It comprises formal and informal instruments—including global governmental and nongovernmental organizations, regimes, actors, frameworks, and agreements—created to balance interests and meet global water challenges that span national and regional boundaries. It informs the way challenges are tackled (or not) at the regional and international levels by various players (from governmental bodies to civil society organizations) and suggests opportunities for, and barriers to, meeting global objectives. Global water governance also facilitates interaction and dialogue among key players to inform the development of solutions to problems at local, national, and regional levels to ease global pressures.

## Evaluating the Effectiveness of Global Water Governance Today

Current global water governance systems were established during a time when approaches to water resource development and management differed from those encountered today (Jury and Vaux 2007). Persistent and emerging water challenges suggest that an assessment is needed to determine how global water governance efforts can be improved to more effectively address twenty-first-century water challenges and to leverage opportunities afforded by new thinking and innovative technologies. We describe below some key deficiencies and recommend ways in which governance can be improved to better address major freshwater concerns.

### *Intergovernmental Organizations Lack Clear Leadership and Coordination*

A large number of organizations exist to address water challenges at various scales—particularly the United Nations system, multilateral lending institutions, and regional basin organizations—all working on different aspects of water management and service delivery. While global summits and forums have helped to identify major challenges and issue areas, implementation of coherent action is hampered by differing agendas among organizations and agencies that overlap in some areas but not in others.

At the international level, leadership and coordinated action within the water sector could emerge from the United Nations' system of agencies and programs. UN-Water was created in 2003 to serve as the interagency coordinating mechanism to promote coherence and coordination of UN system actions and other nontraditional partners and stakeholders (e.g., public and private sectors and civil society) related to the implementation of the international agenda defined by the Millennium Declaration and the World Summit on Sustainable Development. UN-Water, however, has several deficiencies. In particular, it “does not have a strong mandate,” nor does it make centralized policies (Pahl-Wostl et al. 2008, 427). UN-Water also has its own areas of focus (water and climate change, water quality, water supply and sanitation, and transboundary water), which fail to address the full range of water-related challenges. Additionally, inadequate personnel and funding hamper UN-Water's goal of promoting collaboration among the various agencies and programs that focus on different water-related issues and challenges, among them the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations Children's Fund (UNICEF), the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), and the World Meteorological Organization (WMO).

The lack of clear leadership manifests itself in several ways. In particular, bilateral funding agencies are more likely to focus their efforts on their own priorities. For example, the German development agency GIZ has spent considerable resources on addressing the food-water-energy nexus, climate change, and access to water and sanitation. The US Agency for International Development (USAID), on the other hand, is focused on biodiversity, food security, climate change, and water access and sanitation. While all of these efforts are aligned with global priorities, lack of coordination can hinder their effectiveness.

**Recommendation:** Secure a Sustainable Funding Source and a Stronger Mandate for Coordinating Intergovernmental Organizations

The global nature of water-related challenges requires clear leadership and coordination. Intergovernmental agreements produced at world summits and forums require effective intergovernmental organizations to play the leading role in coordinating action. The United Nations system, as the sole global governance organization with the legitimacy and authority of member governments, must lead. UN-Water offers a potential starting point, given its existing mandate to coordinate action. To fulfill its mission, however, it (or any other intergovernmental mechanism established to coordinate action) must be given the resources and an empowered mandate to do so. This requires governments to fulfill pledges made at previous UN summits (such as the 2002 World Summit on Sustainable Development, or Johannesburg Summit) to ensure that financial resources are made available. It also requires political will from the United Nations to provide a stronger mandate for the organization and the ability to overcome traditional interagency rivalry that hampers cooperation.

**Recommendation:** Promote Greater Collaboration to Build Understanding and Coordinate Action

To effectively address the interlinked nature of the problems, it is imperative that water-related action be led not from within a silo but rather with a deep understanding of the cross-sector issues—for example, taking into consideration development, energy, biodiversity, climate change, food security, and more. Building this understanding requires close, continuous collaboration among the different organizations and individuals involved. UN-Water's 2013 theme of international cooperation is a positive step in that direction. Government-led efforts to encourage participation by actors through multi-stakeholder processes (such as the parallel meetings at Rio+20, the 2012 United Nations Conference on Sustainable Development) are key to promoting this collaboration. Likewise, the United Nations' current approach to developing the new Sustainable Development Goals is an encouraging development. By instituting a process that brings together development agencies, civil society groups, and the private sector to define water-related goals and potential actions, the UN approach promotes better understanding, which can lead to more coordinated action and better outcomes.

*The Role of Nongovernmental Actors Is Expanding*

Today, a study of global governance cannot be limited to merely governmental or intergovernmental processes. The rise and influence of a broad range of new actors, with their own sources of authority and power, are indicative of a more complicated global governance structure. These actors, who come from the private, nongovernmental, academic, and media sectors, act independently or, increasingly, in networks to bring about new thinking and solutions. These new global actors have fostered innovation and performed important functions, such as serving as watchdogs of governmental and private sector activities within the water sector. However, concerns have been raised about some who are engaged in public policy, particularly regarding their legitimacy, accountability, and relationship with existing public governance structures. For example, some of these new initiatives may be undermining government-led efforts, operating outside of local priorities, or, in the case of some privately led initiatives, engaging in policy capture (see, e.g., the discussion of corporate actions regarding water in chapter 2 of this volume). Their

centers of authority or the constituencies for whom they speak has also been a subject of debate. Although it is clear that these actors will continue to play an important role in global water governance, efforts should be made to understand what their role should be and their relationship with government-led efforts.

**Recommendation:** Explore and Develop Guidelines and Principles to Help Govern Nongovernmental Processes

As more parties become involved, effort is needed to better understand and define the roles and responsibilities of each in order to leverage unique capabilities. For entities that are actively engaging in areas that are in the traditional realm of governments, clear guidance as to how these new processes should interact with existing processes is needed. Realizing that these processes can potentially undermine one another, some organizations, such as the United Nations' CEO Water Mandate, have developed guidelines and principles to govern how the private sector engages in water policy (see, e.g., Morrison et al. 2010). More efforts like these are needed to ensure that civil society and private sector efforts and initiatives complement existing government-led processes where possible.

Some potential overarching principles developed for sustainability standards systems (many of which are global action networks, or GANs) that could serve as starting points for further exploration include the following (Ward and Ha 2012):

*Respect* the unique roles of governments and states.

*Engage* public sector actors.

*Support* sharing of information and resources with public sector actors.

*Build on* existing public sector and international norms.

*Assess and review* the range of public sector implications and relationships.

*Water Sector Funding Is Inadequate and Too Narrowly Focused*

The international community, including the major economies and international organizations, has played a significant role in funding water sector improvements, especially in developing countries. Yet funding remains limited and too narrowly focused. Funding commitments made by major economies at the 2002 Johannesburg Summit and among the Group of Eight countries have thus far not materialized. Additionally, a recent survey conducted by the World Health Organization (2012) finds that overall funding for the water sector is low—and is skewed toward capital expenditures for drinking water systems in urban areas. Expenditures for sanitation, operation and maintenance costs, and rural systems are much lower.

**Recommendation:** Develop Financing Mechanisms to Support Ongoing Operation and Maintenance Costs

Funding is needed to support ongoing operation and maintenance costs of water infrastructure. Available funding is insufficient to operate and maintain the existing infrastructure or to support the people and institutions needed to manage it effectively. As a result, systems are poorly managed or fall into disrepair, increasing the long-term costs. Additional funding is needed to support the ongoing operation and maintenance of new and existing water-related infrastructure.

### *New Funders Often Fail to Abide by Environmental and Social Lending Standards*

For much of the twentieth century, the World Bank, the Asian Development Bank, inter-governmental agencies, and bilateral donors were the main funders of large-scale infrastructure in the developing world. In recent years, new economic realities and players have emerged. Commercial banks and energy and construction companies in the global South are playing an increasingly important role and are fundamentally changing water resource management. For instance, Pacific Environment's China program director, Kristen McDonald, and her colleagues reported in 2009 that Chinese financial institutions, state-owned enterprises, and private firms were involved in at least ninety-three major dam projects overseas. These and other new players—predominantly energy and construction companies from Thailand, Vietnam, China, Russia, and Malaysia—had not adopted internationally accepted environmental and social lending standards and norms. Furthermore, these new funders forced the World Bank and the Asian Development Bank to reconfigure their own lending practices to further dilute their environmental and social safeguards (Molle et al. 2009).

#### **Recommendation:** Establish New Lending Standards and Compliance Strategies

Commercial banks and energy and construction companies play an increasingly important role in financing water resource development projects. In the case of dam construction, for example, these new players do not meet even the World Bank's standards—which are already weaker than the recommendations of the World Commission on Dams. The failure to abide by social and environmental lending standards poses a threat to local environmental and social systems. New environmental and social lending standards are needed to ensure that lending promotes sustainable development objectives. The new players, along with civil society organizations, should be included in crafting and designing these new standards in order to ensure compliance.

### *Knowledge and Technology Transfer Efforts Remain Largely Top-Down*

Over the past several decades, water-related knowledge and technological innovation have grown tremendously, with new techniques and ideas emerging from governmental bodies, independent research institutions, and academic bodies around the world. The challenge lies in getting this knowledge and technology to places that can implement them. Intergovernmental processes to foster technology and knowledge transfers—mainly through forums such as the annual Water Environment Federation Technical Exhibition and Conference (WEFTEC) and the like—have predominantly been in a top-down manner. There is growing recognition, however, that even innovative technologies that are thought to be highly effective may not be appropriate everywhere. Each technology is developed and crafted according to local circumstances, which can differ dramatically from one region to another. As a result, an off-the-shelf approach to technology and knowledge transfers may not lead to the desired outcome or may lead to unintended consequences. Implementation of Green Revolution concepts to industrialize agriculture in the Punjab region of India provides an example of a top-down, single-focus transfer of knowledge and technology that has led to several unintended consequences, including groundwater overdraft in some areas. Today, the state of Punjab is trying to manage these problems by revisiting and reforming state agricultural policy and regulations using a more bottom-up technology and knowledge transfer approach (Tiwana et al. 2007).



**Recommendation:** Promote Open-Access Knowledge Transfer

Over the past few decades, there has been tremendous growth in the technologies available for transferring knowledge and information. Geospatial technologies, the Internet, and mobile devices are just a few of the technologies available to improve communication. Although reliance on such technologies must be carefully considered, given the global variations in their application and use, they can provide tremendous opportunity for new ways of getting information to water users and of connecting water stakeholders and researchers with one another and with decision makers. Global institutions can play an important role in facilitating the use and distribution of these new technologies. Extending access to new and emerging scientific findings can enable and empower the local research community to better understand and identify local problems and design or demand specific solutions to improve local water governance (Jury and Vaux 2005; Hutchings et al. 2012). There is also a need for better communication of complicated scientific knowledge to policy makers and decision makers in order to influence development of comprehensive management strategies and inform the policy-making process.

**Recommendation:** Facilitate Effective Technology Transfer by Engaging Local Communities in the Decision-Making Process

Empowering local communities to identify their water issues and solutions allows them to select an approach that more closely aligns with their social and cultural realities. On-site education and capacity building play a major role in facilitating successful and effective bottom-up or horizontal technology and knowledge transfer. Especially in regions with very limited access to and understanding of state-of-the-art technological solutions, or with limited institutional capacity to provide local technological training, international institutions such as the UNESCO-IHE Institute for Water Education can foster capacity building and educational efforts to facilitate implementation and operational learning of imported technologies. Also, continuous monitoring and performance assessment of a transferred technology can provide an opportunity to adjust and calibrate implementation and operational processes to prevent undesirable outcomes. Global institutions can also facilitate focused research and development investment, especially by those in the developed world with financial resources, to advance technologies and make them more accessible to the developing world.

**Recommendation:** Improve Understanding and Communication of Risk and Uncertainty

Some uncertainty inherent in hydrologic and water resource management systems is unavoidable. Yet the development of management practices and strategies relies heavily on future supply and demand predictions, which are fraught with uncertainty. Water resource managers around the world use various supply and demand predictions in their decision-making processes. A better understanding of the uncertainties and risks associated with them can lead to the development of more effective planning and management strategies that reflect these limitations. New decision support tools should include an uncertainty assessment component, which would offer an array of decisions and the uncertainties and risks associated with them in order to provide an opportunity for adaptive and flexible management approaches. Effective communication of these uncertainties and risks to policy makers and the general public is also an important element of adaptive and flexible water resource management practice (UN 2012a).

### *Data Collection Efforts Are Inadequate*

Good data and ongoing monitoring activities are the cornerstones of effective water management and governance. We live in an information era, and vast amounts of water data are collected in different ways and at a variety of temporal and spatial scales, from local stream gauges to global satellites. Current attempts at information sharing, such as UN-Water's Activity Information System, Documentation Center, and Key Water Indicator Portal, provide key data necessary to tackle the water challenges identified earlier. Despite these improvements, there are still regions lacking basic water data and information. Even when the data are collected, they are often not widely available or their quality is poor. Efforts are needed to improve the collection, compilation, and reporting of comprehensive water-related data.

#### **Recommendation:** Develop a Centralized Global Water Data Portal

The rational management of water is predicated on the availability of comprehensive data. Capacity needs to be developed in all countries to collect, manage, and analyze water information. Some of the key data needed include precipitation, runoff, virtual water flows, groundwater levels, and overall water demand and supply. Where resources are inadequate to collect and compile these data, they should be provided through international aid or other mechanisms. Also, as developing countries undergo economic transitions, monitoring and reporting need to be integrated into new laws. These efforts would benefit from a centralized global water portal in which to assemble the reported data, especially where local governments lack the financial or technological capacity to provide such services. Finally, international data protocols, standard data formats, and sharing arrangements are needed in order to increase comparability of data worldwide.

#### **Recommendation:** Leverage New Data Collection Technologies

New local data collection and monitoring efforts are emerging that engage stakeholders through crowdsourcing, or reporting of information through electronic devices. Mobile connectivity is outpacing fixed landline phones and access to computers, especially in many developing countries that lack telephone network infrastructures. New monitoring efforts that use cell phones and other RSS technologies, such as the WASH SMS Project, capitalize on the widespread and rapidly growing use of mobile devices throughout the world to facilitate the flow of information between communities, governmental entities, and service providers (Hutchings et al. 2012). These data can provide timely information on local water systems, including the availability and quality of water. Small-scale, local data collection and reporting efforts such as these should be encouraged.

### *Lack of Transparency and Accountability Limits the Effectiveness of Water Sector Investments and Fosters Corruption*

The water sector lacks transparency and adequate participation from key stakeholders, especially in marginalized communities, and this in turn leads to an accountability deficit and can result in ineffective or inefficient management strategies and investments. A 2008 report by Transparency International and the Water Integrity Network finds that a lack of transparency and participation contributes to rampant corruption across the water sector, including in water management, drinking water and sanitation service provision, irrigation, and hydropower development. The water sector is especially prone to corruption because of the complex system of agencies responsible for its management

and delivery; the growing presence of private actors and informal providers that operate in legal gray zones (where the actors are the de facto water service providers allowed to operate by governments but who may not have official license); and the large sums of money required for infrastructure investments. Addressing the issue is especially challenging because of the general focus within the sector on technological solutions rather than governance. The report further finds that the poor and most vulnerable are the most likely victims because they are more exposed to the informal sector (where corruption is more prevalent) and have limited resources and avenues to voice their concerns. This, in turn, exacerbates corruption because those most affected by it are unable to call for greater accountability (Transparency International and Water Integrity Network 2008).

**Recommendation:** Adopt New Standards, Codes, and Best Practices for Water Resource Development and Management to Promote Greater Transparency and Participation

Water resource development and management are guided by a series of standards, codes, and best practices. These standards, codes, and practices, which include both mandatory and voluntary initiatives, must provide a regulatory framework that brings about greater transparency, promotes participation and oversight to tackle corrupt practices, and develops best-practice guidance where regulatory frameworks are weak or poorly implemented. Both governments and GANs can play a key role in their formulation. For example, Kenya has adopted a human rights-based approach to the water sector that places an emphasis on transparency and participation. Likewise, the United Nations' CEO Water Mandate released its *Corporate Water Disclosure Guidelines: Public Exposure Draft* in an effort to promote greater transparency in the private sector's water use and allow stakeholders to better evaluate this use. These efforts are encouraging; however, more can and should be done.

**Recommendation:** Promote Capacity Building and Increase Participation in Water Management

To bring about greater participation in water management and better implementation of frameworks that promote transparency, serious effort is needed to build the capacity of governmental officials and civil society groups, especially community-based organizations. Governments and GANs can provide technical know-how and financial resources to ensure that local governmental officials and community-based organizations, two groups with an intimate knowledge of local problems, can be key advocates for change. For example, the Freshwater Action Network focuses much of its effort on providing capacity building to its civil society members in order for them to engage in decision-making processes, call for greater transparency, and hold governmental and private sector actors accountable.

**Recommendation:** Empower Communities through Long-Term and Short-Term Education and Outreach Efforts

Education and outreach promote greater understanding about a particular issue and can help facilitate change by redefining acceptable behaviors and social norms. Knowledge is power; hence, it can empower communities, especially the poor and most vulnerable, to demand change and accountability. While education and outreach efforts often occur at the local level, global efforts can provide educational tools, platforms, and strategies

for planning effective educational programs. For example, the UNESCO-IHE Institute for Water Education, established in the Netherlands in 2003, was developed to educate and train professionals and build the capacity of sector organizations, knowledge centers, and other institutions in developing countries and countries in transition. These efforts are needed at every scale. Household- and community-scale efforts can promote behavioral changes, facilitate grassroots support and demand for better regulations and enforcement, and bring about transparency and accountability. Education and capacity building at larger scales can promote effective interventions at the watershed, national, and international levels to develop better standards, regulation, and enforcement.

*There Has Been a Failure to Adopt Broad-Based Agreements on Transboundary Watercourses*

Many rivers, lakes, and groundwater aquifers are shared by two or more nations, and most of the planet's available freshwater crosses political borders, ensuring that politics inevitably intrude on water policy. Indeed, international river basins cover about half of Earth's land surface, and about 40 percent of the world's population relies on these shared water sources. Since transboundary watersheds traverse political and jurisdictional lines, heterogeneous and sometimes conflicting national laws and regulatory frameworks make management a major challenge, particularly when no single national government has authority over another. As such, transboundary water management often requires the creation of international guidelines or specific agreements between riparian states.

While the value of transboundary watershed treaties has regularly been demonstrated, there are political and financial constraints that make their adoption difficult in many parts of the world. In 1997, the General Assembly of the United Nations adopted the Convention on the Law of the Non-Navigational Uses of International Watercourses. This UN convention sets forth principles for equitable and reasonable utilization of international watercourses and for equitable participation. More than a decade after its adoption by the vast majority of the General Assembly, however, the convention has not yet obtained enough signatures to enable it to enter into force and effect. As of February 22, 2013, thirty countries had ratified or acceded to the convention; thirty-five signatures are needed for the convention to enter into force.<sup>1</sup>

**Recommendation:** Bring into Force the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses

As much as we hope that treaties will be developed in all transboundary watersheds to foster cooperation and collaboration among all riparian states, political and financial constraints make this difficult in many areas of the world. Therefore, adopting an effective international legal framework is a critical step in addressing future challenges. The 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses represents an important contribution to the strengthening of the rule of law regarding the protection and preservation of international watercourses, and it should be brought into force.

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1. See International Water Law Project, Status of the Watercourse Convention as of 22 February 2013, [http://www.internationalwaterlaw.org/documents/intldocs/watercourse\\_status.html](http://www.internationalwaterlaw.org/documents/intldocs/watercourse_status.html).

### *Existing Interbasin Agreements Lack Flexibility*

Global climate change will pose a wide range of challenges to freshwater resources, altering water quantity, water quality, and system operations and imposing new governance complications. For countries whose watersheds and river basins lie wholly within their own political boundaries, adapting to increasingly severe climatic variability and changes will be difficult enough. When those water resources cross borders and implicate multiple political entities and actors, sustainable management of shared water resources in a changing climate will be especially difficult and will require active coordination, engagement, and participation of all the actors sharing the basin. In particular, most transboundary water agreements are based on the assumption that future water supply and quality will not change. Moreover, most treaties and international agreements fail to include adequate mechanisms for addressing changing social, economic, or climate conditions (for an early analysis of this problem, see Goldenman 1990 and Gleick 2000).

### **Recommendation:** Improve Flexibility of Existing Interbasin Agreements

No two water treaties are the same. Each is developed under unique circumstances, addresses different concerns, and has a particular set of constraints. Additionally, climate change will affect each basin differently. As a result, each treaty must be evaluated to determine what flexibility mechanisms currently exist and where significant vulnerabilities remain. This process should be started before a problem arises so as to improve the atmosphere for cooperation and negotiation. Additionally, transboundary watershed countries should consider incorporating provisions into existing treaties to allow for greater flexibility in the face of change, including (1) creation of flexible allocation strategies and water quality criteria; (2) agreement on response strategies for extreme events, such as floods and drought; (3) development of clear amendment and review procedures to allow for changing hydrologic, social, and climatic conditions or in response to new scientific knowledge; and (4) establishment of joint management institutions that can, for example, facilitate a climate vulnerability and adaptation assessment (Cooley and Gleick 2011).

## Conclusions

Throughout the twentieth century, water governance efforts emphasized the local and regional scales, in part because water challenges were largely perceived as local issues. However, there is growing recognition that the scope and complexity of water-related challenges extend beyond national and regional boundaries and therefore cannot be adequately addressed solely by national or regional policies. Discussions about global water governance, however, have been limited. Water governance studies that have taken a broader perspective have largely focused on transboundary water resources. Global water governance has also been discussed within the context of other, more prominent global governance challenges (notably climate change and energy) and within discussions of global development objectives. However, there has been little to no discussion about global water governance that looks more holistically at global water challenges and the structures and approaches needed to meet these challenges.



In this chapter, we have defined global water governance, identified key deficiencies in global water governance, and offered recommendations for how it can be improved to better address major water concerns in the twenty-first century. We noted that the global dimensions of water governance are difficult and complex issues. Such governance and the institutional structures that accompany it are complicated by local, regional, and national factors. Indeed, there is no single practice or policy that will “solve” the water challenges facing the world today. This chapter, however, provides several paths forward to more efficient and effective water governance in an effort to promote a more robust and sustainable approach to solving water problems in the twenty-first century.

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# Shared Risks and Interests

## The Case for Private Sector Engagement in Water Policy and Management

Peter Schulte, Stuart Orr, and Jason Morrison

Some practitioners have suggested there is a strong business case for companies to advance sustainable water management in their operations, supply chain, and society more broadly. The concept of “shared risk” articulates that the conditions that drive water risks for industry also create risk for other segments of society and that there is a shared interest across sectors in more sustainable water management and robust water governance processes. Others have challenged the legitimacy of this concept, citing inherent conflicts between corporate and other societal uses of water and a history of corporate policies that prioritize profit over the public interest. This chapter explores this debate. In doing so, it strives to demonstrate shared interest among sectors and an opportunity for companies to contribute to sustainable water management, but it also acknowledges that there are indeed conflicting interests that pose real threats to the public interest. Though there is significant potential for a more progressive and enlightened corporate stance in the ways companies view and advance public interest goals, we are surely only at the beginning of this paradigm shift. Ultimately, this chapter aims to foster a nuanced debate of how the private sector can meaningfully support and facilitate strong water governance in ways that simultaneously improve business viability and advance the public interest.

Industry relies on freshwater both directly, to manufacture goods, and indirectly, in the production of supplies that feed industrial processes. Water is used as a solvent; to cool industrial processes, dilute contaminants, irrigate crops, and extract fossil fuels; and as a key ingredient in many products, among other uses. In response to water scarcity and pollution, inadequate management systems, and associated challenges in a growing number of regions around the world, businesses are increasingly making the strategic decision to promote and invest in sustainable water management (CDP 2012; Ceres 2009). Their decisions are based on their growing understanding that water risks are caused not only by a company’s own water use and pollution but also by the watershed context in which the company operates.

Many water-intensive companies seek to improve water-use efficiency and ensure adequate wastewater treatment in their operations, while others are going beyond their “factory fence lines” to encourage and facilitate more sustainable water management throughout their supply chain and to engage with the watersheds in which they operate

(Pegram et al. 2009; Newborne and Mason 2012; Morrison et al. 2010). They do so through a variety of means, including but not limited to the following (Morrison et al. 2010):

- Facilitating water-use efficiency and pollution reduction measures of other actors in their watersheds
- Advocating for efficient, equitable, and ecologically sustainable water policies and practices at the local, national, and international scales
- Sharing data and information to improve public water management
- Investing in public water infrastructure expansions or upgrades
- Using internal facilities to meet local water supply and treatment needs
- Using financial and technical resources to support local water institutions in catchment planning and management
- Supplementing infrastructure to ensure local supply to communities and industry

The stated objective of these “beyond the fence line” engagement strategies, often collectively referred to as “policy engagement” (Morrison et al. 2010), is to reduce business risk by supporting a stable business environment and ensuring consistent access to water supplies, thereby strengthening a company’s license to operate and building a company’s standing among its stakeholders. These efforts also seek to identify and reduce the company’s adverse impacts on a region’s water-related challenges. Such strategies are grounded in the premise that they advance the public interest and are mutually beneficial to companies, their stakeholders, and other actors in the watershed. This, in turn, stems from the idea that many water-related risks, such as scarcity, pollution, inadequate infrastructure, insufficient management capacity, and climate change, affect a wide range of actors and are shared among companies, governments, civil society, communities, and other actors (Pegram et al. 2009).

While many companies are beginning to engage in water policy as a key element of their water management strategies, some nongovernmental organizations (NGOs) and academics are calling into question whether such strategies truly advance the public interest. Some, such as the Public Services International Research Unit (PSIRU), as detailed in its article “Conflicts, Companies, Human Rights, and Water—A Critical Review of Local Corporate Practices and Global Corporate Initiatives,” argue that such strategies in reality perpetuate a history of undue corporate influence on public policy that subverts the public interest in favor of corporate profit (Hall and Lobina 2012). This argument is based largely on the following interrelated notions:

- Companies do not have an economic incentive to promote sustainable conditions beyond their fence lines (apart from public relations gains).
- Companies have an interest in weak water-related governance, which allows them to continue socially and environmentally harmful, yet profitable, practices and as such strive to undermine democratic processes.
- Water risks are not “shared”; many issues that companies consider risks, namely regulation, are actually a boon to communities and ecosystems.

This chapter sets out to explore, and in some instances challenge, these notions. It acknowledges the real threat of corporate policy capture and greenwashing as well as the

inherent asymmetries in conceptions of water risk—yet raises the notion that current conditions offer a much greater incentive for companies to align their water-related policies and practices with the public interest than has been the case in the past. This position is nuanced and requires careful consideration of numerous aspects of water policy, among them inclusiveness, transparency, and collaboration. We argue, however, that there is a great opportunity for companies, governments, civil society groups, communities, and others to collaborate to achieve shared water-related objectives and that this is a worthy endeavor if done in a way that advances the public interest and aligns with global sustainable development goals. This potential lies at the heart of the “shared risk proposition” and the prospect of better aligning water challenges as shared objectives with mutually beneficial outcomes, as opposed to each stakeholder “fighting its corner” to the detriment of the others.

It is important to note that the debate on shared risk is separate and distinct from critiques of the privatization of water service provision. The privatization debate focuses on the legitimacy of private sector companies (as opposed to public agencies) being tasked with the delivery of water services (Gleick et al. 2002). The debate being explored here, in contrast, focuses on the role of private companies that use large volumes of water or cause water pollution, or both, and as a result can either exacerbate or potentially solve local water-related challenges.

## The Business Case for Investing in Sustainable Water Management

Is there an economic and strategic business case for developing sustainable water management strategies? There is growing evidence supporting such a case, as we discuss here. This evidence includes both direct economic advantages that can accrue to forward-looking companies and social and community advantages that come from proactively identifying and reducing water-related risks.

### Questioning the Business Incentive for Action

One critique against a private sector role in advancing sustainable water management suggests that companies do not have an economic incentive to do so and therefore cannot be relied upon to fulfill this role (Hall and Lobina 2012). This argument suggests that company efforts to mitigate adverse impacts caused by their operations or to advance sustainable water management more generally—by, for example, investing in improving the water-use efficiency of other actors or facilitating aquifer recharge schemes—are simply greenwash; that is, they are pursued to create the appearance of a responsible business for public relations gains without a good faith effort to advance the public interest. The PSIRU article cited earlier (Hall and Lobina 2012), referring to a Coca-Cola project aimed at recharging aquifers in India, states:

Although increasing recharge of aquifers is a genuine way of reducing local water stress, these initiatives are not sustainable ways of delivering it. The companies do not have any direct economic incentive to fund such recharges—the economic return is a public relations gain from being seen to act responsibly. In effect, the incentive for water efficiency is created

entirely by public campaigns against the abstractions, and by general public and political pressure for greater environmental responsibility.

This argument rightly implies that corporate initiatives driven purely by altruistic motives cannot be relied upon as a long-term solution to water sustainability challenges. There is no evidence to suggest that companies will behave in this manner consistently and reliably over the long term. However, this argument also suggests that corporate water sustainability efforts are driven solely by a company's desire to be perceived as responsible despite growing evidence to the contrary (see CDP 2012). It overlooks the wide range of water-related business risks that create strong economic incentives for companies to invest in sustainable water management throughout their supply chains and in the watersheds in which they operate as a means of promoting long-term business viability (Pegram et al. 2009; Hepworth 2012; Ceres 2009; Larson et al. 2012). Moreover, it has also been shown that there can be real economic advantages to improving water-use efficiency or reducing the volume of wastewater produced that must then be treated (Ceres 2009).

## Unsustainable Water Conditions and Business Risk

Water-related business risks are driven as much, if not more, by unsustainable watershed conditions beyond a company's fence lines, such as water scarcity or pollution, as they are by the company's water-related performance (Pegram et al. 2009; Larson et al. 2012; Morrison et al. 2010). As a case in point, an ultra-water-efficient factory located in a region of severe water stress or facing other water-related challenges can still face significant water risk. In 2012, 53 percent of Fortune Global 500 companies responding to a CDP questionnaire<sup>1</sup> reported that they had experienced detrimental water-related impacts during the previous five years, while 68 percent identified water as a risk to their business (CDP 2012). This reflects trends and real incidents that are moving the goalposts for the way companies view their internal efforts to drive operational efficiencies—no longer as an endgame of sustainability performance. The external basin conditions and contexts, where water risk ultimately resides, necessitate a broader endgame. This new awareness, and the reality that a business's water-related challenges can be fully addressed only through external engagement beyond the factory fence line, are being captured under the emerging paradigm of “water stewardship” (Hepworth and Orr 2013).

A lack of water in the most basic sense limits the amount of water a company can use and therefore the amount of goods it can produce. For example, in 2011, Gap Inc. cut its annual profit forecast by 22 percent as a result of production limitations driven by water shortages in Texas, India, Pakistan, and Brazil (Larson et al. 2012). Water scarcity also has secondary adverse impacts on business, with significant implications, for example, on the production of energy on which industry relies. In 2001, energy production in São Paulo, Brazil, was highly constrained as a result of both severe drought and governmental energy tariff policies (CLSA 2006). In order to prevent blackouts, the government imposed quotas aimed at reducing energy consumption by 10–35 percent. Many industries

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1. CDP (formerly called the Carbon Disclosure Project) is an NGO based in the United Kingdom that leverages market forces such as investors, customers, and governments to incentivize companies and cities across the world to measure and disclose information about their environmental and sustainability performance, including that related to water management.

based in Brazil's southeast were plagued by reductions in operational capacity, production delays, or increased production costs (CLSA 2006). Additionally, for many industries, degraded ambient water quality increases the level of treatment, and therefore cost, required to purify water to appropriate levels for industrial production (JPMorgan 2008).

Societal expectations for corporate sustainability, including efficient and responsible water-related policies and practices, are also on the rise. Companies perceived to mismanage scarce water resources are likely to suffer damaged reputations, especially when company operations negatively affect basic human and environmental needs or contravene legal requirements. Effective advocacy campaigns in India have already forced the Coca-Cola Company to close its plant in the village of Plachimada, Kerala, and pay \$48 million in damages because of the belief that Coca-Cola's groundwater pumping hindered communities' ability to extract the water needed to maintain their livelihoods (India Resource Center 2010). The loss of such goodwill can be a real economic loss.

Furthermore, consumers increasingly choose products on the basis of the perceived sustainability and social responsibility of companies' practices and policies. In the United Kingdom, expenditure on ethical goods and services has tripled in the past decade (The Co-Operative Bank 2009). Eighty-one percent of Koreans, 70 percent of Singaporeans, and nearly half of British consumers are willing to pay a premium for environmentally friendly products (Czarnowski 2009). Companies perceived to have better water-related practices may thus see improved brand value and a subsequent expansion in sales. The Alliance for Water Stewardship's March 2013 release of its beta standard for water stewardship suggests that stakeholders' ability to assess companies with respect to the adequacy of their water-related activities is arriving quickly (Alliance for Water Stewardship 2013). Furthermore, the financial community is increasingly seeking to invest in companies that are managing short- and long-term water-related risks and that are striving to meet stakeholders' expectations regarding water. Shareholder resolutions on water—mostly focused on the food, beverage, oil, and chemical industries—more than quadrupled over the past ten years (Ceres 2009).

Ensuing water-related development challenges, along with the changing landscape of stakeholder expectations, are creating very real economic incentives for companies to behave in a manner that is deemed responsible. It would be shortsighted to dismiss these potentially paradigm-shifting levers toward corporate sustainability because they diverge from previous corporate actions. In the past, the pressures and the companies' responses to water differed from those being pursued in today's highly branded, globalized, and increasingly water-stressed world (Hepworth and Orr 2013). Instead, we should ask how these new levers can drive changes that benefit businesses, communities, and ecosystems alike and how we can avoid one-sided outcomes and greenwashing that undermine such opportunities.

## Do Businesses and Other Watershed Actors Have a Shared Interest in Robust Governance and Sustainable Water Management?

Businesses, communities, ecosystems, governments, and others may face common water-related challenges, but they may not share an interest in the same solutions to such challenges. Indeed, this is another core argument of those skeptical of a meaningful private sector role in driving more sustainable water management. Considering the notion of



regulatory water-related business risks, for instance, the PSIRU (Hall and Lobina 2012, 15) contends that

for communities and ecosystems, regulation is not a risk but a positive opportunity for democratic and peaceful limitation of competing (including corporate) behavior. By contrast, the [work of the United Nations' CEO Water Mandate] has the anti-democratic implication that companies would be subject to less risks if there was no democratic government and no civil society.

This is, at least in part, a valid argument. Companies can be negatively affected by strict regulations that limit their activities, and thus they often consider them a business risk (as would, for that matter, a local smallholder farmer facing limited water allocations). The 2012 CDP Global Water Report states that 51 percent of companies consider "tightening withdrawal limits" a risk, while 30 percent consider "restricted water operational permits" a risk (CDP 2012). However, water-intensive companies are also negatively affected by a lack of regulation on other actors in their watershed that eventually leads to the depletion or degradation of a shared resource. This creates a not uncommon scenario in which a wide range of actors using a common pool resource are threatened both by the possibility of their own resource use being regulated and by the unregulated resource use of other actors.

Regulation that is coherent and consistently applied is positive for society and reduces risk to business. We live in a world where ecosystems and communities do face regulatory risks when government fails to regulate polluters, allocations, permits, fines, fees, and use, or to oversee and manage the socioeconomic trade-offs inherent in particularly stressed basins. Water-using companies are similarly negatively affected by such poor public management and oversight. The same CDP report found that 54 percent of companies responding consider "regulatory uncertainty" a risk (CDP 2012). Nonetheless, for detractors to suggest that risks would be lower for companies if government and civil society were silent or absent truly misses the point. We recognize that some companies have a long history of polluting waterways, have failed to meet minimum legal requirements, or have operated where the rules of the game are poorly enforced—and that companies in turn have benefited from these situations. Such companies should be exposed and duly penalized. Yet in even those parts of the world where the rules are most lax or where the issue of water pollution, for example, is most acute, things are changing. Companies increasingly see higher risk where water challenges are great and effective water governance is not in place. Water is the one resource for which some companies actually seek clear and consistent regulatory signals and policies and in which coherence allows them to plan, protect, and avoid negative impacts (Pegram et al. 2009). As expressed in the 2012 CDP report, companies may indeed complain when they do not have enough water to operate their facilities, yet the alternative is to be exposed to wide criticism and fear of regulatory response, which can be draconian and reactive.

In Beilun District in the city of Ningbo, Zhejiang Province, China, the local government is trying to balance the need for both industrial development and ecological protection. Local authorities have literally shut down more than seventy-two factories, large to small, that were failing to adhere to local water regulations (*Shanghai Daily* 2013). A similar picture is emerging all over the developing world, where, because of the scale of the issue and lack of capacity, governments are closing down facilities that breach pollu-



tion controls. On the one hand, this solves an immediate problem, but it also creates the space for more engaged dialogue with companies seeking to adhere to rules and comply with local standards. This is especially true as corporate awareness of water-related risks is strengthened by information from emerging risks tools (see WRI 2013 and WWF 2013). It also appears that a company's ability to ensure a license to operate—social and legal—is increasingly predicated on its playing by formal rules and, where these are not in place, on adhering to the best practices defined internationally.

A Coca-Cola plant in the Indian village of Kaladera, Rajasthan, is located in a watershed where groundwater levels dropped from 9 to 38 meters below ground level between 1986 and 2006, reportedly leading to increased costs for irrigation for local farmers, reduced availability of drinking water, and reduced milk yield (Karnani 2012). The Coca-Cola plant, established in 1999, undoubtedly contributed to this phenomenon during its tenure in the watershed. However, between 1984 and 1996 the rate of decline already averaged 0.5 meter per year, and in 1998 the Central Ground Water Board had already deemed the area “overexploited,” before the Coca-Cola plant was operational (Karnani 2012). Thus, groundwater depletion in Kaladera has coincided not only with Coca-Cola's presence but also with rising water demand due to population growth, urbanization, and more water-intensive lifestyles (Karnani 2012). The plant employs up to 250 people and accounts for less than 2.7 percent of local water extraction for 70 percent of the time and less than 0.9 percent for 40 percent of the time (Karnani 2012). In May 2004, at its highest levels, the plant accounted for 8 percent of local water extraction (Karnani 2012). As a well-resourced and well-known actor that clearly contributes to groundwater depletion, Coca-Cola is deemed largely responsible for this problem by local stakeholders, who are calling for closure of the plant.

Arguably, the core problem to be resolved in Kaladera, and in many other places around the world, is not just the exploitation of water resources by one industrial water user but widespread overexploitation enabled by the lack of a functioning management regime to regulate the utilization of a limited shared resource. A robust water governance system (with direct regulatory oversight) would incentivize widespread water-use efficiency while also denying permits to those unable to demonstrate responsible use. Coca-Cola has the financial and technical resources to facilitate and support such water governance. By contrast, shutting down the Coca-Cola plant may or may not slow the rate of groundwater depletion. The company has also been rolling out implementation of its “water neutrality” policy, which includes investing in watershed projects (e.g., rainwater harvesting) geared toward offsetting the amount of water use in the company's direct operation. It can be argued that closing the plant by itself would do little to solve the region's systemic long-term groundwater overdraft problem as long as governmental authorities do not have the resources, capacity, and will to effectively manage the watershed.

## Do Companies, Communities, Ecosystems, and Others Have a Shared Risk Driven by Water Challenges?

The belief that companies have an incentive to invest in sustainable water management beyond their fence lines is grounded in the concept of shared risk. Though water risks are often distributed unevenly, the idea that companies share a need with the public for reliable water services and sustainable water management is getting traction (Hepworth and Orr 2013; Newborne and Mason 2012). In Colombia, for example, the indigenous

vegetation of mountainous upland ecosystems is being cleared to make room for agriculture and cattle grazing. Without this vegetation, which traps water and protects soil, there is greater sedimentation in local waterways, on which the downstream city of Bogotá relies for its water supply. In recent years, this sedimentation has severely degraded water quality in the area, raising treatment costs for the local water utility, residential users, and businesses in the area, such as SABMiller's Bavaria. In order to address this shared risk, Bavaria has teamed up with The Nature Conservancy, other local NGOs, the Bogotá water company, and governmental agencies to remove sedimentation (Water Futures Partnership 2013).

Today in Kenya, integrated approaches to water, energy, and land are being undertaken by a range of actors living and working in the region, including small landholders, major horticultural businesses, the tourism sector, and local, national, and international authorities. Lake Naivasha, Kenya, has experienced declines in water supply and quality attributed to a variety of causes. The multiple water challenges have created risks for all water users who rely on healthy ecosystems for their livelihoods and future. Even though the export farmers have improved agricultural water-use efficiency to reach record levels, the cumulative effect of multiple water users had driven the lake to record low inflows. The consumer markets and retail companies purchasing Lake Naivasha's produce faced high reputational risks because of their poor understanding of the water demands of their suppliers and the perceptions of their customers (ERD 2012). The concept of shared risk was used to bring users together to work closely on joint action plans, funding local water-user associations, promoting and setting up reallocation plans, and creating incentives for government to better protect and manage the lake. These outcomes, supported and largely driven by the private sector, have been integral in advancing more sustainable management of the region. The underlying shared need for effective governance of the lake has united the stakeholders (WWF 2012). The Lake Naivasha example illustrates that while the criticism of shared risk has focused mainly on multinational companies with visible brands, the private sector in Kenya was largely represented by small and medium enterprises (SMEs). These companies, Kenyan and international, saw a clear business case based on economic incentives and opportunities to engage proactively with other water users. The focus on stewardship and shared risk should not negate the fact that most implementation of projects on the ground will be negotiated through SMEs—either through supply chain pressures around buyer protocol for stewardship or because these companies are embedded in their local communities and understand the water situation and business case from multiple perspectives.

Shared risk does not imply that water challenges create an equal and similar burden or sense of urgency for all stakeholders. There are specific challenges in facilitating this shift, resulting from the generally differing languages and expectations of various stakeholders regarding needs, time frames, and modes of communication. It is necessary to ask: *Risk of what and risk to whom?* The risk to an individual differs from societal or business risks, and certain groups will be more vulnerable than others. Water scarcity and pollution can be subjective in this sense. For a farmer, the danger may be back-to-back years of below-average rainfall. For the owner of a processing plant, the risk might be a sudden, temporary cessation of stream flow during peak operation time. For a government, risks might include the increasing costs of accessing water for utilities and the implications of higher energy costs, or failure to deliver on economic growth and development pathways because of poor water management (Orr and Cartwright 2010).

Rather, the concept of shared risk elevates local water challenges as a shared problem and in doing so suggests that we address these challenges in proactive and collaborative ways. Consider the alternative to this, which is the proposition that stakeholders facing similar challenges need not (or should not) speak or engage with one another over shared resources and should be ruled only by governmental policy, regulation, and fines, a premise that leaves those operating in geographies absent of good water governance to instead fight over resources. Critiques against shared risk, knowingly or not, indirectly (or directly) appear to advocate this position, yet collaboration and inclusion of all water users, including corporate and industrial actors, lies at the heart of sustainable water resource management and particularly integrated water resource management (IWRM)—the chief paradigm of reconciling water management challenges among shared users. Collaboration and integrated management also lie at the heart of the “soft path for water” approach (Gleick 2002; Wolff and Gleick 2002). IWRM is a process that involves identifying the multiple adverse impacts and trade-offs associated with current or proposed sectoral policies so that they can be subjected to a political process of informed decision making (Rama Mohan Rao et al. 2003). IWRM evolved as a response to the perception that this identification of trade-offs had historically been bypassed—that water management had been “unintegrated,” with various governmental ministries managing and using water independently and the voices of multiple users not being heard.

## How Do Other Water Users Benefit from Private Sector Involvement?

Regardless of whether companies benefit from robust water governance, for the “shared risk” concept to function, water managers and those advocating for the public interest must themselves benefit from companies operating in a stressed watershed. Companies can provide vital employment and tax revenues for local communities, contribute to gross domestic product and foreign exchange, and help governments deliver on poverty, growth, and development challenges. The example of Lake Naivasha showed that 10 percent of foreign exchange to Kenya could be linked to the output of the lake’s produce and horticulture trade (WWF 2012). Government for the first time saw how water-related risk not only could drive businesses to relocate elsewhere but also could feed the perception that Kenya was an unstable place to do business, which could undermine much-needed foreign investment over the long term.

Companies can begin to contribute to sustainable water management in simple yet beneficial ways. For example, they can provide sorely needed financial resources to augment water supply, especially in places where water governance is weak and capital is limited. Sasol, a global integrated energy and chemical company with its main production facilities in South Africa, has recognized water security as a material challenge to its operations, some of which are highly reliant on the Vaal River system. Sasol uses about 4 percent of the catchment yield; municipalities use approximately 30 percent, of which water losses can be as high as 45 percent of urban use because of the aging infrastructure (Greenwood et al. 2012). Sasol has approached a number of municipalities to implement water conservation initiatives (Greenwood et al. 2012). One such project used Sasol funds to adjust the pressure management system within a township, reducing water leakage in off-peak hours and boosting water supply. This project saves 28 megaliters per day at a modest capital cost of \$500,000, funded by Sasol with an operation and mainte-

nance (O&M) cost of US\$0.02 per cubic meter (Sasol 2010). By comparison, a project to improve internal water-use efficiency at a Sasol plant, which was also being undertaken at the time, required \$50 million in capital expenditures and saved only 18 megaliters a day, with an O&M cost of US\$2.00 per cubic meter (Sasol 2010). Sasol's implementation of this "beyond the fence line" water strategy has created systemwide water savings and supported local water security to the benefit of all while reducing water management costs for both local government and the business itself. This is a salient example of a win-win scenario, where the company was able to invest in the most cost-effective savings and where private and public interests were fully aligned.

Financial resources are just one of the tools industry can bring to the table. Companies can also help introduce new technology to improve water-use efficiency and water quality, collection of water-related data that supports informed water management decisions, and privileged access to national decision-making processes that NGOs and small communities may lack. For example, Intel teamed up with the City of Chandler, Arizona, to devise a collaborative approach to water management that includes building an advanced reverse osmosis facility to treat rinse water from Intel's manufacturing facility to drinking water standards before being returned to the municipal groundwater source and nearby farmlands (Morrison et al. 2010).

The lack of financial, technological, and informational resources in many watersheds underscores the reality that current governmental expenditures and investments in sustainable water resource management are low in many places across the globe (Ginneken et al. 2011; WaterAid 2011). In many cases, this may be due to corruption or a lack of awareness of the importance of sustainable water management. In other cases, it is because many governments face many competing demands for resources and policy attention and may lack the resources needed to manage water in a sustainable and equitable manner (WaterAid 2011). The private sector can play a critical role in bridging this resource and capacity deficit, especially in the context of partnerships and collaborative projects that harness the expertise, knowledge, and legitimacy of NGOs, academia, and governmental agencies. Playing this role, however, also requires that serious and careful attention be paid to protecting the public interest, addressing equity concerns, and preventing "policy capture."

## Utilizing Corporate Resources While Ensuring Public Interest Outcomes and Preventing Policy Capture

Critical to this debate is the question of how to use corporate resources toward mutually beneficial outcomes while ensuring that companies act in a manner that aligns with the public interest and that avoids undue corporate influence. Though we see emerging levers that incentivize companies to act in a responsible manner, there are also important and powerful conflicting interests and competing incentives that may lead to perverse and unbalanced outcomes (Morrison et al. 2010; Hepworth et al. 2010). Below is a list of some of the most salient tensions and barriers to beneficial private sector involvement in water policy and management that must be navigated.

*Many companies will not actively promote stringent regulatory frameworks that increase operational costs, limit production, or significantly undermine*

*company influence in water decision making.* There is a tension between a company's desire for a governance system that effectively manages others' water use (and therefore prevents challenges related to water scarcity and pollution) and its desire to prevent limitations to its own water use or stringent guidelines on water quality that drive up its own operational costs. These conflicting interests may not disincentivize company investment in or promotion of water-use efficiency among other water users in a particular basin, but they do call into question a company's incentive to meaningfully facilitate development of a governance scheme that could potentially limit its own production or increase operational costs. Similarly, while many companies may seek to implement projects that have public interest outcomes (e.g., addressing municipal nonrevenue water losses or riparian restoration or source water protection) and build their reputation among local stakeholders in doing so, only the rare company will choose to promote water governance processes such that their own influence on water decision making is significantly lessened.

*Companies are unlikely to be the leading advocates for the prioritization of domestic water uses (i.e., human right to water and sanitation) over their own water use.* In light of the recently affirmed human right to water and sanitation (United Nations 2010), water governance systems and legal frameworks in the twenty-first century are increasingly likely to include provisions that prioritize domestic and other water uses above those for industry. For example, the state water policy in Rajasthan (where Kaladera is located) stipulates that water allocations should be prioritized to drinking water, irrigation, power generation, and industry, in that order (Department of Water Resources 2000). While water uses to meet basic human needs are a clear societal priority (and in fact typically represent only a small proportion of water use in a basin), companies may not be inclined to proactively advocate for water management regimes that deprioritize their own water use, and thus champions of such causes will typically need to come from other segments of society, including explicit governmental commitment.

*There exists the potential for greenwashing of company claims and for industry initiatives that create the perception of responsible practice without tangible water sustainability and public interest outcomes.* As demonstrated in this chapter, there are economic drivers for companies to invest in and promote sustainable water management inside and outside of their fence lines such that watershed challenges and associated business risks are better managed. However, history also shows that some of these drivers, especially those regarding license to operate and brand value, can hinge on the *perception* of action rather than genuine action itself. This leaves open the potential for greenwashing initiatives that foster a perception of good practice without any tangible benefits to the public interest. As the issue of water is tackled by a growing number of companies, the likelihood increases that claims regarding stewardship and industry-led initiatives, which perhaps serve the corporate social responsibility agenda far more



than a strategic one, will proliferate. The onus will be on many of the practitioners and NGOs that support the corporate water stewardship paradigm, as well as academics and peer businesses, to differentiate between spurious claims and substantive efforts. While many critics will use these examples as straw men to criticize all corporate action on water, the case for validating claims and auditing performance should create stronger accountability and monitoring toward genuine shared outcomes.

*Some investors and corporate executives may be prone to react to short-term pressures that do not enhance sustainable water management rather than to tackle long-term sustainability drivers.* Much of the rationale regarding shared risk and collective action implicitly hinges on companies' assessing and managing risk on a long-term time horizon. For instance, companies considering long-term business viability will be much more likely to invest in water-use efficiency measures and sustainable water supply than will companies seeking to maximize profit in the near term. Likewise, many investors who have a short-term perspective and continue to orient around quarterly earnings statements may find it difficult to fathom the justification for long-term engagement in water governance in a particular region that will garner positive results only over a five- to ten-year time horizon. Even within a company, corporate social responsibility and sustainability departments may seek approval for programs and corollary expenditures based on long-term considerations and planning only to be confronted by unsupportive senior executives and legal departments who require shorter-term, more guaranteed returns on such company investments. This creates another tension. Though water-intensive companies certainly have incentives to support sustainable water management over the long term, such investments may be derailed or undermined by those seeking more immediate returns.

*Some business models and operational contexts may not offer strong drivers for action.* A significant number of companies have strong incentives to ensure sustainable access to water in a single location over the long term. These businesses, such as geographically bound mining or oil and gas companies, typically must operate in particular locations to be economically viable. Furthermore, SMEs may not have the economic means to simply move away from water-stressed settings. Others, however, have greater flexibility in the location of their facilities and supply chain and may not intend to remain in one watershed for an extended period of time. Such enterprises might be inclined to shift operations and supply chains away from water-challenged areas, thus leading to less dependence on those specific regions and perhaps even improving their perception among some key stakeholders when doing so. This "move away from the problem" alternative undermines incentives for companies to make substantial long-term investments in improving water governance in water-stressed areas.

## Moving Forward: Unlocking Mutually Beneficial Corporate Action on Water

The existence of competing economic incentives for long-term sustainable thinking and short-term profit motives reveals a number of complex and difficult questions, such as the following:

- Multinational companies in many cases are a great boon to local economies, in both developed and emerging economic contexts. What is the appropriate balance between “high economic value” water uses and public interest water uses?
- How can companies already driving action on water be encouraged to offer a louder voice within their value chains and the wider business community?
- Should industry avoid water-stressed regions or instead focus its investment in these areas?
- In many parts of the world, businesses and governments alike are complicit in a system that often results in unbalanced corporate representation in water policy. What role can and should companies play in facilitating more democratic processes (especially in areas of weak governance)?
- What can companies that are genuinely interested in facilitating sustainable water management do to ease the skepticism of potential partners?
- How can companies be encouraged to consider more long-term profit drivers in the face of more immediate short-term profit motives and shareholder pressure that may incentivize unsustainable practices?
- How can companies and others encourage increased investment in areas experiencing water stress and weak governance when these areas are identified as high-risk locations?

These are difficult questions, and the conflicts inherent within them will certainly invite some to argue that companies should not play a meaningful role in public water management. It must be recognized, however, that companies have always engaged in water policy, and given the very significant challenges facing global water security, dogmatic stances for or against corporate engagement not only fail to reflect reality but also are likely to be counterproductive (Hepworth and Orr 2013). Instead, these tensions and questions should underscore the need to strengthen positive incentives for responsible and sustainable private sector action and to begin a meaningful discussion on what that can and should look like. Such a discussion can shed light on unsustainable practices where they exist, highlight examples of beneficial corporate action, and ultimately help determine the most appropriate role for the private sector in addressing our shared twenty-first-century water challenges. There is compelling evidence to suggest that businesses’ role should not be limited to simply implementing operational efficiencies and being accountable for direct water-related adverse impacts on ecosystems and communities; it should be expanded such that companies are encouraged, if not expected, to make a positive contribution to broader watershed challenges that affect a wide range of stakeholders and actors.



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# Sustainable Water Jobs

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Many jobs, in different sectors of the economy, are required to manage, deliver, and treat the freshwater required to satisfy our commercial, institutional, industrial, agricultural, and domestic needs for goods and services. A range of sustainable water strategies to address twenty-first-century water challenges have emerged that reach far beyond the conventional water sector. Growing attention is being given to sustainable measures such as low-impact development, water reuse, watershed restoration, water conservation and efficiency, and many other proven and promising practices. As the country shifts to more sustainable water management, new services, occupations, and markets are emerging. In addition, over the next decade there will be a need for major investments in the nation's aging infrastructure for wastewater, stormwater, and drinking water along with ongoing operation and maintenance jobs to sustain that infrastructure. Many of these jobs are eligible for public funding and have been the focus of increased funding through the American Recovery and Reinvestment Act of 2009 (ARRA) and other federal and state policies. However, information is needed to help local, state, and federal agencies; utilities; companies; unions; and nonprofit entities adopt strategies that maximize job creation and other potential benefits of these practices.<sup>1</sup>

The need to take advantage of any opportunities for increased quantity and quality of employment opportunities is acute: 12 million workers in the United States who are interested in working and available to work are unemployed (US BLS 2012a). Millions more are working but remain in financial distress, with basic needs, such as health care, unmet. Some 10.5 million US workers were employed for more than half of the past year yet still have an income below the official poverty level (US BLS 2012b). For working parents in poverty, constraints on their ability to provide stable and appropriate child care can pass their hardship onto their children. Research now shows that these forms of inequality are harmful to economic growth and that regions and countries with greater equality experienced more vigorous economic growth (Treuhaft et al. 2011).

The jobs generated by sustainable water strategies have rarely been analyzed or tracked, yet a growing body of research points to significant numbers of jobs in certain sectors and in certain places. The types of jobs involved in implementing sustainable water strategies cover a broad range of occupations. In a recent study conducted by the Pacific Institute (Moore et al. 2013), 136 water-related occupations were identified in agriculture, urban residential and commercial settings, restoration and remediation, alter-

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1. This chapter is modified and updated from a recent study by the Pacific Institute titled "Sustainable Water Jobs: A National Assessment of Water-Related Green Job Opportunities," available at [http://www.pacinst.org/reports/sustainable\\_water\\_jobs/](http://www.pacinst.org/reports/sustainable_water_jobs/).

native water sources, and stormwater management. The number of employment opportunities created by sustainable water practices can be very high. The data available point to the creation of 10–15 jobs for every \$1 million invested in alternative water supplies; 5–20 in stormwater management; 12–22 in urban conservation and efficiency; around 15 in agricultural efficiency and quality; and 10–72 jobs per \$1 million invested in restoration and remediation.

This research suggests that water is a worthy arena for exploring green jobs and that if we continue to separate our efforts in water sustainability and economic opportunity, we may miss opportunities to strengthen both through integration. There is now greater awareness of the promise of green jobs—the potential for crafting economic strategies that reduce environmental impacts while creating high-quality work opportunities. But these efforts have largely focused on energy efficiency and renewable energy. This chapter summarizes the conclusion that the growing efforts to develop green jobs by investing in sustainable water systems are merited.

At the conclusion of this chapter, we also evaluate some of the challenges of developing these water jobs, including the need for better information for various stakeholders, such as workforce development and community-based organizations, labor unions, utilities and public water agencies, and businesses. The comprehensive assessment (Moore et al. 2013) looks in more detail at the full spectrum of sustainable water strategies and provides foundational information regarding the following questions:

- What are the best practices across sectors for sustainable water management and use?
- What activities and occupations are involved when these practices are adopted?
- What data are available to quantify the jobs generated by these practices?
- What is the quality of these sustainable water occupations, what is their growth in the overall economy, and what are the demographics of the workforce in these professions?
- How can disadvantaged communities be linked to job opportunities in the water sector?

## Water Challenges in Today's Economy

As we enter the second decade of the twenty-first century, the United States faces a complex and evolving set of freshwater challenges (Christian-Smith and Gleick 2012). Despite the fact that the nation is, on average, a comparatively water-rich country, we are reaching absolute limits on our ability to take more water from many river systems, such as the Colorado, Sacramento–San Joaquin, and Chattahoochee River systems. We are also overpumping groundwater aquifers, including those in the Great Plains and California's Central Valley. Wetlands and aquatic ecosystems and fisheries are in decline. Continued population and economic growth are adding new demands for water, in competition with other uses. Many of the nation's water bodies are contaminated, and 42 percent of the nation's total stream length is considered to be in poor condition (US EPA 2006).

Much of our water infrastructure has not been adequately maintained, and confidence in our tap water system is falling. The US Environmental Protection Agency (EPA) pro-

jects that if we maintain current levels of investment in water systems through 2020, the percentage of the nation's water pipes considered "poor," "very poor," or "life elapsed" will reach 44 percent (US EPA 2002). Unresolved public health threats from contaminated drinking water exist in a growing number of communities, and the affordability of water for low-income users is a growing concern. Climate changes compound many of these challenges by altering water availability and quality and increasing the risk of both floods and droughts. A nationwide study analyzing water demand and supply under future climate change scenarios found that 70 percent of US counties may be at moderate to extreme risk of their water demand surpassing water supply by 2050 (NRDC 2010).

In the past, the traditional approach to meeting these challenges has relied on building massive, centralized, capital-intensive infrastructure, such as large dams and reservoirs. This approach has brought many benefits, but it has also come at great social, economic, and environmental costs, many of which were either ignored, undervalued, or unknown at the time (Gleick 2002). Currently, nearly 40 percent of North American freshwater and diadromous fish species are imperiled because of physical modifications to rivers and lakes (Jelks et al. 2008). Other consequences of traditional water development include loss of valuable ecological services that aquatic ecosystems provide, such as water filtration and retention, as well as massive energy demands to move and treat water and substantial and heavily subsidized costs.

The water challenges our nation faces must be addressed with strategies that avoid the negative outcomes of the past. To develop these strategies, water managers and others are rethinking approaches to ensure that sufficient water resources are available to meet anticipated needs in ways that improve, rather than ignore, social equity, ecological conditions, and long-term sustainability of human-ecological systems. Many of these approaches reflect "soft-path" principles, which include taking advantage of the potential for decentralized facilities, efficient technologies, flexible public and private institutions, innovative economic instruments, and human capital (Gleick 2002). We define sustainable water strategies as those that reduce or eliminate water contamination, restore watershed systems, and increase efficient use of natural, societal, and financial resources. We group the diverse range of techniques that meet these criteria into five overarching strategies:

1. Urban water conservation and efficiency
2. Stormwater management
3. Restoration and remediation
4. Alternative water sources
5. Agricultural water efficiency and quality

For each of these strategies, we review the technical and economic processes involved, identify the occupations of workers carrying out these activities, and assess the numbers of jobs created for each \$1 million invested.

## Improving the Efficiency of Urban Water Use

Techniques to improve urban water conservation and efficiency allow for the increased production of goods and services while maintaining or even reducing overall water use in urban areas. These efforts are also referred to as demand management or water productivity improvements. Urban water conservation and efficiency measures include in-



stalling efficient appliances and fixtures, improving water-use metering, improving landscape efficiency, xeriscaping, and replacing or repairing pipes to reduce water loss within the water conveyance and distribution system (see table 3.1) (Gleick et al. 2003). Water treated and reused on-site at a smaller scale is often referred to as grey water, which includes water from clothes washers, showers, and faucets for use on outdoor landscapes, for flushing toilets, and for other nonpotable uses.

Despite efficiency gains over the past twenty-five years, current urban water use in the United States remains wasteful. Inefficient fixtures and appliances are still commonplace, particularly in homes built prior to 1994,<sup>2</sup> in a range of commercial, institutional, and industrial settings. Even in a relatively dry and densely populated state such as California, where many water agencies have taken the concerns about water supply constraints seriously, far more can be done. A 2003 analysis by the Pacific Institute found that existing, cost-effective technologies and policies can reduce California's urban water demand by more than 30 percent (Gleick et al. 2003), and a follow-up study done in 2005 found continued room for improvement (Gleick et al. 2005). These findings have been echoed by studies and programs in other regions. For example, a Seattle study found that installing new, water-efficient fixtures and appliances reduced single-family indoor use by nearly 40 percent (Mayer et al. 2000). Experiences from other countries, such as Australia, offer insights into the levels of urban efficiency that can be achieved under difficult circumstances. For example, in South East Queensland, Australia, during a severe, long-term drought, total urban demand dropped to only 67 gallons per capita per day, and residential demand, including both indoor and outdoor uses, reached 43 gallons per capita per day (Queensland Water Commission 2010; Heberger 2012).

In addition to saving water, water conservation and efficiency measures provide a number of other benefits. Conservation and efficiency techniques can reduce costs for drinking water and wastewater treatment systems by reducing overall water delivery requirements. Reductions in demand can also reduce energy use and associated greenhouse gas emissions for water systems. Landscape efficiency improvements reduce chemical and fertilizer needs and subsequent runoff into local streams and waterways. High-efficiency appliances can also reduce detergent requirements for dishwashers and washing machines.

**TABLE 3.1** Urban Water Conservation and Efficiency Techniques

|                         |   |
|-------------------------|---|
| Appliances and fixtures | Installing water-efficient appliances and fixtures in residences and in commercial, industrial, and institutional (CII) settings.                           |
| Landscaping             | Utilizing landscape efficiency improvements, including advanced irrigation technologies and controllers, mulching, and low-water-use plants.                |
| Reduction of water loss | Replacing or repairing pipes to reduce water loss within the water conveyance and distribution system.  |
| Grey water              | Collecting, treating, and using water from clothes washers, showers, and faucets on-site for outdoor irrigation, toilet flushing, or other nonpotable uses. |

Source: Gleick et al. (2003).

2. National water efficiency standards for some fixtures were signed into law in 1992; implementation began in 1994.

The economic process of implementing urban conservation and efficiency measures involves a range of research, manufacturing, installation, and maintenance activities. Research and development, for example, generates new water-efficient technologies and practices, including mobile applications, soil moisture sensors, weather-based irrigation controllers, appliances and fixtures, and sensors (e.g., for cooling towers). Manufacturing activity produces these new tools and products, which are then distributed through wholesale and retail sales to businesses, utilities, and home owners. Design and planning programs at water agencies can help provide information to consumers or develop pricing strategies that encourage investment or more careful water use.

Figure 3.1 provides a summary of the occupations associated with urban water efficiency projects. Workers in these categories range from scientists developing new technologies to surveyors and landscape architects measuring water use and planning for improvements. Plumbers, construction laborers, and landscaping workers install and often maintain water-efficient technologies and vegetation, while public relations specialists raise awareness among community members and consumers.

Urban water efficiency projects create jobs, although limited data are available to develop accurate estimates (table 3.2). Early efforts to quantify the number of jobs created by urban water efficiency projects include the 1992 Madres del Este de Los Angeles Santa Isabel partnership, which estimated that a community-based program to install low-flush toilets created twenty-five full-time and three part-time jobs (Lerner 1997). In a more comprehensive analysis, the Alliance for Water Efficiency modeled the jobs created by investments in seven types of water conservation and efficiency programs, finding that 14.6 to 21.6 jobs in total employment were generated per \$1 million invested (Alliance for Water Efficiency 2008). A similar study in Los Angeles by the Economic Roundtable gathered information on eleven urban water efficiency projects, ranging from bathroom retrofits to a green garden program, and found that the projects generated 11.8 jobs per \$1 million invested, including 6 direct, 2.6 indirect, and 3.3 induced jobs.

## Managing Stormwater

Stormwater runoff is a major cause of water pollution in the United States. Ten millimeters (a little more than three-eighths of an inch) of rain over a one-hectare (approximately two-acre) parking lot produces 100 cubic meters (over 26,000 gallons) of stormwater runoff and can carry a noxious mixture of soils, sediments, oils, chemicals, and other substances into local waterways. In some areas, combined sewers transport both stormwater and wastewater to treatment systems, which can be overwhelmed during high flows and release untreated wastewater into local waterways. For many years, water agencies have been trying to improve stormwater management, redesign and rebuild sewers, and reduce these untreated releases.

Upgrading existing conventional infrastructure to manage stormwater comes at considerable financial cost, which has encouraged urban areas to look for alternative ways to address stormwater runoff. According to the EPA's 2008 Clean Watersheds Needs Survey, approximately \$189 billion is needed for pipe repair, new pipes, combined sewer overflow corrections, and stormwater management programs (US EPA 2008). Low-impact development (LID), or "green infrastructure," consists of alternative approaches that include systems and techniques intended to infiltrate, evaporate, and reuse stormwater on





**FIGURE 3.1 OCCUPATIONS IN URBAN WATER CONSERVATION AND EFFICIENCY**

**TABLE 3.2** Jobs per \$1 Million Invested in Urban Conservation and Efficiency Projects

| Project Type   | Total Employment<br>(Jobs per \$1<br>Million Invested) | Units and Methods  | Source                               |
|--|--|--|--------------------------------------|
| Eleven water conservation projects in Los Angeles County                                     | 11.8   | Total employment, including direct employment from expense reports and modeled indirect and induced employment | Burns and Flaming (2011)             |
| Evapotranspiration irrigation controller rebate/direct install programs                      | 20.4   | Total employment modeled using categorized program expenses as inputs  | Alliance for Water Efficiency (2008) |
| Water system loss control  | 21.6   | (same as previous)   | Alliance for Water Efficiency (2008) |
| High-efficiency toilet rebate program  | 18   | (same as previous)   | Alliance for Water Efficiency (2008) |
| High-efficiency toilet direct install program  | 17.2   | (same as previous)   | Alliance for Water Efficiency (2008) |
| Industrial water/energy survey and retrofit program  | 15.6   | (same as previous)   | Alliance for Water Efficiency (2008) |
| Retrofit cooling towers with conductivity and pH controllers                                 | 15.4   | (same as previous)   | Alliance for Water Efficiency (2008) |
| Restaurant surveys and direct install equipment retrofits                                    | 14.6   | (same as previous)   | Alliance for Water Efficiency (2008) |
| Installation of 5,439 grey water systems in new residential properties in Los Angeles County | 5.3  | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software                   | Burns and Flaming (2011)             |

the site where it is generated.<sup>3</sup> Of the \$189 billion funding gap identified by the survey, \$17.4 billion is related to green infrastructure projects (US EPA 2008).

Sustainable stormwater management practices and techniques include rainwater harvesting, bioswales and other forms of stormwater retention, permeable pavement, green roofs, and other efforts to reduce impervious areas (see table 3.3). Portland, Oregon, and other cities have programs to disconnect downspouts, rerouting rooftop drainage pipes to rain barrels, cisterns, or permeable areas instead of the storm sewer.

3. According to the EPA, low-impact development is “an approach to land development (or redevelopment) that works with nature to manage stormwater as close to its source as possible” (US EPA 2012b). In this chapter we use the terms “low-impact development” and “green infrastructure” interchangeably.

**TABLE 3.3** Stormwater Management Techniques

|                         |  |
|-------------------------|--|
| Downspout disconnection | Downspouts are disconnected and rooftop drainage pipes are rerouted to drain rainwater into rain barrels, cisterns, or permeable areas instead of the storm sewer. |
| Rainwater harvesting    | Rainwater is harvested and stored for later use.   |
| Rain gardens            | Rain gardens (also known as bioretention or bioinfiltration cells) collect runoff from rooftops, sidewalks, and streets into shallow, vegetated basins.            |
| Planter boxes           | Planter boxes are urban rain gardens with vertical walls and open or closed bottoms that collect and absorb runoff from sidewalks, parking lots, and streets.      |
| Bioswales               | Bioswales retain and filter stormwater as it moves through vegetated, mulched, or xeriscaped channels.   |
| Permeable pavements     | Permeable pavements infiltrate, treat, or store rainwater where it falls.  |
| Green roofs             | Green roofs are covered with growing media and vegetation and enable rainfall infiltration and evapotranspiration of stored water.                                 |
| Urban forestry          | Trees in urban areas reduce and slow stormwater runoff by intercepting precipitation in their leaves and branches.   |
| Land conservation       | Land conservation protects open spaces and sensitive natural areas within and adjacent to cities.  |

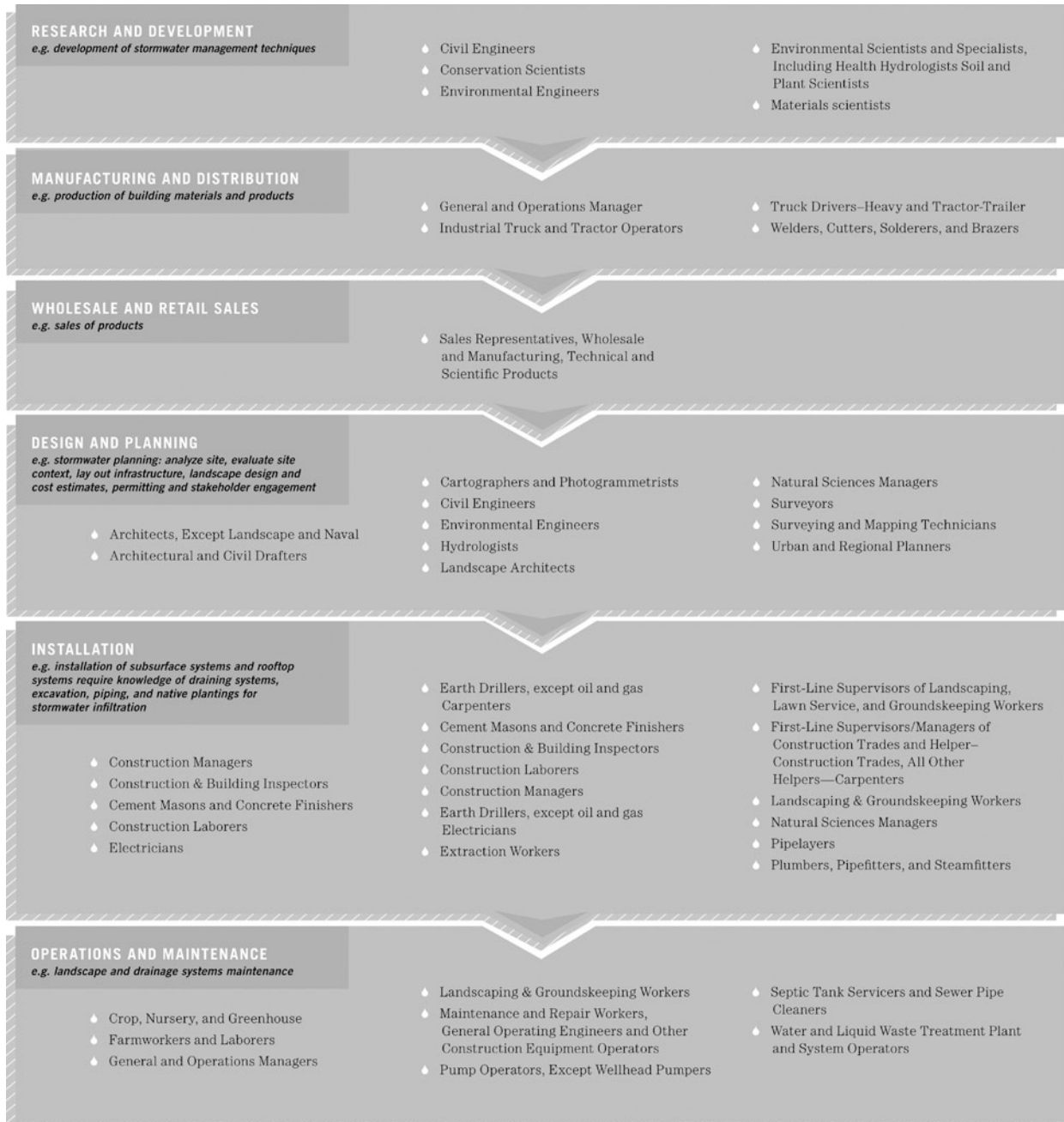
Source: US EPA (2012a).

The environmental benefits of these approaches include minimizing the impacts of urban runoff on local streams and the marine environment, reducing local flooding, recharging local groundwater supplies, and improving the reliability and flexibility of water supplies.

These approaches are typically less costly than conventional stormwater management techniques, with capital savings ranging from 15 percent to 80 percent (US EPA 2007). A recent report showed that 75 percent of 479 green infrastructure projects either kept costs the same or reduced costs, compared with the same projects that used more traditional infrastructure (American Rivers et al. 2012). Additionally, research has consistently shown a positive correlation between proximity to green spaces and home and property values (Crompton 2005).

It is difficult to determine how much green infrastructure has already been installed. According to the Greenroof & Greenwall Projects Database, more than 970 projects have resulted in the installation of more than 14 million square feet of green roofs in the United States (Greenroofs.com 2012), though these figures likely underestimate the true extent of this practice. Other practices, such as changes in landscaping and drainage systems, construction of rain gardens, and urban tree planting, have not yet been comprehensively quantified.

Figure 3.2 shows occupations involved in stormwater management. The range of occupations includes broad construction professions, septic tank servicers, sewer pipe cleaners, welders, cutters, and fitters for manufacturing, and more. Most of the occupations listed are traditionally within the landscaping and engineering sector and utilize similar techniques to address stormwater issues, though more sustainable water strate-



**FIGURE 3.2 OCCUPATIONS IN STORMWATER MANAGEMENT**

gies are designed to prevent and control stormwater runoff rather than simply diverting it to stormwater drains. New skills for these traditional occupations include knowledge of green roof design and installation, experience in working with new building materials (e.g., permeable pavement), and familiarity with land-use planning, site design, slope, and drainage.

Several studies have sought to quantify the jobs created through sustainable stormwater management projects (see table 3.4). A recent analysis found that four stormwater

projects in Los Angeles generated 13.8 jobs per \$1 million invested, with average wages of \$52,800. An estimated 73 percent of workers involved in these projects lived within the county, an indication of the local economic activity that these projects can generate. Likewise, stormwater projects in the District of Columbia's green roofs initiative produced 19.7 jobs for every \$1 million invested. A prospective analysis of proposed investments in Philadelphia, Pennsylvania, finds that committing \$1.6 billion over the next twenty years will create over 8,600 jobs, or about 5.3 jobs per \$1 million invested (BUCIP 2010).

However, there is one caveat to mention in these economic and job impacts. Estimates show promising overall workforce growth, but the anticipated demand for entry-level work in stormwater projects is lower than in other sectors. Professional services such as architectural and engineering services, financial institutions, and scientific and technical consulting tend to benefit from these economic impacts, while the construction services experience disproportionately low growth (Burns and Flaming 2011; BUCIP 2010).

## Restoring and Remediating Ecosystems

Ecological restoration is the process of returning the chemical, physical, and biological components of a degraded ecosystem to a close approximation of predisturbance conditions. Environmental remediation—a subset of restoration—is the process of targeted removal of specific toxic substances or pollutants from soil or water. Whereas restoration generally focuses on returning an ecosystem to its natural state, remediation targets lands contaminated with substances harmful to human health and the environment.

**TABLE 3.4** Jobs per \$1 Million Invested in Stormwater Management Projects

| Project Type  | Total Employment<br>(Jobs per \$1 Million<br>Invested) |  | Units and Methods  | Source   |
|---|--|--|--|--|
|   |  |  |  |  |
| Washington, DC, green roofs initiative                                      | 19.65  |  | Total jobs based on total green roof area covered, in square feet                            | American Rivers and Alliance for Water Efficiency (2008) |
| National investment in green stormwater infrastructure                      | 10   |  | Modeled total jobs (direct/indirect/induced) using macroeconomic and spending multiplier     | Green for All et al. (2011)                              |
| Operation and maintenance budget of four stormwater projects in Los Angeles | 13.8   |  | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software | Burns and Flaming (2011)                                 |
| Montgomery County, Maryland, stormwater system construction                 | 10.8   |  | Montgomery County expects to employ 3,300 for a three-year project                           | Chesapeake Bay Foundation (2011)                         |
| Philadelphia, Pennsylvania, stormwater investment                           | 5.3  |  | Modeled total jobs (direct/indirect/induced) using IMPLAN system over next twenty years      | BUCIP (2010)   |

Restoration can improve water quality and aquatic ecosystem health and can be achieved using both natural and artificial techniques. The EPA has identified three restoration techniques that deal with water quality (US EPA 1995):

1. In-stream techniques applied within the water system. For example, streams that have been channeled can be restored to achieve more natural geometry, meander, sinuosity, substrate composition, structural complexity, aeration, and stream bank stability.
2. Riparian techniques applied to the land area surrounding or bordering the water system. This can include planting of native riparian vegetation or construction of fencing to protect delicate riparian plants.
3. Upland or surrounding watershed techniques designed to reduce non-point source pollution from upstream lands within the watershed.

Although they are integral aspects of environmental restoration, techniques used for upland or surrounding watershed zones are cataloged here under stormwater management and agricultural efficiency. Table 3.5 lists some examples of in-stream and riparian restoration techniques.

Removal of contaminants in remediation projects can also be important, especially in aquatic systems, where pollutant transport is a risk. As shown in table 3.6, a wide range of techniques can be used to remediate groundwater and surface water, including phytoremediation, in which plants are used to absorb harmful contaminants, and installation of permeable reactive barriers, in which membranes are used to capture or treat groundwater contaminant plumes. Another important aspect of environmental remediation is the use of new technologies to characterize and monitor contamination (US EPA 2012c).

The work of restoration and remediation planning and design involves various technical assessments, coordinated planning, permitting, ecological research, design, and cost estimation. Planning and assessment activities include the review of aerial photographs, topographic maps, and results from soil tests and borings and engagement with regulatory

**TABLE 3.5** Restoration Techniques

|           |   |
|-----------|---|
| In-stream | <ul style="list-style-type: none"> <li>• Streambed reconfiguration</li> <li>• Restoration of natural meander patterns</li> <li>• Daylighting of urban creeks from stormwater sewers</li> <li>• Root wad/tree revetments</li> <li>• Live stakes, live fascines, brush mattresses, branch packings, brush layering, vegetated geogrids, and live cribwalls</li> <li>• Channel deflectors and channel constrictors</li> <li>• Boulder clusters</li> <li>• Log drop structures</li> <li>• Removal of artificial structures</li> </ul> |
| Riparian  | <ul style="list-style-type: none"> <li>• Wetland restoration</li> <li>• Restoration of riparian corridor vegetation</li> <li>• Levee setbacks or removal</li> <li>• Control of timing, location, and extent of water diversions</li> <li>• Construction of fences and gates in riparian corridor to control access</li> </ul>   |

Source: US EPA (1995).



agencies and stakeholders (NOAA, n.d.). Design of restoration projects typically entails the application of engineering, landscape architecture, river ecology, and expertise in geomorphology. Cost estimates are developed using standardized unit material and labor costs and regional or municipal multipliers. The construction phase of restoration and remediation projects is typically labor-intensive and involves some use of heavy machinery. In-stream and riparian restoration is typically implemented with a mix of hand labor and heavy machinery for digging and bank alteration.

A large number of occupations are involved in restoration and remediation activities (figure 3.3). Workers in these occupations range from the environmental and civil engineers who develop designs to sales representatives and truck drivers who sell and deliver products, to scientists with expertise in river systems and aquatic ecology, to masons and laborers who construct the projects. Workers in newer occupations, such as brown-field redevelopment specialists and conservation technicians, also have skills required for these projects.

The number of jobs created by restoration and remediation projects is highly variable, ranging from about 15 to 72 total jobs per \$1 million invested (table 3.7). For example, \$10.6 million spent on restoring the Cache River basin in Illinois generated approximately 36 jobs for each \$1 million invested (Caudill 2008). This includes 22 workers directly employed in the project and an additional 14 indirect and induced jobs, according to a study commissioned by the US Fish and Wildlife Service. About half of the direct jobs and 85 percent of the indirect and induced jobs were created locally in the four counties where the project took place. Likewise, dam removal on Ohio's Euclid Creek cost more than \$500,000 and generated 38 jobs, or 72 jobs per \$1 million invested.

Studies have found that the number of jobs created can vary depending on how much labor-intensive or equipment-intensive work must be done. For instance, a study by the University of Oregon's Institute for a Sustainable Environment estimates that direct employment in equipment-intensive watershed contracting is only 4.8 jobs per \$1 million invested because labor is a relatively small proportion of total spending (36 percent) and worker payroll costs are relatively high (about \$55,000 per job). By contrast, direct employment in labor-intensive projects is 13.8 jobs per \$1 million, with labor making up 67 percent of spending and payroll costs averaging \$31,000 per job, resulting in more and lower-wage jobs (Nielsen-Pincus and Moseley 2010).

**TABLE 3.6** Remediation Techniques

|                                  |  |
|----------------------------------|--|
| Extraction or removal techniques | <ul style="list-style-type: none"> <li>• Multiphase extraction</li> <li>• Natural attenuation</li> </ul>   |
| Containment techniques           | <ul style="list-style-type: none"> <li>• Evapotranspiration covers</li> </ul>  |
| In situ treatment techniques     | <ul style="list-style-type: none"> <li>• Thermal treatment</li> <li>• Flushing</li> <li>• Oxidation</li> <li>• Air sparging</li> <li>• Permeable reactive barriers</li> <li>• Phytotechnologies</li> <li>• Groundwater-circulating wells</li> <li>• Nanotechnology</li> <li>• Natural attenuation</li> </ul> |



**FIGURE 3.3 OCCUPATIONS IN RESTORATION AND REMEDIATION**

**TABLE 3.7** Jobs per \$1 Million Invested in Restoration and Remediation Projects

| <b>Project Type</b>                           | <b>Total Employment<br/>(Jobs per \$1 Million<br/>Invested)</b> | <b>Units and Methods</b>  | <b>Source</b>                                    |
|---|---|---|--|
| Cache River restoration in Illinois           | 36  | Includes direct jobs recorded in project reports and modeled indirect and induced jobs        | Caudill (2008)                                   |
| Everglades restoration                        | 20  | Modeled total jobs (direct/indirect/induced) using generic Sector 36 national multipliers     | Everglades Foundation (2010), 125                |
| In-stream restoration projects in Oregon      | 14.7  | Modeled total jobs (direct/indirect/induced) using data from survey of grants and contractors | Nielsen-Pincus and Moseley (2010)                |
| Riparian restoration projects in Oregon       | 23.1  | Modeled total jobs (direct/indirect/induced) using data from survey of grants and contractors | Nielsen-Pincus and Moseley (2010)                |
| Wetlands restoration projects in Oregon       | 17.6  | Modeled total jobs (direct/indirect/induced) using data from survey of grants and contractors | Nielsen-Pincus and Moseley (2010)                |
| Restoration of four rivers in Massachusetts   | 10–13   | Modeled total jobs (direct/indirect/induced) using generic state-level multipliers            | Massachusetts Department of Fish and Game (2012) |
| Removal of two dams near Watervliet, Michigan | 19  | Total jobs noted in project summary   | Great Lakes Coalition (2012)                     |
| Removal of dam on Euclid Creek in Ohio        | 72.2  | Jobs noted in project summary; may not be full-time equivalents                               | Gershman and Alexander (2012)                    |

## Developing Alternative Water Sources

Traditional water sources include rivers, lakes, and groundwater, as well as artificial reservoirs created by dams. In the past few years, however, alternative water sources have begun to play an increasingly important role in supplementing water systems where traditional sources have become harder or more expensive to develop. Such alternative sources include a range of unconventional supplies, such as rainwater, stormwater, grey water, and reclaimed water. Projects to capture these alternative water sources can be implemented by a water utility or at the facility level by households or businesses. For the purposes of this report, this strategy focuses on activities at the utility scale; other actions at the site level, such as rainwater harvesting and grey water reuse, are captured in

other strategies. We also describe conjunctive use, or aquifer storage and recovery (ASR), as a means of storing these alternative sources for later use.

Broadly, water reuse refers to the process of treating and reusing wastewater for a beneficial purpose. Potential uses include agricultural and landscape irrigation, industrial processing and cooling, domestic uses, dust control, construction activities, concrete mixing, artificial lakes, replenishment of groundwater basins (referred to as groundwater recharge, discussed in more detail below), and even direct potable reuse in some circumstances. Treatment levels can be tailored for the intended purpose and the level of human contact, which can help save money and energy when the quality does not have to meet drinking water standards. Water can be distributed from a wastewater treatment facility or treated and reused directly on-site (such as at a home or an industrial facility). Techniques to treat and reuse grey water on-site are discussed in the urban water conservation and efficiency strategy.

A growing number of communities across the United States are already beginning to move in the direction of encouraging and expanding the use of reclaimed water. According to the EPA's Clean Watersheds Needs Survey, an investment of approximately \$4.4 billion is needed to build, rehabilitate, or replace infrastructure for distribution of reclaimed water (American Rivers et al. 2012). In 2004, the EPA estimated total wastewater reuse in the United States at 1.7 billion gallons per day and growing at a rate of 15 percent per year. The same report estimates that 32 billion gallons of wastewater are produced each day, of which 12 billion gallons per day are discharged directly into an ocean or estuary. Portions of these flows could be made available for reuse (US EPA 2004).

Alternative sources can be captured and stored underground for later use. The term "conjunctive use" describes the coordinated use of groundwater and surface water to optimize supply and storage. When surface water supplies are plentiful, they can be used instead of groundwater or to recharge groundwater basins. Also known as aquifer storage and recovery (ASR), this technique can recharge groundwater through surface spreading, infiltration pits and basins, or subsurface injection. This practice not only increases the availability of water when it is most needed but also can add an additional treatment step; reduce evaporation and evapotranspiration, as compared with surface storage; and enhance the sustainability of groundwater storage by preventing subsidence. The EPA is aware of 1,203 aquifer recharge and ASR injection wells that are capable of operating; however, it is unclear how much water is injected into these wells each year (US EPA 2009).

Multiple activities are involved throughout the process of developing alternative water supply sources.<sup>4</sup> Research and development includes the development of new membranes with higher recovery rates and sensors that can provide real-time water quality readings. Manufacturing and distribution involves production and delivery of all of the products used throughout the process, including membranes, chemicals, and pumps. The planning phase can be extensive and can include a technical analysis of existing water supply conditions and future needs. Construction of treatment and storage facilities includes grading and paving the site and constructing the buildings. Ongoing operation and maintenance work is needed to ensure compliance with treatment requirements and to read meters, replace membranes, and repair the system.

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4. The focus of this section is utility-scale alternative water supplies. Grey water systems are included as an urban water efficiency strategy.

Figure 3.4 summarizes the many occupations engaged in developing alternative water supplies throughout the development process. The planning phase, for example, employs environmental engineers, hydrologists, landscape architects, urban planners, and other highly skilled professionals. Facilities and water and sewage operations staff are responsible for ongoing operations and maintenance.

Studies of the number of jobs generated by alternative water supply projects are limited. Table 3.8 is based on several case studies in Los Angeles County, where major investments have been made in recycled water and groundwater facilities (Burns and Flaming 2011). These case studies suggest the creation of roughly 10 to 14 jobs per \$1 million invested. For example, the design and installation of recycled water projects produced more than 12 jobs per \$1 million invested, including 6.6 direct jobs, 2.3 indirect jobs, and 3.7 induced jobs. Most of the direct work was performed by companies located in the area. Likewise, groundwater remediation projects in Los Angeles generated 12.8 jobs per \$1 million invested.

## Improving Agricultural Water Efficiency and Quality

Agriculture is the largest consumer of water in the nation, and while great advances in water efficiency in this sector have been made, additional gains are available through implementation of improved water management techniques (Christian-Smith and Gleick 2012). These practices are meant to reduce water waste and, in some cases, improve crop quality and yield. They include improving irrigation technologies and scheduling, reducing erosion, lining canals, increasing pump efficiency, restoring riparian areas, recycling tailwater on-farm, and constructing spill reservoirs at the water supplier scale.

Practices such as these can help reduce on-farm water use as well as improve water quality. Farmers are constantly implementing new technologies and management practices to improve their products. In many cases, water savings are a cobenefit of practices that are meant to decrease input costs or improve crop quality. Precision irrigation, in particular, has been shown to do both. And, according to the Census of Agriculture, flood irrigation declined by 5 percent nationwide between 2003 and 2008, replaced by more precise sprinkler and drip irrigation. Nevertheless, 39 percent of irrigated land nationwide is still flood irrigated, and there is significant room for improvement in all areas of agricultural water management. The 2007 Census of Agriculture found that at least 23 percent of farms and ranches surveyed utilized conservation methods such as no-till or conservation tillage, runoff collection or filtration, fencing of animals from streams, and other practices (NASS 2007). Agricultural runoff is also a major source of pollution of surface water and groundwater, and thus conservation practices designed to reduce runoff can also contribute to improved water quality and ecosystem health.

Agricultural efficiency and runoff management is designed to improve the productivity of agricultural water use and water quality through more efficient irrigation management techniques, such as irrigation scheduling, tailwater recycling, drip irrigation, and conservation tillage (see table 3.9). Figure 3.5 shows some of the occupations associated with this strategy. We note, however, that thus far little attention has been given to the number and types of jobs related to improved agricultural water management. Additional research and analysis are needed to develop a more comprehensive list.

Installation and operation and maintenance are the two most labor-intensive phases of the process. Installation can entail trenching, piping, earthmoving, and installing





**FIGURE 3.4 OCCUPATIONS IN THE DEVELOPMENT OF ALTERNATIVE WATER SOURCES**

pumps, water filters, water meters, water control devices, and irrigation equipment. A majority of this work is performed by construction laborers and agricultural technicians. In order for these technologies to work effectively, operation and maintenance must be performed regularly by maintenance and repair workers, agricultural inspectors, and service repair workers. Irrigation systems are often installed by construction crews, typi-



**TABLE 3.8** Jobs per \$1 Million Invested in Alternative Water Supply Projects

| Project Type  | Total Employment<br>(Jobs per \$1 Million Invested) |  | Source                   |
|---|---|--|--------------------------|
|   | Invested  | Units and Methods  |                          |
| Eighteen recycled water design and installation projects in Los Angeles and surrounding region    | 12.5  | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software | Burns and Flaming (2011) |
| Operation and maintenance of two recycled water projects  | 9.8   | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software | Burns and Flaming (2011) |
| Two groundwater remediation design and installation projects                                      | 12.8  | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software | Burns and Flaming (2011) |
| Operation and maintenance of Tujunga Wellfield Liquid Phase Granular Activated Carbon Project Two | 13.9  | Modeled total jobs (direct/indirect/induced) using IMPLAN system 2009 data and 2011 software | Burns and Flaming (2011) |

**TABLE 3.9** Agricultural Water Management Techniques

|   |  |
|---|--|
| Agricultural water efficiency techniques          | <ul style="list-style-type: none"> <li>• Improving irrigation scheduling</li> <li>• Improving irrigation technology (e.g., sprinkler and drip irrigation systems)</li> <li>• Lining canals and employing other seepage control options</li> <li>• Recycling tailwater on-farm</li> <li>• Increasing pump efficiency</li> <li>• Constructing spill reservoirs and conducting district reoperation to reduce water waste</li> <li>• Utilizing mulching and other techniques to increase soil water-holding capacity</li> <li>• Capturing stormwater flows for later use (e.g., on-farm ponds for frost and heat control and irrigation)</li> </ul> |
| Agricultural water quality improvement techniques | <ul style="list-style-type: none"> <li>• Planting cover crops</li> <li>• Constructing fencing around water bodies and streams</li> <li>• Utilizing conservation tillage or no-till</li> <li>• Restoring riparian zones or constructing buffer zones</li> <li>• Improving irrigation scheduling and using technology that reduces runoff</li> </ul>   |

cally made up of a foreman and skilled laborers. The crews are often trained by the dealer or contractor or by the water supplier and have very specific skill sets that are difficult to find. The labor-intensive components occur in implementing the installation and operations stage, while the irrigation technologies dominate the business aspect of the process. Other occupations essential to installation include precision agriculture technician, agricultural technician, purchasing agent, and buyer of farm products.

A recent analysis found that implementation of a range of agricultural best management practices would generate 14.6 jobs per \$1 million invested (Rephann 2010). Re-



FIGURE 3.5 OCCUPATIONS IN AGRICULTURAL WATER EFFICIENCY AND QUALITY

searchers found that if full implementation of agricultural practices outlined in the 2005 Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy were achieved, 11,751 person-years of employment would be created (Chesapeake Bay Foundation 2011). The majority of direct jobs generated would be in construction, construction-related services, and agricultural and forestry support industries. Additional indirect and induced jobs would be created in other industries.

An additional set of occupations that appear in multiple sustainable water strategies are general roles that we did not include in the descriptions of different strategies. These include the following:

- Accountants and auditors
- Bookkeeping, accounting, and auditing clerks
- Building cleaning workers, all other
- Business operations specialists, all other
- Chief executives
- Executive secretaries and administrative assistants
- First-line supervisors and managers of office and administrative support workers
- General and operations managers
- Human resources managers
- Management analysts
- Managers of office and administrative support workers
- Marketing managers
- Office and administrative support workers, all other
- Office clerks—general
- Public relations specialists
- Receptionists and information clerks
- Secretaries, except legal, medical, and executive
- Vocational education teachers, postsecondary

## Job Quality and Growth in Sustainable Water Occupations

Who is currently working in sustainable water occupations, and in what conditions? Which of these occupations would be appropriate for focused efforts to increase opportunities for disadvantaged communities? These questions are key to identifying strategies that advance ecological preservation and address economic inequality. It is clear from the previous section and other analyses that significant jobs are created when many types of sustainable water strategies are implemented. For these strategies to achieve the goal of advancing economic equality, there must be sufficient opportunities and appro-

priate pathways for disadvantaged communities to access these opportunities (Moore et al. 2013).

Our approach to identifying green job opportunities is to focus on jobs that are already growing in the overall economy, recognizing that we may be able to take action to make them grow greener and faster. This is rooted in some important lessons from past green job efforts. Much of the previous investment in green jobs went into preparing workers for occupations that were green and entirely new, such as solar installers and energy auditors, yet the demand for graduates of these programs fell short. Because these workers were not prepared with a broader set of skills that qualified them for conventional occupations, they were left with limited options for employment. We follow the Center on Wisconsin Strategy (White et al. 2012) and others who recognize that all occupations will likely change as sustainable strategies reshape the tasks they carry out, but the priority for training new workers should be on green skills embedded in a broader set of skills for growing occupations. Our analysis to identify sustainable water occupations that are more opportune is guided by the following questions:

- Which sustainable water occupations are expected to have significant future growth beyond any growth in the water-related industries?
- What level of education and experience is required to gain employment in these occupations?
- What are the wages and the level of union representation in these occupations?
- What are the demographics of the current workforce in sustainable water occupations?
- In which occupations are workers required to have unique skills in order to be able to work on sustainable water projects?
- What educational pathways and barriers may exist to workers from disadvantaged communities seeking employment in these occupations?

We focus on occupations for which at least 100,000 job openings are projected for the year 2020. This is the threshold used by the Occupational Information Network (O\*NET) for its Bright Outlook status.

The level of education and experience required for workers to access employment can be a barrier or a pathway, depending on the accessibility of educational opportunities that match time availability, language, cost, and prerequisites to the worker. The appropriate level of education and experience also depends on aspirations of the prospective workers. An occupation that requires higher education may be completely appropriate for a community college student setting a ten-year goal, whereas an adult parent with little time to go back to school may be looking for a shorter pathway into an occupation with family-supporting wages.

Twenty-seven sustainable water-related occupations have more than 100,000 job openings projected for 2020 in the overall economy and have relatively accessible education and experience requirements consistent with job zones 1 through 3 as defined by O\*NET. Nine of these occupations require little or no previous work experience or education (job zone 1); eight require some experience and education (job zone 2); and ten require experience and some formal education (job zone 3).

Of the twenty-seven sustainable water-related occupations with a high number of projected openings, half have median wages above the national median wage of \$16.57 per hour. Of those in job zone 1, the median hourly wage ranges from \$10.50 to \$14.50. In job zone 2, median hourly wage ranges from the \$11.50 earned by laborers and freight movers to the \$20 of operating engineers. Median wages of occupations in job zone 3 vary widely, with recreation workers and maintenance and repair workers earning \$10.50 and \$17, respectively, and business operations specialists and agricultural managers earning more than \$30 per hour.

Unionization in these occupations varies from the low 4–7 percent of farmworkers and recreation workers to 20 percent of construction workers and plumbers. For the management-level occupations, union representation is not applicable, but for occupations such as brownfield site manager, business operations specialist, and first-line office supervisor, workers may be eligible for union representation. These latter three occupations are notable because they have low union representation yet have among the highest median hourly wages. The occupations with higher levels of union representation are also among those with extremely low percentages of female workers.

The gender makeup of the workforce in these sustainable water occupations suggests a dividing line between clerical occupations and those that involve managerial or manual labor roles. For all but four of the fifteen occupations for which worker demographic data are available, the percentage of female workers is well below the national average of 47 percent. The four occupations with an above-average number of female workers are office clerk; receptionist and information clerk; bookkeeping, accounting, and auditing clerk; and business specialist, all of which are at least two-thirds women.

The racial makeup of workers in sustainable water occupations ranges from the predominantly white agricultural managers to the disproportionately Latino and African American laborers and truck drivers. Latino, African American, and Asian American workers constitute 30 percent of US workers and make up a similar proportion of workers in clerical occupations and carpenters. These workers are underrepresented in positions as farmers, ranchers, and other agricultural managers (6 percent); general and operations managers (17 percent); bookkeeping, accounting, and auditing clerks (20 percent); electricians (22.5 percent); operating engineers and other construction equipment operators (22 percent); and business operations specialists (25 percent).

The underrepresentation of people of color working as agricultural managers and general managers is concerning, given that these occupations are the two of the highest-paid sustainable water occupations that do not require advanced degrees. Agricultural managers and general managers are projected to have 235,000 and 410,000 openings in 2020 and currently have median hourly wages of \$31 and \$45.75, respectively.

Ten sustainable water occupations are projected to have more than 100,000 job openings by 2020 and require higher education and experience consistent with job zones 4 and 5. These occupations tend to have higher median wages and lower percentages of women, workers of color, and union representation than those requiring less education and training. Median hourly wages range from the \$21 and \$22 earned by executive secretaries and graphic designers to above \$35 for sales representatives of wholesale products and manufacturers of technical products, civil engineers, management analysts, and construction managers. Women represent less than half the national average percentage of the workforce in positions as construction managers, cost estimators, and civil engineers, and women are also underrepresented as chief executives and manage-

ment analysts. Union representation among these occupations is expectably low, considering that they are commonly management-level positions. Chief executives are the only occupation categorized in job zone 5, requiring the highest level of education and experience, and receive a median wage of \$80 hourly.

## Conclusions

The United States faces a complex set of water-related challenges that can be addressed only with a greater commitment to invest in sustainable solutions. Failure to rise to this challenge will leave crumbling infrastructure, contaminated waterways, and water shortages that threaten public health, economic growth, and ecosystems in myriad ways. Sustainable approaches take advantage of the potential for decentralized facilities; efficient technologies; flexible public, private, and community-based institutions; innovative economics; and human capital. These solutions can be grouped into five major strategies: urban water conservation and efficiency, stormwater management, restoration and remediation, alternative water sources, and agricultural water efficiency and quality.

The types of jobs involved in implementing sustainable water strategies cover a broad range of occupations. Our full analysis (Moore et al. 2013) identified 136 occupations involved in the work of achieving more sustainable water outcomes in agriculture, urban residential and commercial settings, restoration and remediation, alternative water sources, and stormwater management.

The extent of employment created by sustainable water practices is substantial. The data available point to 10–15 jobs per \$1 million invested in alternative water supplies; 5–20 in stormwater management; 12–22 in urban conservation and efficiency; 14.6 in agricultural efficiency and quality; and 10–72 jobs per \$1 million invested in restoration and remediation. The view that environmental conservation produces net job losses is not supported by any of the data on sustainable water projects.

The potential for job creation through implementation of sustainable water strategies has been largely ignored by policy makers, scholars, and practitioners, with the efforts on green jobs mostly limited to energy efficiency and renewable energy activities. This has left a gap in understanding and action on these opportunities.

Many of the occupations involved in sustainable water projects are also projected to have high demand in the overall economy. Thirty-seven sustainable water occupations are projected in the overall economy to have more than 100,000 job openings by 2020. Workers trained to advance water sustainability in these occupations will likely experience high demand and have the competitive edge of holding green skills. The high number of workers who will move into these occupations also means that there may be a growing demand for occupational training, creating an opportunity to train a new generation with the green skills that will make their sector more sustainable.

Numerous sustainable water occupations are accessible to workers without advanced degrees. Twenty-seven of the thirty-seven occupations projected to have 100,000 job openings by 2020 generally require on-the-job training, with some requiring previous experience and associate's degrees or technical training but not graduate degrees. This translates to a more feasible pathway to employment for adults without formal education beyond high school.

While data are limited, the existing training and education programs preparing work-



ers with the skills needed in sustainable water fields appear nascent and small in scale. Conventional educational and job training resources such as community colleges and union apprenticeships are only beginning to integrate green skills into their water-related occupational training. And the link to disadvantaged communities is even more tenuous. Our analysis identified fewer than a dozen independent nonprofit organizations in the United States that are providing disadvantaged communities with job training and certification for sustainable water-related careers.

Existing programs linking disadvantaged communities to sustainable water opportunities face multiple challenges in designing and implementing programs, meeting the scale of need, and placing program graduates. Programs have difficulty matching training to actual labor demand for particular occupations and skills. Certifications and licensing related to sustainable water occupations too often are accepted in too small a geographic area or too narrow an industry to provide workers and employers with the needed level of confidence in their value.

Existing training programs have also developed promising strategies for connecting disadvantaged communities to sustainable water jobs. Hybrid models that both train and hire workers through coordinated business and nonprofit branches have found greater success in placing graduates and maintaining stable funding. Organizations with contracts to provide operation and maintenance services for public and private entities have also found a more stable source of funding and practical work experience for participants. However, training programs are unlikely to achieve substantial economic improvements for disadvantaged communities unless they are coupled with policy that increases and targets demand for new workers.

## Recommendations

The research points to several action areas in research, policy, and community organizing that would facilitate greater opportunities in sustainable water jobs. These opportunities can best be understood, planned for, and taken advantage of with future efforts that consider the following recommendations.

### Improve and Expand Data Collection and Research

Agencies managing state revolving funds and other state and federal funding programs should require grantees and loan recipients to submit information on job types and numbers using a template aligned with standard occupational codes.

Models for financing the ongoing operation and maintenance of sustainable water projects must be developed, piloted, and refined to ensure that desired environmental and economic outcomes are sustained. This research should start with the lessons of leading efforts at the local scale, such as those related to stormwater in Portland and Philadelphia.

Workforce development and training organizations must increase their capacity to track and evaluate job placement and other program outcomes to strengthen the feedback loop that will improve programming and broader understanding of best practices.

Economic research projecting job generation of sustainable water projects should incorporate data on the occupations and types of firms specific to these projects, as in some cases they differ significantly from those involved in conventional water project industries.

## Integrate Sustainable Job Priorities into Policy and Planning

Water utilities, state water agencies, planning departments, and other public entities funding and managing sustainable water projects should implement “high-road” strategies that consider job quality, training, and targeted hiring as an integral component of project design and implementation. This should include local hiring and minority hiring requirements and incentives that increase contracting with and hiring of individuals from local and disadvantaged communities.

Considering the strong interdependence between water and energy use, policy and workforce efforts to take advantage of the win-win solutions at this nexus should be strengthened.

Better planning for and investment in financing of the ongoing operation and maintenance of sustainable water projects is needed to ensure that the maximum environmental and employment benefits are realized.

## Support Community Programs and Partnerships

Unions, community-based organizations, and environmental advocates should join together in envisioning and promoting policies and funding programs that incorporate high-road work opportunities into sustainable water projects.

Workforce development and training organizations must build stronger partnerships with unions and employers to ensure that training is well aligned with emerging occupations and skill sets, and they must increase placement rates for program participants.

Training programs seeking to improve access of disadvantaged communities to sustainable water jobs should focus on occupations that are projected to have high labor demand in the overall economy. Data on the labor demand generated by sustainable water projects alone is not robust enough to justify training workers for these jobs unless their training will also prepare them to qualify for conventional occupations in demand.

Partnerships between industry associations, labor unions, and training programs are needed to develop, deliver, and evaluate and update standardized training and certification that reflects actual skills needed and that is accessible to disadvantaged communities. This should include the creation of a centralized, up-to-date clearinghouse of training curriculum and certification standards.

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# Hydraulic Fracturing and Water Resources

## What Do We Know and Need to Know?

Heather Cooley and Kristina Donnelly

According to some energy analysts, natural gas is “poised to enter a golden age” as a result of the availability and development of large volumes of new sources of unconventional natural gas, including coal bed methane, tight gas, and shale gas. Historically, natural gas production from unconventional reserves has been limited. In 2010, unconventional natural gas accounted for about 14 percent of total global natural gas production. The International Energy Agency (IEA) projects that by 2013 annual production from unconventional sources will triple and will represent about one-third of all natural gas production (IEA 2012). While North America, especially the United States and Canada, dominated unconventional gas production in 2010, growth in unconventional gas production is expected widely around the world (IEA 2012). China, in particular, is projected to experience major increases in production, becoming the second-largest producer after the United States. While shale gas accounts for the vast majority of growth in natural gas production, some growth is also projected for tight gas.

Natural gas is typically classified as conventional or unconventional. Conventional natural gas is generally held as a pocket of gas *beneath* a rock layer with low permeability and flows freely to the surface once the well is drilled. By contrast, unconventional natural gas is more difficult to extract because it is trapped *in* rock with very low permeability. Extracting natural gas from unconventional sources is more complex and costly than conventional natural gas recovery. Technological improvements, however, have made extraction from unconventional sources more economically viable in recent years. In particular, the combination of horizontal drilling and hydraulic fracturing has greatly increased the productivity of natural gas wells. These new techniques have also raised concerns about the adverse environmental and social consequences of these practices, especially effects on water resources.

To date, much of the debate about hydraulic fracturing has centered on the use of chemicals and concerns that these chemicals could contaminate drinking water. In response, numerous states have passed or are considering regulations requiring natural gas operators to disclose the chemicals used during well injection. Additionally, the Groundwater Protection Council and the Interstate Oil and Gas Compact Commission



have established a public website that allows companies to voluntarily disclose water and chemical usage for wells since January 2011 that have been hydraulically fractured, although it is of note that these data are not subject to third-party verification and are not in a format that can be searched or aggregated.

The debate has been particularly controversial in the United States, where the majority of unconventional natural gas development has been concentrated. To better identify and understand the key issues, the Pacific Institute conducted extensive interviews with a diverse group of stakeholders, including representatives from state and federal agencies, academia, industry, environmental groups, and community-based organizations from across the United States. This chapter provides a short summary of the key issues identified in the interviews and in an initial assessment and synthesis of existing research. It especially examines the impacts of hydraulic fracturing and unconventional natural gas extraction on water resources and identifies areas in which more information is needed. More detail is available in the full report (Cooley and Donnelly 2012).

## Overview of Hydraulic Fracturing

Hydraulic fracturing, or fracking, refers to the process by which fluid is injected into wells under high pressure to create cracks and fissures in rock formations that improve the production of these wells. These fissures can extend more than 300 meters (1,000 feet) from the well (Veil 2010). The fracturing fluid consists of water, chemical additives, and a propping agent. The propping agent—typically sand, ceramic beads, or another incompressible material—holds open the newly created fissures to allow the natural gas to flow more freely. In the first few days to weeks after completion of the fracturing process, the well pressure is released and some of the fracturing fluid (referred to as flowback) flows back to the surface through the well bore. Some unknown volume of fracturing fluid, along with its chemical additives, remains underground. Over longer time periods, any water naturally present in the ground (referred to as produced water) continues to flow through the well to the surface. The flowback and produced water, which can be considerably saltier than seawater and contain a variety of other contaminants (IOGCC and ALL Consulting 2006), are typically stored on-site in tanks or pits before reuse, treatment, or disposal. There are varying and conflicting reports on whether and to what extent wells will be fracked multiple times over their productive life (Nicot et al. 2011), although this will likely depend on local geology, spacing of wells, and natural gas prices.

Hydraulic fracturing was first developed in the early twentieth century but was not commercially applied until the mid- to late 1940s. Although initially developed to improve the production of oil and gas wells, hydraulic fracturing has been used in other applications, including development of drinking water wells (NHDES 2010), disposal of wastes, and enhancement of electricity production from geothermal energy sources. Hydraulic fracturing is standard practice for extracting natural gas from unconventional sources, including coal beds, shale, and tight sands, and is increasingly being applied to conventional sources to improve their productivity. While the process is the same, the various applications of hydraulic fracturing differ in their water requirements, the amount and types of chemicals employed, and the quantity and quality of wastewater generated.



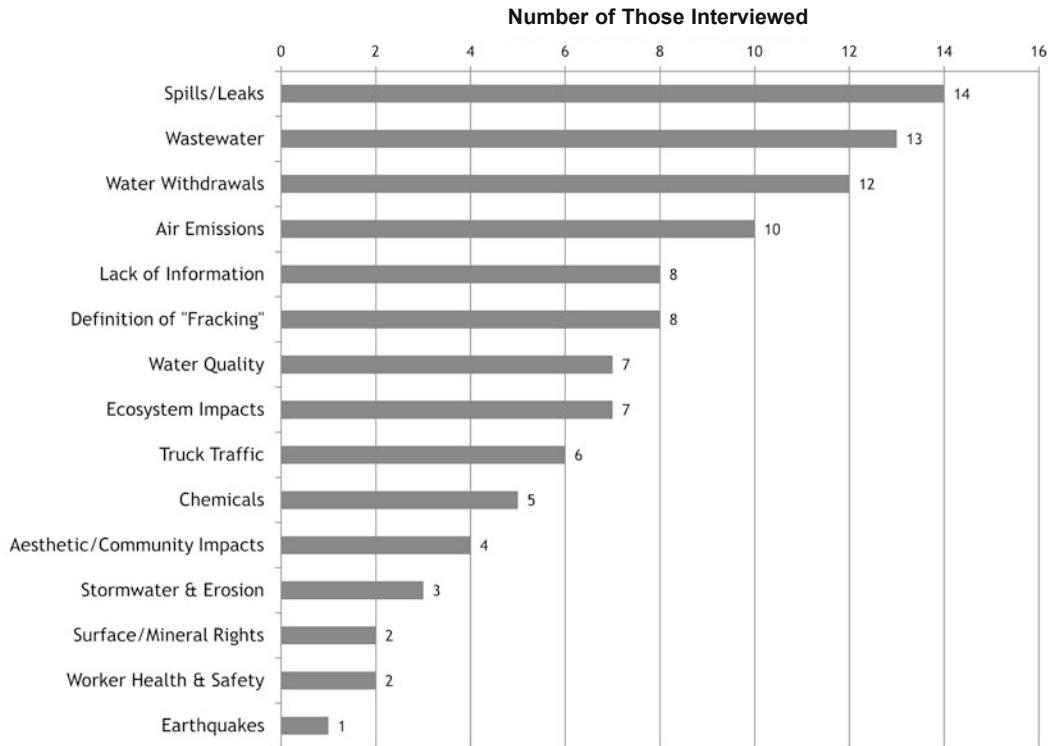
We note that there is no single definition of “hydraulic fracturing.” Some, including industry representatives, define hydraulic fracturing narrowly, referring only to the process by which fluids are injected into a well bore. They argue that some of the challenges, such as wastewater disposal, spills, and leaks, are common to all oil and gas operations and therefore are not specifically associated with hydraulic fracturing. Others, however, define the issue more broadly to include impacts associated with well construction and completion, the hydraulic fracturing process itself, and well production and closure (US EPA 2011c; ProPublica 2012). For these groups, hydraulic fracturing and unconventional natural gas production are synonymous because hydraulic fracturing has allowed for the development of these unconventional natural gas resources. Without hydraulic fracturing, shale gas production would be far more limited. For the purposes of this analysis, we use a broader definition of hydraulic fracturing to include impacts associated with well construction and completion, the hydraulic fracturing process itself, and well production and closure (Cooley and Donnelly 2012).

## Concerns Associated with Hydraulic Fracturing Operations

Hydraulic fracturing has generated a tremendous amount of controversy. There are daily media reports from outlets across the United States, Canada, South Africa, Australia, France, England, and elsewhere about environmental, social, economic, and community impacts. In an effort to identify the key issues, the Pacific Institute interviewed sixteen representatives of state and federal agencies, academia, industry, environmental groups, and community-based organizations in the United States. Their responses are summarized in figure 4.1. Although the sample size was relatively small, the interviews were extensive, and the detailed responses from these diverse stakeholders are similar across the spectrum and indicative of the broad range of concerns associated with hydraulic fracturing raised in other forums.

All of the interviewees indicated that impacts on the availability and quality of water resources were among the primary concerns associated with hydraulic fracturing operations. Water-related findings of the interviews include the following:

- Spills and leaks were the most commonly cited concern, with fourteen of the sixteen people interviewed expressing concern.
- Thirteen of the interviewees considered wastewater treatment and disposal to be key challenges. One industry representative noted that wastewater management was perhaps a larger issue than chemical usage.
- Three-quarters of the interviewees were concerned about the water requirements of hydraulic fracturing. This concern was not limited to interviewees in the most arid regions; rather, it was expressed by people working in various regions across the United States. In some cases, the concern was directly related to the effects of large water withdrawals on the availability of water for other uses. In other cases, concern was related to how large withdrawals would affect water quality.



**FIGURE 4.1 KEY CONCERNS IDENTIFIED BY INTERVIEWEES**

*Note:* Results are based on interviews with sixteen representatives of state and federal agencies, academia, industry, environmental groups, and community-based organizations.

- Nearly half of the interviewees explicitly identified water quality as a key issue. Many of the other concerns mentioned, such as spills, leaks, and wastewater management, also imply concern about water quality. One interviewee expressed concern about surface water contamination associated with air emissions.
- Less than one-third of those interviewed specifically identified chemical usage and the associated risk of groundwater contamination as key issues, although many more expressed concern about groundwater contamination more broadly. Some of the interviewees thought that with so much attention given to chemical usage, inadequate attention is given to some of the other issues, such as wastewater disposal and methane migration, which may ultimately pose more serious risks.
- One issue identified in our interviews that was not directly related to environmental impacts was the overall lack of information, with half of those interviewed describing it as a key problem. Several commented on the complexity of the issues and the difficulty of explaining the technology to the general public.

## Water Challenges

In this section, we summarize the available information on the following key water-related concerns identified by those interviewed: (1) water withdrawals; (2) groundwater contamination associated with well drilling and production; (3) wastewater management; (4) truck traffic and its impacts on water quality; (5) surface spills and leaks; and (6) stormwater management. This information is largely drawn from a review of the academic and gray literature and from media reports. Our focus throughout this chapter is on shale gas, although we discuss other unconventional natural gas sources for which information is readily available. Here, we evaluate the impacts associated with well construction and completion, the hydraulic fracturing process itself, and well production and closure.

### Water Withdrawals

The drilling and fracking of a horizontal shale gas well uses large volumes of water, although the amount of water required is both variable and uncertain. The US Environmental Protection Agency (EPA) reports that fracturing of shale gas wells requires between 2.3 million and 3.8 million gallons of water per well (US EPA 2011c).<sup>1</sup> An additional 40,000–1,000,000 gallons is required to drill the well (GWPC and ALL Consulting 2009). This is considerably more water than is required for conventional gas wells and even for coal bed methane because the wells to access shale gas are deeper. Water requirements for hydraulic fracturing of coal bed methane, for example, range from 50,000 to 350,000 gallons per well (US EPA 2011c), although we note that these estimates may be outdated and may not include the application of more recent water-intensive processes.

New data, however, suggest that the water requirements for fracking of shale gas wells might be both much larger and more variable than is reported by the EPA (table 4.1). For example, Thomas Beauduy (2011) of the Susquehanna River Basin Commission finds that fracking in the Marcellus Shale region requires, on average, about 4.5 million gallons per well. Water requirements can be even greater within Texas's Eagle Ford Shale area, where fracking can use up to 13 million gallons of water per well (Nicot et al. 2011), with additional water required to drill the wells. These data highlight the significant variation among shale formations, driven in part by differences in the depth to the target formation, even among wells within close proximity of one another (Nicot et al. 2011). Estimation of water requirements is further complicated by uncertainty about how many times a single well will be fracked over the course of its productive life and by limited publicly available data.

Water for hydraulic fracturing is typically withdrawn from one location or watershed over several days (Veil 2010). Additionally, in some cases, the water is taken from "remote, often environmentally sensitive headwater areas" (Beauduy 2011, 34), where even small withdrawals can significantly affect the flow regime. As a result, while fracking may account for a small fraction of a state's or even a basin's water supply, there can be more severe local impacts. Additionally, much of the water injected underground either is not

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1. While *The World's Water* volumes prefer to consistently use metric units, much of the research on water and fracking discussed here is based on work done in the United States, so we have opted to report the original units. For reference, one cubic meter contains 264.2 gallons. Additional conversion factors can be found in the Water Units, Data Conversions, and Constants section near the end of this book.

**TABLE 4.1** Water Requirements for Hydraulic Fracturing by Shale Plays in Texas

| Shale Play                                | Water Requirements (Gallons per Well) |                |              |
|---|---------------------------------------|----------------|--------------|
|   | Low Value                             | Median Value   | High Value   |
| Barnett Shale                             | < 1 million                           | 2.6 million    | > 8 million  |
| Haynesville and Bossier Shales            | < 1 million                           | 5.5–6 million  | > 10 million |
| Eagle Ford Shale                          | 1 million                             | 6–6.5 million  | 13 million   |
| Woodford, Pearsall, and Barnett-PB Shales | < 1 million                           | 0.75–1 million | < 5 million  |

Source: Estimated on the basis of data in Nicot et al. (2011).

recovered or is unfit for further use once it is returned to the surface, usually requiring disposal in an underground injection well. This water use represents a consumptive use if it is not available for subsequent use within the basin from which it was extracted. In some cases, water is treated and reused for subsequent fracking jobs, although this is still fairly uncommon, and no national estimate on the prevalence of this practice is available (US GAO 2012).

There is some evidence that the water requirements for hydraulic fracturing are already creating conflicts with other uses and could constrain future natural gas production in some areas. For example, in Texas, a major drought in 2011 prompted water agencies in the region to impose mandatory reductions in water use. Water agencies, some of which sold water to natural gas companies, indicated they might have to reconsider these sales if the drought persisted. Natural gas companies also tried to purchase water from local farmers, offering \$9,500 to nearly \$17,000 per million gallons of water (Carroll 2011). Likewise, at an auction of unallocated water in Colorado during the spring of 2012, natural gas companies successfully bid for water that had previously been largely claimed by farmers, raising concerns among some about the impacts on agriculture in the region and on ecosystems dependent on return flows (Finley 2012).

Concerns over water availability are not limited to drier climates. Pennsylvania is generally considered a relatively water-rich state. However, in August 2011, thirteen previously approved water withdrawal permits in Pennsylvania's Susquehanna River basin were temporarily suspended because of low stream levels; eleven of these permits were for natural gas projects (Susquehanna River Basin Commission 2011). While parts of the state were abnormally dry, the basin was not experiencing a drought at the time, suggesting that natural gas operations are already creating conflict with other water uses under normal conditions. In many basins, the application of fracking is still in its infancy and continued development could dramatically increase future water requirements and further intensify conflicts with other uses.

While water withdrawals directly affect the availability of water for other uses, water withdrawals can also affect water quality. For example, withdrawals of large volumes of water can adversely affect groundwater quality through a variety of means, such as mobilizing naturally occurring substances, promoting bacterial growth, causing land subsidence, and mobilizing lower-quality water from surrounding areas. Similarly, withdrawals from surface water can affect the hydrology and hydrodynamics of the source water (US EPA 2011c), and reductions in the volume of water in a surface water body can reduce the ability to dilute municipal or industrial wastewater discharges.

Given the proposed expansion of drilling in many regions, conflicts between natural gas companies and other users are likely to intensify. More and better data are needed on

the volume of water required for hydraulic fracturing and the major factors that determine the volume, such as well depth and the nature of the geologic formation. Additional analysis is needed on the cumulative impacts of water withdrawals on local water availability, especially given that water for hydraulic fracturing can be a consumptive use of water. Finally, more research is needed to identify and address the impacts of these large water withdrawals on local water quality. This work must be done on a basin-by-basin level.

## Groundwater Contamination Associated with Well Drilling and Production

Groundwater contamination from shale gas operations can occur through a variety of mechanisms. Natural gas is located at various depths, often (but not always) far below underground sources of drinking water. A well bore, however, must sometimes be drilled through these drinking water sources in order to access the gas. Chemicals and natural gas can escape the well bore if it is not properly sealed and cased. While there are state requirements for well casing and integrity, accidents and failures still occur, as was demonstrated by an explosion in Dimock Township, Pennsylvania (see box 4.1 for more information). Old, abandoned wells can also potentially serve as migration pathways (US EPA 2011b) for contaminants to enter groundwater systems. States have estimated that there are roughly 150,000 undocumented and abandoned oil and gas wells in the United States (IOGCC 2008). Natural underground fractures, as well as those potentially created during the fracturing process, could also serve as conduits for groundwater contamination (Myers 2012). Finally, coal bed methane is generally found at shallower depths and in closer proximity to underground sources of drinking water, and therefore accessing natural gas from this source might pose a greater risk of contamination.

Much of the debate about groundwater contamination—and some of the most striking visual images showing water and burning natural gas coming out of home faucets—is related to reports of methane contamination in drinking water. Nearly 90 percent of shale gas is composed of methane. A study in New York and Pennsylvania found that methane levels in drinking water wells in active gas production areas (less than 1 kilometer, or about five-eighths of a mile, from wells) were seventeen times higher than in those outside of active gas production areas. An isotopic analysis of the methane suggests that the methane in the active gas production areas originated from deep underground (Osborn et al. 2011).

Methane is not currently regulated in drinking water, although it can pose a public health risk. Robert B. Jackson of Duke University and his colleagues (2011) note that methane is not regulated in drinking water because it is not known to affect water's potability and does not affect its color, taste, or odor. Methane, however, is released from water into the atmosphere, where it can cause explosions, fires, asphyxiation, and other health or safety problems. The 2009 New Year's Day drinking water well explosion in Dimock, Pennsylvania, for example, was due to methane buildup associated with natural gas production. The US Department of the Interior recommends taking mitigative action when methane is present in water at concentrations exceeding 10 milligrams per liter (mg/l) (Elt Schlager et al. 2001). A recent study, however, notes that research on the health effects is limited and recommends that "an independent medical review be initiated to evaluate the health effects of methane in drinking water and households" (Jackson et al. 2011, 5).

#### **BOX 4.1** Dimock Township, Pennsylvania

Dimock Township is located in northeastern Pennsylvania's Susquehanna County, the heart of some of the most productive drilling areas in the Marcellus Shale play. On New Year's Day in 2009, a residential water well in Dimock exploded as a result of methane buildup in the well. Further investigation found methane gas in drinking water wells and in the headspaces of drinking water wells that provide water to local residents. These water wells were located near drilling wells owned and operated by Cabot Oil & Gas Corporation, and in February 2009 the Pennsylvania Department of Environmental Protection (DEP) issued a notice of violation against the company, which stated that Cabot had discharged natural gas, failed to properly cement casings, and failed to prevent natural gas from entering fresh groundwater (PA DEP 2009). Pennsylvania has what is called a "rebuttable presumption" for drinking water pollution, whereby the oil and gas operator is assumed to be responsible for drinking water pollution that occurs within 1,000 feet and within six months of a drilling operation, unless the company can provide baseline data to refute the claim. In the absence of baseline data, the company is required to replace the water that has reportedly been lost or degraded (025 Pa. Code §78.51). Cabot was ordered to install methane detectors in nine homes and provide drinking water to four homes in the affected area (Lobins 2009).

The DEP conducted an investigation into the methane contamination and determined that Cabot was responsible for polluting thirteen drinking water wells, which was later revised to include an additional five wells (PA DEP 2010). Other violations were found, including several cases of improper or insufficient casings and excessive borehole pressure. In November 2009, the DEP entered into a consent order and settlement agreement with Cabot that required the company to permanently restore or replace water supplies for the affected homes and fix any wells identified to have improper or insufficient casing (PA DEP 2009). Cabot was also ordered to cease drilling in the area, and the company was later completely banned from fracking new or existing wells until authorized by the DEP.

Six well owners signed agreements with Cabot and had water treatment systems installed, including methane venting systems, although most were still using bottled water because they lacked confidence in the treatment systems. Twelve well owners refused to sign agreements with Cabot and took part in a civil suit. Cabot continued to provide temporary water service to these twelve homes. In October 2011, however, the DEP formally stated that Cabot had fully complied with the consent order and was no longer required to provide drinking water to Dimock residents (Legere 2011). The DEP allowed Cabot to stop providing water to the twelve homes that had not installed the water treatment systems because Cabot had provided a solution and the well owners had been given sufficient time to sign the agreement (US EPA 2011a).



Despite a subsequent announcement in December 2011 from the US Environmental Protection Agency (EPA) that Dimock water was safe to drink, local residents submitted results from their own testing, which indicated that the water was polluted (McAllister and Gardner 2012). In January 2012, the EPA began sampling water at sixty-four homes in the area and supplying drinking water to four households that had shown elevated levels of contaminants that pose a health concern (US EPA 2012a). Results of the testing indicated that although five homes showed elevated levels of arsenic, barium, and manganese—all naturally occurring substances not necessarily linked to fracking—the private wells did not have contaminant levels that posed a health concern or exceeded the safe range for drinking water (US EPA 2012b). The EPA's testing also concluded that elevated levels of methane were present in some of the wells, although Cabot disputes whether the methane resulted directly from the drilling.

There is also significant concern about groundwater contamination from hydraulic fracturing fluids, although limited data are available. According to draft reports released in December 2011 and September 2012, however, EPA testing detected the presence of chemicals commonly associated with hydraulic fracturing in drinking water wells in Pavillion, Wyoming (US EPA 2011b, 2012c). Encana Oil and Gas Inc., the company responsible for the natural gas wells, disputed the findings of the study, criticizing the EPA's testing methods and assumptions as well as the processes used to construct the monitoring wells and analyze the results (see box 4.2 for additional information).

Real analysis of the likelihood and extent of groundwater contamination is hindered by a lack of baseline data and confusion about definitions. Without baseline data, it is difficult to confirm or deny reports of groundwater contamination. In 2009, regulatory officials submitted signed statements to the United States Congress asserting that there were no confirmed cases of groundwater contamination associated with the hydraulic fracturing process (NYSDEC 2011). Likewise, an American Petroleum Institute report states that “there are zero confirmed cases of groundwater contamination connected to the fracturing operation in one million wells hydraulically fractured over the last 60 years” (American Petroleum Institute 2010). Yet documented cases in Dimock, Pennsylvania; possibly in Pavillion, Wyoming; and elsewhere provide evidence of groundwater contamination. In these cases, however, the contamination was associated with well casing integrity and wastewater disposal, not the process of injecting fluids underground *per se*—and so the issue is clouded by definitions.

## Wastewater Management

Natural gas drilling also produces liquid waste. After completion of the fracturing process, well pressure is released and some of the fracturing fluid, along with naturally occurring substances, returns to the surface through the well bore. This mixture, commonly referred to as flowback, returns to the surface over the course of several hours to weeks

after the fracturing process is completed (GWPC and ALL Consulting 2009). The amount of fracturing fluid that is actually recovered has not been well quantified and is likely to be highly variable, depending on local formation characteristics. While various sources quote estimates for the fracture fluid recovery rate (Beauduy 2011; Hoffman 2010; US EPA 2011c), a report by the Groundwater Protection Council (GWPC) and ALL Consulting (2009, 67) notes that “it is not possible . . . to differentiate flow back water from natural formation water.” Thus, these estimates are likely based on assumptions rather than on actual data.

In addition to flowback, natural gas operations may generate produced water. Produced water “is any water that is present in a reservoir with the hydrocarbon resource and is produced to the surface with the crude oil or natural gas” (Veil et al. 2004, 1). Produced water can consist of natural formation water, that is, groundwater; naturally occurring substances, such as radioactive materials, metals, and salts; and even some residual fracturing fluid. The physical and chemical properties of produced water depend on the local geology (Veil et al. 2004). Flowback and produced water often have very high levels of total dissolved solids (TDS), in some cases exceeding 200,000 mg/l (Kargbo et al. 2010), nearly three times higher than seawater. In a recent report, the US Government Accountability Office (US GAO 2012) found that the volume of produced water generated by a given well varies depending on the type of hydrocarbon produced, the geographic location of the well, and the method of production.

Wastewater resulting from natural gas production is temporarily stored in pits, embankments, or tanks at the well site and then transported, usually via pipeline or truck, to a disposal site. Pits can lead to groundwater contamination, particularly if the pits are unlined or if the integrity of the lining is compromised. In Pavillion, Wyoming, for example, high concentrations of benzene, xylenes, and other organic compounds associated with gasoline and diesel were found in groundwater samples from shallow monitoring wells near pits (US EPA 2011b) (see box 4.2 for additional information on Pavillion, Wyoming).

Wastewater from natural gas operations can be disposed of using a variety of methods. In most areas, the primary way to dispose of wastewater from natural gas operations is by injection into a Class II well.<sup>2</sup> In 1988, the EPA made a determination that oil and gas waste is exempt from hazardous waste regulations under the Resource Conservation and Recovery Act of 1976. As a result, oil and gas wastes can be disposed of in Class II wells rather than in Class I hazardous waste wells.<sup>3</sup> Class II wells are subject to less stringent requirements than are Class I wells, and therefore disposal in Class II wells presents a greater risk of contaminating groundwater and triggering earthquakes than in Class I wells (Hammer and VanBriesen 2012).

The EPA estimates that there are about 144,000 Class II wells in operation in the United States, about 20 percent of which are disposal wells for brine and other fluids from oil and natural gas production. A Class II well might be an on-site well operated by the natural gas company or, more commonly, an off-site well operated by a commercial third

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2. An injection well is a site where fluids, such as water, wastewater, brine, or water mixed with chemicals, are injected deep underground into porous rock formations, such as sandstone or limestone, or into or below the shallow soil layer. Injection wells are used for long-term storage, waste disposal, enhancement of oil production, mining, and prevention of saltwater intrusion.

3. States can adopt more stringent regulations if desired.

## **BOX 4.2** Pavillion, Wyoming

The Pavillion gas field is located in central Wyoming in the Wind River basin, the upper portion of which serves as the primary source of drinking water for the area. Oil and gas exploration began in the area in the 1950s and increased dramatically between 1997 and 2006. The Pavillion gas field is composed of a mix of sandstone and shale; at the time of this writing, the field had 169 vertical gas production wells. Encana Oil and Gas Inc. owns the rights to the Pavillion field and began drilling in the area in 2004 after acquiring another drilling company. Encana has not drilled any new wells since 2007 (US EPA 2011b).

In 2008, domestic well owners began complaining about taste and odor problems, and residents believed these issues to be linked to nearby natural gas activities. In response to complaints from local residents, the EPA initiated an investigation, collecting four rounds of water samples from thirty-five domestic wells and two municipal wells between 2009 and 2011. The EPA also installed two deep monitoring wells in 2010 and took two rounds of samples from each of these wells. According to a draft report released in December 2011, EPA testing found chemicals commonly associated with hydraulic fracturing in drinking water wells in the area (US EPA 2011b). The EPA also found that concentrations of dissolved methane in the domestic wells were higher near the gas production wells. The report concluded that nearby drilling activities had “likely enhanced gas migration” (US EPA 2011b).

Encana is disputing the EPA’s preliminary findings. According to Encana, methane is “commonly known” to occur in the shallow groundwater aquifers in the area (Encana Oil and Gas Inc. 2011b) and is expected, given that the Pavillion gas field is also quite shallow (Encana Oil and Gas Inc. 2011a). Furthermore, Encana argues that Pavillion has always had poor water quality, referencing historical reports that levels of sulfate, total dissolved solids, and pH “commonly exceed state and federal drinking water standards” (Encana Oil and Gas Inc. 2011b). A 2011 report from the Wyoming Water Development Commission confirms that Pavillion’s water is generally of poor quality and has often had taste and odor problems. However, the Commission states that nearly all of the private wells meet federal and state drinking water standards (James Gores & Associates 2011). One of the challenges associated with the EPA’s analysis is that baseline data are not available to support claims about impacts on groundwater quality.

Encana continues to dispute the findings of the study, criticizing the EPA’s testing methods and assumptions as well as the processes used to construct the monitoring wells and analyze the results (Gardner 2012). Although the EPA has indicated its intention to submit the report to scientific review, the comment period on the draft report has been extended several times, most recently until September 2013, while the EPA collects and distributes new information and meets with stakeholders (*Federal Register* 2013).

party (Veil 2010). In some cases, wastewater receives partial treatment prior to disposal to avoid clogging the well (Hammer and VanBriesen 2012).

With the proper safeguards, disposing of wastewater by underground injection reduces the risk of releasing wastewater contaminants into the environment; however, it increases the risk of earthquakes and can require the transport of wastewater over long distances (Hammer and VanBriesen 2012; Keranen et al. 2013). Some states do not have sufficient injection well capacity to handle the volume of wastewater generated from expanding hydraulic fracturing operations, so wastewater is transported to neighboring states for disposal (Veil 2010). For example, as of late 2010, Pennsylvania had only seven active disposal wells, and some wastewater had been hauled to Ohio, West Virginia, and other states for disposal (STRONGER 2010; Veil 2010).<sup>4</sup>

Flowback and produced water have been treated at municipal wastewater treatment plants (GWPC and ALL Consulting 2009), although this practice is both uncommon and controversial. Municipal systems are not typically designed to handle this type of wastewater, which can potentially disrupt the treatment process and discharge salts and other contaminants into the environment. In 2008 and 2009, TDS levels exceeded drinking water standards along Pennsylvania's Monongahela River, a major source of drinking water that receives discharges from facilities handling wastewater from natural gas production (STRONGER 2010). In 2009, excess TDS, primarily from mining discharges, "wiped out 26 miles of stream" in Greene County, Pennsylvania (STRONGER 2010, 22). In response, regulations for new or expanded facilities that accept oil and gas wastewater, including municipal wastewater treatment plants and centralized treatment plants, were passed in 2010 that set strict monthly discharge limits for TDS, chlorides, barium, and strontium (STRONGER 2010). Municipal wastewater treatment plants in Pennsylvania can still receive wastewater from "grandfathered" natural gas operations, although this has now been virtually eliminated (Hammer and VanBriesen 2012).

Wastewater reuse is becoming more common, driven in large part by the challenges associated with wastewater disposal and in part by the growing difficulty of finding new sources of water for fracking operations. Reusing wastewater for new fracking activities reduces the total volume of water required, helping to minimize impacts associated with water withdrawals. Wastewater can also be reused for irrigation, dust control on unpaved roads, and deicing of roads (US EPA 2011c; Hammer and VanBriesen 2012). In most cases, the wastewater must be treated prior to reuse, but in others it is simply blended with freshwater to bring the levels of TDS and other constituents down to an acceptable range (Veil 2010). Treatment for reuse can occur at the well site using a mobile plant or at a centralized industrial facility. Some downsides of reuse include the need for more on-site storage, energy requirements for the treatment processes, and additional transportation needed to haul wastewater to the treatment plant and among sites. Additionally, concentrated treatment residuals, including brine, must be disposed of in some manner and may require dilution (NYSDEC 2011).

Wastewater treatment and disposal associated with hydraulic fracturing may prove to be a larger issue than some of the other water-related risks. Yet to date there has been little discussion about the risks that wastewater treatment and disposal pose. In some areas, they may physically or economically constrain natural gas operations. Additional work is needed

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4. Applications for at least twenty additional disposal wells are presently before the EPA (STRONGER 2010).

to understand the nature of the risk of wastewater treatment and disposal to human health and the environment and to identify where it may constrain natural gas operations.

## Truck Traffic

Hydraulic fracturing operations generate a large amount of truck traffic. All of the materials and equipment needed for activities associated with hydraulic fracturing, including water and chemicals, are typically transported to the site by trucks (US EPA 2011c). Additionally, wastewater from natural gas operations is usually removed by tanker truck to the disposal site or to another well for reuse. Using information from the natural gas industry, the New York State Department of Environmental Conservation estimates that high-pressure hydraulic fracturing in a horizontal well would require 3,950 truck trips per well during early development of the well field (NYSDEC 2011), two to three times more than is required for conventional vertical wells (see table 4.2). Much of the truck traffic is concentrated over the first fifty days following well development. Truck traffic could be reduced by nearly 30 percent if pipelines were used to move water between sites, although pipelines can create other concerns, such as leaks, spills, and right-of-way controversies.

Truck traffic raises a variety of other water-related social and environmental concerns. Trucks increase wear and erosion on local roads and increase the risk of spills, both of which can pollute local surface water and groundwater. In addition, because so much of new drilling is occurring in rural locations, new roads must be built to accommodate the truck traffic, increasing habitat fragmentation and ecological disturbances.

**TABLE 4.2** Truck Traffic Estimates for Vertical and Horizontal Wells

| Well Pad Activity                         | Horizontal Well |             | Vertical Well |             |
|---|-----------------|-------------|---------------|-------------|
|   | Heavy Truck     | Light Truck | Heavy Truck   | Light Truck |
| Drill pad construction                    | 45              | 90          | 32            | 90          |
| Rig mobilization                          | 95              | 140         | 50            | 140         |
| Drilling fluids                           | 45              |             | 15            |             |
| Non-rig drilling equipment                | 45              |             | 10            |             |
| Drilling (rig crew, etc.)                 | 50              | 140         | 30            | 70          |
| Completion chemicals                      | 20              | 326         | 10            | 72          |
| Completion equipment                      | 5               |             | 5             |             |
| Hydraulic fracturing equipment            | 175             |             | 75            |             |
| Hydraulic fracturing water hauling        | 500             |             | 90            |             |
| Hydraulic fracturing sand                 | 23              |             | 5             |             |
| Produced water disposal                   | 100             |             | 42            |             |
| Final pad preparation                     | 45              | 50          | 34            | 50          |
| Miscellaneous                             | —               | 85          | —             | 85          |
| Total one-way, loaded trips per well      | 1,148           | 831         | 398           | 507         |
| <b>Total vehicle round trips per well</b> | <b>3,950</b>    |             | <b>1,810</b>  |             |

Source: NYSDEC (2011).

Note: Light trucks have a gross vehicle weight rating that ranges from 0 to 14,000 pounds. Heavy trucks have a gross vehicle weight rating in excess of 26,000 pounds. The gross vehicle weight is the maximum operating weight of the vehicle, including the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers, and cargo but excluding any trailers.

## Surface Spills and Leaks

All fossil-fuel extraction activities come with some risk of surface water or groundwater contamination from the accidental or intentional release of waste. In the case of hydraulic fracturing, common wastes of concern include fracking fluid, additives, flowback, and produced water. Fluids released onto the ground from spills or leaks can run off into surface water and seep into groundwater.

Spills can occur at any stage during the drilling life cycle. Chemicals are hauled to the site, where they are mixed to form the fracturing fluid. Accidents and equipment failure during on-site mixing of the fracturing fluid can release chemicals into the environment. Above ground storage pits, tanks, or embankments can fail. Vandalism and other illegal activities can also result in spills and improper wastewater disposal. For example, in Canton Township, Pennsylvania, a January 2012 spill of 20,000 gallons of hydraulic fracturing wastewater is being investigated as “criminal mischief” (Clarke 2012). In a larger incident in March 2012, criminal charges were filed against a waste-hauling company and its owner for illegally dumping millions of gallons of produced water into streams and mine shafts and on properties across southwestern Pennsylvania (Pennsylvania Attorney General 2012). Given the large volume of truck traffic associated with hydraulic fracturing, truck accidents can also lead to chemical and wastewater spills. In December 2011, a truck accident in Mifflin Township, Pennsylvania, released fracking wastewater into a nearby creek (Reppert 2011).

While there are reports of spills and leaks associated with hydraulic fracturing operations, the national extent of the problem is not yet well understood. A recent report from Pennsylvania documented a string of violations in the Marcellus Shale region, many of which could result in surface spills and leaks, including 155 industrial waste discharges, 162 violations of wastewater impoundment construction regulations, and 212 faulty pollution prevention practices (Pennsylvania Land Trust Association 2010), during the thirty-two-month period from January 2008 to August 2010. New research provides documentation of twenty-four cases in six states of adverse health effects on humans, companion animals, livestock, horses, and wildlife associated with natural gas operations, including spills and leaks (Bamberger and Oswald 2012). Additional research is needed on the frequency, severity, cause, and impact of spills associated with hydraulic fracturing.

## Stormwater Management

Stormwater runoff carries substances from the land surface that can be detrimental to water quality and ecosystem health and deposits them into local waterways. While runoff is a natural occurrence, human disturbances to the land surface have increased the timing, volume, and composition of runoff. According to the EPA, a 0.4-hectare (one-acre) construction site with no runoff controls can contribute thirty to forty metric tons of sediment each year, comparable to the runoff from six and one-half hectares (sixteen acres) of natural vegetated meadow (US EPA 2007a; Schueler 1994). Drilling for natural gas contributes to this problem, as the process requires disturbances to the land surface. Modern natural gas drilling requires the clearing of three or more hectares (typically seven to eight acres) per well pad, which includes area for the pad itself plus additional land for access roads, waste pits, truck parking, equipment, and more (Johnson 2010). Runoff can also contain pollutants from contact with drilling and construction equipment as well as with storage facilities for fracking fluid and produced water.



Stormwater discharges are regulated by state and local governments. The National Pollutant Discharge Elimination System (NPDES) program regulates stormwater runoff at the federal level, although states can receive primacy to administer their own permitting program. At the federal level, oil and gas operations have been afforded special protections and are exempt from provisions in the Clean Water Act. Consequently, oil and gas operators are not required to obtain a stormwater permit unless, over the course of operation, the facility generates stormwater discharge containing a reportable quantity of oil or hazardous substances or the facility violates a water quality standard (40 CFR 122.26(c)(1)(iii)).<sup>5</sup> In 2005, the definition of oil and gas exploration and production was broadened to include construction and related activities, although regulations still require well pads larger than one acre to apply for an NPDES stormwater permit (Wiseman 2012).<sup>6</sup> A 2005 study of the surface water impacts of natural gas drilling noted the difficulty of monitoring and suggested that few facilities were monitoring in a way that would allow them to determine whether they even required an NPDES permit (US EPA 2007b).

## Conclusions

Energy analysts project massive increases in domestic natural gas production over the next twenty-five years. This increase is expected to be largely supplied by unconventional sources, especially shale gas. Although previously too expensive to develop, unconventional natural gas resources have become more economically viable in recent years as a result of the application of horizontal drilling and hydraulic fracturing. These technological advances have allowed for a rapid expansion of natural gas development both in areas accustomed to natural gas operations and in new areas.

Hydraulic fracturing has generated a tremendous amount of controversy in recent years. Hydraulic fracturing is hailed by some as a game changer that promises increased energy independence, job creation, and lower energy prices. Others have called for a temporary moratorium or a complete ban on hydraulic fracturing because of concern over environmental, social, and public health concerns. There are daily media reports on this topic from outlets across the United States and in a host of other countries, including Canada, South Africa, Australia, France, and England.

In an effort to identify the key issues, the Pacific Institute interviewed a diverse set of representatives of state and federal agencies, academia, industry, environmental groups, and community-based organizations in the United States. Despite the diversity of viewpoints, there was surprising agreement about the range of concerns and issues associated with hydraulic fracturing. Interviewees identified a broad set of social, economic, and environmental concerns, foremost among which are impacts of hydraulic fracturing on the availability and quality of water resources. In particular, key water-related concerns identified by the interviewees included (1) water withdrawals; (2) groundwater contamination associated with well drilling and production; (3) wastewater management; (4) truck traffic and its impacts on water quality; (5) surface spills and leaks; and (6) stormwater management (Cooley and Donnelly 2012).

Much of the media attention on hydraulic fracturing and its risk to water resources has centered on the use of chemicals in the fracturing fluids and the risk of groundwater

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5. This requirement will not be met by sediment discharges alone.

6. States can implement stronger requirements if desired.

contamination. The mitigation strategies identified to address this concern have centered on disclosure and, to some extent, the use of less toxic chemicals. Risks associated with fracking chemicals, however, are not the only issues that must be addressed. Indeed, interviewees more frequently identified as key issues the overall water requirements of hydraulic fracturing and the quantity and quality of wastewater generated.

Most significantly, a lack of credible and comprehensive data and information is a major impediment to identifying or clearly assessing the key water-related risks associated with hydraulic fracturing and to developing sound policies to minimize those risks. Given the nature of the business, industry has an incentive to keep the specifics of its operations secret in order to gain a competitive advantage, avoid litigation, and so forth. Additionally, there are few peer-reviewed scientific studies on the process and its environmental impacts. While much has been written about the interaction of hydraulic fracturing and water resources, the majority of this writing is either industry or advocacy reports that have not been peer-reviewed. As a result, the discourse around the issue is largely driven by opinion. This hinders a comprehensive analysis of the potential environmental and public health risks and identification of strategies to minimize these risks.

Finally, the dialogue about hydraulic fracturing has been marked by confusion and obfuscation because of a lack of clarity about the terms used to characterize the process. For example, the American Petroleum Institute and other industry groups, using a narrow definition of fracking, argue that there is no link between their activities and groundwater contamination (American Petroleum Institute 2010), despite observational evidence of groundwater contamination in Dimock, Pennsylvania, and Pavillion, Wyoming, that appears to be linked to the integrity of the well casings and of wastewater storage. Additional work is needed to clarify terms and definitions associated with hydraulic fracturing to support more fruitful and informed dialogue and to develop appropriate energy, water, and environmental policy.

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# Water Footprint

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We use water for a variety of purposes in our daily lives: for drinking, bathing, washing our clothes, watering our gardens, and more. These direct uses of water, however, are only part of the story. Water is also required to produce nearly everything we use and consume, from the food we eat and the clothes we wear to the technological devices that are integral to our modern society. Because this indirect water isn't visible in the product, it is also often referred to as "embedded," "embodied," or "virtual" water. A full measure, therefore, of the water footprint of an individual, industrial sector, or society is the combination of direct water use and the water used indirectly to provide the goods and services consumed.

As pressures on water resources intensify globally, there is growing interest in evaluating the complex ways in which everyday human activities affect the world's water resources. Traditionally water has been thought of as a local or regional issue, but as globalization has forged increasing interconnectedness among people and economies, better understanding is needed of the ways in which observed impacts to water systems have important global dimensions. The "water footprint" has emerged as one tool for identifying and quantifying these impacts.

In recent years, there has been an explosion of interest in developing the methods and data necessary for evaluating and comparing water footprints. In this chapter we discuss the concept of a water footprint and how it is related to other footprint indicators, such as the carbon footprint and the ecological footprint; how the water footprint is calculated; some findings from recent research; and finally what the water footprint means in the context of California.

## The Water Footprint Concept

The water footprint of a product (good or service) has been defined as the quantity of freshwater consumptively used, both directly and indirectly, throughout its supply chain (Hoekstra et al. 2011). Consumptive and nonconsumptive uses of water occur at almost every step along the supply chain of a product, but the water footprint counts only the consumptive portion because the nonconsumptive portion can theoretically be used for other purposes (see box 5.1). For example, an average of 140 liters (37 gallons) of water is consumptively used to produce a standard 125-milliliter (4.2-ounce) cup of coffee, including the water required to grow the coffee crop and process the beans. In fact, all food products require water in their production. Meat and dairy products tend to be very



**BOX 5.1** A Note About Water Use

The water literature is rife with confusing and often misleading terminology to describe water use—“water withdrawal,” “consumptive use,” “nonconsumptive use,” “real water,” “paper water,” and more. It is important to clarify these terms, as different meanings can lead to different or conflicting conclusions. A water *withdrawal* is commonly defined as water taken from a source and used for some human need. Water withdrawals can be divided into two categories, consumptive and nonconsumptive use. *Consumptive use* typically refers to “water withdrawn from a source and made unavailable for reuse in the same basin, such as through conversion to steam, losses to evaporation, seepage to a saline sink, or contamination” (Gleick 2003, 278). Additionally, water that is incorporated into goods or plant and animal tissue is unavailable for reuse and thus is also considered a consumptive use. *Nonconsumptive use*, on the other hand, refers to water that can be made available for reuse within the basin from which it was extracted, such as through return flows or recoverable wastewater discharge into water bodies.

water intensive because water is required not only for bathing and hydrating the animals but also, and especially, for all the feed they eat over their life span.

It isn't just food that requires water to produce. The water footprint of cotton clothing, for example, includes the water for growing cotton, processing and dyeing fabric, and various finishing procedures—and the footprint of a typical T-shirt has been estimated at almost 2,500 liters (over 650 gallons) (Chapagain et al. 2006; Mekonnen and Hoekstra 2010).<sup>1</sup> Many industrial products, such as electronics and cars, can require vast amounts of water in their production, from the mining of various metals to the transport, processing, and disposal of a wide range of materials. Energy production is also a significant consumer of water. Generation of a megawatt-hour (MWh) of electricity, enough to supply the average US household for about a month, consumes an average of 1,100 liters (288 gallons) in the western United States (Cooley et al. 2011), but it can consume around 250,000 liters (65,000 gallons) for inefficient hydroelectricity produced in a hot, dry climate (Mekonnen and Hoekstra 2012). The production of goods is often much more water intensive than the provision of services, but even service industries such as hospitality (e.g., hotels), food (restaurants), health care (hospitals), and recreation (golf courses, reservoirs) can require significant levels of consumptive water use.

These are examples of just some of the products that are a part of our everyday lives, and they all require some amount of consumptive water use before we purchase and use or consume them. When we consume them, there is a connection between our action and the water that was consumptively used because our action has generated a demand for that use. The water footprint is therefore considered a consumption-based metric

1. This figure does not include the water used to wash the product over its life.

because it attributes the water use to the consumer rather than the producer. While this is the opposite of the way we have historically thought about water use, it is actually conceptually very close to other, more familiar ways of measuring people's interactions with the global environment.

## Water, Carbon, and Ecological Footprints and Nexus Thinking

Just as the water footprint is a consumption-based metric, so too are the carbon footprint and the ecological footprint. A carbon footprint measures the greenhouse gas emissions associated with people's activities and consumption habits in order to create a better understanding of their contribution to global climate change. Transportation and other energy-intensive activities, for example, tend to generate large carbon footprints because so much of the global population's energy system is based on fossil fuels instead of renewable forms of energy. The ecological footprint measures the amount of biologically productive land and water area that is appropriated by a product or activity; it is measured as the amount of "global hectares" required to sustain an individual or population (see <http://www.footprintnetwork.org>).

Table 5.1 compares water, carbon, and ecological footprint indicators. There may be synergies as well as trade-offs in these indicators. For example, some renewable energy technologies that have a lower carbon footprint, such as photovoltaics, also have a lower water footprint. However, crop varieties that are less water intensive might be grown only in regions requiring more extensive land use or more transportation fuels to get them to market. It is important to engage in "nexus thinking" (e.g., the water-energy nexus) by considering the interactions of a range of environmental indicators when making decisions, whether personal, business, or governmental.

Furthermore, these consumption-based indicators should not be understood to replace or obviate the need for production-based indicators. Traditional regulation and other ways of working with producers are still directly relevant to reducing impacts to the local environment. Rather, consumption-based indicators provide a perspective that creates options for new leverage points in addressing their respective concerns. For the water footprint, this concern has to do with water availability in the places where products are produced. The next section discusses details of the water footprint and how it is measured.

### Calculating a Water Footprint

A water footprint provides a metric and methodology for quantifying consumptive use, including additional qualitative features about the water used, such as where the water comes from, the kinds and quality of water used, and more, as discussed below. The basic approach in calculating a water footprint is to combine consumptive water-use factors (volume per unit of production) for individual goods and services with statistics on production, trade, and consumption of those goods and services. The Water Footprint Network (WFN) advanced the methodology described in the *Water Footprint Assessment Manual* (Hoekstra et al. 2011).

The water footprint is often reported as three components: green water, blue water, and grey water. Green water is the amount of precipitation and soil moisture that is di-

**TABLE 5.1** Comparison of Footprint Indicators

| Indicator            | Measurement      | Concern                              |
|----------------------|------------------|--------------------------------------|
| Water footprint      | Consumptive use  | Water availability and quality       |
| Carbon footprint     | Greenhouse gases | Climate change                       |
| Ecological footprint | Global hectare   | Land and bioproductivity degradation |

rectly consumed in an activity, as in growing crops. Blue water is the amount of surface water or groundwater that is applied and consumed in an activity, as in growing crops or manufacturing an industrial good. Finally, grey water<sup>2</sup> is the water needed to assimilate pollutants from a production process back into water bodies at levels that meet governing standards, regardless of whether those standards are actually met (Hoekstra et al. 2011). The green, blue, and grey water metrics are calculated for individual processes and then aggregated on the basis of the consumption patterns of the unit of interest.

Because a water footprint is based on the goods and services consumed, it can be calculated at different levels of consumer activity, that is, for individuals, households, regions, states, nations, or even all of humanity. Trade is an important consideration when calculating water footprints, as the various processes required to produce a final good often take place in different countries. Using the example of a cotton T-shirt, the cotton may be grown in India, woven into fabric and dyed in China, and finished in Mexico before heading to market in the United States. Thus, the water footprint of that T-shirt will be geographically distributed according to the structure of its supply chain (Chapagain et al. 2006).

Green, blue, and grey water footprints are often combined and reported as a single value in the literature. Each, however, has a distinct ecological and social context. Green water pertains to rainwater and soil moisture occurring where crops are grown and thus may be significant only to the degree it makes water unavailable for other land uses, alternative crops, or native vegetation. Blue water, by contrast, represents a deliberate extraction and allocation of surface water or groundwater resources, often with pumping and conveyance systems used to extract and deliver water where it is needed. Grey water is an indicator of water quality rather than a measure of consumptive water use. Even though the contamination of surface waters is by definition a consumptive use, contaminated water can often still serve multiple uses, such as navigation or cooling. Thus, in order to eliminate double counting of upstream grey water footprints by downstream blue water uses, as well as to avoid confusing their distinct ecological contexts, we think it is appropriate to present each type of water separately.

The quantitative measure of a green, blue, or grey water footprint, by itself, might reveal little about the consequences or local impacts of that water use. Additional information (and often subjective evaluation) is required to estimate the impact of a water footprint. If the water consumed comes from areas where water is relatively abundant, the social and environmental impacts may be far less than for the same consumption from a region where water is scarce. Such a contextualized analysis of the relative impacts of a water footprint is generally called a water footprint sustainability assessment in the literature (Hoekstra et al. 2011). These assessments are rarer in the literature, so here we present only the quantitative dimensions of water footprint analyses in addition to our more contextualized report on California's water footprint.

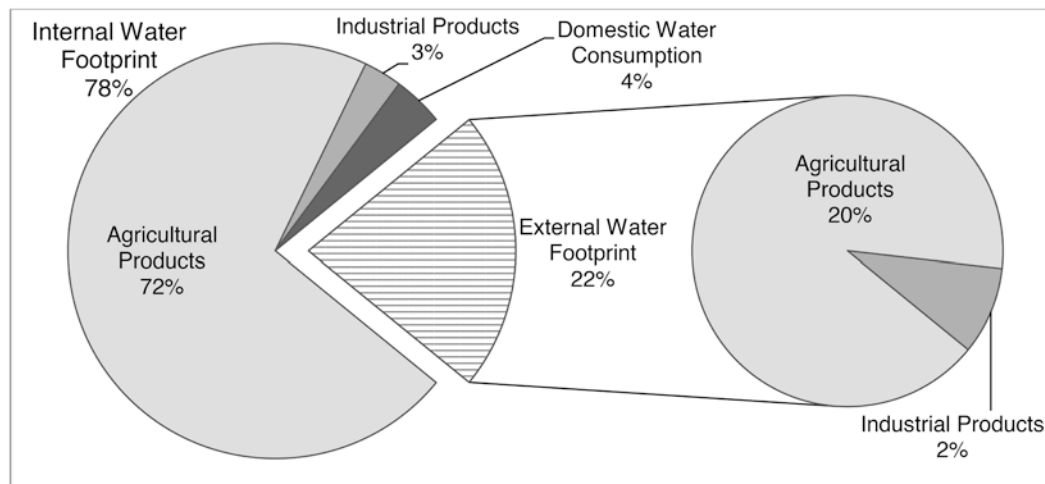
2. Not to be confused with wastewater that is reused directly on a site, often also called grey water or greywater.

## Water Footprint Findings

The water footprint concept has developed substantially in scientific literature over the past decade and resulted in numerous publications and extensive data sets, many of which have come about through the work of the Water Footprint Network. With some exceptions, this research has focused on the scale of national consumption and international trade. This is understandable, given that the national level is often where most production and trade statistics are gathered and reported, but ideally the science would advance to be able to identify water footprints of more hydrologically appropriate units, such as river basins. Another limitation of these findings is that they account only for bilateral trade flows, thus missing consumptive water uses that may have occurred further upstream in the supply chain of a product. Additionally, we note that while the scope of products covered is substantial, these figures do not include the water footprints of energy products, mining activities, or traded service industries such as tourism and call centers.

Beginning at the global level, Arjen Hoekstra and Mesfin Mekonnen (2012) of the University of Twente in the Netherlands found that the water footprint of global consumption, averaged between 1998 and 2005, was about 9.1 trillion cubic meters (around 7.4 billion acre-feet) per year.<sup>3</sup> By comparison, that is about 500 times the average annual flow of the Colorado River in its natural state (Cohen et al. 2001). Around three-quarters of the global water footprint is green water, 11 percent is blue water, and 15 percent is grey water. Ninety-two percent is associated with the consumption of agricultural products, while industrial products make up 5 percent and direct water consumption makes up just 4 percent (figure 5.1). Twenty-two percent of the global water footprint is “external,” meaning that it pertains to internationally traded products.

Water footprints, however, vary tremendously from country to country. The United States, for example, has one of the highest per capita water footprints in the world, at



**FIGURE 5.1 GLOBAL WATER FOOTPRINT BROKEN DOWN BY TYPES OF CONSUMPTIVE USE**

Source: Mekonnen and Hoekstra (2011).

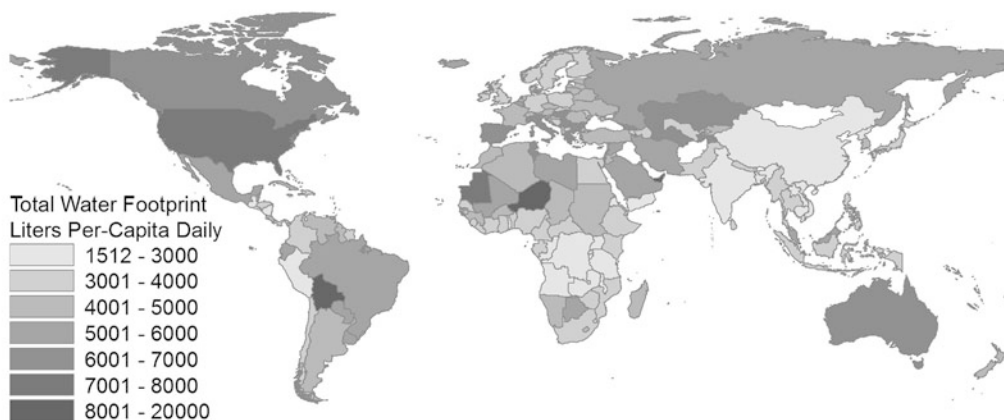
3. One acre-foot is the amount of water that would fill one acre to a depth of one foot and is approximately 325,851 gallons, or 1,233,482 liters.

nearly 8,000 liters per capita per day (LPCD), or 2,100 gallons per capita per day (GPCD) (Mekonnen and Hoekstra 2011). Other developed countries have an average water footprint of around 5,000 LPCD (1,300 GPCD), and the global average is just under 4,000 LPCD (1,000 GPCD). Several developing countries, such as China and India, have per capita water footprints that are well below the global average; however, their large populations and rapidly rising standards of living, if accompanied by rising water use, will have substantial impacts on the world's water resources. Figure 5.2 shows the per capita total water footprint for nearly every country in the world.

Another important dimension of a nation's water footprint is its relative dependence on internal versus external water resources (figure 5.3). As mentioned earlier, 22 percent of the entire global water footprint pertains to traded goods, and many nations rely heavily on international markets to make up for local water deficits. For the most part, these are countries with very little agricultural production capacity within their territory to begin with, including small, geographically isolated nations such as Malta and Brunei; nations with challenging topography, such as Japan and Switzerland; and nations with extreme climates, such as Iceland and Kuwait. One interesting standout case is the Netherlands, which is 95 percent externally dependent despite its large agricultural economy. Conversely, nations whose water footprint is mostly internal typically either are more isolated economically, as is Myanmar, or have abundant resources for agricultural production, as does the United States. In fact, the United States not only has one of the largest water footprints in the world but also is a massive exporter of water-intensive products to other countries.

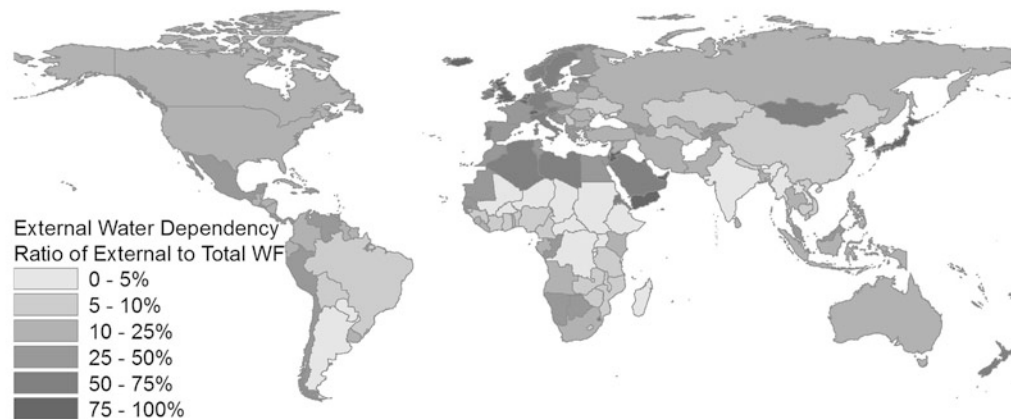
## The Question of Scale: California's Water Footprint

Delving beneath the level of national water footprint assessments is difficult in terms of data availability, but it is important to understand how water footprint patterns and outcomes might change with scale. California, as a case of a subnational unit, is interesting because it is the state with the largest population and gross domestic product in the nation (about one-eighth on both counts). California represents a substantial share of US



**FIGURE 5.2 NATIONAL PER CAPITA WATER FOOTPRINTS**

Source: Mekonnen and Hoekstra (2011).



**FIGURE 5.3 EXTERNAL WATER DEPENDENCE OF NATIONS**

*Source:* Mekonnen and Hoekstra (2011).

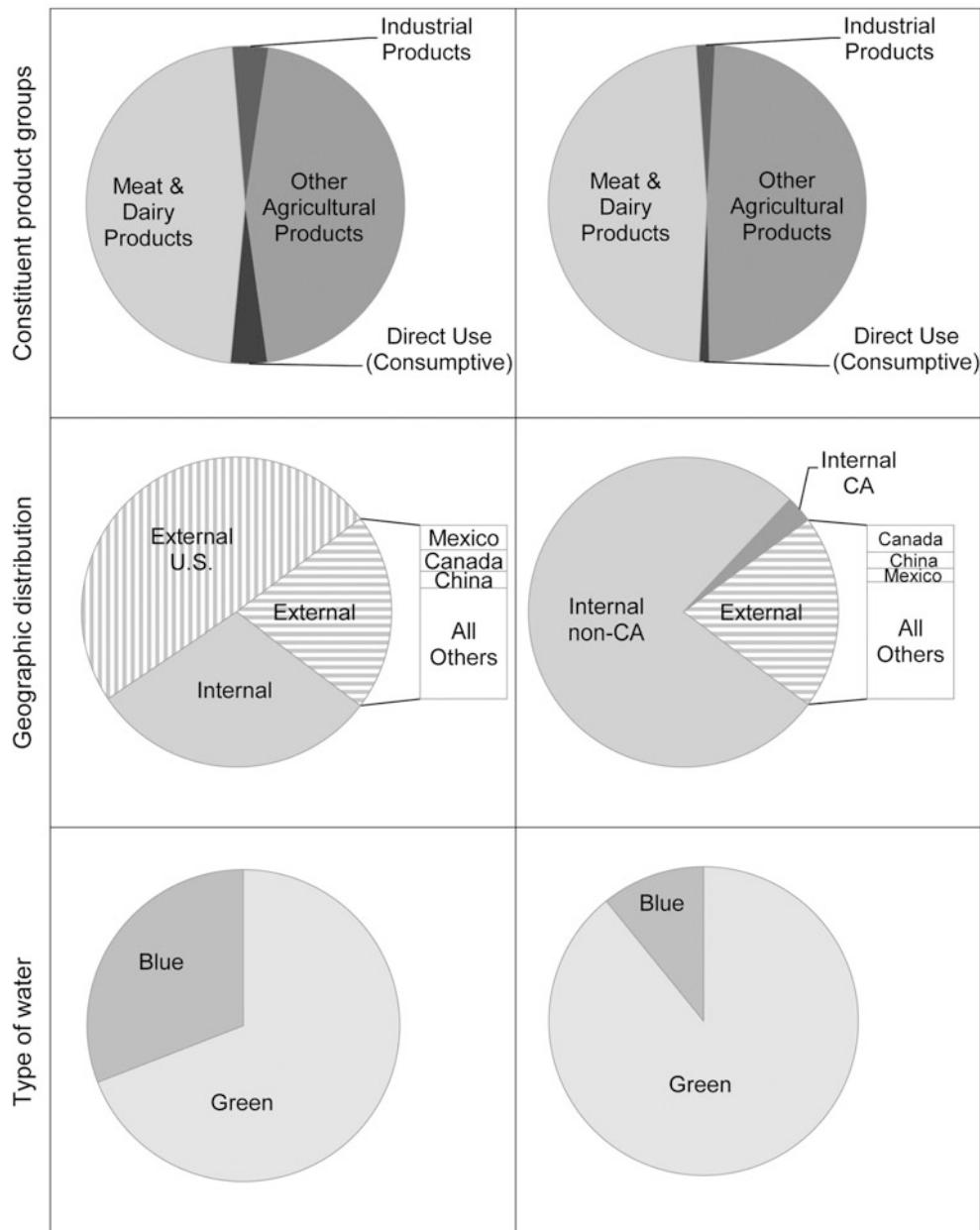
economic activity, in terms of both consumption and production, so we might expect its water footprint to be similar to that of the United States as a whole. Yet the state is unique climatically and hydrologically, with minimal precipitation during the summer and fall and very little runoff flowing out of its borders. In fact, California derives about 10 percent of its annual surface water supplies from its neighbors (CDWR 2009).

The Pacific Institute recently completed an assessment of California's water footprint, and we briefly present the results here (Fulton et al. 2012). Our analysis, summarized in figure 5.4, found that the water footprint of the average Californian is about the same as that of the average American in terms of size and breakdown of products. However, it is very different in two important respects. First, whereas the United States as a whole is a net virtual water exporter, California is a net importer. This creates a unique situation wherein decision makers in California must consider the fact that the water footprint of in-state consumption pertains more to water resources in other states and other countries than to California's own water resources. On the one hand, this means that if California experiences a severe drought, the impact on consumers may not be so detrimental. This situation might be strategic in that California enjoys the benefits of being able to consume water-intensive products without having to consume scarce local water resources (though California already consumes a substantial part of its own water resources). Conversely, this may make California consumers more susceptible to droughts or water-related issues elsewhere, and Californians must consider the effect their consumption habits may have on exacerbating those impacts. Further research is needed to understand the specific water-related impacts in locations where the goods that Californians consume are produced.

The second important difference relates to the "type" of water. Despite the per capita water footprints being nearly equal, California's has a much larger share of blue water than does that of the United States as a whole. This means that the state relies more on applied surface water (primarily in irrigation), which has trade-offs with other uses, such as supporting ecosystems. Additionally, blue water irrigation systems may have specific



vulnerabilities with respect to climate change that are different from the vulnerabilities of production systems that depend on green water. More research is also needed in this area. Nevertheless, these particular aspects of California's water footprint suggest a set of vulnerabilities and policy options that would likely be overlooked in a national assessment.



**FIGURE 5.4 COMPARISON OF US AND CALIFORNIA WATER FOOTPRINTS BY PRODUCTS, GEOGRAPHIC DISTRIBUTION, AND TYPE OF WATER**

California's per capita water footprint (left column) and that of the United States (right column) are compared along three dimensions: constituent product groups (top row), geographic distribution (middle row), and type of water (bottom row).

## Conclusion

Continued population growth and improved living standards are creating new patterns of production and consumption that are likely to place increasing demands on the world's water resources. Water resources are already strained in many locations, and the complex ways in which these processes occur require further attention. The water footprint tool, still evolving in concept and method, has begun to illuminate some of the important dimensions of the ways in which people, economies, and water resources are interconnected. The concept is reasonably analogous to the carbon footprint and the ecological footprint, tools that have made substantial inroads with international policy and business strategy. Important insights have already resulted from footprint analyses, and the approach offers promise for assisting decision making at a number of levels, from individuals to businesses to governing bodies at various scales.

National-level water footprints have been calculated for nearly every country on Earth, and we now have a good sense of how affluence and increased consumption (particularly of some products, such as meat) affect demand for the world's water resources. Trade is an important way in which countries can overcome local water scarcity by importing virtual water. But trade also provides a way in which distant water resources might be overexploited or mismanaged without the knowledge of the consumer who is benefiting from that water use. The more we know about how these causes and effects occur, the better the world's water resources can be managed.

The case of California illustrates how a water footprint assessment at the state level can yield very different results from assessments at larger scales. This dynamic is very important to understand, since California consumers and state agencies will be able to make better-informed decisions than if they were to rely on a nationwide assessment. Specifically, our assessment shows that California is more dependent on water resources outside of its borders than is the United States as a whole and that the state is more reliant on blue water. These aspects of California's water footprint make decision making in relation to such challenges as climate change unique.

But the state level is not necessarily the ideal scale at which water footprint information best applies. Many economic and water management decisions are made at the state level, but there has also been a movement in the past ten to fifteen years to shift many important management decisions to the scale of river basins. This seems appropriate, given that populations living within river basins (e.g., the Colorado and Nile River basins) have a hydrologic commonality and should to some degree share in water-related decision making. For example, upstream populations can shift their water footprint away from local resources by importing products produced downstream, thereby allowing water to provide ecological benefits along more of the river's reach. These types of basin-level decisions are more difficult when they require the crossing of political boundaries, and the field of transboundary water management has a lot to offer on this subject. Water footprint research is just beginning to move in the direction of using the river basin as a more appropriate unit of analysis.

Other exciting applications and improvements of the water footprint method have to do with the study of how water footprints change over time. This information is especially important in examining how particular countries or regions develop and change their production and consumption habits. For example, while the US population and economy have continued to grow, domestic water withdrawals have been basically

steady since about 1980 (Gleick 2003). In part, this is the result of improvements in efficiency of water use through various technologies in the agricultural, power production, manufacturing, commercial, and residential sectors. But the economy overall has also changed, with more of the products we consume being produced outside of our borders. The water footprint method, applied over a time series, can shed light on the extent to which the apparent leveling of overall water use in the United States has been in part an externalizing of water use.

Overall, the water footprint tool is useful in answering a number of questions pertaining to the relationship between people and the world's water resources. At its core, it provides a description of the quantity, type, and location of water resources required to produce products and to fulfill the consumption habits of individuals or populations. As populations grow and change, the connections between their actions and the global environment need to be better understood. The world's water resources are being pressured on numerous fronts, as evidenced in the other chapters in this book. The water footprint tool, though still evolving, is beginning to provide us with another way in which to better understand and reduce human impacts on those resources.

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# Key Issues for Seawater Desalination in California

## Cost and Financing

Heather Cooley and Newsha Ajami

In June 2006, the Pacific Institute released *Desalination, with a Grain of Salt*, an assessment of the advantages and disadvantages of seawater desalination for California (Cooley et al. 2006). At that time, there were twenty-one active seawater desalination proposals along the California coast. Since then, only one project, a small plant in Sand City, has been permitted and built. A second project, in Carlsbad, has all of the necessary permits, finally secured financing in December 2012, and is now under construction. Interest in seawater desalination, however, remains high in California, and many agencies are conducting technical and environmental studies and pilot projects to determine whether to develop full-scale facilities.

In 2011, the Pacific Institute initiated a new research project on seawater desalination. As part of that effort, we conducted some twenty-five one-on-one interviews with industry experts, water agencies, environmental and community groups, and regulatory agencies to identify some of the key outstanding issues for seawater desalination projects in California. Among the key issues raised were the cost and financing of seawater desalination projects, the marine impacts, and the energy requirements and associated greenhouse gas emissions. In this chapter, we provide a short summary of the costs of various projects and the spatial and temporal variability associated with these costs. We also describe some of the project-related risks associated with desalination plants. Finally, we provide two case studies of seawater desalination projects in the United States to highlight some of the issues involving cost and financing of these projects.

## How Much Does Seawater Desalination Cost?

The biggest barrier to widespread use of desalination technology remains its relatively high cost. Most desalination capacity worldwide has been built where natural renewable water resources are extremely limited and where energy resources critical for operating desalination systems are abundant and inexpensive, such as in the Arabian Gulf region.

In other regions, however, alternative sources of water supply and improvements in water efficiency are still largely less costly than the water produced at desalination facilities. Costs have declined considerably over the past forty years, although they are unlikely to decline much further, barring a major technological breakthrough.

There are many components and definitions of the cost of a desalination project, and uncertainty about these terms can lead to confusion about cost comparisons, especially among those without a finance background. In this chapter, we explain the cost terminologies. We also compare costs among proposed and recently constructed plants and describe some of the factors that contribute to the large variability among projects. We conclude by comparing the cost of seawater desalination with that of other water alternatives.

It is important to note that this chapter describes *financial* costs. There are other costs that may not be captured in a financial analysis because they are not internalized in the project developer's cost stream or are not subject to market-like transactions (NRC 2008). For example, seawater intake screens kill marine organisms. These impacts have a cost associated with them that some other group or individual bears, for example, reductions in fish populations that affect local fishermen. These costs may be captured in an economic analysis. But unless they are internalized in the project through, for example, a requirement to restore or enhance wetlands, they will not be factored into the financial feasibility of a project and are not included in this report.

## Cost Terminology

In this section, we provide a short introduction to some of the terms used to describe the financial costs of a desalination project.

### *Capital Costs and Operation and Maintenance Costs*

The primary cost components of a seawater desalination plant are commonly divided into two major categories: capital costs and operation and maintenance (O&M) costs. Capital costs are those costs incurred during construction of the project and include expenses associated with planning, permitting, designing, and constructing the project. Other capital costs include expenses associated with buying or leasing equipment, purchasing the site, and mitigating environmental impacts.

Capital costs may also include the cost to finance the project—referred to as the cost of capital. The capital required to develop desalination projects is not free, and the project developer must pay to access it. The cost of capital includes the cost of debt (for those projects financed with debt) and the cost of equity (for those projects financed with private equity). The cost of debt is based on the interest rate of the debt incurred for the project, that is, the bond or loan, and reflects the compensation a lender demands for the risks involved in the project (Pemberton 2003). The cost of equity is the return paid to private equity investors to compensate for the risk they undertake by investing their capital. Generally, the greater the perceived risks of the project, the harder and costlier it is to secure capital.

In addition to capital costs, there are O&M costs associated with desalination plants. O&M costs represent the ongoing costs of operating the plant, including expenses associated with replacement membranes for reverse osmosis systems, pre- and post-treatment chemicals, energy to run the plant, environmental monitoring, and labor for

plant operators. Some O&M costs, such as labor, are fixed; they do not vary with respect to the amount of water produced. Other O&M costs, such as the costs of energy and chemicals, are variable.

Capital and O&M costs are often reported in different ways, which can complicate project cost comparisons. Capital costs are reported as onetime, fixed costs. O&M costs, by contrast, are typically reported as annual costs. In order to determine the total annual cost of a desalination plant, the capital and O&M costs must be put on similar footing. The most common approach is to spread the capital costs, which include the cost to finance the project, over the life of the project, for example, for twenty or thirty years, to produce an annualized capital cost. The annualized capital cost and the annual O&M cost are added together to produce a total annual cost.

Figure 6.1 shows an annual cost breakdown of a typical seawater desalination plant. Although variable from project to project, the annualized capital cost typically accounts for about one-third of the annual cost of a seawater desalination plant. O&M costs account for the remaining two-thirds. Generally, energy costs—at 36 percent of the annual cost—represent the single largest O&M cost and are of similar magnitude as the annualized capital cost. Depending on the desalination process and local site conditions, chemical costs can also be significant, accounting for about 12 percent of the total annual cost.

### *Unit Cost*

In addition to reporting capital and O&M costs, water managers often report the unit cost of water, that is, the cost per cubic meter (or acre-foot or thousand gallons) of water produced. The unit cost of water is derived from the annual cost (the annualized capital cost plus the O&M cost) and the annual production of water from the plant. Specifically, it is determined by the following formula:

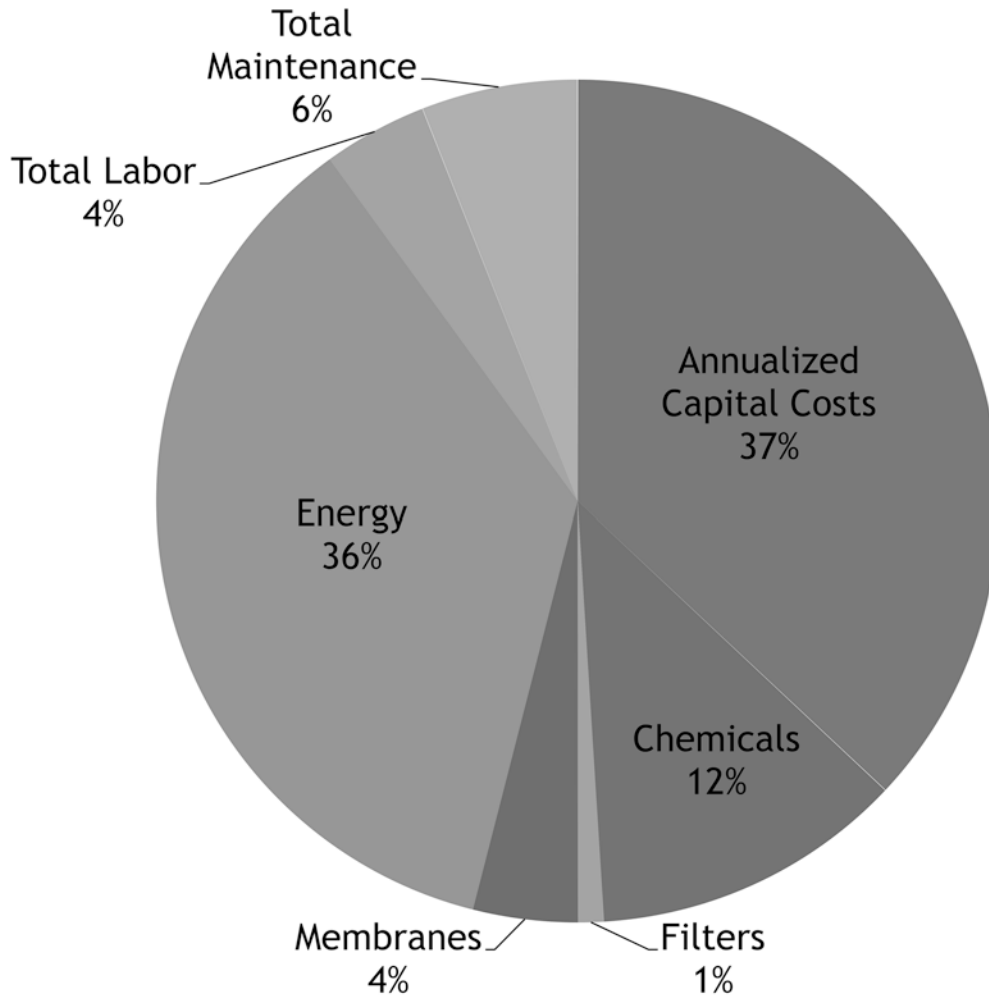
$$\text{unit cost} = \frac{\text{annualized capital cost} + \text{annual O\&M cost}}{\text{annual amount of water produced}}$$

Given that the project cost is driven, in part, by the size of the plant, the unit cost effectively normalizes the cost of the project by the volume of water produced. It can also be useful for comparing projects of different sizes and for comparing various water supply and demand management alternatives.

## Desalination Cost Estimates

Discussions about the actual cost of desalination plants have been muddled and muddled because estimates have been provided in a variety of units, years, and ways that are not directly comparable. Some report the cost of the desalination plant alone. Others include the costs for additional infrastructure needed to integrate the desalination plant into the rest of the water system, which can be significant. Some estimates include the cost to finance the project, while others do not. In some regions, governmental subsidies hide some of the real costs. And local conditions, such as water salinity, options for disposing of brine, level of environmental regulation, and labor or land costs, vary widely. For example, the capital cost of the proposed Carlsbad Desalination Project is currently estimated at \$537 million. An additional \$239 million is needed to build a pipeline to transport the water to customers and make other water system improvements





**FIGURE 6.1 ANNUAL COST BREAKDOWN OF A TYPICAL SEAWATER DESALINATION PLANT**

Source: NRC (2008).

Note: Estimate is for a reverse osmosis plant and is based on the following assumptions: capacity of 190,000 cubic meters ( $m^3$ ) per day (50 million gallons per day); constant energy costs at \$0.07 per kilowatt-hour (kWh); membrane life of five years; nominal interest rate of 5 percent; and a depreciation period of twenty-five years.

(Lee 2013).<sup>1</sup> Given the inconsistent nature of estimates, the public, media, and analysts must exercise caution when comparing claims of costs for different projects.

Table 6.1 shows capital, O&M, and unit cost estimates for proposed plants in California and several recently constructed plants in Florida and Australia. O&M costs shown here are based on estimates made the year the project was completed; these costs change over time and may not reflect current O&M costs. Costs for desalination plants in Australia were converted into US dollars using the conversion rates that were in effect in the year that the plant was completed. We have not adjusted the apparent year of each reported cost for inflation because inflation varies from country to country. Even without

1. Note that these estimates do not include financing costs, which substantially increase the lifetime cost of the project.

adjustment to current-year dollars, however, it is apparent from the table that costs vary far more widely than can be explained solely by inflation or currency exchange rates.

As shown in table 6.1, large plants tend to have higher capital and O&M costs than small plants, but this is not always the case. For example, the Kwinana Desalination Plant in Perth, Western Australia, has a capital cost of less than \$330 million and an O&M cost of \$17 million per year. By contrast, the Gold Coast Desalination Plant in Tugun, Queensland, is slightly smaller but has much higher capital and O&M costs, at \$890 million and \$30 million per year, respectively. The Gold Coast plant was considerably more expensive than the Perth plant because steel and labor costs were dramatically higher when the plant was constructed. Additionally, the Gold Coast plant used a more complicated intake design and required the construction of a longer pipeline to distribute the water to customers (Crisp 2012).

Unit costs are also highly variable among projects. Variability among desalination projects is driven by a range of site- and project-specific factors. Land prices and labor costs, for example, can vary considerably among projects. Likewise, energy prices can have a major influence on the project cost. For example, the average electricity price of the Gold Coast Desalination Plant was \$0.15 per kilowatt-hour (kWh) in 2009–2010 (Robertson 2010). Currently, electricity prices for industrial customers in California are about \$0.10 per kilowatt-hour (US EIA 2012).<sup>2</sup> Other project- and site-specific factors that affect the cost include source water temperature and salinity, intake and outfall design, environmental mitigation requirements, interest rates and loan period, project team experience, permitting requirements, and the presence of hidden and visible subsidies (Cooley et al. 2006; WateReuse Association 2012).

It is important to note that desalination costs are not static but can vary over time. Many of the estimates shown in table 6.1 are engineering estimates based on the initial project design. Actual production costs can be higher because of increases in the capital and O&M costs or a reduction in the amount of water produced. Capital costs may change if the price of materials, such as cement or steel, or the cost of borrowing money changes. Major project delays are also likely to increase capital costs.

O&M costs can also change over the life of the desalination plant as a result of changes in input costs or in the lifetime of major equipment. Energy, for example, represents a major cost component (figure 6.1), and short- and long-term increases in energy prices can increase production costs. If energy accounts for 36 percent of the annual production cost, a 25 percent increase in energy costs would increase the cost of produced water by 9 percent. Similarly, membranes typically last for five to seven years, although in some cases ten years is possible. If the actual lifetime of the membranes exceeds five to seven years, the production cost may be lower than the initial estimate. Conversely, if the membranes foul more quickly, O&M costs increase.

The cost of produced water from a desalination plant is especially sensitive to changes in the amount of water produced. As described previously, the unit cost of water is determined by dividing the annual costs by the amount of water of produced. Typically, unit cost estimates during the design and planning of a project are based on the assumption that the desalination plant will operate at or near full capacity. If the plant produces less water, however, the unit cost increases (figure 6.2). Take, for example, a plant that

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2. This was the price in 2012 for industrial customers.

**TABLE 6.1** Desalination Costs for Proposed and Recently Constructed Plants

| <b>Project</b>  | <b>Capacity<br/>(m<sup>3</sup>/d)</b> | <b>Capital Cost<sup>a</sup><br/>(\$ Millions)</b> | <b>O&amp;M Cost<sup>b</sup><br/>(\$ Millions)</b> | <b>Unit Cost<sup>c</sup><br/>(\$/m<sup>3</sup>)</b> | <b>Dollars<sup>d</sup><br/>are in . . .</b> | <b>Status</b>  | <b>Data Source</b>                      |
|---|---------------------------------------|---|---|---|---|----------------|---|
| Santa Cruz/<br>Soquel Creek<br>Water District                       | 9,480                                 | \$114   | \$3–\$4   | n/a   | 2012<br>dollars                             | Proposed       | Luckenbach<br>(2012)                    |
| California<br>American<br>Water <sup>e</sup>                        | 18,600–30,300                         | \$175–\$207                                       | \$7.77–\$11                                       | \$2.06–\$2.63                                       | 2012<br>dollars                             | Proposed       | Separation<br>Processes, Inc.<br>(2012) |
| Deep Water<br>Desal <sup>e</sup>                                    | 18,600–30,300                         | \$134–\$160                                       | \$9.38–\$12.3                                     | \$1.94–\$2.53                                       | 2012<br>dollars                             | Proposed       | Separation<br>Processes, Inc.<br>(2012) |
| The People's<br>Moss Landing<br>Water Desal<br>Project <sup>e</sup> | 18,600–30,300                         | \$161–\$190                                       | \$7.06–\$10.1                                     | \$1.90–\$2.42                                       | 2012<br>dollars                             | Proposed       | Separation<br>Processes, Inc.<br>(2012) |
| Tampa Bay,<br>Florida   | 94,800                                | \$158   | n/a   | \$0.89  | 2007<br>dollars                             | Complete       | See chapter<br>text                     |
| Gold Coast<br>Desalination<br>Plant <sup>f</sup>                    | 125,000                               | \$888   | \$30  | \$1.61  | 2009<br>dollars                             | Complete       | Pankratz (2012)                         |
| Kwinana<br>Desalination<br>Plant, Perth <sup>f</sup>                | 144,000                               | \$330   | \$17  | \$0.99  | 2008<br>dollars                             | Complete       | NWC (2008)                              |
| Carlsbad<br>Desalination<br>Plant                                   | 190,000                               | \$776   | \$49–\$54   | \$1.54–\$1.78                                       | 2012<br>dollars                             | Proposed       | Lee (2013);<br>SDCWA (2012a)            |
| Camp<br>Pendleton   | 190,000–<br>379,000                   | \$1,300–<br>\$1,900                               | \$45–\$105  | \$1.54–\$1.90                                       | 2009<br>dollars                             | Proposed       | SDCWA<br>(2012d)                        |
| Kurnell<br>Desalination<br>Plant, Sydney <sup>f</sup>               | 208,000                               | \$1,565   | \$47  | \$1.95  | 2008<br>dollars                             | Complete       | NWC (2008)                              |
| Southern<br>Seawater<br>Desalination<br>Plant <sup>f</sup>          | 273,000                               | \$1,466   | n/a   | \$2.29  | 2012<br>dollars                             | Complete       | Pankratz (2012)                         |
| Port Stanvac,<br>Adelaide <sup>f</sup>                              | 273,000                               | \$1,878   | \$136   | \$1.94  | 2012<br>dollars                             | In<br>progress | Pankratz<br>(2012); Kemp<br>(2012)      |
| Wonthaggi<br>Desalination<br>Plant,<br>Melbourne <sup>f</sup>       | 413,000                               | \$3,651   | \$63  | \$5.31  | 2012<br>dollars                             | Complete       | Pankratz (2012)                         |

*(continued)*

**TABLE 6.1** *continued*

Note: n/a = not available.

<sup>a</sup>Capital costs here are based on capital expenditures and include the cost of the desalination plant plus any other infrastructure required to integrate the desalination plant into the rest of the water system. The cost to finance the project is not included.

<sup>b</sup>O&M costs include the operation and maintenance costs of the desalination plant and any other infrastructure required to integrate the desalination plant into the rest of the water system.

<sup>c</sup>The unit cost captures capital and O&M costs as well as the cost to finance the project.

<sup>d</sup>Costs have not been adjusted for inflation. Unless otherwise indicated, we assume that cost estimates are provided in the year in which the project was completed.

<sup>e</sup>The actual capacity of these projects may differ from what is stated here. The study these estimates were drawn from (Separation Processes, Inc. 2012) adjusted the plant capacities to make a more accurate comparison among projects in the region.

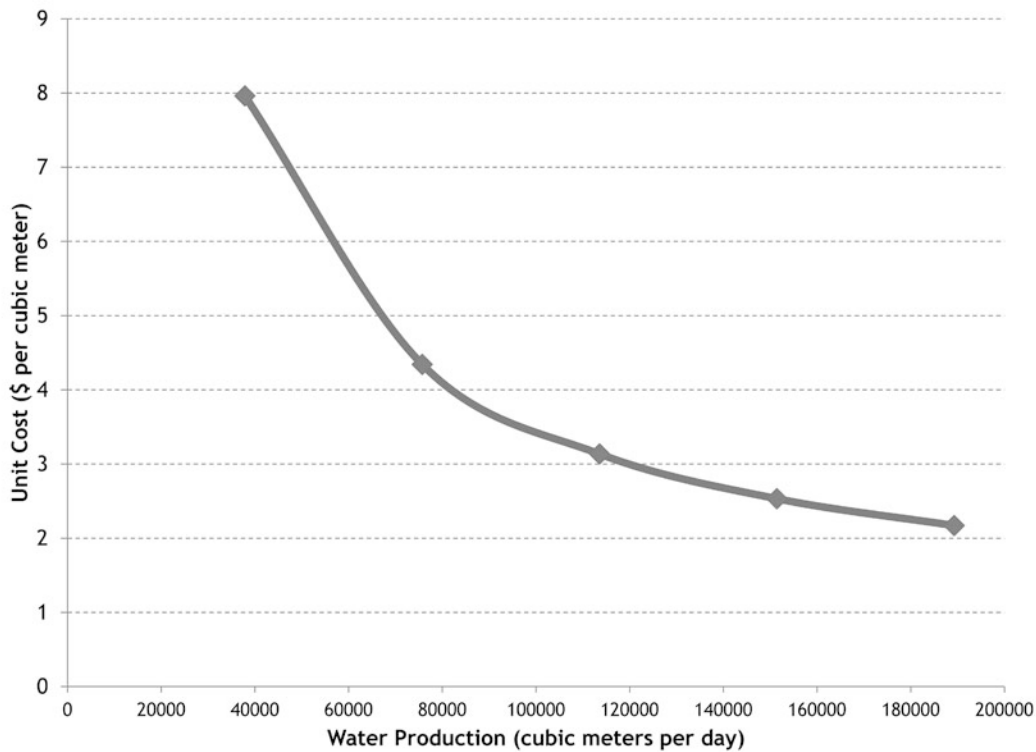
<sup>f</sup>Costs for plants in Australia were converted into US dollars using conversion rates for the year in which the cost estimates were made.

produces 190,000 cubic meters (m<sup>3</sup>) of water per day, or 50 million gallons per day (MGD), at a cost of \$2.17 per m<sup>3</sup> (\$2,700 per acre-foot) at full capacity; an estimated one-third of the cost is fixed, and the remaining two-thirds of the cost is variable. If the operator reduces water production to 150,000 m<sup>3</sup> per day (40 MGD), on average, then the unit cost of water increases to \$2.53 per m<sup>3</sup> (\$3,100 per acre-foot). If the operator further reduces water production to 38,000 m<sup>3</sup> per day (10 MGD), then the unit cost increases to more than \$7.96 per m<sup>3</sup> (\$9,800 per acre-foot).

## Cost Comparisons

Seawater desalination has traditionally been considerably more expensive than most other water supply and demand management options, but cost comparisons made on the basis of the cost of existing water supplies can be misleading. The costs of existing supplies are often far below the investment needed to construct and maintain these systems because of heavy subsidies from state and federal investments. Additionally, current water prices often fail to include costs for adequately maintaining and improving water systems. As a result, the public often has a somewhat distorted perception of the cost of a reliable supply of high-quality water, making it difficult for water utilities to justify their investment in more expensive water supply options, such as desalination.

Consequently, a comparison of the cost of new seawater desalination systems should be based on the *marginal cost* of water: the cost of providing, or saving, the next increment of water. The marginal cost of water varies considerably among communities and changes over time. As a result, these costs should be evaluated periodically on a case-by-case basis. A recent analysis of water alternatives for San Diego County, California—a region where construction of multiple desalination plants is under consideration—finds that seawater desalination has the highest marginal cost of all plausible alternatives (table 6.2). The marginal cost of recycled water is also relatively high, although treating the water to potable levels and using the existing distribution system can reduce this cost considerably. New surface water and groundwater are less expensive than recycled water or seawater desalination, although these supplies are limited. In many cases, conservation and efficiency improvements have the lowest marginal cost.



**FIGURE 6.2 AN EXAMPLE OF THE RELATIONSHIP BETWEEN DESALINATION PLANT PRODUCTION AND UNIT COST**

*Note:* Based on a desalination plant with a capacity of 190,000 m<sup>3</sup> per day (50 MGD).

**TABLE 6.2** Example of the Marginal Cost of Water in San Diego County

| Water Alternative                        | Cost per Cubic Meter | Cost per Acre-Foot |
|--|----------------------|--------------------|
| <b>Imported water</b>                    | \$0.71–\$0.79        | \$875–\$975        |
| <b>Surface water</b>                     | \$0.32–\$0.65        | \$400–\$800        |
| <b>Groundwater</b>                       | \$0.30–\$0.89        | \$375–\$1,100      |
| <b>Seawater desalination</b>             | \$1.46–\$2.27        | \$1,800–\$2,800    |
| <b>Recycled water (nonpotable)</b>       | \$1.30–\$2.11        | \$1,600–\$2,600    |
| <b>Recycled water (potable)</b>          | \$0.97–\$1.46        | \$1,200–\$1,800    |
| <b>Water conservation and efficiency</b> | \$0.12–\$0.81        | \$150–\$1,000      |

*Source:* Equinox Center (2010).

*Note:* All costs are in 2010 dollars. Cost estimates for water conservation and efficiency are based on costs to the water agency, for example, estimated expenditures on educational initiatives or incentives for conservation measures divided by the cumulative water savings, and do not include costs or savings to the customer. One acre-foot equals 1,233 cubic meters.

The cost associated with wastewater conveyance and treatment is another factor that is often excluded from cost comparisons. The introduction of a new source of water increases the amount of wastewater that must be collected, treated, and disposed of. Some communities may have adequate wastewater treatment capacity, and the additional costs would simply be the variable O&M costs associated with that treatment. In other

communities, however, wastewater treatment capacity may need to be expanded, which represents an additional, and in some cases significant, capital cost to the community. While these costs would apply to all of the water supply projects under consideration to meet demand, the costs would not be incurred if water demand were met through water conservation and efficiency improvements.

## Desalination Projects and Risk

Large-scale projects, such as desalination plants, include a variety of risks that affect the ability to attract financing, the rate of return, and the overall viability of a project. Each project will have a unique set of risks that vary in their relative importance. Some of the risks that have been identified for seawater desalination projects include the following (Pemberton 2003; Wilcox and Whitney 2004; Wolfs and Woodroffe 2002; Schiller 2012):

*Permitting risks* are risks that governmental permits and approvals required to construct or operate the project will not be issued or will be issued only subject to onerous conditions.

*Design and technology risks* are risks that can be attributed to the use of a design or technology that fails to deliver at expected service levels.

*Construction risks* arise during the construction period. Construction risks can be attributed to poor project design, ineffective project management, inexperienced contractors, or lack of effective communication among the various contractors working on a project.

*Operational and performance risks* arise during the operation and maintenance period and can be attributed to inexperienced operators, higher than anticipated operating costs, product water that fails to meet required standards, or underperformance of equipment.

*Financial risks* are influenced by the financial status of the borrower, changes in interest rates, fluctuation in foreign exchange rates (if the project relies on foreign investment), and changes to pricing of construction or operational phase insurance.

*Market risks* can be caused by unrealistic demand assessments and water production assumptions, reluctance of customers to buy the produced water, and reluctance of those with rate-making authority to approve rate increases to cover new costs.

*Political risks* are associated with political decisions that affect the cost or viability of the project and can relate to laws, tax rates, governmental permissions, and other factors. These risks may be associated with decisions made by elected or appointed officials or by the public through, for example, a referendum.<sup>3</sup>

*Force majeure risks* are the risks of events that render the construction or operation of the project impossible, either temporarily or permanently. A

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3. For example, in November 2012, Santa Cruz residents passed Measure P, which guarantees residents the right to vote on whether to pursue a seawater desalination project in the future.



force majeure event includes an extraordinary event or circumstance that prevents one or both parties from fulfilling their obligations under the contract and is beyond the control of the parties, such as an earthquake, flood, hurricane, war, strike, or riot.

Recent experience suggests that a key risk associated with seawater desalination plants is overly optimistic assumptions about future demand for the produced water and underappreciation of the availability of less expensive alternatives. This is a type of market risk that is also often referred to as demand risk. Water managers often have multiple sources of water to choose from to meet water demand. Desalination is among the most expensive options, and water managers may reduce the output of a desalination plant when demand drops or when less expensive options are available. As noted above, reducing the output can increase the overall unit cost of the produced water considerably, which can further reduce demand or make other supply options even more economically attractive. In response, water managers may temporarily or permanently shut down the desalination plant. This can reduce the variable operating costs associated with the plant, especially energy and chemical costs, but ultimately leave ratepayers to pay off a plant while receiving little to no benefit from it. Additionally, as desalination expert Tom Pankratz notes, “frequent stopping and starting, or long-term mothballing, may not only affect the short-term performance of a plant, it may actually be detrimental to the system itself” (Pankratz 2011).

Recent experience in Australia highlights demand risk (table 6.3). The Australian government has made a massive investment in seawater desalination plants in response to a severe and persistent drought, developing six major plants since 2006. The first plant, with a capacity of 37 MGD, was built in Perth, became operational in late 2006, and continues to operate at or near full capacity. A second plant, the Southern Seawater Desalination Plant, is being developed in the same region and should be completed in 2013. Other plants were built in New South Wales, Victoria, and South Australia. While many consider the first Perth plant to be a success, the four other plants built in recent years have been or will be put into standby mode as a result of reductions in demand and the availability of less expensive alternatives.

For example, the Kurnell Desalination Plant in Sydney, New South Wales, was completed in January 2010 but was mothballed in July 2012 because less expensive surface water sources are available.<sup>4</sup> Likewise, the Wonthaggi Desalination Plant in Victoria was completed in December 2012. Although the plant performed as designed, the government announced it would not be ordering water from the plant in 2013. Similarly, the Port Stanvac Desalination Plant, south of Adelaide, South Australia, is expected to be completed in 2013, but in an October 2012 statement, SA Water’s chief executive, John Ringham, announced that “to keep costs down for our customers, SA Water is planning to use our lower-cost water sources first, which will mean placing the desalination plant in stand-by mode when these cheaper sources are available” (Kemp 2012). The desalination plant, which cost nearly \$1.9 billion, is slated to go on standby mode in 2015.

Experience in Santa Barbara, California, and in Tampa Bay, Florida, provides further evidence of demand risk. During a severe multiyear drought in California (1987–1992), the City of Santa Barbara partnered with several local water agencies to build a seawater desalination plant. The plant was completed in March 1992, and shortly thereafter the

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4. If reservoir levels fall below 80 percent capacity, the desalination plant will be restarted.

**TABLE 6.3** Operational Status of Recently Constructed Desalination Plants

| Facility Name                                      | Location                           | Date Operational                                  | Plant Capacity (MGD) | Plant Capacity (m <sup>3</sup> /day) | Status  |
|--|------------------------------------|---|----------------------|--------------------------------------|---|
| <b>Tampa Bay Desalination Plant</b>                | Tampa Bay, Florida                 | 2007  | 25                   | 95,000                               | In intermittent use   |
| <b>Gold Coast Desalination Plant<sup>a</sup></b>   | Tugun, Queensland, Australia       | February 2009                                     | 33                   | 125,000                              | In standby mode since December 2010 because of high operating cost and operational issues |
| <b>Kurnell Desalination Plant<sup>b</sup></b>      | Sydney, New South Wales, Australia | January 2010                                      | 66                   | 250,000                              | In standby mode since July 2012 because reservoirs are full                               |
| <b>Kwinana Desalination Plant</b>                  | Perth, Western Australia           | November 2006                                     | 38                   | 144,000                              | Operational   |
| <b>Southern Desalination Plant</b>                 | Binningup, Western Australia       | September 2011 (phase 1);<br>March 2013 (phase 2) | 72                   | 270,000                              | Phase 1 is operational; phase 2 is under construction                                     |
| <b>Wonthaggi Desalination Plant<sup>c</sup></b>    | Victoria, Australia                | December 2012                                     | 109                  | 413,000                              | In standby mode since January 2013  |
| <b>Port Stanvac Desalination Plant<sup>d</sup></b> | Adelaide, South Australia          | 2013  | 72                   | 270,000                              | Will be put in standby mode in 2015   |

*Sources:*<sup>a</sup>Marschke (2012).<sup>b</sup>AAP Newswire (2012).<sup>c</sup>Hosking (2012).<sup>d</sup>Kemp (2012).

drought ended. The plant was eventually decommissioned, as the cost to produce the water was too high to warrant its use during non-drought periods. In addition, the high cost of building the plant and connecting to the California State Water Project raised local water prices enough to encourage substantial additional conservation, further decreasing need for the plant. Similarly, Florida's Tampa Bay Seawater Desalination Project was completed in 2008 in an effort to reduce groundwater pumping. Since it was built, that plant has operated far below its full capacity as a result of periodic operational issues, reductions in regional water demand, and availability of less expensive alternatives.

## Project Delivery Methods

Planning, designing, financing, constructing, and operating major water projects, such as desalination plants, can be challenging. Such projects are often accomplished by public agencies or through various types of public-private partnerships. The delivery of large-scale water projects may involve different parties and stakeholders, including the owner, designers and engineers, construction contractors, operation contractors, external financiers, and consumers. The project delivery method determines how these multiple groups relate to one another. There is a range of project delivery methods; among the most common are the following:

*Design-bid-build (DBB)*. This is a traditional project delivery approach for municipal infrastructure projects in which the owner, that is, the public water provider, determines that a project is needed and secures financing for the project. The owner works with an engineer to define the project and develop plans with detailed specifications; the owner then solicits bids from multiple contractors to construct the project; the contractor that provides the lowest bid that meets all of the criteria is selected; and operations are performed by the owner or by a contract operator.

*Design-build (DB)*. The owner develops the project concept and secures financing; the owner then hires a design-build team to construct the project for a lump-sum fixed price or a guaranteed maximum price; operations are performed by the owner or by a contract operator.

*Design-build-operate (DBO)*. The owner develops the project concept and secures financing; the owner hires a single team responsible for the development, design, construction, and long-term operation of the project.

*Design-build-own-operate-transfer (DBOOT)*. The contractor is responsible for the design, construction, and long-term operation of the project. In contrast with the more traditional project delivery methods, the contractor must secure financing for the project and initially owns the facility; the water agency agrees to purchase the water at an agreed-upon price over a certain period (these purchase agreements allow the contractor to secure the necessary financing); the contract contains provisions for the transfer of ownership of the facility to the water provider on an agreed-upon date.

*Design-build-own-operate (DBOO)*. In this variation of the DBOOT delivery method the contractor is responsible for the design, financing, construction, and long-term operation of the project, and the water agency agrees to purchase the water at an agreed-upon price over a certain period. Unlike the situation with a DBOOT, however, there is no asset transfer at the end of the project.

Each project delivery method has advantages and disadvantages with respect to how risk is shared among parties, the length of the process, and other factors. Some of these advantages and disadvantages are described in table 6.4. A key difference among the project delivery methods is the degree to which innovation in technology and design is integrated into the project. The water sector in the United States has traditionally employed the DBB delivery model. With DBB, the public utility or agency (owner

of the project) plays a central role, selecting different groups to design, construct, and possibly operate the project. DBB contracts are generally awarded on the basis of lowest cost (NRC 2008). Thus, there is often little incentive to implement innovative designs and technologies that may have a higher capital cost but that reduce operating costs and result in a less expensive project overall. With a DBO delivery method, by contrast, the DBO contractor is responsible for operation of the project. Thus, the contractor has an incentive to promote innovative designs and technologies that can optimize and improve the operability of the project.

Another key difference among the various project delivery methods is the party required to secure financing. Under the DBB, DB, and DBO delivery methods, the water provider secures project financing, largely by issuing debt (bonds or loans). Under the DBOO and DBOOT delivery methods, by contrast, the contractor secures financing by issuing debt or obtaining private equity or both. One possible drawback in using this approach, however, is the high cost of private capital, which is reflected in the final price of desalinated water. Proponents of this delivery method, however, argue that the higher costs (which are borne by the consumer) are offset by lower risk for the water provider, higher efficiency of the contractor, and technology performance guarantees (Texas Water Development Board 2002).

## Risk Allocation among Project Partners

A key element of any public-private partnership is the allocation of risk among the project partners. With DBB contracts, the owner—typically the public—carries most of the risks associated with the project. By contrast, with DBO and DBOOT contracts, the contractor bears more of the risk (figure 6.3). By assuming a specific risk, the project partner is responsible for any additional cost (or savings) associated with that risk and cannot pass that cost along to the other project partner. For example, if Partner A assumes the construction risk for the project, and the cost of construction is higher than anticipated, Partner A must pay the additional cost of construction and cannot pass those costs along to Partner B. Likewise, if construction costs are lower than anticipated, Partner A captures that savings and does not pass the savings on to Partner B.

The project sponsor is expected to identify the risks associated with the project and determine the appropriate risk and responsibility allocation prior to the procurement process and contract development. This allows the interested parties to understand the



**FIGURE 6.3 RISK ALLOCATION UNDER VARIOUS PROJECT DELIVERY METHODS**

underlying risks and responsibilities and price their proposal accordingly, since the contractual risk structure is directly related to pricing (Wilcox and Whitney 2004). In theory, a particular risk should be allocated among parties such that the party with the greatest ability to control the outcome takes on that risk. There are some risks, however, that are outside the control of both parties.

As described above, demand risk is one of the key risks associated with desalination projects. The quantity of water that will be purchased is set forth in a long-term water purchase agreement—also referred to as an off-take agreement. This agreement is negotiated prior to construction of the project and is often needed to secure financing. Among the most common forms of off-take agreement is the “take-or-pay” contract. Under a take-or-pay contract, the buyer agrees to pay for a minimum amount of water from the seller on a certain date even if the buyer does not need the water. This type of contract provides guaranteed revenue for the seller but commits the buyer to a purchase even if actual demand drops. A minimum commitment to a large volume of water, however, provides a disincentive for water agencies to pursue more cost-effective water supply and water conservation and efficiency programs. Thus, take-or-pay contracts, if structured poorly, can result in significant exposure to demand risk and higher costs for the buyer—a problem noticed long ago in the context of energy take-or-pay contracts.<sup>5</sup>

## Case Studies

In the following section, we provide two case studies that emphasize several elements of seawater desalination projects, including their cost, how they are financed, the structure of the public-private partnership, and the risks associated with the projects. The first case study looks in detail at the Tampa Bay Seawater Desalination Project, which is the largest plant built in North America to date and has been the subject of several in-depth assessments. The second case study focuses on the proposed desalination project in Carlsbad, California, which has been in development for more than a decade, has received all of the necessary permits, and finally secured financing in December 2012.

### Tampa Bay Seawater Desalination Project

Like many communities around the United States, the Tampa Bay, Florida, region has been experiencing significant growth combined with increasing constraints on water availability. Overpumping of local groundwater resources in the region has forced communities to think about alternative water solutions. In the late 1990s, some water managers and planners thought seawater desalination might be a key element of the region's long-term water future. The Tampa Bay Seawater Desalination Project faced several major delays but was completed in 2007 (Cooley 2009). It is the first large-scale seawater desalination project constructed in the United States.

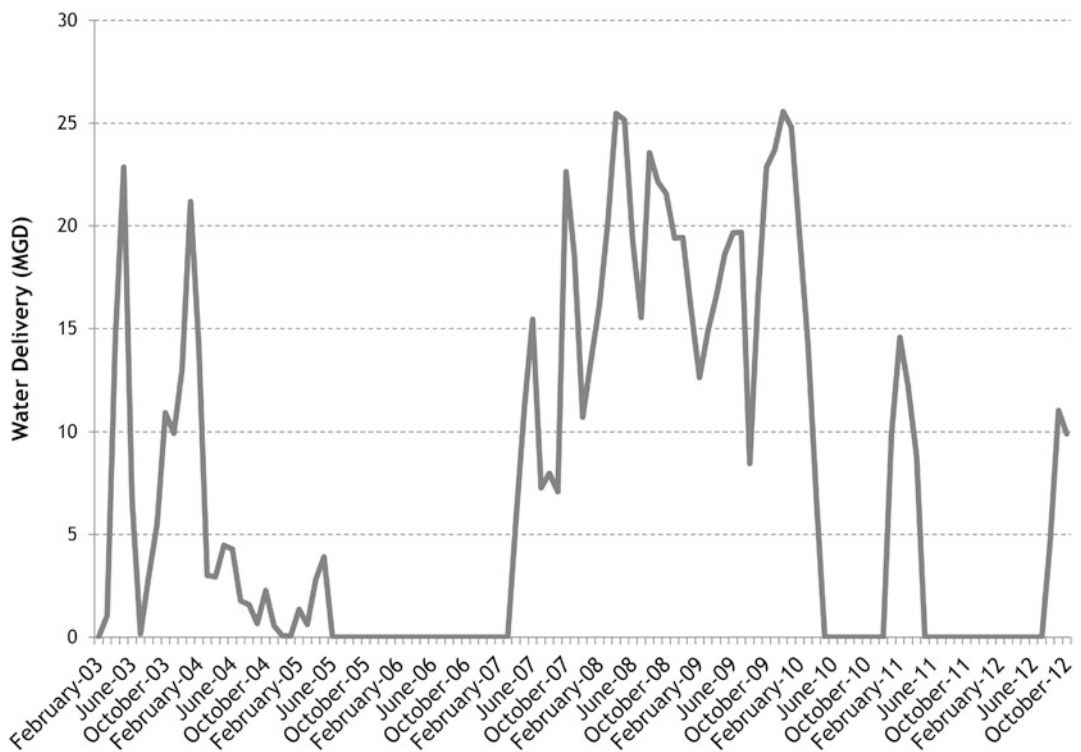
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5. A summary of problematic energy take-or-pay contracts can be found here: [http://www.jbsenergy.com/energy/papers/blueprint/blueprint.html#\\_Toc2576605](http://www.jbsenergy.com/energy/papers/blueprint/blueprint.html#_Toc2576605). Similarly, take-or-pay contracts for natural gas caused serious problems for both suppliers and consumers and required federal intervention in the 1980s and 1990s (<http://www.naturalgas.org/regulation/history.asp>). See also the Carlsbad case study in this chapter for some issues that can arise with a take-or-pay contract.

Since its completion in 2007, the plant has operated far below its design capacity of 95,000 m<sup>3</sup> per day (25 MGD). Figure 6.4 shows the plant's average monthly water production between 2003 and October 2012. During some short periods, the plant operated at or near capacity. In others, the plant operated at reduced capacity or was in standby mode. In 2013, Tampa Bay Water plans to operate the plant at a higher capacity (averaging 42,000 m<sup>3</sup> per day, or 11 MGD) because a local water reservoir is undergoing repair. Once this is complete, however, production from the desalination plant will likely be reduced once again because cheaper water supply alternatives are available. A recent analysis by Tampa Bay Water found that implementing cost-effective conservation and efficiency programs in the region would reduce water demand by 2035 by 150,000 m<sup>3</sup> per day (40 MGD) (Tampa Bay Water 2012), significantly more water than is produced by the seawater desalination plant and at a lower cost.

### *Project Delivery Method*

In response to ongoing water supply concerns, the West Coast Regional Water Supply Authority—later to become Tampa Bay Water—issued a request for proposals (RFP) to design, build, operate, and own a desalination plant in 1996. The RFP allowed the project developer to select the size and location of the plant as well as the operations and method of seawater desalination. In July 1999, after a two-and-a-half-year solicitation process, Tampa Bay Water entered into a water purchase agreement with S&W Water, LLC—a partnership between Stone & Webster and Poseidon Resources Corporation.



**FIGURE 6.4 AVERAGE MONTHLY WATER PRODUCTION FROM TAMPA BAY SEAWATER DESALINATION PLANT, 2003–2012**

*Note:* The design capacity of the plant is 95,000 cubic meters per day (25 MGD).



**TABLE 6.4** Advantages and Disadvantages of Various Project Delivery Methods

|                        | Advantages  | Disadvantages   | Works best when...   |
|------------------------|---|---|--|
| Design-bid-build (DBB) | <ul style="list-style-type: none"> <li>Well understood by all involved parties</li> <li>Potential for high degree of owner control and involvement</li> <li>Independent oversight of construction contractor</li> </ul>   | <ul style="list-style-type: none"> <li>Segments design, construction, and operation and reduces collaboration</li> <li>Linear process increases schedule duration</li> <li>Prone to disputes and creates opportunities for risk avoidance by the designer and construction contractor</li> <li>Low-bid contractor selection reduces creativity and increases risks of performance problems</li> <li>Risks are mostly borne by the owner</li> <li>May not allow for economies of scale in operations</li> <li>For new technologies, operability may not be the primary design concern</li> </ul> | <ul style="list-style-type: none"> <li>Operation of facility is minimal or well understood by owner</li> <li>Project requires high degree of public oversight</li> <li>Owner wants to be extensively involved in the design</li> <li>Schedule is not a priority</li> </ul>   |
| Design-build (DB)      | <ul style="list-style-type: none"> <li>Collaboration between designer and contractor</li> <li>Parallel processes reduce duration</li> <li>Reduces design costs</li> <li>Reduces potential for disputes between designer and construction contractor</li> <li>Single point of accountability</li> <li>Can promote design innovation</li> <li>Provides more certainty about costs at an earlier stage</li> <li>Allows owner to assign certain risks to DB team</li> </ul> | <ul style="list-style-type: none"> <li>Owner may not be as familiar with DB process or contract terms</li> <li>Reduces owner control and oversight</li> <li>Design and “as-built” drawings not as detailed</li> <li>Eliminates “independent oversight” role of the designer</li> <li>Does not inherently include incentives for operability and construction quality, as does DBO or DBOOT approach</li> <li>Higher cost to compete</li> </ul>  | <ul style="list-style-type: none"> <li>Time is critical, but existing conditions and desired outcomes are well defined</li> <li>Project uses conventional, well-understood technology</li> <li>Owner is willing to relinquish control over design details</li> <li>Operational and aesthetic issues are easily defined</li> <li>Early contractor input will likely save time or money</li> </ul> |

|  |   |  |
|--|---|--|
| <p>Design-build-operate (DBO)</p> <ul style="list-style-type: none"> <li>• Allows collaboration among designer, construction, contractor, and operator</li> <li>• Parallel processes reduce duration</li> <li>• Operator input on new technologies and design</li> <li>• DBO contractor has built-in incentive to ensure quality, since contractor will be long-term operator</li> <li>• Single point of accountability</li> <li>• Allows owner to assign certain risks to DBO contractor</li> <li>• Economies of scale for operations</li> <li>• Collaboration, long-term contract, and appropriate risk allocation can cut costs</li> <li>• Defines long-term expenses for rate setting</li> </ul> | <ul style="list-style-type: none"> <li>• Reduces owner involvement</li> <li>• Owner may not be familiar with DBO contracting</li> <li>• High cost to compete may limit competition</li> <li>• Depending on contract terms, may give operator incentives to overcharge for ongoing renewals and replacements or to neglect maintenance near the end of the contract term</li> <li>• Operations contract may limit long-term flexibility</li> <li>• Requires multiphase contract</li> </ul> | <ul style="list-style-type: none"> <li>• Owner's staff does not have experience in operating the type of facility</li> <li>• Input conditions to the facility can be well defined and the number of external influences affecting plant operations is limited</li> <li>• Owner is comfortable with less direct control during design, construction, and operation</li> </ul> |
| <p>Design-build-own-operate-transfer (DBOOT)</p> <ul style="list-style-type: none"> <li>• Same as with DBO, plus the following:</li> <li>• Can be used where project expenditures exceed public borrowing capacity</li> <li>• Beneficial when preserving public credit for other projects is important</li> <li>• Can isolate owner from project risk</li> </ul>   | <ul style="list-style-type: none"> <li>• Same as with DBO, but lack of public financing increases the cost of money</li> </ul>  | <ul style="list-style-type: none"> <li>• Public financing cannot be obtained</li> <li>• Transfer of technology risk is important</li> </ul>  |

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*Source:* Adapted from Texas Water Development Board (2002) and NRC (2008).

Under the initial agreement, S&W Water would develop a desalination plant capable of supplying 95,000 m<sup>3</sup> per day (25 MGD) to Tampa Bay Water and would sell that water at a fixed price. The agreement was structured as a BOOT arrangement that would allow Tampa Bay Water to buy the plant after thirty years or earlier, if desired.

Soon after the water purchase agreement was signed, the project began encountering problems. In June 2000, Stone & Webster declared bankruptcy, leaving Poseidon without an engineering and construction partner. Poseidon then hired Covanta Energy to construct the plant, and a new partnership emerged: Tampa Bay Desal. Obtaining financing for the project, however, proved to be difficult. Covanta Energy had a poor bond rating and was unable to secure financing for the construction bonds. Tampa Bay Water, however, had a more favorable AA bond rating, which would allow it to obtain financing at a lower interest rate and thereby reduce the financing cost. In early 2002, Tampa Bay Water bought Poseidon's interest in the project while retaining the engineering and construction company (Covanta Construction) to complete the project. At the time, the plant's design and permitting were complete, while construction was only 30 percent complete (Smith 2009). Tampa Bay Water signed a thirty-year O&M contract with Covanta Tampa Bay, Inc. (a subsidiary of Covanta Energy) to operate the facility.<sup>6</sup> This move effectively restructured the DBOOT procurement into a DBO contract, whereby Tampa Bay Water assumed ownership and many of the risks associated with the plant.

Before Covanta Tampa Bay could commence the separate thirty-year O&M contract, the plant was required to meet certain performance standards. Covanta Construction was unable to meet the test standards after repeated attempts and finally declared bankruptcy in 2003. In 2004, the parties agreed to a settlement whereby Tampa Bay Water paid Covanta nearly \$5 million to end its contract. In return, Tampa Bay Water retained full control of the facilities and the operating contract. In late 2004, Tampa Bay Water signed a DBO contract with American Water-Pridesa, a joint venture between American Water and Acciona Agua, to repair deficiencies and operate the plant on a long-term basis.

Under the current operating contract, Tampa Bay Water must pay American Water-Pridesa about \$7 million per year regardless of whether water is produced by the plant. This base contract covers the fixed O&M costs for the plant plus some return to the operator. Tampa Bay Water pays variable operating costs (chemicals and electricity) separately. This contract allows Tampa Bay Water to reduce the plant's production if cheaper alternatives are available.

### *Project Cost*

The initial capital cost for the desalination plant and the fifteen-mile pipeline to connect it to the water system was estimated to be \$110 million. Initial performance tests in 2003, however, revealed thirty-one deficiencies in the plant. To fix the plant, Tampa Bay Water signed a \$29 million, two-year contract with American Water-Pridesa. Major improvements were made to the pre-treatment, reverse osmosis, and post-treatment system, and the final capital cost of the project was \$158 million, more than 40 percent above the original cost.

Initially, desalination proponents were excited by the Tampa Bay project and by the apparent price breakthrough. In the initial water purchase agreement, S&W Water made a binding commitment to *deliver* desalinated water in the first year of operation at an unprecedented wholesale cost of \$0.45 per m<sup>3</sup> (\$557 per acre-foot), with a thirty-year

6. The O&M contract was worth \$300–\$360 million and was Covanta Tampa Bay's only asset (Wright 2003).

average cost of \$0.55 per m<sup>3</sup> (\$678 per acre-foot) (Heller 1999). This was well below the cost of water from other recent desalination plants. By comparison, in that same year the Singapore Public Utilities Board announced plans to build a large desalination plant to produce water at an estimated cost of between \$1.98 and \$2.31 per m<sup>3</sup> (\$2,440 and \$2,850 per acre-foot, respectively), with an additional cost to deliver water to customers (*U.S. Water News* 1999).

The project developers were unable to deliver on the initial cost estimates, and the cost estimates have increased. Additionally, as noted above, the production of water from the plant has varied dramatically since the project was completed in 2007, further affecting the unit cost (figure 6.4). According to recent estimates from Tampa Bay Water, the unit cost of water from the desalination plant is \$1.05 per m<sup>3</sup> (\$1,300 per acre-foot) if the plant is operating at full capacity (Vatter 2012).<sup>7</sup> Officials at Tampa Bay Water, however, indicate that the plant will operate at an average production of 40,000 m<sup>3</sup> per day (11 MGD) from October 2012 through October 2013, which is considerably less than full capacity. At this reduced capacity, the unit cost of water is estimated at \$1.30 per m<sup>3</sup> (\$1,600 per acre-foot), more than double the original cost estimate (Vatter 2012).

### *Project Financing*

The Tampa Bay Seawater Desalination Project was originally structured as a BOOT agreement, which usually employs some combination of debt and equity financing. Tax-exempt private-activity bonds provided 90 percent of the project's capital cost (Lokiec and Kronenberg 2001), and the remaining 10 percent was provided as an equity stake by the project developer. In 2007, however, Tampa Bay Water bought out Poseidon's interest in the project using short-term, variable interest rate bonds and became the sole owner of the plant. Tampa Bay Water selected this financing strategy because interest rates were low at the time. Furthermore, the bonds would be repaid shortly after the project was completed because the Southwest Florida Water Management District (SWFWMD), a regional agency that regulates and permits water resources for west-central Florida, agreed to provide \$85 million of the project's eligible capital costs over an eighteen-month period upon completion. The SWFWMD obtained these funds through voter-approved, locally collected ad valorem property taxes designated for water supply creation.

### *Summary*

When the Tampa Bay desalination plant was announced, it was hailed as a breakthrough for desalination in the United States and sparked enormous interest and excitement. But the project encountered several technical and managerial challenges. The experiences of Tampa Bay Water can help to inform the development of projects under consideration elsewhere. Some of the lessons that can be learned about cost, financing, and risk include the following:

- Anticipate the transfer of ownership at any point of the project and consider what actions will be taken if that transfer occurs.
- Exercise caution when transferring ownership under a DBOOT contract. The new owners must recognize that they are assuming many of the risks associated with the project.

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7. This estimate includes O&M plus the annual debt service cost, assuming that the full capital cost of the project was financed at Tampa Bay Water's average bond rate over thirty years.

- Ensure that those submitting proposals have relevant experience with desalination projects.
- Minimize demand risk by implementing cost-effective water supply alternatives prior to the development of the project.
- Consider establishing a minimum operating contract, rather than a take-or-pay contract, to allow the water supplier to adjust production of the plant if cheaper alternatives are available.

## Carlsbad Desalination Project

Poseidon Resources Corporation is working to build a 190,000 m<sup>3</sup> per day (50 MGD) desalination facility at the Encina Power Station in the city of Carlsbad. The project would utilize the Encina Power Station's existing surface intake and outfall structures. Poseidon began developing the project in 1998, and in 2003 it constructed a demonstration facility at the site. The project has been highly contested, with local and environmental groups filing more than a dozen legal challenges, including lawsuits and permit appeals, against the project. By November 2009, Poseidon had received all of the permits required to build and operate the plant and announced it would begin to secure financing. Financing was finally secured in December 2012. Here we provide a detailed case study of the cost, financing, and partnerships associated with the project.

### *Project Cost*

Numerous and contradictory cost estimates for the Carlsbad Desalination Project have been put forth since the project was initiated in the late 1990s. In May 2002, initial capital cost estimates for the desalination plant were \$260 million (Green 2002), dramatically less than other plants of similar size at the time. Estimates for the desalination plant and distribution pipeline were quoted at \$270 million in 2002 (Jimenez 2002) and \$320 million in 2009 (Schwartz 2009). By October 2011, however, projected costs had increased to \$950 million, more than three and one-half times the original cost. It is difficult to determine why these costs grew so dramatically over the ten-year period because there has been a lack of transparency regarding assumptions about financing, inflation rates, energy costs, interest repayment, related facilities, and other factors.

The water purchase agreement provided detailed cost estimates for the project. According to these figures, the capital cost of the project is \$767 million (Lee 2013). Of that amount,

- \$537 million is needed for the planning, permitting, design, construction, mitigation, and legal costs associated with the desalination plant;
- \$159 million is needed to build a ten-mile pipeline to transport the desalinated water from the coast to the regional water distribution system; and
- \$80 million is needed for indirect costs associated with water system improvements, including relining and rehabilitating a five-and-one-half-mile section of the distribution pipeline and modifying the Twin Oaks Valley Water Treatment Plant to accommodate desalinated water flows.

In addition to the capital costs, operating and maintaining these facilities would cost an additional \$49–\$54 million each year (Lee 2013).<sup>8</sup> Financing costs for the project, including bond repayments and the return to the equity investors, exceed \$1 billion (Lee 2013).

As described previously, the unit cost of water is determined by dividing the annual capital and O&M costs by the amount of water produced. In 2002, Poseidon estimated that the unit cost of water would be \$0.65 per m<sup>3</sup> (\$800 per acre-foot) (Green 2002). In the initial contracts with local water agencies, Poseidon agreed to sell desalinated water at the same price that the agencies paid for imported water. Poseidon was willing to take a loss on the project in the short term, with the belief that imported water supplies would eventually be more expensive than the desalinated water and that they would recover these costs over the long term. Today, water agencies pay less than \$0.81 per m<sup>3</sup> (\$1,000 per acre-foot) for treated water from the Metropolitan Water District of Southern California (MWD), which is more expensive than Poseidon's original cost estimate but considerably less than the most recent estimates for the project.

Like the total cost, the unit price of water has also grown tremendously as the project has developed. By July 2010, the unit cost for water had increased to \$0.89 per m<sup>3</sup> (\$1,100 per acre-foot) plus an additional \$0.41 per m<sup>3</sup> (\$500 per acre-foot) (in 2010 dollars) for delivery charges (SDCWA 2010). Since that time, the unit cost has continued to rise in response to changes in the plant design, inflation rates, improved financing estimates, and more. The most recent figures from the San Diego County Water Authority (SDCWA, or Water Authority) estimate that the cost to produce desalinated water and to integrate it into the existing distribution system is about \$1.55–\$1.76 per m<sup>3</sup> (\$1,900–\$2,200 per acre-foot) (in 2012 dollars) (SDCWA 2012a).<sup>9</sup> Note that the cost estimates—both the total cost and the unit cost—will likely change as the project advances.

A key question is how the cost of desalination compares with the cost of other water supply alternatives. A recent analysis by the Water Authority finds that the marginal cost of new supply within the San Diego area ranges from \$1.20 to \$1.93 per m<sup>3</sup> (\$1,475–\$2,375 per acre-foot) (in 2011 dollars) (table 6.5). The cost of water from the proposed seawater desalination plants—Carlsbad and Camp Pendleton—are at the high end of the range. Desalinated brackish groundwater and recycled water are considerably less expensive. This analysis, however, does not include an evaluation of the cost of water conservation and efficiency measures, many of which provide water for considerably less than \$1.22 per m<sup>3</sup> (\$1,500 per acre-foot) (Gleick et al. 2003).

### *Project Delivery Method*

The Carlsbad desalination project has been in development since 1998 as a public-private partnership. The project partners—and the relationships between those partners—have changed considerably over the past fourteen years. In December 2001, Poseidon completed an initial study for the City of Carlsbad and proposed to build a desalination plant at the Encina Power Station. The original proposal was structured as a DBOO agreement, whereby Poseidon would retain ownership of the facility and would ask the regional water agencies, including the City of Carlsbad and the Water Authority, to sign a thirty-year contract to purchase water directly from Poseidon (La Rue 2001).

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8. This includes O&M costs for the entire project, that is, the desalination plant, the conveyance pipeline, and the efficiency losses at the Twin Oaks Valley Water Treatment Plant.

9. The range in the unit price reflects a purchase of 48,000 to 54,000 acre-feet per year.



**TABLE 6.5** Marginal Unit Cost of Water

| Water Alternative   | Cost per Cubic Meter | Cost per Acre-Foot |
|---|----------------------|--------------------|
| <b>Brackish groundwater (Mission Basin Narrows)</b>                   | \$1.39               | \$1,717            |
| <b>Brackish groundwater (Otay River)</b>                              | \$1.20–\$1.69        | \$1,475–\$2,086    |
| <b>Indirect potable reuse (City of San Diego)</b>                     | \$1.60–\$1.93        | \$1,975–\$2,375    |
| <b>Indirect potable reuse (North San Diego County Regional Reuse)</b> | \$1.32–\$1.40        | \$1,628–\$1,730    |
| <b>Seawater desalination (Camp Pendleton)</b>                         | \$1.54–\$1.90        | \$1,900–\$2,340    |

Source: SDCWA (2012d).

Note: These costs refer to estimates for specific projects and are directly from the SDCWA. The costs shown in this table refer to average estimates across the regions. All costs are in 2011 US dollars and exclude any grants or incentives. The cost listed for the City of San Diego's indirect potable reuse project includes wastewater-related costs that could reduce the unit cost by up to \$600 per acre-foot (\$0.49 per cubic meter). This figure also excludes the costs of conservation and efficiency, water transfers from agriculture, and additional water from regional providers.

By 2002, the partnership had shifted to a DBOOT arrangement. In November 2002, the Water Authority approved the outline of a partnership with Poseidon to build a desalination plant in Carlsbad. Under the proposed agreement, Poseidon would obtain the permits, secure the financing, and supervise the construction. The power plant's owner, Cabrillo Power, would operate and maintain the facility. The Water Authority would be the sole purchaser of water and would be responsible for building the pipelines that distribute the water. Poseidon would initially own the plant but would sell it to the Water Authority after five years of operation (Jimenez 2002).

Negotiations between Poseidon and the Water Authority were on-again, off-again between 2003 and 2005. Unable to reach an agreement, the two sides resolved to pursue separate, competing projects at the Encina Power Station: one by the Water Authority and the other by Poseidon. In mid-2006, however, the Water Authority announced it would no longer pursue a desalination plant in Carlsbad (Rodgers 2006). Poseidon continued to pursue water purchase agreements with local agencies. By late 2009, Poseidon had received all of the permits it needed to build the plant and had signed water purchase agreements with a number of local agencies (Burge 2009). With these agreements in place and with the withdrawal of the Water Authority, the Carlsbad Desalination Project in effect shifted to a DBOO arrangement.

In mid-2010, the structure of the project abruptly shifted back to a DBOOT arrangement. In July 2010, the Water Authority approved key terms to be the sole purchaser of water from Poseidon. Water Authority staff began negotiating specific elements of the agreement, including the water purchase price, allocation of risk, and options to eventually purchase the project's pipeline and the entire desalination plant (SDCWA 2010). In September 2012, after more than two years of negotiation, the Water Authority released the water purchase agreement for a public review period prior to a vote by the county board of directors. Under this agreement, Poseidon would be responsible for designing, permitting, financing, constructing, and operating the desalination plant and would be the owner of the plant during the contract term.<sup>10</sup> The Water Authority would have the

10. The contractor for the project would be a joint venture of Kiewit Infrastructure West and J.F. Shea Construction. IDE Technologies would provide the process technology (e.g., the pumps and membranes) and would also operate and maintain the desalination plant.

right to purchase the plant after ten years of commercial operation under previously specified terms and conditions or to take over ownership of the plant after thirty years for \$1. The Water Authority may also purchase the plant if Poseidon is unable to secure financing or if the venture goes bankrupt (SDCWA 2012c). It is of note that in Tampa Bay, Florida, the project contractors were unable to secure financing, prompting Tampa Bay Water to purchase Poseidon's interest in the project and assume many of the project-related risks.

The pipeline needed to convey the desalinated water from the coast to the distribution system would be developed under a separate DB agreement between the Water Authority and Poseidon. The Water Authority would own and maintain the pipeline and would finance the project using municipal bonds. Poseidon, however, would assume responsibility for payment of the bonds in the event that Poseidon is unable to complete the desalination project. The Water Authority would also assume responsibility for completing and financing other water system improvements, specifically, relining the conveyance pipeline and upgrading the Twin Oaks Valley Water Treatment Plant.

The process for selecting Poseidon as the project partner was different from the typical process in a DBOOT arrangement. Ordinarily, the public agency solicits proposals for a project. Interested parties then submit their qualifications and, if accepted, submit a proposal that includes some cost estimate. The public agency then selects a proposal on the basis of a variety of factors, including cost. The Water Authority, however, did not allow other parties to submit proposals and determine which one offered the best alternative. Without this process, it is difficult to determine whether the best proposal was selected.

### *Risk Allocation*

One key element of the water purchase agreement between Poseidon and the Water Authority is the allocation of risk among the project partners. As shown in table 6.6, project-related risks are split between Poseidon and the Water Authority. Poseidon, for example, assumes the risks associated with construction of the plant; this includes ensuring that the project is completed on time, on cost, and according to design standards. Poseidon also assumes certain operational risks, including those associated with the amount of energy consumed, the costs of membrane performance and replacement, and chemical costs. Additionally, if Poseidon fails to produce water, then Poseidon must cover the debt service cost for the desalination plant and the Water Authority's conveyance pipeline.

The Water Authority also assumes several project-related risks that could further increase the price of water. For example, the Water Authority assumes the risk associated with changes in law or regulations that generally apply to water treatment facilities and wastewater dischargers. Thus, any additional costs associated with complying with these laws or regulations would allow Poseidon to increase the price of water. The State Water Resources Control Board, for example, is considering amendments to the California Ocean Plan that could increase the costs associated with brine discharge. Under the purchase agreement, capital costs of up to \$20 million (in 2010 dollars) could be passed along to the Water Authority. The Water Authority also assumes the risk associated with inflation and rising electricity prices, and thus Poseidon can increase the price of water because of costs associated these factors.

The Water Authority also assumes the risk associated with sustaining demand for the water produced by the desalination plant. The water purchase agreement is structured as a take-or-pay contract, and under these terms the Water Authority must pay for the water

TABLE 6.6 Project Risk Allocation

| Risk Description  | Poseidon                       | San Diego County Water Authority |
|---|--------------------------------|----------------------------------|
| <b>Construction risk—facility is not completed on time, on cost, and according to design standards</b>  | X                              |                                  |
| <b>Permitting risk—current permit and environmental mitigation requirements increase</b>  | X                              |                                  |
| <b>Change in law risk—future unanticipated laws or regulations increase operating costs</b>   | X                              | X                                |
| <b>Technology risk—plant technology does not perform as expected</b>  | X                              |                                  |
| <b>Output risk—plant is not able to produce the projected volume of water</b>   | X                              |                                  |
| <b>Operating margin risk—the price of water is not adequate to generate enough revenue to pay expenditures or may increase more than projected</b>  | X<br>(budget cap)              | X<br>(subject to CPI)            |
| <b>Pipeline operating risk—the pipeline connecting the plant to the regional aqueduct system and associated facilities is unable to transport acceptable water to the SDCWA's wholesale customers</b> | X                              | X                                |
| <b>Electricity—changes in the cost or amount of electricity used will affect the water price</b>  | X<br>(electricity consumption) | X<br>(electricity price)         |
| <b>Force majeure events</b>   | X (insurable)                  | X (uninsurable)                  |

Source: SDCWA (2012b).

Note: The San Diego County Water Authority (SDCWA) assumes those risks, and costs, that affect all water treatment plant operators and wastewater dischargers and the cost of power plant improvements (with a cap of up to \$20 million in capital and \$2.5 million in annual operating costs; these estimates are in 2010 dollars).

regardless of whether that water is needed. In a July 2012 meeting, SDCWA staff indicated that current regional water demands do not justify a fixed commitment to purchase the entire output of the plant, which is equivalent to 69,000 megaliters (MI) per year. Rather, staff suggested that the agreement be based on a lower contract minimum of 59,000 MI per year and that fixed costs be allocated on the basis of that purchase amount.

Based on the staff's recommendation, the 2012 water purchase agreement establishes a take-or-pay contract with a minimum demand commitment of 59,000 MI per year. Thus, the Water Authority must purchase at least 59,000 MI per year of the most expensive water available, even if demand declines or if cheaper alternative supplies are available. This exposes the Water Authority to significant demand risk and could have major cost implications for the Water Authority and its ratepayers. One option is for the Water Authority to consider a contract that establishes an even lower minimum commitment. While this may increase the unit cost of water, it would allow the Water Authority to reduce some operating costs, especially energy and chemical costs.

### *Project Financing*

Efforts to finance the project began in late 2009. At that time, the cost estimate for the project was \$300 million. Stephen Howard, head of the infrastructure group at Barclays Capital, which was seriously considering the plant at the time, was quoted as saying that a \$300 million project was feasible, but “if this project was north of \$800 million to \$1 billion, it would probably be very challenging” (Schwartz 2009). Today, costs are squarely within this range.

Financing for the project was finally secured in December 2012, shortly after the water purchase agreement was approved. Nearly 80 percent of the project’s cost was financed through tax-exempt private-activity bonds. The remaining 20 percent was provided by cash equity from Stonepeak Infrastructure Partners (Brennan 2013).<sup>11</sup> Standard & Poor’s assigned a “BBB–” credit rating to the project, which is the lowest investment rating and was expected to increase the cost of financing the project. Despite the low rating, the project received a 4.78 percent yield on the bonds for the desalination plant and 4–4.5 percent for the pipeline. Higher rates of return are expected for the equity providers. The Water Authority estimates that the cost to finance the project would be \$227 million.

### *Summary*

It is not yet clear whether the Carlsbad Desalination Project will succeed. However, the project raises several issues that should be considered by other developers seeking to pursue desalination project, particularly the following:

- The project was negotiated in a noncompetitive environment, which raises concerns about whether the best project was selected, especially in relation to the cost, design, and operation of the plant.
- Demand risk is a major concern for the project. Alternative supplies and conservation and efficiency improvements are available at lower cost than the desalination project.
- The take-or-pay contract establishes a high minimum commitment to purchase water. This would prevent the Water Authority from pursuing cheaper water alternatives as they become available.
- The Water Authority should consider a lower minimum commitment, which would allow it the flexibility to reduce plant output and capture potentially significant financial savings from lower O&M expenses.

## Conclusions

Economics—including both the cost of the water produced and the complex financial arrangements needed to develop a project—are important factors that will determine the ultimate success and extent of desalination in California. In this chapter we provided detailed information about the cost of seawater desalination projects, how they are financed, and some of the risks associated with these projects.

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11. Stonepeak Infrastructure Partners, formerly the infrastructure investment division of Blackstone, is an equity investment firm that focuses on traditional infrastructure assets, especially in North America.

## How Much Does Desalination Really Cost?

Our analysis finds that the cost to produce water from a desalination plant is highly variable. Recent estimates for plants proposed in California range from \$1.54 to \$2.43 per m<sup>3</sup> (\$1,900 to more than \$3,000 per acre-foot). Although the cost of seawater desalination has declined considerably over the past twenty years, desalination costs remain high, and major cost breakthroughs are unlikely to occur in the near to mid term. Indeed, desalination costs may increase in response to rising energy prices.

The public and decision makers must exercise caution when comparing cost estimates for different seawater desalination projects. In many cases, costs are reported in ways that are not directly comparable. For example, some report the cost of the desalination plant alone, whereas others include the additional infrastructure, such as conveyance pipelines, needed to integrate the desalination plant into the rest of the water system. Some estimates include the cost to finance the project, and others do not. Even when there is an apples-to-apples comparison, a number of site- and project-specific factors, such as energy, land, and labor costs, make cost comparisons difficult.

Furthermore, costs associated with wastewater conveyance and treatment (and many other indirect costs to ecosystems) are often excluded from desalination cost comparisons. The introduction of a new source of water increases the amount of wastewater that must be collected, treated, and disposed of. Some communities may have adequate wastewater treatment capacity, and the additional costs would simply be the variable O&M costs associated with that treatment. In other communities, however, wastewater treatment capacity may need to be expanded, which represents an additional, and in some cases significant, capital cost to the community. While these costs would apply to all of the water supply projects under consideration to meet demand, the costs would not be incurred if water demand were met through water conservation and efficiency improvements.

## What Are Some of the Risks Associated with Seawater Desalination Projects?

Several risks can affect a seawater desalination project's cost, ability to attract financing, and overall viability. Many of these risks are not unique to seawater desalination projects; rather, they apply broadly to all major infrastructure projects. These include risks associated with permitting, construction, operations, and changes in law.

But as recent experience in the United States and Australia has shown, desalination projects entail risks specific to large water supply projects, including demand risk. Demand risk is the risk that water demand will be insufficient to justify continued full-time operation of the desalination plant as a result of the availability of less expensive water supply and demand management alternatives. In Australia, for example, four of the six desalination plants that have been developed since 2006 are being placed in standby mode. Likewise, the Tampa Bay Seawater Desalination Project operates considerably below full capacity because demand is lower than expected and less expensive water supply options are available. Demand risk raises serious concerns about the size and timing of desalination projects.

In some regions, seawater desalination can make an important contribution to the availability and reliability of water resources. However, it remains among the most ex-

pensive options available to meet water demands. Additionally, project developers may pursue large plants in an effort to capture economies of scale and reduce the unit cost of water. This can, however, lead to oversized projects that ultimately increase demand risk and threaten the long-term viability of a project.

## How Are Desalination Projects Structured?

Issues regarding financing and the allocation of project costs and risks are tied to the way the project is structured. Many project developers in California are using some form of public-private partnership. The private sector's involvement in seawater desalination projects is not new. The private sector has developed several small plants to supply high-quality water for specific industrial purposes, such as for use on oil and gas platforms. Likewise, a desalination project in Santa Barbara, completed in 1992, was operated and partially owned by a private company. In some cases, the private sector's involvement is limited to conducting feasibility studies and preparing environmental documents as requested by the public project developer. In other cases, however, a private entity owns and operates the desalination plant and sells water directly to a public agency. Public-private partnerships provide a mechanism to access private capital and allocate risks among the project partners. They can, however, be highly contentious because of concerns about openness and transparency of data and financial information and the allocation of the risk among the project partners.

Additionally, utilities that are developing seawater desalination plants must be sure that there is a demand for that water, especially when establishing minimum commitments under take-or-pay contracts. A take-or-pay contract provides guaranteed revenue for the seller but commits the buyer to a purchase even if actual demand drops. This exposes the buyer to demand risk and provides a disincentive for water agencies to pursue more cost-effective water supply and water conservation and efficiency programs.

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# Zombie Water Projects

Peter H. Gleick, Matthew Heberger, and Kristina Donnelly

Terraforming is not science fiction but reality: humans are remaking the surface of our planet. We are altering the composition of the planet's atmosphere and fundamentally changing the entire global climate. We remove mountains and dig miles beneath the surface for minerals. We cut down and destroy entire forests. We wipe out species and communities of species. We divert and consume entire rivers. We've stored so much water behind artificial reservoirs that we've actually (very modestly) changed the planet's orbital dynamics. But we've lost sight of a fundamental principle: "can" does not mean "should." Modern civilization must learn that the ability to do something doesn't mean that we actually should, especially in the field of large-scale geoengineering. And this is especially true in the field of large water projects.

A key characteristic of the world's hydrologic cycle is the uneven distribution of water in both space and time. While the planet, as a whole, has plenty of water, problems of availability arise in regions and seasons in which water is limited. These problems with distribution have led to a wide variety of solutions to store and move water from regions or periods of abundance to regions or periods of scarcity. In ancient times, moving water meant carrying it on one's back, or digging short irrigation ditches from rivers to agricultural fields, or, by the time of the ancient Romans, constructing elaborate gravity-fed aqueducts tens or even hundreds of kilometers long. But it wasn't until the industrial age, with the energy of fossil fuels and the invention of machines that could pump water uphill, that humans began to conceive of and implement truly long-distance transfers of water. Today, there are no technical constraints on how far water can be moved; our limitations are political, economic, and environmental. But even these constraints do not stop people from dreaming of ever more grandiose schemes to try to help solve global water problems.

As any consumer of popular culture today knows, a zombie is an undead creature, something that was killed but came back to "life," in some form, to terrify, entertain, and gross people out. Zombies are big business. Zombie books, movies, costumes, makeup, computer games, and more are probably worth billions to our economy (not to mention the value of extra sales of axes, chain saws, and shotguns to people who never hunt or cut down trees).

But not all zombies are fictional, and some are potentially really dangerous—at least to our pocketbooks and environment. These include zombie water projects, which we define as large, costly water projects that are proposed, killed off for one reason or another, and brought back to life, even if the project itself is socially, politically, economically, or environmentally unjustified. We offer here—in an only partly tongue-in-cheek effort—a list of some major zombie water projects from the past century: serious proposals

for massive projects to use, divert, or transfer water that died only to come back to life in one form or another.

We do not believe that any of the following zombie water projects will ever be built or implemented. But, as in movie zombies, we can never really be sure if they are truly dead.

## The North American Water and Power Alliance— NAWAPA

One of the largest water projects ever proposed was the North American Water and Power Alliance (NAWAPA). Stretching over the entire North American continent, it would have altered the hydraulic landscape in massive, dramatic ways. While never built, it remains a paper monument to the engineering mentality that in the past century dominated, and to some extent still dominates, water planning and thinking.

### History

The North American Water and Power Alliance, or NAWAPA, was a plan first proposed in the 1950s to divert the flows of large rivers in western Canada and Alaska to the United States and Mexico. The project, named for the intergovernmental alliance that would run the project, would modify watersheds and water flows for much of the North American continent, and backers claimed it would “completely solve the water shortage problem” for generations to come (Special Subcommittee on Western Water Development 1964).

The grandiose plan has been called the “most outsize engineering project ever conceived” (Rothfeder 2004, 111) and “the water scheme to beat all water schemes,” grander in scale than any river manipulation project ever imagined (Worster 1992, 315). Its total cost was estimated by backers in 1964 at \$100–\$200 billion over thirty years, a large sum considering that total federal government spending was about \$110 billion in 1964. Accounting for inflation alone, and not considering increases in land value or construction costs, the project would cost \$0.7–1.4 trillion in 2013, nearly 10 percent of the United States’ annual economic output, or 40 percent of annual federal spending.

The project to divert rivers in Alaska and the Pacific Northwest to the lower forty-eight states was first imagined in the late 1950s by Donald McCord Baker, an engineer with the Los Angeles Department of Water and Power. He approached Ralph M. Parsons, president of the Ralph M. Parsons Company, one of the country’s largest engineering and construction companies,<sup>1</sup> headquartered in nearby Pasadena. Parsons was so taken with the idea that he vigorously promoted it his entire life, including endowing the NAWAPA Foundation to advance the cause. In addition, in the 1960s, Parsons assembled “several former Bureau of Reclamation engineers . . . to make money consulting and designing resource projects for countries around the world” (Worster 1992, 315).

The project also gained the attention of US senator Frank E. Moss, a Democrat from Utah, for whom the project became a lifelong interest. At Moss’s instigation, the Sen-

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1. It remains so to this day, having built large projects, such as a Washington, DC, airport and the Goddard Space Flight Center in Maryland, and securing a \$243 million contract in 2004 to build 150 hospitals in Iraq. The latter project erupted in controversy when it was later found that only twenty hospitals were completed (Mandel 2006).

ate Public Works Committee studied the proposal, and the Senate held a series of hearings on the subject. The committee report concluded that the project “warrants a serious analysis” while acknowledging that merely to conduct a “thorough engineering study” to find out whether the project was actually feasible and cost-effective would take years and cost millions. Such a study was never authorized by Congress, but Moss continued to push for the project. He wrote a book promoting NAWAPA called *The Water Crisis* in 1967, and, after losing his bid for reelection in 1976, he was hired by Parsons as a lobbyist. The proposal was also treated seriously by the executive branch of the federal government: the US secretary of state traveled to Canada to discuss the project, and the NAWAPA Foundation sent groups of American dignitaries north to tour project sites.

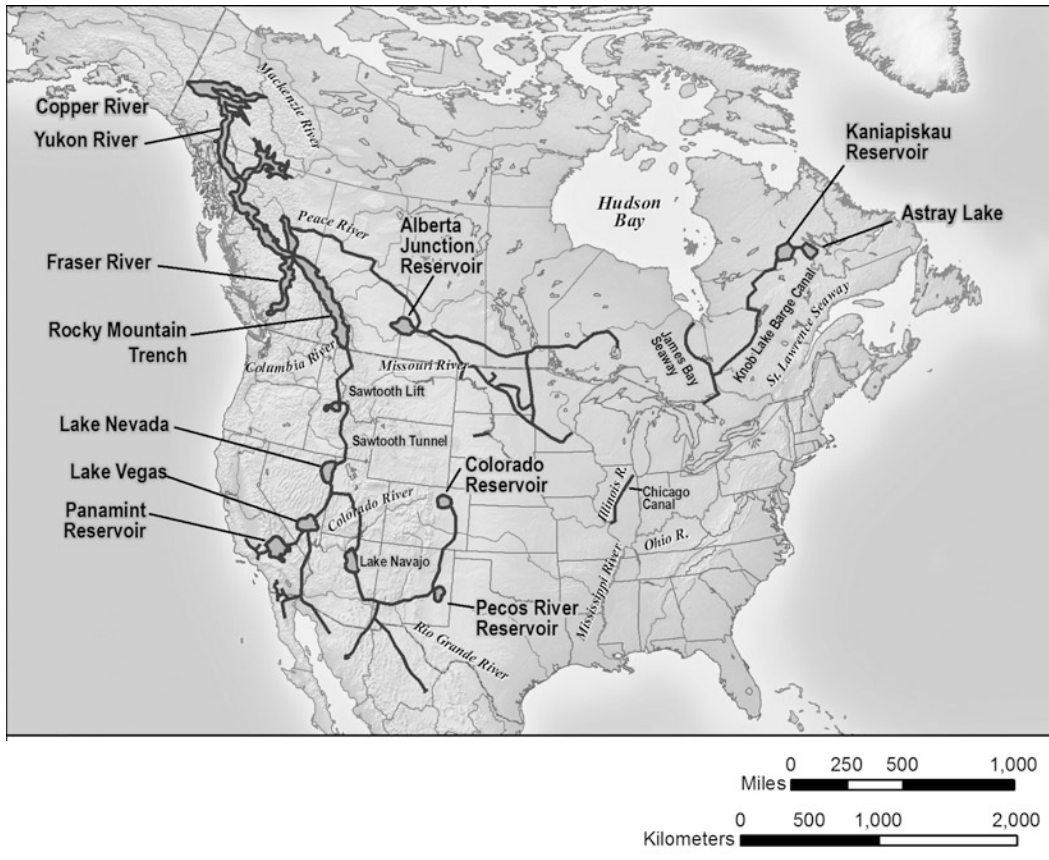
Promoters of NAWAPA emphasized impending water shortages and the need for traditional technological and infrastructural solutions. Concern was especially great for the arid and semi-arid Southwest, where groundwater reserves were dwindling in Texas’s Upper Rio Grande region and in Colorado, the Great Basin, and Southern California. Because NAWAPA would take thirty years to construct, its backers argued, it was important to begin before it was too late: “the water crisis is a problem of serious and far-reaching implications” that will “grow steadily worse until it reaches alarming proportions in the years 1980 and 2000” (Special Subcommittee on Western Water Development 1964, 11). Frank Moss, the Democratic senator from Utah, noted that current water withdrawals in the United States stood at 300 billion gallons per day, or 27 percent of stream flow. By 1980, he argued, population growth and expanded industry and irrigation would increase demand to 900 billion gallons per day, or 80 percent of available stream flow. The forecasted increases in water use never occurred. According to the US Geological Survey, total water withdrawals peaked at 350 billion gallons per day in 1980 and have declined slightly since then, even while the country’s population and agricultural output have continued to rise steadily (Gleick 2003; Kenny et al. 2009).

## Project Design

It was perhaps inevitable that some ambitious planner or engineer, confronted with the aridity and water scarcity of the American Southwest, would eventually look north. Some of the continent’s largest rivers, in terms of flow, are found in Southeast Alaska, the Canadian province of British Columbia, and the Yukon Territory and “pour wasted and unused” into the Pacific and Arctic Oceans (NAWAPA 1964). NAWAPA’s goal was nothing less than “total water management” on a continental scale, requiring the construction of 3,151 individual projects, including dams, canals, pipelines, tunnels, and pumping stations to divert freshwater from this region of plenty to cities and farms on the Canadian prairie, in the United States, and as far away as Mexico. The catchment area of the project covers an area of 3.4 million square kilometers (1.3 million square miles) and by some estimates accounts for a quarter of all runoff in North America (see figure 7.1).

The plan called for diverting up to 20 percent of the flow of the Tanana, Susitna, and Yukon Rivers in Alaska. In British Columbia, it would tap the Churchill, Blackstone, Slave, Coppermine, Peace, and Mackenzie Rivers. Diversions from these rivers would be redirected to fill a natural valley that runs the length of British Columbia, the Rocky Mountain Trench, second in size only to the Great Rift Valley in East Africa. When filled, the reservoir would extend 800 kilometers (500 miles), average 16 kilometers (10 miles) in width, and be capable of storing 500 cubic kilometers (400 million acre-feet) of water.





**FIGURE 7.1 MAP OF NORTH AMERICA SHOWING THE MAJOR WATER PROJECTS FOR NAWAPA**

Source: Map by Matthew Heberger.

NAWAPA's water projects extend from northwestern British Columbia, the Yukon Territories, and Alaska to Mexico and the St. Lawrence Seaway.

This would be the largest reservoir on the continent, sixteen times bigger than Lake Mead, behind Hoover Dam on the Colorado River.

From the southern end of this new reservoir, a canal would extend southeast through the prairies in the provinces of Alberta, Saskatchewan, Manitoba, and Ontario and into Lake Superior, delivering irrigation water along the way and sending flow into the Great Lakes (figure 7.1). Among its purported benefits would be to “alleviate falling levels and degraded quality of the Great Lakes” (NAWAPA 1964). The “Canadian–Great Lakes Waterway” would also open the long-dreamed-of waterway across the continent, allowing barge traffic from Alaska all the way to New Orleans or Montreal.

At the southern end of the Rocky Mountain Trench, another set of canals, tunnels, and lift pumps would send water to the Columbia River basin, the high plains of Idaho and Montana, and farther south. In northern Nevada, the main canal would split. A western fork would direct water southwest toward Las Vegas, Los Angeles, San Diego, the Colorado River delta, and the Baja California Peninsula. The eastern fork would send irrigation water to Colorado, Utah, New Mexico, Texas, and the northern Mexican states of Sonora and Chihuahua.

Among the other astounding facts about the project are that it would require the movement of 25 million cubic meters (32 million cubic yards) of earth and the use of



27 million metric tons (30 million tons) of steel (NAWAPA 1964). These figures were announced in a promotional film produced by Parsons and were apparently meant to stoke the imagination of Americans, who, it has been argued, “have a predilection for technological solutions to problems, especially if the solution involves the construction of an impressive structure” (Sewell et al. 1967, 11).

## Purported Benefits

Parsons’s spokesmen admitted that “at first or casual glance, the size of the concept may seem unrealistic or fanciful.” The company insisted, however, that more careful analysis revealed it to be “feasible from an engineering standpoint and economically realistic” (NAWAPA 1964). Much of the contemporary criticism of NAWAPA cited here comes from a twenty-page article, “NAWAPA: A Continental Water System,” printed in the *Bulletin of the Atomic Scientists* and containing an analysis of the project by prominent experts in the fields of economics, political science, engineering, and fisheries (Sewell et al. 1967).

While the plan relied on contemporary technologies such as concrete arch and earth-then dams, there was legitimate concern about whether it was even technically realistic. The plan called for a dam 570 meters (1,700 feet) high, taller than a 170-story building and taller by far than the highest dam that had ever been built, Hoover Dam, at 220 meters (725 feet). (In 2013, the world’s tallest dam is the Nurek Dam in Tajikistan, at 300 meters, or 980 feet.) Critics also noted that much of the construction was to take place in the Rocky Mountains and would involve the blasting and moving of solid rock.

Among the main benefits of NAWAPA would be increased water supply for agriculture and cities. The planners foresaw a West with a rapidly growing population and increasing water use. Overall, the system was designed to deliver 150 cubic kilometers (120 million acre-feet) per year of water annually to thirty-three American states and seven Canadian provinces. To put this in perspective, this is about one-third of the average outflow of the Mississippi River and about eight times the natural flow of the Colorado River. This flow would allow Mexico to triple its irrigated acreage, would nearly double irrigated area in the United States by adding 16 million hectares (40 million acres), and would add 3 million hectares (7 million acres) in Canada. Further, it would allow the United States to recover thousands of acres of formerly productive farmland that had been “degraded by the Colorado River’s excessive mineral content.”

Project proponents played into growing unease about population growth by saying that America had a duty to produce more food and calling NAWAPA the “only hope of averting worldwide famine.” Furthermore, “additional reclamation in the West,” it was claimed, would support the “development of 230,000 family-size farms, . . . 40,000 local retail enterprises, and \$4 billion in retail trade annually.” Even with promised water deliveries, this would have been unlikely, as the irrigated western small family farm had long been proven an elusive fantasy. The mythos of Reclamation—converting dry and barren land into irrigated cropland, divided into 160-acre parcels to support family farms—was, by the 1960s, no longer a viable dream. These relatively small holdings, by western standards, and the high cost of farm inputs made it tough to break even. While irrigation water is used to grow valuable citrus fruits and vegetables in Southern California and Arizona, irrigation in the High Plains has never been very productive because of the short growing season, with most irrigation water today used to grow pasture for grazing cattle. Imported water would also potentially reduce pressure on the overpumped

Ogallala Aquifer, which was being drained at alarming rates by farmers in the High Plains states from Nebraska to Texas.

Another benefit would be an increase in freshwater inflows to the Great Lakes, which in the 1960s were in deplorable condition as a result of pollution from industry and pesticides and fertilizer in agricultural runoff. Further, residents became alarmed when water levels in Lakes Huron and Michigan dropped to their lowest levels in one hundred years. But to economist James Crutchfield, attempting to dilute pollution with additional inflow would have been foolishly expensive and unlikely to succeed. A cheaper and more effective solution would have been to “reduce pollution load” through the “establishment and enforcement of adequate receiving water standards” (Sewell et al. 1967, 20). Indeed, this strategy was later pursued through federal clean water legislation.

Electrical generation was another promised benefit; hydroelectric dams would generate 100 million kilowatts of electrical power, 30 percent of which would be needed to lift water over mountain ranges. The remainder would be sold for competitive prices on the open market, which, proponents stated, would stimulate industry and new economic activities. It would have increased North America’s electrical output by one-sixth with “clean hydroelectric power—no pollution, no CO<sub>2</sub>, no acid rain” (Reisner 1986, 505). University of Washington professor of civil engineering E. Roy Tinney called the allocation of water and power facilities suboptimal, declaring the project little more than “a map of potential hydropower sites” (Sewell et al. 1967, 23). The project could be accused of planning unnecessary hydroelectric facilities to make up for revenue shortfalls from water projects that could never pay for themselves. Journalist Marc Reisner would later criticize the US Bureau of Reclamation for bundling bad water projects with “cash-register dams” to make projects look economically feasible when considered from a “river basin perspective” (Reisner 1986, 42).

Abundant electricity and inexpensive canal transportation would benefit Canada, NAWAPA advocates claimed, by opening access to its mineral-rich northern regions. However, enthusiasm for these new opportunities was tempered by the reality that land would have been flooded: “The reservoirs not only flood good farming land and destroy natural habitat, they also eliminate large forest resources and inundate as yet unknown mineral deposits” (Sewell et al. 1967, 23). Reservoirs would also have flooded the lands of some First Nations people and cities such as Prince George, British Columbia, whose population today is 70,000.

Among the more dubious claims by Parsons were that “fish and game would increase” and the creation of “new scenic waterways” would enhance tourism. Even contemporary observers were skeptical of these claims, which in hindsight seem even more preposterous. A critic wrote, “I boggle at the thought that western Canadians, or American visitors, would regard a giant man-made lake as an acceptable substitute for the magnificent recreational area that it would despoil” (Sewell et al. 1967, 19). The project would have been devastating to salmon fisheries in every major river in British Columbia. Dams and diversions would have either cut off or submerged breeding habitat for migrating salmon on the Tanana, Bella Coola, Dean, Chilcotin, and Fraser Rivers, which were “among the most important salmon rivers on earth” since the destruction of the fisheries of the Columbia and Sacramento Rivers.

Luna Leopold, professor of hydrology at the University of California, Berkeley, wrote: “The environmental damage that would be caused by that damned thing can’t even be described. It could cause as much harm as all the dam-building we have done in a hundred years” (quoted in Reisner 1986, 510). Today, several Pacific salmon are listed

as federally protected endangered species in the United States, making the construction of new dams on America's northwestern rivers increasingly unlikely. In fact, in order to help recovering salmon populations, the Bonneville Power Administration, Oregon's state-owned hydropower utility, spends \$170 million per year on a fish and wildlife recovery program in the Snake River and Columbia River watersheds (Garrick et al. 2009, 378), and some dams are even being removed. The United States Congress passed the Wild and Scenic Rivers Act in 1968 with the intention of protecting rivers from damming and development for the enjoyment of future generations. The National Environmental Policy Act followed in 1969, requiring federally funded projects to undergo a thorough environmental review, which by law must consider the "no project" alternative.

## Public Acceptance

At the time, economist James Crutchfield called the NAWAPA proposal "symptomatic of a growing public dissatisfaction with the planning of water development" in the United States. Despite huge investments, the problems of pollution and overuse were evident everywhere. Cold war rivalry may have also played a role. Historian Donald Worster wrote that the project "had about it the irresistible logic of an imperial history," comparing it to rival plans in the Soviet Union to reverse the flow of Siberia's north-flowing rivers to water a new breadbasket in the country's arid central plains (Worster 1992, 316). Project backers certainly played into the public's anxieties, proclaiming that "ultimately, the decision to build NAWAPA—or a project similar to it—will determine, in some part, the future economic well-being in North America" (NAWAPA 1964).

Despite its appeal, Worster wrote, the scheme arrived both too early and too late to win broad acceptance: too early because at the time there were other, more readily exhaustible water supplies that could be tapped. Planned or ongoing projects such as the California State Water Project or the Central Arizona Project were already controversial and massive drains on the public purse. Critics in the 1960s pointed out that even if there were a need for massive new water supplies, the NAWAPA scheme would not be the most economical way to provide them. Possible alternatives included desalination, recycling, "depollution," reduction of leaks in cities, and decrease of waste through better technology and pricing. And NAWAPA arrived too late because in the mid-1960s the environmental movement was growing and the Reclamation era was coming to an end. Rachel Carson had published the groundbreaking *Silent Spring* in 1962, awakening Americans to the perils of pollution from pesticides and herbicides, and many people were already acquainted with Aldo Leopold's "land ethic" (Lee 1978, 557).

## Reception by Canada

At the time of its introduction, it was noted that the proposal "aroused relatively little enthusiasm in Canada," but as the idea gained momentum, more Canadians became "openly hostile to the whole idea, viewing it as an attempt to plunder Canadian resources" (Sewell et al. 1967, 9). Canada is endowed with more freshwater per person than any other nation: it ranks first in renewable freshwater but, with 34 million people, only thirty-sixth in terms of population. A prominent American political scientist noted that, at the time, some Americans held the view that Canadians had "an obligation to share their water resource with the United States" and suggested in 1967 that the United States could conceivably "apply pressure on the Canadian government to change its policy, backed

up perhaps by sanctions of various kinds” (Sewell et al. 1967, 9)—a strategy unlikely to further endear the project to Canadians.

Canada has historically opposed most water export schemes (Rothfeder 2004). Federal water policy promulgated by the environment ministry in 1987, during the administration of conservative Brian Mulroney, stated, “The Government of Canada emphatically opposes large-scale exports of our water. We have another reason for our opposition; the inter-basin diversions necessary for such exports would inflict enormous harm on both the environment and society, especially in the North, where the ecology is delicate and where the effects on Native cultures would be devastating” (Environment Canada 1987). However, the lack of a federal law regarding water transfers left the issue to the provinces, and there is no formal federal ban on such transfers.

Few Canadians believed the project would ever be built, but any mention of NAWAPA by an American politician continues to draw a vigorous negative response from the Canadian press. Despite widespread public opposition, the plan also receives occasional support from British Columbia politicians. Currently, one of the province’s largest sources of income is its logging industry, which harms the environment and is also subject to boom-and-bust cycles, depending on the economy and the housing market in the United States. By contrast, agriculture is more dependable: “water could be sold through forty-year contracts . . . ensuring a steady, predictable income every year” (Reisner 1986, 511).

Statements by the United Nations and international trade agreements may further limit the Canadian government’s ability to impose a ban on all water transfers. At the United Nations’ 1992 International Conference on Water and the Environment in Dublin, the delegates issued a statement recognizing water as an “economic good” in response to the increasing scarcity, conflict, and overuse. To some, the declaration made it seem “inconceivable that Canada could continue to oppose water transfers and reject NAWAPA” (Rothfeder 2004, 111).

Trade liberalization may also play a role in facilitating international water projects. In 1994, the United States, Canada, and Mexico signed the North American Free Trade Agreement (NAFTA) with a goal of reducing barriers to trade and investment by eliminating tariffs on many imports among the three countries. A provision of the agreement (chapter 11) “backs the right of companies to sue if they believe that their ability to trade freely is hampered in any way” (Rothfeder 2004, 112). In fact, this occurred in 1999, when a California company, Sun Belt Water, sued the Canadian government over its prohibition on shipping freshwater by marine tanker from British Columbia (Boyd 2003).

## Renewed Interest and Current Status

As with many zombie water projects, interest in NAWAPA seems to fade away only to be revived decades later. In the 1980s, the American economy was recovering from recession and inflation at the same time a severe drought occurred across the western states, sparking widespread concern over food prices. At a 1980 meeting in California titled “A High-Technology Policy for U.S. Reindustrialization,” sponsored by the fringe Fusion Energy Foundation, Dr. Nathan Snyder of the Parsons Company “reintroduced NAWAPA to a large and enthusiastic audience” (Reisner 1986, 508).

As recently as 2008, Michael Campana, professor of hydrogeology at Oregon State University, wrote that he had “heard talk about ‘bringing NAWAPA back,’ just as I have heard people suggest reviving a plan to study the diversion of Columbia River water to

the Southwest USA” (Campana 2008). In recent years, the project has again been promoted by controversial political figure Lyndon LaRouche through his advocacy organization LaRouchePAC (LaRouche was behind the Fusion Energy Foundation, mentioned above). LaRouche has run for the US presidency eight times, and although he began his political career in the radical leftist student politics of the 1960s, his views are now considered ultraconservative. His reputation has been tarnished by a tax fraud conviction, for which he served fifteen years in prison; apparent anti-Semitism; climate change denial; and the promotion of 9/11 conspiracy theories (*Wikipedia* 2013).

Although it seems doubtful that NAWAPA, as originally planned in the 1950s and 1960s, will ever be built, some of its individual components have already come to fruition. The overall scheme of NAWAPA included diversions and hydropower on rivers flowing into Hudson Bay in eastern Canada. Beginning in 1971, the government of Quebec has built hydroelectric dams on rivers in the James Bay watershed, including the La Grande and Eastmain Rivers. The James Bay Project currently generates 16,000 megawatts (equivalent to the output of twenty-four average coal power plants), providing half of the province’s electricity and making electricity one of the province’s major exports. The James Bay Project continues to expand, with construction of dams on the Rupert River having begun in 2010.

Lest we consider NAWAPA finally laid to rest, consider the scene described by Marc Reisner in the epilogue to his classic book *Cadillac Desert*. In 1981, British Columbia premier Bill Bennett visited San Francisco to give a talk at the Commonwealth Club. When an audience member asked whether British Columbia would sell water to the United States, he replied with a firm “No.” He then added, “But come and see me in twenty years” (Reisner 1986, 513). And consider the words of Tom McCall, governor of Oregon from 1967 to 1975: “This is a plan that will not roll over and die. It may be fifty years, or it may be a hundred years, but something like it will be built.”

## The Reber Plan

Water policy and planning in the twentieth century was dominated in California, as it was in many other places, by an engineering mentality. A massive imbalance between when and where precipitation fell, where runoff flowed, and where demand for water occurred required major replumbing, and this led to the construction of some of the world’s largest water transfer systems in California, including the Los Angeles Aqueduct, the California State Water Project, and the federal Central Valley Project. Today, these and other systems transfer billions of cubic meters of water every year from the wetter, mountainous northern regions of the state to the drier agricultural lands of the Central Valley and the cities along California’s coast.

California also served as a critical region during World War II, providing food, major seaports and airports, railroad terminuses, munitions plants, shipyards, troop-staging areas, and workers for the massive Pacific war effort. It may be no surprise, therefore, to learn that the combination of the war effort and the engineering approach to water produced one of the most significant water zombies ever designed—the Reber Plan for San Francisco Bay.



## History

Freshwater runoff from California's two largest rivers, the Sacramento and San Joaquin, merges in the Central Valley Delta region, once one of the biggest inland aquatic ecosystems in the world (figure 7.2). That water then flows into San Francisco Bay and out the Golden Gate to the Pacific Ocean. So much freshwater once flowed out of the bay during peak runoff season that early explorers reported finding plumes of freshwater outside the Golden Gate in the Pacific Ocean (Presidio Trust, 2012). This system also supported some of the world's largest anadromous fisheries—primarily salmon—with millions of fish being born in the rivers, living part of their lives in the oceans, and then returning to their upstream habitats to spawn.

The Reber Plan—also called the San Francisco Bay Project—was developed by John Reber, a schoolteacher and theatrical producer. Reber's idea was to transform San Francisco Bay from the largest natural estuary and coastal ecosystem on the West Coast into a completely artificial engineered system. Two major earth and rock-fill dams would be constructed, one between the city of Richmond and Marin County and one between Oakland and San Francisco (where the current Richmond–San Rafael Bridge and San Francisco–Oakland Bay Bridge now stand). These dams would turn the upper and lower parts of the bay into freshwater reservoirs, permitting the destruction of 20,000 acres (80 square kilometers) of marshes and wetlands with landfill on most of the eastern side of the bay. Highways and railroads would cross the dams, and a lock system the size of the Panama Canal would be built to permit shipping to reach the ports of Oakland, Stockton, and Sacramento (figures 7.2 and 7.3).

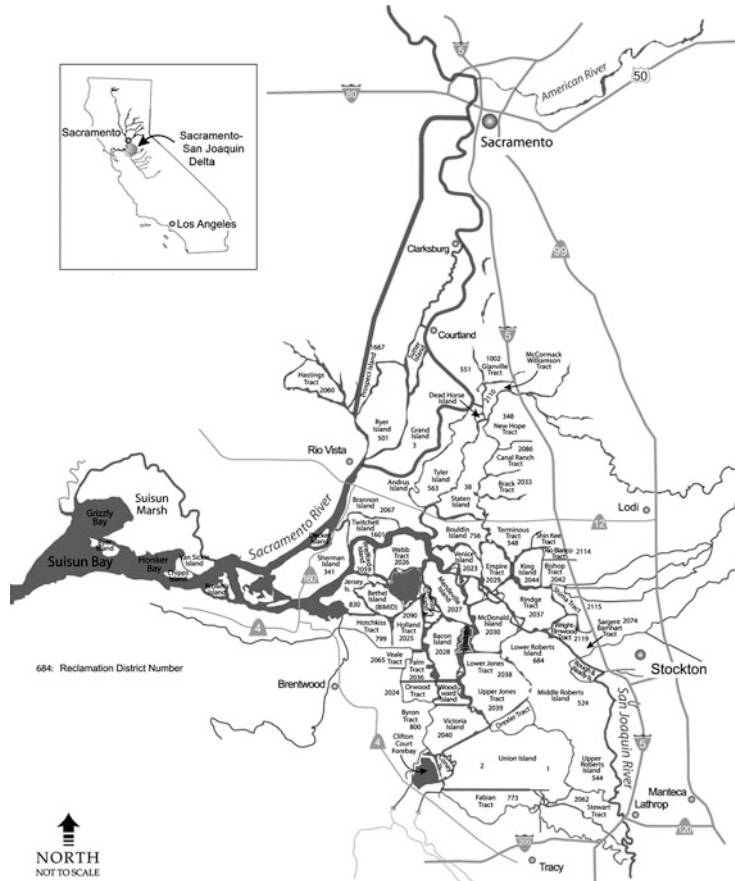
Gray Brechin, a historical geographer from the University of California, Berkeley, wrote that part of the motivation for the plan was fear that Japan would attack the West Coast. "Political cartoons of the day show that people were terrified," Brechin says. "The Reber Plan seemed to provide the answer; people could be moved in and out of the area relatively quickly" (Sinclair 2011).

Supporters of the Reber Plan also argued that the freshwater reservoirs created by the dams would solve California's water problems by capturing water that was "lost" out the Golden Gate. That water could then be sent throughout the state to meet growing demands. Many newspapers supported parts of the plan when it was proposed, the Joint Army and Navy Board requested a report (Nishkian 1946), and Congress even held some initial hearings in December 1949.

## Project Review and Demise

The US Army Corps of Engineers was ordered to build a working hydraulic model of San Francisco Bay to see whether the Reber Plan would work. In 1957 the corps built the model, more than one and one-half acres in size, in Marin County. It created a physical representation of an area from the Pacific Ocean to Sacramento and Stockton, including San Francisco Bay, San Pablo Bay, and Suisun Bay and a portion of the Sacramento–San Joaquin Delta. (KQED, n.d.) Testing began in 1959, and corps engineers determined that the Reber Plan would be catastrophic for the ecosystem, flows, and chemistry of the estuary and for San Francisco Bay. The reservoirs, instead of storing freshwater, would become enormous evaporation ponds, incapable of providing any discernible amount of freshwater. Contaminants would build up in the bay, and commercial and natural fish-





**FIGURE 7.2 THE SACRAMENTO–SAN JOAQUIN DELTA IN NORTH-CENTRAL CALIFORNIA**

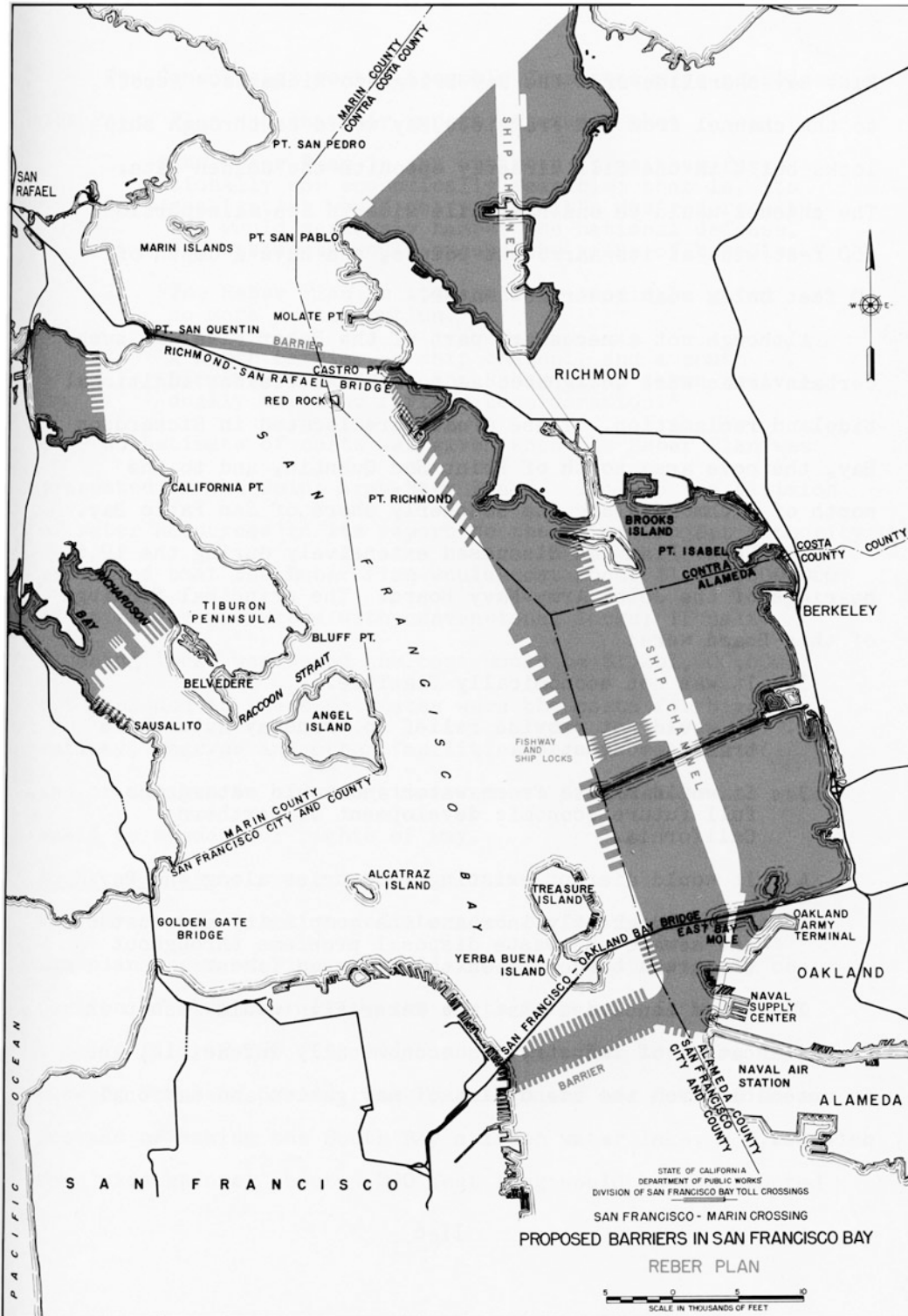
*Source:* US Geological Survey.

The Sacramento–San Joaquin Delta, where California’s two largest rivers meet, was a historically rich ecosystem but now provides much of the water transferred south for urban and agricultural developments.

eries would be completely eliminated. The idea for the project was also overwhelmed by changing perceptions of the value of San Francisco Bay, a growing national environmental movement, and a decrease in the perceived need for the military benefits the plan ostensibly offered. While the Reber Plan attracted considerable attention, it was ultimately opposed by the State of California, the US Bureau of Reclamation, and the US Army Corps of Engineers, and it never proceeded beyond the initial hearings and physical testing.

## Alaskan Water Shipments

Most large-scale water transfers have been limited to water that can be moved overland through pipes and aqueducts. Transfers across bodies of water, especially salt water, have been constrained by distance and technology and limited by needs that could be satisfied with cheaper and more practical local alternatives. Despite this, proposals periodically arise for large-scale bulk water transfers by sea from regions of water abundance



**FIGURE 7.3 THE REBER PLAN**

*Source:* University of California, Water Resources Center Archives.

Conceived in the 1940s, the Reber Plan would have turned San Francisco Bay into a completely artificial, militarized system. The proposed water benefits turned out to be unrealistic.

to regions of severe scarcity. Until the late twentieth century, such transfers that actually occurred were done with bulk tankers, like the kind used to ship oil, typically called very large crude carriers (VLCCs) or ultra large crude carriers (ULCCs).

Occasionally tankers have been constructed solely for the purpose of carrying potable water, which requires very strict water quality protections. Over the past two decades, however, some entrepreneurs have sought to develop and commercialize giant reusable, towable plastic bladders dedicated to the business of water transfers. We wrote about this technology in volume 1 of *The World's Water* (Gleick 1998), describing some short-term commercial experiments with bulk water bags in the Mediterranean and the long-term efforts of entrepreneur Terry Spragg to develop “Spragg Bags” for both water transfers and emergency response.

In the late 1990s, a company called Aquarius Water Trading and Transportation developed and built water bags that were briefly used for commercial deliveries of water from Piraeus, Greece, to Aegina—a distance of around twenty kilometers (about twelve and a half miles). A Norwegian company, Nordic Water Supply, also developed a bag system designed to deliver water from Turkey to northern Cyprus. This project also failed to be economically and politically viable (Gleick 1998). More recent proposals include the following example of an effort to move water from Alaska to commercial markets overseas.

## History

In the past decade, a proposal to ship water from Sitka, Alaska, to Asia or the Middle East has been proposed and promoted several times. Each time, the idea has run into the wall of economics, collapsed, lain fallow for a while, and then, like most zombie water projects, gotten up and staggered around again (Gleick 2011).

Here are the basics of the idea: In 2006, the town of Sitka in southeastern Alaska built a forty-two-inch-diameter pipeline connecting a local reservoir (Blue Lake Reservoir in Tongass National Forest) and the local port at Sawmill Cove. The waters of the lake are replenished by nearly one hundred inches (2.5 meters) of annual precipitation and some additional glacier melt. The pipeline is capable of delivering 22,500 gallons of water per minute, or around 32 million gallons per day (Alaska Water Project 2013). That same year, a local company, True Alaska Bottling Company (TAB), and a financial partner—S2C Global Systems from San Antonio, Texas—secured a contract from the town to sell just around 3 billion gallons of water a year (11 million cubic meters) in bulk from this reservoir at a rate of around one cent per gallon. The company proposed that water be fed through an underground pipe system leading 2,000 feet offshore to permit loading of deepwater ships. In an early proposal, S2C Global Systems said it was developing a hub with an Indian port on the Arabian Sea (Barclay 2010).

## Project Limitations

The company has never been able to capitalize on the contract, and it missed a series of deadlines imposed by the town to complete financial deals for the water. In late 2010, for the third time in four years, TAB and S2C Global Systems missed a deadline, for a minimum annual shipment of 50 million gallons by early December 2010. No water has been shipped in the years since the contract was first signed, in 2006 (Walton 2010b). The

city amended and extended the contract each time but increased export minimums and imposed fees on the company.<sup>2</sup>

Despite the project's limitations, the Sitka Economic Development Association has been a strong supporter. In 2010, Garry White, executive director of the association, commented on the project. "This water is falling into the ocean less than a mile from the lake," he noted. "The community sees an opportunity to take this resource that flows out into the ocean and make it a driver for us."

The biggest problem with the project, as with many such large-scale water transfer ideas, is the high cost of transportation. Moving water from Sitka, Alaska, to Asia or the Middle East involves massive energy costs for operating large tankers. Typical medium-sized water tankers can carry as much as 100 million gallons per trip. If the water is worth even a penny a gallon (more than typical desalinated water costs), a tanker with 100 million gallons is worth only around a million dollars. Capital and operating costs for tankers far exceed the value of water as a cargo. The costs are increased by the fact that even high-quality water, as is available in Sitka, will deteriorate in quality in a tanker over time, requiring additional treatment and expense. Professor James McNiven at Dalhousie University in Nova Scotia observed (Barclay 2010):

If that water sits in the hold of a tanker for weeks traveling across the ocean, when it arrives it's not spring water anymore; you're going to have to clean it up. As a business proposition this gets to be very expensive and chances are the economics don't work.

In an interview with Circle of Blue in August 2010, S2C's president, Rod Bartlett, optimistically suggested that the cost of purchasing and shipping water from Sitka to India would be on the order of \$0.07 per gallon, ten times the cost of even the most expensive desalinated water. Why there would ever be a buyer for this water is hard to explain (Walton 2010a) when the alternative is a cheaper (albeit still costly) desalination plant built and owned locally.

Nevertheless, the project proponents are still pursuing buyers for the water. As of early January 2013, the City and Borough of Sitka's website included an ad for bulk water exports that linked to a commercial Sawmill Cove solicitation for "proposals from companies or individuals who are interested in bulk fresh water export. We currently have 19,047 acre feet available annually for sale" (City and Borough of Sitka, Alaska 2013).

## Las Vegas Valley Pipeline Project

Nevada is a water-short state, given the paucity of natural rainfall, high average temperatures, and large and rapidly growing population centers of Reno and, especially, Las Vegas. Water management around Las Vegas was the responsibility of individual water districts until 1991, when seven neighboring water agencies joined together to form the Southern Nevada Water Authority (SNWA). The seven member agencies are the cities of Las Vegas, North Las Vegas, Boulder City, and Henderson and the water and reclamation districts of Las Vegas Valley, Big Bend, and Clark County.

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2. In early 2013, the TAB website said the company was owned by Cove Partners LLC, an investment and hotel company located in Lebanon, Oregon.

Although the individual water districts maintain control over their own daily operations, the SNWA is in overall charge of managing the region's water resources and ensuring future supply (SNWA 2007). As part of this responsibility, the SNWA considers and evaluates long-term plans, including costly and politically controversial proposals. One of these is the Las Vegas Valley Pipeline Project—a potential water zombie.

## History

Las Vegas is a desert. The city itself was created as a consequence of the construction of Boulder (now Hoover) Dam on the Colorado River and the creation of Lake Mead, the only significant source of water in the region (SNWA 2006). In the late 1920s, when seven western states that share the Colorado River were negotiating how to apportion flows, the southern Nevada region had a very low population and little to no agricultural or industrial water demand as compared with the other basin states. Partly as a result, during the negotiations Nevada was allocated 300,000 acre-feet per year (AFY) of water, just 4 percent of the total amount estimated for the lower basin. Today, nearly all of it goes to the Las Vegas region (Clark County), where 2 million people—72 percent of Nevada's total population—reside.

As Nevada's population has grown through the twentieth century, there have been efforts to modify or renegotiate the Colorado River "Law of the River"—the set of compacts, agreements, contracts, regulations, and court decisions that govern management of the Colorado River (US BOR 2007). However, these efforts are highly controversial and are largely ignored by the other basin states, which also are experiencing increased demand for a limited resource. Part of the argument against reallocation of the Colorado River flow was based on the fact that Nevada had other in-state resources that could be developed, as the other lower basin states had done.

As a result, southern Nevada has considered several options for increasing its available water supplies, including development of five northern groundwater basins. In 1989, the Las Vegas Valley Water District (LVVWD) applied to the Nevada State Engineer (NSE) for permission to drill 146 groundwater wells in twenty-eight different sub-basins in White Pine, Lincoln, and northern Clark Counties. The permits requested up to 840,000 AFY (over a billion cubic meters per year) from wells as much as 500 kilometers (300 miles) from the city (Reinhold 1991) and drew substantial opposition from local residents, public interest groups, and federal agencies. More than 3,600 protests were filed with the State Engineer's Office (Reinhold 1991). When asked about the groundwater project in 1994, the SNWA's director, Patricia Mulroy, said that although others were calling it "the singularly most stupid idea anyone's ever had," concern over the applications helped draw attention to Nevada's water needs (Christensen 1994). The groundwater permits, along with other water development proposals, were used to argue for changes to the Law of the River (Greene and Hynes 1996). One article notes that Mulroy said that the applications for rural groundwater would be dropped if the agency's Colorado River apportionment were to increase (Egan 1994). Within a few years, Las Vegas would end up with new rights to the Virgin River, a second pipeline into Lake Mead, and a water-banking agreement with Arizona.



## Recent Developments

The groundwater development project was revived in 2004 in the form of a proposed major pipeline to northeastern Nevada counties during a prolonged drought in the Colorado River basin (Casey 2004). Before the drought, the SNWA had been expecting future water deliveries to come from surplus and banked supplies on the Colorado; however, falling lake levels put new pressures on those resources, and the SNWA could no longer count on their supply. Projections suggested that if drought conditions continued, at least one of the SNWA's water intakes from Lake Mead could be unusable as early as 2012. Plans were made to build a third, deeper intake, and in February 2004 the SNWA's board approved a plan to move forward with new plans to tap northern Nevada groundwater resources. The SNWA submitted a right-of-way application for construction of the pipeline to the US Bureau of Land Management (BLM) in 2004.

State permitting agencies approved new SNWA groundwater applications in Spring Valley in April 2007 and applications in Delamar, Dry Lake, and Cave Valleys in July 2008. However, these rulings were followed by nearly four years of efforts to delay implementation, including two court cases, required resubmission of the appropriations applications, and public hearings, meetings, and a mandatory reopening of the protest period. In March 2012, the NSE again approved the applications for the four basins, with even greater pumping allowances as well as modified requirements for research, monitoring, and reporting. The rulings also required expanded hydrologic and biological monitoring, preparation of annual reports, completion of baseline studies, and development of efforts to mitigate adverse effects.

The BLM published a final environmental impact statement (EIS) for the pipeline system and associated infrastructure in August 2012 and approved the right-of-way in December. The EIS recommended approval of a modified plan that would support transfer of nearly 115,000 acre-feet per year through over 300 miles of pipeline, at an estimated cost of just under \$4 billion for the "preferred alternative" (US BOR 2012) (see table 7.1). A coalition of ranchers, farmers, rural local governments, and environmentalists appealed the state engineer's 2012 ruling. Oral arguments were scheduled for June 2013, and if the decision is appealed (which is likely regardless of the ruling) the case could move into 2014 (Eggen 2012).

Concerns about the project have changed little since its inception. They focus on the effects that groundwater pumping and withdrawals would have on local ecosystems and existing water users in the northern valleys, equity concerns about massive water transfers from rural communities to urban centers, the long-term impact of climate change on water needs and availability, and the science behind the groundwater models and demand assumptions. Opponents are particularly concerned that groundwater in the extraction areas is already overallocated and that pumping at the proposed levels will draw down the water table by hundreds of feet. Although the SNWA has promised to monitor and to stop pumping should major drawdown occur, opponents argue that once negative effects are recognized, it will be too late to recover and too difficult politically to reduce extraction (Deacon 2009). Some opponents describe the project as a twenty-first-century version of the Los Angeles water grab from the Owens Valley, or the movie *Chinatown* with its political intrigue, corruption, and land speculation. In that instance, in the early 1900s Los Angeles obtained the rights to take water from a distant rural community and disrupted the farming culture and environmental conditions there.



**TABLE 7.1** Withdrawal Volumes for the Groundwater Development Project (Acre-Feet per Year)

| Location        | SNWA Applications | NSE Ruling |                 |                        |
|-----------------|-------------------|------------|-----------------|------------------------|
|                 |                   | 2007/2008  | NSE Ruling 2012 | BLM EIS, Alternative F |
| Spring Valley   | 91,224            | 60,000     | 61,127          | 84,370                 |
| Delamar Valley  | 11,584            | 2,493      | 6,042           | 6,591                  |
| Dry Lake Valley | 11,584            | 11,584     | 11,584          | 11,584                 |
| Cave Valley     | 11,584            | 4,678      | 5,235           | 11,584                 |
| Total           | 125,976           | 78,755     | 83,988          | 114,129                |
| Snake Valley    | 50,679            |            |                 |                        |

Source: US BLM (2012).

## The Special Problems with Snake Valley

Although the proposals for groundwater extraction have always included plans to pump water from Snake Valley, obtaining approval for this piece of the effort has been considerably more complicated than for the other basins. The Snake Valley basin straddles the border of Nevada and Utah and is the only basin in the proposal that is shared with another state (Deacon 2009).<sup>3</sup> In 2004, Congress passed an act that would allow the groundwater development project to be constructed on federal lands; however, it also required the SNWA to come to an agreement with Utah over Snake Valley (P.L. 108-424). The two states reached a tentative agreement in 2009 (State of Utah 2009); however, as of early 2013, Utah still had not signed. And then, suddenly and unexpectedly, the governor of Utah, Gary Herbert, announced in April 2013 that he would not sign the agreement to share the groundwater in the joint basin. Governor Herbert said that he based his decision on feedback from local Snake Valley residents, including ranchers, landowners, Native American tribes, and governmental officials, most of whom opposed the agreement.

“A majority of local residents do not support the agreement with Nevada,” the governor said. “Therefore, I cannot in good conscience sign the agreement because I won’t impose a solution on those most impacted that they themselves cannot support” (*Salt Lake Tribune* 2013).

The SNWA considered suing Utah for not signing the agreement, but as of mid-2013 it had not yet taken action.

## Las Vegas Pipeline Summary

Is this a zombie water project? We’re not sure. It is unclear whether the project is politically, economically, or environmentally viable and will move forward, although the SNWA maintains it is indispensable to the future of the city. The economic recession that began in 2008 slowed growth in the Las Vegas area, and increased conservation efforts have improved the water situation, though not by much and perhaps only temporarily. The city’s heavy dependence on the Colorado River, combined with very little industrial or agricultural use, means that the bulk of the efforts to modify demands must fall on

3. However, it is not the only transboundary basin potentially affected.

residential users. As some studies have suggested, far more could be done in this area (Cooley et al. 2007). Ensuring that southern Nevada has a sustainable supply of water will certainly require changes in both supply and demand management, but in the long run, there will have to be changes to regional development policies as well.

The project doesn't appear to be dead yet, and indeed, it may actually be built. But it is clear that it represents the kind of project that would have been built in the twentieth century, when society didn't care about, or didn't understand, the social and environmental implications of unrestrained long-distance water extraction and transfers.

## Diverting the Missouri River to the West

Another proposal for a massive interbasin water diversion is the idea of moving Missouri or Mississippi River water west to the arid and semi-arid parts of the country. While far smaller in scope than the NAWAPA project described earlier, water diversion from the Missouri or Mississippi basin would still be an enormous undertaking. Water would be moved in massive pipes and aqueducts, requiring large amounts of energy to pump water over mountains and leading to ecological and social dislocations in downstream regions.

### History

There is a long history of ideas, efforts, actual expenditures, and construction projects designed to move Missouri River water somewhere else. As early as 1889, the Constitutional Convention of North Dakota considered a proposal to build a canal to divert Missouri River water in Montana to the Red River for irrigation. The infamous Garrison Diversion Project and its related components (proposed and partially built in the 1930s, 1940s, and 1950s) is a case in which hundreds of millions of dollars have been spent to try to do things that ultimately have failed to satisfy political, environmental, and social needs (Springer 2013).

### Recent Efforts at Revival

The concept has always been seen as far-fetched, yet like traditional zombies, it is never seen as really dead. In 2012, the idea was raised again when the US Bureau of Reclamation included it as one of many possibilities for rethinking management of the Colorado River. The study by the Bureau of Reclamation ("the Basin Study") was the culmination of a two-year effort to develop and analyze future supply and demand scenarios for the seven states that share the Colorado River (Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming) (US BOR 2012). In the bureau's analysis, the project was described as a 670-mile pipeline to divert water from one of the Mississippi River's major tributaries to help seven arid states in the West (Salter 2012). The core of the idea is to build diversion dams along the Missouri and its tributaries to divert water during periods of high flow and move water west. If the water goes to users in the upper part of the Colorado River basin, for example, downstream users hope that upstream users would forgo some of their formal Colorado River legal allotments, permitting increased use lower in the basin. They suggest that the project would cost an estimated \$11.2 billion

and take thirty years to complete, though such initial cost estimates have a long history of being largely guesswork.

The Basin Study is a multiyear, multi-participant assessment of the growing challenges facing the most important river basin in the arid western United States—the Colorado. It shows that water demands in the basin already exceed the river’s available supply—a situation the Pacific Institute previously defined in a paper in the *Proceedings of the National Academy of Sciences* as having reached “peak water” (Gleick and Palaniappan 2010). The situation will worsen as water demands grow with population and if, as scientists now expect, water supply in the river diminishes with climate changes. Just as important as identifying water scarcity problems is identifying the options for addressing or preventing them. The Basin Study offers over a hundred different options and strategies for increasing supply or reducing demand. Many make sense; a few are far-fetched and seriously out of touch with reality, including the idea to divert the Missouri River. It did, however, receive considerable attention in the media when it was released, reflecting the fascination the public and the media have with massive engineering ideas.

This kind of proposal has been made especially forcefully by the city of Las Vegas, which (as described earlier in this chapter) faces serious water constraints as a result of uncontrolled development. As stated in 2011 by Patricia Mulroy, director of the Southern Nevada Water Authority (Velotta 2011),

it makes no difference to the corn and the alfalfa whether it gets Colorado River water or Mississippi water or Missouri water. . . . You could improve the transportation and cargo transports on the Mississippi River, which have been severely impaired this year by flood conditions, and at the same time provide some security for those communities that have lost everything by pulling some of that water off and moving it. . . . It’s more water than the system down there can handle. Let’s use it. Let’s recharge the Ogallala aquifer, let’s replace some Colorado River users. Let them use some of this and leave the other water in the Colorado River for those states that are west of the Colorado.

From a narrow technological perspective, there is no doubt that such a pipeline can be built: a treatment plant, massive pumping stations, and a 600-mile-plus pipeline to move water. Technically, this is standard engineering, albeit on a large scale.

## Project Limitations

But some observers note that it is a dangerous idea whose time has come and gone again, and in this era of fiscal limits, the federal government should not spend one penny even studying it, much less invest in such a thing. Why? The project is predicated on three assumptions—all false:

First, it assumes that conservation and efficiency will not be sufficient to limit water demand and that we must find more “supply.”

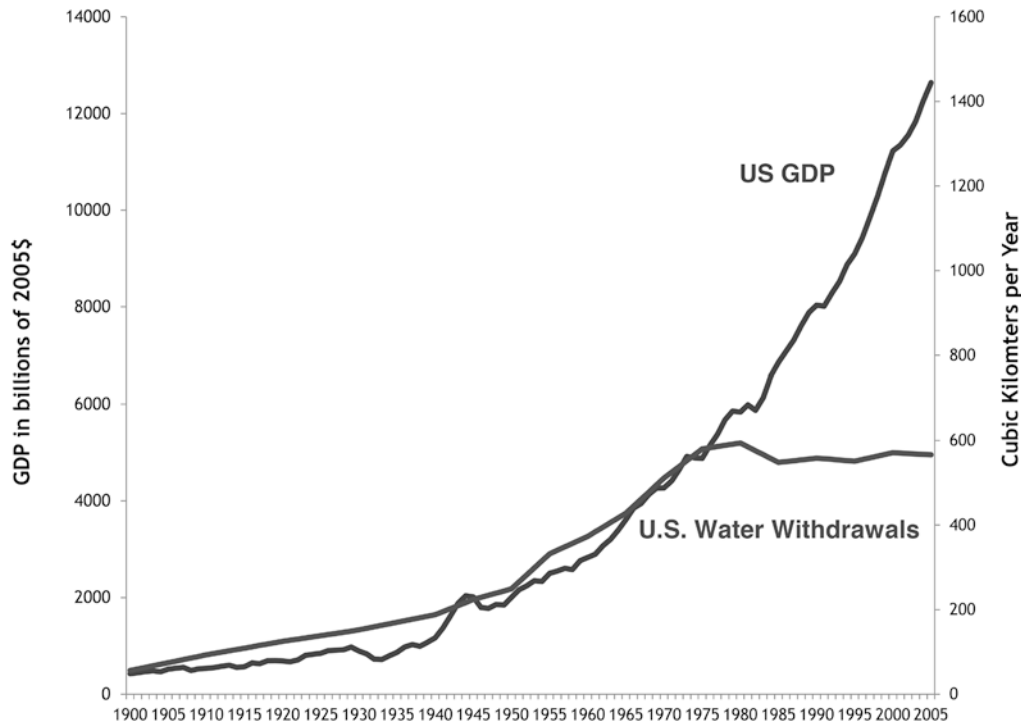
Second, it assumes that money, energy, and the environment don’t matter.

Third, it assumes that there is excess water in the Missouri River to transfer.

Water demands should not be assumed to grow without limits. In the first case, water managers, planners, local officials, and others are all trained to assume that water demands must grow inexorably with population and the economy and that the only re-

sponse is to find new sources of water. Recent experience in the western United States and many other regions—indeed, in the United States as a whole—shows that we can cut water use substantially by improving efficiency, cutting waste, and changing use patterns while populations and economies continue to grow. Figure 7.4 shows that this has been the case in the United States for over thirty years, during which time total water use has actually declined—and new studies show that vast untapped and relatively low-cost efficiency improvements remain. Moreover, it is long past time we had a real conversation about land use, urban planning, and population policies instead of assuming they have no implications for water policy.

In the second case, a pipeline taking water west from the Missouri River makes sense only if you deeply discount or ignore economic, energy, and environmental factors. Such a pipeline would cost—at a minimum—tens of billions of dollars to build and would require massive energy inputs to run. Here is just one piece of this puzzle: moving water from the Missouri River at Leavenworth, Kansas (often described as a logical diversion point), to Denver, Colorado, would require a pipeline at least 600 miles long pumping water uphill around 5,000 feet (see figure 7.5). Even doing the math on the back of an envelope shows that the energy costs for pumping alone, with conservative assumptions, would be at least \$1,000 per acre-foot of water. Add in the additional costs of financing and building such a pipeline and the power plants to run it, of operating it, and of treating and distributing the water, and we're looking at some of the most expensive water



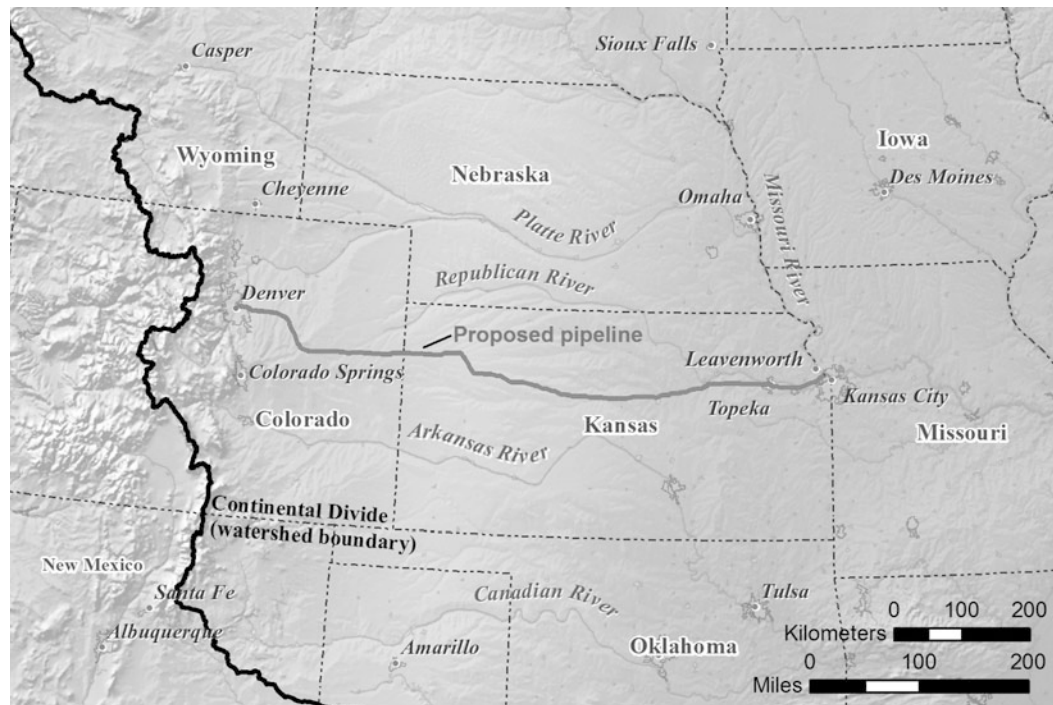
**FIGURE 7.4 US WATER USE AND GROSS DOMESTIC PRODUCT**

Source: Gleick and Palaniappan 2010.

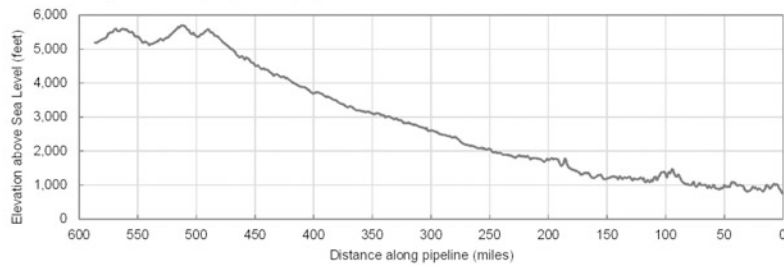
The graph shows US water withdrawals from 1900 to 2005 in cubic kilometers per year plotted against US gross domestic product in 2005 adjusted dollars. Note that water withdrawals are no longer growing with population and the economy but have actually declined.

in the world (not including bottled water—another story). Even more ambitious, and costly, would be trying to move any of the water over the Rocky Mountains, where the additional pumping and energy costs would skyrocket.

Finally, the idea is also largely predicated on the assumption that the Missouri River has excess water. This, of course, depends on how you define “excess” and who is doing the defining. Some of the proposals try to argue that water would be diverted only during infrequent high flow, or flood, events, which would further dramatically increase the unit cost of water, since huge, costly infrastructure would be idle for long periods of time. It is unlikely that, if actually built, the system would be operated in this manner. But it is also ironic that the idea was presented at exactly the same time—the 2012–2013 seasons—that massive, severe drought cut the flows of the Missouri and Mississippi Rivers to record low levels, barges were being stranded, downstream users were demanding more upstream releases, and Midwest agriculture was suffering from water shortages. The US Army Corps of Engineers—the federal agency responsible for managing the



Elevation profile of proposed pipeline:



**FIGURE 7.5 ONE POSSIBLE ROUTE FOR THE DIVERSION OF MISSOURI RIVER WATER TO DENVER AND THE COLORADO FRONT RANGE**

This figure also presents the distance/elevation profile showing that water would have to be moved nearly 600 miles and be pumped nearly 5,000 feet up, at a huge energy cost.

river—declined requests for more water from the Missouri River to alleviate shortages on the Mississippi because such releases would have come at the expense of upstream users, drinking water supplies, environmental conditions, and hydropower generation.

## Conclusions

We've reached the era of peak water, even on big rivers such as the Missouri or for untapped resources such as northern-flowing rivers in Alaska and Canada. There are many other potential candidates for the category of "zombie water projects." There is the proposal to divert water from the Gulf of California back north to the Salton Sea. There is the proposal to cut a canal or run a pipeline from the Mediterranean Sea or the Red Sea to the Dead Sea (see the In Brief report in this volume for a detailed update on this idea). There has been talk for decades about building a massive canal in the Jonglei region of Sudan on the Nile to dry up the ecologically valuable inland Sudd swamps there and cut evaporative losses on the Nile. The Chinese are building a massive south–north canal system that may be quite alive.

While we can continue to fantasize about developing new water supplies by building larger and larger engineering projects to move water longer and longer distances, destroying ever more distant ecosystems in the name of satisfying uncontrolled and unquestioned sprawl and development in arid regions, perhaps it is time to ask: Just because we can, should we? And once we ask that question, the answer typically comes back quickly: No, we shouldn't. There are often far more environmentally, politically, and economically sound solutions that should be considered first. And many of these zombie water projects should be left for dead.

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# The Syrian Conflict and the Role of Water

Peter H. Gleick

There is a long history of conflicts over water—consistently documented in each previous volume of *The World's Water* biennial assessments, going back to the first, in 1998. The Pacific Institute also maintains a searchable online chronology of such conflicts going back five thousand years.<sup>1</sup> There were dozens of new examples in the past two years, in countries from Latin America to Africa to Asia. Access to water and the control of water systems have been causes of conflict, weapons used during conflicts, and targets of conflict, but there are also growing risks of violence over the role that water plays in development disputes and economic activities. One especially disturbing example of a major conflict, with complicated but direct connections to water, has developed since 2010: the unraveling of Syria and the escalation of massive civil war there.

## Syria and Water

Syria's political dissolution is, like almost all conflicts, the result of complex, interrelated factors. In this case, the conflict was influenced by an especially repressive and unresponsive political regime, the erosion of the economic health of the country, and a wave of political reform sweeping over the entire Middle East and North Africa region. But in a detailed assessment, Francesco Femia and Caitlin Werrell (2012) of the Center for Climate and Security in Washington, DC, noted that factors related to drought, agricultural failure, water shortages, and water mismanagement also played an important role in nurturing Syria's "seeds of social unrest" and contributing to violence. In particular, they argue that a very severe drought led to persistent crop failures, which in turn led to very significant dislocation and migration of rural communities to the cities. These factors in turn contributed to urban unemployment and economic dislocations and social unrest.

Water has always been a scarce resource in the region—one of the driest in the world. Syria receives, on average, less than 250 millimeters (not quite 10 inches) of rainfall annually. All of its major rivers (the Tigris, Euphrates, and Orontes Rivers and the Yarmouk, a tributary of the Jordan) are shared with neighboring countries. And Syria, like the region as a whole, experiences periodic droughts. Over the past century (from 1900 to 2005) there were six significant droughts in Syria, in which average monthly winter precipitation dropped to only one-third of normal. Five of these droughts lasted only one season;

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1. The chronology can be found at <http://www.worldwater.org/conflict.html>, and a version appears in this volume of *The World's Water*.

the sixth lasted two. Starting in 2006, however, and lasting into 2011, Syria experienced a multi-season extreme drought and agricultural failures, described by Shahrzad Mohtadi as the “worst long-term drought and most severe set of crop failures since agricultural civilizations began in the Fertile Crescent many millennia ago” (Mohtadi 2012).

Robert Worth of the *New York Times* noted that this drought contributed to a series of social and economic dislocations (Worth 2010). The United Nations estimated that by 2011, the drought was affecting 2–3 million people, with 1 million driven into food insecurity. More than 1.5 million people—mostly agricultural workers and family farmers—moved from rural regions to cities and temporary settlements near urban centers, especially on the outskirts of Aleppo, Hama, Homs, Damascus, and Dara’a.

In 2008, a diplomatic cable from the US embassy in Damascus to the US Department of State in Washington warned of the implications of the drought, with a review of local opinions and concerns as well as insights from the Food and Agriculture Organization of the United Nations (FAO).<sup>2</sup> During the drought, FAO Syrian representative Abdullah bin Yehia provided a briefing on the impacts, described as a “perfect storm” when combined with other economic and social pressures. At that time, concerns were expressed that the population displacements “could act as a multiplier on social and economic pressures already at play and undermine stability in Syria.” In July 2008, Syria’s minister of agriculture stated publicly to UN officials that the economic and social fallout from the drought was “beyond our capacity as a country to deal with.” This warning was perceptive and prescient: some of the earliest political unrest began around the town of Dara’a, which saw a particularly large influx of farmers displaced from their lands by crop failures.

The political problem was worsened by water mismanagement, poor planning, and policy errors. The regime of Bashar al-Assad traditionally provided large subsidies for the production of water-intensive crops, such as wheat and cotton, and flood irrigation systems are largely inefficient. Groundwater supplies were reportedly overpumped, leading to dropping groundwater levels and rising production costs. Water withdrawals upstream by Turkey for its own agricultural production in the southern Anatolia region further reduced surface flows inside Syria. All of these factors contributed to growing economic and political uncertainty.

Suzanne Saleeby, writing for *Jadaliyya*, a magazine published by the Arab Studies Institute, analyzed the links between economic and environmental conditions and the subsequent political unrest. Saleeby (2012) argued, “The regime’s failure to put in place economic measures to alleviate the effects of drought was a critical driver in propelling such massive mobilizations of dissent.”

Saleeby noted that the Assad regime made great strides in improving access to water, building water infrastructure that benefited rural communities and expanded agricultural production. But she also noted that the vast expansion of irrigated agriculture in the region, especially of nonfood industrial crops, worsened water shortages in rural areas and led to salination of farmland.

These effects increased vulnerability to subsequent droughts. At the same time, governmental sales of land in recent years to private agricultural interests led to growing mistrust and concern about corruption. Extensive exploitation of groundwater led to substantial drops in groundwater levels and, in some regions, contamination by salts and

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2. These observations were cited in the diplomatic cable, published at <http://wikileaks.org/cable/2008/11/08DAMASCUS847.html>. The accuracy of this cable’s contents has not been verified, but these statements appear to be in the public record.

nitrites, making local wells (for example, in the ar-Raqqah region) unfit for human use. In all of these cases, trends toward privatization “corroded customary law over boundary rights” (Saleeby 2012), further worsening local tensions. These complex factors contributed to the extent and severity of the unrest (Saleeby 2012):

It is logical to conclude that escalating pressures on urban areas due to internal migration, increasing food insecurity, and resultant high rates of unemployment have spurred many Syrians to make their political grievances publically known. One might look to the city of Deir ez-Zor, one of Syria's most dangerously dry areas, to locate deeply rooted seeds in the harvest of dissent. The northeastern city experienced one of the strongest sieges by the Syrian army at the beginning of Ramadan after popular uprisings spread across its parched expanse. As a local activist told *Syria Today*, the citizens of Deir ez-Zor “are suffering and complain that they have had no help from the authorities who tell them what type of crops they have to plant, and have a monopoly on buying up what they produce.” Also among the cities whose residents' livelihoods were most crippled by recent drought was Daraa, historically a “bread basket” of Syria. Additionally, Hama remains a major destination for drought-displaced farmers despite suffering its own water scarcity woes. In all three centers of popular uprisings lie important narratives of livelihoods lost and families left wanting.

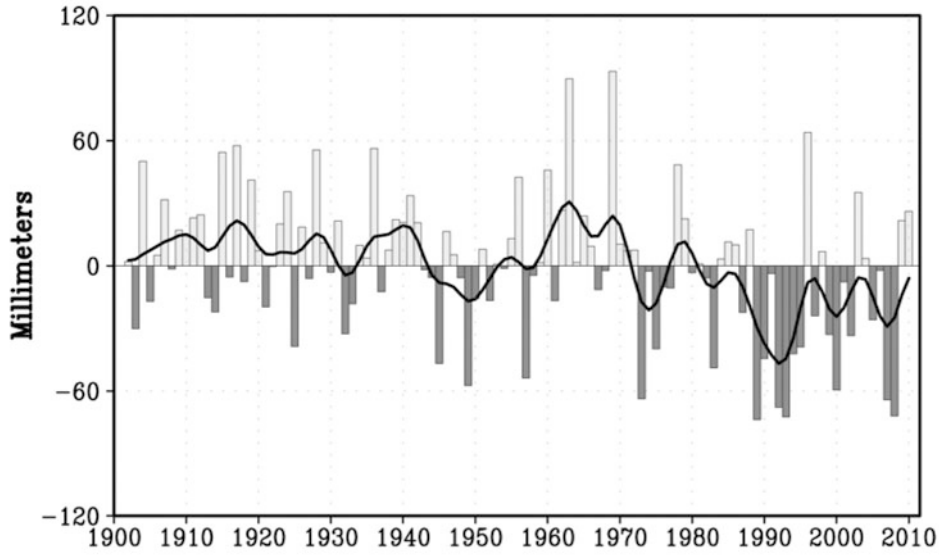
## Other Links between Water and Conflicts in Syria

After serious conflict in Syria developed, violence worsened and spread. In 2012, incidental impacts on urban water distribution systems were reported, as were specific, intentional attacks on water systems because of their strategic value. During fighting around the city of Aleppo in 2012, the major pipeline delivering water to the city was badly damaged, and in September the city of about 3 million people was suffering shortages of drinking water (BBC 2012). In late November 2012, anti-Assad Syrian rebels overran governmental forces and captured the Tishrin Dam, a hydroelectric dam on the Euphrates River, after heavy clashes (Mroue 2012). The dam supplies several areas of Syria with electricity and is considered to be of major strategic importance to the Syrian regime. In February 2013, anti-Assad forces captured the Tabqa Dam, also called the al-Thawrah Dam, which is the largest hydroelectric dam in the country and provides much of the electricity for the city of Aleppo (BBC 2013).

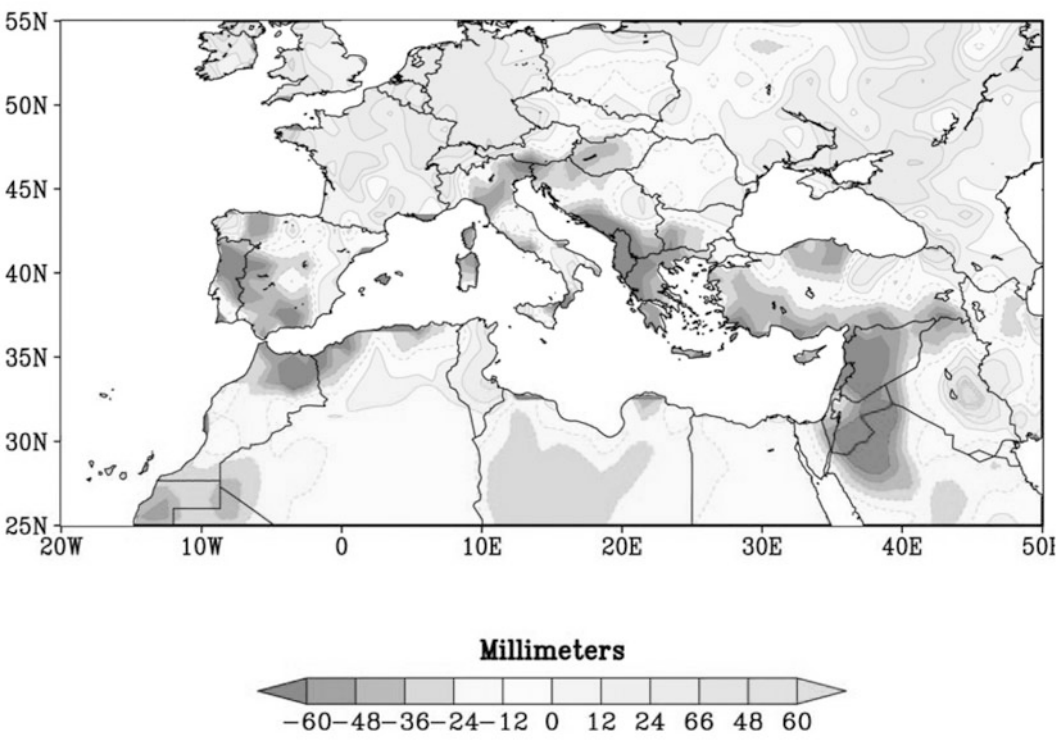
## The Role of Climate Change

Indications for the future are not promising: on top of political unrest and economic dislocations, the region faces challenges posed by growing populations, the lack of international agreements over shared water resources, poor water management, and the increasing risks of climate change. In 2008, the World Bank was already warning of future climate risks (World Bank 2008):

According to the latest IPCC assessment, the climate is predicted to become even hotter and drier in most of the MENA [Middle East and North Africa] region. Higher temperatures and reduced precipitation will result in higher frequency and severity of droughts, an effect that is already materializing in the Maghreb.



**FIGURE WB 1.1 MILLIMETERS OF RAINFALL DURING WINTER PERIODS FROM 1902 TO 2010, SHOWING A DROP IN RAINFALL IN 1971–2010**  
*Source: NOAA (2011).*



**FIGURE WB 1.2 FOUR DARKEST SHADES INDICATE THE AREAS AROUND THE MEDITERRANEAN THAT EXPERIENCED SIGNIFICANTLY DRIER WINTERS DURING 1971–2010 THAN IN 1902–2010**  
*Source: NOAA (2011).*



A research paper published in 2012 suggested that climate change is already beginning to influence long-term droughts in the region including Syria by reducing winter rainfall (see figures [IB 1.1](#) and [IB 1.2](#)) (Hoerling et al. 2012). That study suggests that winter droughts are increasingly common and that human-caused climate change is playing a role. Martin Hoerling of the National Oceanic and Atmospheric Administration's Earth System Research Laboratory, one of the study's authors, stated, "The magnitude and frequency of the drying that has occurred is too great to be explained by natural variability alone" (NOAA 2011).

If the international community wants to reduce the risks of local and international political conflicts and violence over water, more effort will have to be put into recognizing these risks and improving the tools needed to reduce them.

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# The Red Sea–Dead Sea Project Update

Kristina Donnelly

The Dead Sea is a terminal lake with great historical, cultural, and economic significance. The sea sits at the confluence of East and West, on the borders of the Hashemite Kingdom of Jordan, Israel, and the Palestinian National Authority, an area that has transported people, goods, and ideas for generations. For at least the past 150 years, serious proposals have been made to engineer a connection between the Red Sea, the Mediterranean Sea, and the Dead Sea. The political, social, water, and environmental needs of the region have each, over time, contributed to the endurance of this idea; hammers, as they say, tend to manifest a great deal of nails, and humans have an affinity for large, complex hammers. Over time, the proposal has been offered as a means to facilitate transportation, generate electricity, supply freshwater through desalination, and advance broader regional peace and economic development. This Water Brief report summarizes both the history of and recent events in the proposals to build major infrastructure in this region.<sup>1</sup>

## Projects to Improve Transportation

The first proposals date as far back as the 1850s, when the British suggested that a canal linking the Red Sea to the Mediterranean Sea could serve as an alternative to the Suez Canal as a route from Europe to India (Allen 1855). Political considerations regarding Egypt made finding alternatives to the Suez Canal attractive for the British and then for Israel (Ofner 1946; *New York Times* 1956). As early as 1883, a British member of Parliament noted the “immense importance of obtaining, if possible, a waterway to India independent of the Suez Canal, and all its untoward complications” (Martin 1883). The idea persisted through the mid-twentieth century (Wallenstein 1966). As proposed, creation of a waterway suitable for navigation would completely alter the local environment and would flood important cultural, religious, and historical sites (*San Francisco Chronicle* 1883). Ultimately, Israel chose to build a rail system over a canal to link the Mediterranean to the Red Sea, although even this project was never completed.

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1. We chose not to include this section in the earlier chapter on zombie water projects because it isn't clear that the idea is fully dead—yet.

## Projects to Expand Energy

As the lowest point on Earth, the Dead Sea has tremendous potential for hydroelectric power generation. In 1902, Theodor Herzl, the founder of modern Zionism, wrote about a canal that would take advantage of the 400-meter (1,310-foot) elevation difference between the Red Sea and the Mediterranean to generate hydroelectric power. As the cost of oil rose in the 1970s, Israel began studying the feasibility study of a canal project for energy generation, with navigation listed only as a potential “fringe” benefit (Torgerson 1979). Jordan objected to the plan, as one option would have passed through the Gaza Strip, and in response began studying the feasibility of a hydropower canal from the Red Sea to the Dead Sea (Khoury 1980). Over time, canal proposals have considered other kinds of energy generation besides hydropower, including nuclear power and solar energy fields (Wallenstein 1966; Torgerson 1979). Although energy generation would also become another “fringe” benefit of future canal proposals, it remains a key component to reducing overall project costs.

## Projects to Produce Freshwater

The project began to take its modern shape during the Middle East peace talks in the early 1990s, when freshwater scarcity and drastically increasing populations were threatening the water security of the entire region (Wolf and Newton 2007). In order to address some of the region's critical water issues, the peace process brought about the formation of the Multilateral Working Group on Water Resources. At a meeting of the group in 1993, Israel proposed desalinating Red Sea water to provide 1 billion cubic meters of water to the region, particularly Jordan (Schmetzer 1993).

It was envisioned that this project would be part of a much larger regional economic development plan to facilitate peace, with the *London Observer* calling it “the development centerpiece of the Middle East peace accords” (Holmes 1994; *Wisconsin State Journal* 1994; Land 1994). Both sides began referring to the section of the Jordan Rift Valley between the Red Sea and the Dead Sea as “Peace Valley” (Peres 1994). However, by 1995 the project had been shelved as a result of onerous bureaucracy, deteriorating relations, lack of funding, and failure of the parties to agree on design and management. At that time, the project was estimated to cost \$4.2 billion, and the World Bank and other international monetary officials were making it clear that the money would not come from the international community (Rodan 1995; Izenberg 1997). There would be little movement on the idea until changing circumstances offered a fresh application for the proposal.

## Projects to Restore the Dead Sea

The Dead Sea has slowly been shrinking throughout the twentieth and twenty-first centuries. Israel, Jordan, and Syria began diverting the Jordan River in the 1960s, and everyone knew that the Dead Sea would slowly disappear as a result (Wallenstein 1966). Located in an area that receives less than 100 millimeters (under 4 inches) of rain per year and where temperatures often exceed 45°C, the Dead Sea is completely reliant on

inflow for its continued existence. It is estimated that the total inflow to the Dead Sea has been reduced from around 1,250 million cubic meters (MCM) per year in 1950 to around 260 MCM per year in 2010. Furthermore, much of the water left in the lower Jordan River consists of raw sewage, agricultural runoff, fish pond water, and saline spring water (Gafny et al. 2010). Lucrative chemical production facilities on the southern shore of the sea have also contributed to the decline. In order to extract potash and other chemical products, the chemical industries pump water from the upper Dead Sea to the lower section, into solar evaporation ponds. Without this pumping, the southern Dead Sea would completely dry up. Paradoxically, the southern portion of the sea is now suffering from rising levels: waste materials left over from the mineral extraction process are causing the water levels to increase by 20 centimeters per year. This means that the majority of the tourism activity taking place on the Israeli side of the Dead Sea is at risk from flooding, and large-scale dredging plans are being discussed (Udasin and Hartman 2011).

The Dead Sea shoreline now sits 426 meters (m) below sea level, more than 30 m lower than in the 1960s. Without any intervention, the sea is expected to drop by another 150 m, stabilizing around 543 m below sea level, by the mid-twenty-second century (Coyne et Bellier et al. 2012).

Although one canal project noted the replenishment of the Dead Sea as a potential benefit as early as the 1980s (Khoury 1980), the idea would not take prominence until the late 1990s, when sinkholes began to appear on both the Israeli and Jordanian shores. Sinkholes form when declining sea levels move the interface of fresh and saline groundwater, bringing undersaturated water into contact with salt formations. This freshwater dissolves these formations, leaving behind underground caverns that can eventually collapse (Yechieli et al. 2002). These sinkholes have swallowed up roads, houses, and other infrastructure on the shorelines,<sup>2</sup> which has had, and will continue to have, negative consequences for the local and national economies.

## A Combined Plan

In 2001, the Center for Middle East Peace and Economic Cooperation revived the concept, in a project dubbed the "Peace Conduit," this time with saving the Dead Sea as a major objective, with other benefits being the production of drinking water, generation of hydropower, and a reduction in regional conflict (Lazaroff 2001). Israel and Jordan announced their commitment to the project in 2002 during the World Summit on Sustainable Development in Johannesburg, South Africa (Gavrieli and Bein 2007).

In 2005, Israel, the Palestinian Authority, and Jordan signed an agreement for a \$15.5 million feasibility study, funded through a multidonor trust fund administered by the World Bank (Al Bawaba 2005; Urquhart 2005). In 2013, the World Bank issued the final three draft reports: a feasibility study, an environmental and social assessment, and a study of alternatives.<sup>3</sup> The reports tentatively conclude that a \$10 billion pipeline is feasible, though risky and not without environmental and social impacts.

The proposed plan would convey 2,000 MCM per year of Red Sea water to a desalina-

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2. Sometimes even people: [http://www.nbcnews.com/id/31475786/ns/world\\_news-environment/t/dead-sea-sinkholes-swallow-plans/#.UVgTQaLZ7jI](http://www.nbcnews.com/id/31475786/ns/world_news-environment/t/dead-sea-sinkholes-swallow-plans/#.UVgTQaLZ7jI).

3. The World Bank held a series of stakeholder meetings in February 2013 and planned to issue the final report documents in June (World Bank 2013).

tion plant in Jordan, south of the southern tip of the chemical industries' evaporation ponds. By 2060, the plant would produce more than 820 MCM per year, with 550 MCM per year for Jordan, 60 MCM per year for Israel, 60 MCM for Palestine, and 200 MCM left unallocated. Despite the inclusion of a hydropower facility in the preferred option, by 2060 the desalination plant would still require at least an additional 6,140 gigawatt-hours of energy per year.<sup>4</sup> Leftover brine waste would be used to replenish the Dead Sea, stabilizing the level around 416 m below sea level by 2054. Potential impacts from this brine include precipitation of gypsum, which could create whitening events, stimulate algae blooms, or otherwise alter the water's aesthetics.

## Criticisms of the Project

It is unclear whether an effective multinational organization could form and carry out such a cumbersome and lengthy project. In order to access international support and financing, the project partners would need to set up a legal and institutional framework "founded on internationally accepted law and good practice" (Coyne et Bellier et al. 2012). That could mean Israel would need to recognize that the Palestinian Authority has rights to the Dead Sea, which it has not yet done. As noted in the feasibility study, "one particularly powerful lesson to be learnt from experience elsewhere is that good governance requires a strong and autonomous regulatory authority." It has not yet been made clear what kind of regulatory authority could be created, how it would operate, who would pay for it, and what its roles and responsibilities would be.

Moreover, anti-Israel sentiment is high in Jordan and the Palestinian Authority, and any collaborative projects are often widely perceived as "normalizing" the occupation in Palestine. The feasibility study and other reports have considered a Jordanian-led project, with bilateral agreements set up to sell water and electricity to Israel and Jordan. However, a unilateral project would still require multinational cooperation and agreement.

None of the individual countries has the financial means or political support to unilaterally move forward, and international financing is crucial. Although the feasibility study considered whether the project could be built in phases in order to alleviate some financial pressure, the study concluded that at least 75 percent of the project's total capacity would be needed in the first phase to make the project financially viable. The feasibility study concluded that a mix of funding sources would be needed in order to meet the \$10 billion price tag, and it outlined a list of preconditions that international financiers would likely have prior to investing, including implementing multinational agreements, making improvements to existing water infrastructure, and increasing the institutional capacity of the water sector.

In addition, environmental organizations and the chemical industries remain critical, citing concerns about Dead Sea and Red Sea water quality and environmental impacts, as well as potential environmental and groundwater impacts in the Arava Valley. Both Israel and Jordan harvest chemicals from the rich, mineral-laden waters of the Dead Sea, and industries on both sides of the border are concerned that the impact of

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4. Energy and cost estimates include the energy required to pump potable water to Amman but not to Israel or the Palestinian Authority.

mixing the desalination brine with water from the Dead Sea will threaten their lucrative operations.

The freshwater component of the project, while important, is less pressing now than it was at the beginning of the twenty-first century. Israel is already moving forward with its own coastal desalination program, which is expanding the freshwater available internally. The feasibility study concluded that it would be economically feasible to deliver water only to the low-elevation demand centers in the Dead Sea basin and the Arava Valley, where demand has been estimated to be 60 MCM per year. It is unclear whether the benefits of the project offer enough incentive for Israel's continued participation. In Jordan, the Disi Water Conveyance Project is expected to be completed in 2013 and will transport 100 MCM of water to Amman from the Disi Aquifer, which lies beneath southern Jordan and Saudi Arabia. Although the pressing need for freshwater in Jordan is expected to be temporarily assuaged by the project, water from this groundwater basin is not a sufficient or sustainable supply.

The idea to link the Mediterranean Sea or the Red Sea with the Dead Sea is not new, although the purpose and scope have changed considerably over time. The factors that have influenced these changes—population, politics, economics, and natural resource needs—are not static and will continue to shift. It is unclear whether the proposed alternative, or some other iteration, can meet all these needs simultaneously and for all stakeholders in the region.

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# Water and Conflict

## Events, Trends, and Analysis (2011-2012)

Peter H. Gleick and Matthew Heberger

Violence over freshwater has a long and distressing history. For nearly two decades, the Pacific Institute has been tracking, analyzing, and cataloging instances of conflict over water resources (see box WB 3.1).

In recent years, there has been an increase in reported cases of water-related disputes and violence. Figure WB 3.1 shows the average number of events per year from 1931 to 2012, averaged over two-year reporting periods. Part of this increase is almost certainly due to improvements in reporting; new Internet tools that permit more comprehensive collection and dissemination of news, data, and information; and more widespread awareness of the issue. But it is also possible that part of the increase is due to growing tensions and disputes over limited freshwater resources and the unresolved political challenges associated with “peak water”—the limits imposed on the availability of both renewable and nonrenewable water resources (Gleick and Palaniappan 2010). Without more information and a more comprehensive analysis, we are not able at this point to make any definitive statement about how to attribute the observed trends in this field, but we put forward the hypothesis, subject to better data and analysis, that the risks of water-related disputes involving violence are increasing. Others have also expressed this hypothesis, based on estimates of growing absolute and per capita scarcity of water, water contamination, and the extensive reliance of agriculture and some urban uses on nonrenewable sources of water that are rapidly being depleted (see, e.g., CSIS and Sandia National Laboratories 2005; US DIA 2012; Leurig 2012).

This idea is also at odds with some academic and popular writing that argues that the fear of water wars is overblown (Kramer et al. 2013). Part of that argument is based on the observation that there are substantial numbers of historical agreements and political treaties over shared interstate water systems and a long history of cooperation and negotiation when disputes develop. But the argument against water “wars” is different from the broader issue of water-related conflicts. And it is somewhat of a “straw man” argument: the “water wars” discussions are almost always found in the popular media, not academic analyses, and while wars are almost never solely or primarily about water, water-related violence, at many different scales, does occur.

Furthermore, much of the discussion and analysis of water wars focuses on *transnational*, or *interstate*, disputes, while there appears to be a growing threat of *subnational*, or *intrastate*, water conflicts. This distinction is further discussed and analyzed below, but we note that the prevalence and availability of international mechanisms to reduce the risks of interstate conflicts may offer little or no help in the area of intrastate conflicts.

### **BOX WB 3.1** The Pacific Institute Water Conflict Chronology

The Pacific Institute maintains a comprehensive database, the Water Conflict Chronology, at <http://www.worldwater.org>. An update is also provided every two years in this biennial water report, *The World's Water*, published by Island Press. Using these data, the Pacific Institute produces theoretical research papers, historical reviews, and regional case studies on water conflicts. We have organized workshops on lessons from regional water disputes in the Middle East, Central Asia, and Latin America. We have brought together experts from the fields of traditional and nontraditional arms control and helped coordinate a workshop on the role of science and religion in reducing the risks of water-related violence, which was held at the Pontifical Academy of Sciences of the Vatican.

The full Water Conflict Chronology includes integrated Google Maps; time, location, and subject filters; and a separate searchable bibliography.\* The nature of entries in the chronology can be described and categorized in different ways. The Institute has split the categories, or types, of conflicts as follows, though other groupings and distinctions can also be useful:

*Military tool* (state actors): water resources, or water systems themselves, are used by a nation or state as a weapon during a military action.

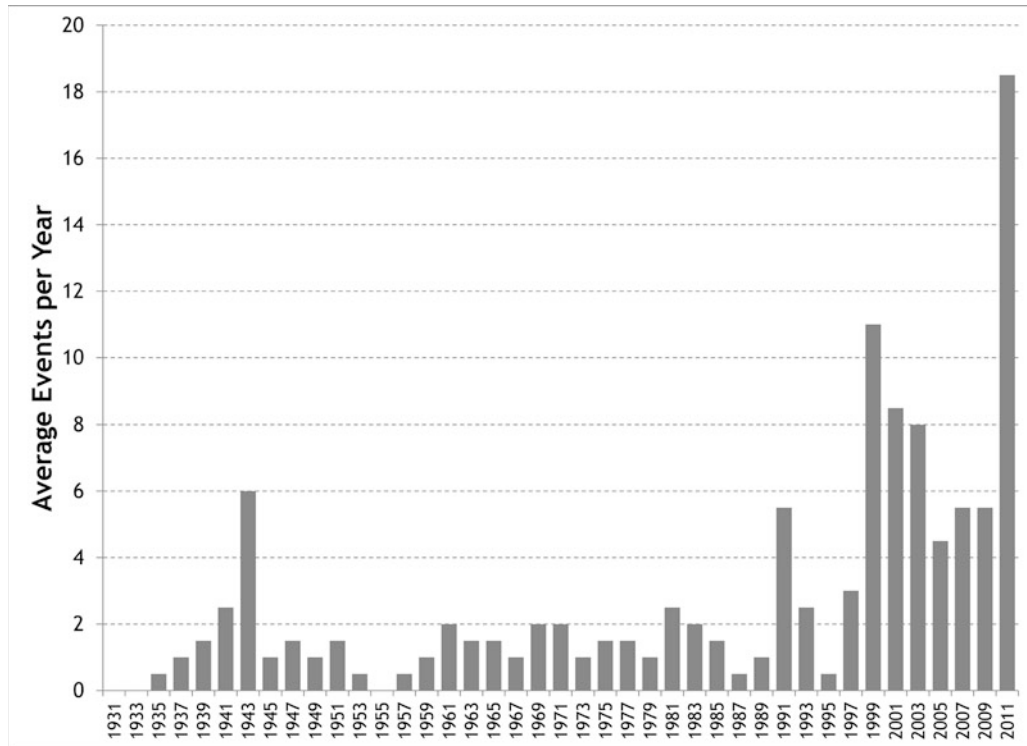
*Military target* (state actors): water resources or water systems are targets of military actions by nations or states.

*Terrorism or domestic violence, including cyberterrorism* (nonstate actors): water resources or water systems are the targets or tools of violence or coercion by nonstate actors. A distinction is drawn between environmental terrorism and ecoterrorism (see Gleick 2006).

*Development dispute* (state and nonstate actors): water resources or water systems are a major source of contention and dispute in the context of economic and social development.

The Water Conflict Chronology has appeared in every volume of *The World's Water* since 1998. It continues to be one of the most popular features of the Pacific Institute's work, and it is used regularly by the media and by academics interested in understanding more about both the history and character of disputes over water resources (Zakaria 2013).

\*Water Conflict Chronology, <http://worldwater.org/chronology.html>.



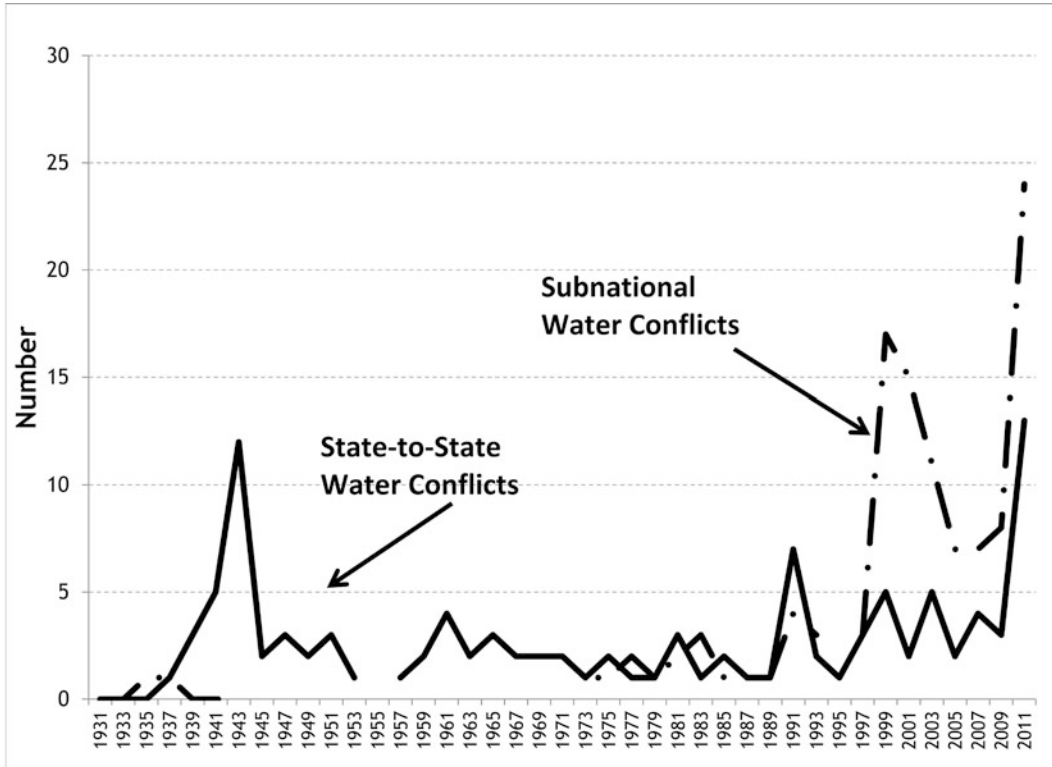
**FIGURE WB 3.1 NUMBER OF REPORTED WATER CONFLICT EVENTS PER YEAR, 1931–2012 (AVERAGED OVER TWO-YEAR PERIODS TO SMOOTH FOR CROSS-YEAR EVENTS AND UNEVEN REPORTING)**

As shown here, it is precisely these subnational conflicts that appear to be increasing in scope and severity. In that sense, it is not water wars that the international community must address but the far broader lethal causes of water conflicts overall, especially conflicts over equitable access to water, strategies for sharing during shortages, and water contamination.

There is also evidence of a shift in the nature of these conflicts, away from water disputes between nations and toward subnational and local violence over water access. Figure WB 3.2 shows the changes in the number and proportion of reported events at the transnational and subnational levels. The growing risk of subnational water conflicts was noted as far back as 1998 in the first volume of *The World's Water* (Gleick 1998, 105):

Traditional political and ideological questions that have long dominated international discourse are now becoming more tightly woven with other variables that loomed less large in the past, including population growth, transnational pollution, resource scarcity and inequitable access to resources and their use.

Part of this shift is almost certainly due to improved local reporting of water conflicts, but part is also likely to reflect the greater availability of diplomatic and political tools at the international level that permit disputing parties to move toward cooperation rather than conflict. Such tools are notoriously weak at the local level, especially in countries with young or weak political institutions. And the greater prevalence of international



**FIGURE WB 3.2 INCIDENCE OF REPORTED WATER-RELATED CONFLICTS FOR TRANSNATIONAL EVENTS (SOLID LINE) AND SUBNATIONAL EVENTS (DASHED LINE). IN THE PAST TWO DECADES, WATER CONFLICTS HAVE BEEN DOMINATED BY SUBNATIONAL DISPUTES.**

mechanisms to reduce the risks of interstate conflicts over water does little or nothing to reduce the risks of intrastate, or subnational, violence.

The latest version of the Water Conflict Chronology includes events from 2011 and 2012 plus new events from other years added by our research, submissions from colleagues and researchers, and contributions from the public. We continue to welcome such contributions.

## 2011 and 2012 Update

In 2011 and 2012, violence over water was reported in every major developing region of the world, especially the Middle East, Africa, and Asia, with additional important examples in Latin America. Below, we provide an update with key examples from this two-year period. The full chronology and list are available online.<sup>1</sup>

1. Corrections, additions, and modifications are welcome. Send full citations and supporting information to [pgleick@pacinst.org](mailto:pgleick@pacinst.org).

## Southern and Western Asia (India, Afghanistan, Pakistan, Iran)

In Afghanistan, three separate events were reported, in April, July, and December 2012. In mid-April, 150 schoolgirls were reported to have been sickened by poison in their school water supply in an intentional attack thought to have been carried out by religious conservatives opposed to the education of women (Hamid 2012). In July, seven children were killed by a bomb thought to have been intended for Afghan police and planted at a freshwater spring in the Taywara District of western Ghor Province (Shah 2012). In December, in a sign of broader tensions over water between Afghanistan, Iran, and Pakistan, which share several rivers, Afghans defending the Machalgho Dam were killed. The dam is being developed for irrigation and local power supply. This dispute is just one of several surrounding the international waters of the region (Mashal 2012).

The year 2012 also saw a series of water-related conflicts within and between India, Pakistan, and Afghanistan. India has long experienced internal (state-to-state) disputes over water, especially between Karnataka and Tamil Nadu over the Cauvery River in a dispute that has been going on since at least 1991. At that time, court rulings allocating water from Karnataka to Tamil Nadu led to riots in Bangalore that killed twenty-three people, mostly Tamils. In 2002, a farmer in Karnataka jumped into a reservoir, killing himself, to protest water deliveries to Tamil Nadu (Circle of Blue 2012). Violence broke out again in 2012 when the state of Karnataka stopped the flow of water to Tamil Nadu, in violation of an order by the Supreme Court of India. In October 2012, thousands of farmers in Karnataka tried to prevent the release of water from two dams (Krishna Raja Sagar and Kabini Dams) on the Cauvery River. Injuries to protestors and police were reported (Circle of Blue 2012). The water releases were ordered by the Indian Supreme Court, which required that Karnataka meet deliveries to the downstream state of Tamil Nadu despite severe drought. The dispute continued later in the year when Karnataka again stopped releases downstream (*Indian Express* 2012).

Separately, scuffles and protests broke out around New Delhi during the summer of 2012 as residents surrounded water delivery trucks and fought over water (Reuters 2012a). That summer was the hottest in thirty-three years, leading to extensive energy and water shortages.

In an international dispute between Pakistan and India, Pakistani militants were reported to have attacked and sabotaged water systems, flood protection works, and dams in the Wullar Lake region of northern Kashmir. In August 2012, water engineers and workers were attacked and explosives were detonated at the unfinished Tulbul Navigation Lock/Wullar Dam, which Pakistan claims would violate the Indus Water Treaty with India by cutting water flows to Pakistan (Hassan 2012).

## The Middle East and North Africa (MENA) Region

Serious examples of the use of water as a target and weapon of war were reported in Libya, during the civil war there, and in the long-standing dispute over borders, land, settlements, and water control in Israel and Palestine in 2011. Cross-border and subnational disputes over water were reported in northern Africa in 2012 involving Egypt, Ethiopia, and Sudan, and separately, within both Sudan/South Sudan and Egypt over water allocation and scarcity.



## Libya

During the 2011 Libyan Civil War, forces loyal to dictator Muammar Gaddafi took control of a water operations center, cutting off the water supply to Tripoli. The system controls Libya's so-called Great Manmade River—a system of pumps, pipes, and canals that brings water from distant aquifers to Tripoli and other cities. Half the country was left without running water, prompting the United Nations and neighboring countries to mobilize tanker ships to deliver water to coastal cities (Circle of Blue 2011; UPI 2011).

## Sudan, Egypt, and Ethiopia

Continuing violence in Sudan had displaced hundreds of thousands of refugees, leading to an increase in deaths from water shortages. Violence broke out in March 2012 in refugee camps, where large numbers of people faced serious water scarcity. Fighting was reported at the limited water points in the Jamam refugee camp (McNeish 2012). The international aid group Médecins Sans Frontières reported in June 2012 that as many as ten refugees were dying daily as water ran out in refugee camps in South Sudan (Ferrie 2012).

Within Egypt, farmers from the Abu Simbel region held over two hundred tourists hostage in June in a protest over the inadequate provision of irrigation water for local farms. The farmers captured the tourists after they had visited famous attractions in the region but released them after officials agreed to a temporary release of water (*Egypt Independent* 2012). Shortly after this, a series of public protests over shortages of drinking and irrigation water took place, extending across seven Egyptian governorates. Some of these protests were violent: in Beni Suef Governorate, one person was killed and many were injured during a conflict over irrigation water; in Minya, villagers clashed with officials over water shortages and water pollution; in Fayoum, hundreds of people protesting water shortages blocked a highway and set fires (Ooska News 2012).

In a transnational dispute involving Egypt, Ethiopia, and Sudan in September and October 2012, information was released about a possible secret agreement between Egypt and Sudan about an airfield that could be used to attack a major Ethiopian dam under construction. The dam, now known as the Grand Ethiopian Renaissance Dam (GERD), has also been called the Millennium Dam or the Hidase Dam. If built, GERD will be one of the largest dams in the world and the largest hydroelectric facility in Africa, located just upstream of the Ethiopian-Sudanese border on the Blue Nile. Egypt has expressed concerns about reductions in water flows reaching its citizens. The claim in 2012, strongly denied by Egypt, was that Egypt and Sudan had reached an agreement to permit Egypt to use Sudanese territories to launch attacks on GERD if diplomatic efforts failed to resolve water-sharing disputes between Egypt and Ethiopia. The allegations originated in an internal 2010 e-mail made available by WikiLeaks (*Sudan Tribune* 2012; Al Arabiya News 2012).

## Yemen

In September 2011, political violence in Yemen's capital, Sana'a, led to secondary impacts on access to water. Damage to infrastructure contributed to "acute water and power shortages, forcing residents to rely on power generators and buy water extracted from wells and sold on a thriving black market" (AP 2011). The violence arose during the Yemeni uprising that followed the Tunisian Revolution in early 2011 and coincided with mass protests in Egypt and other parts of the Middle East. During the violence, gov-

environmental soldiers shelled neighborhoods and destroyed many traditional rooftop water tanks, worsening the problem of water access.

## Israel and Palestine

Two separate incidents involving conflicts and violence over water were reported in 2011 in Israel and Palestine—a region with an especially long history of water disputes. In the first, Israel's military was reported to have destroyed nine water tanks in the Bedouin village of Amniyr in the South Hebron Hills in the West Bank, Palestine. Later, soldiers destroyed pumps and wells in the Jordan Valley villages of Al-Nasaryah, Al-Akrabanyah, and Beit Hassan (Abuwara 2011). In the second incident, Israeli settlers near Qasra, a West Bank village of 6,000, were reported to have destroyed crops—including olive trees—and a water well (Bsharat and Ramadan 2011).

## Syria

In a period (2011–2012) in which there were a large number of water-related conflicts, one particularly disturbing event occurred with a complicated but direct connection to water: the unraveling of Syria and the escalation of massive civil war there (see In Brief 2). Syria's political dissolution, like almost all conflicts, is the result of complex and inter-related factors, including an especially repressive and unresponsive political regime, the erosion of the economic health of the country, and a wave of political reform sweeping over the entire Middle East and North Africa region. But in hindsight, factors related to drought, agricultural failure, water shortages, and water mismanagement appear to have played an important role in nurturing “seeds of social unrest” as well; see the separate In Brief on this topic in this volume.

## Latin America

Violence over water was reported widely in Latin America in 2012. Incidents involved Brazil, Bolivia, Chile, Peru, and Guatemala. Three events were reported in Brazil in 2012: one associated with a controversy over control and management of indigenous lands, one during a dispute over dam construction, and violence associated with ongoing drought and water shortages. In the first instance, Brazil's federal police were investigating reports that water used by an indigenous tribe had been poisoned by nearby landowners who were attempting to gain control over disputed land. Since 2009, three men from this tribe had been reported killed in this dispute (AP 2012). In November 2012, work on the controversial \$13 billion Belo Monte Dam was halted after protesters burned buildings at three dam sites. Several local groups and environmentalists fear that the dam across the Xingu River, a tributary of the Amazon, will damage local communities and their way of life, but the conflict also has economic roots (Phys.org 2012). Northeastern Brazil also saw growing conflicts after severe drought reduced water availability. News agencies report that on average, one person a day was being killed as a result of “water wars” that involved locals fighting over scarce supplies (Catholic Online 2012).

There is a growing dispute over water from the Silala/Siloli River, which originates in Bolivia in the highlands of the Andes and flows to Chile. Bolivia recently linked an ongoing argument about access to the Pacific coast with the flows of water in a shared river:

the Silala/Siloli (*The Economist* 2012a). In Guatemala, human rights activists protesting the impacts of mining on local water quality and water rights were attacked. In June 2012, a local activist was shot, mirroring another incident in 2010 when an activist had been shot while protesting the impacts of mining on water quality and local water rights (Amnesty International 2012).

In Peru, several incidents involving protests, injuries, and deaths were reported in regions with opposition to large-scale mining operations because of concerns over water quality and water rights. In July 2012, four people were reported to have been killed in clashes between protestors and police over the proposed multibillion-dollar Minas Conga gold mine (Yeager 2012). Protests focused on pollution, concern about water supplies, and economic issues have significantly slowed, and temporarily completely halted, all work at the mine (Reuters 2012b). A similar protest over the Xstrata Tintaya copper mine in May 2012 led to two deaths and fifty injuries (Reuters 2012c).

## Central Asia

Central Asia, including the former Soviet republics, where almost all of the major rivers cross international borders, has been the scene of long-simmering tensions over water (Water Politics 2012). In this region, there are especially clear links between water and energy—a growing concern in other parts of the world as well. In 2012, a major dispute developed over water allocation and management among the Central Asian countries of Tajikistan, Kyrgyzstan, and Uzbekistan. Tensions among countries in the region have been growing for some time because of water scarcity, rivers that cross political borders, dam construction and management, and a lack of cooperative institutional agreements or institutions. In April 2012, Tajikistan protested that Uzbekistan had stopped deliveries of natural gas because of a disagreement over a hydropower dam. Uzbekistan cut gas deliveries needed by Tajikistan because of concerns over efforts to build a hydroelectric power station that Uzbekistan said would disrupt water supplies for its citizens. Gas flow was resumed after a new contract was signed (Kozhevnikov 2012).

This event was perceived to be part of a larger long-standing dispute over two major proposed hydropower dams in Kyrgyzstan and Tajikistan.<sup>2</sup> These dams would be the largest ever built in Central Asia and would potentially affect water deliveries and availability to the downstream nations of Uzbekistan, Turkmenistan, and Kazakhstan, all of which have expressed their concerns. By some estimates, the Rogun Dam would significantly reduce summer water availability and increase winter flows, depending on operations. There is concern that if the dams are built, economic and political tensions among the countries will escalate. Uzbekistan has the ability to cut off natural gas exports to both Kyrgyzstan and Tajikistan, and as noted above, it has actually done so. In September 2012, the leader of Uzbekistan, Islam Karimov, stated that the Rogun Dam could lead to “not just serious confrontation, but even wars” (*The Economist* 2012b). This regional dispute is further complicated by political relationships with Russia. Russia has strategic interests in the region and has supported Kyrgyzstan and Tajikistan in return for an agreement to host Russian military bases for several decades to come (Borisov 2012).

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2. The Kambarata-1 hydropower plant, proposed by Kyrgyzstan for the Naryn River, a tributary of the Syr Darya; and the Rogun Dam, proposed by Tajikistan for the Vakhsh River, a tributary of the Amu Darya.

## Other Regions in Africa

Several instances of violent clashes over access to water between pastoralists and farmers were reported in many parts of Africa in 2012. The worst cases occurred in Kenya, but additional conflicts were reported between communities in Mali and Burkina Faso, in Mali and Mauritania, in Kenya and Uganda, in Kenya and Somalia, and within Tanzania.

### *Somalia/Kenya*

In September 2012, Kenyan military officials reported that Al-Shabaab insurgent fighters had poisoned a water well and damaged water infrastructure for another well near the port city of Kismayu in an effort to counter the participation of Kenyan troops as part of the African Union Mission in Somalia (AMISOM) (Wabala 2012).

### *Kenya*

Extensive violence over water was reported in Kenya in 2012, with more than one hundred deaths in clashes between farmers and cattle herders over land and water (*New York Times* 2012). This conflict is part of a long-running dispute between the Pokomo people—mostly farmers near the Tana River—and the Orma, seminomadic cattle herders. In 2001, at least 130 people were killed in a string of clashes in the same district and between the same two communities over access to land and a river (Google News 2012a). There is some indication, however, that the current conflict is being exacerbated by Kenyan and foreign investment in vast tracts of land for food and biofuel cultivation, putting pressure on local resources (BBC 2012). Additional violence, including deaths, was reported in 2012 in disputes over access to water in the poorest slums around Nairobi (Njeru 2012).

### *Mali/Burkina Faso, Mali/Mauritania, Kenya/Uganda, Kenya/Somalia, and Tanzania*

The past few years have seen a series of increasingly violent clashes over access to water and land between nomadic herders, pastoralists, and settled villagers. In May 2012, a clash along the border between Dogon tribesmen from Mali and nomadic Fulani herders from Burkina Faso killed at least thirty people after the revocation of an earlier agreement to share water and pastureland (Xinhua News 2012b).

The conflict in Mali is also having repercussions in neighboring Mauritania, with protests and violence over water shortages reaching the capital, Nouakchott. By July 2012, over 70,000 Malian refugees were seeking asylum in Mauritania, putting added pressure on scarce food and water supplies. This led to protests in the capital over “the lack of water” (Taha 2012).

In August 2012, fighting between two clans in the Lower Jubba region of South Somalia killed at least three people and wounded five. Reports from the village of Waraq (near the border with Kenya) indicated that the dispute originated with a disagreement over the ownership of new water wells (Shabelle Media Network 2012).

Cross-border tensions are also growing between Uganda and Kenya after Kenyan Pokot herdsman crossed the border in search of water and pasture. Borders are often ignored in the region, where traditional pastoralists move herds to follow rains and grazing opportunities. In October 2012, the Ugandan government deployed more than 5,000 soldiers to the region in order to contain armed conflict among pastoralists from the two countries (Bii 2012).

Violence between farmers and pastoralists has also expanded in Tanzania's south-eastern Rufiji River valley, a region hit by drought. In May 2012, a farmer was killed in a conflict with a herdsman in a dispute over access to water in the southern regions of Lindi and Mtwara. Five more people died and many more were injured in subsequent violence. According to local sources, the violence has been worsened in the past five years by prolonged drought (Makoye 2012).

## South Africa

Protesters in Cape Town, South Africa, rioted over local failure to deliver adequate water and power to poor communities. Hundreds of protesters burned tires, destroyed cars, and threw rocks at police in August 2012 after continued disappointment and anger over the lack of basic services (Xinhua News 2012a).

## Asia-Pacific Region

Amnesty International reported in 2011 that women in the slums of the Solomon Islands are "continually harassed, attacked, and raped" when they are forced to walk long distances in unsafe areas in order to find clean water. A survey showed that 92 percent of households do not have a tap in their home and that local water sources are often polluted (Amnesty International 2011). Violence over access to a water source was reported in Maluku, Indonesia. Clashes in early 2012 led to several deaths and injuries (*Jakarta Globe* 2012).

## Conclusions

Water-related violence has a long history and continues to be a global and regional problem. The past several years have seen an increase in the total number of reports of violent conflict over water. Unlike the situation in the early and middle parts of the twentieth century, an increasing proportion of reported cases have to do with subnational disputes, terrorism, and local violence rather than transnational incidents. Many are small in scale, involving local violence over water allocations and use or violence over local development decisions that affect environmental and economic conditions at the community scale. But more and more of the reported cases have their roots in water scarcity and competition for a fixed resource that is reaching peak limits (Gleick and Palaniappan 2010).

Much has been written in recent years about the nature of water-related conflicts and the need for improved international cooperation. Far less attention has been given to what appears to be the more significant risk: subnational violence and competition. Some of this violence has been, and will remain, local. But some may spill over into the international arena: the ongoing civil war in Syria (at the time of this writing) is a critical example in which water shortages, mismanagement, drought, and subsequent economic and population dislocations appear to have contributed directly to the political unraveling of that country.

The data suggest that the challenges of water conflicts are growing, not shrinking, es-

pecially at the subnational scale. Far better mechanisms and far greater efforts are needed to address these kinds of conflicts.

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# Water Conflict Chronology

Peter H. Gleick and Matthew Heberger

The full Pacific Institute Water Conflict Chronology, updated for 2010–2012, appears below. A summary of recent events is provided in Water Brief 3 in this volume. As noted in volume 7 of *The World's Water*, a detailed, interactive online database now provides integrated Google Maps and filters to permit readers and researchers to view entries filtered by time period, location, and subject. It also includes a separate searchable bibliography.

The Water Conflict Chronology has appeared in every volume of *The World's Water* since 1998. It continues to be one of the most popular features of this report, and we continue to seek out and include additions sent by readers and researchers around the world. The chronology is increasingly being used by media and academics, and in 2013 it was cited by Fareed Zakaria (2013) of CNN.

The current categories or types of conflicts include the following:

*Military tool* (state actors): water resources, or water systems themselves, are used by a nation or state as a weapon during a military action.

*Military target* (state actors): water resources or water systems are targets of military actions by nations or states.

*Terrorism or domestic violence, including cyberterrorism* (nonstate actors): water resources or water systems are the targets or tools of violence or coercion by nonstate actors. A distinction is drawn between environmental terrorism and ecoterrorism (see Gleick 2006).

*Development disputes* (state and nonstate actors): water resources or water systems are a major source of contention and dispute in the context of economic and social development.

Please email any contributions with full citations and supporting information to [pgleick@pipeline.com](mailto:pgleick@pipeline.com).

## Water Conflict Chronology

### May 2013 Update

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| Date          | Parties Involved      | Basis of Conflict                | Violent or in Violent |        | Description   | Sources                  |
|---------------|-----------------------|----------------------------------|-----------------------|--------|---|--------------------------|
|               |                       |                                  | Context?              |        |   |                          |
| 3000 BC       | Ea, Noah              | Religious account                | No                    | Threat | Ancient Sumerian legend recounts the deeds of the deity Ea, who punished humanity for its sins by inflicting the earth with a six-day storm. The Sumerian myth parallels the biblical account of Noah and the deluge, although some details differ.   | Hatami and Gleick (1994) |
| 2500 BC       | Lagash, Umma          | Military tool                    | Yes                   |        | The dispute over the "Gu'edena" (edge of paradise) region begins. Urlama, King of Lagash from 2450 to 2400 BC, diverts water from this region to boundary canals, drying up boundary ditches to deprive Umma of water. His son Il cuts off the water supply to Girsu, a city in Umma.   | Hatami and Gleick (1994) |
| 1790 BC       | Hammurabi             | Development dispute              | No                    |        | The Code of Hammurabi for the State of Sumer lists several laws pertaining to irrigation that address negligence of irrigation systems and water theft.   | Hatami and Gleick (1994) |
| 1720-1684 BC  | Abi-Eshuh, Iluma-Ilum | Military tool                    | Yes                   |        | A grandson of Hammurabi, Abish or Abi-Eshuh, dams the Tigris to prevent the retreat of rebels led by Iluma-Ilum, who declared the independence of Babylon. This failed attempt marks the decline of the Sumerians, who had reached their apex under Hammurabi.  | Hatami and Gleick (1994) |
| circa 1300 BC | Sisera, Barak, God    | Religious account; Military tool | Yes                   |        | The Old Testament gives an account of the defeat of Sisera and his "nine hundred chariots of iron" by the unmounted army of Barak on the fabled Plains of Esdraelon. God sends heavy rainfall in the mountains, and the Kishon River overflows the plain and immobilizes or destroys Sisera's technologically superior forces ("... the earth trembled, and the heavens dropped, and the clouds also dropped water," Judges 5:4; "... The river of Kishon swept them away, that ancient river, the river Kishon," Judges 5:21). | Scofield (1967)          |
| 1200 BC       | Moses, Egypt          | Military tool; Religious account | Yes                   |        | When Moses and the retreating Jews find themselves trapped between the Pharaoh's army and the Red Sea, Moses miraculously parts the waters of the Red Sea, allowing his followers to escape. The waters close behind them and cut off the Egyptians.  | Hatami and Gleick (1994) |
| 720-705 BC    | Assyria, Armenia      | Military tool                    | Yes                   |        | After a successful campaign against the Halidians of Armenia, Sargon II of Assyria destroys their intricate irrigation network and floods their land.   | Hatami and Gleick (1994) |

|                |                                 |                                   |     |   |   |
|----------------|---------------------------------|-----------------------------------|-----|---|---|
| 705–682 BC     | Sennacherib, Babylon            | Military tool; Military target    | Yes | In quelling rebellious Assyrians in 695 BC, Sennacherib razes Babylon and diverts one of the principal irrigation canals so that its waters wash over the ruins.  | Hatami and Gleick (1994)                |
| 701 BC         | Israel (Judah), Assyria         | Military tool; Military maneuvers | Yes | When King Hezekiah of Judah sees that Sennacherib of Assyria is coming in war, he has springs and a brook outside Jerusalem stopped to keep water from the Assyrians. ("So there was gathered much people together, who stopped all the fountains, and the brook that ran through the midst of the land, saying, Why should the kings of Assyria come, and find much water?," 2 Chronicles 32:1–4).   | Scofield (1967)                         |
| 681–699 BC     | Assyria, Tyre                   | Military tool; Religious account  | Yes | Esarhaddon, an Assyrian, refers to an earlier period when gods, angered by insolent mortals, created destructive floods. According to inscriptions recorded during his reign, Esarhaddon besieges Tyre, cutting off food and water.   | Hatami and Gleick (1994)                |
| 669–626 BC     | Assyria, Arabia, Elam           | Military tool; Military target    | Yes | Assurbanipal's inscriptions also refer to a siege against Tyre, although scholars attribute it to Esarhaddon. In campaigns against both Arabia and Elam in 645 BC, Assurbanipal, son of Esarhaddon, dries up wells to deprive Elamite troops. He also guards wells from Arabian fugitives in an earlier Arabian war. On his return from victorious battle against Elam, Assurbanipal floods the city of Sapihel, an ally of Elam. According to inscriptions, he dams the Ulai River with the bodies of dead Elamite soldiers and deprives dead Elamite kings of their food and water offerings. | Hatami and Gleick (1994)                |
| 612 BC         | Egypt, Persia, Babylon, Assyria | Military tool                     | Yes | A coalition of Egyptian, Median (Persian), and Babylonian forces attacks and destroys Nineveh, the capital of Assyria. Nebuchadnezzar's father, Nebopolassar, leads the Babylonians. The converging armies divert the Khosr River to create a flood, which allows them to elevate their siege engines on rafts.   | Hatami and Gleick (1994)                |
| 605–562 BC     | Babylon                         | Military tool                     | No  | Nebuchadnezzar builds immense walls around Babylon, using the Euphrates and canals as defensive moats surrounding the inner castle.   | Hatami and Gleick (1994); Drower (1954) |
| 6th century BC | Assyria                         | Military target; Military tool    | Yes | Assyrians poison the wells of their enemies with rye ergot.   | Eitzen and Takafuji (1997)              |
| 590–600 BC     | Cirrhra, Delphi                 | Military tool                     | Yes | Athenian legislator Solon reportedly has roots of <i>Helleborus</i> thrown into a small river or aqueduct leading from the Pleistrus River to Cirrha during a siege of this city. The enemy forces become violently ill and are defeated as a result. Some accounts have Solon building a dam across the Plesitus River, cutting off the city's water supply. Such practices were widespread.   | Absolute Astronomy (2006)               |

## Water Conflict Chronology *continued*

| Date       | Parties Involved  | Basis of Conflict | Violent Conflict or in the Context of Violence? |    | Description   | Sources                     |
|------------|-------------------|-------------------|---|----|---|-----------------------------|
|            |                   |                   | Yes   | No |   |                             |
| 558–528 BC | Babylon           | Military tool     | Yes   |    | On his way from Sardis to defeat Nabonidus at Babylon, Cyrus faces a powerful tributary of the Tigris, probably the Diyalah. According to Herodotus's account, the river drowns his royal white horse and presents a formidable obstacle to his march. Cyrus, angered by the "insolence" of the river, halts his army and orders them to cut 360 canals to divert the river's flow. Other historians argue that Cyrus needed the water to maintain his troops on their southward journey, while another asserts that the construction was an attempt to win the confidence of the locals. | Hatami and Gleick (1994)    |
| 539 BC     | Babylon           | Military tool     | Yes   |    | According to Herodotus, Cyrus invades Babylon by diverting the Euphrates above the city and marching troops along the dry riverbed. This popular account describes a midnight attack that coincided with a Babylonian feast.  | Hatami and Gleick (1994)    |
| 430 BC     | Athens            | Military tool     | Yes   |    | During the second year of the Peloponnesian War, a plague breaks out in Athens. The Spartans are accused of poisoning the cisterns of the Piraeus, the source of most of Athens's water.  | Strategy Page (2006)        |
| 355–323 BC | Babylon           | Military tool     | Yes   |    | Returning from the razing of Persepolis, Alexander proceeds to India. After the Indian campaigns, he heads back to Babylon via the Persian Gulf and the Tigris, where he tears down defensive weirs that the Persians had constructed along the river. Arrian describes Alexander's disdain for the Persians' attempt to block navigation, which he saw as "unbecoming to men who are victorious in battle."  | Hatami and Gleick (1994)    |
| 210–209 BC | Rome and Carthage | Military tool     | Yes   |    | In 210 BC, Scipio crosses the Ebro to attack New Carthage. During a short siege, Scipio leads a breaching column through a supposedly impregnable lagoon located on the landward side of the city; a strong northerly wind combined with the natural ebb of the tide leaves the lagoon shallow enough for the Roman infantry to wade through. New Carthage is quickly taken.  | Fonner (1996); Gowan (2004) |
| 52 BC      | Rome, Gaul        | Military tool     | Yes   |    | Caesar constructs water-filled ditches as a blockade during the Siege of Alesia in Gaul, site of modern-day Alise-Sainte-Reine in Côte d'Or, near Dijon, France.  | <i>Wikipedia</i> (2011a)    |



|           |                                     |                                |               |   |   |
|-----------|-------------------------------------|--------------------------------|---------------|---|---|
| 51 BC     | Rome, Gaul                          | Military target                | Yes           | Caesar attacks water supplies during the siege of Uxellodunum by undermining one of the local springs and placing attackers near the other. Shortage of water leads to the surrender of the Gauls.  | History of War Online (2011)  |
| 49 BC     | France, Rome                        | Military tool                  | Yes           | During the first year of the Great Roman Civil War, Julius Caesar's troops lay siege to the walled city of Massilia (modern-day Marseille) using siege towers and battering rams and by digging "mines" or tunnels to undermine the city walls. Massilians defend their city with "dogged determination"; tactics include directing water through pipes to wash down on attackers, which the Romans counter by covering siege buildings with bricks and "several coatings of stucco." Defenders also excavate a large basin inside the walls, filling it with water. As the Roman miners reach the walls, the tunnels are flooded with water and collapse. Massilia ultimately surrenders after a five-month siege. | Illustrated History of the Roman Empire (2011); Caesar (1906); <i>Wikipedia</i> (2013a) |
| AD 30     | Roman Empire (Pontius Pilate), Jews | Development dispute            | Yes           | Roman Procurator Pontius Pilate uses sacred money to divert a stream to Jerusalem. The Jews are angered by the diversion, and tens of thousands gather to protest. Pilate's soldiers mingle among the crowd and, with daggers hidden in their garments, attack the protesters. "A great number" are slain and wounded and the "sedition" is ended.  | Josephus (AD 90)  |
| 537       | Goths and Rome                      | Military tool; Military target | Yes           | In the sixth century AD, as the Roman Empire begins to decline, the Goths besiege Rome and cut almost all of the aqueducts leading into the city. In AD 537, this siege succeeds. The only aqueduct that continues to function is the Aqua Virgo, which runs almost entirely underground.   | Rome Guide (2004); InfoRoma (2004)  |
| 1187      | Saladin and the Crusaders           | Military tool                  | Yes           | Saladin is able to defeat the Crusaders at the Horns of Hattin in 1187 by denying them access to water. In some reports, Saladin fills all the wells along the way with sand and destroys the villages of the Maronite Christians, who would supply the Christian army with water.  | Lockwood (2006); Priscoli (1998)  |
| 1503      | Florence and Pisa                   | Military tool                  | No: Plan only | Leonardo da Vinci and Machiavelli plan to divert the Arno River away from Pisa during a conflict between Pisa and Florence.   | Honan (1996)  |
| 1573–1574 | Holland and Spain                   | Military tool                  | Yes           | In 1573, at the beginning of the Eighty Years' War against Spain, the Dutch flood the land to break the siege of Spanish troops on the town Alkmaar. The same defense is used to protect Leiden in 1574. This strategy becomes known as the Dutch Water Line and is used frequently for defense in later years.   | Dutch Water Line (2002)   |

## Water Conflict Chronology *continued*

| Date      | Parties Involved      | Basis of Conflict                  | Violent Conflict or in the Context of Violence? |           | Description  | Sources                              |
|-----------|-----------------------|------------------------------------|---|-----------|--|--------------------------------------|
|           |                       |                                    | Development                                     | Violence? |  |                                      |
| 1626–1629 | Spain, Dutch Republic | Development dispute; Military tool | No  |           | The Spanish Habsburgs attempt to prevent ship traffic on the River Rhine from reaching the Dutch Republic in order to damage the Dutch economy. Plans are also made to divert water from the Rhine to lands under Spanish control, to dry up downstream cities in Holland. The first stage is a canal between the Rhine and Meuse Rivers, between the cities of Rheinberg and Venlo. Plans for a later stage call for a connection between the Meuse and the Scheldt to circumvent the Scheldt Estuary, controlled by the Dutch. Although some 60 kilometers of canal are constructed, the plan fails because of changed military conditions and lack of funding. Parts of the canal are still visible in present-day Germany. | Israel (1997); Bachiene (1791)       |
| 1642      | China; Ming Dynasty   | Military tool                      | Yes   |           | The Huang He's dikes are breached for military purposes. In 1642, "toward the end of the Ming dynasty (1368–1644), General Gao Mingheng used the tactic near Kaifeng in an attempt to suppress a peasant uprising."  | Hillel (1991)                        |
| 1672      | French, Dutch         | Military tool                      | Yes   |           | Louis XIV starts the third of the Dutch Wars in 1672, in which the French overrun the Netherlands. In defense, the Dutch open their dikes and flood the country, creating a watery barrier that is virtually impenetrable.   | <i>Columbia Encyclopedia</i> (2000a) |
| 1748      | United States         | Development dispute; Terrorism     | Yes   |           | Ferry house on Brooklyn shore of East River burns down. New Yorkers accuse Brooklymites of having set the fire as revenge for unfair East River water rights.  | MCNY (n.d.)                          |
| 1777      | United States         | Military tool                      | Yes   |           | British and Hessians attack the water system of New York. "The enemy wantonly destroyed the New York water works" during the War for Independence.   | Thatcher (1827)                      |
| 1804      | France, Holland       | Development dispute; Military tool | No  |           | Napoleon orders the construction of a canal between Neuss and Venlo to connect the Rhine and Meuse Rivers, in order to divert trade from the Batavia Republic to the Southern Netherlands, then under French control. Three-quarters of the canal is completed, but work stops because of lack of funds.   | Israel (1997)                        |
| 1841      | Canada                | Development dispute; Terrorism     | Yes   |           | A reservoir in Ops Township, Upper Canada (now Ontario), is destroyed by neighbors who consider it a hazard to health.   | Forkey (1998)                        |

|            |  |                                |     |   |                              |
|------------|--|--------------------------------|-----|---|------------------------------|
| 1844       | United States                              | Development dispute; Terrorism | Yes | A reservoir in Mercer County, Ohio, is destroyed by a mob that considers it a health hazard.  | Scheiber (1969)              |
| 1850s      | United States                              | Development dispute; Terrorism | Yes | A New Hampshire dam that had impounded water for factories downstream is attacked by local residents unhappy about its effect on water levels.  | Steinberg (1990)             |
| 1853–1861  | United States                              | Development dispute; Terrorism | Yes | The banks and reservoirs of the Wabash and Erie Canal in southern Indiana are repeatedly destroyed by mobs regarding it as a health hazard.   | Fatout (1972); Fickle (1983) |
| 1860–1865  | United States                              | Military tool; Military target | Yes | General William T. Sherman's memoirs contain an account of Confederate soldiers poisoning ponds by dumping the carcasses of dead animals into them. Other accounts suggest this tactic was used by both sides.  | Eitzen and Takafuji (1997)   |
| 1862       | United States Union and Confederate armies | Military tool                  | Yes | During the US Civil War, Confederate forces near Yorktown use dams to flood the Warwick River and cut off Union troops. "The enemy is pushed behind a . . . branch of the Warwick river in which they control the depths of water by dams. McClellan did not intend to pass that stream at that time, or at that point where the skirmish took place. But the troops, finding the stream fordable went over (under whose immediate orders does not appear) and the water was then deepened so that they were measurably cut off." | Hitchcock (1862)             |
| 1863       | United States                              | Military tool                  | Yes | General Ulysses S. Grant, during the Civil War campaign against Vicksburg, cuts levees in the battle against the Confederates.  | Grant (1885); Barry (1997)   |
| 1870s      | China                                      | Development dispute            | No  | An unauthorized dam in Hubei, China, is constructed by locals and removed by government (twice).  | Rowe (1988)                  |
| 1870s–1881 | United States                              | Development dispute            | Yes | Recurrent friction and eventual violent conflict over water rights in the vicinity of Tularosa, New Mexico, involves villagers, ranchers, and farmers.  | Rasch (1968)                 |
| 1887       | United States                              | Development dispute; Terrorism | Yes | A canal reservoir in Paulding County, Ohio, is dynamited by a mob regarding it as a health hazard. State militia are called out to restore order.   | Walters (1948)               |
| 1890       | Canada                                     | Development dispute; Terrorism | Yes | A partly successful attempt is made to destroy a lock on the Welland Canal in Ontario, Canada, either by Fenians protesting English policy in Ireland or by agents of Buffalo, New York, grain handlers unhappy about the diversion of trade through the canal.   | Styran and Taylor (2001)     |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved                                     | Basis of Conflict              | Violent Conflict or in the Context of Violence? |           | Description  | Sources             |
|-----------|--|--------------------------------|---|-----------|--|---------------------|
|           |  |                                |   |           |  |                     |
| 1898      | Egypt, France, Britain                               | Military tool; Political tool  | Military  |           | Military conflict nearly ensues between Britain and France when a French expedition attempts to gain control of the headwaters of the White Nile. While the parties ultimately negotiate a settlement of the dispute, the incident has been characterized as having “dramatized Egypt’s vulnerable dependence on the Nile, and fixed the attitude of Egyptian policy-makers ever since.” | Moorehead (1960)    |
| 1907–1913 | Owens Valley, Los Angeles, California                | Terrorism; Development dispute | Yes   |           | The Los Angeles Valley aqueduct/pipeline suffers repeated bombings in an effort to prevent diversions of water from the Owens Valley to Los Angeles.   | Reisner 1993        |
| 1908–1909 | United States  | Development dispute            | Yes   |           | Violence, including a murder, is directed against agents of a land company that had claimed title to Reelfoot Lake in northwestern Tennessee; the agents had attempted to levy charges for fish taken and threatened to drain the lake for agriculture.  | Vanderwood (1969)   |
| 1915      | German Southwest Africa                              | Military tool                  | Yes   |           | Union of South African troops capture Windhoek, capital of German Southwest Africa, in May. Retreating German troops poison wells—“a violation of the Hague convention.”   | Daniel (1995)       |
| 1935      | California, Arizona                                  | Development dispute            | Military  | maneuvers | Arizona calls out the National Guard and militia units to its border with California to protest the construction of Parker Dam and diversions from the Colorado River; the dispute ultimately is settled in court. The militia mount machine guns on commandeered ferries and patrol the river, earning the nickname the “Arizona Navy.”   | Reisner (1986/1993) |
| 1937      | Republican government of Spain, Spanish Nationalists | Military target                | Yes   |           | During the Spanish Civil War, two concrete gravity dams, at Burguillo and Ordunte, are attacked by the Nationalist army, with a two-and-one-half-ton charge placed in an inspection gallery at Ordunte. There is some limited damage, which is repaired in 1938–1939.  | Pagan (2005)        |

|           |                          |                                   |     |  |  |
|-----------|--------------------------|-----------------------------------|-----|--|--|
| 1938      | China and Japan          | Military tool;<br>Military target | Yes | Chiang Kai-shek orders the destruction of flood control dikes of the Huayuankou section of the Huang He (Yellow) River, in order to flood areas threatened by the Japanese army. West of Kaifeng, dikes are destroyed with dynamite, spilling water across the flat plain. Even though the flood destroys part of the invading army and mires its equipment in mud, Wuhan, headquarters of the Nationalist government, is taken by the Japanese in October. Floodwaters cover an area variously estimated as between 3,000 and 50,000 square kilometers, killing Chinese estimated in numbers between “tens of thousands” and “one million.” | Hillel (1991);<br>Yang Lang<br>(1989/1994)   |
| 1939–1940 | Netherlands,<br>Germany  | Military tool                     | Yes | During the mobilization of the Dutch at the beginning of World War II, 1939–1940, the Dutch attempt to flood the Gelderse Vallei with the New Dutch Water Defence Line, which had been completed in 1885. During the German invasion in May 1940, large areas are inundated.   | IDG (1996)   |
| 1939–1942 | Japan, China             | Military target;<br>Military tool | Yes | Japanese chemical and biological weapons activities reportedly include tests by “Unit 731” against military and civilian targets in which water wells and reservoirs are laced with typhoid and other pathogens.   | Harris (1994)  |
| 1940      | Finland, Soviet Union    | Military tool                     | Yes | Partisan Finns manipulate the waters of the Saimaan Canal (Finland) in order to flood surrounding land and hinder Soviet troop movements during the Soviet-Finnish conflict.   | Malik (2005)   |
| 1940–1945 | Multiple parties         | Military target                   | Yes | Hydroelectric dams are routinely bombed as strategic targets during World War II.  | Gleick (1993)  |
| 1941      | USSR and Germany         | Military target                   | Yes | The strategically important Dnieper hydropower plant in the Ukraine is targeted by both Soviet and German troops during World War II. On August 18, 1941, the dam and power plant are dynamited by Soviet troops retreating before advancing German forces. The facility is bombed again in 1943 by retreating German troops.  | Pagan (2005);<br><i>New York Times</i><br>(1941); Makarov<br>(2005); AHF<br>(2004) |
| 1941      | Germany,<br>Soviet Union | Military tool                     | Yes | In November, Soviet troops flood the area south of the Istra Reservoir near Moscow in an effort to slow the German advance. Just a few weeks later, German troops used the same tactic to create a water barrier to halt advances by the Soviet 16th Army.   | Malik (2005)   |
| 1941–1943 | Germany,<br>USSR         | Military target                   | Yes | World War II inflicts enormous harm to hydroelectric systems in the Soviet Union. Over two-thirds of the hydroelectric power stations are lost.  | Malik (2005)   |

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## Water Conflict Chronology *continued*

| Date | Parties Involved                       | Basis of Conflict | Violent Conflict or in the Context of Violence? |    | Description  | Sources                         |
|------|--|-------------------|---|----|--|---------------------------------|
|      |  |                   | Yes   | No |  |                                 |
| 1943 | Britain, Germany                       | Military target   | Yes   |    | The British Royal Air Force bombs dams on the Möhne, Sorpe, and Eder Rivers in Germany (May 16 and 17). A Möhne Dam breach kills 1,200 and destroys all downstream dams for fifty kilometers. The flood that occurs after the breaching of the Eder Dam reaches a peak discharge of 8,500 cubic meters per second, nine times higher than the highest flood observed. Many houses and bridges are destroyed, and sixty-eight are killed.   | Kirschner (1949); Semann (1950) |
| 1944 | Germany, Italy, Britain, United States | Military tool     | Yes   |    | German forces use waters from the Isoletta Dam (Liri River) in January and February to successfully destroy British assault forces crossing the Garigliano River (downstream of the Liri River). The German army then dams the Rapido River, flooding a valley occupied by the American army.  | US ACE (1953)                   |
| 1944 | Germany, Italy, Britain, United States | Military tool     | Yes   |    | The German army floods the Pontine Marshes, on the coast of Italy southeast of Rome, by stopping pumps and opening dikes, in order to disrupt Allied forces who had established a beachhead at Anzio. Allied forces are surrounded by German artillery and pinned down for months by heavy shelling. The purpose of the flooding is to bring mosquitoes and malaria, "deliberately introduced as an act of biological warfare." This has a limited military impact but devastates the local population, which the Third Reich wished to punish for disloyalty. | US ACE (1953); Evans (2008)     |
| 1944 | Germany, Allied forces                 | Military tool     | Yes   |    | Germans flood the Ay River in France in July, creating a lake two meters deep and several kilometers wide, slowing an advance on Saint Lô, a German communications center in Normandy.   | US ACE (1953)                   |
| 1944 | Germany, Allied forces                 | Military tool     | Yes   |    | Germans flood the Ill River Valley during the Battle of the Bulge (winter 1944–1945), creating a lake sixteen kilometers long, three to six kilometers wide, and one to two meters deep, greatly delaying the American army's advance toward the Rhine.  | US ACE (1953)                   |
| 1944 | United States, Japan                   | Military target   | Yes   |    | The US bombardment of a Japanese-occupied island in June targets water supply points, resulting in severe shortages.   | Stewart (n.d.)                  |
| 1944 | Finland, USSR                          | Military target   | Yes   |    | In June, the Soviet air force attacks the Svir River Dam, near Leningrad, then under the control of the Finnish military.  | Orlenko (1981); AHF (2004)      |



|             |                              |                                    |     |  |  |
|-------------|------------------------------|------------------------------------|-----|--|--|
| 1945        | Romania, Germany             | Military target                    | Yes | In one of the few verified German tactical uses of biological warfare, German forces pollute a large reservoir in northwestern Bohemia, Czechoslovakia, with sewage. See also the entry for the Pontine Marshes in 1944.   | SIPRI (1971)   |
| 1947 onward | Bangladesh, India            | Development dispute                | No  | A partition divides the Ganges River between Bangladesh and India; construction of the Farakka barrage by India, beginning in 1962, increases tension; short-term agreements settle disputes in 1977–1982, 1982–1984, and 1985–1988; and a thirty-year treaty is signed in 1996.   | Butts (1997); Samson and Charrier (1997)                             |
| 1947–1960s  | India, Pakistan              | Development dispute                | No  | A partition leaves the Indus River basin divided between India and Pakistan; disputes over irrigation water ensue, during which India stems the flow of water into irrigation canals in Pakistan. The Indus Waters Agreement is reached in 1960, after twelve years of World Bank–led negotiations.  | Bingham et al. (1994)  |
| 1948        | Arabs, Israelis              | Military tool                      | Yes | Arab forces cut off West Jerusalem's water supply in the first Arab–Israeli war.   | Wolf (1995); Wolf (1997)   |
| 1948        | Arabs, Israelis              | Military tool                      | Yes | Water and food supplies are cut off during an Arab siege of Jerusalem from December 1, 1947, to July 10, 1948. Arab forces block the road to Jerusalem in an attempt to defeat Jewish Jerusalem. Shortages cause Israelis to begin rationing water on May 12, limiting each person to two gallons (eight liters) per day, of which four pints (two liters) are for drinking. | Collins and LaPierre (1972); Joseph (1960); <i>Wikipedia</i> (2011b) |
| 1950s       | Korea, United States, others | Military target                    | Yes | Centralized dams on the Yalu (Amnok) River serving North Korea and China are attacked during the Korean War.   | Gleck (1993)   |
| 1951        | Korea, United Nations        | Military tool; Military target     | Yes | North Korea releases flood waves from the Hwachon Dam, damaging floating bridges operated by UN troops in the Pukhan Valley. The US Navy then sends planes to destroy the spillway crest gates.  | US ACE (1953)  |
| 1951        | Israel, Jordan, Syria        | Military tool; Development dispute | Yes | Jordan makes public its plans to irrigate the Jordan Valley by tapping the Yarmouk River. Israel responds by commencing drainage of the Huleh swamps, located in the demilitarized zone between Israel and Syria; border skirmishes ensue between Israel and Syria.  | Wolf (1997); Samson and Charrier (1997)                              |
| 1951        | United States, Korea         | Military target                    | Yes | The Hwachon Dam in Korea, completed in 1944, becomes both a target and a tool of opposing forces during the Korean War. In 1951, North Korea opens the dam to flood downstream areas and slow advancing UN forces. In response, the US Navy sends aircraft to bomb the dam, in the last known American use of aerial torpedoes in war.                                       | Calcagno (2004)  |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved             | Basis of Conflict                    | Violent Conflict or in the Context of Violence? |    | Description   | Sources  |
|-----------|------------------------------|--------------------------------------|---|----|---|--|
|           |                              |                                      | Yes   | No |   |  |
| 1953      | Israel, Jordan, Syria        | Development dispute; Military target | Yes   |    | Israel begins construction of its National Water Carrier to transfer water from the north of the Sea of Galilee out of the Jordan River basin to the Negev Desert for irrigation. Syrian military actions along the border and international disapproval lead Israel to move its intake to the Sea of Galilee.  | Naff and Matson (1984); Samson and Charrier (1997) |
| 1958      | Egypt, Sudan                 | Military tool; Development dispute   | Yes   |    | Egypt sends an unsuccessful military expedition into disputed territory amid pending negotiations over Nile waters, Sudanese general elections, and an Egyptian vote on Sudan-Egypt unification; the Nile Water Treaty is signed when a pro-Egyptian government is elected in Sudan.  | Wolf (1997)  |
| 1960s     | North Vietnam, United States | Military target                      | Yes   |    | Irrigation water supply systems in North Vietnam are bombed during the Vietnam War. An estimated 661 sections of dikes are damaged or destroyed.  | IWCT (1967); Gleick (1993); Zemmali (1995)         |
| 1962      | Israel, Syria                | Development dispute; Military target | Yes   |    | Israel destroys irrigation ditches in the lower Tarfiq in the demilitarized zone. Syria complains.  | Naff and Matson (1984)                             |
| 1962–1967 | Brazil, Paraguay             | Military tool; Development dispute   | Military maneuvers                              |    | Negotiations between Brazil and Paraguay over development of the Paraná River are interrupted in 1962 by a unilateral show of military force by Brazil, which invades the area and claims control over the Guaira Falls site. Military forces are withdrawn in 1967 following an agreement for a joint commission to examine development in the region. | Murphy and Sabadell (1986)                         |
| 1963–1964 | Ethiopia, Somalia            | Development dispute; Military tool   | Yes   |    | Creation of boundaries in 1948 leaves Somali nomads under Ethiopian rule; border skirmishes occur over disputed territory in the Ogaden Desert, where critical water and oil resources are located. A cease-fire is negotiated only after several hundred are killed.   | Wolf (1997)  |
| 1964      | Cuba, United States          | Military tool                        | No  |    | On February 6, the Cuban government cuts off the normal water supply to the US Naval Base at Guantanamo Bay in retaliation for the US seizure of four Cuban fishing boats days earlier near Florida.  | <i>Guantanamo Bay Gazette</i> (1964)               |
| 1964      | Israel, Syria                | Military target                      | Yes   |    | Headwaters of the Dan River on the Jordan River are bombed at Tell El-Qadi in a dispute about sovereignty over the source of the Dan.   | Naff and Matson (1984)                             |

|           |                                 |                                    |            |  |   |
|-----------|---------------------------------|------------------------------------|------------|--|---|
| 1965      | Zambia, Rhodesia, Great Britain | Military target                    | No         | President Kenneth Kaunda calls on the British government to send troops to Kariba Dam to protect it from possible saboteurs from the Rhodesian government.   | Chenje (2001)   |
| 1965      | Israel, Palestinians            | Terrorism                          | Yes        | The first attack ever by the Palestinian National Liberation Movement Al-Fatah is made on the diversion pumps for the Israeli National Water Carrier. The attack fails.  | Naff and Matson (1984); Dolatyar (1995)                               |
| 1965–1966 | Israel, Syria                   | Military tool; Development dispute | Yes        | Fire is exchanged over an “all-Arab” plan to divert the Jordan River headwaters (Hasbani and Banias) and presumably preempt the Israeli National Water Carrier; Syria halts construction of its diversion in July 1966.  | Wolf (1995); Wolf (1997)  |
| 1967      | Israel, Syria                   | Military target; Military tool     | Yes        | Israel destroys the Arab diversion works on the Jordan River headwaters. During the Arab-Israeli War, Israel occupies Golan Heights, with the Banias tributary to the Jordan; Israel occupies the West Bank.   | Gleick (1993); Wolf (1995); Wolf (1997); Wallenstein and Swain (1997) |
| 1967–1972 | Vietnam, United States          | Military tool                      | Yes        | The US military, in “Operation Popeye,” uses silver iodide for cloud seeding over Indochina (Vietnam) in an attempt to extend the monsoon season and stop the flow of materiel along Ho Chi Minh Trail. “Continuous rainfall was intended to slow down the truck traffic and was relatively successful.”                       | Plant (1995); Troung and Cooper (2003)                                |
| 1969      | Israel, Jordan                  | Military target; Military tool     | Yes        | Israel, suspicious that Jordan is overdiverting the Yarmouk, leads two raids to destroy the newly built East Ghor Canal. Secret negotiations, mediated by the United States, lead to an agreement in 1970.   | Samson and Charrier (1997)  |
| 1970      | United States                   | Terrorism                          | No: Threat | The Weathermen, a group opposed to American imperialism and the Vietnam War, allegedly attempt to obtain biological agents to contaminate the water supply systems of US urban centers.  | Kupperman and Trent (1979); Eitzen and Takafuji (1997); Purver (1995) |
| 1970      | Chinese citizens                | Development dispute                | Yes        | Conflicts over excessive water withdrawals from, and subsequent water shortages in, China’s Zhang River had been worsening for over three decades between villages in Shenxian and Linzhou counties. In the 1970s, militias from competing villages fight over withdrawals. (See also entries for 1976, 1991, 1992, and 1999.) | <i>China Water Resources Daily</i> (2002)                             |

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## Water Conflict Chronology *continued*

| Date  | Parties Involved            | Basis of Conflict                                   | Violent Conflict or in the Context of Violence? |  | Description   | Sources  |
|-------|-----------------------------|---|---|--|---|--|
|       |                             |   |   |  |   |  |
| 1970s | Argentina, Brazil, Paraguay | Development dispute                                 | No  |  | Brazil and Paraguay announce plans to construct a dam at Itaipu on the Paraná River, causing concern in Argentina about downstream environmental repercussions and the efficacy of Argentina's own planned dam project downstream. Argentina demands to be consulted during the planning of Itaipu, but Brazil refuses. An agreement is reached in 1979 that provides for the construction of both Brazil's and Paraguay's dams at Itaipu and Argentina's Yacyreta Dam. | Wallenstein and Swain (1997)                         |
| 1972  | United States               | Terrorism   | No: Threat                                      |  | Two members of the right-wing "Order of the Rising Sun" are arrested in Chicago with thirty to forty kilograms of typhoid cultures, with which they allegedly planned to poison the water supply in Chicago, St. Louis, and other cities. Experts say the plan would have been unlikely to cause health problems, given that the water is chlorinated.  | Eitzen and Takafuji (1997)                           |
| 1972  | United States               | Terrorism   | No: Threat                                      |  | There is a reported threat to contaminate the water supply of New York City with nerve gas.   | Purver (1995)  |
| 1972  | North Vietnam               | Military target                                     | Yes   |  | The United States bombs dikes in the Red River delta, rivers, and canals during a massive bombing campaign.   | <i>Columbia Encyclopedia</i> (2000b)                 |
| 1973  | Germany                     | Terrorism   | No: Threat                                      |  | A German biologist threatens to contaminate water supplies with anthrax bacilli and botulinum toxin unless he is paid \$8.5 million.  | Jenkins and Rubin (1978); Kupperman and Trent (1979) |
| 1974  | Iraq, Syria                 | Military target; Military tool; Development dispute | Military maneuvers                              |  | Iraq threatens to bomb the al-Thawra (Tabaqaq) Dam in Syria and masses troops along the border, alleging that the dam has reduced the flow of Euphrates River water to Iraq.  | Gleick (1994)  |

|             |  |   |                    |   |   |
|-------------|--|---|--------------------|---|---|
| 1975        | Iraq, Syria                                  | Development dispute; Military tool              | Military maneuvers | As upstream dams are filled during a low-flow year on the Euphrates, Iraqis claim that flow reaching its territory is "intolerable" and ask the Arab League to intervene. Syrians claim they are receiving less than half the river's normal flow and pull out of an Arab League technical committee formed to mediate the conflict. In May, Syria closes its airspace to Iraqi flights and both Syria and Iraq reportedly transfer troops to their mutual border. Saudi Arabia successfully mediates the conflict. | Gleick (1993); Gleick (1994); Wolf (1997) |
| 1975        | Angola, South Africa                         | Military goal; Military target                  | Yes                | South African troops move into Angola to occupy and defend the Ruacana hydropower complex, including the Gové Dam on the Kunene River. The goal is to take possession of and defend the water resources of southwestern Africa and Namibia.   | Meissner (2000)                           |
| 1976        | China  | Development dispute                             | Yes                | A local militia chief is shot to death in a clash over the damming of the Zhang River. Conflicts over excessive water withdrawals and subsequent water shortages from China's Zhang River had been worsening for over three decades. (See also entries for 1970, 1991, 1992, 1999.)   | <i>China Water Resources Daily</i> (2002) |
| 1977        | United States                                | Terrorism                                       | Yes                | A North Carolina reservoir is contaminated with unknown materials. According to Clark, "Safety caps and valves were removed, and poison chemicals were sent into the reservoir. . . . Water had to be brought in."  | Clark (1980); Purver (1995)               |
| 1978 onward | Egypt, Ethiopia                              | Development dispute; Political tool             | No                 | There are long-standing tensions over the Nile, especially the Blue Nile, originating in Ethiopia. Ethiopia's proposed construction of dams on the headwaters of the Blue Nile leads Egypt to repeatedly declare the vital importance of water. "The only matter that could take Egypt to war again is water" (Anwar Sadat, 1979). "The next war in our region will be over the waters of the Nile, not politics" (Boutros Boutros-Ghali, 1988).  | Gleick (1991); Gleick (1994)              |
| 1978–1984   | Sudan  | Development dispute; Military target; Terrorism | Yes                | Demonstrations in Juba, Sudan, in 1978 opposing the construction of the Jonglei Canal lead to the deaths of two students. Construction of the canal is suspended in 1984 following a series of attacks on the construction site.  | Suliman (1998); Keluel-Jang (1997)        |
| 1980s       | Mozambique, Rhodesia/ Zimbabwe, South Africa | Military target; Terrorism                      | Yes                | Power lines from Cahora Bassa Dam are repeatedly destroyed during a fight for independence in the region. The dam is targeted by RENAMO (the Mozambican National Resistance).   | Chenje (2001)                             |
| 1980–1988   | Iran, Iraq                                   | Military tool                                   | Yes                | Iran diverts water to flood Iraqi defense positions.  | Plant (1995)                              |
| 1981        | Iran, Iraq                                   | Military target; Military tool                  | Yes                | Iran claims to have bombed a hydroelectric facility in Kurdistan, thereby blacking out large portions of Iraq, during the Iran-Iraq War.  | Gleick (1993)                             |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved       | Basis of Conflict                 | Violent Conflict or in the Context of Violence? |        | Description  | Sources                                       |
|-----------|------------------------|-----------------------------------|---|--------|--|---|
|           |                        |                                   | Yes   | No     |  |   |
| 1981–1982 | Angola, Namibia        | Military target;<br>Military tool | Yes   |        | Water infrastructure, including dams and the major Cunene-Cuvvelai pipeline, is targeted during the conflicts in Namibia and Angola in the 1980s.  | Turton (2005)                                 |
| 1982      | United States          | Terrorism                         | No  | Threat | Los Angeles police and the FBI arrest a man who is preparing to poison the city's water supply with a biological agent.  | Livingston (1982); Eitzen and Takafuji (1997) |
| 1982      | Israel, Lebanon, Syria | Military tool                     | Yes   |        | Israel cuts off the water supply to Beirut during a siege.   | Wolf (1997)                                   |
| 1982      | Guatemala              | Development dispute               | Yes   |        | In Río Negro, 177 civilians are killed over opposition to the Chixoy hydroelectric dam.  | Levy (2000)                                   |
| 1983      | Lebanon                | Terrorism                         | Yes   |        | An explosives-laden truck disguised as a water delivery vehicle destroys a barracks in a US military compound, killing more than 300 people. The attack is blamed on Hezbollah, with the support of the Iranian government.  | BBC (2007)                                    |
| 1983      | Israel                 | Terrorism                         | No  |        | The Israeli government reports that it has uncovered a plot by Israeli Arabs to poison the water in Galilee with “an unidentified powder.”   | Douglass and Livingstone (1987)               |
| 1984      | United States          | Terrorism                         | Yes   |        | Members of the Rajneeshee religious cult contaminate a city water supply tank in The Dalles, Oregon, using salmonella bacteria. A community outbreak of over 750 cases occurs in a county that normally reports fewer than 5 cases per year.   | Clark and Deininger (2000)                    |
| 1985      | United States          | Terrorism                         | No  |        | Law enforcement authorities discover that a small survivalist group in the Ozark Mountains of Arkansas known as The Covenant, the Sword, and the Arm of the Lord (CSA) has acquired a drum containing thirty gallons of potassium cyanide, with the apparent intent to poison water supplies in New York, Chicago, and Washington, DC. CSA members believe that such attacks would make the Messiah return more quickly by punishing unrepentant sinners. The objective appears to be mass murder in the name of a divine mission rather than a change in governmental policy. | Tucker (2000); NTI (2005)                     |



|      |                              |                                    |            |  |                              |
|------|------------------------------|------------------------------------|------------|--|------------------------------|
| 1986 | North Korea, South Korea     | Military tool                      | No         | North Korea's announcement of its plans to build the Kumgansan hydroelectric dam on a tributary of the Han River upstream of Seoul raises concerns in South Korea that the dam could be used as a tool for ecological destruction or war.  | Gleick (1993)                |
| 1986 | Lesotho, South Africa        | Development dispute; Military goal | Yes        | South Africa supports a bloodless coup by Lesotho's defense forces. Immediately afterward, the two countries agree to share water from the Highlands of Lesotho, following thirty years of unsuccessful negotiations. There is disagreement over the degree to which water is a motivating factor for either party.  | Mohamed (2001)               |
| 1986 | Lesotho, South Africa        | Military goal; Development dispute | Yes        | South Africa supports a coup in Lesotho over support for the African National Congress, opposition to apartheid, and water. The new government in Lesotho quickly signs the Lesotho Highlands water agreement.   | American University (2000b)  |
| 1988 | Angola, South Africa, Cuba   | Military goal; Military target     | Yes        | Cuban and Angolan forces launch an attack on Calueque Dam via land and then air. Considerable damage is inflicted on the dam's wall, and the power supply to the dam is cut. The water pipeline to Owamboland is cut and destroyed.  | Meissner (2000)              |
| 1990 | South Africa                 | Development dispute                | No         | A pro-apartheid council cuts off water to the Wesselton township of 50,000 blacks following protests over miserable sanitation and living conditions.  | Gleick (1993)                |
| 1990 | Iraq, Syria, Turkey          | Development dispute; Military tool | No         | The flow of the Euphrates is interrupted for a month as Turkey finishes construction of the Ataturk Dam, part of the Grand Anatolia Project. Syria and Iraq protest that Turkey now has a weapon of war. In mid-1990, Turkish president Turgut Ozal threatens to restrict water flow to Syria to force it to withdraw support for Kurdish rebels operating in southern Turkey. | Gleick (1993); Gleick (1995) |
| 1991 | Iraq, Kuwait, United States  | Military target                    | Yes        | During the Gulf War, Iraq destroys much of Kuwait's desalination capacity during its retreat.  | Gleick (1993)                |
| 1991 | Canada                       | Terrorism                          | No: Threat | A threat is made via an anonymous letter to contaminate the water supply of the city of Kelowna, British Columbia, with "biological contaminants." The motive is apparently "associated with the Gulf War." The security of the water supply is increased in response, and no group is identified as the perpetrator.  | Purver (1995)                |
| 1991 | Iraq, Turkey, United Nations | Military tool                      | No: Threat | The United Nations discusses use of the Ataturk Dam in Turkey to cut off flows of the Euphrates to Iraq.   | Gleick (1993)                |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved            | Basis of Conflict                   | Violent Conflict or in the Context of Violence? |     | Description   | Sources  |
|-----------|-----------------------------|-------------------------------------|---|-----|---|--|
|           |                             |                                     | Military target                                 | Yes |   |  |
| 1991      | Iraq, Kuwait, United States | Military target                     | Yes   |     | During the Persian Gulf War, Allied Coalition forces damage Baghdad's modern water supply and sanitation system—intentionally and unintentionally. “Four of seven major pumping stations were destroyed, as were 31 municipal water and sewerage facilities—20 in Baghdad—resulting in sewage pouring into the Tigris. Water purification plants were incapacitated throughout Iraq” (Arbuthnot 2000). Following the damage, the <i>New England Journal of Medicine</i> reports that during the first eight months of 1991, childhood deaths in Iraq increase by 47,000 and the country's infant mortality rate doubles, to 92.7 per 1,000 live births. | Gleick (1993); Arbuthnot (2000); Barrett (2003)          |
| 1991      | China                       | Development dispute                 | Yes   |     | In December 1991, Huanglongkou village and Qianyu village exchange mortar fire over the construction of new water diversion facilities. Conflicts over excessive water withdrawals and subsequent water shortages from China's Zhang River had been worsening for over three decades. (See also entries for 1970, 1976, 1992, and 1999.)  | <i>China Water Resources Daily</i> (2002)                |
| 1991–2001 | United States, Iraq         | Military target; Military tool      | No  |     | The United States deliberately pursues a policy of destroying Iraq's water systems through sanctions and withholding contracts.   | Nagy (2001)  |
| 1991–2007 | Karnataka, India            | Development dispute                 | Yes   |     | Violence erupts when Karnataka rejects an interim order handed down by the Cauvery Waters Tribunal, set up by the Supreme Court of India. The tribunal had been established in 1990 to settle two decades of dispute between Karnataka and Tamil Nadu over irrigation rights to the Cauvery River.  | Gleick (1993); Butts (1997); American University (2000a) |
| 1992      |                             | Political tool; Development dispute | Military maneuvers                              |     | Citing environmental concerns, Hungary abrogates a 1977 treaty with Czechoslovakia concerning construction of the Gabčíkovo/Nagymaros project. Slovakia continues construction unilaterally, completes the dam, and diverts the Danube into a canal inside the Slovak Republic. Massive public protest and movement of military to the border ensue; the issue is taken to the International Court of Justice.  | Gleick (1993)  |
| 1992      | Turkey                      | Terrorism                           | Yes   |     | Lethal concentrations of potassium cyanide are reportedly discovered in the water tanks of a Turkish Air Force compound in Istanbul. The Kurdish Workers' Party (PKK) claims credit.  | Chelyshev (1992)   |

|      |                       |                                |     |  |   |
|------|-----------------------|--------------------------------|-----|--|---|
| 1992 | Bosnia, Bosnian Serbs | Military tool                  | Yes | The Serbian siege of Sarajevo, Bosnia and Herzegovina, includes a cutoff of all electrical power and the water feeding the city from the surrounding mountains. The lack of power cuts the two main pumping stations inside the city, despite pledges from Serbian nationalist leaders to United Nations officials that they would not use their control of Sarajevo's utilities as a weapon. Bosnian Serbs take control of water valves regulating flow from wells that provide more than 80 percent of water to Sarajevo; the reduced water flow to the city is used to "smoke out" Bosnians.  | Burns (1992); Husarska (1995)             |
| 1992 | China                 | Development dispute            | Yes | In August 1992, bombs are set off along a Zhang River distribution canal, collapsing part of the canal and causing flooding and economic losses. Violence continues in the late 1990s with confrontations, mortar attacks, and bombings. Conflicts over excessive water withdrawals and subsequent water shortages from China's Zhang River had been worsening for over three decades. (See also entries for 1970, 1976, 1991, and 1999.)  | <i>China Water Resources Daily</i> (2002) |
| 1992 | Moldova, Russia       | Military target                | Yes | In June, hostilities between Moldova and Russia in a short but intense conflict include a rocket-artillery attack on the hydroelectric turbines at the Dubossary power station on the Nistru (or Dniester) River.  | Malik (2005); Belitser et al. (2009)      |
| 1993 | Iran                  | Terrorism                      | No  | A report suggests that proposals were made at a meeting of fundamentalist groups in Tehran, under the auspices of the Iranian Foreign Ministry, to poison water supplies of major cities in the West "as a possible response to Western offensives against Islamic organizations and states."  | Haeri (1993)                              |
| 1993 | Yugoslavia            | Military target; Military tool | Yes | The sixty-five-meter-high Peru a Dam on the Cetina River was Yugoslavia's second-largest hydroelectric facility before the country's breakup with the Croatian War beginning in 1991. On January 28, 1993, Serbian/Yugoslav army forces detonate explosives at the dam in an attempt to wipe out Croatian villages and the port city of Omiš. A successful Croatian counterattack allows military engineers to reach the dam and release water in time to prevent it from bursting, saving an estimated twenty to thirty thousand civilians. Credit for preventing a dam burst is also given to British Marine Captain Mark Gray, a UN observer, for opening gates to reduce water levels prior to the attack. | Gleick (1993); Rathfelder (2007)          |

## Water Conflict Chronology *continued*

| Date      | Parties Involved    | Basis of Conflict             | Violent Conflict or in the Context of Violence? |    | Description  | Sources   |
|-----------|---------------------|-------------------------------|---|----|--|---|
|           |                     |                               |   |    |  |   |
| 1993–2003 | Iraq                | Military tool                 | No  | No | To quell opposition to his government, Saddam Hussein reportedly poisons and drains the water supplies of southern Shiite Muslims, the Madan. The marshes of southern Iraq are intentionally targeted. The European Parliament and UN Human Rights Commission deplore the use of water as a weapon in the region.  | Gleick (1993); American University (2000c); National Geographic News (2001) |
| 1994      | Moldova, Russia     | Terrorism                     | No: Threat                                      |    | Moldavian general Nikolay Matveyev reportedly threatens to contaminate the water supply of the Russian 14th Army in Tiraspol, Moldova, with mercury.   | Purver (1995)   |
| 1998/1994 | United States       | Cyberterrorism                | No  |    | The <i>Washington Post</i> reports that a twelve-year-old computer hacker has broken into the SCADA computer system that runs Arizona's Roosevelt Dam, gaining complete control of the dam's massive floodgates. The cities of Mesa, Tempe, and Phoenix, Arizona, are downstream of this dam. This report turns out to be incorrect. A hacker did break into the computers of an Arizona water facility, the Salt River Project in the Phoenix area. But he was twenty-seven, not twelve, and the incident occurred in 1994, not 1998. And while clearly trespassing in critical areas, the hacker never could have had control of any dams, leading investigators to conclude that no lives or property were ever threatened. | Gellman (2002); Lemos (2002)  |
| 1995      | Ecuador, Peru       | Military tool; Political tool | Yes   |    | Armed skirmishes arise in part because of disagreement over the control of the headwaters of the Cenepa River. Wolf argues that this is primarily a border dispute simply coinciding with the location of a water resource.  | Samson and Charrier (1997); Wolf (1997)                                     |
| 1997      | Singapore, Malaysia | Political tool                | No  |    | Malaysia, which supplies about half of Singapore's water, threatens to cut off that supply in retribution for criticisms by Singapore of policy in Malaysia.   | Zachary (1997)  |
| 1998      | Tajikistan          | Terrorism; Political tool     | No: Threat                                      |    | Tajik guerrilla commander Makhmud Khudoberdiyev threatens to blow up a dam on the Kairakkhum channel if his political demands are not met.   | WRR (1998)  |
| 1998      | Angola              | Military tool; Political tool | Yes   |    | In September, fierce fighting between UNITA and Angolan governmental forces breaks out at Gove Dam on the Kunene River for control of the installation.  | Meissner (2001)   |

|           |                              |                                     |     |  |  |
|-----------|------------------------------|-------------------------------------|-----|--|--|
| 1998      | Democratic Republic of Congo | Military target; Terrorism          | Yes | Attacks are made on Inga Dam during efforts to topple President Kabila. Electricity supplies from Inga Dam and water supplies to Kinshasa are disrupted.   | Chenje (2001); Human Rights Watch (1998)   |
| 1998–1999 | Kosovo                       | Terrorism; Political tool           | Yes | Water supplies and wells are contaminated by Serbs disposing of the bodies of Kosovar Albanians. There are also reports of Yugoslav federal forces poisoning wells with carcasses and hazardous materials.   | CNN (1999); Hickman (1999)                 |
| 1998–2000 | Eritrea and Ethiopia         | Military target                     | Yes | Water-pumping plants and pipelines in the border town of Adi Quala are destroyed during the civil war between Eritrea and Ethiopia.  | ICRC (2003)                                |
| 1999      | Lusaka, Zambia               | Terrorism; Political tool           | Yes | A bomb blast destroys Lusaka's main water pipeline, cutting off water for the city, population 3 million.  | <i>FTGWR</i> (1999)                        |
| 1999      | Yugoslavia                   | Military target                     | Yes | Belgrade reports that NATO planes have targeted a hydroelectric plant during the Kosovo campaign.  | Reuters (1999c)                            |
| 1999      | Bangladesh                   | Development dispute; Political tool | Yes | Fifty people are hurt during strikes called to protest power and water shortages. Protests are led by former prime minister Begum Khaleda Zia over a decrease in public services and deterioration of law and order.                                       | Ahmed (1999)                               |
| 1999      | Yugoslavia                   | Military target                     | Yes | NATO targets utilities and shuts down water supplies in Belgrade. NATO bombs bridges on Danube, disrupting navigation.   | Reuters (1999b)                            |
| 1999      | Yugoslavia                   | Political tool                      | Yes | Yugoslavia refuses to clear war debris (downed bridges) on the Danube unless financial aid for reconstruction is provided; European countries on the Danube fear that flooding due to winter ice dams will result. Diplomats deny environmental blackmail. | Simons (1999)                              |
| 1999      | Kosovo                       | Political tool                      | Yes | Serbian engineers shut down the water system in Pristina prior to occupation by NATO.  | Reuters (1999a)                            |
| 1999      | South Africa                 | Terrorism                           | Yes | A homemade bomb is discovered at a water reservoir at Wallmansthal, near Pretoria. It is thought to have been meant to sabotage water supplies to farmers.   | <i>Pretoria Dispatch</i> (1999)            |
| 1999      | Angola                       | Terrorism; Political tool           | Yes | One hundred bodies are found in four drinking water wells in central Angola.   | <i>International Herald Tribune</i> (1999) |
| 1999      | Puerto Rico, United States   | Political tool                      | No  | Protesters block water intake to Roosevelt Roads Navy Base in opposition to US military presence and the navy's use of the Blanco River, following chronic water shortages in neighboring towns.   | <i>New York Times</i> (1999)               |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved                                 | Basis of Conflict                  | Violent Conflict or in the Context of Violence? |    | Description  | Sources                                   |
|-----------|--|------------------------------------|---|----|--|---|
|           |  |                                    | Yes   | No |  |   |
| 1999      | China  | Development dispute; Terrorism     | Yes   |    | Around the Chinese New Year, farmers from Hebei and Henan Provinces fight over limited water resources. Heavy weapons, including mortars and bombs, are used and nearly one hundred villagers are injured. Houses and facilities are damaged, and the total loss reaches US\$1 million.  | <i>China Water Resources Daily</i> (2002) |
| 1999      | East Timor                                       | Military tool; Terrorism           | Yes   |    | Militia opposing East Timor independence kills pro-independence supporters and throws their bodies in a water well.  | BBC (1999)                                |
| 1999      | Yemen  | Development dispute                | Yes   |    | Yemen sends 700 soldiers to quell fighting that claimed six lives and injured sixty in clashes that erupted between two villages fighting over a local spring near Ta'iz. The village of Al-Marzuh believed it was entitled to exclusive use of a spring because the spring was located on its land; the neighboring village of Quradah believed its right to the water had been affirmed in a fifty-year-old court verdict. The dispute erupted in violence. President Ali Abdullah Saleh intervenes by summoning the sheikhs of the two villages to the capital and sorts out the problem by dividing the water into halves. | Al-Qadhi (2003)                           |
| 1999–2000 | Namibia, Botswana, Zambia                        | Military goal; Development dispute | No  |    | On Sedudu/Kasikili Island, in the Zambezi/Chobe River, a dispute arises about the border and access to water. The conflict is presented to the International Court of Justice.   | ICJ (1999)                                |
| 2000      | Ethiopia   | Development dispute                | Yes   |    | A man is stabbed to death during a fight over clean water during the famine in Ethiopia.   | Sandrasagra (2000)                        |
| 2000      | Central Asia: Kyrgyzstan, Kazakhstan, Uzbekistan | Development dispute                | No  |    | Kyrgyzstan cuts off water to Kazakhstan until coal is delivered; Uzbekistan cuts off water to Kazakhstan for nonpayment of debt.   | Pannier (2000)                            |
| 2000      | France, Belgium, Netherlands                     | Terrorism                          | Yes   |    | In July, workers at the Cellatex chemical plant in northern France dump 5,000 liters of sulfuric acid into a tributary of the Meuse River after they are denied workers' benefits. A French analyst points out that this is the first time "the environment and public health were made hostage in order to exert pressure, an unheard-of situation until now."  | <i>Christian Science Monitor</i> (2000)   |



|      |                        |                            |     |  |  |
|------|------------------------|----------------------------|-----|--|--|
| 2000 | Hazarajat, Afghanistan | Development dispute        | Yes | Violent conflicts break out over water resources in the villages of Burna Legan and Taina Legan, and in other parts of the region, as drought depletes local resources.  | Cooperation Center for Afghanistan (2000)<br><i>FTGWR</i> (2000)   |
| 2000 | India: Gujarat         | Development dispute        | Yes | Water riots are reported in some areas of Gujarat in protest of authority's failure to arrange an adequate supply of tanker water. Police are reported to have shot into a crowd at Falla village near Jamnagar, resulting in the deaths of three and injuries to twenty following protests against the diversion of water from the Kankavati Dam to Jamnagar town.                                  |  |
| 2000 | Bolivia                | Development dispute        | Yes | Massive protests, riots, and violence result from efforts to privatize the water system of Cochabamba, Bolivia.  | Shultz and Draper (2009)   |
| 2000 | United States          | Terrorism                  | No  | A drill simulating a terrorist attack on the Nacimiento Dam in Monterey County, California, gets out of hand when two radio stations report it as a real attack.   | Gaura (2000)   |
| 2000 | Kenya                  | Development dispute        | Yes | A clash between villagers and thirsty monkeys leaves eight monkeys dead and ten villagers wounded. The duel started after water tankers brought water to a drought-stricken area and the monkeys, desperate for water, attacked the villagers.   | BBC (2000); Okoko (2000)   |
| 2000 | Australia              | Cyberterrorism             | Yes | In Queensland, Australia, police arrest a man for using a computer and radio transmitter to take control of the Maroochy Shire wastewater system and release sewage into parks, rivers, and property.  | Gellman (2002)   |
| 2000 | China                  | Development dispute        | Yes | Civil unrest erupts over the use and allocation of water from Baiyangdian Lake, the largest natural lake in northern China. Several people die in riots by villagers in July in Shandong after officials cut off water supplies. In August, six die when officials in the southern province of Guangdong blow up a water channel to prevent a neighboring county from diverting water.               | Pottinger (2000)   |
| 2001 | Israel, Palestine      | Terrorism; Military target | Yes | Palestinians destroy water supply pipelines to the West Bank settlement of Yitzhar and to Kibbutz Kisufim. The Agbat Jabar refugee camp near Jericho disconnects from its water supply after Palestinians loot and damage local water pumps. Palestinians accuse Israel of destroying a water cistern, blocking water tanker deliveries, and attacking materials for a wastewater treatment project. | <i>Israel Line</i> (2001a); <i>Israel Line</i> (2001b); ENS (2001) |

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## Water Conflict Chronology *continued*

| Date | Parties Involved                       | Basis of Conflict              | Violent Conflict or in the Context of Violence? |    | Description  | Sources   |
|------|--|--------------------------------|---|----|--|---|
|      |  |                                | Yes   | No |  |   |
| 2001 | Pakistan                               | Development dispute; Terrorism | Yes   |    | Civil unrest erupts over severe water shortages caused by the long-term drought. Protests begin in March and April and continue into summer, involving riots, four bombs in Karachi (June 13), one death, twelve injuries, and thirty arrests. Ethnic conflicts arise as some groups "accuse the government of favoring the populous Punjab province [over Sindh Province] in water distribution."   | Nadeem (2001); Solomon (2001)                       |
| 2001 | Macedonia                              | Terrorism; Military target     | Yes   |    | Water flow to Kumanovo (population 100,000) is cut off for twelve days in a conflict between ethnic Albanians and Macedonian forces. Valves of Glazinja and Lipkovo Lakes are damaged.   | AFP (2001); Macedonia Information Agency (2001)     |
| 2001 | China                                  | Development dispute            | Yes   |    | In an act to protest the destruction of fisheries by uncontrolled water pollution, fishermen in northern Jiaying City, Zhejiang Province, dam a large industrial wastewater canal for twenty-three days. The wastewater discharges into the neighboring Shengze Town, Jiangsu Province, killing fish and threatening public health.  | China Ministry of Water Resources (2001)            |
| 2001 | Philippines                            | Terrorism                      | No  |    | The militant Islamist separatist group Abu Sayyaf threatens to poison the water supply in Isabela, a mainly Christian town on Basilan Island in the country's south. In October, residents in six nearby villages suspect contamination because the water smells like gasoline. Local officials respond by closing pipelines and bringing in drinking water by truck. In the months following the 9/11 attacks on New York, numerous false alarms of terrorist activity are reported around the world. | World Environment News (2001); Fenton et al. (2001) |
| 2001 | Afghanistan                            | Military target                | Yes   |    | American forces bomb the hydroelectric facility at Kajaki Dam in Helmand Province, cutting off electricity for the city of Kandahar. The dam itself is not targeted.   | BBC (2001); Parry (2001)                            |
| 2001 | Pokomo farmers and Orma cattle herders | Development dispute            | Yes   |    | At least 130 people are killed in a string of clashes between Pokomo farmers and Orma people, seminomadic cattle herders, over access to land and river water.   | AFP (2012)  |

|      |                              |                              |            |  |  |
|------|------------------------------|------------------------------|------------|--|--|
| 2002 | Nepal                        | Terrorism;<br>Political tool | Yes        | The Khumbuwan Liberation Front (KLF) blows up a 250-kilowatt hydroelectric powerhouse in Nepal's Bhojpur District, cutting off power to Bhojpur and surrounding areas. The damage takes six months to repair and costs 10 million Rs (US\$120,000). During 2002, Maoist rebels destroy more than seven micro-hydro projects, a water supply intake, and supply pipelines to Khalanga, in western Nepal.  | <i>Kathmandu Post</i> (2002); <i>FTGWR</i> (2002)                                |
| 2002 | Rome, Italy                  | Terrorism                    | No: Threat | Italian police arrest four Moroccans allegedly planning to contaminate the water supply system in Rome with a cyanide-based chemical, targeting buildings that include the United States embassy. Ties to Al-Qaeda are suggested.  | BBC (2002)   |
| 2002 | Kashmir, India               | Development<br>dispute       | Yes        | Two people are killed and twenty-five others are injured in Kashmir when police fire at a group of villagers clashing over water sharing. The incident takes place in Garend village in a dispute over sharing water from an irrigation stream.  | <i>Japan Times</i> (2002)  |
| 2002 | United States                | Terrorism                    | No: Threat | Papers seized during the arrest of a Lebanese imam at a mosque in Seattle include "instructions on poisoning water sources" from a London-based Al-Qaeda recruiter. The FBI issues a bulletin to computer security experts around the country indicating that Al-Qaeda terrorists may have been studying American dams and water supply systems in preparation for new attacks. "U.S. law enforcement and intelligence agencies have received indications that al-Qaeda members have sought information on Supervisory Control And Data Acquisition (SCADA) systems available on multiple SCADA-related Web sites," reads the bulletin, according to SecurityFocus. "They specifically sought information on water supply and wastewater management practices in the U.S. and abroad." | McDonnell and Meyer (2002); MSNBC (2002)   |
| 2002 | Colombia                     | Terrorism                    | Yes        | Colombian rebels in January damage a gate valve in the dam that supplies most of Bogotá's drinking water. The Revolutionary Armed Forces of Colombia (FARC) detonates an explosive device planted on a German-made gate valve located inside a tunnel in the Chingaza Dam.   | <i>WaterWeek</i> (2002)  |
| 2002 | Karnataka, Tamil Nadu, India | Development<br>dispute       | Yes        | There is continuing violence over allocation of water from the Cauvery (Kaveri) River between Karnataka and Tamil Nadu, with riots, property destruction, more than thirty injuries, and arrests through September and October.  | <i>The Hindu</i> (2002a); <i>The Hindu</i> (2002b); <i>Times of India</i> (2002) |

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## Water Conflict Chronology *continued*

| Date | Parties Involved              | Basis of Conflict              | Violent Conflict or in the Context of Violence? |        | Description  | Sources  |
|------|-------------------------------|--------------------------------|---|--------|--|--|
|      |                               |                                | No:   | Yes    |  |  |
| 2002 | United States                 | Terrorism                      | No:   | Threat | The Earth Liberation Front threatens the water supply for the town of Winter Park, Co. Previously, this group claimed responsibility for the destruction of a ski lodge in Vail, Colorado, that threatened lynx habitat.   | Crecente (2002); AP (2002)   |
| 2002 | Botswana, Bushmen             | Development dispute            | Yes   |        | Botswana's president, Festus Mogae, sends troops to the Kalahari Desert to destroy wells and empty water sources of indigenous Khoisan people (also known as Bushmen), ostensibly in an effort to remove them from their ancestral lands and assimilate them into modern society. Critics accuse the government of taking away water rights in favor of mining interests and label the government's actions a "siege"; Botswana is condemned by international observers. Against expectations, a band of Bushmen retreat into the desert and survive for years with little outside assistance. | Workman (2009)   |
| 2002 | Bolivian irrigators, townsmen | Development dispute            | Yes   |        | Violence erupts between irrigators and the townsmen of Tarata over the use of water from the Laka Laka Dam. After local authorities begin diverting some water to cultivate gardens in the town, irrigators in the downstream area of Arbietao protest that their water rights are being violated. Irrigators destroy a portion of the town's pipeline, and townsmen retaliate by vandalizing part of an irrigation canal.   | Bustamante et al. (2004)   |
| 2003 | United States                 | Terrorism                      | No:   | Threat | Al-Qaeda threatens US water systems via a call to a Saudi Arabian magazine. Al-Qaeda does not "rule out . . . the poisoning of drinking water in American and Western cities."   | AP (2003b); Waterman (2003); NewsMax (2003); <i>US Water News</i> (2003) |
| 2003 | United States                 | Terrorism                      | Yes   |        | Four incendiary devices are found in the pumping station of a Michigan water-bottling plant. The Earth Liberation Front claims responsibility, accusing Ice Mountain Water Company of "stealing" water for profit. Ice Mountain is a subsidiary of Nestle Waters.  | AP (2003a)   |
| 2003 | Colombia                      | Terrorism; Development dispute | Yes   |        | A bomb blast at the Cali Drinking Water Treatment Plant kills three workers on May 8. The workers were members of a trade union involved in intense negotiations over privatization of the water system.   | PSI (2003)   |

|           |                             |   |            |   |   |
|-----------|-----------------------------|---|------------|---|---|
| 2003      | Jordan                      | Terrorism                                 | No: Threat | Jordanian authorities arrest Iraqi agents in connection with a botched plot to poison the water supply that serves American troops in the eastern Jordanian desert near the border with Iraq. The scheme involves the poisoning of a water tank that supplies American soldiers at a military base in Khao, which lies in an arid region of the eastern frontier near the industrial town of Zarqa. | MJS (2003)                                    |
| 2003      | Iraq, United States, others | Military target                           | Yes        | During the US-led invasion of Iraq, water systems are reportedly damaged and destroyed by different parties, and major dams are military objectives of the US forces. Damage directly attributable to the war includes vast segments of the water distribution system and the Baghdad water system, damaged by a missile.   | UNICEF (2003); ARC (2003)                     |
| 2003      | Iraq                        | Terrorism                                 | Yes        | Insurgents bomb a main water pipeline in Baghdad. City engineers say this is the first strike against Baghdad's water system during the Iraq War, which began in March 2003. The bombing occurs when an explosive is fired at the six-foot-wide water main in the northern part of Baghdad, says Hayder Muhammad, chief engineer for the city's water treatment plants.                             | Tierney and Worth (2003)                      |
| 2003-2007 | Sudan, Darfur               | Military tool; Military target; Terrorism | Yes        | The ongoing civil war in Sudan includes violence against water resources. In 2003, villagers from around Tina say that bombings have destroyed water wells. In Khasan Basao, they allege that water wells have been poisoned. In 2004, wells in Darfur are intentionally contaminated as part of a strategy of harassment against displaced populations.  | Amnesty International (2004); Reuters (2004b) |
| 2004      | Mexico                      | Development dispute                       | Yes        | Two Mexican farmers had argued for years over water rights to a small spring used to irrigate a small corn plot near the town of Pihuamo. In March, these farmers shoot and kill each other.  | Guardian (2004)                               |
| 2004      | Pakistan                    | Terrorism                                 | Yes        | In military action aimed at Islamic terrorists, including Al-Qaeda and the Islamic Movement of Uzbekistan, homes, schools, and water wells are damaged and destroyed.   | Reuters (2004a)                               |
| 2004      | India, Kashmir              | Terrorism                                 | Yes        | Twelve Indian security forces are killed by an improvised explosive device planted in an underground water pipe during a "counter-insurgency operation in Khanabal area in Anantnag district."  | TNN (2004)                                    |
| 2004      | China                       | Development dispute                       | Yes        | Tens of thousands of farmers stage a sit-in against the construction of the Pubugou Dam on the Dadu River in Sichuan Province. Riot police are deployed to quell the unrest, and one person is killed. Witnesses also report the deaths of a number of residents. (See China, 2006, for a follow-up.)   | BBC (2004a); VOA (2004)                       |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved     | Basis of Conflict              | Violent Conflict or in the Context of Violence? |    | Description   | Sources                                  |
|-----------|----------------------|--------------------------------|---|----|---|--|
|           |                      |                                | Yes   | No |   |  |
| 2004      | China, United States | Military target                | No  |    | A 2004 Pentagon report on China's military capacity raises the concept of Taipei adopting military systems capable of being used as a tool for deterring Chinese military coercion by "presenting credible threats to China's urban population or high-value targets, such as the Three Gorges Dam." China promptly denounces "a U.S. suggestion" that Taiwan's military target the Three Gorges Dam, leading the United States to deny that it had so urged.   | <i>China Daily</i> (2004); US DOD (2004) |
| 2004      | South Africa         | Development dispute            | Yes   |    | Poor delivery of water and sanitation services in Phumelela Township leads to several months of protests. No one is killed during the protests, but a few people are seriously injured, and municipal property is damaged.  | CDE (2007)                               |
| 2004      | Gaza Strip           | Terrorism; Development dispute | Yes   |    | The United States halts two water development projects as punishment to the Palestinian Authority for its failure to find those responsible for a deadly attack on a US diplomatic convoy in October 2003.  | AP (2004)                                |
| 2004      | India                | Development dispute            | Yes   |    | Four people are killed in October and more than thirty are injured in November in ongoing protests by farmers over allocations of water from the Indira Gandhi Irrigation Canal in Sriganaganagar District, which borders Pakistan. Authorities impose curfews on the towns of Gharsana, Raola, and Anoopgarh.  | Indo-Asian News Service (2004)           |
| 2004–2006 | Ethiopia             | Development dispute            | Yes   |    | At least 250 people are killed and many more are injured in clashes over water wells and pastoral lands. Villagers call the clashes the "War of the Well" and describe "well warlords, well widows, and well warriors." A three-year drought has led to extensive violence over limited water resources, worsened by the lack of effective governmental and central planning.   | BBC (2004b); AP (2005); Wax (2006)       |
| 2005      | Kenya                | Development dispute            | Yes   |    | Police are sent to the northwestern part of Kenya to control a major violent dispute between Kikuyu and Maasai groups over water. More than twenty people are killed in fighting in January. By July, the death toll exceeds ninety, principally in the rural center of Turbi. The tensions arose over grazing and water. Maasai herdsman accused a local Kikuyu politician of diverting a river to irrigate his farm, depriving downstream livestock. Fighting displaces more than 2,000 villagers, reflecting tensions between nomadic and settled communities. | BBC (2005); Ryu (2005); Lane (2005)      |



|      |                    |   |     |  |   |
|------|--------------------|---|-----|--|---|
| 2005 | Ukraine            | Terrorism                                 | Yes | On April 13, the Kiev Hydropower Station on the Dnieper River receives a threat that forty rail cars filled with explosives have been placed on a portion of levees holding back the reservoir.  | Levitsky (2005)   |
| 2006 | Yemen              | Development dispute                       | Yes | Local media report a struggle between the Hajja and Amran tribes over a well located between the two governorates in Yemen. According to news reports, armed clashes between the two sides force many families to leave their homes and migrate. News reports confirm that authorities have arrested twenty people in an attempt to stop the fighting. | Al-Ariqi (2006)   |
| 2006 | China              | Development dispute                       | Yes | Chinese authorities execute a man who took part in protests against the Pubugou Dam in Sichuan Province in 2004 (see the 2004 China entry). Chen Tao was convicted of killing a policeman but is executed before legal appeals are completed.  | BBC (2006a); Coonan (2006)                                  |
| 2006 | Ethiopia           | Development dispute                       | Yes | At least twelve people die and over twenty are wounded in clashes over water and pasture in the Somali border region.  | BBC (2006b)   |
| 2006 | Ethiopia and Kenya | Development dispute                       | Yes | At least forty people die in Kenya and Ethiopia in continuing clashes over water, livestock, and grazing land. Fighting takes place in southern Ethiopia in the region of Oromo and in the northern Kenya Marsabit District.   | Reuters (2006)  |
| 2006 | Sri Lanka          | Military tool; Military target; Terrorism | Yes | Tamil Tiger rebels cut the water supply to government-held villages in northeastern Sri Lanka. Sri Lankan governmental forces then launch attacks on the reservoir, declaring the Tamil actions to be terrorism. As of August, conflict around the water blockade had claimed over 425 lives.  | BBC (2006c); BBC (2006d); Gutierrez (2006)                  |
| 2006 | Israel, Lebanon    | Military target; Terrorism                | Yes | Hezbollah rockets damage a wastewater plant in Israel. Israeli counterattacks damage water systems throughout southern Lebanon, including tanks, pipes, pumping stations, and facilities along the Litani River.   | Science (2006); Amnesty International (2006); Murphy (2006) |
| 2006 | Sudan              | Development dispute                       | Yes | Militia of the Merowe Dam Militia Implementation Unit in Sudan attack a gathering of villagers concerned about the community impacts of the dam at a school in Amri village, killing three farmers and injuring more than fifty others.  | Bosshard (2009)   |
| 2007 | India              | Development dispute                       | Yes | Thousands of farmers breach security and storm the area of Hirakud Dam to protest allocation of water to industry. Minor injuries are reported during the conflict between the farmers and police.   | Statesman News Service (2007)                               |

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## Water Conflict Chronology *continued*

| Date | Parties Involved                   | Basis of Conflict                    | Violent Conflict or in the Context of Violence? |    | Description  | Sources                       |
|------|------------------------------------|--------------------------------------|---|----|--|-------------------------------|
|      |                                    |                                      | Yes   | No |  |                               |
| 2007 | Afghanistan                        | Military target; Terrorism           | Yes   |    | The Kajaki Dam is the scene of major fighting between Taliban and NATO forces, mainly British and Dutch. The Taliban is attempting to make it impossible to work on reconstruction of the dam and power lines to boost output.   | Friel (2007)                  |
| 2007 | Canada                             | Terrorism                            | No  |    | A Toronto man previously accused of attempted murder and illegal possession of explosives is charged with eight more counts of attempted murder after allegedly tampering with bottled water, which he injected with an unspecified liquid.  | <i>Toronto Star</i> (2007)    |
| 2007 | Burkina Faso, Ghana, Côte d'Ivoire | Development dispute                  | Yes   |    | Declining rainfall has led to growing fights between animal herders and farmers with competing needs. In August, 2007 people are forced to flee their homes by fighting in Zounweogo Province.   | UN OCHA (2007)                |
| 2007 | Israel, Palestine                  | Development dispute                  | No  |    | Israel's sanctions against Gaza cause water shortages and a growing public health risk. In particular, restrictions on fuel, spare parts, and maintenance equipment threaten the functioning of Gaza's already limited water and sanitation system.  | Oxfam (2007)                  |
| 2007 | Sydney residents                   | Development dispute                  | Yes   |    | A thirty-six-year-old Australian is charged with murder after killing a man during a fight over water restrictions in Sydney. A number of incidents have been reported following ten years of drought and water restrictions, leading scholars to suggest a "link between persistent urban water restrictions and civil unrest."   | ABC News (2007); Crase (2009) |
| 2007 | Sudan                              | Development dispute                  | Yes   |    | Angry villagers in Sudan stage protests against Kajbar Dam; four villagers are killed by governmental militia.   | Bosshard (2009)               |
| 2008 | Nigeria                            | Development dispute                  | Yes   |    | A protest over the price of water in Nyanya, Abuja, Nigeria, results in violence, including the beating of water vendors.  | Yakubu (2008)                 |
| 2008 | China, Tibet                       | Military target; Development dispute | Yes   |    | China launches a political crackdown in Tibet. At least some observers note the importance of Tibet for the water resources of China, though the political complications between Tibet and China extend far beyond water. As noted: "Tibet is referred to in some circles as the 'world's water tower'; the Tibetan plateau is home to vast reserves of glaciated water, the sources of 10 of the largest rivers in Asia, including the Yellow, Yangtze, Mekong, Brahmaputra, Salween, Hindus and Sutlej among others. By some estimates, the Tibetan plateau is the source of fresh water for fully a quarter of the world's population." | Sharife (2008)                |

|      |                                  |                                    |     |  |  |
|------|----------------------------------|------------------------------------|-----|--|--|
| 2008 | Pakistan                         | Terrorism                          | Yes | In October, the Taliban threatens to blow up Warsak Dam, the main water supply for Peshawar, during a governmental offensive in the region.  | Perlez and Shah (2008)                   |
| 2008 | Murulle, Garre clans             | Development dispute                | Yes | Fighting over boreholes in arid northern Kenya kills at least four people as competition for resources grows in the drought-hit region between the Murulle and Garre clans in Elwak, Mandera District.   | Reuters (2008)                           |
| 2009 | China, India                     | Development dispute; Military tool | No  | China claims a part of historical Tibet that is now under Indian control as part of the state of Arunachal Pradesh. To influence this territorial dispute, China tries to block a \$2.9 billion Asian Development Bank loan to India because it would help finance Indian water projects in the disputed area.   | Wong (2009)                              |
| 2009 | Ethiopian Oromia, Somali regions | Development dispute                | Yes | Ethiopian Somalis attack a Borana community in the Oromia region over ownership of a new borehole being drilled on the disputed border between them. Three people from the Oromia village of Kafa are killed and seven are injured, and the entire community is driven from their homes. The drilling rig is destroyed.  | BBC (2009)                               |
| 2009 | Indian citizens                  | Development dispute                | Yes | A family in Madhya Pradesh State in India is killed by a small mob for illegally drawing water from a municipal pipe. Others run to collect water for themselves before the water in the pipe runs out. Drought and inequality in water distribution lead to increasing conflict in the region. Indian media report more than fifty violent clashes in the state capital, Bhopal, during May alone. Since January, twelve people have been killed and even more have been injured. | Singh (2009)                             |
| 2009 | Mumbai residents, police         | Development dispute                | Yes | Police clash with hundreds of Mumbai residents protesting water cuts. One man is killed, and a dozen others are injured. Mumbai authorities are forced to ration supplies after the worst monsoon season in decades.   | Chandran (2009)                          |
| 2009 | North Korea, South Korea         | Political tool                     | Yes | Without previous warning, North Korea releases 40 million cubic meters of water from the Hwanggag Dam, causing a flash flood on the Imjin River. In South Korea, at least six fishermen and campers drown. North Korea claims that the water had to be urgently released and promises to warn the South of future releases. South Korea fears that North Korea could use the water of the dam as a weapon during a violent conflict.   | Choe (2009)                              |
| 2010 | Pakistani tribes                 | Development dispute; Military tool | Yes | More than one hundred are dead and scores are injured following two weeks of tribal fighting in Parachinar, in the Kurram region of Pakistan near the Afghanistan border. The conflict over irrigation water began as the Shalozan Tangi tribe cut off supplies to the Shalozan tribe. Some report that Al-Qaeda may be involved; others claim that sectarian violence is to blame, as one group is Sunni Muslim and the other Shiite.   | <i>Express Tribune</i> (2010); AP (2010) |

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## Water Conflict Chronology *continued*

| Date | Parties Involved                 | Basis of Conflict                    | Violent Conflict or in the Context of Violence? |    | Description  | Sources                      |
|------|----------------------------------|--------------------------------------|---|----|--|------------------------------|
|      |                                  |                                      | Yes   | No |  |                              |
| 2010 | Afghanistan                      | Terrorism                            | Yes   |    | A remote-controlled bomb hidden in a water truck kills three people, including two children, in the eastern Afghan province of Khost, which borders Pakistan.  | AP (2009)                    |
| 2010 | Pakistani Mangal, Tori tribes    | Development dispute                  | Yes   |    | A water dispute in Pakistan's tribal region leads to 116 deaths. In early September, the Mangal tribe cuts off the supply of irrigation water to lands used by the neighboring Tori tribe, leading to fighting.  | CNN (2010)                   |
| 2010 | India                            | Development dispute                  | Yes   |    | A protest over water shortages in the National Capital Territory of Delhi in India leads to violence. Erratic water supply and cutoffs in the Kondli area of Mayur Vihar in East Delhi cause a violent protest and several injuries.   | Gosh (2010)                  |
| 2010 | Guatemala                        | Development dispute                  | Yes   |    | Two unidentified gunmen on a motorbike shoot an activist protesting the impacts of mining on water quality and local water rights.   | Amnesty International (2012) |
| 2010 | Protestors, authorities in India | Development dispute                  | Yes   |    | At least three deaths and dozens of injuries are reported during protests over land and water given away for a power plant in Sompeta, in Srikakulam District in Andhra Pradesh, India.  | <i>The Hindu</i> (2010)      |
| 2011 | Yemen                            | Military target                      | Yes   |    | Violence in Yemen's capital, Sana'a, leads to "acute water and power shortages, forcing residents to rely on power generators and buy water extracted from wells and sold on a thriving black market." The violence arises during the Yemeni uprising during the Arab Spring protests across the Middle East. During the violence, governmental soldiers shell neighborhoods and destroy many rooftop water tanks. | Shah (2012)                  |
| 2011 | Solomon Islands                  | Development dispute                  | Yes   |    | Amnesty International reports that women in the slums of the Solomon Islands must walk more than a kilometer to fetch clean water and are "continually harassed, attacked, and raped." A survey shows that 92 percent of households do not have a tap in their home and that local water sources are often polluted, forcing women to walk through unsafe areas.   | Amnesty International (2011) |
| 2011 | Israel, Palestinians             | Development dispute; Military target | Yes   |    | Israel's military destroys nine water tanks in the Bedouin village of Amniyr in the South Hebron Hills in the West Bank, Palestine. Later, soldiers destroy pumps and wells in the Jordan Valley villages of Al-Nasaryah, Al-Akrabanyah, and Beit Hassan.  | Aburawa (2011)               |
| 2011 | Israel, Palestine                | Development dispute; Military target | Yes   |    | Israelis from nearby settlements attack Qasra, a West Bank village of 6,000, destroying crops and a water well. Attackers previously burned down a mosque and damaged hundreds of olive trees.   | Bsharat and Ramadan (2011)   |

|           |             |                                    |     |   |   |
|-----------|-------------|------------------------------------|-----|---|---|
| 2011–2012 | Syria       | Development dispute; Military goal | Yes | Severe political conflict in Syria has been aggravated by the multiyear drought gripping the region. More than 1.5 million people—mostly farmers and their families—have moved to cities and their outskirts. In 2008, US diplomats in Syria warned that the influx of rural people to cities “could act as a multiplier on social and economic pressures already at play and undermine stability in Syria.” Political unrest begins in March 2011 in Dara’a and soon escalates into civil war as ousters seek to overturn the regime of President Bashar al-Assad and the ruling Ba’ath Party. | Mohhtadi (2012); Worth (2010); Femia and Werrell (2012) |
| 2012      | Libya       | Military tool                      | Yes | During the 2011 Libyan Civil War, forces loyal to dictator Muammar Gaddafi gain control of a water operations center and cut off water supply to the capital. The system controls Libya’s “Great Manmade River”—a system of pumps, pipes, and canals that brings water from distant aquifers to Tripoli and other cities. Half the country is left without running water, prompting the United Nations and neighboring countries to mobilize tanker ships to deliver water to coastal cities.   | Circle of Blue (2011); UPI (2011)                       |
| 2012      | Afghanistan | Terrorism                          | Yes | Up to 150 schoolgirls are reported sickened by poison in a school water supply in an intentional attack thought to have been carried out by religious conservatives opposed to the education of women.  | Hamid (2012)  |
| 2012      | Afghanistan | Terrorism                          | Yes | Seven children are killed by a bomb thought to have been intended for Afghan police and planted at a freshwater spring in Ghor Province.  | Shah (2012)   |
| 2012      | Afghanistan | Military target; Terrorism         | Yes | Islamist militants execute militia members defending the Machalgho Dam in eastern Afghanistan. The dam is being developed for irrigation and local power supply. This dispute is one of several surrounding the international waters of Afghanistan, Iran, and Pakistan, which share several rivers.  | Mashal (2012)   |
| 2012      | India       | Development dispute                | Yes | Thousands of farmers in Karnataka try to prevent the release of water from two dams (Krishna Raja Sagar and Kabini) on the Cauvery River. Injuries to protestors and police are reported. The water releases were ordered by the Supreme Court of India, which required Karnataka to deliver water to the downstream state of Tamil Nadu despite severe drought. The dispute continues later in the year when Karnataka again halts releases.   | Circle of Blue (2012); <i>Indian Express</i> (2012)     |
| 2012      | India       | Development dispute                | Yes | Scuffles and protests break out around New Delhi during the summer as residents surround water delivery trucks and fight over water. The summer is the hottest in thirty-three years, leading to extensive energy and water shortages.  | Reuters (2012a)   |

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## Water Conflict Chronology *continued*

| Date | Parties Involved | Basis of Conflict                    | Violent Conflict or in the Context of Violence? |                 | Description   | Sources                         |
|------|------------------|--------------------------------------|---|-----------------|---|---------------------------------|
|      |                  |                                      | Yes   | No              |   |                                 |
| 2012 | India, Pakistan  | Development dispute; Military target | Yes   |                 | Violence erupts in the latest event in the dispute between Pakistan and India over the waters of the Indus River basin. Pakistani militants attack and sabotage water systems, flood protection works, and dams in the Wullar Lake region of northern Kashmir. They attack engineers and workers and detonate explosives at the unfinished Tulbul Navigation Lock/Wullar Dam. Pakistan claims the new dam violates the Indus Water Treaty by cutting flows to Pakistan. | UI Hassan (2012)                |
| 2012 | Brazil           | Development dispute                  | Yes   |                 | Brazil's federal police respond to reports that water used by the indigenous Guarani-Kaiowa tribe has been poisoned by nearby landowners attempting to gain control over disputed land. Since 2009, the dispute has led to the deaths of three tribesmen; tribesmen say the water runs through sacred land.   | AP (2012)                       |
| 2012 | Brazil           | Development dispute                  |   | Property damage | Work on the controversial \$13 billion Belo Monte Dam is halted after protesters burn buildings at three dam sites.   | Phys.org (2012)                 |
| 2012 | Brazil           | Development dispute                  | Yes   |                 | Northeastern Brazil sees growing conflicts after severe drought reduces water availability. News agencies report that one person a day is being killed in "water wars" that involve locals fighting over scarce supplies.   | Catholic Online (2012)          |
| 2012 | Peru             | Development dispute                  | Yes   |                 | Several incidents of protests, injuries, and deaths are reported in regions of Peru where residents oppose large mines because of concerns over water quality and water rights. Police kill four protesters in clashes over the proposed Canadian-operated \$5 billion Minas Conga gold mine.   | Reuters (2012b); Yeager (2012)  |
| 2012 | Peru             | Development dispute                  | Yes   |                 | Protests because of concerns over water quality and water rights around the Xstrata Tintaya copper mine lead to two deaths and fifty injuries.  | Reuters (2012c)                 |
| 2012 | Egypt            | Development dispute                  | Yes   |                 | Farmers from the Abu Simbel region in Egypt hold over 200 tourists hostage to protest inadequate irrigation water. The farmers had captured the tourists after they visited nearby monuments. They release them after officials agree to a temporary release of water.  | <i>Egypt Independent</i> (2012) |
| 2012 | Egypt            | Development dispute                  | Yes   |                 | Public protests over drinking and irrigation water shortages take place across Egypt. Several protests turn violent: in Beni Suef, one person is killed and many are injured during a conflict over irrigation water; in Minya, villagers clash with officials over water shortages and water pollution; in Fayyoom, hundreds of people protesting water shortages block a highway and set fires.   | Ooska News (2012)               |



|      |  |                                      |     |  |   |
|------|--|--------------------------------------|-----|--|---|
| 2012 | Somalia, Kenya   | Military target                      | Yes | Somali Al-Shabaab insurgents poison a well and damage water infrastructure near the port city of Kismayo, Somalia. Insurgents are fighting Kenyan peacekeeping troops participating in the African Union mission in Somalia.   | Wabala (2012)                                       |
| 2012 | Kenya  | Development dispute                  | Yes | Violence, including several deaths, occurs during disputes over access to water in the poorest slums around Nairobi, Kenya.  | Njeru (2012)  |
| 2012 | Tajikistan, Uzbekistan                                       | Development dispute                  | Yes | Uzbekistan cuts natural gas deliveries to Tajikistan in retaliation over a Tajik hydroelectric dam that Uzbeks say will disrupt water supplies. Gas flows resume after a new contract is signed.   | Kozhevnikov (2012)                                  |
| 2012 | Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, Kazakhstan | Development dispute                  | No  | Tensions escalate over two proposed dams in central Asia: Kambarata-1 in Kyrgyzstan and the Rogun Dam in Tajikistan. These dams could affect water supplies in the downstream nations of Uzbekistan, Turkmenistan, and Kazakhstan. Uzbekistan's president, Islam Karimov, says the dams could cause "not just serious confrontation, but even wars."   | <i>The Economist</i> (2012)                         |
| 2012 | Sudan, South Sudan   | Development dispute                  | Yes | Violence breaks out at water points in the Jamam refugee camp in South Sudan. Médecins Sans Frontières reports that as many as ten refugees die every day because of water shortages at refugee camps in South Sudan.  | McNeish (2012); Ferrie (2012)                       |
| 2012 | Egypt, Ethiopia, Sudan                                       | Development dispute; Military target | Yes | Information is leaked about an alleged secret agreement that would allow Egypt to build an air base in Sudan to attack the Grand Ethiopian Renaissance Dam (GERD). Egypt is concerned that the dam, under construction in Ethiopia just upstream of Sudan on the Blue Nile, would reduce flows into its territory. The news reports, strongly denied by Egypt, claim that Sudan would allow Egypt to launch attacks if diplomatic efforts fail to resolve water-sharing disputes between Egypt and Ethiopia. The allegations are based on an internal 2010 e-mail made available by Wikileaks. | <i>Sudan Tribune</i> (2012); Al Arabiya News (2012) |
| 2012 | Mali, Burkina Faso   | Development dispute                  | Yes | A clash along the border between Dogon villagers from Mali and nomadic Fulani herders from Burkina Faso kills at least thirty people after an earlier agreement to share water and pastureland is revoked. Chaos following a military coup in March is partly responsible for the breakdown in law and order in Mali.  | Xinhua News (2012b)                                 |
| 2012 | Mali, Mauritania   | Development dispute                  | Yes | Protests and violence over water shortages erupt in the capital of Mauritania, Nouakchott. By July, over 70,000 Malian refugees are seeking asylum in Mauritania, putting pressure on scarce food and water supplies.  | Taha (2012)   |

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## Water Conflict Chronology *continued*

| Date      | Parties Involved | Basis of Conflict   | Violent Conflict or in the Context of Violence? |    | Description   | Sources                              |
|-----------|------------------|---------------------|---|----|---|--------------------------------------|
|           |                  |                     | Yes   | No |   |                                      |
| 2012      | Somalia          | Development dispute | Yes   |    | In August, fighting between two clans in the Lower Jubba region of south Somalia kills at least three people and wounds five. Reports from the village of Waraq (near the border with Kenya) indicate that the dispute began over the ownership of new water wells.   | Shabelle Media Network (2012)        |
| 2012      | Uganda, Kenya    | Development dispute | Yes   |    | Tensions lead to violence between Uganda and Kenya after Kenyan Pokot herdsmen cross the border seeking water and pasture. In October, the Ugandan government sends 5,000 soldiers to control violence among pastoralists from the two countries.   | Bii (2012)                           |
| 2012      | Tanzania         | Development dispute | Yes   |    | Violence between farmers and pastoralists expands in Tanzania's southeastern Rufiji Valley, a region hit by drought. A farmer is killed in a conflict with a herdsman over access to water in the southern regions of Lindi and Mtwara. Five more people die and many more are injured in subsequent violence. According to local sources, violence has worsened during the prolonged drought.  | Makoye (2012)                        |
| 2012      | South Africa     | Development dispute | Yes   |    | Protesters in poor communities of Cape Town, South Africa, riot over inadequate water and power. Hundreds burn tires, destroy cars, and throw rocks at police in anger over the lack of basic services.   | Xinhua News (2012a)                  |
| 2012      | Syria            | Military target     | Yes   |    | During the Syrian Civil War, the major pipeline delivering water to the city of Aleppo is badly damaged. The city of 3 million suffers severe shortages of drinking water.  | BBC (2012a)                          |
| 2012      | Syria            | Military target     | Yes   |    | In November, Syrian rebels fighting the government of President Bashar al-Assad overrun governmental forces and capture the Tishrin hydroelectric dam on the Euphrates River, after days of heavy clashes. The dam supplies electricity to part of Syria and is considered strategically important to the Syrian regime.  | Mroue (2012)                         |
| 2012      | Indonesia        | Development dispute | Yes   |    | Violence breaks out over access to a water source in Maluku, Indonesia. Rival mobs from two villages attack each other "with sharp weapons, guns and explosives," causing several deaths and injuries.  | Antara (2012)                        |
| 2012–2013 | Kenya            | Development dispute | Yes   |    | Extensive violence over water is reported in Kenya, with more than one hundred deaths in clashes between farmers and cattle herders. The conflict is part of a long-running dispute between Pokomo farmers and Orma people, seminomadic cattle herders, over land and water. The current conflict is exacerbated by Kenyan and foreign investment in vast tracts of land for food and biofuel cultivation, putting pressure on local resources. (See also the entry in 2001.) | AFP (2012); <i>Wikipedia</i> (2013b) |

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# Total Renewable Freshwater Supply by Country (2013 Update)

## Description

Average annual renewable freshwater resources are listed by country, updating data table 1 in the previous versions of *The World's Water*. Data in this table from the AQUASTAT database of the Food and Agriculture Organization of the United Nations (FAO) were updated to reflect the most recent data in that database as of May 2013. However, because these data are typically produced by modeling or estimation, rather than measurement, we continue to use data from other sources where appropriate (even if older than data in AQUASTAT). For example, most data for European countries come from the Eurostat data set of the European Union. Data for Timor-Leste and for the Occupied Palestinian Territory (as defined by AQUASTAT) were added in this volume.

Data in this table typically comprise both renewable surface water and groundwater supplies, including surface inflows from neighboring countries. The FAO refers to this as total natural renewable water resources. Flows to other countries are not subtracted from these numbers. All quantities are in cubic kilometers per year (km<sup>3</sup>/yr). These data represent average freshwater resources in a country—actual annual renewable supply will vary from year to year.

## Limitations

These detailed country data should be viewed, and used, with caution. The data come from different sources and were estimated over different periods. Many countries do not directly measure or report internal water resources data, so some of these entries were produced using indirect methods.

Not all of the annual renewable water supply is available for use by the countries to which it is credited here; some flows are committed to downstream users. For example, under treaty requirements, Sudan must pass significant flows downstream to Egypt. Other countries, such as Turkey, Syria, and France, to name only a few, also pass significant amounts of water to other users. The annual average figures hide large seasonal, interannual, and long-term variations.

## Sources

The 2013 update was compiled by P. H. Gleick, Pacific Institute.

When a recent source uses older data previously cited here, we have tried to leave the original citation date and source.

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**DATA TABLE 1** Total Renewable Freshwater Supply by Country (2013 Update)

| Region        | Country  | Annual Renewable Water Resources (km <sup>3</sup> /yr) | Year of Estimate | Source of Estimate |
|---------------|--|--|------------------|--------------------|
| <b>AFRICA</b> | Algeria  | 11.6   | 2005             | c                  |
|               | Angola   | 148.0  | 2011             | i                  |
|               | Benin  | 25.8   | 2001             | j                  |
|               | Botswana                                       | 12.2   | 2011             | i                  |
|               | Burkina Faso                                   | 12.5   | 2011             | i                  |
|               | Burundi  | 12.5   | 2011             | i                  |
|               | Cameroon                                       | 285.5  | 2003             | k                  |
|               | Cape Verde                                     | 0.3  | 2005             | c                  |
|               | Central African Republic                       | 144.4  | 2005             | c                  |
|               | Chad   | 43.0   | 1987             | b                  |
|               | Comoros  | 1.2  | 2005             | c                  |
|               | Congo  | 832.0  | 1987             | b                  |
|               | Congo, Democratic Republic<br>(formerly Zaire) | 1283   | 2001             | j                  |
|               | Côte d'Ivoire                                  | 81   | 2001             | j                  |
|               | Djibouti                                       | 0.3  | 2005             | c                  |
|               | Egypt  | 57.3   | 2011             | i                  |
|               | Equatorial Guinea                              | 26   | 2001             | j                  |
|               | Eritrea  | 6.3  | 2001             | j                  |
|               | Ethiopia                                       | 122.0  | 2011             | i                  |
|               | Gabon  | 164.0  | 1987             | b                  |
|               | Gambia   | 8.0  | 2005             | c                  |
|               | Ghana  | 53.2   | 2001             | j                  |
|               | Guinea   | 226.0  | 1987             | b                  |
|               | Guinea-Bissau                                  | 31.0   | 2005             | c                  |
|               | Kenya  | 30.7   | 2005             | c                  |
|               | Lesotho  | 3.0  | 2011             | i                  |
|               | Liberia  | 232.0  | 1987             | b                  |
|               | Libya  | 0.6  | 2005             | c                  |
|               | Madagascar                                     | 337.0  | 2005             | c                  |
|               | Malawi   | 17.3   | 2001             | j                  |
|               | Mali   | 100.0  | 2005             | c                  |
|               | Mauritania                                     | 11.4   | 2005             | c                  |
|               | Mauritius                                      | 2.8  | 2005             | c                  |
|               | Morocco  | 29.0   | 2005             | c                  |
|               | Mozambique                                     | 217.1  | 2005             | c                  |
|               | Namibia  | 17.7   | 2005             | c                  |
|               | Niger  | 33.7   | 2005             | c                  |
|               | Nigeria  | 286.2  | 2005             | c                  |
|               | Réunion  | 5.0  | 1988             | k                  |
|               | Rwanda   | 9.5  | 2005             | c                  |
|               | Senegal  | 38.8   | 2011             | i                  |
|               | Sierra Leone                                   | 160.0  | 1987             | b                  |
|               | Somalia  | 14.2   | 2005             | c                  |
|               | South Africa                                   | 51.4   | 2011             | i                  |
|               | Sudan  | 64.5   | 2005             | c                  |
|               | Swaziland                                      | 4.5  | 1987             | b                  |
|               | Tanzania                                       | 96.3   | 2011             | i                  |

*continues*

DATA TABLE 1 *continued*

| Region                                       | Country                  | Annual Renewable<br>Water Resources (km <sup>3</sup> /yr) | Year of<br>Estimate | Source of<br>Estimate |
|--|--------------------------|---|---------------------|-----------------------|
|  | Togo                     | 14.7  | 2001                | j                     |
|  | Tunisia                  | 4.6   | 2005                | c                     |
|  | Uganda                   | 66.0  | 2005                | c                     |
|  | Zambia                   | 105.2   | 2001                | j                     |
|  | Zimbabwe                 | 20.0  | 1987                | b                     |
| <b>NORTH<br/>AND<br/>CENTRAL<br/>AMERICA</b> | Antigua and Barbuda      | 0.1   | 2000                | h                     |
|  | Bahamas                  | 0.0   | 2011                | i                     |
|  | Barbados                 | 0.1   | 2003                | k                     |
|  | Belize                   | 18.6  | 2000                | h                     |
|  | Canada                   | 2902.0  | 2011                | i                     |
|  | Costa Rica               | 112.4   | 2000                | h                     |
|  | Cuba                     | 38.1  | 2000                | h                     |
|  | Dominica                 | nd  | nd                  |                       |
|  | Dominican Republic       | 21.0  | 2000                | h                     |
|  | El Salvador              | 25.2  | 2001                | j                     |
|  | Grenada                  | nd  | nd                  |                       |
|  | Guatemala                | 111.3   | 2000                | h                     |
|  | Haiti                    | 14.0  | 2000                | h                     |
|  | Honduras                 | 95.9  | 2000                | h                     |
|  | Jamaica                  | 9.4   | 2000                | h                     |
|  | Mexico                   | 457.2   | 2000                | h                     |
|  | Nicaragua                | 196.7   | 2000                | h                     |
|  | Panama                   | 148.0   | 2000                | h                     |
|  | St. Kitts and Nevis      | 0.02  | 2000                | h                     |
|  | Trinidad and Tobago      | 3.8   | 2000                | h                     |
|  | United States of America | 3069.0  | 1985                | l                     |
| <b>SOUTH<br/>AMERICA</b>                     | Argentina                | 814.0   | 2000                | h                     |
|  | Bolivia                  | 622.5   | 2000                | h                     |
|  | Brazil                   | 8233.0  | 2000                | h                     |
|  | Chile                    | 922.0   | 2000                | h                     |
|  | Colombia                 | 2132.0  | 2000                | h                     |
|  | Ecuador                  | 424.0   | 2011                | i                     |
|  | Guyana                   | 241.0   | 2000                | h                     |
|  | Paraguay                 | 336.0   | 2000                | h                     |
|  | Peru                     | 1913.0  | 2000                | h                     |
|  | Suriname                 | 122.0   | 2003                | k                     |
|  | Uruguay                  | 139.0   | 2000                | h                     |
|  | Venezuela                | 1233.2  | 2000                | h                     |
| <b>ASIA</b>                                  | Afghanistan              | 65.3  | 2011                | i                     |
|  | Bahrain                  | 0.1   | 2008                | u                     |
|  | Bangladesh               | 1227.0  | 1999                | f                     |
|  | Bhutan                   | 78.0  | 2011                | i                     |
|  | Brunei                   | 8.5   | 2011                | i                     |
|  | Cambodia                 | 476.1   | 1999                | f                     |
|  | China                    | 2738.8  | 2008                | r                     |
|  | India                    | 1911.0  | 2011                | i                     |
|  | Indonesia                | 2019.0  | 2011                | i                     |
|  | Iran                     | 137.5   | 2008                | u                     |

|                                    |        |      |      |
|------------------------------------|--------|------|------|
| Iraq                               | 89.9   | 2011 | i    |
| Israel                             | 1.8    | 2008 | u    |
| Japan                              | 430.0  | 1999 | f    |
| Jordan                             | 0.9    | 2008 | u    |
| Korea Democratic People's Republic | 77.1   | 1999 | f    |
| Korea Republic                     | 69.7   | 1999 | f    |
| Kuwait                             | 0.02   | 2008 | u    |
| Laos                               | 333.6  | 2003 | k    |
| Lebanon                            | 4.5    | 2008 | u    |
| Malaysia                           | 580.0  | 1999 | f    |
| Maldives                           | 0.03   | 1999 | f    |
| Mongolia                           | 34.8   | 1999 | f    |
| Myanmar                            | 1168.0 | 2011 | i    |
| Nepal                              | 210.2  | 1999 | f    |
| Oman                               | 1.4    | 2008 | u    |
| Pakistan                           | 247.0  | 2011 | i    |
| Palestinian Territory, Occupied    | 0.8    | 2011 | i    |
| Philippines                        | 479.0  | 1999 | f    |
| Qatar                              | 0.1    | 2008 | u    |
| Saudi Arabia                       | 2.4    | 2008 | u    |
| Singapore                          | 0.6    | 1975 | d    |
| Sri Lanka                          | 52.8   | 2011 | i    |
| Syria                              | 16.8   | 2008 | u    |
| Taiwan                             | 67.0   | 2000 | p    |
| Thailand                           | 438.6  | 2011 | i    |
| Turkey                             | 211.6  | 2011 | i    |
| United Arab Emirates               | 0.2    | 2008 | u    |
| Vietnam                            | 884.0  | 2011 | i    |
| Yemen                              | 2.1    | 2008 | u    |
| <b>EUROPE</b>                      |        |      |      |
| Albania                            | 41.7   | 2001 | n    |
| Austria                            | 84.0   | 2007 | s    |
| Belgium                            | 20.0   | 2007 | s    |
| Bosnia and Herzegovina             | 37.5   | 2003 | k    |
| Bulgaria                           | 107.2  | 2010 | s    |
| Croatia                            | 105.5  | 1998 | m, o |
| Cyprus                             | 0.3    | 2007 | s    |
| Czech Republic                     | 16.0   | 2007 | s    |
| Denmark                            | 16.3   | 2007 | s    |
| Estonia                            | 12.3   | 2007 | s    |
| Finland                            | 110.0  | 2007 | s    |
| France                             | 186.3  | 2007 | s    |
| Germany                            | 188.0  | 2007 | s    |
| Greece                             | 72.0   | 2007 | s    |
| Hungary                            | 116.4  | 2007 | s    |
| Iceland                            | 170.0  | 2007 | s    |
| Ireland                            | 51.0   | 2013 | s    |
| Italy                              | 175.0  | 2007 | s    |
| Luxembourg                         | 1.6    | 2007 | s    |
| Macedonia                          | 6.4    | 2001 | n    |
| Malta                              | 0.07   | 2005 | s    |
| Netherlands                        | 89.7   | 2007 | s    |

*continues*



DATA TABLE 1 *continued*

| Region         | Country            | Annual Renewable<br>Water Resources (km <sup>3</sup> /yr) | Year of<br>Estimate | Source of<br>Estimate |
|----------------|--------------------|---|---------------------|-----------------------|
|                | Norway             | 384.0   | 2013                | s                     |
|                | Poland             | 63.1  | 2007                | s                     |
|                | Portugal           | 73.6  | 2007                | s                     |
|                | Romania            | 42.3  | 2013                | s                     |
|                | Serbia-Montenegro* | 208.5   | 2003                | k                     |
|                | Slovakia           | 80.3  | 2013                | s                     |
|                | Slovenia           | 32.1  | 2007                | s                     |
|                | Spain              | 111.1   | 2007                | s                     |
|                | Sweden             | 186.2   | 2013                | s                     |
|                | Switzerland        | 53.5  | 2007                | s                     |
|                | United Kingdom     | 164.0   | 2013                | s                     |
| <b>FORMER</b>  | Armenia            | 7.8   | 2008                | u                     |
| <b>SOVIET</b>  | Azerbaijan         | 34.7  | 2008                | u                     |
| <b>UNION</b>   | Belarus            | 58.0  | 1997                | e                     |
|                | Estonia            | 12.8  | 1997                | e                     |
|                | Georgia            | 63.3  | 2008                | u                     |
|                | Kazakhstan         | 107.5   | 2011                | i                     |
|                | Kyrgyzstan         | 23.6  | 2011                | i                     |
|                | Latvia             | 33.7  | 2011                | i                     |
|                | Lithuania          | 24.5  | 2007                | s                     |
|                | Moldova            | 11.7  | 1997                | e                     |
|                | Russia             | 4508.0  | 2011                | i                     |
|                | Tajikistan         | 21.9  | 2011                | i                     |
|                | Turkmenistan       | 24.8  | 2011                | i                     |
|                | Ukraine            | 139.5   | 1997                | e                     |
|                | Uzbekistan         | 48.9  | 2011                | i                     |
| <b>OCEANIA</b> | Australia          | 336.1   | 2005                | t                     |
|                | Fiji               | 28.6  | 1987                | b                     |
|                | New Zealand        | 397.0   | 1995                | g                     |
|                | Papua New Guinea   | 801.0   | 1987                | b                     |
|                | Solomon Islands    | 44.7  | 1987                | b                     |
|                | Timor-Leste        | 8.2   | 2011                | i                     |

\*Referred to as Yugoslavia in previous volumes of *The World's Water*.

# Freshwater Withdrawal by Country and Sector (2013 Update)

## Description

As with data table 1, this table on freshwater withdrawals has appeared in some form in every volume of *The World's Water* and remains highly popular. The use of water varies greatly from country to country and from region to region. Data on water use by regions and by different economic sectors are among the most sought after in the water resources area. Ironically, these data are often the least reliable and most inconsistent of all water resources information. This table includes the data available on total freshwater withdrawals by country in cubic kilometers per year and cubic meters per person per year, using national population estimates from 2010. The table also gives the breakdown of that water use by the municipal, agricultural, and industrial sectors, in both percentage of total water use and cubic meters per person per year. Note that “municipal” withdrawals were previously called “domestic” withdrawals and now often include some estimates of commercial and institutional use in the single category.

Data for a number of countries have been updated in this table since the previous volume of *The World's Water*. The AQUASTAT database of the Food and Agriculture Organization of the United Nations (FAO) continues to provide the bulk of the data, but we also work to update water-use data using country-specific sources. The data sources are explicitly identified.

“Withdrawal” typically refers to water taken from a water source for use. It does not refer to water “consumed” in that use. The domestic sector typically includes household and municipal uses as well as commercial and governmental water use. The industrial sector includes water used for power plant cooling and industrial production. The agricultural sector includes water for irrigation and livestock.

## Limitations

Extreme care should be used when applying these data. They come from a wide variety of sources and are collected using a wide variety of approaches, with few formal standards. As a result, this table includes data that are actually measured, estimated, modeled using different assumptions, or derived from other data. The data also come from different years, making direct intercomparisons difficult. For example, some water-use data are over twenty years old. Also note that the per capita water-use estimates are computed using withdrawals from different years, but population estimates are normalized for 2010.

As noted in past volumes of *The World's Water*, the FAO AQUASTAT data set, while the most comprehensive single database, contains inadequate information on sources and assumptions and often contains modeled rather than measured values. Data from this database should be used with great care and with appropriate caveats about their quality.

Another major limitation of these data is that they do not include the use of rainfall in agriculture—what is sometimes referred to as “green water.” Many countries use a significant fraction of the rain falling on their territory for agricultural production, but this water use is neither accurately measured nor reported in this data set. We repeat our regular call for a systematic reassessment of water-use data and for national and international commitments to collect and standardize this information.

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**DATA TABLE 2** Freshwater Withdrawal by Country and Sector (2013 Update)

| Region            | Country  | Year | Total<br>Freshwater<br>Withdrawal<br>(km <sup>3</sup> /yr) | Per<br>Capita<br>Withdrawal<br>(m <sup>3</sup> /p/yr) | Domestic   |                      | Industrial |                      | Agricultural |                      | Source | 2010<br>Population<br>(millions) |
|-------------------|--|------|--|---|------------|----------------------|------------|----------------------|--------------|----------------------|--------|----------------------------------|
|                   |  |      |  |   | Use<br>(%) | m <sup>3</sup> /p/yr | Use<br>(%) | m <sup>3</sup> /p/yr | Use<br>(%)   | m <sup>3</sup> /p/yr |        |                                  |
| AFRICA            | Algeria  | 2001 | 5.70   | 161   | 24         | 39                   | 15         | 61                   | 24           | 98                   | f      | 35.42                            |
|                   | Angola   | 2005 | 0.70   | 37  | 45         | 17                   | 34         | 21                   | 13           | 8                    | f      | 18.99                            |
|                   | Benin  | 2001 | 0.13   | 14  | 32         | 5                    | 23         | 45                   | 3            | 6                    | f      | 9.21                             |
|                   | Botswana                                       | 2000 | 0.19   | 96  | 41         | 39                   | 18         | 41                   | 17           | 39                   | f      | 1.98                             |
|                   | Burkina Faso                                   | 2001 | 0.72   | 44  | 39         | 17                   | 2          | 59                   | 1            | 26                   | f      | 16.29                            |
|                   | Burundi  | 2000 | 0.29   | 34  | 17         | 6                    | 6          | 77                   | 2            | 26                   | f      | 8.52                             |
|                   | Cameroon                                       | 2000 | 0.97   | 49  | 17         | 8                    | 7          | 76                   | 3            | 37                   | f      | 19.96                            |
|                   | Cape Verde                                     | 2000 | 0.02   | 39  | 7          | 3                    | 2          | 91                   | 1            | 36                   | f      | 0.51                             |
|                   | Central African Republic                       | 2005 | 0.07   | 16  | 83         | 13                   | 17         | 1                    | 3            | 0                    | f      | 4.51                             |
|                   | Chad   | 2005 | 0.88   | 76  | 12         | 9                    | 12         | 76                   | 9            | 58                   | f      | 11.51                            |
|                   | Comoros  | 1999 | 0.01   | 14  | 48         | 7                    | 5          | 47                   | 1            | 7                    | f      | 0.69                             |
|                   | Congo, Democratic Republic<br>(formerly Zaire) | 2005 | 0.68   | 10  | 68         | 7                    | 21         | 11                   | 2            | 1                    | f      | 67.83                            |
|                   | Congo, Republic of                             | 2000 | 0.05   | 13  | 70         | 9                    | 22         | 9                    | 3            | 1                    | f      | 3.76                             |
|                   | Côte d'Ivoire                                  | 2005 | 1.50   | 70  | 41         | 29                   | 21         | 38                   | 15           | 26                   | f      | 21.57                            |
|                   | Djibouti                                       | 2000 | 0.02   | 23  | 84         | 19                   | 0          | 16                   | 0            | 4                    | f      | 0.88                             |
|                   | Egypt  | 2000 | 68.30  | 809   | 8          | 62                   | 6          | 86                   | 49           | 695                  | f      | 84.47                            |
| Equatorial Guinea | 2000   | 0.02 | 29   | 79  | 23         | 15                   | 6          | 4                    | 2            | f                    | 0.69   |                                  |
| Eritrea           | 2004   | 0.58 | 111  | 5   | 6          | 0                    | 95         | 0                    | 105          | f                    | 5.22   |                                  |
| Ethiopia          | 2002   | 5.60 | 66   | 6   | 4          | 0                    | 94         | 0                    | 62           | f                    | 84.98  |                                  |
| Gabon             | 2005   | 0.14 | 93   | 61  | 57         | 10                   | 29         | 9                    | 27           | f                    | 1.50   |                                  |
| Gambia            | 2000   | 0.09 | 51   | 38  | 20         | 19                   | 43         | 10                   | 22           | f                    | 1.75   |                                  |
| Ghana             | 2000   | 0.98 | 40   | 24  | 10         | 10                   | 66         | 4                    | 27           | f                    | 24.33  |                                  |
| Guinea            | 2001   | 0.55 | 53   | 38  | 20         | 9                    | 53         | 5                    | 28           | f                    | 10.32  |                                  |

*continues*

**Data Table 2.** *continued*

| Region                | Country       | Year  | Total<br>Freshwater<br>Withdrawal (km <sup>3</sup> /yr) | Per<br>Capita<br>Withdrawal (m <sup>3</sup> /p/yr) | Domestic Use (%) |                   |                     | Industrial Use (%) |                   |                     | Agricultural Use (%) |                   |                     | Source | 2010<br>Population<br>(millions) |
|-----------------------|---------------|-------|---|--|------------------|-------------------|---------------------|--------------------|-------------------|---------------------|----------------------|-------------------|---------------------|--------|----------------------------------|
|                       |               |       |   |  | Domestic<br>Use  | Industrial<br>Use | Agricultural<br>Use | Domestic<br>Use    | Industrial<br>Use | Agricultural<br>Use | Domestic<br>Use      | Industrial<br>Use | Agricultural<br>Use |        |                                  |
| AFRICA,<br>cont.      | Guinea-Bissau | 2000  | 0.18  | 109  | 13               | 5                 | 82                  | 14                 | 5                 | 90                  | f                    | 1.65              |                     |        |                                  |
|                       | Kenya         | 2003  | 2.74  | 67   | 17               | 4                 | 79                  | 11                 | 2                 | 53                  | f                    | 40.86             |                     |        |                                  |
|                       | Lesotho       | 2000  | 0.04  | 19   | 46               | 46                | 9                   | 9                  | 9                 | 2                   | f                    | 2.08              |                     |        |                                  |
|                       | Liberia       | 2000  | 0.13  | 32   | 54               | 36                | 9                   | 17                 | 11                | 3                   | f                    | 4.10              |                     |        |                                  |
|                       | Libya         | 2000  | 4.30  | 657  | 14               | 3                 | 83                  | 92                 | 20                | 545                 | f                    | 6.55              |                     |        |                                  |
|                       | Madagascar    | 2000  | 16.50   | 819  | 1                | 1                 | 98                  | 8                  | 8                 | 803                 | f                    | 20.15             |                     |        |                                  |
|                       | Malawi        | 2005  | 1.40  | 89   | 11               | 4                 | 86                  | 10                 | 4                 | 77                  | f                    | 15.69             |                     |        |                                  |
|                       | Mali          | 2000  | 6.50  | 488  | 9                | 1                 | 90                  | 44                 | 5                 | 439                 | f                    | 13.32             |                     |        |                                  |
|                       | Mauritania    | 2005  | 1.40  | 416  | 7                | 2                 | 91                  | 29                 | 8                 | 379                 | f                    | 3.37              |                     |        |                                  |
|                       | Mauritius     | 2003  | 0.73  | 563  | 30               | 3                 | 68                  | 169                | 17                | 383                 | f                    | 1.30              |                     |        |                                  |
|                       | Morocco       | 2000  | 12.60   | 389  | 10               | 3                 | 87                  | 39                 | 12                | 339                 | f                    | 32.38             |                     |        |                                  |
|                       | Mozambique    | 2001  | 0.88  | 38   | 19               | 3                 | 78                  | 7                  | 1                 | 29                  | f                    | 23.41             |                     |        |                                  |
|                       | Namibia       | 2002  | 0.29  | 131  | 25               | 5                 | 70                  | 33                 | 6                 | 92                  | f                    | 2.212             |                     |        |                                  |
|                       | Niger         | 2005  | 0.98  | 62   | 30               | 3                 | 67                  | 19                 | 2                 | 41                  | f                    | 15.89             |                     |        |                                  |
|                       | Nigeria       | 2005  | 13.00   | 82   | 31               | 15                | 54                  | 25                 | 12                | 44                  | f                    | 158.26            |                     |        |                                  |
|                       | Rwanda        | 2000  | 0.15  | 15   | 24               | 8                 | 68                  | 4                  | 1                 | 10                  | f                    | 10.28             |                     |        |                                  |
|                       | Senegal       | 2002  | 2.22  | 173  | 4                | 3                 | 93                  | 7                  | 5                 | 161                 | f                    | 12.86             |                     |        |                                  |
|                       | Sierra Leone  | 2005  | 0.21  | 36   | 52               | 26                | 22                  | 19                 | 9                 | 8                   | f                    | 5.84              |                     |        |                                  |
|                       | Somalia       | 2003  | 3.30  | 352  | 1                | 0                 | 99                  | 4                  | 0                 | 351                 | f                    | 9.36              |                     |        |                                  |
|                       | South Africa  | 2000  | 12.50   | 248  | 31               | 6                 | 63                  | 77                 | 15                | 156                 | f                    | 50.49             |                     |        |                                  |
| Sudan and South Sudan | 2005          | 27.60 | 639   | 4  | 1                | 95                | 26                  | 4                  | 607               | f                   | 43.19                |                   |                     |        |                                  |
| Swaziland             | 2000          | 1.04  | 865   | 2  | 1                | 97                | 17                  | 9                  | 839               | f                   | 1.20                 |                   |                     |        |                                  |
| Tanzania, Republic of | 2002          | 5.20  | 115   | 10   | 0                | 89                | 12                  | 0                  | 103               | f                   | 45.04                |                   |                     |        |                                  |
| Togo                  | 2002          | 0.17  | 25  | 53   | 2                | 45                | 13                  | 1                  | 11                | f                   | 6.78                 |                   |                     |        |                                  |

|                                  |      |        |       |    |    |    |     |     |      |   |        |
|----------------------------------|------|--------|-------|----|----|----|-----|-----|------|---|--------|
| Tunisia                          | 2001 | 2.85   | 275   | 13 | 4  | 82 | 36  | 11  | 225  | f | 10.37  |
| Uganda                           | 2002 | 0.32   | 9     | 48 | 14 | 38 | 5   | 1   | 4    | f | 33.80  |
| Zambia                           | 2002 | 1.50   | 113   | 18 | 8  | 73 | 20  | 9   | 83   | f | 13.26  |
| Zimbabwe                         | 2002 | 4.21   | 333   | 14 | 7  | 79 | 47  | 23  | 263  | f | 12.64  |
| <b>NORTH AND CENTRAL AMERICA</b> |      |        |       |    |    |    |     |     |      |   |        |
| Antigua and Barbuda              | 2005 | 0.008  | 90    | 63 | 21 | 15 | 57  | 19  | 14   | f | 0.09   |
| Barbados                         | 2005 | 0.10   | 390   | 20 | 26 | 54 | 78  | 101 | 210  | f | 0.26   |
| Belize                           | 2000 | 0.22   | 703   | 5  | 49 | 46 | 35  | 344 | 323  | f | 0.313  |
| Canada                           | 2006 | 45.08  | 1,330 | 20 | 69 | 12 | 260 | 913 | 157  | g | 33.89  |
| Costa Rica                       | 2003 | 0.54   | 116   |    |    |    | 0   | 0   | 0    | h | 4.64   |
| Cuba                             | 2007 | 4.40   | 393   | 27 | 17 | 56 | 106 | 67  | 220  | f | 11.20  |
| Dominica                         | 2004 | 0.02   | 301   |    |    |    |     |     |      | d | 0.07   |
| Dominican Republic               | 2005 | 5.50   | 538   | 26 | 1  | 72 | 140 | 5   | 387  | f | 10.23  |
| El Salvador                      | 2007 | 1.80   | 291   | 22 | 14 | 64 | 64  | 41  | 186  | f | 6.19   |
| Guatemala                        | 2006 | 3.50   | 243   | 15 | 31 | 54 | 37  | 75  | 131  | f | 14.38  |
| Haiti                            | 2000 | 1.20   | 118   | 19 | 4  | 78 | 22  | 5   | 92   | f | 10.19  |
| Honduras                         | 2006 | 2.10   | 276   | 16 | 23 | 60 | 44  | 63  | 165  | f | 7.62   |
| Jamaica                          | 2000 | 0.41   | 150   | 34 | 17 | 49 | 51  | 26  | 73   | f | 2.73   |
| Mexico                           | 2009 | 80.40  | 727   | 14 | 9  | 77 | 102 | 67  | 557  | f | 110.65 |
| Nicaragua                        | 2001 | 1.40   | 240   | 13 | 2  | 85 | 31  | 5   | 204  | f | 5.82   |
| Panama                           | 2000 | 0.91   | 259   | 23 | 2  | 76 | 60  | 5   | 197  | f | 3.51   |
| St. Lucia                        | 2005 | 0.02   | 115   |    |    |    |     |     |      | d | 0.17   |
| St. Vincent and the Grenadines   | 1995 | 0.01   | 92    |    |    |    |     |     |      | d | 0.11   |
| Trinidad and Tobago              | 2000 | 0.23   | 171   | 66 | 25 | 9  | 113 | 43  | 15   | f | 1.34   |
| United States of America         | 2005 | 482.20 | 1,518 | 13 | 46 | 41 | 193 | 699 | 626  | e | 317.64 |
| <b>SOUTH AMERICA</b>             |      |        |       |    |    |    |     |     |      |   |        |
| Argentina                        | 2000 | 32.60  | 802   | 22 | 12 | 66 | 176 | 96  | 529  | f | 40.67  |
| Bolivia                          | 2000 | 2.60   | 259   | 21 | 12 | 67 | 54  | 31  | 174  | f | 10.03  |
| Brazil                           | 2006 | 58.07  | 297   | 28 | 17 | 55 | 83  | 52  | 162  | f | 195.42 |
| Chile                            | 2007 | 26.70  | 1,558 | 4  | 10 | 86 | 62  | 156 | 1340 | f | 17.13  |
| Colombia                         | 2000 | 12.70  | 274   | 57 | 4  | 39 | 156 | 10  | 107  | f | 46.30  |
| Ecuador                          | 2005 | 9.90   | 719   | 13 | 6  | 81 | 93  | 43  | 582  | f | 13.77  |

*continues*



**Data Table 2.** *continued*

| Region                     | Country     | Year   | Total<br>Freshwater<br>Withdrawal (km <sup>3</sup> /yr) | Per<br>Capita<br>Withdrawal (m <sup>3</sup> /p/yr) | Domestic Use (%) |                   |                     | Industrial Use (%) |                   |                     | Agricultural Use (%) |                   |                     | Source | 2010<br>Population<br>(millions) |
|----------------------------|-------------|--------|---|--|------------------|-------------------|---------------------|--------------------|-------------------|---------------------|----------------------|-------------------|---------------------|--------|----------------------------------|
|                            |             |        |   |  | Domestic<br>Use  | Industrial<br>Use | Agricultural<br>Use | Domestic<br>Use    | Industrial<br>Use | Agricultural<br>Use | Domestic<br>Use      | Industrial<br>Use | Agricultural<br>Use |        |                                  |
| SOUTH<br>AMERICA,<br>cont. | Guyana      | 2000   | 1.64  | 2,154  | 2                | 1                 | 98                  | 36                 | 19                | 2111                | f                    | 0.76              |                     |        |                                  |
|                            | Paraguay    | 2000   | 0.49  | 76   | 20               | 8                 | 71                  | 15                 | 6                 | 54                  | f                    | 6.46              |                     |        |                                  |
|                            | Peru        | 2000   | 19.30   | 654  | 7                | 8                 | 85                  | 46                 | 52                | 556                 | f                    | 29.50             |                     |        |                                  |
|                            | Suriname    | 2000   | 0.67  | 1,278  | 4                | 3                 | 93                  | 57                 | 37                | 1183                | f                    | 0.52              |                     |        |                                  |
|                            | Uruguay     | 2000   | 3.70  | 1,097  | 11               | 2                 | 87                  | 121                | 22                | 955                 | f                    | 3.37              |                     |        |                                  |
|                            | Venezuela   | 2000   | 9.10  | 313  | 49               | 8                 | 44                  | 154                | 25                | 138                 | f                    | 29.04             |                     |        |                                  |
|                            | Afghanistan | 2000   | 20.30   | 697  | 1                | 1                 | 99                  | 7                  | 7                 | 690                 | f                    | 29.12             |                     |        |                                  |
|                            | Armenia     | 2007   | 2.90  | 938  | 30               | 4                 | 66                  | 281                | 41                | 616                 | f                    | 3.09              |                     |        |                                  |
| ASIA                       | Azerbaijan  | 2005   | 12.21   | 1,367  | 4                | 19                | 76                  | 55                 | 260               | 1039                | f                    | 8.93              |                     |        |                                  |
|                            | Bahrain     | 2003   | 0.36  | 442  | 50               | 6                 | 45                  | 221                | 27                | 199                 | f                    | 0.81              |                     |        |                                  |
|                            | Bangladesh  | 2008   | 35.87   | 253  | 10               | 2                 | 88                  | 25                 | 5                 | 222                 | f                    | 141.82            |                     |        |                                  |
|                            | Bhutan      | 2008   | 0.34  | 480  | 5                | 1                 | 94                  | 24                 | 5                 | 451                 | f                    | 0.71              |                     |        |                                  |
|                            | Brunei      | 1994   | 0.09  | 221  | nd               | nd                | nd                  |                    |                   |                     | c                    | 0.41              |                     |        |                                  |
|                            | Cambodia    | 2006   | 2.20  | 146  | 4                | 2                 | 94                  | 6                  | 3                 | 137                 | f                    | 15.05             |                     |        |                                  |
|                            | China       | 2007   | 578.9   | 425  | 12               | 23                | 64                  | 52                 | 99                | 272                 | j                    | 1,361.76          |                     |        |                                  |
|                            | Cyprus      | 2000   | 0.21  | 239  | 27               | 1                 | 71                  | 65                 | 3                 | 170                 | b                    | 0.88              |                     |        |                                  |
|                            | Georgia     | 2005   | 1.80  | 427  | 20               | 22                | 58                  | 85                 | 94                | 247                 | f                    | 4.22              |                     |        |                                  |
|                            | India       | 2010   | 761.00  | 627  | 7                | 2                 | 90                  | 46                 | 14                | 567                 | f                    | 1,214.46          |                     |        |                                  |
| Indonesia                  | 2000        | 113.30 | 487   | 12   | 7                | 82                | 58                  | 34                 | 400               | f                   | 232.52               |                   |                     |        |                                  |
|                            | 2004        | 93.30  | 1,243   | 7  | 1                | 92                | 85                  | 12                 | 1143              | f                   | 75.08                |                   |                     |        |                                  |
| Iraq                       | 2000        | 66.00  | 2,097   | 7  | 15               | 79                | 147                 | 315                | 1657              | f                   | 31.47                |                   |                     |        |                                  |
| Israel                     | 2004        | 1.95   | 268   | 36   | 6                | 58                | 97                  | 16                 | 156               | f                   | 7.29                 |                   |                     |        |                                  |
| Japan                      | 2001        | 90.00  | 709   | 19   | 18               | 63                | 135                 | 127                | 446               | f                   | 127.00               |                   |                     |        |                                  |
| Jordan                     | 2005        | 0.94   | 145   | 31   | 4                | 65                | 45                  | 6                  | 95                | f                   | 6.47                 |                   |                     |        |                                  |
| Kazakhstan                 | 2010        | 21.10  | 1,339   | 4  | 30               | 66                | 54                  | 402                | 884               | f                   | 15.75                |                   |                     |        |                                  |

|                                    |      |        |       |    |    |    |     |     |      |   |        |
|------------------------------------|------|--------|-------|----|----|----|-----|-----|------|---|--------|
| Korea Democratic People's Republic | 2005 | 8.70   | 363   | 10 | 13 | 76 | 36  | 47  | 276  | f | 23.99  |
| Korea Republic                     | 2002 | 25.47  | 525   | 26 | 12 | 62 | 136 | 63  | 326  | f | 48.50  |
| Kuwait                             | 2002 | 0.91   | 299   | 44 | 2  | 54 | 132 | 6   | 162  | f | 3.05   |
| Kyrgyzstan                         | 2006 | 8.00   | 1,441 | 3  | 4  | 93 | 45  | 58  | 1340 | f | 5.55   |
| Laos                               | 2005 | 3.50   | 544   | 4  | 5  | 91 | 23  | 27  | 495  | f | 6.44   |
| Lebanon                            | 2005 | 1.31   | 308   | 29 | 11 | 60 | 89  | 34  | 185  | f | 4.25   |
| Malaysia                           | 2005 | 11.20  | 401   | 35 | 43 | 22 | 140 | 173 | 88   | f | 27.91  |
| Maldives                           | 2008 | 0.006  | 19    | 95 | 5  | 0  | 18  | 1   | 0    | c | 0.31   |
| Mongolia                           | 2009 | 0.55   | 204   | 13 | 43 | 44 | 26  | 88  | 90   | f | 2.70   |
| Myanmar                            | 2000 | 33.23  | 658   | 10 | 1  | 89 | 66  | 4   | 586  | f | 50.50  |
| Nepal                              | 2006 | 9.50   | 318   | 2  | 0  | 98 | 6   | 0   | 312  | f | 29.85  |
| Oman                               | 2003 | 1.32   | 455   | 10 | 1  | 88 | 45  | 5   | 400  | f | 2.91   |
| Pakistan                           | 2008 | 183.50 | 993   | 5  | 1  | 94 | 52  | 8   | 933  | f | 184.75 |
| Palestine Territory, Occupied      | 2005 | 0.42   | 95    | 48 | 7  | 45 | 46  | 7   | 43   | f | 4.41   |
| Philippines                        | 2009 | 81.6   | 872   | 8  | 10 | 82 | 70  | 87  | 715  | f | 93.62  |
| Qatar                              | 2005 | 0.44   | 294   | 39 | 2  | 59 | 115 | 6   | 174  | f | 1.51   |
| Saudi Arabia                       | 2006 | 23.67  | 902   | 9  | 3  | 88 | 81  | 27  | 793  | f | 26.25  |
| Singapore                          | 1975 | 0.19   | 39    | 45 | 51 | 4  | 18  | 20  | 2    | b | 4.84   |
| Sri Lanka                          | 2005 | 13.00  | 637   | 6  | 6  | 87 | 38  | 38  | 554  | f | 20.41  |
| Syria                              | 2005 | 16.80  | 746   | 9  | 4  | 88 | 67  | 30  | 657  | f | 22.51  |
| Tajikistan                         | 2006 | 11.50  | 1,625 | 6  | 4  | 91 | 98  | 65  | 1479 | f | 7.07   |
| Thailand                           | 2007 | 57.31  | 841   | 5  | 5  | 90 | 40  | 41  | 760  | f | 68.14  |
| Turkey                             | 2003 | 40.10  | 530   | 15 | 11 | 74 | 78  | 58  | 393  | f | 75.71  |
| Turkmenistan                       | 2004 | 28.00  | 5,409 | 3  | 3  | 94 | 162 | 162 | 5085 | f | 5.18   |
| United Arab Emirates               | 2005 | 4.00   | 849   | 15 | 2  | 83 | 127 | 17  | 705  | f | 4.71   |
| Uzbekistan                         | 2005 | 56.00  | 2,015 | 7  | 3  | 90 | 141 | 60  | 1813 | f | 27.79  |
| Vietnam                            | 2005 | 82.00  | 921   | 1  | 4  | 95 | 9   | 37  | 875  | f | 89.03  |
| Yemen                              | 2005 | 3.57   | 147   | 7  | 2  | 91 | 10  | 3   | 134  | f | 24.26  |
| <b>EUROPE</b>                      |      |        |       |    |    |    |     |     |      |   |        |
| Albania                            | 2006 | 1.30   | 410   | 43 | 18 | 39 | 176 | 74  | 160  | f | 3.17   |
| Austria                            | 2002 | 3.70   | 441   | 18 | 79 | 3  | 79  | 348 | 13   | f | 8.39   |
| Belarus                            | 2000 | 4.30   | 448   | 27 | 54 | 19 | 121 | 242 | 85   | f | 9.59   |

*continues*

**Data Table 2.** *continued*

| Region          | Country                | Year  | Total<br>Freshwater<br>Withdrawal (km <sup>3</sup> /yr) | Per<br>Capita<br>Withdrawal (m <sup>3</sup> /p/yr) | Domestic Use (%)    |                       |                         | Industrial Use (%)  |                       |                         | Agricultural Use (%) |                       |                         | Source | 2010<br>Population<br>(millions) |
|-----------------|------------------------|-------|---|--|---------------------|-----------------------|-------------------------|---------------------|-----------------------|-------------------------|----------------------|-----------------------|-------------------------|--------|----------------------------------|
|                 |                        |       |   |  | Domestic<br>Use (%) | Industrial<br>Use (%) | Agricultural<br>Use (%) | Domestic<br>Use (%) | Industrial<br>Use (%) | Agricultural<br>Use (%) | Domestic<br>Use (%)  | Industrial<br>Use (%) | Agricultural<br>Use (%) |        |                                  |
| EUROPE<br>cont. | Belgium                | 2007  | 6.20  | 580  | 12                  | 88                    | 1                       | 70                  | 510                   | 7                       | b, f                 | 10.70                 |                         |        |                                  |
|                 | Bosnia and Herzegovina | 2009  | 0.34  | 90   |                     |                       |                         |                     |                       |                         |                      | 3.76                  |                         |        |                                  |
|                 | Bulgaria               | 2009  | 6.10  | 814  | 16                  | 68                    | 16                      | 130                 | 553                   | 130                     | f                    | 7.50                  |                         |        |                                  |
|                 | Croatia                | 2010  | 0.63  | 143  | 85                  | 14                    | 1                       | 121                 | 20                    | 1                       | f                    | 4.41                  |                         |        |                                  |
|                 | Czech Republic         | 2007  | 1.70  | 163  | 41                  | 57                    | 2                       | 67                  | 93                    | 3                       | f                    | 10.41                 |                         |        |                                  |
|                 | Denmark                | 2009  | 0.66  | 120  | 58                  | 5                     | 36                      | 70                  | 6                     | 43                      | f                    | 5.48                  |                         |        |                                  |
|                 | Estonia                | 2007  | 1.80  | 1,344  | 3                   | 97                    | 1                       | 40                  | 1304                  | 13                      | f                    | 1.34                  |                         |        |                                  |
|                 | Finland                | 2005  | 1.60  | 299  | 25                  | 72                    | 3                       | 75                  | 215                   | 8                       | f                    | 5.35                  |                         |        |                                  |
|                 | France                 | 2007  | 31.60   | 504  | 18                  | 69                    | 12                      | 91                  | 348                   | 61                      | f                    | 62.64                 |                         |        |                                  |
|                 | Germany                | 2007  | 32.30   | 394  | 12                  | 68                    | 20                      | 47                  | 268                   | 78                      | b                    | 82.06                 |                         |        |                                  |
|                 | Greece                 | 2007  | 9.50  | 849  | 9                   | 2                     | 89                      | 76                  | 17                    | 756                     | f                    | 11.18                 |                         |        |                                  |
|                 | Hungary                | 2007  | 5.60  | 562  | 12                  | 83                    | 5                       | 67                  | 466                   | 28                      | f                    | 9.97                  |                         |        |                                  |
|                 | Iceland                | 2005  | 0.17  | 516  | 50                  | 8                     | 42                      | 258                 | 41                    | 217                     | f                    | 0.33                  |                         |        |                                  |
|                 | Ireland                | 1994  | 1.18  | 257  | 23                  | 77                    | 0                       | 58                  | 198                   | 0                       | f                    | 4.59                  |                         |        |                                  |
|                 | Italy                  | 2000  | 45.40   | 755  | 20                  | 36                    | 44                      | 151                 | 272                   | 332                     | f                    | 60.10                 |                         |        |                                  |
|                 | Latvia                 | 2002  | 0.40  | 179  | 38                  | 49                    | 13                      | 68                  | 87                    | 23                      | f                    | 2.24                  |                         |        |                                  |
|                 | Lithuania              | 2007  | 2.40  | 737  | 7                   | 90                    | 3                       | 52                  | 664                   | 22                      | f                    | 3.26                  |                         |        |                                  |
|                 | Luxembourg             | 1999  | 0.06  | 116  | 63                  | 37                    | 1                       | 73                  | 43                    | 1                       | b                    | 0.49                  |                         |        |                                  |
|                 | Macedonia              | 2007  | 1.00  | 489  | 21                  | 67                    | 12                      | 103                 | 328                   | 59                      | f                    | 2.04                  |                         |        |                                  |
|                 | Malta                  | 2002  | 0.05  | 122  | 63                  | 1                     | 35                      | 77                  | 1                     | 43                      | f                    | 0.41                  |                         |        |                                  |
| Moldova         | 2007                   | 1.10  | 308   | 14   | 83                  | 3                     | 43                      | 255                 | 9                     | f                       | 3.58                 |                       |                         |        |                                  |
| Netherlands     | 2008                   | 10.60 | 637   | 12   | 87                  | 1                     | 76                      | 554                 | 6                     | f                       | 16.65                |                       |                         |        |                                  |
| Norway          | 2006                   | 2.90  | 597   | 28   | 43                  | 29                    | 167                     | 257                 | 173                   | b                       | 4.86                 |                       |                         |        |                                  |
| Poland          | 2009                   | 12.00 | 315   | 31   | 60                  | 10                    | 98                      | 189                 | 32                    | f                       | 38.04                |                       |                         |        |                                  |

|                    |      |       |       |    |    |    |     |     |      |     |        |
|--------------------|------|-------|-------|----|----|----|-----|-----|------|-----|--------|
| Portugal           | 2002 | 8.50  | 792   | 8  | 19 | 73 | 63  | 150 | 578  | f   | 10.73  |
| Romania            | 2003 | 6.50  | 307   | 22 | 61 | 17 | 67  | 187 | 52   | f   | 21.19  |
| Russian Federation | 2000 | 76.68 | 546   | 20 | 60 | 20 | 109 | 328 | 109  | b,f | 140.37 |
| Serbia             | 2009 | 4.10  | 418   | 17 | 82 | 2  | 71  | 343 | 8    | f   | 9.80   |
| Slovakia           | 2007 | 0.69  | 128   | 47 | 50 | 3  | 60  | 64  | 4    | f   | 5.41   |
| Slovenia           | 2009 | 0.94  | 464   | 18 | 82 | 1  | 84  | 381 | 5    | f   | 2.02   |
| Spain              | 2008 | 32.50 | 717   | 18 | 22 | 61 | 129 | 158 | 437  | f   | 45.32  |
| Sweden             | 2007 | 2.60  | 280   | 37 | 59 | 4  | 103 | 165 | 11   | f   | 9.29   |
| Switzerland        | 2000 | 2.60  | 342   | 40 | 58 | 2  | 137 | 199 | 7    | f   | 7.59   |
| Ukraine            | 2005 | 19.20 | 423   | 24 | 70 | 6  | 101 | 296 | 25   | f   | 45.43  |
| United Kingdom     | 2007 | 13.00 | 210   | 57 | 33 | 10 | 120 | 69  | 21   | a,f | 61.90  |
| <b>OCEANIA</b>     |      |       |       |    |    |    |     |     |      |     |        |
| Australia          | 2010 | 59.84 | 2,782 | 16 | 11 | 74 | 445 | 306 | 2058 | i   | 21.51  |
| Fiji               | 2000 | 0.08  | 94    | 28 | 11 | 61 | 26  | 10  | 57   | f   | 0.85   |
| New Zealand        | 2002 | 4.80  | 1,115 | 21 | 4  | 74 | 234 | 45  | 825  | f   | 4.30   |
| Papua New Guinea   | 2005 | 0.39  | 57    | 57 | 43 | 0  | 32  | 24  | 0    | a,f | 6.89   |
| Solomon Islands    | 1987 |       |       | 40 | 20 | 40 | 0   | 0   | 0    | a,f | 0.54   |
| Timor-Leste        | 2004 | 1.17  | 1,064 | 8  | 1  | 91 | 85  | 11  | 968  | f   | 1.10   |

*Notes:*

Figures may not add to totals because of independent rounding.

Population data from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision. Total

Population, Both Sexes. Estimates 2010 (New York: United Nations, 2009). [http://esa.un.org/unpd/wpp2008/all-wpp-indicators\\_components.htm](http://esa.un.org/unpd/wpp2008/all-wpp-indicators_components.htm).

US data include freshwater only; previous data included saline water.

China data include Hong Kong.

# Access to Improved Drinking Water by Country, 1970–2008 & 2011 Update

## Description

Safe drinking water is one of the most basic human requirements, and one of the Millennium Development Goals (MDGs) by 2015 is to reduce by half the proportion of people unable to reach or afford safe drinking water. As a result, estimates of access to safe drinking water are a cornerstone of most international assessments of progress, or lack thereof, toward solving global and regional water problems.

Data are given here in two related tables.

**Data table 3A** includes the percentage of urban, rural, and total populations, by country, with access to improved drinking water for 1970, 1975, 1980, 1985, 1990, 1994, 2000, 2002, 2004, 2005, and 2008—similar to data table 3 in the previous volume of *The World's Water*. In the current volume, however, these previous data are sorted alphabetically by country rather than separated by regions.

**Data table 3B** provides an update of the percentage of national, urban, and rural populations with improved drinking water for 2011, the most recent year for which data are available. This table also includes the percentage of country populations in urban and rural categories for 2011.

The World Health Organization (WHO) / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation collected the data presented here over various periods. Most of the data presented were drawn from responses by national governments to WHO questionnaires. Participants in data collection include the JMP, the United Nations Children's Fund, and the Water Supply and Sanitation Collaborative Council, which has continued sector monitoring and aims to support and strengthen the monitoring efforts of individual countries. The forty largest countries in the developing world account for 90 percent of population in these regions. As a result, the World Health Organization spent extra effort in collecting comprehensive data for these countries.

Data for 2000 and later reflect a significant change in definition. Data are now reported for populations with and without access to an “improved” drinking water supply. An improved drinking water source is defined as one that, “by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter.”

According to the World Health Organization, the following technologies were included in the assessment as representing an improved water supply:

- Household connection
- Public standpipe
- Borehole
- Protected dug well
- Protected spring
- Rainwater collection

In comparison, an unimproved drinking water source refers to

- Unprotected well
- Unprotected spring
- Rivers or ponds
- Vendor-provided water
- Bottled water
- Tanker truck water

## Limitations

A review of water and sanitation coverage data from the 1980s and 1990s shows that the definition of safe, or improved, water supply and sanitation facilities differs from one country to another and for a given country over time. Indeed, some of the data from individual countries often showed rapid and implausible changes in the level of coverage from one assessment to the next. This indicates that some of the data are also unreliable, irrespective of the definition used. Countries used their own definitions of “rural” and “urban.”

For the 1996 data, two-thirds of the countries reporting indicated how they defined “access.” At the time, the definition most commonly centered on walking distance or time from household to water source, such as a public standpipe, which varied from 50 to 2,000 meters and 5 to 30 minutes. Definitions sometimes included considerations of quantity, with the acceptable limit ranging from 15 to 50 liters per capita per day.

WHO/JMP assessments since 2000 have attempted to shift from gathering information from water providers only to including consumer-based information. The current approach uses household surveys in an effort to assess the actual use of facilities. “Reasonable access” was broadly defined as the availability of at least 20 liters per person per day from a source within 1 kilometer of the user’s dwelling. A drawback of this approach is that household surveys are not conducted regularly in many countries. Thus, direct comparisons between countries, and across time within the same country, are difficult. Direct comparisons are additionally complicated by the fact that these data hide disparities between regions and socioeconomic classes.

Access to water, as reported by WHO/JMP assessments, does not imply that the level of service or quality of water is “adequate” or “safe.” In addition, the household surveys and censuses on which the JMP relies also measure “use” and not “access.” The assess-



ment questionnaire did not include any methodology for discounting coverage figures to allow for intermittence of supply or poor quality of the water supplies. However, the instructions stated that piped systems should not be considered “functioning” unless they were operating at over 50 percent capacity on a daily basis and that hand pumps should not be considered functioning unless they were operating for at least 70 percent of the time, with a lag between breakdown and repair not exceeding two weeks. These aspects were taken into consideration when estimating coverage for countries for which national surveys had not been conducted. More details of the methods used beginning with the 2000 assessment, and their limitations, can be found at [http://www.who.int/docstore/water\\_sanitation\\_health/Globassessment/GlobalTOC.htm](http://www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm).

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**DATA TABLE 3A Access to Safe Drinking Water by Country, 1970–2008**

| Region and Country     | Percentage of Population with Access to Improved Drinking Water |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |
|------------------------|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|----|----|----|----|
|                        | URBAN   |      |      |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |
|                        | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008  | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005  | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008 |    |    |    |    |
| Afghanistan            | 18  | 40   | 28   | 38   | 40   | 39   | 19   | 19   | 63   | 66   | 78    | 1    | 5    | 8    | 17   | 19   | 5    | 11   | 11   | 31   | 33    | 39   | 3    | 9    | 8    | 17   | 23   | 12   | 13   | 13   | 13   | 39   | 41   | 48 |    |    |    |
| Albania                |   |      |      |      |      |      | 99   | 99   | 98   | 98   | 96    |      |      |      |      |      |      |      | 95   | 94   | 97    | 98   |      |      |      |      |      |      |      | 97   | 96   | 97   | 97   |    |    |    |    |
| Algeria                | 84  | 100  |      | 85   |      |      | 88   | 92   | 88   | 88   | 85    | 61   |      | 55   |      |      | 94   | 80   | 80   | 81   | 79    |      | 77   |      | 68   |      |      | 94   | 87   | 85   | 85   | 83   |      |    |    |    |    |
| American Samoa         |   |      |      |      |      | 100  |      |      |      |      |       |      |      |      |      | 100  |      |      |      |      |       |      |      |      |      |      |      |      | 100  |      |      |      |      |    |    |    |    |
| Angola                 |   |      | 85   | 87   | 73   | 69   | 34   | 70   | 75   | 54   | 60    |      | 10   | 15   | 20   | 15   | 40   | 40   | 40   | 39   | 38    |      |      | 26   | 33   | 35   | 32   | 38   | 50   | 53   | 47   | 50   |      |    |    |    |    |
| Anguilla               |   |      |      |      |      |      |      |      | 60   |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      | 60   |      |    |    |    |    |
| Antigua and Barbados   |   |      |      |      |      |      | 95   | 95   | 95   | 95   | 95    |      |      |      |      |      |      |      | 89   | 89   |       |      |      |      |      |      |      |      |      | 91   | 91   |      |      |    |    |    |    |
| Argentina              | 69  | 76   | 61   | 63   |      |      | 85   | 97   | 98   | 98   | 98    | 12   | 26   | 17   | 17   |      | 30   |      | 80   | 80   | 80    | 80   | 56   | 66   | 54   | 56   |      | 79   |      | 96   | 96   | 97   |      |    |    |    |    |
| Armenia                |   |      |      |      |      |      | 99   | 99   | 99   | 98   | 98    |      |      |      |      |      |      |      | 80   | 80   | 89    | 93   |      |      |      |      |      |      | 92   | 92   | 95   | 96   |      |    |    |    |    |
| Aruba                  |   |      |      |      |      |      | 100  | 100  | 100  | 99   | 99    |      |      |      |      |      |      |      | 100  | 100  | 100   | 100  |      |      |      |      |      |      | 100  | 100  | 100  | 100  |      |    |    |    |    |
| Australia              |   |      |      |      |      |      | 100  | 100  | 100  | 100  | 100   |      |      |      |      |      |      |      | 100  | 100  | 100   | 100  |      |      |      |      |      |      | 100  | 100  | 100  | 100  |      |    |    |    |    |
| Azerbaijan             |   |      |      |      |      |      | 95   | 95   | 88   | 88   | 88    |      |      |      |      |      |      |      | 59   | 59   | 66    | 71   |      |      |      |      |      |      | 77   | 77   | 77   | 77   | 80   |    |    |    |    |
| Bahamas                | 100   | 100  | 100  | 100  | 98   |      | 99   | 98   | 98   | 98   | 98    | 12   | 13   |      |      | 75   |      | 86   | 86   | 86   |       |      | 65   | 65   | 100  | 100  | 90   |      | 96   | 97   |      |      |      |    |    |    |    |
| Bahrain                | 100   | 100  |      |      |      |      | 100  | 100  | 100  | 100  | 100   | 94   | 100  |      | 100  | 0    |      |      |      |      |       |      | 99   | 100  |      |      |      |      |      |      |      |      |      |    |    |    |    |
| Bangladesh             | 13  | 22   | 26   | 24   | 39   | 100  | 99   | 82   | 82   | 85   | 85    | 47   | 61   | 40   | 49   | 89   | 97   | 97   | 72   | 72   | 78    | 78   | 45   | 56   | 39   | 46   | 81   | 97   | 97   | 75   | 74   | 80   | 80   |    |    |    |    |
| Barbados               | 95  | 100  | 99   | 100  | 100  |      | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 98   | 99   | 100  |      |      |      |      |       |      | 98   | 100  | 99   | 99   | 100  |      | 100  | 100  | 100  | 100  |      |    |    |    |    |
| Belize                 |   |      |      |      |      |      | 99   | 100  | 95   | 96   | 83    | 100  | 100  | 97   | 99   |      |      |      | 82   | 82   | 94    | 100  |      |      |      |      |      |      | 68   | 64   | 74   | 89   | 76   | 91 | 91 | 95 | 99 |
| Benin                  | 83  | 100  | 26   | 80   | 73   | 41   | 74   | 79   | 78   | 82   | 84    | 20   | 20   | 15   | 34   | 43   | 53   | 55   | 60   | 57   | 65    | 69   | 29   | 34   | 18   | 50   | 54   | 50   | 63   | 68   | 67   | 72   | 75   |    |    |    |    |
| Bhutan                 |   |      | 50   |      | 60   | 75   | 86   | 86   | 86   | 99   | 99    |      |      | 5    | 19   | 30   | 54   | 60   | 60   | 60   | 88    | 88   |      |      | 7    |      |      | 32   | 64   | 62   | 62   | 62   | 91   | 92 |    |    |    |
| Bolivia                | 92  | 81   | 69   | 75   | 76   | 78   | 93   | 95   | 95   | 95   | 96    | 2    | 6    | 10   | 13   | 30   | 22   | 55   | 68   | 68   | 63    | 67   | 33   | 34   | 36   | 43   | 53   | 55   | 79   | 85   | 85   | 84   | 86   |    |    |    |    |
| Bosnia and Herzegovina |   |      |      |      |      |      |      |      | 99   | 100  | 100   |      |      |      |      |      |      |      | 96   | 97   | 98    |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |
| Botswana               | 71  | 95   |      | 84   | 100  |      | 100  | 100  | 100  | 99   | 99    | 26   | 39   |      | 46   | 88   |      |      | 90   | 90   | 90    | 90   | 29   | 45   |      | 53   | 91   |      | 95   | 95   | 95   | 95   | 95   |    |    |    |    |
| Brazil                 | 78  | 87   | 83   | 85   | 95   | 85   | 95   | 96   | 96   | 98   | 99    | 28   |      | 51   | 56   | 61   | 31   | 54   | 58   | 57   | 81    | 84   | 55   |      | 72   | 77   | 87   | 72   | 87   | 89   | 90   | 95   | 97   |    |    |    |    |

*continues*

**DATA TABLE 3A** *continued*

| Region and Country       | Percentage of Population with Access to Improved Drinking Water |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |       |      |      |      |      |      |    |    |    |    |    |    |
|--------------------------|---|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|-------|------|------|------|------|------|----|----|----|----|----|----|
|                          | URBAN   |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |    |    |    |    |    |    |
|                          | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004  | 2005 | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994  | 2000 | 2002 | 2004 | 2005 | 2008 |    |    |    |    |    |    |
| British Virgin Island    | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |    |    |    |    |    |    |
| Brunei                   | 100   |      |      |      |      |      |      |      |       |      | 95   |      |      |      |      |      |       |      |      |      |      |      |    |    |    |    |    |    |
| Darussalam               |   |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |       |      |      |      |      |      |    |    |    |    |    |    |
| Bulgaria                 | 35  | 50   | 27   | 43   | 84   | 82   | 94   | 91   | 95    | 100  |      |      |      |      |      |      |       |      |      |      |      |      |    |    |    |    |    |    |
| Burkina Faso             | 77  | 90   | 98   | 92   | 96   | 90   | 92   | 85   | 83    | 100  | 10   | 23   | 31   | 69   | 70   | 44   | 54    | 65   | 72   | 12   | 25   | 31   | 67 | 78 | 51 | 61 | 70 | 76 |
| Burundi                  |   |      |      |      |      |      |      |      |       |      | 20   | 21   | 43   | 49   |      | 78   | 77    | 71   | 71   |      |      |      |    |    |    |    |    |    |
| Cambodia                 | 77  |      |      |      |      |      |      |      |       |      |      |      |      |      |      | 25   | 29    | 35   | 51   | 56   |      |      |    |    |    |    |    |    |
| Cameroun                 |   |      |      |      |      |      |      |      |       |      | 21   |      | 24   | 45   |      | 42   | 41    | 44   | 48   | 51   | 32   |      |    |    |    |    |    |    |
| Canada                   |   |      |      |      |      |      |      |      |       |      |      |      |      |      |      | 99   | 99    | 99   | 99   | 99   |      |      |    |    |    |    |    |    |
| Cape Verde               | 100   | 83   | 100  | 83   | 70   | 64   | 86   | 86   | 85    | 100  | 21   | 50   |      |      | 34   | 89   | 73    | 73   | 82   | 82   |      |      |    |    |    |    |    |    |
| Cayman Islands           | 100   | 98   |      |      |      |      |      |      |       |      |      |      |      |      |      |      |       |      |      |      |      |      |    |    |    |    |    |    |
| Central African Republic | 13  | 19   | 18   | 80   | 93   | 93   | 89   | 92   |       |      | 26   | 18   | 43   | 61   | 61   | 50   | 51    |      |      |      |      |      |    |    |    |    |    |    |
| Chad                     | 47  | 43   |      |      | 48   | 31   | 40   | 41   | 66    | 67   | 24   | 23   |      |      | 17   | 26   | 32    | 43   | 43   | 44   | 27   | 26   |    |    |    |    |    |    |
| Chile                    | 67  | 78   | 100  | 98   | 94   | 99   | 100  | 100  | 99    | 99   | 13   | 28   | 17   | 29   | 37   | 66   | 59    | 58   | 75   | 75   | 56   | 70   | 84 | 87 |    |    |    |    |
| China                    |   |      |      |      | 87   | 93   | 94   | 92   | 93    | 98   |      |      |      |      | 68   | 89   | 66    | 68   | 67   | 78   | 82   |      |    |    |    |    |    |    |
| Colombia                 | 88  | 86   | 93   | 100  | 87   | 88   | 98   | 99   | 99    | 99   | 28   | 33   | 73   | 76   | 82   | 48   | 73    | 71   | 71   | 73   | 63   | 64   | 86 |    |    |    |    |    |
| Comoros                  |   |      |      |      |      |      |      |      |       |      |      |      |      |      |      | 95   | 96    | 82   | 96   | 97   |      |      |    |    |    |    |    |    |
| Congo                    | 63  | 81   | 42   |      |      |      |      |      |       |      | 6    | 9    | 7    |      |      | 17   | 17    | 27   | 34   | 34   | 27   | 38   | 20 |    |    |    |    |    |
| Congo, Cook Islands      | 33  | 38   |      |      | 52   | 68   | 37   | 89   | 83    | 82   | 80   | 4    | 12   | 21   | 24   | 23   | 26    | 29   | 28   | 28   | 11   | 19   |    |    |    |    |    |    |
| Cook Islands             |   |      |      |      | 100  | 99   | 100  | 100  | 98    | 97   | 101  |      |      | 88   | 100  | 100  | 88    | 88   | 88   |      |      |      |    |    |    |    |    |    |
| Costa Rica               | 98  | 100  | 100  | 100  | 85   | 98   | 100  | 100  | 100   | 100  | 59   | 56   | 82   | 83   |      | 99   | 98    | 92   | 92   | 90   | 91   | 74   | 72 | 90 | 91 |    |    |    |
| Côte d'Ivoire            | 98  |      |      |      | 57   | 59   | 90   | 98   | 97    | 92   | 93   | 29   |      | 80   | 81   | 65   | 74    | 74   | 67   | 68   | 44   |      |    |    |    |    |    |    |
| Cuba                     | 82  | 96   |      |      | 100  | 96   | 99   | 95   | 95    | 96   | 15   |      |      |      | 91   | 85   | 82    | 78   | 78   | 83   | 89   | 56   |    |    |    |    |    |    |
| Cyprus                   | 100   | 94   |      |      | 100  | 100  | 100  | 100  | 100   | 100  |      |      |      |      | 100  | 100  | 100   | 100  | 100  | 100  |      |      |    |    |    |    |    |    |

|                     |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
|---------------------|-----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|----|----|-----|----|----|----|-----|-----|----|----|----|----|----|----|-----|----|----|----|----|----|----|--|--|
| Djibouti            | 50  | 50  | 77  | 100 | 82  | 76  | 95 | 98  | 20  | 20  | 100 | 100 | 67 | 59 | 55  | 52 | 43 | 45 | 90  | 100 | 80 | 73 | 89 | 92 |    |    |     |    |    |    |    |    |    |  |  |
| Dominica            |     |     | 100 | 100 | 100 | 96  |    |     | 100 | 90  | 90  | 93  |    |    |     |    |    |    | 100 | 97  | 97 | 95 |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Democratic Republic |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Dominican Republic  | 72  | 88  | 85  | 82  | 74  | 83  | 98 | 97  | 89  | 87  | 14  | 27  | 34 | 33 | 45  | 67 | 70 | 85 | 91  | 83  | 84 | 37 | 55 | 60 | 62 | 67 | 71  | 79 | 93 | 95 | 87 | 86 |    |  |  |
| East Timor          |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Ecuador             | 76  | 67  | 79  | 81  | 63  | 82  | 81 | 92  | 97  | 96  | 97  | 7   | 8  | 20 | 31  | 44 | 55 | 51 | 77  | 89  | 86 | 88 | 34 | 36 | 50 | 57 | 55  | 70 | 71 | 86 | 94 | 92 | 94 |  |  |
| Egypt               | 94  | 88  | 95  | 82  | 96  | 100 | 99 | 100 | 100 | 100 | 93  | 64  | 86 | 50 | 94  | 97 | 97 | 96 | 98  | 98  | 98 | 93 | 84 | 90 | 64 | 95 | 98  | 98 | 98 | 99 | 99 | 99 |    |  |  |
| El Salvador         | 71  | 89  | 67  | 68  | 87  | 78  | 88 | 91  | 94  | 94  | 94  | 20  | 28 | 40 | 40  | 15 | 37 | 61 | 68  | 70  | 73 | 76 | 40 | 53 | 50 | 51 | 47  | 55 | 74 | 82 | 84 | 86 | 87 |  |  |
| Equatorial Guinea   |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Eritrea             |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Estonia             |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Ethiopia            | 61  | 58  | 69  |     |     |     |    |     |     |     |     | 1   | 9  |    |     |    |    |    |     |     |    |    | 6  | 8  | 16 |    |     |    |    |    |    |    |    |  |  |
| Fiji                | 78  | 89  | 94  | 96  | 100 | 43  | 43 |     |     |     | 15  | 56  | 66 | 69 | 100 | 51 | 51 |    |     |     |    |    | 37 | 69 | 77 | 80 | 100 | 47 | 47 |    |    |    |    |  |  |
| French Guiana       |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| French Polynesia    |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Gabon               |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Gambia              | 97  | 85  | 97  | 100 |     |     |    |     |     |     |     | 3   | 50 | 48 |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Gaza Strip          |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Georgia             |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Ghana               | 86  | 86  | 72  | 93  | 63  | 70  | 87 | 93  | 88  | 89  | 90  | 14  | 33 | 39 | 49  | 49 | 68 | 64 | 68  | 74  | 74 | 35 | 35 | 45 | 56 | 21 | 56  | 64 | 79 | 75 | 78 | 82 | 82 |  |  |
| Grenada             | 100 | 100 |     |     |     |     |    |     |     |     |     | 47  | 77 |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guadeloupe          |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guam                |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guatemala           | 88  | 85  | 90  | 72  | 92  |     |    |     |     |     |     | 12  | 14 | 18 | 14  | 43 |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guinea              | 68  | 69  | 69  | 41  | 100 | 61  | 72 | 78  | 78  | 89  | 89  |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guinea-Bissau       |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Guyana              | 100 | 100 | 100 | 100 | 100 | 90  | 98 | 83  | 83  | 96  | 98  | 63  | 75 | 60 | 65  | 71 | 45 | 91 | 83  | 83  | 90 | 93 | 75 | 84 | 72 | 76 | 81  | 61 | 94 | 83 | 83 | 92 | 94 |  |  |
| Haiti               |     |     |     |     |     |     |    |     |     |     |     |     |    |    |     |    |    |    |     |     |    |    |    |    |    |    |     |    |    |    |    |    |    |  |  |
| Honduras            | 99  | 99  | 93  | 56  | 85  | 81  | 97 | 99  | 95  | 95  | 95  | 10  | 13 | 40 | 45  | 48 | 53 | 82 | 82  | 81  | 74 | 77 | 34 | 41 | 59 | 49 | 64  | 65 | 90 | 90 | 87 | 94 | 86 |  |  |

*continues*

DATA TABLE 3A continued

| Region and Country                         | Percentage of Population with Access to Improved Drinking Water |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |       |      |      |      |      |      |
|--|---|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|-------|------|------|------|------|------|
|  | URBAN   |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |
|  | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004  | 2005 | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994  | 2000 | 2002 | 2004 | 2005 | 2008 |
| Hong Kong                                  | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 95   | 96   | 96   | 96   | 96   | 96   | 96    | 96   | 96   | 96   | 96   | 96   |
| Hungary                                    | 60  | 80   | 77   | 76   | 86   | 85   | 92   | 96   | 95    | 95   | 96   | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |
| India                                      | 10  | 41   | 35   | 43   | 35   | 78   | 91   | 89   | 87    | 90   | 89   | 6    | 18   | 31   | 50   | 69   | 79    | 86   | 82   | 83   | 81   | 84   |
| Indonesia                                  | 68  | 76   | 82   | 100  | 89   | 99   | 99   | 98   | 99    | 98   | 98   | 1    | 4    | 19   | 36   | 33   | 54    | 65   | 69   | 69   | 70   | 71   |
| Iran                                       | 83  | 100  | 100  | 93   | 96   | 97   | 97   | 93   | 91    | 91   | 91   | 11   | 30   | 50   | 75   | 77   | 89    | 83   | 84   | 84   | 84   | 84   |
| Iraq                                       | 100   | 100  | 100  | 99   | 96   | 97   | 97   | 93   | 91    | 91   | 91   | 7    | 11   | 54   | 54   | 41   | 48    | 50   | 50   | 53   | 55   | 55   |
| Israel                                     | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |
| Jamaica                                    | 100   | 100  | 55   | 99   | 81   | 98   | 98   | 98   | 98    | 98   | 98   | 48   | 79   | 46   | 93   | 59   | 87    | 88   | 88   | 89   | 89   | 89   |
| Japan                                      | 98  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 59   | 65   | 88   | 97   | 84   | 91    | 91   | 91   | 91   | 91   | 91   |
| Jordan                                     | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 2    | 4    | 15   | 49   | 31   | 46    | 46   | 48   | 52   | 52   | 52   |
| Kazakhstan                                 | 100   | 100  | 85   | 93   | 91   | 82   | 77   | 77   | 78    | 78   | 78   | 25   | 63   | 25   | 53   | 53   | 53    | 54   | 54   | 54   | 54   | 54   |
| Kenya                                      | 93  | 91   | 82   | 77   | 77   | 78   | 78   | 78   | 78    | 78   | 78   | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |
| Kiribati                                   | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 38   | 33   | 61   | 48   | 76   | 71    | 71   | 71   | 83   | 88   | 88   |
| Korea Demo-<br>cratic People's<br>Republic | 84  | 95   | 86   | 90   | 100  | 97   | 97   | 97   | 99    | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |
| Korea Republic                             | 60  | 100  | 86   | 97   | 98   | 98   | 98   | 99   | 99    | 99   | 99   | 38   | 33   | 61   | 48   | 76   | 71    | 71   | 71   | 83   | 88   | 88   |
| Kuwait                                     | 97  | 100  | 28   | 47   | 40   | 59   | 66   | 79   | 74    | 72   | 72   | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 100  | 100  | 100  |
| Kyrgyzstan                                 | 97  | 100  | 28   | 47   | 40   | 59   | 66   | 79   | 74    | 72   | 72   | 39   | 32   | 20   | 25   | 39   | 100   | 38   | 43   | 47   | 51   | 51   |
| Laos                                       | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 96   | 96   | 96   | 96   | 96   | 96    | 96   | 96   | 96   | 96   | 96   |
| Latvia                                     | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 58   | 66   | 75   | 75   | 93   | 92    | 92   | 92   | 92   | 92   | 92   |
| Lebanon                                    | 100   | 65   | 37   | 65   | 14   | 98   | 88   | 92   | 96    | 97   | 97   | 51   | 89   | 87   | 87   | 87   | 87    | 87   | 87   | 87   | 87   | 87   |
| Lesotho                                    | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 29   | 39   | 90   | 43   | 51   | 54    | 57   | 57   | 57   | 57   | 57   |
| Liberia                                    | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 3    | 17   | 15   | 36   | 52   | 91    | 76   | 79   | 83   | 85   | 85   |
| Libya                                      | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 15   | 53   | 30   | 62   | 61   | 67    | 68   | 68   | 68   | 68   | 68   |
| Madagascar                                 | 67  | 76   | 80   | 81   | 83   | 85   | 75   | 77   | 71    | 71   | 71   | 58   | 87   | 96   | 72   | 72   | 72    | 72   | 72   | 72   | 72   | 72   |
|  | 29  | 47   | 45   | 50   | 40   | 41   | 41   | 41   | 41    | 41   | 41   | 11   | 25   | 21   | 31   | 29   | 47    | 45   | 50   | 40   | 41   | 41   |





**DATA TABLE 3A** *continued*

|                       |  | Percentage of Population with Access to Improved Drinking Water |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |     |
|-----------------------|--|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|-----|
|                       |  | URBAN   |      |      |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |      |      |      |      |      |      |      |     |
| Region and Country    |  | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008  | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005  | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008 |     |
| Panama                |  | 100   | 100  | 100  | 100  | 88   | 99   | 99   | 97   | 97   | 97   | 97    | 41   | 54   | 62   | 64   | 86   | 79   | 79   | 83   | 83   | 83    | 83   | 69   | 77   | 81   | 82   | 83   | 87   | 91   | 90   | 93   | 93   | 93   |     |
| Papua New Guinea      |  | 44  | 30   | 55   | 95   | 94   | 84   | 88   | 88   | 87   | 87   | 87    | 72   | 19   | 10   | 15   | 20   | 17   | 32   | 32   | 32   | 33    | 33   | 33   | 70   | 20   | 16   | 26   | 32   | 28   | 42   | 39   | 39   | 40   | 40  |
| Paraguay              |  | 22  | 25   | 39   | 53   | 61   | 95   | 100  | 99   | 98   | 99   | 99    | 5    | 5    | 9    | 8    | 9    | 58   | 62   | 68   | 93   | 66    | 66   | 66   | 11   | 13   | 21   | 28   | 34   | 79   | 83   | 86   | 83   | 86   | 86  |
| Peru                  |  | 58  | 72   | 68   | 73   | 68   | 74   | 87   | 87   | 89   | 90   | 90    | 8    | 15   | 18   | 17   | 24   | 24   | 51   | 66   | 65   | 58    | 61   | 61   | 35   | 47   | 50   | 55   | 55   | 60   | 77   | 81   | 83   | 81   | 82  |
| Philippines           |  | 67  | 82   | 49   | 49   | 93   | 93   | 92   | 90   | 87   | 93   | 93    | 20   | 31   | 43   | 54   | 72   | 77   | 80   | 77   | 82   | 85    | 87   | 87   | 36   | 50   | 45   | 52   | 81   | 85   | 87   | 85   | 85   | 90   | 91  |
| Qatar                 |  | 100   | 100  | 76   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 75   | 83   | 43   |      |      | 100  | 100  | 100  | 99   | 99    | 99   | 99   | 95   | 97   | 71   |      |      | 100  | 100  | 100  | 100  | 100  | 100 |
| Republic of Moldova   |  |   |      |      |      |      |      |      |      |      |      |       | 97   | 97   | 96   | 96   |      | 88   | 88   | 85   | 85   | 85    | 85   | 85   | 92   | 92   | 90   | 90   | 90   | 92   | 92   | 90   | 90   | 90   | 90  |
| Romania               |  |   |      |      |      |      |      |      |      |      |      |       | 91   | 91   |      |      | 16   | 16   |      |      |      |       |      |      | 57   | 57   |      |      |      | 57   | 57   |      |      |      |     |
| Russian Federation    |  |   |      |      |      |      |      |      |      |      |      |       | 99   | 100  | 98   | 98   | 88   | 88   | 89   | 89   | 89   | 89    | 89   | 89   | 96   | 97   | 96   | 96   | 96   | 96   | 97   | 96   | 96   | 96   | 96  |
| Rwanda                |  | 81  | 84   | 48   | 79   | 84   | 60   | 92   | 92   | 80   | 77   | 77    | 66   | 68   | 55   | 48   | 67   | 40   | 69   | 69   | 63   | 62    | 62   | 62   | 67   | 68   | 55   | 50   | 68   | 41   | 73   | 74   | 66   | 65   | 65  |
| Samoa                 |  | 86  | 100  | 97   | 100  | 100  | 95   | 91   | 90   | 90   | 90   | 90    | 23   | 94   |      |      | 77   | 100  | 88   | 87   | 87   | 87    | 87   | 87   | 17   | 43   |      |      |      | 99   | 88   | 88   | 88   | 88   | 88  |
| São Tomé and Príncipe |  |   |      |      |      |      |      |      |      |      |      |       | 89   | 89   | 88   | 89   | 45   | 73   | 73   | 81   | 89   | 89    | 89   | 89   | 79   | 79   | 45   | 45   | 45   | 79   | 79   | 79   | 85   | 85   | 89  |
| Saudi Arabia          |  | 100   | 97   | 92   | 100  | 100  | 100  | 97   | 97   | 97   | 97   | 97    | 37   | 56   | 87   | 88   | 64   | 64   |      |      |      |       |      |      | 49   | 64   | 90   | 94   | 95   | 95   | 95   |      |      |      |     |
| Senegal               |  | 87  | 56   | 77   | 79   | 65   | 82   | 92   | 90   | 92   | 91   | 92    | 25   | 38   | 26   | 28   | 28   | 65   | 54   | 60   | 51   | 52    | 52   | 52   | 43   | 53   | 42   | 50   | 78   | 72   | 76   | 68   | 68   | 69   | 69  |
| Serbia                |  |   |      |      |      |      |      |      |      |      |      |       | 99   | 99   |      |      |      |      |      |      |      |       |      |      | 99   | 99   |      |      |      | 99   | 99   |      |      |      |     |
| Serbia and Montenegro |  |   |      |      |      |      |      |      |      |      |      |       | 99   | 99   |      |      | 86   | 86   |      |      |      |       |      |      | 93   | 93   |      |      |      | 93   | 93   |      |      |      |     |
| Seychelles            |  |   |      |      |      |      |      |      |      |      |      |       | 100  | 100  | 94   | 100  |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |     |
| Sierra Leone          |  | 75  | 50   | 68   | 80   | 58   | 23   | 75   | 75   | 82   | 86   | 86    | 1    | 2    | 7    | 20   | 21   | 31   | 46   | 46   | 33   | 26    | 26   | 26   | 12   | 14   | 24   | 39   | 34   | 28   | 57   | 57   | 51   | 49   | 49  |
| Singapore             |  | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   |      |      |      |      |      |      |      |      |      |       |      |      | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100 |
| Slovakia              |  |   |      |      |      |      |      |      |      |      |      |       | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 100  | 100  | 99   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100 |
| Solomon Islands       |  | 96  | 82   | 94   | 94   | 94   | 94   | 94   | 94   | 95   | 95   | 95    | 45   | 58   | 58   | 58   | 65   | 65   | 65   | 65   | 65   | 65    | 65   | 65   | 62   | 71   | 70   | 70   | 70   | 71   | 70   | 70   | 70   | 70   | 70  |





**DATA TABLE 3B** Access to Improved Drinking Water by Country, 2011 Update

| Country                             | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Drinking Water |                                  |                                     |
|-------------------------------------|-----------------|-------|---|----------------------------------|-------------------------------------|
|                                     | Urban           | Rural | Urban Improved<br>Total Improved                                      | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|                                     | %               | %     | (%)   | (%)                              | (%)                                 |
| Afghanistan                         | 24              | 76    | 85  | 53                               | 61                                  |
| Albania                             | 53              | 47    | 95  | 94                               | 95                                  |
| Algeria                             | 73              | 27    | 85  | 79                               | 84                                  |
| American Samoa                      | 93              | 7     | 100   | 100                              | 100                                 |
| Andorra                             | 87              | 13    | 100   | 100                              | 100                                 |
| Angola                              | 59              | 41    | 66  | 35                               | 53                                  |
| Anguilla                            | 100             | 0     | 95  |                                  | 95                                  |
| Antigua and Barbuda                 | 30              | 70    | 98  | 98                               | 98                                  |
| Argentina                           | 93              | 7     | 100   | 95                               | 99                                  |
| Armenia                             | 64              | 36    | 100   | 98                               | 99                                  |
| Aruba                               | 47              | 53    | 98  | 98                               | 98                                  |
| Australia                           | 89              | 11    | 100   | 100                              | 100                                 |
| Austria                             | 68              | 32    | 100   | 100                              | 100                                 |
| Azerbaijan                          | 54              | 46    | 88  | 71                               | 80                                  |
| Bahamas                             | 84              | 16    | 96  | 96                               | 96                                  |
| Bahrain                             | 89              | 11    | 100   | 100                              | 100                                 |
| Bangladesh                          | 28              | 72    | 85  | 82                               | 83                                  |
| Barbados                            | 44              | 56    | 100   | 100                              | 100                                 |
| Belarus                             | 75              | 25    | 100   | 99                               | 100                                 |
| Belgium                             | 97              | 3     | 100   | 100                              | 100                                 |
| Belize                              | 45              | 55    | 97  | 100                              | 99                                  |
| Benin                               | 45              | 55    | 85  | 69                               | 76                                  |
| Bermuda                             | 100             | 0     |   |                                  |                                     |
| Bhutan                              | 36              | 64    | 100   | 96                               | 97                                  |
| Bolivia (Plurinational<br>State of) | 67              | 33    | 96  | 72                               | 88                                  |
| Bosnia and Herzegovina              | 48              | 52    | 100   | 98                               | 99                                  |
| Botswana                            | 62              | 38    | 99  | 93                               | 97                                  |
| Brazil                              | 85              | 15    | 100   | 84                               | 97                                  |
| British Virgin Islands              | 41              | 59    |   |                                  |                                     |
| Brunei Darussalam                   | 76              | 24    |   |                                  |                                     |
| Bulgaria                            | 73              | 27    | 100   | 99                               | 99                                  |
| Burkina Faso                        | 27              | 73    | 96  | 74                               | 80                                  |
| Burundi                             | 11              | 89    | 82  | 73                               | 74                                  |
| Cambodia                            | 20              | 80    | 90  | 61                               | 67                                  |
| Cameroon                            | 52              | 48    | 95  | 52                               | 74                                  |
| Canada                              | 81              | 19    | 100   | 99                               | 100                                 |
| Cape Verde                          | 63              | 37    | 91  | 86                               | 89                                  |
| Cayman Islands                      | 100             | 0     | 96  |                                  | 96                                  |
| Central African Republic            | 39              | 61    | 92  | 51                               | 67                                  |
| Chad                                | 22              | 78    | 71  | 44                               | 50                                  |
| Channel Islands                     | 31              | 69    |   |                                  |                                     |
| Chile                               | 89              | 11    | 100   | 90                               | 98                                  |
| China                               | 51              | 49    | 98  | 85                               | 92                                  |
| China, Hong Kong SAR                | 100             | 0     |   |                                  |                                     |
| China, Macao SAR                    | 100             | 0     |   |                                  |                                     |
| Colombia                            | 75              | 25    | 100   | 72                               | 93                                  |

*continues*

DATA TABLE 3B *continued*

| Country                                  | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Drinking Water |                                  |                                     |
|--|-----------------|-------|---|----------------------------------|-------------------------------------|
|  | Urban           | Rural | Urban Improved<br>Total Improved                                      | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|  | %               | %     | (%)   | (%)                              | (%)                                 |
| Comoros                                  | 28              | 72    |   | 97                               |                                     |
| Congo                                    | 64              | 36    | 95  | 32                               | 72                                  |
| Cook Islands                             | 74              | 26    | 100   | 100                              | 100                                 |
| Costa Rica                               | 65              | 35    | 100   | 91                               | 96                                  |
| Côte d'Ivoire                            | 51              | 49    | 91  | 68                               | 80                                  |
| Croatia                                  | 58              | 42    | 100   | 97                               | 99                                  |
| Cuba                                     | 75              | 25    | 96  | 86                               | 94                                  |
| Cyprus                                   | 70              | 30    | 100   | 100                              | 100                                 |
| Czech Republic                           | 73              | 27    | 100   | 100                              | 100                                 |
| Democratic People's<br>Republic of Korea | 60              | 40    | 99  | 97                               | 98                                  |
| Democratic Republic<br>of the Congo      | 34              | 66    | 80  | 29                               | 46                                  |
| Denmark                                  | 87              | 13    | 100   | 100                              | 100                                 |
| Djibouti                                 | 77              | 23    | 100   | 67                               | 92                                  |
| Dominica                                 | 67              | 33    | 96  |                                  |                                     |
| Dominican Republic                       | 70              | 30    | 82  | 81                               | 82                                  |
| Ecuador                                  | 67              | 33    | 96  | 82                               | 92                                  |
| Egypt                                    | 43              | 57    | 100   | 99                               | 99                                  |
| El Salvador                              | 65              | 35    | 94  | 81                               | 90                                  |
| Equatorial Guinea                        | 39              | 61    |   |                                  |                                     |
| Eritrea                                  | 21              | 79    |   |                                  |                                     |
| Estonia                                  | 69              | 31    | 99  | 97                               | 99                                  |
| Ethiopia                                 | 17              | 83    | 97  | 39                               | 49                                  |
| Faeroe Islands                           | 41              | 59    |   |                                  |                                     |
| Falkland Islands (Malvinas)              | 74              | 26    |   |                                  |                                     |
| Fiji                                     | 52              | 48    | 100   | 92                               | 96                                  |
| Finland                                  | 84              | 16    | 100   | 100                              | 100                                 |
| France                                   | 86              | 14    | 100   | 100                              | 100                                 |
| French Guiana                            | 76              | 24    | 95  | 75                               | 90                                  |
| French Polynesia                         | 51              | 49    | 100   | 100                              | 100                                 |
| Gabon                                    | 86              | 14    | 95  | 41                               | 88                                  |
| Gambia                                   | 57              | 43    | 92  | 85                               | 89                                  |
| Georgia                                  | 53              | 47    | 100   | 96                               | 98                                  |
| Germany                                  | 74              | 26    | 100   | 100                              | 100                                 |
| Ghana                                    | 52              | 48    | 92  | 80                               | 86                                  |
| Greece                                   | 61              | 39    | 100   | 99                               | 100                                 |
| Greenland                                | 85              | 15    | 100   | 100                              | 100                                 |
| Grenada                                  | 39              | 61    |   |                                  |                                     |
| Guadeloupe                               | 98              | 2     | 99  | 100                              | 99                                  |
| Guam                                     | 93              | 7     | 99  | 99                               | 99                                  |
| Guatemala                                | 50              | 50    | 99  | 89                               | 94                                  |
| Guinea                                   | 35              | 65    | 90  | 65                               | 74                                  |
| Guinea-Bissau                            | 44              | 56    | 94  | 54                               | 72                                  |
| Guyana                                   | 28              | 72    | 98  | 93                               | 95                                  |
| Haiti                                    | 53              | 47    | 77  | 48                               | 64                                  |
| Honduras                                 | 52              | 48    | 96  | 81                               | 89                                  |

| Country                             | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Drinking Water |                       |                       |
|-------------------------------------|-----------------|-------|---|-----------------------|-----------------------|
|                                     | Urban           | Rural | Urban Improved  | Rural Improved        | National Improved     |
|                                     | %               | %     | Total Improved<br>(%)   | Total Improved<br>(%) | Total Improved<br>(%) |
| Hungary                             | 69              | 31    | 100   | 100                   | 100                   |
| Iceland                             | 94              | 6     | 100   | 100                   | 100                   |
| India                               | 31              | 69    | 96  | 89                    | 92                    |
| Indonesia                           | 51              | 49    | 93  | 76                    | 84                    |
| Iran (Islamic Republic of)          | 69              | 31    | 98  | 90                    | 95                    |
| Iraq                                | 66              | 34    | 94  | 67                    | 85                    |
| Ireland                             | 62              | 38    | 100   | 100                   | 100                   |
| Isle of Man                         | 51              | 49    |   |                       |                       |
| Israel                              | 92              | 8     | 100   | 100                   | 100                   |
| Italy                               | 68              | 32    | 100   | 100                   | 100                   |
| Jamaica                             | 52              | 48    | 97  | 89                    | 93                    |
| Japan                               | 91              | 9     | 100   | 100                   | 100                   |
| Jordan                              | 83              | 17    | 97  | 90                    | 96                    |
| Kazakhstan                          | 54              | 46    | 99  | 90                    | 95                    |
| Kenya                               | 24              | 76    | 83  | 54                    | 61                    |
| Kiribati                            | 44              | 56    | 87  | 50                    | 66                    |
| Kuwait                              | 98              | 2     | 99  | 99                    | 99                    |
| Kyrgyzstan                          | 35              | 65    | 96  | 85                    | 89                    |
| Lao People's Democratic<br>Republic | 34              | 66    | 83  | 63                    | 70                    |
| Latvia                              | 68              | 32    | 100   | 96                    | 98                    |
| Lebanon                             | 87              | 13    | 100   | 100                   | 100                   |
| Lesotho                             | 28              | 72    | 91  | 73                    | 78                    |
| Liberia                             | 48              | 52    | 89  | 60                    | 74                    |
| Libyan Arab Jamahiriya              | 78              | 22    |   |                       |                       |
| Liechtenstein                       | 14              | 86    |   |                       |                       |
| Lithuania                           | 67              | 33    | 98  |                       |                       |
| Luxembourg                          | 85              | 15    | 100   | 100                   | 100                   |
| Madagascar                          | 33              | 67    | 78  | 34                    | 48                    |
| Malawi                              | 16              | 84    | 95  | 82                    | 84                    |
| Malaysia                            | 73              | 27    | 100   | 99                    | 100                   |
| Maldives                            | 41              | 59    | 100   | 98                    | 99                    |
| Mali                                | 35              | 65    | 89  | 53                    | 65                    |
| Malta                               | 95              | 5     | 100   | 100                   | 100                   |
| Marshall Islands                    | 72              | 28    | 93  | 97                    | 94                    |
| Martinique                          | 89              | 11    | 100   | 100                   | 100                   |
| Mauritania                          | 41              | 59    | 52  | 48                    | 50                    |
| Mauritius                           | 42              | 58    | 100   | 100                   | 100                   |
| Mayotte                             | 50              | 50    |   |                       |                       |
| Mexico                              | 78              | 22    | 96  | 89                    | 94                    |
| Micronesia (Fed. States of)         | 23              | 77    | 95  | 88                    | 89                    |
| Monaco                              | 100             | 0     | 100   |                       | 100                   |
| Mongolia                            | 69              | 31    | 100   | 53                    | 85                    |
| Montenegro                          | 63              | 37    | 100   | 95                    | 98                    |
| Montserrat                          | 14              | 86    | 99  | 99                    | 99                    |
| Morocco                             | 57              | 43    | 98  | 61                    | 82                    |
| Mozambique                          | 31              | 69    | 78  | 33                    | 47                    |
| Myanmar                             | 33              | 67    | 94  | 79                    | 84                    |
| Namibia                             | 38              | 62    | 99  | 90                    | 93                    |

*continues*



DATA TABLE 3B *continued*

| Country                          | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Drinking Water |                                  |                                     |
|----------------------------------|-----------------|-------|---|----------------------------------|-------------------------------------|
|                                  | Urban           | Rural | Urban Improved<br>Total Improved                                      | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|                                  | %               | %     | (%)   | (%)                              | (%)                                 |
| Nauru                            | 100             | 0     | 96  |                                  | 96                                  |
| Nepal                            | 17              | 83    | 91  | 87                               | 88                                  |
| Netherlands                      | 83              | 17    | 100   | 100                              | 100                                 |
| Netherlands Antilles             | 93              | 7     |   |                                  |                                     |
| New Caledonia                    | 62              | 38    | 98  | 98                               | 98                                  |
| New Zealand                      | 86              | 14    | 100   | 100                              | 100                                 |
| Nicaragua                        | 58              | 42    | 98  | 68                               | 85                                  |
| Niger                            | 18              | 82    | 100   | 39                               | 50                                  |
| Nigeria                          | 50              | 50    | 75  | 47                               | 61                                  |
| Niue                             | 38              | 62    | 99  | 99                               | 99                                  |
| Northern Mariana Islands         | 91              | 9     | 97  | 97                               | 97                                  |
| Norway                           | 79              | 21    | 100   | 100                              | 100                                 |
| Occupied Palestinian Territory   | 74              | 26    | 82  | 82                               | 82                                  |
| Oman                             | 73              | 27    | 95  | 85                               | 92                                  |
| Pakistan                         | 36              | 64    | 96  | 89                               | 91                                  |
| Palau                            | 84              | 16    | 97  | 86                               | 95                                  |
| Panama                           | 75              | 25    | 97  | 86                               | 94                                  |
| Papua New Guinea                 | 12              | 88    | 89  | 33                               | 40                                  |
| Paraguay                         | 62              | 38    | 99  |                                  |                                     |
| Peru                             | 77              | 23    | 91  | 66                               | 85                                  |
| Philippines                      | 49              | 51    | 93  | 92                               | 92                                  |
| Poland                           | 61              | 39    | 100   |                                  |                                     |
| Portugal                         | 61              | 39    | 100   | 100                              | 100                                 |
| Puerto Rico                      | 99              | 1     |   |                                  |                                     |
| Qatar                            | 99              | 1     | 100   | 100                              | 100                                 |
| Republic of Korea                | 83              | 17    | 100   | 88                               | 98                                  |
| Republic of Moldova              | 48              | 52    | 99  | 93                               | 96                                  |
| Réunion                          | 94              | 6     | 99  | 98                               | 99                                  |
| Romania                          | 53              | 47    | 99  |                                  |                                     |
| Russian Federation               | 74              | 26    | 99  | 92                               | 97                                  |
| Rwanda                           | 19              | 81    | 80  | 66                               | 69                                  |
| Saint Kitts and Nevis            | 32              | 68    | 98  | 98                               | 98                                  |
| Saint Lucia                      | 18              | 82    | 98  | 93                               | 94                                  |
| Saint Vincent and the Grenadines | 49              | 51    | 95  | 95                               | 95                                  |
| Samoa                            | 20              | 80    | 97  | 98                               | 98                                  |
| San Marino                       | 94              | 6     |   |                                  |                                     |
| São Tomé and Príncipe            | 63              | 37    | 99  | 94                               | 97                                  |
| Saudi Arabia                     | 82              | 18    | 97  | 97                               | 97                                  |
| Senegal                          | 43              | 57    | 93  | 59                               | 73                                  |
| Serbia                           | 56              | 44    | 99  | 99                               | 99                                  |
| Seychelles                       | 54              | 46    | 96  | 96                               | 96                                  |
| Sierra Leone                     | 39              | 61    | 84  | 40                               | 57                                  |
| Singapore                        | 100             | 0     | 100   |                                  | 100                                 |
| Slovakia                         | 55              | 45    | 100   | 100                              | 100                                 |
| Slovenia                         | 50              | 50    | 100   | 99                               | 100                                 |
| Solomon Islands                  | 20              | 80    | 93  | 76                               | 79                                  |

| Country                               | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Drinking Water |                       |                       |
|---------------------------------------|-----------------|-------|---|-----------------------|-----------------------|
|                                       | Urban           | Rural | Urban Improved  | Rural Improved        | National Improved     |
|                                       | %               | %     | Total Improved<br>(%)   | Total Improved<br>(%) | Total Improved<br>(%) |
| Somalia                               | 38              | 62    | 66  | 7                     | 30                    |
| South Africa                          | 62              | 38    | 99  | 79                    | 91                    |
| South Sudan                           | 18              | 82    | 63  | 55                    | 57                    |
| Spain                                 | 77              | 23    | 100   | 100                   | 100                   |
| Sri Lanka                             | 15              | 85    | 99  | 92                    | 93                    |
| Sudan                                 | 33              | 67    | 66  | 50                    | 55                    |
| Suriname                              | 70              | 30    | 97  | 81                    | 92                    |
| Swaziland                             | 21              | 79    | 93  | 67                    | 72                    |
| Sweden                                | 85              | 15    | 100   | 100                   | 100                   |
| Switzerland                           | 74              | 26    | 100   | 100                   | 100                   |
| Syrian Arab Republic                  | 56              | 44    | 93  | 87                    | 90                    |
| Tajikistan                            | 27              | 73    | 92  | 57                    | 66                    |
| TFYR Macedonia                        | 59              | 41    | 100   | 99                    | 100                   |
| Thailand                              | 34              | 66    | 97  | 95                    | 96                    |
| Timor-Leste                           | 28              | 72    | 93  | 60                    | 69                    |
| Togo                                  | 38              | 62    | 90  | 40                    | 59                    |
| Tokelau                               | 0               | 100   |   | 97                    | 97                    |
| Tonga                                 | 23              | 77    | 99  | 99                    | 99                    |
| Trinidad and Tobago                   | 14              | 86    | 98  | 93                    | 94                    |
| Tunisia                               | 66              | 34    | 100   | 89                    | 96                    |
| Turkey                                | 72              | 28    | 100   | 99                    | 100                   |
| Turkmenistan                          | 49              | 51    | 89  | 54                    | 71                    |
| Turks and Caicos Islands              | 94              | 6     |   |                       |                       |
| Tuvalu                                | 51              | 49    | 98  | 97                    | 98                    |
| Uganda                                | 16              | 84    | 91  | 72                    | 75                    |
| Ukraine                               | 69              | 31    | 98  | 98                    | 98                    |
| United Arab Emirates                  | 84              | 16    | 100   | 100                   | 100                   |
| United Kingdom                        | 80              | 20    | 100   | 100                   | 100                   |
| United Republic of Tanzania           | 27              | 73    | 79  | 44                    | 53                    |
| United States of America              | 82              | 18    | 100   | 94                    | 99                    |
| United States Virgin Islands          | 95              | 5     | 100   | 100                   | 100                   |
| Uruguay                               | 93              | 7     | 100   | 98                    | 100                   |
| Uzbekistan                            | 36              | 64    | 98  | 81                    | 87                    |
| Vanuatu                               | 25              | 75    | 98  | 88                    | 91                    |
| Venezuela (Bolivarian<br>Republic of) | 94              | 6     |   |                       |                       |
| Vietnam                               | 31              | 69    | 99  | 94                    | 96                    |
| Western Sahara                        | 82              | 18    |   |                       |                       |
| Yemen                                 | 32              | 68    | 72  | 47                    | 55                    |
| Zambia                                | 39              | 61    | 86  | 50                    | 64                    |
| Zimbabwe                              | 39              | 61    | 97  | 69                    | 80                    |

# Access to Improved Sanitation by Country, 1970–2008 & 2011 Update

## Description

Adequate sanitation is also a fundamental requirement for basic human well-being, and improving access to sanitation is one of the Millennium Development Goals (MDGs). Data are given here in two related tables.

**Data table 4A** includes the percentage of urban, rural, and total populations, by country, with access to improved sanitation for 1970, 1975, 1980, 1985, 1990, 1994, 2000, 2002, 2004, 2005, and 2008—similar to data table 4 in the previous volume of *The World's Water*. In the current volume, however, these previous data are sorted alphabetically by country rather than separated by regions.

**Data table 4B** provides an update of the percentage of national, urban, and rural populations with improved sanitation for 2011, the most recent year for which data are available. This table also includes the percentage of country populations in urban and rural categories for 2011.

The World Health Organization (WHO) / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation collected the data presented here over various periods. Most of the data presented were drawn from responses by national governments to questionnaires. Participants in data collection include the JMP, the United Nations Children's Fund, and the Water Supply and Sanitation Collaborative Council, which has continued sector monitoring and aims to support and strengthen the monitoring efforts of individual countries. Countries used their own definitions of “rural” and “urban.”

For all WHO assessments since 2000, new definitions were provided for “improved” sanitation with allowance for acceptable local technologies. For MDG monitoring, an improved sanitation facility is defined as one that hygienically separates human excreta from human contact.

The following technologies were included in the 2000 assessment as representing improved sanitation:

- Connection to a public sewer
- Connection to a septic system
- Pour-flush latrine

- Simple pit latrine
- Ventilated improved pit latrine

In comparison, unimproved sanitation facilities refer to the following:

- Public or shared latrine
- Open pit latrine
- Bucket latrine

## Limitations

As is the case with drinking water data, definitions for access to sanitation vary from country to country and from year to year within the same country. Countries generally regard sanitation facilities that break the fecal-oral transmission route as adequate. In urban areas, adequate sanitation may be provided by connections to public sewers or by household systems such as pit privies, flush latrines, septic tanks, and communal toilets. In rural areas, pit privies, pour-flush latrines, septic tanks, and communal toilets are considered adequate. Direct comparisons between countries and across time within the same country are difficult and are additionally complicated by the fact that these data hide disparities between regions and socioeconomic classes.

WHO assessments since 2000 have attempted to shift from gathering information from water providers only to including consumer-based information. The current approach uses household surveys in an effort to assess the actual use of facilities. Access to sanitation services, as reported by the World Health Organization, does not imply that the level of service is “adequate” or “safe.” The assessment questionnaire did not include any methodology for discounting coverage figures to allow for intermittence or poor quality of the service provided. More details of the methods used, and their limitations, can be found at [http://www.who.int/docstore/water\\_sanitation\\_health/Globassessment/GlobalTOC.htm](http://www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm).

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**DATA TABLE 4A** Access to Sanitation by Country, 1970–2008

| Region and Country     | Percentage of Population with Access to Improved Sanitation |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     |     |     |     |     |     |     |
|------------------------|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
|                        | URBAN   |      |      |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     |     |     |     |     |     |     |
|                        | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008  | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005  | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008 |    |    |    |    |     |     |     |     |     |     |     |
| Afghanistan            | 69  | 63   | 5    | 13   | 38   | 25   | 16   | 49   | 56   | 60   | 16    | 15   |      |      |      |      |      |      |      |      |       | 21   | 21   |      |      |      |      |      |      |      |      |      | 8    | 12 | 8  | 34 | 35 | 37  |     |     |     |     |     |     |
| Albania                |   |      |      |      |      |      | 99   | 99   |      |      |       |      |      | 81   | 84   |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    | 89 | 91  |     |     |     |     |     |     |
| Algeria                | 13  | 100  | 80   |      | 90   | 99   | 99   | 99   | 98   | 98   | 6     | 50   | 40   |      | 47   | 82   | 82   | 86   | 88   |      |       | 9    | 67   |      |      | 57   |      |      |      |      |      |      | 73   | 92 | 92 | 94 | 95 |     |     |     |     |     |     |     |
| Angola                 |   |      | 40   | 29   | 25   | 34   | 70   | 56   | 80   | 86   |       |      | 15   | 16   | 20   | 8    | 30   | 16   | 15   | 18   |       |      |      |      | 20   | 19   | 21   | 16   | 44   | 30   | 31   | 50   | 57   |    |    |    |    |     |     |     |     |     |     |     |
| Anguilla               |   |      |      |      |      |      |      | 99   | 99   |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    | 99  |     |     |     |     |     |     |
| Antigua and Barbuda    |   |      |      |      |      |      | 98   | 98   | 98   | 98   |       |      |      |      | 94   | 94   |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    | 95 | 95  |     |     |     |     |     |     |
| Argentina              | 87  | 100  | 80   | 75   |      | 89   |      | 92   | 91   | 91   | 79    | 83   | 35   | 35   |      | 48   |      | 83   | 77   | 77   |       | 85   | 97   |      |      | 69   |      |      |      |      |      | 85   |      |    |    | 91 | 90 | 90  |     |     |     |     |     |     |
| Armenia                |   |      |      |      |      |      | 96   | 96   | 95   | 95   |       |      |      |      | 61   | 61   | 79   | 80   |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    | 84 | 83  | 89  | 90  |     |     |     |     |
| Australia              |   |      |      |      |      | 100  | 100  | 100  | 100  | 100  |       |      |      |      | 100  | 100  | 100  | 100  |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    | 100 | 100 | 100 | 100 |     |     |     |
| Azerbaijan             |   |      |      |      |      |      | 73   | 73   | 55   | 51   |       |      |      |      | 36   | 36   | 34   | 39   |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    | 55  | 54  | 45  | 45  |     |     |     |
| Bahamas                | 100   | 100  | 88   | 100  | 98   |      | 93   | 100  | 100  | 100  | 13    | 13   |      |      | 2    | 94   | 100  | 100  | 100  | 100  |       | 66   | 65   |      |      | 88   | 100  | 63   |      |      |      |      |      |    |    |    | 93 | 100 | 100 | 100 |     |     |     |     |
| Bahrain                |   |      |      |      |      | 100  | 100  | 100  | 100  | 100  |       |      |      |      | 0    |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     | 100 |     |     |     |     |     |
| Bangladesh             | 87  | 40   | 21   | 24   | 40   | 77   | 82   | 75   | 51   | 57   | 56    |      |      | 1    | 3    | 4    | 30   | 44   | 39   | 35   | 48    | 52   | 6    | 5    |      | 3    | 5    | 10   | 35   | 53   | 48   | 39   | 50   | 53 |    |    |    |     |     |     |     |     |     |     |
| Barbados               | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 99   | 99   | 100  | 13    | 13   |      |      | 2    | 94   | 100  | 100  | 100  | 100  |       | 66   | 65   |      |      | 88   | 100  | 63   |      |      |      |      |      |    |    |    |    | 93  | 100 | 100 | 100 |     |     |     |
| Belarus                |   |      |      |      |      |      |      | 93   |      |      |       |      |      |      |      |      |      | 61   |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     | 84  |     |     |     |     |     |
| Belize                 |   |      | 62   | 87   | 76   | 23   | 59   | 71   | 71   | 89   | 93    |      |      | 75   | 45   | 22   | 87   | 21   | 25   | 25   | 84    | 86   |      |      |      |      | 69   | 66   | 50   | 57   | 42   | 47   | 47   | 47 | 47 | 47 | 86 | 90  |     |     |     |     |     |     |
| Benin                  | 83  |      | 48   | 58   | 60   | 54   | 46   | 58   | 59   | 22   | 24    | 1    |      | 4    | 20   | 35   | 6    | 6    | 12   | 11   | 3     | 4    | 14   |      |      | 16   | 33   | 45   | 20   | 23   | 32   | 33   | 11   | 12 |    |    |    |     |     |     |     |     |     |     |
| Bhutan                 |   |      |      |      |      |      | 80   | 66   | 65   | 65   | 87    | 87   |      |      | 3    | 18   | 70   | 70   | 70   | 54   | 54    |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     | 7   | 41  | 69  | 70  | 64  | 65  |
| Bolivia                | 25  |      | 37   | 33   | 38   | 58   | 82   | 58   | 60   | 33   | 34    | 4    | 9    | 4    | 10   | 14   | 16   | 38   | 23   | 22   | 9     | 9    | 12   |      |      | 18   | 21   | 26   | 41   | 66   | 45   | 46   | 24   | 25 |    |    |    |     |     |     |     |     |     |     |
| Bosnia and Herzegovina |   |      |      |      |      |      |      | 99   |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     |     | 95  |     |     |     |     |
| Botswana               |   |      |      |      |      |      |      | 57   | 57   | 72   | 74    |      |      |      | 28   | 85   |      | 25   | 25   | 36   | 39    |      |      |      |      |      |      |      |      |      |      |      |      |    |    |    |    |     | 41  | 42  | 57  | 60  |     |     |
| Brazil                 | 85  |      | 86   | 84   | 55   | 85   | 83   | 83   | 86   | 87   | 24    |      |      | 1    | 1    | 32   | 3    | 40   | 35   | 37   | 37    | 37   | 58   |      |      | 63   | 71   | 44   | 77   | 75   | 75   | 78   | 80   |    |    |    |    |     |     |     |     |     |     |     |
| British Virgin Islands |   |      |      |      |      |      | 100  | 100  | 100  | 100  | 13    | 13   |      |      | 2    | 94   | 100  | 100  | 100  | 100  | 100   |      | 66   | 65   |      |      | 88   | 100  | 63   |      |      |      |      |    |    |    |    |     |     |     | 93  | 100 | 100 | 100 |

*continues*







**DATA TABLE 4A** *continued*

| Region and Country                 | Percentage of Population with Access to Improved Sanitation |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|------------------------------------|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|------|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|--|
|                                    | URBAN   |      |      |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                                    | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008  | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005  | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| India                              | 85  | 87   | 27   | 31   | 44   | 70   | 73   | 58   | 59   | 54   | 54    | 1    | 2    | 1    | 2    | 3    | 14   | 14   | 18   | 22   | 18    | 21   | 18   | 20   | 7    | 9    | 14   | 29   | 31   | 30   | 33   | 28   | 31   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Indonesia                          | 50  | 60   | 29   | 33   | 79   | 73   | 87   | 71   | 73   | 66   | 67    | 4    | 5    | 21   | 38   | 30   | 40   | 52   | 38   | 40   | 33    | 36   | 12   | 15   | 23   | 37   | 44   | 51   | 66   | 52   | 55   | 49   | 52   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Iran                               | 100   | 100  | 96   | 100  | 100  | 89   | 86   | 86   |      |      |       | 48   | 59   | 43   |      | 35   | 37   | 74   | 78   |      |       | 70   | 78   | 69   |      | 72   | 67   | 81   | 84   |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Iraq                               | 82  | 75   | 100  | 96   | 100  | 96   | 93   | 95   | 95   | 76   | 76    | 1    |      | 11   |      | 31   | 48   | 48   | 48   | 61   | 66    | 66   | 47   | 47   |      | 74   | 36   | 79   | 80   | 79   | 71   | 73   |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Israel                             | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   | 92   | 91   | 2    | 90   | 66   | 68   | 69   | 84   | 84   | 100   | 100  | 94   | 94   | 7    | 91   | 84   | 80   | 80   | 83   | 83   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Jamaica                            | 100   | 100  | 12   | 92   | 98   | 90   | 91   | 82   | 82   | 82   | 82    |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Japan                              | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Jordan                             | 94  | 92   | 100  | 100  | 100  | 94   | 94   | 98   | 98   | 98   | 98    |      |      | 34   | 100  | 98   | 85   | 87   | 96   | 97   |       |      |      |      | 70   |      | 100  | 95   | 93   | 93   | 93   | 98   | 98   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kazakhstan                         | 100   | 87   | 87   | 97   | 97   | 97   | 97   | 97   | 97   | 97   | 97    |      |      |      |      | 98   | 52   | 52   | 98   | 98   |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kenya                              | 85  | 98   | 89   | 69   | 96   | 56   | 46   | 27   | 27   | 27   | 27    | 45   | 48   | 19   |      | 81   | 81   | 43   | 41   | 31   | 32    | 50   | 55   | 30   |      | 77   | 86   | 48   | 43   | 30   | 31   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kiribati                           | 91  | 100  | 54   | 59   | 59   | 49   |      |      |      |      |       | 49   | 100  | 44   | 22   | 22   | 22   | 22   | 22   | 22   | 22    | 22   | 100  | 48   | 39   | 40   | 35   |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Korea Democratic People's Republic | 99  | 58   | 58   |      |      |      |      |      |      |      |       | 100  | 60   | 60   |      |      |      |      |      |      |       |      | 99   | 59   | 59   |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Korea Republic                     | 59  | 80   | 100  | 100  | 67   | 76   |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kuwait                             | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   |      |      |      |      |      |      |      |      |      |       |      | 100  | 100  |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kyrgyzstan                         | 100   | 75   | 75   | 94   | 94   | 94   | 100  | 75   | 75   | 94   | 94    |      |      |      |      | 100  | 51   | 51   | 93   | 93   |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Laos                               | 10  | 13   | 30   | 70   | 84   | 61   | 67   | 77   | 86   | 86   | 86    | 2    | 4    |      | 8    | 13   | 34   | 14   | 20   | 30   | 38    | 3    | 5    |      | 12   | 24   | 46   | 24   | 30   | 43   | 53   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Latvia                             |   |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Lebanon                            | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100   |      |      |      |      | 100  | 92   | 87   | 87   | 87   |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Lesotho                            | 44  | 51   | 13   | 22   | 1    | 93   | 61   | 61   | 39   | 40   | 40    | 10   | 12   | 14   | 14   | 7    | 96   | 32   | 32   | 25   | 25    | 11   | 13   | 14   | 15   | 6    | 92   | 37   | 37   | 28   | 29   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Liberia                            | 100   | 100  | 100  | 100  | 6    | 38   | 49   | 49   | 24   | 25   | 25    | 9    |      | 2    |      | 2    | 7    | 7    | 4    | 4    |       |      | 19   |      |      |      | 18   | 26   | 27   | 16   | 17   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Libya                              | 100   | 100  | 100  | 100  | 97   | 97   | 97   | 97   | 97   | 97   | 97    | 54   | 69   | 72   |      | 30   | 96   | 96   | 96   | 96   |       |      | 67   | 79   | 88   |      | 97   | 97   | 97   | 97   | 97   | 97   |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Madagascar                         | 88  | 9    | 55   | 50   | 70   | 49   | 48   | 15   | 15   | 15   | 15    | 9    |      |      |      | 3    | 70   | 27   | 26   | 9    | 10    |      |      |      |      | 15   | 42   | 33   | 34   | 11   | 11   |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Malawi                             | 100   | 100  | 100  | 100  | 70   | 96   | 66   | 62   | 51   | 51   | 51    | 43   | 43   | 55   | 60   | 94   | 41   | 98   | 93   | 95   | 95    | 59   | 60   | 70   | 75   | 94   |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Malaysia                           | 100   | 100  | 100  | 100  | 94   | 95   | 96   | 96   | 96   | 96   | 96    |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |



**DATA TABLE 4A** *continued*

| Region and Country    |     | Percentage of Population with Access to Improved Sanitation |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|-----|---|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|------|------|------|------|
|                       |     | URBAN   |      |      |      |      |      |      |      |      |      | RURAL |      |      |      |      |      |      |      |      |      | TOTAL |      |      |      |      |      |      |      |      |      |      |      |
|                       |     | 1970  | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 | 2008  | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005  | 2008 | 1970 | 1975 | 1980 | 1985 | 1990 | 1994 | 2000 | 2002 | 2004 | 2005 |
| Peru                  | 52  | 57  | 67   | 76   | 62   | 90   | 72   | 74   | 79   | 81   | 16   | 0     | 12   | 20   | 10   | 40   | 33   | 32   | 33   | 36   | 36   | 36    | 36   | 49   | 59   | 44   | 76   | 62   | 63   | 66   | 68   |      |      |
| Philippines           | 90  | 76  | 81   | 83   | 79   | 92   | 81   | 80   | 78   | 80   | 40   | 44    | 67   | 56   | 63   | 71   | 61   | 59   | 65   | 69   | 57   | 56    | 75   | 67   | 70   | 83   | 73   | 72   | 73   | 76   |      |      |      |
| Qatar                 | 100 | 100   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 16   | 100   | 100  | 85   |      | 100  | 100  | 100  | 100  | 100  | 83   | 100   |      |      |      | 100  | 100  | 100  | 100  | 100  |      |      |      |
| Republic of Moldova   |     |   |      |      |      | 86   | 86   | 86   |      |      |      |       |      |      |      | 52   | 52   |      |      |      |      |       |      |      |      |      | 68   | 68   |      |      |      |      |      |
| Romania               |     |   |      |      |      | 86   | 89   |      |      |      |      |       |      |      |      | 10   |      |      |      |      |      |       |      |      |      |      | 51   |      |      |      |      |      |      |
| Russian Federation    |     |   |      |      |      | 93   | 93   |      |      |      |      |       |      |      |      | 70   | 70   |      |      |      |      |       |      |      |      |      | 87   | 87   |      |      |      |      |      |
| Rwanda                | 83  | 87  | 60   | 77   | 88   | 12   | 56   | 56   | 47   | 50   | 52   | 56    | 50   | 55   | 17   | 8    | 38   | 38   | 49   | 55   | 53   | 57    | 51   | 56   | 21   | 8    | 41   | 42   | 49   | 54   |      |      |      |
| Samoa                 | 100 | 100   | 86   | 100  | 100  | 95   | 100  | 100  | 100  | 100  |      |       |      |      | 100  | 100  | 100  | 100  | 100  | 100  |      |       |      |      |      | 100  | 100  | 100  | 100  | 100  |      |      |      |
| São Tomé and Príncipe |     |   |      |      |      | 32   | 32   | 29   | 30   |      |      |       | 15   |      |      | 20   | 20   | 17   | 19   |      |      |       |      | 15   |      |      | 24   | 25   | 24   | 26   |      |      |      |
| Saudi Arabia          | 67  | 91  | 81   | 100  | 100  | 100  | 100  | 100  | 100  | 100  | 11   | 35    | 50   | 33   |      | 100  |      |      |      |      | 21   | 47    | 70   | 82   |      | 100  |      |      |      |      |      |      |      |
| Senegal               |     |   |      |      |      | 100  | 87   | 57   | 83   | 94   | 70   | 79    | 68   | 69   | 38   | 40   | 48   | 34   | 34   | 36   | 38   |       | 36   |      | 46   | 58   | 70   | 52   | 57   | 49   | 51   |      |      |
| Serbia and Montenegro |     |   |      |      |      | 97   | 97   |      |      |      |      |       |      |      |      | 77   | 77   |      |      |      |      |       |      |      |      |      | 87   | 87   |      |      |      |      |      |
| Seychelles            |     |   |      |      |      |      |      |      |      |      |      |       |      |      |      | 100  | 100  |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |
| Sierra Leone          |     |   |      |      |      | 31   | 60   | 55   | 17   | 23   | 53   | 53    | 23   | 24   | 6    | 10   | 31   | 8    | 31   | 30   | 6    |       |      |      | 12   | 24   | 39   | 11   | 28   | 39   | 39   | 12   | 13   |
| Singapore             |     |   |      |      |      | 80   | 99   | 99   | 100  | 100  | 100  | 100   | 100  | 100  |      |      |      |      |      |      |      |       |      |      |      | 80   | 99   | 100  | 100  | 100  | 100  |      |      |
| Slovakia              |     |   |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |      |      |      |      |
| Solomon Islands       |     |   |      |      |      | 80   | 73   | 44   | 73   | 98   | 98   | 98    | 98   | 98   | 21   | 2    | 18   | 18   | 18   | 18   |      |       |      |      |      | 13   | 34   | 31   | 31   | 31   | 32   |      |      |
| Somalia               |     |   |      |      |      | 77   | 44   |      |      |      |      |       |      |      | 35   | 5    | 14   | 14   | 7    | 6    |      |       |      |      |      |      |      |      |      |      |      |      |      |
| South Africa          |     |   |      |      |      | 79   | 99   | 86   | 79   | 83   | 84   |       |      |      | 12   | 73   | 44   | 46   | 64   | 65   |      |       |      |      |      |      | 46   | 86   | 67   | 65   | 75   | 77   |      |
| Sri Lanka             | 76  | 68  | 80   | 65   | 68   | 33   | 91   | 98   | 98   | 87   | 88   | 61    | 55   | 63   | 39   | 45   | 58   | 80   | 89   | 88   | 92   | 64    | 59   | 67   | 44   | 50   | 52   | 83   | 91   | 91   | 88   | 91   |      |
| St. Kitts             |     |   |      |      |      | 96   | 96   | 96   | 96   | 96   |      |       |      |      |      | 96   | 96   | 96   | 96   | 96   |      |       |      |      |      |      | 96   | 95   | 96   | 96   | 96   |      |      |
| St. Lucia             |     |   |      |      |      | 89   | 89   |      |      |      |      |       |      |      |      | 89   | 89   |      |      |      |      |       |      |      |      |      | 89   | 89   |      |      |      |      |      |







**DATA TABLE 4B** Access to Improved Sanitation by Country, 2011 Update

| Country                             | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Sanitation |                                  |                                     |
|-------------------------------------|-----------------|-------|---|----------------------------------|-------------------------------------|
|                                     | Urban           | Rural | Urban Improved<br>Total Improved                                  | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|                                     | %               | %     | (%)   | (%)                              | (%)                                 |
| Afghanistan                         | 24              | 76    | 46  | 23                               | 28                                  |
| Albania                             | 53              | 47    | 95  | 93                               | 94                                  |
| Algeria                             | 73              | 27    | 98  | 88                               | 95                                  |
| American Samoa                      | 93              | 7     | 97  | 97                               | 97                                  |
| Andorra                             | 87              | 13    | 100   | 100                              | 100                                 |
| Angola                              | 59              | 41    | 86  | 19                               | 59                                  |
| Anguilla                            | 100             | 0     | 98  |                                  | 98                                  |
| Antigua and Barbuda                 | 30              | 70    | 91  | 91                               | 91                                  |
| Argentina                           | 93              | 7     | 96  | 98                               | 96                                  |
| Armenia                             | 64              | 36    | 96  | 81                               | 90                                  |
| Aruba                               | 47              | 53    | 98  | 98                               | 98                                  |
| Australia                           | 89              | 11    | 100   | 100                              | 100                                 |
| Austria                             | 68              | 32    | 100   | 100                              | 100                                 |
| Azerbaijan                          | 54              | 46    | 86  | 78                               | 82                                  |
| Bahamas                             | 84              | 16    |   |                                  |                                     |
| Bahrain                             | 89              | 11    | 99  | 99                               | 99                                  |
| Bangladesh                          | 28              | 72    | 55  | 55                               | 55                                  |
| Barbados                            | 44              | 56    |   |                                  |                                     |
| Belarus                             | 75              | 25    | 92  | 97                               | 93                                  |
| Belgium                             | 97              | 3     | 100   | 100                              | 100                                 |
| Belize                              | 45              | 55    | 93  | 87                               | 90                                  |
| Benin                               | 45              | 55    | 25  | 5                                | 14                                  |
| Bermuda                             | 100             | 0     |   |                                  |                                     |
| Bhutan                              | 36              | 64    | 74  | 29                               | 45                                  |
| Bolivia (Plurinational<br>State of) | 67              | 33    | 57  | 24                               | 46                                  |
| Bosnia and Herzegovina              | 48              | 52    | 100   | 92                               | 96                                  |
| Botswana                            | 62              | 38    | 78  | 42                               | 64                                  |
| Brazil                              | 85              | 15    | 87  | 48                               | 81                                  |
| British Virgin Islands              | 41              | 59    | 98  | 98                               | 97                                  |
| Brunei Darussalam                   | 76              | 24    |   |                                  |                                     |
| Bulgaria                            | 73              | 27    | 100   | 100                              | 100                                 |
| Burkina Faso                        | 27              | 73    | 50  | 6                                | 18                                  |
| Burundi                             | 11              | 89    | 45  | 51                               | 50                                  |
| Cambodia                            | 20              | 80    | 76  | 22                               | 33                                  |
| Cameroon                            | 52              | 48    | 58  | 36                               | 48                                  |
| Canada                              | 81              | 19    | 100   | 99                               | 100                                 |
| Cape Verde                          | 63              | 37    | 74  | 45                               | 63                                  |
| Cayman Islands                      | 100             | 0     | 96  |                                  | 96                                  |
| Central African Republic            | 39              | 61    | 43  | 28                               | 34                                  |
| Chad                                | 22              | 78    | 31  | 6                                | 12                                  |
| Channel Islands                     | 31              | 69    |   |                                  |                                     |
| Chile                               | 89              | 11    | 100   | 89                               | 99                                  |
| China                               | 51              | 49    | 74  | 56                               | 65                                  |
| China, Hong Kong SAR                | 100             | 0     |   |                                  |                                     |
| China, Macao SAR                    | 100             | 0     |   |                                  |                                     |
| Colombia                            | 75              | 25    | 82  | 65                               | 78                                  |
| Comoros                             | 28              | 72    |   |                                  |                                     |

*continues*

DATA TABLE 4B *continued*

| Country                                  | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Sanitation |                                  |                                     |
|--|-----------------|-------|---|----------------------------------|-------------------------------------|
|  | Urban           | Rural | Urban Improved<br>Total Improved                                  | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|  | %               | %     | (%)   | (%)                              | (%)                                 |
| Congo                                    | 64              | 36    | 19  | 15                               | 18                                  |
| Cook Islands                             | 74              | 26    | 95  | 95                               | 95                                  |
| Costa Rica                               | 65              | 35    | 95  | 92                               | 94                                  |
| Côte d'Ivoire                            | 51              | 49    | 36  | 11                               | 24                                  |
| Croatia                                  | 58              | 42    | 99  | 98                               | 98                                  |
| Cuba                                     | 75              | 25    | 94  | 87                               | 92                                  |
| Cyprus                                   | 70              | 30    | 100   | 100                              | 100                                 |
| Czech Republic                           | 73              | 27    | 100   | 100                              | 100                                 |
| Democratic People's<br>Republic of Korea | 60              | 40    | 88  | 73                               | 82                                  |
| Democratic Republic<br>of the Congo      | 34              | 66    | 29  | 31                               | 31                                  |
| Denmark                                  | 87              | 13    | 100   | 100                              | 100                                 |
| Djibouti                                 | 77              | 23    | 73  | 22                               | 61                                  |
| Dominica                                 | 67              | 33    |   |                                  |                                     |
| Dominican Republic                       | 70              | 30    | 86  | 74                               | 82                                  |
| Ecuador                                  | 67              | 33    | 96  | 86                               | 93                                  |
| Egypt                                    | 43              | 57    | 97  | 93                               | 95                                  |
| El Salvador                              | 65              | 35    | 79  | 53                               | 70                                  |
| Equatorial Guinea                        | 39              | 61    |   |                                  |                                     |
| Eritrea                                  | 21              | 79    |   | 4                                |                                     |
| Estonia                                  | 69              | 31    | 100   | 94                               | 98                                  |
| Ethiopia                                 | 17              | 83    | 27  | 19                               | 21                                  |
| Faeroe Islands                           | 41              | 59    |   |                                  |                                     |
| Falkland Islands (Malvinas)              | 74              | 26    |   |                                  |                                     |
| Fiji                                     | 52              | 48    | 92  | 82                               | 87                                  |
| Finland                                  | 84              | 16    | 100   | 100                              | 100                                 |
| France                                   | 86              | 14    | 100   | 100                              | 100                                 |
| French Guiana                            | 76              | 24    | 95  | 76                               | 90                                  |
| French Polynesia                         | 51              | 49    | 97  | 97                               | 97                                  |
| Gabon                                    | 86              | 14    | 33  | 30                               | 33                                  |
| Gambia                                   | 57              | 43    | 70  | 65                               | 68                                  |
| Georgia                                  | 53              | 47    | 96  | 91                               | 93                                  |
| Germany                                  | 74              | 26    | 100   | 100                              | 100                                 |
| Ghana                                    | 52              | 48    | 19  | 8                                | 13                                  |
| Greece                                   | 61              | 39    | 99  | 97                               | 99                                  |
| Greenland                                | 85              | 15    | 100   | 100                              | 100                                 |
| Grenada                                  | 39              | 61    |   |                                  |                                     |
| Guadeloupe                               | 98              | 2     | 97  | 90                               | 97                                  |
| Guam                                     | 93              | 7     | 97  | 97                               | 97                                  |
| Guatemala                                | 50              | 50    | 88  | 72                               | 80                                  |
| Guinea                                   | 35              | 65    | 32  | 11                               | 18                                  |
| Guinea-Bissau                            | 44              | 56    | 33  | 8                                | 19                                  |
| Guyana                                   | 28              | 72    | 88  | 82                               | 84                                  |
| Haiti                                    | 53              | 47    | 34  | 17                               | 26                                  |
| Honduras                                 | 52              | 48    | 86  | 74                               | 81                                  |
| Hungary                                  | 69              | 31    | 100   | 100                              | 100                                 |
| Iceland                                  | 94              | 6     | 100   | 100                              | 100                                 |

| Country                             | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Sanitation |                       |                       |
|-------------------------------------|-----------------|-------|---|-----------------------|-----------------------|
|                                     | Urban           | Rural | Urban Improved  | Rural Improved        | National Improved     |
|                                     | %               | %     | Total Improved<br>(%)   | Total Improved<br>(%) | Total Improved<br>(%) |
| India                               | 31              | 69    | 60  | 24                    | 35                    |
| Indonesia                           | 51              | 49    | 73  | 44                    | 59                    |
| Iran (Islamic Republic of)          | 69              | 31    | 100   | 99                    | 100                   |
| Iraq                                | 66              | 34    | 86  | 80                    | 84                    |
| Ireland                             | 62              | 38    | 100   | 98                    | 99                    |
| Isle of Man                         | 51              | 49    |   |                       |                       |
| Israel                              | 92              | 8     | 100   | 100                   | 100                   |
| Italy                               | 68              | 32    |   |                       |                       |
| Jamaica                             | 52              | 48    | 78  | 82                    | 80                    |
| Japan                               | 91              | 9     | 100   | 100                   | 100                   |
| Jordan                              | 83              | 17    | 98  | 98                    | 98                    |
| Kazakhstan                          | 54              | 46    | 97  | 98                    | 97                    |
| Kenya                               | 24              | 76    | 31  | 29                    | 29                    |
| Kiribati                            | 44              | 56    | 51  | 30                    | 39                    |
| Kuwait                              | 98              | 2     | 100   | 100                   | 100                   |
| Kyrgyzstan                          | 35              | 65    | 94  | 93                    | 93                    |
| Lao People's Democratic<br>Republic | 34              | 66    | 87  | 48                    | 62                    |
| Latvia                              | 68              | 32    |   |                       |                       |
| Lebanon                             | 87              | 13    | 100   |                       |                       |
| Lesotho                             | 28              | 72    | 32  | 24                    | 26                    |
| Liberia                             | 48              | 52    | 30  | 7                     | 18                    |
| Libyan Arab Jamahiriya              | 78              | 22    | 97  | 96                    | 97                    |
| Liechtenstein                       | 14              | 86    |   |                       |                       |
| Lithuania                           | 67              | 33    | 95  |                       |                       |
| Luxembourg                          | 85              | 15    | 100   | 100                   | 100                   |
| Madagascar                          | 33              | 67    | 19  | 11                    | 14                    |
| Malawi                              | 16              | 84    | 50  | 53                    | 53                    |
| Malaysia                            | 73              | 27    | 96  | 95                    | 96                    |
| Maldives                            | 41              | 59    | 97  | 98                    | 98                    |
| Mali                                | 35              | 65    | 35  | 14                    | 22                    |
| Malta                               | 95              | 5     | 100   | 100                   | 100                   |
| Marshall Islands                    | 72              | 28    | 84  | 55                    | 76                    |
| Martinique                          | 89              | 11    | 94  | 73                    | 92                    |
| Mauritania                          | 41              | 59    | 51  | 9                     | 27                    |
| Mauritius                           | 42              | 58    | 92  | 90                    | 91                    |
| Mayotte                             | 50              | 50    |   |                       |                       |
| Mexico                              | 78              | 22    | 87  | 77                    | 85                    |
| Micronesia (Fed. States of)         | 23              | 77    | 83  | 47                    | 55                    |
| Monaco                              | 100             | 0     | 100   |                       | 100                   |
| Mongolia                            | 69              | 31    | 64  | 29                    | 53                    |
| Montenegro                          | 63              | 37    | 92  | 87                    | 90                    |
| Montserrat                          | 14              | 86    |   |                       |                       |
| Morocco                             | 57              | 43    | 83  | 52                    | 70                    |
| Mozambique                          | 31              | 69    | 41  | 9                     | 19                    |
| Myanmar                             | 33              | 67    | 84  | 74                    | 77                    |
| Namibia                             | 38              | 62    | 57  | 17                    | 32                    |
| Nauru                               | 100             | 0     | 66  |                       | 66                    |
| Nepal                               | 17              | 83    | 50  | 32                    | 35                    |

*continues*

DATA TABLE 4B *continued*

| Country                             | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Sanitation |                                  |                                     |
|-------------------------------------|-----------------|-------|---|----------------------------------|-------------------------------------|
|                                     | Urban           | Rural | Urban Improved<br>Total Improved                                  | Rural Improved<br>Total Improved | National Improved<br>Total Improved |
|                                     | %               | %     | (%)   | (%)                              | (%)                                 |
| Netherlands                         | 83              | 17    | 100   | 100                              | 100                                 |
| Netherlands Antilles                | 93              | 7     |   |                                  |                                     |
| New Caledonia                       | 62              | 38    | 100   | 100                              | 100                                 |
| New Zealand                         | 86              | 14    |   |                                  |                                     |
| Nicaragua                           | 58              | 42    | 63  | 37                               | 52                                  |
| Niger                               | 18              | 82    | 34  | 4                                | 10                                  |
| Nigeria                             | 50              | 50    | 33  | 28                               | 31                                  |
| Niue                                | 38              | 62    | 100   | 100                              | 100                                 |
| Northern Mariana Islands            | 91              | 9     | 98  | 98                               | 98                                  |
| Norway                              | 79              | 21    | 100   | 100                              | 100                                 |
| Occupied Palestinian<br>Territory   | 74              | 26    | 95  | 93                               | 94                                  |
| Oman                                | 73              | 27    | 97  | 95                               | 97                                  |
| Pakistan                            | 36              | 64    | 72  | 34                               | 47                                  |
| Palau                               | 84              | 16    | 100   | 100                              | 100                                 |
| Panama                              | 75              | 25    | 77  | 54                               | 71                                  |
| Papua New Guinea                    | 12              | 88    | 57  | 13                               | 19                                  |
| Paraguay                            | 62              | 38    |   |                                  |                                     |
| Peru                                | 77              | 23    | 81  | 38                               | 72                                  |
| Philippines                         | 49              | 51    | 79  | 69                               | 74                                  |
| Poland                              | 61              | 39    | 96  |                                  |                                     |
| Portugal                            | 61              | 39    | 100   | 100                              | 100                                 |
| Puerto Rico                         | 99              | 1     | 99  | 99                               | 99                                  |
| Qatar                               | 99              | 1     | 100   | 100                              | 100                                 |
| Republic of Korea                   | 83              | 17    | 100   | 100                              | 100                                 |
| Republic of Moldova                 | 48              | 52    | 89  | 83                               | 86                                  |
| Réunion                             | 94              | 6     | 98  | 95                               | 98                                  |
| Romania                             | 53              | 47    |   |                                  |                                     |
| Russian Federation                  | 74              | 26    | 74  | 59                               | 70                                  |
| Rwanda                              | 19              | 81    | 61  | 61                               | 61                                  |
| Saint Kitts and Nevis               | 32              | 68    |   |                                  |                                     |
| Saint Lucia                         | 18              | 82    | 70  | 64                               | 65                                  |
| Saint Vincent and the<br>Grenadines | 49              | 51    |   |                                  |                                     |
| Samoa                               | 20              | 80    | 93  | 91                               | 92                                  |
| San Marino                          | 94              | 6     |   |                                  |                                     |
| São Tomé and Príncipe               | 63              | 37    | 41  | 23                               | 34                                  |
| Saudi Arabia                        | 82              | 18    | 100   | 100                              | 100                                 |
| Senegal                             | 43              | 57    | 68  | 39                               | 51                                  |
| Serbia                              | 56              | 44    | 98  | 96                               | 97                                  |
| Seychelles                          | 54              | 46    | 97  | 97                               | 97                                  |
| Sierra Leone                        | 39              | 61    | 22  | 7                                | 13                                  |
| Singapore                           | 100             | 0     | 100   |                                  | 100                                 |
| Slovakia                            | 55              | 45    | 100   | 100                              | 100                                 |
| Slovenia                            | 50              | 50    | 100   | 100                              | 100                                 |
| Solomon Islands                     | 20              | 80    | 81  | 15                               | 29                                  |
| Somalia                             | 38              | 62    | 52  | 6                                | 24                                  |

| Country                               | 2011 Population |       | 2011 Fraction of Population<br>with Access to Improved Sanitation |                       |                       |
|---------------------------------------|-----------------|-------|---|-----------------------|-----------------------|
|                                       | Urban           | Rural | Urban Improved  | Rural Improved        | National Improved     |
|                                       | %               | %     | Total Improved<br>(%)   | Total Improved<br>(%) | Total Improved<br>(%) |
| South Africa                          | 62              | 38    | 84  | 57                    | 74                    |
| South Sudan                           | 18              | 82    | 16  | 7                     | 9                     |
| Spain                                 | 77              | 23    | 100   | 100                   | 100                   |
| Sri Lanka                             | 15              | 85    | 83  | 93                    | 91                    |
| Sudan                                 | 33              | 67    | 44  | 13                    | 24                    |
| Suriname                              | 70              | 30    | 90  | 66                    | 83                    |
| Swaziland                             | 21              | 79    | 63  | 55                    | 57                    |
| Sweden                                | 85              | 15    | 100   | 100                   | 100                   |
| Switzerland                           | 74              | 26    | 100   | 100                   | 100                   |
| Syrian Arab Republic                  | 56              | 44    | 96  | 94                    | 95                    |
| Tajikistan                            | 27              | 73    | 95  | 94                    | 95                    |
| TFYR Macedonia                        | 59              | 41    | 97  | 83                    | 91                    |
| Thailand                              | 34              | 66    | 89  | 96                    | 93                    |
| Timor-Leste                           | 28              | 72    | 68  | 27                    | 39                    |
| Togo                                  | 38              | 62    | 26  | 3                     | 11                    |
| Tokelau                               | 0               | 100   |   | 93                    | 93                    |
| Tonga                                 | 23              | 77    | 99  | 89                    | 92                    |
| Trinidad and Tobago                   | 14              | 86    | 92  | 92                    | 92                    |
| Tunisia                               | 66              | 34    | 97  | 75                    | 90                    |
| Turkey                                | 72              | 28    | 97  | 75                    | 91                    |
| Turkmenistan                          | 49              | 51    | 100   | 98                    | 99                    |
| Turks and Caicos Islands              | 94              | 6     |   |                       |                       |
| Tuvalu                                | 51              | 49    | 86  | 80                    | 83                    |
| Uganda                                | 16              | 84    | 34  | 35                    | 35                    |
| Ukraine                               | 69              | 31    | 96  | 89                    | 94                    |
| United Arab Emirates                  | 84              | 16    | 98  | 95                    | 98                    |
| United Kingdom                        | 80              | 20    | 100   | 100                   | 100                   |
| United Republic of Tanzania           | 27              | 73    | 24  | 7                     | 12                    |
| United States of America              | 82              | 18    | 100   | 99                    | 100                   |
| United States Virgin Islands          | 95              | 5     | 96  | 96                    | 96                    |
| Uruguay                               | 93              | 7     | 99  | 98                    | 99                    |
| Uzbekistan                            | 36              | 64    | 100   | 100                   | 100                   |
| Vanuatu                               | 25              | 75    | 65  | 55                    | 58                    |
| Venezuela (Bolivarian<br>Republic of) | 94              | 6     |   |                       |                       |
| Vietnam                               | 31              | 69    | 93  | 67                    | 75                    |
| Western Sahara                        | 82              | 18    |   |                       |                       |
| Yemen                                 | 32              | 68    | 93  | 34                    | 53                    |
| Zambia                                | 39              | 61    | 56  | 33                    | 42                    |
| Zimbabwe                              | 39              | 61    | 52  | 33                    | 40                    |



# MDG Progress on Access to Safe Drinking Water by Region

## Description

The Millennium Development Goals (MDGs)—adopted by the United Nations in 2000—established a set of targets for improving the lives of the world’s poor, ranging from eradicating extreme hunger to reducing child mortality and ensuring environmental sustainability. These targets, agreed to by all countries and leading development institutions throughout the world, consist of eight goals and twenty-one targets. This table presents regional summaries of progress for the years 1990, 2004, 2008, and 2011 (from the 2013 update) as well as the 2015 target levels, measured as the proportion of the population using an improved water source (see data tables 3 and 4 for definitions).

In 2010, the human right to safe water and sanitation was formally recognized by the UN General Assembly and the UN Human Rights Council, but this basic right is not being met universally. In many parts of the world, particularly sub-Saharan Africa and Oceania, a lack of clean water adversely affects human health and development. Using 1990 as a baseline, one target of goal 7 of the MDGs seeks to reduce by half the proportion of people without sustainable access to safe drinking water by 2015.

At the global level, we are on track to meet the target for improving access to safe drinking water; however, not all regions are performing as well as others.

Europe, Latin America, the Caribbean, and much of Asia have met or are on track to meet the established targets. But in Oceania, there has been no progress or conditions have worsened; it is possible that the targets for Northern and Sub-Saharan Africa and South-Eastern Asia can still be met, but time is running out. The global community must continue to intensify efforts in these regions if we hope to achieve the established 2015 targets.

## Limitations

These data give a good picture of the current lack of access to improved water and sanitation services, but comparison with different assessments should be done with extreme care, or not at all, because of changing definitions. For the 2011 update (released in 2013), some regional changes in country assignments slightly change the data from previous years. In particular, the region formerly noted as the Commonwealth of Independent States is now Caucasus and Central Asia.

Country-reported data may reflect national definitions of “improved,” unlike survey data, which were standardized as much as possible. For example, in many African countries the population “without access” to improved sanitation means people with no access to any sanitary facility. In Latin America and the Caribbean, however, it is more likely that those “without access” in fact have a sanitary facility, but the facility is deemed unsatisfactory by local or national authorities. Low coverage figures for Latin America and the Caribbean may in part be a reflection of the comparatively narrow definitions used within that region.

Changes in the source of data also complicate comparisons over time. Prior to 2000, for example, data collected by the World Health Organization was provider based and was collected from service providers, such as utilities, ministries, and water agencies. The data shown here, however, are sometimes user based and were collected from household surveys and censuses. User-based data are more likely to include improvements installed by households or local communities and give a more complete picture of water supply and sanitation coverage.

## Sources

- United Nations. 2007a. The Millennium Development Goals Report. <http://mdgs.un.org/unsd/mdg/Resources/Static/Data/2007%20Stat%20Annex%20current%20indicators.pdf>.
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**DATA TABLE 5 MDG Progress on Access to Safe Drinking Water by Region (Proportion of Population Using an Improved Water Source)**

|  | 1990                   |       |       | 2004  |       |       | 2008  |       |       | 2011  |       |       | 2015 Target |       |       | On target?  |
|--|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------|-------|-------|---|
|  | Urban                  | Rural | Total | Urban | Rural | Total | Urban | Rural | Total | Urban | Rural | Total | Urban       | Rural | Total |   |
|  | <b>Northern Africa</b> | 95    | 82    | 89    | 96    | 86    | 91    | 98    | 87    | 92    | 95    | 89    | 92          | 98    | 91    |   |
| <b>Sub-Saharan Africa</b>  | 82                     | 36    | 49    | 80    | 42    | 56    | 83    | 47    | 60    | 84    | 76    | 72    | 91          | 68    | 75    | Might meet target   |
| <b>Latin America and the Caribbean</b>                                   | 93                     | 60    | 83    | 96    | 73    | 91    | 97    | 80    | 93    | 97    | 85    | 94    | 97          | 80    | 92    | Target met or close to being met  |
| <b>Eastern Asia</b>  | 99                     | 59    | 71    | 93    | 67    | 78    | 98    | 82    | 89    | 98    | 85    | 92    | 100         | 80    | 86    | Target met or close to being met  |
| <b>Southern Asia</b>   | 90                     | 66    | 72    | 94    | 81    | 85    | 95    | 83    | 87    | 95    | 88    | 90    | 95          | 83    | 86    | Target met or close to being met  |
| <b>South-Eastern Asia</b>  | 93                     | 68    | 76    | 89    | 77    | 82    | 81    | 92    | 86    | 94    | 84    | 89    | 97          | 84    | 88    | Target met or close to being met  |
| <b>Western Asia</b>  | 94                     | 70    | 85    | 97    | 79    | 91    | 96    | 78    | 90    | 96    | 78    | 90    | 97          | 85    | 93    | Might meet target   |
| <b>Oceania</b>   | 92                     | 39    | 51    | 80    | 40    | 51    | 92    | 37    | 50    | 95    | 45    | 56    | 96          | 70    | 76    | No progress or deterioration  |
| <b>Commonwealth of Independent States/<br/>Caucasus and Central Asia</b> | 97                     | 84    | 92    | 99    | 80    | 92    | 98    | 87    | 94    | 96    | 79    | 86    | 99          | 92    | 96    | Europe: Progress sufficient to meet target. Asia: Progress insufficient to meet target. |

# MDG Progress on Access to Sanitation by Region

## Description

The Millennium Development Goals (MDGs)—adopted by the United Nations in 2000—established a set of targets for improving the lives of the world’s poor, ranging from eradicating extreme hunger to reducing child mortality and ensuring environmental sustainability. These targets, agreed to by all countries and leading development institutions throughout the world, consist of eight goals and twenty-one targets. This table presents regional summaries of progress for the years 1990, 2004, 2008, and 2011 (from the 2013 update) as well as the 2015 target levels, measured as the proportion of the population using an improved sanitation system (see data tables 3 and 4 for definitions).

Adequate sanitation is also now a recognized human right, but, as with access to safe drinking water, this basic right is not universal. In many parts of the world, particularly for the poor in rural and peri-urban areas, a lack of basic sanitation adversely affects human health and development. Using 1990 as a baseline, one target of goal 7 of the MDGs seeks to reduce by half the proportion of people without sustainable access to sanitation by 2015.

Meeting the sanitation targets has proven to be more challenging than meeting the water target. While an estimated 2.6 billion people lacked access to basic sanitation in 1990, experts predict that well over 2 billion will still lack access to this basic right by 2015 (Ki Moon 2008). Some areas are performing better than others, highlighting a growing regional disparity in access to sanitation. A majority of regions, however, are not on track to meet established targets, and in Oceania and many former Soviet Union countries, there has been no progress or conditions have worsened.

## Limitations

These data give a good picture of the current lack of access to improved water and sanitation services, but comparison with different assessments should be done with extreme care, or not at all, because of changing definitions. For the 2011 update (released in 2013), some regional changes in country assignments slightly change the data from previous years. In particular, the region formerly noted as the Commonwealth of Independent States is now Caucasus and Central Asia.

Country-reported data may reflect national definitions of “improved,” unlike survey data, which were standardized as much as possible. For example, in many African countries the population “without access” to improved sanitation means people with no access to any sanitary facility. In Latin America and the Caribbean, however, it is more likely that those “without access” in fact have a sanitary facility, but the facility is deemed unsatisfactory by local or national authorities. Low coverage figures for Latin America and the Caribbean may in part be a reflection of the comparatively narrow definitions used within that region. For these data, we have not included in the totals the proportion of the population using “shared” facilities—just “improved” ones. Those data can be found in the original source (WHO and UNICEF 2013).

Changes in the source of data also complicate comparisons over time. Prior to 2000, for example, data collected by the World Health Organization came from service providers, such as utilities, ministries, and water agencies. The data shown here, however, are sometimes user based and were collected from household surveys and censuses. User-based data are more likely to include improvements installed by households or local communities and give a more complete picture of water supply and sanitation coverage.

## Sources

- Ki-Moon, B. 2008. United Nations Secretary-General, in message for World Water Day, March 5. New York: United Nations.
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- World Health Organization (WHO) and United Nations Children's Fund (UNICEF). 2013. Progress on Sanitation and Drinking-Water—2013 Update. Geneva, Switzerland.

**DATA TABLE 6** MDG Progress on Access to Sanitation by Region (proportion of population using an improved sanitation facility)

|  | 1990                   |       |       | 2004  |       |       | 2008  |       |       | 2011  |       |       | 2015 Target |       |       | On target?  |
|--|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------|-------|-------|---|
|  | Urban                  | Rural | Total | Urban | Rural | Total | Urban | Rural | Total | Urban | Rural | Total | Urban       | Rural | Total |   |
|  | <b>Northern Africa</b> | 84    | 47    | 65    | 91    | 62    | 77    | 94    | 83    | 89    | 94    | 84    | 90          | 92    | 74    |   |
| <b>Sub-Saharan Africa</b>  | 52                     | 24    | 32    | 53    | 28    | 37    | 44    | 24    | 31    | 42    | 24    | 30    | 76          | 62    | 66    | Progress insufficient to reach the target if prevailing trends persist.   |
| <b>Latin America and the Caribbean</b>                                   | 81                     | 36    | 68    | 86    | 49    | 77    | 86    | 55    | 80    | 87    | 63    | 82    | 91          | 68    | 84    | Progress insufficient to reach the target if prevailing trends persist.   |
| <b>Eastern Asia</b>  | 64                     | 7     | 24    | 69    | 28    | 45    | 61    | 53    | 56    | 76    | 57    | 67    | 82          | 54    | 62    | Already met the target or very close to meeting the target.   |
| <b>Southern Asia</b>   | 54                     | 8     | 20    | 63    | 27    | 38    | 57    | 26    | 36    | 64    | 30    | 41    | 77          | 54    | 60    | Progress insufficient to reach the target if prevailing trends persist.   |
| <b>South-Eastern Asia</b>  | 70                     | 40    | 49    | 81    | 56    | 67    | 79    | 60    | 69    | 81    | 62    | 71    | 85          | 70    | 75    | Progress sufficient to reach the target if prevailing trends persist.   |
| <b>Western Asia</b>  | 97                     | 55    | 81    | 96    | 59    | 84    | 94    | 67    | 85    | 96    | 71    | 88    | 99          | 78    | 91    | Progress insufficient to reach the target if prevailing trends persist.   |
| <b>Oceania</b>   | 80                     | 46    | 54    | 80    | 43    | 53    | 81    | 45    | 53    | 78    | 24    | 36    | 90          | 73    | 77    | No progress or deterioration.   |
| <b>Commonwealth of Independent States/<br/>Caucasus and Central Asia</b> | 92                     | 63    | 82    | 92    | 67    | 83    | 93    | 83    | —     | 96    | 95    | 96    | 96          | 82    | 91    | Europe: No progress or deterioration. Asia: Progress insufficient to reach the target if prevailing trends persist. |



# Monthly Natural Runoff for the World's Major River Basins, by Flow Volume

## Description

These data come from work done by Arjen Hoekstra and Mesfin Mekonnen (2011) to evaluate the regional, national, and global water footprint of human activity. As part of that effort, “natural runoff” was estimated for around 400 river basins, covering some two-thirds of the global land area (excluding Antarctica) and about 65 percent of the global population in 2000. Units for runoff are million cubic meters per month. Data are also provided for the area of the river basin or watershed, in square kilometers.

The natural (undepleted) runoff was estimated by adding the actual runoff data from the Composite Runoff V1.0 database (of Fekete et al. 2002) to the estimated total blue water footprint within the river basin. Because runoff varies naturally over time, these are average estimates. River basin names come from the Global Runoff Data Centre database (GRDC 2007). Note the substantial extremes: just two rivers, the Amazon and Congo Rivers, account for 28 percent of the natural runoff in the river basins listed here.

## Limitations

These data are a combination of measured and estimated or modeled flows. Accurate long-term measurements of river flow are not available for a variety of reasons, including the lack of monitoring stations, the complication of estimating undepleted flows in basins where human withdrawals greatly reduce natural flows, and natural variability of high and low runoff over time. These estimates should be considered only approximate averages, but they provide estimates using a consistent method described in the original sources.

The land areas not covered include Greenland; the Sahara Desert in North Africa; the Arabian Peninsula; the Iranian, Afghan, and Gobi Deserts in Asia; the Mojave Desert in North America; and the Australian desert. Also excluded are many smaller pieces of land, often along the coasts, that do not fall within major river basins.

## Sources

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**DATA TABLE 7 Monthly Natural Runoff for the World's Major River Basins, by Flow Volume**

| Basin ID | Basin Name               | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |           |           |           |           |           |           |           |           |           |           |           | Average   |
|----------|--------------------------|-------------------------|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|          |                          |                         | Jan                                     | Feb       | Mar       | Apr       | May       | Jun       | Jul       | Aug       | Sep       | Oct       | Nov       | Dec       |           |
| 259      | Amazonas                 | 5,880,855               | 950,375.6                               | 705,085.8 | 813,922.6 | 857,876.6 | 713,184.6 | 564,388.1 | 424,106.1 | 299,107.1 | 238,076.7 | 243,680.0 | 298,076.1 | 455,711.2 | 546,965.9 |
| 243      | Congo                    | 3,698,918               | 193,908.5                               | 92,837.8  | 126,684.3 | 138,968.9 | 93,475.1  | 62,522.2  | 55,481.6  | 71,460.1  | 90,395.6  | 111,123.4 | 108,901.0 | 123,157.3 | 105,743.0 |
| 237      | Orinoco                  | 952,173                 | 73,559.9                                | 9,908.6   | 16,110.2  | 48,197.5  | 96,502.6  | 137,370.7 | 156,922.8 | 139,130.4 | 112,036.3 | 103,445.6 | 77,389.5  | 46,830.9  | 84,783.7  |
| 177      | Yangtze<br>(Chang Jiang) | 1,745,094               | 40,746.3                                | 20,673.1  | 48,340.7  | 86,583.8  | 114,954.9 | 136,756.4 | 119,291.0 | 113,382.9 | 101,024.6 | 67,829.6  | 41,278.9  | 25,519.8  | 76,365.2  |
| 195      | Brahmaputra              | 518,011                 | 28,402.7                                | 549.4     | 2,782.9   | 16,852.2  | 46,782.8  | 103,699.0 | 127,521.0 | 128,246.8 | 107,215.1 | 58,846.2  | 31,386.4  | 18,647.3  | 55,911.0  |
| 122      | Mississippi              | 3,196,605               | 79,924.0                                | 66,571.6  | 111,936.2 | 102,147.6 | 83,552.9  | 56,877.9  | 36,359.7  | 27,329.8  | 18,097.4  | 12,199.9  | 20,013.0  | 38,932.9  | 54,495.2  |
| 5        | Yenisei                  | 2,558,237               | 16,135.2                                | 742.2     | 452.4     | 7,752.7   | 162,714.9 | 162,047.8 | 97,190.0  | 64,240.9  | 48,091.7  | 24,440.8  | 14,455.9  | 8,735.1   | 50,583.3  |
| 302      | Paraná                   | 2,640,486               | 105,979.7                               | 72,853.1  | 68,346.4  | 50,136.2  | 39,988.6  | 34,546.3  | 22,504.9  | 18,037.0  | 19,546.7  | 24,410.8  | 32,882.5  | 57,492.3  | 45,560.4  |
| 353      | Ganges                   | 1,024,463               | 32,182.1                                | 10,981.6  | 16,447.4  | 12,896.7  | 12,922.0  | 27,823.6  | 78,624.5  | 128,519.9 | 96,972.9  | 47,842.1  | 32,621.7  | 19,626.1  | 43,121.7  |
| 199      | Irrawaddy                | 411,516                 | 26,908.9                                | 342.4     | 994.5     | 4,301.3   | 10,976.0  | 59,825.7  | 98,546.8  | 111,837.4 | 93,122.6  | 59,380.0  | 30,238.9  | 17,673.9  | 42,845.7  |
| 187      | Mekong                   | 787,257                 | 30,683.5                                | 405.8     | 584.3     | 939.8     | 5,846.3   | 34,283.6  | 85,153.9  | 107,075.0 | 107,961.6 | 64,294.1  | 35,434.1  | 20,497.8  | 41,096.7  |
| 7        | Lena                     | 2,425,551               | 15,771.8                                | 655.1     | 396.4     | 361.9     | 87,091.9  | 124,907.8 | 84,650.4  | 63,046.2  | 53,636.1  | 23,839.3  | 14,390.4  | 8,692.2   | 39,786.6  |
| 25       | Ob                       | 2,701,041               | 6,930.1                                 | 198.1     | 135.9     | 80,842.2  | 148,619.4 | 68,228.3  | 36,839.8  | 23,540.4  | 18,275.7  | 14,074.8  | 6,865.0   | 4,161.9   | 34,059.3  |
| 273      | Tocantins                | 774,718                 | 82,937.0                                | 65,826.8  | 71,926.3  | 45,721.6  | 24,110.4  | 14,567.5  | 8,930.8   | 5,585.4   | 3,923.1   | 3,979.0   | 16,536.2  | 44,543.4  | 32,382.3  |
| 90       | Amur                     | 2,023,520               | 13,098.2                                | 58.9      | 59.3      | 41,918.1  | 57,294.3  | 53,865.4  | 45,446.7  | 49,807.8  | 50,357.7  | 28,455.4  | 14,176.3  | 8,572.4   | 30,259.2  |
| 117      | St. Lawrence             | 1,055,021               | 13,835.1                                | 351.1     | 29,605.6  | 132,375.7 | 51,230.9  | 31,947.4  | 19,602.9  | 13,031.9  | 15,304.9  | 21,038.1  | 22,898.9  | 9,715.3   | 30,078.1  |
| 194      | Nile                     | 3,078,088               | 20,724.2                                | 2,310.3   | 6,660.0   | 16,300.5  | 18,779.0  | 21,757.3  | 48,384.2  | 80,541.4  | 66,624.1  | 36,444.6  | 22,470.9  | 14,322.2  | 29,609.9  |
| 207      | Niger                    | 2,117,889               | 21,778.0                                | 99.0      | 256.2     | 1,297.8   | 4,833.0   | 14,794.5  | 38,348.0  | 80,634.7  | 90,704.8  | 47,626.3  | 23,829.5  | 14,278.6  | 28,206.7  |
| 293      | Zambezi                  | 1,388,572               | 73,279.9                                | 82,019.0  | 68,514.8  | 32,327.8  | 18,268.1  | 10,936.3  | 6,663.6   | 4,203.7   | 2,618.2   | 1,621.8   | 1,305.4   | 21,500.8  | 26,938.3  |
| 19       | Mackenzie                | 1,752,002               | 5,637.8                                 | 86.9      | 53.5      | 9,063.7   | 79,403.5  | 79,172.3  | 46,002.0  | 24,877.4  | 15,732.9  | 10,447.5  | 5,767.0   | 3,484.1   | 23,310.7  |
| 64       | Volga                    | 1,408,279               | 3,091.7                                 | 147.2     | 747.6     | 140,132.1 | 51,088.9  | 28,581.8  | 17,230.0  | 10,747.1  | 6,887.4   | 6,486.8   | 3,165.6   | 1,902.0   | 22,517.4  |
| 168      | Indus                    | 1,139,075               | 11,918.9                                | 9,642.7   | 18,198.4  | 21,870.2  | 18,514.4  | 18,264.8  | 32,379.1  | 40,736.0  | 31,344.3  | 19,300.0  | 10,858.9  | 6,757.3   | 19,982.1  |
| 201      | Xi Jiang                 | 362,894                 | 8,372.9                                 | 2,682.6   | 4,932.3   | 10,762.2  | 25,796.8  | 44,596.4  | 41,263.7  | 42,397.2  | 25,138.3  | 14,767.9  | 8,958.4   | 5,447.9   | 19,593.0  |
| 107      | Columbia                 | 668,562                 | 11,960.9                                | 11,259.5  | 20,903.3  | 38,188.0  | 55,190.6  | 36,849.4  | 18,551.8  | 11,683.5  | 7,290.7   | 5,462.2   | 6,682.2   | 7,923.4   | 19,328.8  |
| 235      | Magdalena                | 261,205                 | 27,118.0                                | 3,452.3   | 6,430.2   | 14,175.3  | 21,211.1  | 18,633.1  | 15,055.6  | 15,479.8  | 18,291.2  | 31,846.5  | 31,789.4  | 20,916.3  | 18,699.9  |

|     |                                  |           |          |          |          |          |          |          |          |          |          |          |          |          |          |
|-----|----------------------------------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 118 | Danube                           | 793,705   | 15,369.2 | 12,969.9 | 30,056.7 | 34,399.1 | 27,077.0 | 19,150.4 | 14,083.1 | 11,248.0 | 10,213.5 | 12,685.9 | 15,065.0 | 12,575.3 | 17,907.8 |
| 16  | Yukon                            | 829,632   | 4,850.3  | 252.5    | 152.7    | 943.7    | 53,166.5 | 48,766.9 | 29,776.4 | 16,607.0 | 12,906.1 | 7,648.1  | 4,212.2  | 2,544.3  | 15,152.2 |
| 334 | Uruguay                          | 265,505   | 15,702.5 | 5,633.7  | 8,112.2  | 13,990.4 | 16,949.4 | 19,158.1 | 16,344.5 | 15,620.3 | 18,876.7 | 20,160.7 | 12,864.3 | 9,587.2  | 14,416.7 |
| 386 | Sungai Kapuas                    | 84,902    | 29,491.3 | 13,356.0 | 15,227.7 | 15,516.0 | 13,513.3 | 10,291.5 | 7,393.4  | 6,608.1  | 8,936.3  | 13,775.6 | 17,293.6 | 17,622.4 | 14,085.4 |
| 265 | Ogooué                           | 222,663   | 22,726.7 | 7,569.4  | 15,733.8 | 20,776.5 | 19,147.2 | 7,950.2  | 4,618.0  | 2,791.3  | 2,505.1  | 8,651.3  | 23,592.1 | 17,443.6 | 12,792.1 |
| 22  | Pechora                          | 312,763   | 2,459.1  | 31.2     | 19.2     | 1,449.0  | 58,305.9 | 38,794.9 | 16,270.2 | 9,630.9  | 7,855.7  | 4,450.1  | 2,542.8  | 1,536.1  | 11,945.4 |
| 354 | Salween                          | 258,475   | 8,366.0  | 95.5     | 592.3    | 1,511.4  | 2,846.6  | 12,055.4 | 24,649.1 | 32,068.1 | 27,586.6 | 18,159.4 | 9,737.1  | 5,522.3  | 11,932.5 |
| 155 | Tigris and Euphrates             | 832,579   | 15,514.6 | 16,609.9 | 22,140.0 | 25,647.8 | 18,735.0 | 10,281.7 | 7,368.3  | 5,738.1  | 3,544.0  | 2,291.3  | 3,575.7  | 7,623.3  | 11,589.1 |
| 124 | Aral Drainage                    | 1,233,148 | 2,546.9  | 4,161.6  | 13,784.1 | 20,140.9 | 23,937.1 | 21,375.9 | 17,965.9 | 12,930.4 | 8,104.3  | 3,850.2  | 1,674.4  | 1,541.5  | 11,001.1 |
| 263 | Rajang                           | 49,944    | 20,497.2 | 8,513.0  | 9,657.7  | 10,211.2 | 9,935.6  | 7,769.6  | 6,882.1  | 6,855.9  | 9,242.6  | 11,129.0 | 11,855.9 | 12,276.9 | 10,402.2 |
| 385 | Sungai Mahakam                   | 75,823    | 18,606.0 | 7,876.5  | 10,134.8 | 13,756.5 | 12,600.1 | 9,668.4  | 6,831.4  | 5,649.9  | 5,951.6  | 7,402.7  | 11,152.8 | 12,616.4 | 10,187.3 |
| 380 | Mamberamo                        | 75,416    | 15,446.4 | 9,453.9  | 12,610.4 | 11,467.8 | 9,723.6  | 7,842.7  | 8,385.4  | 7,964.6  | 8,697.3  | 6,547.6  | 7,173.3  | 8,630.9  | 9,495.3  |
| 281 | Sepik                            | 81,120    | 15,375.9 | 9,555.7  | 12,665.7 | 12,180.9 | 9,397.5  | 7,423.9  | 6,795.9  | 6,812.5  | 7,707.7  | 8,100.4  | 8,084.8  | 9,182.5  | 9,440.3  |
| 290 | São Francisco                    | 628,629   | 27,716.3 | 15,251.7 | 13,981.8 | 7,511.4  | 4,656.8  | 5,028.4  | 4,947.7  | 3,343.7  | 1,665.4  | 1,268.7  | 4,929.8  | 18,730.9 | 9,086.0  |
| 13  | Kolyma                           | 652,850   | 3,721.1  | 160.9    | 97.2     | 58.8     | 5,342.4  | 25,441.2 | 35,941.4 | 16,207.8 | 10,517.4 | 5,575.9  | 3,367.8  | 2,034.2  | 9,038.8  |
| 222 | Grisalva                         | 127,675   | 11,859.4 | 1,204.2  | 664.4    | 610.2    | 1,646.9  | 8,622.6  | 11,809.7 | 13,230.5 | 20,505.5 | 19,300.8 | 10,998.3 | 7,877.1  | 9,027.5  |
| 356 | Lake Chad                        | 2,391,219 | 6,870.6  | 135.4    | 144.7    | 180.2    | 263.0    | 1,227.0  | 7,989.1  | 36,416.6 | 27,951.2 | 14,050.2 | 7,408.8  | 4,490.9  | 8,927.3  |
| 213 | Godavari                         | 311,699   | 6,805.4  | 626.4    | 1,240.0  | 1,477.3  | 1,571.4  | 891.7    | 13,461.6 | 27,528.4 | 26,621.8 | 12,095.3 | 7,347.2  | 4,834.4  | 8,708.4  |
| 83  | Nelson                           | 1,099,380 | 1,698.4  | 40.6     | 35.8     | 29,311.7 | 20,864.5 | 15,143.9 | 8,074.5  | 5,014.9  | 4,579.4  | 4,110.0  | 1,799.8  | 1,090.5  | 7,647.0  |
| 355 | Hong (Red River)                 | 157,657   | 4,779.9  | 80.7     | 104.5    | 254.5    | 1,566.3  | 7,439.6  | 18,447.1 | 22,644.5 | 16,383.8 | 9,602.6  | 5,433.7  | 3,149.0  | 7,490.5  |
| 88  | Fraser                           | 239,678   | 3,955.1  | 1,048.3  | 2,360.7  | 15,356.9 | 26,897.1 | 15,496.8 | 7,432.2  | 4,439.9  | 3,254.0  | 3,618.6  | 3,140.5  | 2,506.4  | 7,458.9  |
| 48  | Northern Dvina (Severnaya Dvina) | 323,573   | 1,021.4  | 35.1     | 22.2     | 44,567.2 | 19,378.9 | 9,541.8  | 5,592.3  | 3,376.1  | 2,058.6  | 2,097.6  | 971.8    | 587.9    | 7,437.6  |
| 245 | Cuyuni                           | 85,635    | 9,798.1  | 3,136.9  | 2,829.9  | 4,268.1  | 9,871.7  | 13,477.9 | 13,021.6 | 10,134.4 | 5,445.8  | 3,587.1  | 3,665.6  | 6,571.4  | 7,150.7  |
| 110 | Rhine                            | 190,522   | 13,179.1 | 7,657.6  | 8,094.3  | 9,602.3  | 8,013.0  | 6,055.1  | 4,779.6  | 4,183.7  | 3,971.9  | 4,514.6  | 6,546.6  | 8,363.7  | 7,080.1  |
| 384 | Sungai Kajang                    | 33,172    | 10,769.4 | 4,092.4  | 5,488.6  | 6,619.3  | 6,870.7  | 5,795.5  | 5,104.8  | 4,917.8  | 6,431.1  | 6,999.8  | 7,819.9  | 6,829.4  | 6,478.2  |

*continues*

**DATA TABLE 7** *continued*

| Basin ID | Basin Name                     | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |          |          |          |          |          |          |          |          |         |         | Average |
|----------|--------------------------------|-------------------------|---|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|---------|---------|
|          |                                |                         | Jan                                     | Feb      | Mar      | Apr      | May      | Jun      | Jul      | Aug      | Sep      | Oct      | Nov     | Dec     |         |
| 219      | Krishna                        | 269,869                 | 4,249.9                                 | 610.7    | 1,255.2  | 1,355.6  | 1,400.2  | 3,256.5  | 16,600.9 | 15,185.1 | 11,795.9 | 6,710.3  | 4,670.2 | 3,427.8 | 5,876.5 |
| 249      | Sanaga                         | 134,252                 | 4,812.3                                 | 3.0      | 236.5    | 2,004.2  | 4,068.5  | 5,840.0  | 7,929.0  | 9,616.8  | 13,725.9 | 13,358.0 | 5,383.1 | 3,156.1 | 5,844.5 |
| 149      | Huang He<br>(Yellow River)     | 988,063                 | 2,702.4                                 | 608.3    | 2,320.1  | 5,166.0  | 8,177.4  | 9,102.2  | 10,309.3 | 9,805.2  | 9,930.4  | 5,872.9  | 3,052.0 | 1,802.8 | 5,737.4 |
| 383      | Uwimbu                         | 29,374                  | 8,952.7                                 | 5,395.2  | 6,379.0  | 5,992.2  | 6,010.0  | 5,432.3  | 5,263.6  | 5,126.4  | 5,387.6  | 4,552.8  | 4,357.4 | 5,401.7 | 5,687.6 |
| 244      | Atrato                         | 34,619                  | 8,908.3                                 | 2,297.1  | 2,736.4  | 4,317.7  | 5,624.4  | 5,876.9  | 5,976.7  | 6,096.9  | 6,689.5  | 7,140.9  | 7,032.0 | 5,537.1 | 5,686.2 |
| 93       | Grande Rivière                 | 111,718                 | 2,729.2                                 | 0.9      | 0.5      | 0.3      | 20,738.4 | 10,192.2 | 6,544.7  | 6,144.0  | 7,187.4  | 7,682.4  | 2,959.2 | 1,787.3 | 5,497.2 |
| 114      | Nottaway                       | 118,709                 | 2,188.3                                 | 0.2      | 0.2      | 13,451.3 | 15,987.7 | 7,640.1  | 5,188.1  | 4,271.3  | 5,083.6  | 6,291.3  | 2,438.0 | 1,434.9 | 5,331.3 |
| 373      | Rovuma                         | 151,949                 | 9,106.2                                 | 15,265.1 | 18,092.1 | 9,319.0  | 4,605.3  | 2,779.5  | 1,678.9  | 1,014.2  | 612.7    | 370.2    | 223.6   | 516.4   | 5,298.6 |
| 252      | Essequibo                      | 68,788                  | 5,069.1                                 | 1,976.6  | 2,110.6  | 2,932.1  | 7,163.7  | 13,057.2 | 11,720.0 | 7,957.4  | 3,936.3  | 2,438.8  | 1,874.9 | 3,105.6 | 5,278.5 |
| 75       | Caniapiscau                    | 105,691                 | 2,297.2                                 | 0.9      | 0.5      | 0.3      | 16,170.7 | 12,475.4 | 6,805.5  | 6,229.8  | 6,669.5  | 6,024.1  | 2,490.3 | 1,504.1 | 5,055.7 |
| 56       | Neva                           | 223,310                 | 1,195.2                                 | 10.6     | 8.8      | 32,169.2 | 9,560.0  | 5,468.9  | 3,272.4  | 1,984.2  | 1,703.3  | 2,586.4  | 1,686.6 | 773.9   | 5,034.9 |
| 210      | Mahanadi<br>(Mahahadi)         | 135,061                 | 3,751.2                                 | 108.6    | 158.0    | 151.1    | 158.2    | 157.6    | 5,209.0  | 21,461.7 | 14,877.9 | 6,698.9  | 4,119.4 | 2,571.8 | 4,951.9 |
| 248      | Cross                          | 52,820                  | 3,986.4                                 | 1.4      | 608.2    | 1,184.8  | 2,346.5  | 4,731.8  | 7,828.2  | 9,133.6  | 11,624.3 | 10,815.8 | 4,452.2 | 2,614.4 | 4,944.0 |
| 257      | Maroni                         | 65,945                  | 3,849.5                                 | 4,583.6  | 5,326.3  | 7,656.9  | 11,080.5 | 10,145.5 | 7,092.8  | 4,342.7  | 2,242.1  | 1,349.5  | 815.1   | 565.6   | 4,920.8 |
| 388      | Batang Hari                    | 42,872                  | 10,918.4                                | 4,536.0  | 5,450.1  | 6,252.7  | 4,790.1  | 2,820.9  | 1,767.2  | 1,540.6  | 2,438.0  | 4,411.4  | 6,272.8 | 7,176.5 | 4,864.6 |
| 218      | Chao Phraya                    | 188,419                 | 4,183.6                                 | 318.1    | 519.8    | 537.6    | 493.6    | 1,640.2  | 5,541.8  | 9,607.1  | 16,009.4 | 10,072.0 | 5,811.4 | 3,059.8 | 4,816.2 |
| 1        | Khatanga                       | 294,908                 | 1,571.7                                 | 58.7     | 35.4     | 21.4     | 221.2    | 25,398.5 | 12,884.8 | 6,944.9  | 4,357.0  | 2,419.0  | 1,461.0 | 882.4   | 4,688.0 |
| 180      | Alabama River<br>and Tombigbee | 113,117                 | 9,397.8                                 | 10,770.1 | 12,232.8 | 8,612.8  | 4,829.3  | 2,684.6  | 1,677.7  | 1,055.0  | 671.1    | 421.7    | 465.0   | 3,348.5 | 4,680.5 |
| 112      | Saguenay<br>(Rivière)          | 91,367                  | 1,984.2                                 | 1.5      | 1.5      | 11,245.1 | 11,251.7 | 8,137.7  | 5,058.6  | 4,100.4  | 4,665.6  | 5,748.5  | 2,173.4 | 1,301.6 | 4,639.2 |
| 27       | Taz                            | 152,086                 | 989.9                                   | 6.0      | 3.6      | 2.2      | 12,922.1 | 23,163.4 | 7,321.6  | 4,370.1  | 3,193.2  | 1,738.0  | 1,049.7 | 634.0   | 4,616.2 |
| 254      | Corantijn                      | 65,528                  | 1,313.6                                 | 829.3    | 1,710.9  | 3,554.5  | 11,297.6 | 13,180.8 | 9,711.4  | 6,084.0  | 3,012.4  | 1,811.6  | 1,094.1 | 692.7   | 4,524.4 |
| 126      | Rhone                          | 97,485                  | 7,316.8                                 | 3,365.1  | 5,895.8  | 6,325.3  | 5,588.7  | 4,446.6  | 2,690.2  | 2,212.7  | 2,277.1  | 3,477.1  | 5,232.4 | 5,154.7 | 4,498.5 |

|     |                                    |         |          |         |          |          |          |          |          |          |          |         |         |         |         |
|-----|------------------------------------|---------|----------|---------|----------|----------|----------|----------|----------|----------|----------|---------|---------|---------|---------|
| 378 | Min Jiang                          | 60,040  | 1,710.0  | 2,261.2 | 6,444.7  | 6,263.4  | 9,721.2  | 10,643.9 | 4,850.2  | 3,725.5  | 2,882.6  | 2,049.4 | 1,340.9 | 880.7   | 4,397.8 |
| 337 | Rio Jacuú                          | 70,798  | 5,005.1  | 2,492.1 | 2,901.2  | 3,920.9  | 4,897.0  | 5,793.0  | 5,339.7  | 5,145.1  | 5,743.1  | 5,136.4 | 3,405.9 | 2,794.2 | 4,381.1 |
| 96  | Dniepr                             | 510,661 | 849.5    | 45.1    | 9,860.5  | 20,513.6 | 7,860.1  | 4,484.4  | 2,811.4  | 1,783.2  | 1,063.7  | 891.9   | 1,449.4 | 588.9   | 4,350.1 |
| 366 | Cuanza                             | 141,391 | 10,360.7 | 7,565.1 | 10,296.0 | 8,746.9  | 3,552.8  | 2,127.7  | 1,286.3  | 779.0    | 472.4    | 307.3   | 304.1   | 5,458.5 | 4,271.4 |
| 286 | Purari                             | 32,140  | 7,089.0  | 4,200.2 | 5,204.7  | 5,335.2  | 4,459.8  | 3,535.0  | 2,952.7  | 3,064.9  | 3,853.1  | 3,615.9 | 3,635.9 | 4,215.8 | 4,263.5 |
| 95  | Churchill,<br>Fleuve<br>(Labrador) | 84,984  | 1,702.6  | 0.0     | 0.0      | 0.0      | 15,223.9 | 10,971.0 | 6,028.7  | 4,689.5  | 4,563.7  | 4,517.0 | 1,848.4 | 1,116.4 | 4,221.8 |
| 266 | Rio Araguari                       | 33,771  | 4,727.0  | 5,377.5 | 6,935.9  | 8,461.5  | 8,118.0  | 7,123.8  | 4,272.9  | 2,486.6  | 1,376.3  | 831.0   | 501.9   | 398.5   | 4,217.6 |
| 21  | Anadyr                             | 171,276 | 1,182.1  | 1.3     | 0.8      | 0.5      | 2,452.2  | 21,998.7 | 10,380.5 | 5,461.5  | 4,105.7  | 2,116.1 | 1,278.1 | 771.9   | 4,145.8 |
| 6   | Indigirka                          | 341,228 | 1,902.5  | 179.7   | 108.5    | 65.6     | 450.9    | 16,809.8 | 14,507.5 | 6,786.0  | 3,631.1  | 2,176.2 | 1,314.4 | 793.9   | 4,060.5 |
| 258 | San Juan<br>(Columbia-<br>Pacific) | 13,898  | 6,064.5  | 2,203.5 | 2,616.1  | 3,456.3  | 4,124.0  | 3,912.7  | 3,904.9  | 3,971.2  | 4,103.4  | 4,529.7 | 4,529.1 | 3,905.9 | 3,943.4 |
| 51  | Kuskokwim                          | 118,114 | 1,269.5  | 1.4     | 0.9      | 0.5      | 16,620.3 | 7,998.3  | 5,470.1  | 5,473.3  | 5,291.7  | 2,398.6 | 1,372.5 | 829.0   | 3,893.8 |
| 71  | Stikine                            | 51,147  | 1,826.9  | 603.3   | 508.0    | 1,656.9  | 9,699.8  | 11,933.0 | 5,766.5  | 3,728.6  | 3,815.5  | 3,379.2 | 1,948.6 | 1,370.5 | 3,853.1 |
| 128 | Po                                 | 73,067  | 4,276.6  | 2,000.0 | 3,536.1  | 5,530.3  | 6,397.4  | 4,452.6  | 2,941.3  | 2,394.4  | 2,314.0  | 2,947.8 | 3,482.3 | 2,857.2 | 3,594.2 |
| 232 | San Juan                           | 41,659  | 5,223.3  | 533.6   | 282.7    | 261.5    | 1,036.0  | 3,952.8  | 4,778.7  | 4,793.9  | 6,119.6  | 7,350.0 | 4,839.9 | 3,921.9 | 3,591.2 |
| 208 | Narmada                            | 95,818  | 2,407.1  | 430.8   | 900.5    | 1,131.7  | 1,138.1  | 445.1    | 7,352.7  | 11,663.1 | 8,745.2  | 3,757.6 | 2,295.3 | 1,586.4 | 3,487.8 |
| 382 | Eilanden                           | 20,077  | 5,431.2  | 3,334.4 | 3,835.7  | 3,751.0  | 3,567.3  | 3,244.7  | 3,235.3  | 3,090.1  | 3,371.3  | 2,701.3 | 2,824.9 | 3,278.9 | 3,472.2 |
| 317 | Tsiribihina                        | 61,992  | 9,631.8  | 9,804.7 | 9,049.7  | 4,154.5  | 2,354.3  | 1,436.8  | 893.2    | 545.1    | 328.9    | 198.3   | 299.2   | 2,841.4 | 3,461.5 |
| 54  | Susitna                            | 49,470  | 1,270.7  | 2.2     | 1.4      | 3,654.1  | 8,319.0  | 8,905.7  | 5,269.7  | 4,095.0  | 4,842.3  | 2,738.5 | 1,370.5 | 827.8   | 3,441.4 |
| 215 | Sittang                            | 34,265  | 2,254.3  | 3.3     | 6.3      | 6.6      | 16.9     | 3,852.3  | 7,852.6  | 10,043.8 | 8,332.3  | 4,900.8 | 2,492.4 | 1,478.4 | 3,436.7 |
| 396 | Lake Turkana                       | 181,536 | 2,082.5  | 9.0     | 100.4    | 1,988.3  | 3,300.7  | 4,415.2  | 6,718.5  | 7,827.8  | 6,549.2  | 4,135.2 | 2,501.6 | 1,394.5 | 3,418.6 |
| 345 | Negro<br>(Argentina)               | 130,062 | 2,461.3  | 98.8    | 347.1    | 1,009.8  | 4,025.3  | 5,859.2  | 6,210.5  | 6,075.1  | 5,030.4  | 4,368.0 | 3,162.3 | 1,740.6 | 3,365.7 |
| 262 | Oyapock                            | 27,076  | 4,282.0  | 4,043.5 | 4,817.3  | 6,249.8  | 6,602.9  | 5,755.6  | 3,526.6  | 2,069.9  | 1,131.7  | 683.3   | 412.7   | 586.7   | 3,346.8 |
| 272 | Rio Capim                          | 54,888  | 1,537.9  | 5,606.4 | 8,799.8  | 7,926.1  | 5,924.9  | 3,782.3  | 2,616.7  | 1,569.4  | 878.6    | 525.8   | 317.7   | 205.5   | 3,307.6 |
| 227 | Volta                              | 414,004 | 2,522.1  | 7.7     | 80.1     | 291.8    | 828.4    | 2,616.6  | 3,570.8  | 8,402.5  | 11,296.3 | 5,427.0 | 2,744.7 | 1,654.9 | 3,286.9 |
| 314 | Rio Doce                           | 86,086  | 12,563.7 | 5,298.4 | 4,242.2  | 2,461.5  | 1,301.4  | 784.3    | 483.1    | 302.0    | 187.0    | 117.8   | 2,334.5 | 9,099.0 | 3,264.6 |
| 58  | Copper                             | 64,960  | 1,090.8  | 0.0     | 0.0      | 17.3     | 7,546.7  | 10,214.6 | 7,440.5  | 4,185.8  | 3,963.1  | 2,215.5 | 1,184.1 | 715.2   | 3,214.5 |

*continues*



**DATA TABLE 7** *continued*

| Basin ID | Basin Name               | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |          |          |          |          |         |         |         |         |         |         | Average |
|----------|--------------------------|-------------------------|---|---------|----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|---------|
|          |                          |                         | Jan                                     | Feb     | Mar      | Apr      | May      | Jun      | Jul     | Aug     | Sep     | Oct     | Nov     | Dec     |         |
| 116      | Moose (Trib. Hudson Bay) | 105,615                 | 1,000.2                                 | 0.6     | 0.6      | 11,334.0 | 9,979.0  | 4,300.8  | 2,527.6 | 1,594.4 | 2,136.5 | 3,024.6 | 1,085.8 | 656.0   | 3,136.7 |
| 31       | Pur                      | 111,351                 | 740.7                                   | 0.3     | 0.3      | 7,186.7  | 15,161.5 | 4,615.2  | 2,795.1 | 2,896.5 | 1,331.2 | 804.1   | 485.8   | 3,001.5 |         |
| 72       | Churchill                | 298,505                 | 789.5                                   | 20.1    | 12.3     | 3,400.0  | 7,724.3  | 3,761.6  | 2,131.7 | 1,960.1 | 1,724.5 | 774.9   | 468.2   | 2,990.7 |         |
| 148      | Sacramento               | 77,209                  | 5,375.8                                 | 6,127.3 | 6,249.1  | 5,067.8  | 3,136.9  | 2,369.0  | 1,708.0 | 1,170.4 | 511.3   | 343.5   | 1,439.3 | 2,963.6 |         |
| 82       | Skeena                   | 42,944                  | 1,078.2                                 | 0.2     | 1,041.9  | 4,491.6  | 8,819.6  | 7,160.8  | 3,082.5 | 2,010.7 | 1,937.6 | 2,313.5 | 1,518.6 | 707.1   | 2,846.9 |
| 98       | Wisla                    | 193,764                 | 947.0                                   | 37.8    | 12,812.8 | 6,810.9  | 4,190.9  | 2,577.5  | 1,781.3 | 1,243.2 | 858.0   | 779.6   | 1,157.5 | 847.9   | 2,837.0 |
| 183      | Huai He                  | 174,310                 | 1,271.4                                 | 1,031.3 | 2,377.3  | 4,348.7  | 4,430.9  | 4,375.0  | 4,755.1 | 3,800.5 | 3,689.6 | 1,900.5 | 1,153.0 | 823.3   | 2,829.7 |
| 99       | Don                      | 425,630                 | 308.1                                   | 29.4    | 4,138.3  | 14,368.8 | 5,709.0  | 3,280.6  | 2,272.7 | 1,517.1 | 801.0   | 444.2   | 431.0   | 212.1   | 2,792.7 |
| 204      | Dong Jiang               | 32,103                  | 861.2                                   | 105.2   | 1,116.0  | 3,077.8  | 5,758.0  | 6,467.3  | 4,881.8 | 4,699.8 | 3,338.0 | 1,558.5 | 934.6   | 567.8   | 2,780.5 |
| 143      | Susquehanna              | 69,080                  | 2,091.9                                 | 1,240.2 | 8,814.7  | 5,917.2  | 3,887.6  | 2,447.9  | 1,522.7 | 1,002.4 | 867.5   | 1,337.0 | 2,499.4 | 1,658.8 | 2,774.0 |
| 127      | Saint John               | 55,152                  | 1,543.0                                 | 1.9     | 1.9      | 13,364.2 | 4,478.5  | 3,060.9  | 1,929.0 | 1,260.9 | 1,384.3 | 2,179.7 | 2,871.4 | 1,012.4 | 2,757.4 |
| 106      | Manicouagan (Rivière)    | 54,205                  | 1,252.8                                 | 0.3     | 0.2      | 524.6    | 8,666.6  | 6,924.6  | 3,691.1 | 2,983.3 | 3,220.2 | 3,479.9 | 1,358.9 | 820.8   | 2,743.6 |
| 202      | Bei Jiang                | 52,915                  | 629.5                                   | 353.9   | 1,921.9  | 4,546.4  | 6,874.5  | 7,013.0  | 3,830.8 | 3,230.7 | 2,159.0 | 1,100.4 | 668.5   | 413.5   | 2,728.5 |
| 268      | Esmeraldas               | 19,796                  | 2,922.0                                 | 4,238.0 | 5,676.0  | 6,743.2  | 4,668.6  | 2,504.1  | 1,398.8 | 876.1   | 589.2   | 579.1   | 755.5   | 966.5   | 2,659.8 |
| 284      | Rufiji                   | 204,639                 | 1,836.2                                 | 3,827.1 | 7,683.8  | 8,804.4  | 4,027.1  | 2,129.0  | 1,285.4 | 779.2   | 473.6   | 288.1   | 176.3   | 418.8   | 2,644.1 |
| 105      | Eastmain                 | 48,838                  | 1,182.9                                 | 0.0     | 0.0      | 2,558.1  | 9,188.6  | 4,899.7  | 2,922.3 | 2,536.0 | 2,987.8 | 3,379.4 | 1,284.2 | 775.6   | 2,642.9 |
| 111      | Albany                   | 123,081                 | 813.0                                   | 0.1     | 0.1      | 8,411.8  | 9,204.2  | 3,827.2  | 2,148.3 | 1,306.1 | 1,776.4 | 2,432.0 | 882.5   | 533.1   | 2,611.2 |
| 2        | Olenek                   | 208,522                 | 1,231.0                                 | 159.8   | 96.5     | 58.3     | 658.3    | 16,431.9 | 5,510.3 | 3,070.3 | 1,870.4 | 1,106.6 | 668.3   | 403.7   | 2,605.5 |
| 346      | Biobio                   | 24,109                  | 1,512.9                                 | 29.1    | 298.7    | 919.1    | 3,736.5  | 4,786.4  | 5,042.5 | 4,670.4 | 4,131.1 | 2,973.2 | 1,809.7 | 1,045.2 | 2,579.6 |
| 240      | Sassandra                | 68,097                  | 2,261.5                                 | 1.4     | 3.2      | 129.1    | 309.3    | 2,250.3  | 3,322.8 | 4,638.5 | 8,322.9 | 5,416.1 | 2,603.4 | 1,487.3 | 2,562.2 |
| 402      | Lake Taymur              | 138,783                 | 723.7                                   | 0.0     | 0.0      | 0.0      | 0.0      | 14,735.9 | 6,387.8 | 3,298.4 | 2,513.9 | 1,300.5 | 785.5   | 474.4   | 2,518.3 |
| 80       | Kamchatka                | 54,104                  | 689.9                                   | 0.0     | 0.0      | 0.0      | 9,603.9  | 7,199.7  | 5,399.2 | 2,604.2 | 1,918.9 | 1,546.8 | 749.0   | 452.4   | 2,513.7 |
| 399      | Lake Titicaca            | 107,215                 | 7,124.5                                 | 5,963.3 | 4,974.8  | 2,951.8  | 1,893.3  | 1,052.7  | 658.3   | 552.1   | 469.3   | 688.1   | 678.7   | 2,594.8 | 2,466.8 |
| 94       | Winisk                   | 106,470                 | 890.2                                   | 2.1     | 1.3      | 3,470.5  | 10,190.2 | 4,433.5  | 2,449.4 | 1,479.2 | 2,350.9 | 2,486.7 | 957.9   | 578.6   | 2,440.9 |

|     |                              |           |         |         |         |         |          |          |         |         |         |         |         |         |         |
|-----|------------------------------|-----------|---------|---------|---------|---------|----------|----------|---------|---------|---------|---------|---------|---------|---------|
| 224 | Mae Klong                    | 28,004    | 1,554.4 | 20.9    | 34.2    | 33.5    | 1,076.4  | 3,580.0  | 5,254.6 | 5,831.8 | 5,582.5 | 3,551.6 | 1,715.1 | 1,031.1 | 2,438.9 |
| 357 | Okavango                     | 705,056   | 4,075.2 | 6,488.8 | 8,619.1 | 3,971.7 | 2,041.0  | 1,233.1  | 745.9   | 452.1   | 274.8   | 167.1   | 100.7   | 882.0   | 2,421.0 |
| 125 | Loire                        | 115,944   | 5,691.9 | 3,966.2 | 3,912.1 | 3,192.9 | 2,280.7  | 1,475.0  | 937.1   | 710.2   | 546.1   | 804.6   | 1,839.3 | 3,262.7 | 2,384.9 |
| 398 | Suriname                     | 24,868    | 2,186.8 | 1,915.0 | 2,088.7 | 2,922.6 | 4,729.6  | 5,013.8  | 3,973.9 | 2,420.7 | 1,213.0 | 729.1   | 440.4   | 526.6   | 2,346.7 |
| 276 | Rio Parnaiba                 | 336,584   | 2,039.6 | 3,746.9 | 7,333.0 | 6,991.8 | 3,124.0  | 1,723.6  | 1,047.6 | 641.5   | 394.0   | 242.4   | 157.1   | 558.8   | 2,333.4 |
| 260 | Pahang                       | 28,437    | 5,776.0 | 1,292.5 | 1,416.5 | 1,962.1 | 1,937.4  | 1,260.3  | 863.4   | 823.6   | 1,395.6 | 2,714.8 | 3,612.5 | 4,175.9 | 2,269.2 |
| 322 | Paraitba Do Sul              | 58,027    | 7,384.0 | 4,105.7 | 3,823.9 | 2,180.1 | 1,239.1  | 759.3    | 470.0   | 308.5   | 264.6   | 590.0   | 1,633.4 | 4,400.3 | 2,263.2 |
| 331 | Murray                       | 1,059,508 | 2,868.3 | 1,379.7 | 1,501.2 | 1,110.5 | 1,279.6  | 2,153.4  | 2,511.6 | 3,164.9 | 3,371.2 | 3,337.6 | 2,314.5 | 2,000.4 | 2,249.4 |
| 220 | Senegal                      | 436,981   | 1,629.1 | 10.0    | 15.2    | 11.7    | 12.0     | 447.8    | 3,062.5 | 8,464.3 | 6,863.4 | 3,270.9 | 1,792.3 | 1,076.7 | 2,221.3 |
| 377 | Fuchun Jiang                 | 37,698    | 1,253.4 | 1,966.9 | 3,249.4 | 3,037.5 | 4,025.8  | 5,573.0  | 2,420.0 | 1,437.2 | 1,282.3 | 886.7   | 707.7   | 572.7   | 2,201.1 |
| 45  | Thelon                       | 238,839   | 478.4   | 0.1     | 0.0     | 0.0     | 6,190.9  | 10,749.7 | 3,370.2 | 2,026.8 | 1,686.6 | 859.5   | 519.1   | 313.5   | 2,182.9 |
| 274 | Kouilou                      | 60,000    | 4,007.3 | 2,400.3 | 3,950.9 | 5,306.6 | 3,068.4  | 1,426.7  | 862.7   | 522.5   | 316.7   | 191.7   | 1,130.5 | 3,001.1 | 2,182.1 |
| 81  | Nass                         | 21,212    | 1,054.0 | 0.0     | 810.7   | 3,441.7 | 6,020.4  | 4,634.1  | 2,047.3 | 1,515.8 | 1,839.7 | 2,607.5 | 1,420.3 | 691.1   | 2,173.5 |
| 209 | Brahmani River<br>(Bhahmani) | 51,973    | 1,562.1 | 33.6    | 53.2    | 42.6    | 38.7     | 549.7    | 3,888.5 | 7,939.2 | 6,035.6 | 3,059.0 | 1,695.6 | 1,049.7 | 2,162.3 |
| 246 | Cavally                      | 30,665    | 2,295.7 | 105.8   | 221.1   | 532.9   | 1,553.0  | 3,418.3  | 2,447.3 | 1,941.8 | 4,204.8 | 4,188.2 | 2,935.7 | 1,654.9 | 2,125.0 |
| 101 | Elbe                         | 139,348   | 2,858.7 | 2,594.5 | 4,899.4 | 3,701.9 | 2,272.5  | 1,577.0  | 1,147.9 | 892.7   | 725.8   | 865.4   | 1,454.7 | 1,857.4 | 2,070.7 |
| 39  | Mezen                        | 76,715    | 372.9   | 4.5     | 2.7     | 3,916.9 | 10,521.7 | 3,855.7  | 2,081.0 | 1,250.6 | 799.5   | 867.4   | 386.3   | 233.3   | 2,024.4 |
| 340 | Negro<br>(Uruguay)           | 70,756    | 1,301.6 | 86.9    | 492.1   | 1,499.0 | 2,274.1  | 3,311.9  | 3,222.8 | 3,290.1 | 3,379.1 | 2,823.2 | 1,553.8 | 846.5   | 2,006.8 |
| 270 | Daule and<br>Vinces          | 41,993    | 2,730.9 | 4,080.6 | 5,260.2 | 4,696.3 | 2,419.3  | 1,482.0  | 915.4   | 644.8   | 472.3   | 447.2   | 458.1   | 400.9   | 2,000.7 |
| 255 | Coppename                    | 24,750    | 1,551.1 | 1,394.4 | 1,540.4 | 2,071.4 | 4,023.6  | 4,578.3  | 3,861.0 | 2,331.4 | 1,160.6 | 695.4   | 420.0   | 321.1   | 1,995.7 |
| 371 | Lurio                        | 61,172    | 4,604.7 | 6,185.0 | 6,089.2 | 2,522.2 | 1,435.2  | 866.8    | 523.5   | 316.3   | 191.1   | 115.4   | 69.7    | 468.0   | 1,948.9 |
| 4   | Yana                         | 233,479   | 896.1   | 72.8    | 44.0    | 26.6    | 159.2    | 7,535.9  | 6,820.7 | 3,807.3 | 1,832.6 | 1,106.8 | 668.5   | 403.8   | 1,947.9 |
| 140 | Ebro                         | 85,159    | 4,220.1 | 2,820.2 | 2,785.8 | 2,876.1 | 2,619.8  | 1,631.9  | 1,192.1 | 853.9   | 509.9   | 561.7   | 873.7   | 2,424.5 | 1,947.5 |
| 364 | Coco                         | 25,502    | 2,767.8 | 143.3   | 70.7    | 43.3    | 48.4     | 1,698.7  | 3,244.2 | 2,959.2 | 3,280.5 | 3,939.1 | 2,788.7 | 2,041.2 | 1,918.8 |
| 74  | George                       | 39,054    | 758.1   | 0.0     | 0.0     | 0.0     | 4,958.0  | 5,039.7  | 3,961.6 | 2,616.4 | 2,618.4 | 1,701.2 | 823.0   | 497.1   | 1,914.5 |
| 221 | Papaloapan                   | 39,885    | 1,877.2 | 12.4    | 16.0    | 15.8    | 11.5     | 477.3    | 2,373.0 | 4,411.2 | 5,780.4 | 4,426.4 | 2,194.2 | 1,261.7 | 1,904.8 |
| 351 | Baker                        | 30,760    | 1,928.9 | 630.2   | 1,099.0 | 1,638.6 | 2,259.5  | 2,536.2  | 2,753.8 | 2,648.6 | 2,149.0 | 1,882.5 | 1,579.4 | 1,282.9 | 1,865.7 |
| 142 | Douro                        | 96,125    | 3,913.4 | 3,031.8 | 4,104.3 | 2,983.9 | 2,057.4  | 1,252.2  | 1,050.6 | 820.4   | 404.1   | 215.0   | 539.3   | 1,650.2 | 1,835.2 |

*continues*

**DATA TABLE 7** *continued*

| Basin ID | Basin Name      | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |         |          |         |         |         |         |         |         |         |         |         |
|----------|-----------------|-------------------------|---|---------|---------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|          |                 |                         | Jan                                     | Feb     | Mar     | Apr      | May     | Jun     | Jul     | Aug     | Sep     | Oct     | Nov     | Dec     | Average |
| 87       | Neman           | 97,300                  | 740.2                                   | 3.4     | 2,540.2 | 8,813.4  | 3,141.2 | 1,745.1 | 1,037.9 | 641.8   | 406.1   | 467.3   | 1,597.2 | 486.5   | 1,801.7 |
| 97       | Ural            | 339,084                 | 324.2                                   | 5.7     | 165.2   | 10,759.3 | 3,817.4 | 2,162.0 | 1,470.8 | 948.2   | 527.8   | 322.1   | 587.8   | 214.5   | 1,775.4 |
| 387      | Batang          | 16,739                  | 3,820.3                                 | 1,460.7 | 1,731.9 | 2,316.9  | 1,825.4 | 1,075.7 | 640.6   | 525.6   | 838.5   | 1,724.9 | 2,579.6 | 2,602.7 | 1,761.9 |
|          | Kuantan         |                         |   |         |         |          |         |         |         |         |         |         |         |         |         |
| 392      | Issyk-Kul       | 191,032                 | 300.5                                   | 48.6    | 2,132.1 | 3,385.1  | 4,295.9 | 3,990.2 | 3,002.3 | 1,671.5 | 1,072.0 | 585.2   | 384.5   | 205.0   | 1,756.1 |
| 137      | Hudson          | 36,893                  | 1,000.4                                 | 26.3    | 4,477.0 | 4,970.6  | 2,745.5 | 1,656.2 | 1,063.5 | 725.6   | 742.5   | 1,044.8 | 1,764.9 | 728.3   | 1,745.5 |
| 138      | Colorado        | 640,464                 | 323.3                                   | 99.7    | 738.0   | 3,046.4  | 5,903.7 | 4,320.1 | 2,390.6 | 1,653.7 | 1,126.8 | 740.4   | 370.5   | 231.4   | 1,745.4 |
|          | (Pacific Ocean) |                         |   |         |         |          |         |         |         |         |         |         |         |         |         |
| 231      | Cauvery         | 91,159                  | 2,091.4                                 | 159.7   | 385.4   | 347.3    | 350.9   | 1,080.8 | 3,669.7 | 3,305.4 | 2,574.1 | 2,347.6 | 2,777.6 | 1,849.0 | 1,744.9 |
| 214      | Tapti           | 65,096                  | 1,243.3                                 | 168.4   | 306.4   | 365.6    | 395.0   | 149.1   | 3,365.4 | 5,169.5 | 5,115.9 | 2,124.1 | 1,333.7 | 886.1   | 1,718.5 |
| 35       | Back            | 141,352                 | 327.2                                   | 0.0     | 0.0     | 0.0      | 5,571.3 | 8,215.3 | 2,637.8 | 1,590.9 | 990.4   | 588.0   | 355.2   | 214.5   | 1,707.6 |
| 271      | Rio Gurupi      | 32,335                  | 491.7                                   | 2,048.7 | 4,647.2 | 4,513.5  | 3,426.0 | 2,151.5 | 1,412.8 | 764.6   | 450.8   | 272.3   | 164.5   | 103.1   | 1,703.9 |
| 264      | Ntem            | 33,527                  | 2,055.6                                 | 8.3     | 442.8   | 1,623.3  | 2,595.7 | 1,808.1 | 791.1   | 470.6   | 1,558.6 | 4,430.8 | 3,192.8 | 1,428.3 | 1,700.5 |
| 352      | Santa Cruz      | 30,600                  | 1,652.2                                 | 385.0   | 560.0   | 1,181.8  | 1,590.7 | 1,850.7 | 1,577.2 | 2,464.8 | 3,221.0 | 3,226.9 | 1,605.8 | 1,042.5 | 1,696.6 |
| 160      | Han-Gang        | 24,772                  | 814.3                                   | 12.5    | 1,372.3 | 1,838.7  | 1,166.9 | 1,200.5 | 4,312.9 | 3,914.3 | 2,697.0 | 1,388.7 | 1,010.5 | 540.7   | 1,689.1 |
|          | (Han River)     |                         |   |         |         |          |         |         |         |         |         |         |         |         |         |
| 379      | Han Jiang       | 30,742                  | 429.5                                   | 189.6   | 1,241.1 | 2,010.5  | 3,792.4 | 4,718.0 | 2,447.5 | 2,125.6 | 1,654.9 | 782.8   | 466.3   | 283.9   | 1,678.5 |
| 100      | Oder            | 116,536                 | 1,032.5                                 | 1,852.6 | 5,896.3 | 3,319.4  | 2,160.7 | 1,462.2 | 947.3   | 682.0   | 505.5   | 478.7   | 627.0   | 1,046.2 | 1,667.5 |
| 89       | Severn (Trib.   | 98,590                  | 593.2                                   | 0.0     | 0.0     | 969.8    | 7,964.8 | 3,325.3 | 1,813.8 | 1,158.6 | 1,429.9 | 1,689.2 | 644.0   | 388.9   | 1,664.8 |
|          | Hudson Bay)     |                         |   |         |         |          |         |         |         |         |         |         |         |         |         |
| 139      | Klamath         | 40,040                  | 3,010.5                                 | 3,574.1 | 3,546.4 | 3,046.4  | 2,001.6 | 1,051.5 | 698.7   | 455.6   | 276.0   | 146.5   | 394.9   | 1,495.2 | 1,641.5 |
| 184      | Apalachicola    | 51,413                  | 2,889.5                                 | 3,847.6 | 4,385.4 | 3,016.0  | 1,572.5 | 912.7   | 651.6   | 531.5   | 402.8   | 235.8   | 202.2   | 1,034.8 | 1,640.2 |
| 76       | Western Dvina   | 89,340                  | 772.7                                   | 2.1     | 2.1     | 9,180.8  | 2,977.1 | 1,713.6 | 1,016.3 | 619.6   | 425.3   | 849.3   | 1,548.2 | 507.4   | 1,634.5 |
|          | (Daugava)       |                         |   |         |         |          |         |         |         |         |         |         |         |         |         |
| 212      | Panuco          | 82,929                  | 1,540.6                                 | 95.9    | 186.5   | 197.5    | 137.9   | 362.8   | 2,013.6 | 2,491.4 | 6,156.6 | 3,524.7 | 1,770.8 | 1,046.5 | 1,627.1 |
| 52       | Vuoksi          | 62,707                  | 334.8                                   | 1.2     | 1.2     | 10,528.9 | 2,968.3 | 1,728.3 | 1,039.2 | 643.3   | 560.3   | 960.4   | 387.0   | 220.0   | 1,614.4 |

|     |                          |         |         |         |         |          |         |         |         |         |         |         |         |         |         |
|-----|--------------------------|---------|---------|---------|---------|----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 306 | Mitchell (N. Au)         | 1,612.8 | 71,725  | 1,080.2 | 6,217.0 | 5,876.8  | 2,616.6 | 1,435.1 | 859.9   | 521.2   | 317.3   | 194.5   | 119.8   | 72.3    | 43.0    |
| 53  | Omega                    | 65,894  | 224.9   | 2.8     | 1.8     | 10,633.8 | 3,402.5 | 1,902.0 | 1,125.9 | 680.1   | 436.9   | 556.4   | 234.8   | 141.1   | 1,611.9 |
| 61  | Vaern-Goeta              | 51,791  | 1,198.3 | 3.2     | 2,259.8 | 5,377.8  | 2,297.5 | 1,379.5 | 819.2   | 707.0   | 791.8   | 1,475.7 | 1,616.9 | 1,037.2 | 1,580.3 |
| 132 | Connecticut              | 27,468  | 934.3   | 7.8     | 3,116.2 | 4,979.1  | 2,528.5 | 1,556.0 | 985.4   | 660.3   | 761.0   | 1,049.6 | 1,699.4 | 665.0   | 1,578.5 |
| 393 | Balkhash                 | 42,3657 | 273.5   | 5.8     | 2,199.0 | 4,046.6  | 4,089.9 | 2,907.0 | 2,102.5 | 1,368.5 | 905.0   | 412.3   | 445.2   | 181.7   | 1,578.1 |
| 37  | Nadym                    | 54,625  | 383.2   | 0.2     | 0.1     | 0.1      | 4,504.7 | 7,346.2 | 2,354.4 | 1,461.2 | 1,502.8 | 687.7   | 415.4   | 250.9   | 1,575.6 |
| 133 | Liao He                  | 194,436 | 678.2   | 20.4    | 220.6   | 1,657.1  | 2,266.7 | 2,171.0 | 2,661.2 | 3,988.1 | 2,606.5 | 1,383.3 | 782.0   | 454.6   | 1,574.1 |
| 282 | Rio Mearim               | 56,687  | 356.4   | 2,713.7 | 5,445.6 | 4,657.5  | 2,321.9 | 1,253.1 | 745.7   | 450.8   | 272.8   | 165.1   | 99.9    | 61.7    | 1,545.3 |
| 238 | Bandama                  | 98,751  | 1,337.1 | 4.0     | 5.7     | 118.4    | 306.8   | 1,520.8 | 1,055.3 | 2,949.0 | 5,574.4 | 3,186.6 | 1,473.0 | 881.5   | 1,534.4 |
| 59  | Gloma                    | 42,863  | 563.2   | 1.3     | 12.0    | 3,439.3  | 3,368.1 | 3,615.4 | 2,048.4 | 1,487.9 | 1,400.5 | 1,344.1 | 677.6   | 369.7   | 1,527.3 |
| 18  | Kemijoki                 | 55,825  | 487.2   | 3.2     | 2.0     | 594.1    | 8,987.0 | 2,448.1 | 1,458.1 | 934.7   | 1,082.1 | 1,366.4 | 516.4   | 312.0   | 1,515.9 |
| 134 | Garonne                  | 55,807  | 3,122.4 | 1,918.1 | 2,169.4 | 2,289.6  | 1,911.6 | 1,113.4 | 759.2   | 594.0   | 474.6   | 657.6   | 1,074.9 | 1,915.8 | 1,500.0 |
| 280 | Rio Pindare              | 39,112  | 253.4   | 2,304.7 | 4,716.9 | 4,525.5  | 2,674.7 | 1,415.4 | 814.8   | 488.9   | 295.4   | 178.6   | 108.0   | 65.3    | 1,486.8 |
| 77  | Aux Melezes              | 41,384  | 637.5   | 0.1     | 0.1     | 0.0      | 5,433.5 | 3,250.9 | 1,841.6 | 1,727.2 | 1,787.2 | 1,696.1 | 691.6   | 417.7   | 1,457.0 |
| 145 | Kura                     | 182,283 | 559.4   | 187.2   | 708.9   | 3,035.7  | 4,111.4 | 2,768.8 | 1,901.8 | 1,396.6 | 913.7   | 766.2   | 692.7   | 413.7   | 1,454.7 |
| 267 | Mira                     | 13,265  | 2,073.0 | 1,259.4 | 1,291.0 | 1,430.0  | 2,032.3 | 1,959.3 | 1,248.7 | 1,229.1 | 1,355.3 | 1,165.3 | 1,283.2 | 912.8   | 1,436.6 |
| 375 | Pyasina                  | 63,889  | 470.7   | 4.9     | 3.1     | 2.0      | 1.3     | 8,582.4 | 2,828.9 | 1,874.0 | 1,803.8 | 814.2   | 491.9   | 297.2   | 1,431.2 |
| 230 | Grande De Matagalpa      | 17,992  | 1,788.5 | 87.6    | 46.4    | 30.2     | 37.4    | 1,350.9 | 2,694.3 | 2,443.9 | 2,701.8 | 2,950.2 | 1,748.2 | 1,248.2 | 1,427.3 |
| 73  | Feuilles (Rivière Aux)   | 37,425  | 673.6   | -       | -       | -        | 2,539.5 | 5,199.5 | 2,051.0 | 1,757.3 | 1,931.8 | 1,773.6 | 731.3   | 441.7   | 1,424.9 |
| 206 | Damodar                  | 43,096  | 1,257.9 | 111.7   | 160.8   | 44.8     | 15.0    | 253.7   | 1,494.8 | 4,751.2 | 4,657.8 | 2,147.4 | 1,316.0 | 850.4   | 1,421.8 |
| 147 | Delaware                 | 26,713  | 1,640.3 | 801.3   | 4,062.4 | 2,255.7  | 1,789.8 | 1,043.1 | 712.5   | 568.2   | 587.3   | 762.0   | 1,406.7 | 1,294.0 | 1,410.3 |
| 217 | Ca                       | 28,747  | 1,447.9 | 56.1    | 26.8    | 23.3     | 154.3   | 584.1   | 1,876.9 | 2,678.4 | 4,330.1 | 2,767.9 | 1,652.1 | 965.9   | 1,380.3 |
| 103 | Weser                    | 43,140  | 3,511.3 | 2,008.3 | 1,895.7 | 1,397.8  | 902.7   | 617.5   | 504.3   | 484.0   | 501.8   | 819.6   | 1,601.5 | 2,294.1 | 1,378.2 |
| 367 | Cunene                   | 110,545 | 1,828.9 | 2,579.9 | 5,240.5 | 2,925.0  | 1,322.8 | 798.9   | 482.7   | 291.8   | 176.4   | 112.8   | 98.1    | 642.6   | 1,375.0 |
| 84  | Hayes (Trib. Hudson Bay) | 105,372 | 339.8   | 7.0     | 4.3     | 2.6      | 7,011.9 | 3,778.4 | 2,054.7 | 1,111.5 | 798.0   | 731.1   | 339.8   | 205.3   | 1,365.4 |
| 241 | Shebelle                 | 805,077 | 1,126.2 | 49.5    | 54.4    | 2,532.2  | 1,755.0 | 1,025.3 | 1,594.0 | 2,005.1 | 1,944.7 | 1,681.9 | 1,610.5 | 791.5   | 1,347.5 |
| 336 | Colorado (Argentina)     | 390,631 | 3,500.8 | 346.2   | 220.9   | 135.4    | 373.1   | 707.2   | 841.7   | 929.8   | 908.5   | 2,371.9 | 3,152.6 | 2,575.4 | 1,338.6 |

*continues*

**DATA TABLE 7** *continued*

| Basin ID | Basin Name            | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |         |         |         |         |         |         |         |         |         |         | Average |
|----------|-----------------------|-------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|          |                       |                         | Jan                                     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     | Oct     | Nov     | Dec     |         |
| 261      | Nyong                 | 34,626                  | 1,269.1                                 | 0.1     | 386.2   | 1,153.1 | 1,817.1 | 1,504.5 | 698.1   | 677.8   | 2,434.6 | 3,389.9 | 1,699.9 | 832.3   | 1,321.9 |
| 349      | Chubut                | 145,352                 | 837.4                                   | 70.0    | 172.1   | 336.2   | 1,273.9 | 2,263.3 | 2,596.8 | 3,116.1 | 2,246.4 | 1,454.2 | 895.8   | 580.3   | 1,320.2 |
| 152      | Tejo                  | 70,352                  | 2,713.3                                 | 2,202.2 | 3,261.5 | 2,062.1 | 1,343.3 | 834.4   | 721.8   | 559.4   | 292.8   | 124.7   | 136.5   | 1,182.1 | 1,286.2 |
| 253      | Kelantan              | 14,420                  | 3,574.8                                 | 439.2   | 342.5   | 417.5   | 434.1   | 481.7   | 494.1   | 561.2   | 1,352.9 | 2,084.8 | 2,431.3 | 2,719.0 | 1,277.8 |
| 362      | Ulua                  | 26,392                  | 1,735.8                                 | 77.7    | 42.4    | 31.4    | 19.3    | 510.5   | 1,791.6 | 1,997.4 | 3,135.9 | 2,748.5 | 1,916.8 | 1,262.0 | 1,272.4 |
| 46       | Angerman              | 32,372                  | 343.5                                   | 0.5     | 0.4     | 4,027.0 | 3,524.6 | 2,685.5 | 1,232.5 | 833.4   | 764.3   | 954.8   | 371.0   | 224.1   | 1,246.8 |
| 119      | Seine                 | 74,228                  | 3,426.9                                 | 2,491.0 | 2,183.7 | 1,663.9 | 1,005.1 | 594.9   | 402.4   | 304.5   | 202.7   | 234.2   | 696.1   | 1,700.9 | 1,242.2 |
| 256      | Kinabatangan          | 14,102                  | 2,820.1                                 | 862.7   | 675.4   | 672.8   | 675.3   | 1,148.9 | 787.8   | 1,142.6 | 1,468.5 | 1,388.6 | 1,249.3 | 1,909.0 | 1,233.4 |
| 205      | Mahi                  | 36,238                  | 884.2                                   | 157.9   | 246.0   | 223.2   | 137.5   | 37.8    | 2,640.9 | 4,426.7 | 3,152.3 | 1,389.2 | 865.8   | 573.5   | 1,227.9 |
| 67       | Nushagak              | 29,514                  | 517.3                                   | 0.0     | 0.0     | 1,308.4 | 4,936.8 | 1,770.2 | 1,042.6 | 1,293.2 | 1,548.5 | 1,382.8 | 561.6   | 339.2   | 1,225.1 |
| 66       | Arnaud                | 44,932                  | 564.3                                   | -       | -       | -       | 632.5   | 5,641.8 | 2,064.4 | 1,543.3 | 1,878.6 | 1,362.9 | 612.6   | 370.0   | 1,222.5 |
| 165      | Shinano,<br>Chikuma   | 11,159                  | 1,100.6                                 | 807.7   | 800.2   | 1,837.3 | 1,864.2 | 1,290.9 | 1,242.1 | 1,006.9 | 1,172.1 | 1,174.8 | 1,150.4 | 1,044.7 | 1,207.7 |
| 171      | Pee Dee               | 46,531                  | 2,824.5                                 | 2,381.4 | 2,346.1 | 1,609.2 | 944.6   | 589.6   | 563.3   | 455.2   | 460.3   | 379.9   | 545.7   | 1,384.2 | 1,207.0 |
| 135      | Ishikari              | 13,783                  | 859.4                                   | 2.4     | 2.4     | 4,390.2 | 1,918.3 | 1,080.5 | 793.8   | 776.5   | 1,178.1 | 1,434.9 | 1,481.8 | 564.3   | 1,206.9 |
| 108      | Little Mecatina       | 17,903                  | 444.5                                   | 0.0     | 0.0     | 0.0     | 6,156.3 | 2,178.5 | 1,505.7 | 1,078.9 | 1,004.0 | 1,263.0 | 482.6   | 291.5   | 1,200.4 |
| 151      | Yongding He           | 214,406                 | 174.7                                   | 403.8   | 1,472.8 | 2,529.4 | 2,501.8 | 1,275.4 | 1,729.3 | 2,397.6 | 1,071.8 | 442.9   | 185.1   | 137.8   | 1,193.5 |
| 23       | Lule                  | 25,128                  | 313.1                                   | 1.0     | 0.6     | 1,119.1 | 3,851.3 | 3,784.3 | 1,895.4 | 1,112.2 | 951.7   | 683.0   | 335.9   | 202.9   | 1,187.5 |
| 131      | Kuban                 | 58,936                  | 1,008.9                                 | 1,275.5 | 1,664.7 | 2,123.9 | 1,943.7 | 1,594.5 | 1,393.7 | 826.2   | 621.9   | 471.0   | 528.0   | 626.0   | 1,173.2 |
| 129      | Penobscot             | 21,169                  | 655.1                                   | 0.6     | 482.1   | 5,554.7 | 1,878.0 | 1,224.9 | 733.4   | 451.5   | 421.6   | 684.5   | 1,327.0 | 429.8   | 1,153.6 |
| 70       | Narva                 | 58,147                  | 710.7                                   | 1.2     | 1.2     | 6,018.5 | 1,937.0 | 1,079.4 | 639.7   | 420.0   | 372.9   | 731.8   | 1,459.3 | 466.4   | 1,153.2 |
| 358      | Tarim                 | 1,051,731               | 241.9                                   | 77.0    | 269.6   | 593.6   | 1,657.0 | 2,845.3 | 3,326.7 | 2,360.3 | 1,351.4 | 540.9   | 295.2   | 164.1   | 1,143.6 |
| 234      | Corubal               | 24,258                  | 882.9                                   | 0.4     | 0.5     | 0.5     | 0.4     | 293.0   | 1,767.6 | 3,594.2 | 3,165.9 | 2,080.6 | 964.3   | 579.0   | 1,110.8 |
| 347      | Waikato               | 15,359                  | 1,209.9                                 | 436.0   | 382.1   | 601.3   | 1,271.4 | 1,642.5 | 1,617.1 | 1,551.8 | 1,388.8 | 1,356.2 | 1,080.3 | 781.6   | 1,109.9 |
| 309      | Jequitinhonha         | 68,549                  | 4,207.8                                 | 1,648.8 | 1,430.8 | 860.3   | 471.5   | 297.0   | 203.6   | 126.2   | 74.1    | 60.4    | 675.7   | 3,152.4 | 1,100.7 |
| 225      | Tranh (Nr<br>Thu Bon) | 9,460                   | 2,007.0                                 | 45.2    | 24.6    | 16.4    | 71.3    | 290.8   | 883.2   | 1,278.8 | 1,770.6 | 2,724.1 | 2,418.9 | 1,615.2 | 1,095.5 |

|     |                               |         |         |         |         |         |         |         |         |         |         |         |         |         |         |
|-----|-------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 289 | Solo (Bengawan Solo)          | 15,146  | 2,855.5 | 2,415.3 | 2,433.6 | 1,722.1 | 949.3   | 531.7   | 332.1   | 222.4   | 171.0   | 106.2   | 250.0   | 1,099.8 | 1,090.8 |
| 316 | Burdekin                      | 130,427 | 690.0   | 3,679.3 | 3,662.4 | 1,887.1 | 1,001.1 | 597.8   | 363.8   | 227.1   | 146.3   | 95.8    | 59.5    | 32.7    | 1,036.9 |
| 120 | Dniestr                       | 72,108  | 407.9   | 13.3    | 3,147.7 | 2,602.1 | 1,528.5 | 1,130.4 | 792.2   | 626.7   | 510.8   | 629.4   | 702.3   | 272.1   | 1,030.3 |
| 320 | Limpopo                       | 415,623 | 1,880.1 | 3,058.9 | 2,803.2 | 1,433.2 | 767.0   | 501.7   | 359.2   | 334.0   | 330.6   | 246.8   | 159.6   | 308.4   | 1,015.2 |
| 161 | Guadalquivir                  | 56,955  | 677.2   | 1,306.6 | 3,139.9 | 1,977.6 | 1,055.0 | 1,003.9 | 1,110.6 | 955.3   | 481.2   | 185.6   | 65.2    | 160.4   | 1,009.9 |
| 169 | Tone                          | 15,739  | 936.2   | 260.8   | 691.8   | 1,057.7 | 983.0   | 973.7   | 1,058.8 | 1,240.9 | 1,561.5 | 1,541.0 | 979.8   | 683.0   | 997.3   |
| 228 | Lempa                         | 18,088  | 888.1   | 2.9     | 7.6     | 10.3    | 11.7    | 547.6   | 1,582.1 | 1,968.2 | 3,042.2 | 2,295.6 | 976.3   | 585.2   | 993.2   |
| 329 | Rio Ribeira Do Iguape         | 25,698  | 2,174.8 | 1,657.5 | 1,425.9 | 887.3   | 735.4   | 782.1   | 538.1   | 442.8   | 601.1   | 860.6   | 773.8   | 987.3   | 988.9   |
| 326 | Orange                        | 972,388 | 1,857.2 | 2,095.4 | 2,246.2 | 1,402.3 | 807.0   | 489.5   | 342.5   | 319.8   | 311.7   | 362.3   | 534.8   | 884.1   | 971.1   |
| 277 | Rio Itapecuru                 | 52,672  | 84.3    | 1,224.8 | 3,260.0 | 3,253.3 | 1,651.3 | 883.6   | 520.8   | 314.3   | 190.4   | 115.4   | 69.7    | 42.3    | 967.5   |
| 167 | Naktong                       | 23,325  | 508.2   | 274.7   | 755.4   | 983.6   | 697.6   | 959.3   | 1,987.4 | 1,879.2 | 1,673.3 | 882.4   | 545.1   | 344.9   | 957.6   |
| 342 | Salado                        | 266,264 | 1,011.5 | 24.7    | 73.2    | 787.5   | 1,228.1 | 1,234.8 | 1,105.6 | 959.3   | 1,261.2 | 1,567.9 | 1,418.0 | 767.6   | 953.3   |
| 190 | Pearl                         | 22,423  | 1,984.2 | 2,012.8 | 2,131.6 | 1,713.4 | 1,094.2 | 598.0   | 392.6   | 256.9   | 162.9   | 99.8    | 148.7   | 752.9   | 945.7   |
| 229 | Gambia                        | 69,874  | 750.8   | 0.3     | 0.3     | 0.3     | 0.3     | 145.1   | 922.2   | 3,078.2 | 3,466.5 | 1,537.8 | 816.1   | 492.4   | 934.2   |
| 92  | Grande Rivière De La Baleine  | 24,257  | 482.1   | 0.0     | 0.0     | 0.0     | 3,057.6 | 1,978.3 | 1,140.9 | 1,097.4 | 1,241.0 | 1,368.9 | 523.3   | 316.1   | 933.8   |
| 211 | Santiago                      | 126,222 | 681.2   | 116.1   | 243.6   | 265.3   | 168.1   | 205.1   | 1,027.8 | 2,651.8 | 3,112.7 | 1,413.6 | 791.4   | 492.4   | 930.8   |
| 315 | Save                          | 114,958 | 2,203.3 | 3,356.1 | 2,440.7 | 1,065.6 | 627.7   | 386.7   | 242.8   | 173.8   | 130.9   | 85.0    | 41.4    | 348.7   | 925.2   |
| 78  | Baleine, Grande Rivière De La | 22,136  | 379.8   | -       | -       | -       | 4,270.1 | 1,505.8 | 1,122.0 | 983.1   | 1,130.8 | 994.3   | 412.3   | 249.0   | 920.6   |
| 36  | Kem                           | 42,081  | 235.3   | 0.5     | 0.4     | 2,642.5 | 3,902.2 | 1,352.6 | 781.6   | 490.1   | 429.8   | 696.2   | 253.6   | 153.2   | 911.5   |
| 69  | Taku                          | 17,968  | 430.1   | 0.0     | 0.0     | 806.8   | 2,508.0 | 2,296.9 | 1,033.2 | 783.7   | 1,027.7 | 1,263.6 | 467.0   | 282.0   | 908.3   |
| 43  | Oulujoki                      | 30,555  | 230.9   | 1.1     | 0.8     | 5,398.3 | 1,702.8 | 939.7   | 562.7   | 373.1   | 416.6   | 710.7   | 247.3   | 149.5   | 894.5   |
| 50  | Nizhny Vyg (Soroka)           | 31,334  | 206.5   | 0.1     | 0.1     | 5,451.2 | 1,622.9 | 926.7   | 553.6   | 334.4   | 420.4   | 626.2   | 224.2   | 135.5   | 875.1   |
| 186 | Altamaha                      | 37,117  | 1,328.3 | 2,248.8 | 2,575.1 | 1,555.3 | 829.5   | 474.6   | 313.9   | 232.8   | 182.4   | 112.6   | 72.0    | 424.7   | 862.5   |
| 363 | Patacua                       | 24,232  | 1,710.9 | 118.6   | 53.8    | 32.7    | 19.7    | 70.9    | 693.4   | 892.9   | 1,438.3 | 2,176.2 | 1,802.4 | 1,293.7 | 858.6   |

continues

**DATA TABLE 7** *continued*

| Basin ID | Basin Name              | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |         |         |         |         |         |         |         |       |       |       | Average |
|----------|-------------------------|-------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|-------|-------|-------|---------|
|          |                         |                         | Jan                                     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     | Oct   | Nov   | Dec   |         |
| 63       | Elsek                   | 28,422                  | 286.1                                   | 0.0     | 0.0     | 584.4   | 2,611.7 | 2,770.9 | 1,100.4 | 738.6   | 961.8   | 680.0 | 310.6 | 187.6 | 852.7   |
| 162      | San Joaquin             | 34,366                  | 707.1                                   | 829.3   | 1,285.7 | 1,335.3 | 1,136.9 | 1,098.6 | 1,267.9 | 1,193.7 | 818.4   | 322.2 | 74.9  | 102.3 | 847.7   |
| 109      | Natashquan<br>(Rivière) | 16,948                  | 291.0                                   | 0.0     | 0.0     | 156.2   | 3,726.8 | 1,620.1 | 1,208.4 | 808.1   | 691.2   | 792.3 | 315.9 | 190.8 | 816.7   |
| 156      | Potomac                 | 32,381                  | 1,355.9                                 | 1,163.5 | 1,705.2 | 1,374.1 | 948.5   | 624.9   | 370.6   | 255.1   | 188.4   | 213.6 | 392.6 | 752.3 | 778.7   |
| 3        | Anabar                  | 85,016                  | 525.8                                   | 85.3    | 51.5    | 31.1    | 18.8    | 4,128.1 | 2,082.3 | 1,011.7 | 602.5   | 354.9 | 214.4 | 129.5 | 769.6   |
| 136      | Merrimack               | 12,645                  | 381.1                                   | 8.4     | 3,157.8 | 1,789.4 | 1,035.9 | 634.7   | 377.8   | 233.8   | 212.7   | 361.4 | 783.0 | 252.8 | 769.1   |
| 115      | Rupert                  | 16,063                  | 311.4                                   | 0.0     | 0.0     | 794.7   | 3,201.0 | 1,189.1 | 796.1   | 677.5   | 758.7   | 894.3 | 338.0 | 204.2 | 763.8   |
| 166      | Roanoke                 | 26,801                  | 1,844.9                                 | 1,467.9 | 1,460.0 | 1,085.8 | 725.1   | 448.3   | 316.0   | 238.3   | 184.2   | 159.1 | 332.5 | 853.9 | 759.7   |
| 291      | Brantas                 | 10,823                  | 1,795.8                                 | 1,741.1 | 1,762.4 | 1,247.5 | 696.8   | 395.2   | 243.3   | 163.6   | 122.2   | 71.2  | 160.7 | 531.2 | 744.2   |
| 350      | Clutha                  | 17,119                  | 1,029.1                                 | 421.2   | 482.8   | 693.8   | 684.7   | 694.4   | 642.0   | 723.7   | 898.4   | 957.1 | 762.4 | 659.5 | 720.8   |
| 158      | Kitakami                | 9,652                   | 690.1                                   | 172.5   | 1,357.6 | 1,082.6 | 802.0   | 551.9   | 581.1   | 590.1   | 631.9   | 775.8 | 828.3 | 528.7 | 716.1   |
| 344      | Rapel                   | 15,689                  | 1,119.4                                 | 178.1   | 113.7   | 66.3    | 510.5   | 1,373.7 | 1,356.5 | 1,185.4 | 876.8   | 701.4 | 412.7 | 681.5 | 714.7   |
| 324      | Mangoky                 | 43,141                  | 1,857.9                                 | 2,203.9 | 1,852.5 | 898.9   | 518.2   | 330.4   | 220.7   | 136.7   | 83.0    | 50.1  | 56.6  | 333.7 | 711.9   |
| 150      | Kizilirmak              | 77,874                  | 199.1                                   | 836.5   | 1,201.8 | 2,397.1 | 1,578.7 | 804.4   | 537.4   | 393.4   | 241.0   | 132.0 | 83.4  | 128.5 | 711.1   |
| 55       | Kymijoki                | 33,623                  | 186.3                                   | 1.0     | 1.0     | 4,570.7 | 1,319.9 | 758.1   | 456.3   | 277.2   | 216.4   | 308.4 | 311.4 | 122.5 | 710.7   |
| 174      | Tenryu                  | 5,769                   | 584.8                                   | 291.0   | 511.3   | 839.0   | 748.4   | 861.4   | 816.6   | 724.3   | 1,026.6 | 888.4 | 635.8 | 438.9 | 697.2   |
| 181      | Savannah                | 27,740                  | 1,501.0                                 | 1,570.4 | 1,658.6 | 1,058.3 | 583.9   | 360.8   | 272.1   | 190.7   | 187.5   | 165.1 | 238.5 | 572.9 | 696.6   |
| 178      | Yodo                    | 8,424                   | 1,063.4                                 | 536.0   | 654.4   | 713.4   | 583.0   | 743.8   | 675.6   | 510.1   | 768.0   | 820.6 | 652.7 | 632.7 | 696.1   |
| 192      | Suwannee                | 26,401                  | 1,043.0                                 | 1,262.4 | 1,316.2 | 797.7   | 415.7   | 300.4   | 613.1   | 756.9   | 714.7   | 385.8 | 211.7 | 527.5 | 695.4   |
| 176      | Kiso                    | 5,419                   | 652.3                                   | 218.1   | 352.4   | 848.3   | 836.4   | 896.9   | 961.9   | 750.1   | 967.8   | 780.0 | 608.0 | 420.8 | 691.1   |
| 123      | Skagit                  | 7,961                   | 951.3                                   | 342.8   | 1,452.8 | 1,747.8 | 975.0   | 491.1   | 287.0   | 173.6   | 108.5   | 409.0 | 751.3 | 600.5 | 690.9   |
| 173      | Cape Fear               | 22,653                  | 1,592.2                                 | 1,301.8 | 1,225.2 | 817.3   | 528.8   | 353.8   | 389.9   | 381.5   | 348.4   | 265.8 | 359.7 | 725.3 | 690.8   |
| 300      | Daly                    | 53,415                  | 783.7                                   | 2,684.1 | 2,482.2 | 919.0   | 552.0   | 333.8   | 202.0   | 122.6   | 74.6    | 45.3  | 27.1  | 16.9  | 686.9   |
| 47       | Thjorsa                 | 7,527                   | 422.1                                   | 33.1    | 91.6    | 1,123.0 | 1,723.6 | 1,322.4 | 662.2   | 584.0   | 668.7   | 840.8 | 478.5 | 288.8 | 686.6   |
| 285      | Rio Jaguaribe           | 72,804                  | 64.1                                    | 11.7    | 1,619.3 | 2,744.3 | 1,562.6 | 861.9   | 515.6   | 319.8   | 213.3   | 142.0 | 92.4  | 60.4  | 683.9   |



|     |                  |         |         |         |         |         |         |         |         |         |         |         |       |         |       |
|-----|------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-------|---------|-------|
| 163 | James            | 23,528  | 1,600.5 | 1,239.3 | 1,248.0 | 954.0   | 670.9   | 429.1   | 258.7   | 169.2   | 122.7   | 160.2   | 381.4 | 857.5   | 674.3 |
| 159 | Mogami           | 6,853   | 969.3   | 827.6   | 1,039.4 | 774.9   | 556.2   | 376.7   | 392.9   | 356.7   | 430.5   | 519.9   | 740.8 | 1,023.9 | 667.4 |
| 239 | Oueme            | 59,843  | 458.8   | 1.0     | 1.1     | 6.9     | 240.8   | 976.7   | 1,265.1 | 1,320.9 | 1,893.3 | 1,037.9 | 499.0 | 301.2   | 666.9 |
| 164 | Bravo            | 510,056 | 263.4   | 84.8    | 204.6   | 657.0   | 1,336.3 | 937.5   | 913.3   | 1,079.5 | 1,202.6 | 640.0   | 304.7 | 204.1   | 652.3 |
| 185 | Brazos           | 117,853 | 747.2   | 874.4   | 717.7   | 986.3   | 929.9   | 587.4   | 962.4   | 828.0   | 508.3   | 179.4   | 80.2  | 367.2   | 647.4 |
| 65  | Dramseiv         | 17,364  | 259.8   | 0.5     | 97.0    | 1,233.4 | 1,458.1 | 1,401.1 | 734.0   | 665.9   | 720.2   | 633.0   | 304.9 | 170.5   | 639.9 |
| 296 | Rio Paraguacu    | 54,607  | 274.1   | 185.7   | 300.7   | 705.2   | 1,494.5 | 1,165.9 | 1,466.7 | 878.0   | 455.0   | 267.7   | 194.3 | 163.9   | 629.3 |
| 191 | Sabine           | 25,612  | 1,109.9 | 1,334.8 | 1,286.5 | 1,307.3 | 936.9   | 456.1   | 276.7   | 165.9   | 101.9   | 62.1    | 86.8  | 295.2   | 618.3 |
| 372 | Messalo          | 24,811  | 941.3   | 1,818.6 | 2,197.0 | 1,098.8 | 548.0   | 330.8   | 199.8   | 120.7   | 72.9    | 44.1    | 26.6  | 16.1    | 617.9 |
| 233 | Geba             | 12,774  | 537.0   | 3.5     | 4.3     | 4.3     | 3.5     | 79.2    | 413.4   | 1,814.0 | 2,305.1 | 1,207.1 | 582.6 | 353.4   | 608.9 |
| 60  | Kokemaenjoki     | 26,616  | 236.7   | 1.6     | 1.5     | 3,662.2 | 1,092.9 | 616.1   | 371.5   | 225.5   | 147.2   | 152.9   | 501.9 | 154.8   | 597.1 |
| 68  | Seal             | 53,440  | 126.4   | 1.6     | 1.0     | 0.6     | 3,534.7 | 1,434.9 | 728.5   | 432.3   | 415.7   | 241.7   | 130.6 | 78.9    | 593.9 |
| 318 | Buzi             | 27,905  | 1,304.7 | 1,917.2 | 1,888.8 | 752.6   | 437.8   | 265.0   | 160.8   | 98.8    | 61.6    | 38.5    | 22.6  | 110.9   | 588.3 |
| 236 | Comoe            | 78,507  | 447.9   | 3.4     | 4.6     | 105.1   | 306.0   | 923.2   | 676.9   | 1,018.0 | 1,509.8 | 1,021.9 | 540.3 | 296.4   | 571.1 |
| 179 | Sebou            | 36,201  | 1,058.8 | 1,081.1 | 1,248.4 | 934.9   | 533.2   | 346.0   | 284.6   | 201.0   | 141.9   | 76.4    | 197.1 | 563.6   | 555.6 |
| 49  | Oelfusa          | 5,678   | 378.5   | 0.0     | 323.1   | 1,726.6 | 690.3   | 685.2   | 565.6   | 398.0   | 471.2   | 658.7   | 434.6 | 320.1   | 554.3 |
| 157 | Guadiana         | 66,020  | 246.7   | 715.8   | 1,619.0 | 1,022.7 | 571.6   | 571.0   | 703.0   | 614.9   | 301.8   | 105.4   | 30.3  | 15.9    | 543.2 |
| 275 | Nyanga           | 12,369  | 1,159.8 | 691.5   | 941.1   | 1,044.4 | 523.6   | 267.4   | 161.5   | 97.5    | 58.9    | 35.6    | 692.8 | 805.1   | 539.9 |
| 10  | Colville         | 57,545  | 185.8   | 1.4     | 0.8     | 0.5     | 45.5    | 1,938.0 | 1,977.6 | 1,034.6 | 579.1   | 324.5   | 196.0 | 118.4   | 533.5 |
| 325 | Fitzroy          | 142,915 | 72.4    | 1,909.6 | 2,134.9 | 885.3   | 493.9   | 300.8   | 192.9   | 132.5   | 101.8   | 79.8    | 54.4  | 35.2    | 532.8 |
| 250 | Pra              | 23,480  | 378.6   | 3.2     | 102.6   | 282.2   | 657.8   | 1,316.6 | 691.0   | 327.9   | 645.8   | 1,039.5 | 483.0 | 247.6   | 514.6 |
| 141 | Rogue            | 14,527  | 1,090.2 | 1,088.4 | 909.0   | 858.5   | 622.6   | 302.4   | 190.5   | 120.0   | 73.0    | 41.5    | 212.2 | 514.3   | 501.9 |
| 403 | Daryacheh-Ye     | 30,336  | 156.1   | 103.1   | 506.3   | 1,527.4 | 1,539.9 | 737.8   | 467.8   | 347.1   | 213.8   | 126.4   | 137.4 | 116.8   | 498.3 |
|     | Orumieh          |         |         |         |         |         |         |         |         |         |         |         |       |         |       |
| 20  | Noatak           | 32,320  | 156.5   | 0.8     | 0.5     | 0.3     | 401.9   | 1,980.3 | 1,099.7 | 624.3   | 629.7   | 275.6   | 166.5 | 100.6   | 453.1 |
| 247 | Tano             | 15,656  | 321.4   | 0.2     | 32.5    | 186.6   | 547.1   | 1,356.6 | 700.0   | 337.1   | 480.9   | 810.9   | 421.8 | 218.4   | 451.1 |
| 154 | Eel (California) | 7,450   | 1,366.1 | 1,258.1 | 927.1   | 540.6   | 304.0   | 173.7   | 105.4   | 63.9    | 38.7    | 23.2    | 15.6  | 579.5   | 449.6 |
| 15  | Muonio           | 37,347  | 143.9   | 13.1    | 8.0     | 213.9   | 2,005.5 | 1,110.4 | 750.1   | 388.4   | 294.9   | 187.3   | 101.6 | 61.4    | 439.9 |
| 189 | Trinity (Texas)  | 46,168  | 588.6   | 822.5   | 766.2   | 973.4   | 839.8   | 365.7   | 234.6   | 152.1   | 98.0    | 66.6    | 52.7  | 255.9   | 434.7 |
| 299 | Roper            | 79,908  | 434.9   | 1,537.1 | 1,682.2 | 599.2   | 358.4   | 216.7   | 131.2   | 79.7    | 48.5    | 29.6    | 17.7  | 10.5    | 428.8 |
| 28  | Kobuk            | 30,242  | 211.1   | 31.8    | 19.2    | 11.6    | 2,063.7 | 1,100.6 | 619.7   | 373.5   | 338.6   | 159.6   | 96.4  | 58.2    | 423.7 |

*continues*

**DATA TABLE 7** *continued*

| Basin ID | Basin Name                  | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |         |         |         |         |         |         |         |       |       |         | Average |
|----------|-----------------------------|-------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|-------|-------|---------|---------|
|          |                             |                         | Jan                                     | Feb     | Mar     | Apr     | May     | Jun     | Jul     | Aug     | Sep     | Oct   | Nov   | Dec     |         |
| 153      | Sakarya                     | 62,483                  | 348.5                                   | 1,016.9 | 1,126.0 | 888.3   | 508.1   | 345.2   | 273.7   | 242.4   | 156.9   | 68.9  | 26.5  | 75.1    | 423.0   |
| 330      | Incomati                    | 46,296                  | 1,039.9                                 | 1,118.5 | 1,027.4 | 517.1   | 276.9   | 173.5   | 113.5   | 83.8    | 67.7    | 43.3  | 129.4 | 456.6   | 420.6   |
| 391      | Escaut<br>(Schelde)         | 21,499                  | 1,351.5                                 | 705.9   | 604.0   | 472.4   | 284.9   | 168.8   | 111.6   | 79.8    | 54.8    | 63.7  | 373.3 | 746.1   | 418.1   |
| 9        | Tana (NO, FI)               | 14,518                  | 71.8                                    | 0.0     | 0.0     | 0.0     | 2,851.4 | 778.3   | 457.0   | 276.1   | 217.4   | 149.0 | 77.9  | 47.1    | 410.5   |
| 144      | Luan He                     | 71,071                  | 174.3                                   | 47.2    | 147.9   | 279.9   | 408.1   | 214.3   | 964.0   | 1,219.0 | 725.2   | 357.8 | 190.0 | 115.8   | 403.6   |
| 188      | Colorado<br>(Caribbean Sea) | 110,640                 | 466.3                                   | 688.6   | 553.1   | 621.2   | 522.3   | 343.0   | 497.7   | 455.0   | 315.6   | 115.8 | 35.9  | 228.7   | 403.6   |
| 223      | Verde                       | 18,343                  | 378.7                                   | 2.9     | 6.5     | 6.9     | 4.5     | 10.1    | 365.4   | 850.4   | 1,648.0 | 893.8 | 414.1 | 250.8   | 402.7   |
| 175      | Santee                      | 40,035                  | 804.8                                   | 794.4   | 752.0   | 496.5   | 298.4   | 193.4   | 174.2   | 169.8   | 140.6   | 124.1 | 150.6 | 395.6   | 374.5   |
| 12       | Anderson                    | 66,492                  | 54.7                                    | 0.4     | 0.2     | 0.1     | 2,548.6 | 797.3   | 434.9   | 262.7   | 158.7   | 95.8  | 57.9  | 35.0    | 370.5   |
| 104      | Attawapiskat                | 30,457                  | 121.7                                   | 0.0     | 0.0     | 0.0     | 2,195.5 | 613.1   | 355.5   | 214.7   | 350.3   | 329.0 | 132.1 | 79.8    | 366.0   |
| 401      | Great Salt Lake             | 74,114                  | 65.3                                    | 237.4   | 354.3   | 782.1   | 915.8   | 634.2   | 481.7   | 350.5   | 213.3   | 121.5 | 68.5  | 66.7    | 357.6   |
| 17       | Palyavaam                   | 31,113                  | 106.3                                   | 0.0     | 0.0     | 0.0     | 0.0     | 1,878.7 | 1,036.4 | 526.4   | 355.2   | 191.1 | 115.4 | 69.7    | 356.6   |
| 404      | Van Gollu                   | 17,737                  | 117.9                                   | 0.6     | 127.0   | 1,118.2 | 1,378.3 | 489.2   | 294.9   | 184.2   | 112.7   | 115.2 | 230.6 | 77.6    | 353.9   |
| 121      | Southern Bug                | 60,121                  | 38.8                                    | 7.9     | 1,840.9 | 967.0   | 519.4   | 311.3   | 205.6   | 138.9   | 77.0    | 43.3  | 27.5  | 18.1    | 349.6   |
| 307      | Majes                       | 18,612                  | 893.9                                   | 994.8   | 875.9   | 436.0   | 232.5   | 139.9   | 84.7    | 52.7    | 34.4    | 31.7  | 29.3  | 363.0   | 347.4   |
| 381      | Lorentz                     | 4,299                   | 493.1                                   | 445.0   | 515.7   | 475.1   | 346.5   | 253.8   | 280.8   | 253.8   | 345.8   | 199.3 | 277.0 | 262.3   | 345.7   |
| 313      | Mucuri                      | 16,732                  | 1,331.8                                 | 412.5   | 315.0   | 254.2   | 167.2   | 113.9   | 88.6    | 50.0    | 28.9    | 21.6  | 212.3 | 1,046.2 | 336.8   |
| 196      | St. Johns                   | 22,489                  | 379.1                                   | 187.4   | 226.0   | 126.3   | 72.7    | 67.3    | 331.1   | 475.2   | 796.6   | 731.2 | 335.3 | 225.9   | 329.5   |
| 376      | Popigay                     | 48,954                  | 84.9                                    | 0.8     | 0.5     | 0.3     | 0.2     | 2,052.3 | 754.1   | 410.5   | 251.2   | 146.9 | 88.7  | 53.6    | 320.3   |
| 40       | Iijoki                      | 16,163                  | 94.2                                    | 0.1     | 0.1     | 1,326.2 | 997.0   | 396.0   | 232.9   | 151.1   | 155.9   | 299.9 | 102.3 | 61.8    | 318.1   |
| 335      | Tugela                      | 30,079                  | 758.7                                   | 786.8   | 752.8   | 372.3   | 204.5   | 126.4   | 86.3    | 74.3    | 66.9    | 64.9  | 86.0  | 376.1   | 313.0   |
| 312      | Gilbert                     | 46,429                  | 183.1                                   | 1,374.9 | 1,126.1 | 428.1   | 256.1   | 154.7   | 93.5    | 56.5    | 34.2    | 20.8  | 12.5  | 7.6     | 312.4   |
| 333      | Maputo                      | 30,938                  | 924.9                                   | 719.0   | 618.4   | 324.5   | 179.7   | 114.6   | 75.2    | 58.1    | 46.2    | 33.2  | 112.3 | 467.1   | 306.1   |
| 298      | Rio De Contas               | 56,526                  | 297.0                                   | 120.1   | 258.0   | 556.9   | 550.1   | 447.9   | 457.9   | 292.5   | 179.2   | 110.9 | 165.1 | 224.8   | 305.0   |

|     |              |         |       |       |         |         |         |         |       |       |       |       |         |       |       |
|-----|--------------|---------|-------|-------|---------|---------|---------|---------|-------|-------|-------|-------|---------|-------|-------|
| 395 | Lake Mar     | 154,330 | 490.2 | 594.7 | 1,026.2 | 504.2   | 261.0   | 162.6   | 112.7 | 87.1  | 80.9  | 85.5  | 95.2    | 137.7 | 303.2 |
|     | Chiquita     |         |       |       |         |         |         |         |       |       |       |       |         |       |       |
| 62  | Thlewiaza    | 64,400  | 91.9  | 10.3  | 6.2     | 3.7     | 1,834.1 | 666.0   | 339.5 | 204.2 | 198.6 | 94.1  | 56.8    | 34.3  | 295.0 |
| 33  | Ponoy        | 13,186  | 127.2 | 0.0   | 0.0     | 0.0     | 1,585.1 | 438.1   | 255.8 | 178.3 | 268.5 | 394.1 | 138.1   | 83.4  | 289.1 |
| 11  | Alazeya      | 85,493  | 184.1 | 31.2  | 18.9    | 11.4    | 6.9     | 1,896.8 | 555.0 | 314.2 | 189.8 | 114.6 | 69.2    | 41.8  | 286.2 |
| 182 | Gono (Go)    | 3,949   | 457.3 | 244.7 | 265.1   | 275.8   | 218.2   | 354.0   | 370.2 | 191.3 | 273.3 | 275.9 | 229.3   | 269.2 | 285.4 |
| 44  | Lagarfjot    | 3,285   | 112.9 | 0.0   | 0.0     | 22.3    | 1,190.7 | 742.9   | 324.1 | 231.6 | 257.6 | 309.8 | 128.1   | 74.0  | 282.9 |
| 130 | St. Croix    | 4,639   | 170.5 | 0.1   | 0.1     | 1,441.8 | 475.5   | 301.5   | 171.5 | 101.8 | 88.6  | 166.9 | 352.7   | 111.8 | 281.9 |
| 24  | Kalixaehven  | 17,158  | 78.3  | 6.6   | 4.0     | 388.6   | 1,237.8 | 757.3   | 351.5 | 203.1 | 137.7 | 118.6 | 57.6    | 34.8  | 281.3 |
| 278 | Rio Acarau   | 14,473  | 22.3  | 31.8  | 810.4   | 1,076.9 | 646.7   | 301.3   | 179.6 | 110.0 | 67.9  | 42.1  | 26.2    | 16.4  | 277.6 |
| 304 | Rio Prado    | 31,674  | 696.0 | 283.3 | 357.3   | 417.6   | 243.4   | 187.0   | 168.8 | 106.4 | 58.7  | 36.6  | 137.5   | 549.1 | 270.1 |
| 14  | Tuloma       | 26,058  | 94.6  | 11.6  | 7.1     | 4.4     | 1,732.1 | 547.3   | 300.0 | 180.4 | 119.2 | 121.3 | 55.2    | 33.5  | 267.2 |
| 200 | Fuerte       | 36,420  | 340.7 | 90.6  | 48.7    | 39.8    | 35.5    | 39.1    | 166.0 | 764.0 | 806.9 | 406.5 | 207.8   | 249.3 | 266.2 |
| 397 | Dead Sea     | 35,444  | 605.0 | 681.7 | 454.0   | 289.3   | 257.0   | 203.5   | 196.8 | 168.4 | 96.6  | 58.6  | 31.9    | 117.9 | 263.4 |
| 226 | Penner       | 54,976  | 568.7 | 34.4  | 52.1    | 45.1    | 43.8    | 41.5    | 158.5 | 151.2 | 182.9 | 360.5 | 1,017.5 | 485.3 | 261.8 |
| 287 | Ruvu         | 17,541  | 121.7 | 122.6 | 361.9   | 952.4   | 722.0   | 287.6   | 174.0 | 106.2 | 64.9  | 39.6  | 23.9    | 73.4  | 254.2 |
| 269 | Tana         | 95,715  | 290.5 | 14.7  | 38.9    | 512.9   | 706.1   | 333.2   | 183.6 | 113.4 | 69.9  | 103.6 | 260.5   | 305.1 | 244.4 |
| 292 | Santa        | 11,883  | 455.4 | 563.1 | 650.9   | 399.4   | 210.8   | 125.2   | 78.5  | 57.1  | 44.0  | 79.5  | 128.6   | 132.8 | 243.8 |
| 203 | San Pedro    | 29,359  | 192.9 | 2.6   | 4.4     | 6.2     | 7.1     | 3.4     | 137.0 | 732.2 | 987.8 | 369.0 | 206.3   | 130.3 | 231.6 |
| 113 | Thames       | 12,359  | 726.2 | 447.7 | 361.1   | 237.6   | 136.9   | 78.4    | 49.7  | 32.4  | 21.8  | 18.4  | 131.8   | 395.2 | 219.8 |
| 102 | Trent        | 9,053   | 691.4 | 368.2 | 303.2   | 213.3   | 137.6   | 80.5    | 56.5  | 51.0  | 49.0  | 67.1  | 198.0   | 402.5 | 218.2 |
| 374 | Galana       | 51,922  | 187.2 | 7.8   | 34.8    | 597.5   | 654.3   | 327.5   | 177.5 | 104.7 | 64.5  | 40.0  | 203.0   | 196.1 | 216.2 |
| 365 | Ocona        | 16,064  | 539.4 | 582.1 | 517.1   | 245.1   | 134.9   | 80.9    | 48.8  | 30.6  | 19.9  | 49.2  | 71.2    | 235.0 | 212.9 |
| 348 | South Esk    | 10,843  | 186.5 | 8.9   | 10.5    | 32.6    | 76.3    | 208.6   | 392.9 | 471.5 | 403.2 | 358.1 | 217.0   | 135.7 | 208.5 |
| 91  | Tweed        | 4,771   | 575.8 | 239.8 | 225.1   | 158.2   | 110.7   | 72.3    | 54.4  | 61.3  | 91.1  | 172.0 | 311.6   | 366.0 | 203.2 |
| 41  | Joekulsa A   | 7,311   | 75.0  | 0.0   | 0.0     | 5.7     | 754.0   | 592.9   | 236.8 | 148.0 | 147.0 | 221.4 | 82.3    | 49.2  | 192.7 |
|     | Fjoellum     |         |       |       |         |         |         |         |       |       |       |       |         |       |       |
| 242 | Mono         | 23,899  | 122.1 | 0.3   | 14.5    | 50.7    | 126.1   | 330.7   | 356.9 | 319.3 | 472.0 | 289.3 | 132.5   | 80.1  | 191.2 |
| 400 | Lake Vartern | 11,337  | 109.1 | 0.5   | 645.9   | 535.8   | 246.0   | 136.0   | 81.3  | 60.0  | 40.2  | 82.5  | 196.1   | 85.7  | 184.9 |
| 38  | Quoich       | 28,218  | 41.6  | -     | -       | -       | -       | 1,216.3 | 349.6 | 199.5 | 128.2 | 74.8  | 45.2    | 27.3  | 173.5 |
| 79  | Spey         | 2,942   | 478.1 | 203.5 | 174.9   | 136.5   | 98.8    | 58.1    | 43.8  | 52.5  | 81.3  | 157.4 | 246.1   | 292.1 | 168.6 |

*continues*

**DATA TABLE 7** *continued*

| Basin ID | Basin Name                 | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |       |       |       |       |         |       |       |       |       |       |       | Average |
|----------|----------------------------|-------------------------|---|-------|-------|-------|-------|---------|-------|-------|-------|-------|-------|-------|---------|
|          |                            |                         | Jan                                     | Feb   | Mar   | Apr   | May   | Jun     | Jul   | Aug   | Sep   | Oct   | Nov   | Dec   |         |
| 251      | Davo                       | 8,460                   | 133.7                                   | 0.2   | 0.2   | 2.0   | 9.6   | 542.8   | 283.0 | 126.7 | 238.1 | 288.6 | 192.8 | 89.5  | 158.9   |
| 57       | Ferguson                   | 15,200                  | 40.3                                    | 0.0   | 0.0   | 0.0   | 0.0   | 1,053.5 | 296.1 | 171.1 | 142.1 | 72.5  | 43.8  | 26.4  | 153.8   |
| 295      | Rio Itapicuru              | 37,593                  | 56.5                                    | 2.3   | 2.1   | 7.2   | 99.2  | 263.0   | 645.3 | 362.8 | 169.7 | 102.3 | 62.2  | 38.4  | 150.9   |
| 288      | Rio Paraiba                | 18,969                  | 37.7                                    | 2.0   | 3.5   | 89.5  | 253.8 | 514.2   | 396.9 | 208.3 | 115.4 | 73.2  | 46.6  | 29.6  | 147.6   |
| 29       | Coppermine                 | 43,016                  | 28.9                                    | 0.1   | 0.1   | 0.0   | 390.0 | 714.8   | 246.4 | 139.9 | 84.5  | 51.0  | 30.8  | 18.6  | 142.1   |
| 34       | Kovda                      | 10,228                  | 30.6                                    | 0.0   | 0.0   | 0.0   | 881.9 | 280.3   | 152.3 | 92.5  | 71.2  | 78.0  | 33.2  | 20.1  | 136.7   |
| 26       | Elice                      | 12,600                  | 30.5                                    | -     | -     | -     | -     | 958.3   | 248.8 | 150.3 | 90.8  | 54.8  | 33.1  | 20.0  | 132.2   |
| 42       | Svarta,                    | 3,430                   | 54.9                                    | 0.0   | 29.3  | 123.6 | 363.8 | 392.6   | 148.0 | 89.0  | 76.1  | 152.2 | 68.9  | 36.0  | 127.9   |
|          | Skagafiroi                 |                         |   |       |       |       |       |         |       |       |       |       |       |       |         |
| 86       | Skjern A                   | 2,818                   | 351.5                                   | 132.9 | 121.1 | 89.0  | 50.8  | 28.9    | 18.4  | 22.4  | 70.4  | 165.2 | 192.5 | 228.6 | 122.6   |
| 283      | Chira                      | 16,700                  | 76.0                                    | 208.7 | 379.5 | 341.5 | 138.2 | 86.6    | 62.2  | 51.9  | 37.8  | 21.8  | 23.1  | 17.1  | 120.4   |
| 32       | Varzuga                    | 8,182                   | 47.2                                    | 0.0   | 0.0   | 0.0   | 683.9 | 188.7   | 110.1 | 66.6  | 112.4 | 140.1 | 51.2  | 30.9  | 119.3   |
| 172      | Chelif                     | 45,249                  | 234.5                                   | 283.5 | 281.9 | 175.3 | 103.2 | 88.2    | 81.1  | 66.7  | 44.4  | 17.2  | 8.8   | 39.5  | 118.7   |
| 279      | Pangani                    | 50,365                  | 34.7                                    | 22.7  | 34.9  | 203.1 | 493.3 | 239.9   | 152.6 | 87.1  | 59.8  | 38.7  | 28.7  | 27.5  | 118.6   |
| 30       | Hayes (Trib. Arctic Ocean) | 22,993                  | 27.0                                    | -     | -     | -     | -     | 834.5   | 225.2 | 133.1 | 80.4  | 48.5  | 29.3  | 17.7  | 116.3   |
| 343      | Blackwood                  | 22,585                  | 79.6                                    | 0.6   | 0.7   | 0.4   | 0.1   | 29.9    | 254.5 | 407.6 | 301.6 | 166.9 | 86.8  | 52.5  | 115.1   |
| 311      | Fitzroy                    | 94,044                  | 5.5                                     | 446.6 | 490.3 | 167.3 | 101.0 | 61.0    | 36.9  | 22.3  | 13.5  | 8.1   | 4.9   | 3.0   | 113.4   |
| 297      | Canete                     | 5,755                   | 257.6                                   | 233.3 | 231.1 | 128.4 | 67.0  | 41.2    | 25.4  | 17.5  | 12.9  | 43.0  | 62.3  | 113.9 | 102.8   |
| 146      | Dalinghe                   | 22,823                  | 58.3                                    | 3.2   | 6.3   | 33.3  | 66.4  | 80.0    | 85.0  | 386.7 | 210.1 | 123.7 | 64.5  | 39.6  | 96.4    |
| 8        | Omoloy                     | 38,871                  | 26.9                                    | 0.7   | 0.4   | 0.2   | 0.2   | 426.1   | 277.1 | 128.9 | 73.6  | 43.7  | 26.4  | 15.9  | 85.0    |
| 85       | Gudena                     | 2,861                   | 259.3                                   | 115.5 | 103.3 | 77.1  | 41.9  | 24.7    | 16.2  | 10.7  | 14.8  | 58.0  | 124.8 | 157.3 | 83.6    |
| 368      | Doring                     | 48,856                  | 44.0                                    | 20.3  | 25.5  | 14.8  | 4.2   | 92.2    | 148.6 | 176.0 | 136.2 | 105.1 | 61.5  | 43.1  | 72.6    |
| 301      | Drysdale                   | 26,016                  | 26.2                                    | 283.6 | 270.5 | 96.7  | 58.3  | 35.2    | 21.3  | 12.8  | 7.8   | 4.7   | 2.8   | 1.7   | 68.5    |
| 216      | Armeria                    | 9,639                   | 60.6                                    | 8.1   | 17.0  | 28.8  | 27.6  | 10.1    | 3.3   | 40.7  | 292.2 | 147.3 | 71.6  | 48.0  | 62.9    |
| 369      | Gamka                      | 45,676                  | 65.3                                    | 14.4  | 28.8  | 40.5  | 41.1  | 51.1    | 45.0  | 62.9  | 111.5 | 105.9 | 87.0  | 55.8  | 59.1    |

|     |                 |           |       |       |      |      |       |       |       |       |      |      |      |      |      |
|-----|-----------------|-----------|-------|-------|------|------|-------|-------|-------|-------|------|------|------|------|------|
| 359 | Horton          | 23,926    | 12.4  | 0.3   | 0.2  | 0.1  | 78.8  | 314.9 | 93.6  | 54.9  | 33.2 | 20.0 | 12.1 | 7.3  | 52.3 |
| 294 | Rio Vaza-Barris | 15,314    | 17.1  | 1.4   | 1.7  | 1.6  | 61.4  | 151.1 | 177.6 | 102.7 | 49.8 | 30.8 | 18.8 | 11.8 | 52.2 |
| 360 | Hornaday        | 14,778    | 12.4  | 0.0   | 0.0  | 0.0  | 0.0   | 181.3 | 145.7 | 70.2  | 37.1 | 22.3 | 13.5 | 8.1  | 40.9 |
| 193 | Yaqui           | 76,182    | 15.8  | 30.2  | 63.2 | 72.9 | 36.0  | 24.2  | 49.0  | 61.5  | 44.6 | 29.0 | 14.8 | 15.8 | 38.1 |
| 339 | Limari          | 11,780    | 118.1 | 101.5 | 40.8 | 21.1 | 12.6  | 27.9  | 18.7  | 17.6  | 14.6 | 15.5 | 11.4 | 31.8 | 36.0 |
| 170 | Salinas         | 12,655    | 11.8  | 34.5  | 58.5 | 36.9 | 32.6  | 47.2  | 66.4  | 68.2  | 42.9 | 9.6  | 2.7  | 1.6  | 34.4 |
| 405 | Ozero Sevan     | 4,765     | 8.6   | 0.7   | 3.8  | 76.9 | 106.9 | 55.9  | 31.2  | 21.0  | 12.9 | 13.1 | 13.9 | 5.9  | 29.2 |
| 197 | Nueces          | 43,878    | 4.2   | 8.4   | 21.4 | 28.3 | 35.8  | 41.5  | 66.6  | 49.3  | 24.4 | 10.5 | 5.4  | 3.8  | 25.0 |
| 341 | Groot-Vis       | 30,441    | 10.7  | 24.1  | 23.0 | 13.9 | 11.7  | 9.5   | 9.9   | 13.2  | 21.7 | 27.3 | 18.9 | 18.9 | 16.9 |
| 338 | Huasco          | 9,872     | 92.1  | 16.5  | 10.1 | 6.1  | 3.7   | 2.4   | 1.6   | 1.4   | 1.6  | 1.5  | 0.6  | 46.0 | 15.3 |
| 198 | San Antonio     | 10,952    | 12.3  | 13.2  | 14.4 | 23.4 | 25.7  | 19.4  | 25.1  | 18.3  | 9.9  | 5.7  | 4.2  | 8.8  | 15.0 |
| 389 | Flinders        | 110,041   | 0.4   | 89.8  | 28.2 | 15.5 | 9.4   | 5.7   | 3.5   | 2.2   | 1.4  | 0.9  | 0.6  | 0.4  | 13.2 |
| 390 | Leichhardt      | 33,399    | 31.9  | 34.8  | 11.9 | 7.2  | 4.4   | 2.6   | 1.6   | 1.0   | 0.6  | 0.4  | 0.2  | 0.1  | 8.1  |
| 310 | Macarthur       | 19,674    | 0.4   | 1.1   | 55.6 | 14.5 | 8.8   | 5.3   | 3.2   | 1.9   | 1.2  | 0.7  | 0.4  | 0.3  | 7.8  |
| 370 | Groot-Kei       | 18,678    | 2.7   | 6.5   | 16.9 | 12.9 | 8.5   | 5.9   | 5.6   | 6.2   | 7.9  | 8.3  | 6.0  | 4.4  | 7.6  |
| 308 | Ord             | 55,686    | 0.0   | 3.9   | 1.5  | 2.7  | 4.2   | 5.2   | 6.4   | 7.5   | 8.1  | 6.6  | 3.6  | 0.2  | 4.2  |
| 305 | Victoria        | 78,462    | 0.1   | 20.4  | 14.0 | 5.5  | 3.3   | 2.0   | 1.2   | 0.7   | 0.4  | 0.3  | 0.2  | 0.1  | 4.0  |
| 361 | Conception      | 25,569    | 0.6   | 1.8   | 3.6  | 4.8  | 3.8   | 4.7   | 4.3   | 5.9   | 5.5  | 4.2  | 1.5  | 1.1  | 3.5  |
| 394 | Eyre Lake       | 1,188,841 | 0.2   | 0.3   | 0.6  | 0.5  | 0.5   | 0.4   | 0.4   | 0.6   | 0.7  | 0.7  | 0.5  | 0.4  | 0.5  |
| 303 | Durack          | 29,363    | 0.0   | 1.9   | 1.6  | 0.6  | 0.4   | 0.2   | 0.1   | 0.1   | 0.1  | 0.0  | 0.0  | 0.0  | 0.4  |
| 319 | Loa             | 50,206    | 0.3   | 0.4   | 0.3  | 0.3  | 0.3   | 0.3   | 0.3   | 0.3   | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  |

# Monthly Natural Runoff for the World's Major River Basins, by Basin Name

## Description

These data are the same as those in data table 7 but sorted by river basin name. The data come from work done by Arjen Hoekstra and Mesfin Mekonnen (2011) to evaluate the regional, national, and global water footprint of human activity. As part of that effort, “natural runoff” was estimated for around 400 river basins, covering some two-thirds of the global land area (excluding Antarctica) and about 65 percent of the global population in 2000. Units for runoff are million cubic meters per month. Data are also provided for the area of the river basin or watershed, in square kilometers.

The natural (undepleted) runoff was estimated by adding the actual runoff data from the Composite Runoff V1.0 database (of Fekete et al. 2002) to the estimated total blue water footprint within the river basin. Because runoff varies naturally over time, these are average estimates. River basin names come from the Global Runoff Data Centre database (GRDC 2007). Note the substantial extremes: just two rivers, the Amazon and Congo Rivers, account for 28 percent of the natural runoff in the river basins listed here.

## Limitations

These data are a combination of measured and estimated or modeled flows. Accurate long-term measurements of river flow are not available for a variety of reasons, including the lack of monitoring stations, the complication of estimating undepleted flows in basins where human withdrawals greatly reduce natural flows, and natural variability of high and low runoff over time. These estimates should be considered only approximate averages, but they provide estimates using a consistent method described in the original sources.

The land areas not covered include Greenland; the Sahara Desert in North Africa; the Arabian Peninsula; the Iranian, Afghan, and Gobi Deserts in Asia; the Mojave Desert in North America; and the Australian desert. Also excluded are many smaller pieces of land, often along the coasts, that do not fall within major river basins.

## Sources

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- Global Runoff Data Centre (GRDC). 2007. Major River Basins of the World. Koblenz, Germany: Federal Institute of Hydrology, Global Runoff Data Centre. Data available at <http://grdc.bafg.de/>.
- Hoekstra, A. Y., and M. M. Mekonnen. 2011. Global Water Scarcity: Monthly Blue Water Footprint Compared to Blue Water Availability for the World's Major River Basins. Value of Water Research Report Series No. 53. Delft, Netherlands: UNESCO-IHE Institute for Water Education. <http://www.waterfootprint.org/Reports/Report53-GlobalBlueWaterScarcity.pdf>.



**DATA TABLE 8** Monthly Natural Runoff for the World's Major River Basins, by Basin Name

| Basin ID | Basin Name                          | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |           |           |           |           |           |           |           |           |           |           |           | Average   |
|----------|-------------------------------------|-------------------------|---|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|          |                                     |                         | Jan                                     | Feb       | Mar       | Apr       | May       | Jun       | Jul       | Aug       | Sep       | Oct       | Nov       | Dec       |           |
| 180      | Alabama River<br>and Tombigbee      | 113,117.4               | 9,397.8                                 | 10,770.1  | 12,232.8  | 8,612.8   | 4,829.3   | 2,684.6   | 1,677.7   | 1,055.0   | 671.1     | 421.7     | 465.0     | 3,348.5   | 4,680.5   |
| 11       | Alazeya                             | 85,493.3                | 184.1                                   | 31.2      | 18.9      | 11.4      | 6.9       | 1,896.8   | 555.0     | 314.2     | 189.8     | 114.6     | 69.2      | 41.8      | 286.2     |
| 111      | Albany                              | 123,081.0               | 813.0                                   | 0.1       | 0.1       | 8,411.8   | 9,204.2   | 3,827.2   | 2,148.3   | 1,306.1   | 1,776.4   | 2,432.0   | 882.5     | 533.1     | 2,611.2   |
| 63       | Aisek                               | 28,422.0                | 286.1                                   | 0.0       | 0.0       | 584.4     | 2,611.7   | 2,770.9   | 1,100.4   | 738.6     | 961.8     | 680.0     | 310.6     | 187.6     | 852.7     |
| 186      | Altamaha                            | 37,117.5                | 1,328.3                                 | 2,248.8   | 2,575.1   | 1,555.3   | 829.5     | 474.6     | 313.9     | 232.8     | 182.4     | 112.6     | 72.0      | 424.7     | 862.5     |
| 259      | Amazonas                            | 5,880,854.9             | 950,375.6                               | 705,085.8 | 813,922.6 | 857,876.6 | 713,184.6 | 564,388.1 | 424,106.1 | 299,107.1 | 238,076.7 | 243,680.0 | 298,076.1 | 455,711.2 | 546,965.9 |
| 90       | Amur                                | 2,023,520.4             | 13,098.2                                | 58.9      | 59.3      | 41,918.1  | 57,294.3  | 53,865.4  | 45,446.7  | 49,807.8  | 50,357.7  | 28,455.4  | 14,176.3  | 8,572.4   | 30,259.2  |
| 3        | Anabar                              | 85,015.5                | 525.8                                   | 85.3      | 51.5      | 31.1      | 18.8      | 4,128.1   | 2,082.3   | 1,011.7   | 602.5     | 354.9     | 214.4     | 129.5     | 769.6     |
| 21       | Anadyr                              | 171,275.8               | 1,182.1                                 | 1.3       | 0.8       | 0.5       | 2,452.2   | 21,998.7  | 10,380.5  | 5,461.5   | 4,105.7   | 2,116.1   | 1,278.1   | 771.9     | 4,145.8   |
| 12       | Anderson                            | 66,491.7                | 54.7                                    | 0.4       | 0.2       | 0.1       | 2,548.6   | 797.3     | 434.9     | 262.7     | 158.7     | 95.8      | 57.9      | 35.0      | 370.5     |
| 46       | Angerman                            | 32,372.0                | 343.5                                   | 0.5       | 0.4       | 4,027.0   | 3,524.6   | 2,685.5   | 1,232.5   | 833.4     | 764.3     | 954.8     | 371.0     | 224.1     | 1,246.8   |
| 184      | Apalachicola                        | 51,412.9                | 2,889.5                                 | 3,847.6   | 4,385.4   | 3,016.0   | 1,572.5   | 912.7     | 651.6     | 531.5     | 402.8     | 235.8     | 202.2     | 1,034.8   | 1,640.2   |
| 124      | Aral Drainage                       | 1,233,148.5             | 2,546.9                                 | 4,161.6   | 13,784.1  | 20,140.9  | 23,937.1  | 21,375.9  | 17,965.9  | 12,930.4  | 8,104.3   | 3,850.2   | 1,674.4   | 1,541.5   | 11,001.1  |
| 216      | Armeria                             | 9,639.1                 | 60.6                                    | 8.1       | 17.0      | 28.8      | 27.6      | 10.1      | 3.3       | 40.7      | 292.2     | 147.3     | 71.6      | 48.0      | 62.9      |
| 66       | Arnaud                              | 44,931.9                | 564.3                                   | -         | -         | -         | 632.5     | 5,641.8   | 2,064.4   | 1,543.3   | 1,878.6   | 1,362.9   | 612.6     | 370.0     | 1,222.5   |
| 244      | Atrato                              | 34,619.5                | 8,908.3                                 | 2,297.1   | 2,736.4   | 4,317.7   | 5,624.4   | 5,876.9   | 5,976.7   | 6,096.9   | 6,689.5   | 7,140.9   | 7,032.0   | 5,537.1   | 5,686.2   |
| 104      | Attawapiskat                        | 30,457.4                | 121.7                                   | 0.0       | 0.0       | 0.0       | 2,195.5   | 613.1     | 355.5     | 214.7     | 350.3     | 329.0     | 132.1     | 79.8      | 366.0     |
| 77       | Aux Melezes                         | 41,384.1                | 637.5                                   | 0.1       | 0.1       | 0.0       | 5,433.5   | 3,250.9   | 1,841.6   | 1,727.2   | 1,787.2   | 1,696.1   | 691.6     | 417.7     | 1,457.0   |
| 35       | Back                                | 141,351.9               | 327.2                                   | 0.0       | 0.0       | 0.0       | 5,571.3   | 8,215.3   | 2,637.8   | 1,590.9   | 990.4     | 588.0     | 355.2     | 214.5     | 1,707.6   |
| 351      | Baker                               | 30,760.3                | 1,928.9                                 | 630.2     | 1,099.0   | 1,638.6   | 2,259.5   | 2,536.2   | 2,753.8   | 2,648.6   | 2,149.0   | 1,882.5   | 1,579.4   | 1,282.9   | 1,865.7   |
| 78       | Baleine,<br>Grande Rivière<br>De La | 22,136.1                | 379.8                                   | -         | -         | -         | 4,270.1   | 1,505.8   | 1,122.0   | 983.1     | 1,130.8   | 994.3     | 412.3     | 249.0     | 920.6     |
| 393      | Balkhash                            | 423,657.4               | 273.5                                   | 5.8       | 2,199.0   | 4,046.6   | 4,089.9   | 2,907.0   | 2,102.5   | 1,368.5   | 905.0     | 412.3     | 445.2     | 181.7     | 1,578.1   |
| 238      | Bandama                             | 98,751.1                | 1,337.1                                 | 4.0       | 5.7       | 118.4     | 306.8     | 1,520.8   | 1,055.3   | 2,949.0   | 5,574.4   | 3,186.6   | 1,473.0   | 881.5     | 1,534.4   |

|     |                      |           |          |         |         |          |          |           |           |           |           |          |          |          |          |
|-----|----------------------|-----------|----------|---------|---------|----------|----------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|
| 388 | Batang Hari          | 42,872.4  | 10,918.4 | 4,536.0 | 5,450.1 | 6,252.7  | 4,790.1  | 2,820.9   | 1,767.2   | 1,540.6   | 2,438.0   | 4,411.4  | 6,272.8  | 7,176.5  | 4,864.6  |
| 387 | Batang Kuantan       | 16,739.0  | 3,820.3  | 1,460.7 | 1,731.9 | 2,316.9  | 1,825.4  | 1,075.7   | 640.6     | 525.6     | 838.5     | 1,724.9  | 2,579.6  | 2,602.7  | 1,761.9  |
| 202 | Bei Jiang            | 52,915.4  | 629.5    | 353.9   | 1,921.9 | 4,546.4  | 6,874.5  | 7,013.0   | 3,830.8   | 3,230.7   | 2,159.0   | 1,100.4  | 668.5    | 413.5    | 2,728.5  |
| 346 | Biobio               | 24,108.6  | 1,512.9  | 29.1    | 298.7   | 919.1    | 3,736.5  | 4,786.4   | 5,042.5   | 4,670.4   | 4,131.1   | 2,973.2  | 1,809.7  | 1,045.2  | 2,579.6  |
| 343 | Blackwood            | 22,584.8  | 79.6     | 0.6     | 0.7     | 0.4      | 0.1      | 29.9      | 254.5     | 407.6     | 301.6     | 166.9    | 86.8     | 52.5     | 115.1    |
| 209 | Brahmani             | 51,973.4  | 1,562.1  | 33.6    | 53.2    | 42.6     | 38.7     | 549.7     | 3,888.5   | 7,939.2   | 6,035.6   | 3,059.0  | 1,695.6  | 1,049.7  | 2,162.3  |
|     | River                |           |          |         |         |          |          |           |           |           |           |          |          |          |          |
|     | (Bhahmani)           |           |          |         |         |          |          |           |           |           |           |          |          |          |          |
| 195 | Brahmaputra          | 518,011.4 | 28,402.7 | 549.4   | 2,782.9 | 16,852.2 | 46,782.8 | 103,699.0 | 127,521.0 | 128,246.8 | 107,215.1 | 58,846.2 | 31,386.4 | 18,647.3 | 55,911.0 |
| 291 | Brantas              | 10,822.6  | 1,795.8  | 1,741.1 | 1,762.4 | 1,247.5  | 696.8    | 395.2     | 243.3     | 163.6     | 122.2     | 71.2     | 160.7    | 531.2    | 744.2    |
| 164 | Bravo                | 510,056.3 | 263.4    | 84.8    | 204.6   | 657.0    | 1,336.3  | 937.5     | 913.3     | 1,079.5   | 1,202.6   | 640.0    | 304.7    | 204.1    | 652.3    |
| 185 | Brazos               | 117,853.1 | 747.2    | 874.4   | 717.7   | 986.3    | 929.9    | 587.4     | 962.4     | 828.0     | 508.3     | 179.4    | 80.2     | 367.2    | 647.4    |
| 316 | Burdekin             | 130,426.5 | 690.0    | 3,679.3 | 3,662.4 | 1,887.1  | 1,001.1  | 597.8     | 363.8     | 227.1     | 146.3     | 95.8     | 59.5     | 32.7     | 1,036.9  |
| 318 | Buzi                 | 27,904.7  | 1,304.7  | 1,917.2 | 1,888.8 | 752.6    | 437.8    | 265.0     | 160.8     | 98.8      | 61.6      | 38.5     | 22.6     | 110.9    | 588.3    |
| 217 | Ca                   | 28,747.0  | 1,447.9  | 56.1    | 26.8    | 23.3     | 154.3    | 584.1     | 1,876.9   | 2,678.4   | 4,330.1   | 2,767.9  | 1,652.1  | 965.9    | 1,380.3  |
| 297 | Canete               | 5,755.2   | 257.6    | 233.3   | 231.1   | 128.4    | 67.0     | 41.2      | 25.4      | 17.5      | 12.9      | 43.0     | 62.3     | 113.9    | 102.8    |
| 75  | Caniapiscau          | 105,690.6 | 2,297.2  | 0.9     | 0.5     | 0.3      | 16,170.7 | 12,475.4  | 6,805.5   | 6,229.8   | 6,669.5   | 6,024.1  | 2,490.3  | 1,504.1  | 5,055.7  |
| 173 | Cape Fear            | 22,652.7  | 1,592.2  | 1,301.8 | 1,225.2 | 817.3    | 528.8    | 353.8     | 389.9     | 381.5     | 348.4     | 265.8    | 359.7    | 725.3    | 690.8    |
| 231 | Cauvery              | 91,159.4  | 2,091.4  | 159.7   | 385.4   | 347.3    | 350.9    | 1,080.8   | 3,669.7   | 3,305.4   | 2,574.1   | 2,347.6  | 2,777.6  | 1,849.0  | 1,744.9  |
| 246 | Cavally              | 30,665.2  | 2,295.7  | 105.8   | 221.1   | 532.9    | 1,553.0  | 3,418.3   | 2,447.3   | 1,941.8   | 4,204.8   | 4,188.2  | 2,935.7  | 1,654.9  | 2,125.0  |
| 218 | Chao Phraya          | 188,419.1 | 4,183.6  | 318.1   | 519.8   | 537.6    | 493.6    | 1,640.2   | 5,541.8   | 9,607.1   | 16,009.4  | 10,072.0 | 5,811.4  | 3,059.8  | 4,816.2  |
| 172 | Chelif               | 45,249.3  | 234.5    | 283.5   | 281.9   | 175.3    | 103.2    | 88.2      | 81.1      | 66.7      | 44.4      | 17.2     | 8.8      | 39.5     | 118.7    |
| 283 | Chira                | 16,699.6  | 76.0     | 208.7   | 379.5   | 341.5    | 138.2    | 86.6      | 62.2      | 51.9      | 37.8      | 21.8     | 23.1     | 17.1     | 120.4    |
| 349 | Chubut               | 145,351.9 | 837.4    | 70.0    | 172.1   | 336.2    | 1,273.9  | 2,263.3   | 2,596.8   | 3,116.1   | 2,246.4   | 1,454.2  | 895.8    | 580.3    | 1,320.2  |
| 72  | Churchill            | 298,505.0 | 789.5    | 20.1    | 12.3    | 3,400.0  | 13,120.8 | 7,724.3   | 3,761.6   | 2,131.7   | 1,960.1   | 1,724.5  | 774.9    | 468.2    | 2,990.7  |
| 95  | Churchill,<br>Fleuve | 84,994.3  | 1,702.6  | 0.0     | 0.0     | 0.0      | 15,223.9 | 10,971.0  | 6,028.7   | 4,689.5   | 4,563.7   | 4,517.0  | 1,848.4  | 1,116.4  | 4,221.8  |
|     | (Labrador)           |           |          |         |         |          |          |           |           |           |           |          |          |          |          |
| 350 | Clutha               | 17,118.9  | 1,029.1  | 421.2   | 482.8   | 693.8    | 684.7    | 694.4     | 642.0     | 723.7     | 898.4     | 957.1    | 762.4    | 659.5    | 720.8    |
| 364 | Coco                 | 25,502.0  | 2,767.8  | 143.3   | 70.7    | 43.3     | 48.4     | 1,698.7   | 3,244.2   | 2,959.2   | 3,280.5   | 3,939.1  | 2,788.7  | 2,041.2  | 1,918.8  |

*continues*

**DATA TABLE 8** *continued*

| Basin ID | Basin Name                  | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |           |           |          |          |          |          |          |           |           |           | Average   |
|----------|-----------------------------|-------------------------|---|----------|-----------|-----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------|
|          |                             |                         | Jan                                     | Feb      | Mar       | Apr       | May      | Jun      | Jul      | Aug      | Sep      | Oct       | Nov       | Dec       |           |
| 336      | Colorado<br>(Argentina)     | 390,631.1               | 3,500.8                                 | 346.2    | 220.9     | 135.4     | 373.1    | 707.2    | 841.7    | 929.8    | 908.5    | 2,371.9   | 3,152.6   | 2,575.4   | 1,338.6   |
| 188      | Colorado<br>(Caribbean Sea) | 110,640.3               | 466.3                                   | 688.6    | 553.1     | 621.2     | 522.3    | 343.0    | 497.7    | 455.0    | 315.6    | 115.8     | 35.9      | 228.7     | 403.6     |
| 138      | Colorado<br>(Pacific Ocean) | 640,463.6               | 323.3                                   | 99.7     | 738.0     | 3,046.4   | 5,903.7  | 4,320.1  | 2,390.6  | 1,653.7  | 1,126.8  | 740.4     | 370.5     | 231.4     | 1,745.4   |
| 107      | Columbia                    | 668,561.9               | 11,960.9                                | 11,259.5 | 20,903.3  | 38,188.0  | 55,190.6 | 36,849.4 | 18,551.8 | 11,683.5 | 7,290.7  | 5,462.2   | 6,682.2   | 7,923.4   | 19,328.8  |
| 10       | Colville                    | 57,544.7                | 185.8                                   | 1.4      | 0.8       | 0.5       | 45.5     | 1,938.0  | 1,977.6  | 1,034.6  | 579.1    | 324.5     | 196.0     | 118.4     | 533.5     |
| 236      | Comoe                       | 78,506.9                | 447.9                                   | 3.4      | 4.6       | 105.1     | 306.0    | 923.2    | 676.9    | 1,018.0  | 1,509.8  | 1,021.9   | 540.3     | 296.4     | 571.1     |
| 361      | Conception                  | 25,569.5                | 0.6                                     | 1.8      | 3.6       | 4.8       | 3.8      | 4.7      | 4.3      | 5.9      | 5.5      | 4.2       | 1.5       | 1.1       | 3.5       |
| 243      | Congo                       | 3,698,918.1             | 193,908.5                               | 92,837.8 | 126,684.3 | 138,968.9 | 93,475.1 | 62,522.2 | 55,481.6 | 71,460.1 | 90,395.6 | 111,123.4 | 108,901.0 | 123,157.3 | 105,743.0 |
| 132      | Connecticut                 | 27,468.3                | 934.3                                   | 7.8      | 3,116.2   | 4,979.1   | 2,528.5  | 1,556.0  | 985.4    | 660.3    | 761.0    | 1,049.6   | 1,699.4   | 665.0     | 1,578.5   |
| 255      | Coppename                   | 24,750.2                | 1,551.1                                 | 1,394.4  | 1,540.4   | 2,071.4   | 4,023.6  | 4,578.3  | 3,861.0  | 2,331.4  | 1,160.6  | 695.4     | 420.0     | 321.1     | 1,995.7   |
| 58       | Copper                      | 64,959.7                | 1,090.8                                 | 0.0      | 0.0       | 17.3      | 7,546.7  | 10,214.6 | 7,440.5  | 4,185.8  | 3,963.1  | 2,215.5   | 1,184.1   | 715.2     | 3,214.5   |
| 29       | Coppermine                  | 43,016.4                | 28.9                                    | 0.1      | 0.1       | 0.0       | 390.0    | 714.8    | 246.4    | 139.9    | 84.5     | 51.0      | 30.8      | 18.6      | 142.1     |
| 254      | Corantijn                   | 65,527.6                | 1,313.6                                 | 829.3    | 1,710.9   | 3,554.5   | 11,297.6 | 13,180.8 | 9,711.4  | 6,084.0  | 3,012.4  | 1,811.6   | 1,094.1   | 692.7     | 4,524.4   |
| 234      | Corubal                     | 24,258.0                | 882.9                                   | 0.4      | 0.5       | 0.5       | 0.4      | 293.0    | 1,767.6  | 3,594.2  | 3,165.9  | 2,080.6   | 964.3     | 579.0     | 1,110.8   |
| 248      | Cross                       | 52,820.2                | 3,986.4                                 | 1.4      | 608.2     | 1,184.8   | 2,346.5  | 4,731.8  | 7,828.2  | 9,133.6  | 11,624.3 | 10,815.8  | 4,452.2   | 2,614.4   | 4,944.0   |
| 366      | Cuanza                      | 141,391.1               | 10,360.7                                | 7,565.1  | 10,296.0  | 8,746.9   | 3,552.8  | 2,127.7  | 1,286.3  | 779.0    | 472.4    | 307.3     | 304.1     | 5,458.5   | 4,271.4   |
| 367      | Cunene                      | 110,545.5               | 1,828.9                                 | 2,579.9  | 5,240.5   | 2,925.0   | 1,322.8  | 798.9    | 482.7    | 291.8    | 176.4    | 112.8     | 98.1      | 642.6     | 1,375.0   |
| 245      | Cuyuni                      | 85,635.0                | 9,798.1                                 | 3,136.9  | 2,829.9   | 4,268.1   | 9,871.7  | 13,477.9 | 13,021.6 | 10,134.4 | 5,445.8  | 3,587.1   | 3,665.6   | 6,571.4   | 7,150.7   |
| 146      | Dalinghe                    | 22,823.1                | 58.3                                    | 3.2      | 6.3       | 33.3      | 66.4     | 80.0     | 85.0     | 386.7    | 210.1    | 123.7     | 64.5      | 39.6      | 96.4      |
| 300      | Daly                        | 53,414.6                | 783.7                                   | 2,684.1  | 2,482.2   | 919.0     | 552.0    | 333.8    | 202.0    | 122.6    | 74.6     | 45.3      | 27.1      | 16.9      | 686.9     |
| 206      | Damodar                     | 43,096.1                | 1,257.9                                 | 111.7    | 160.8     | 44.8      | 15.0     | 253.7    | 1,494.8  | 4,751.2  | 4,657.8  | 2,147.4   | 1,316.0   | 850.4     | 1,421.8   |
| 118      | Danube                      | 793,704.8               | 15,369.2                                | 12,969.9 | 30,056.7  | 34,399.1  | 27,077.0 | 19,150.4 | 14,083.1 | 11,248.0 | 10,213.5 | 12,685.9  | 15,065.0  | 12,575.3  | 17,907.8  |
| 403      | Daryacheh-Ye<br>Orumieh     | 30,335.7                | 156.1                                   | 103.1    | 506.3     | 1,527.4   | 1,539.9  | 737.8    | 467.8    | 347.1    | 213.8    | 126.4     | 137.4     | 116.8     | 498.3     |

|     |                        |             |         |         |         |          |         |          |          |         |         |         |         |         |         |
|-----|------------------------|-------------|---------|---------|---------|----------|---------|----------|----------|---------|---------|---------|---------|---------|---------|
| 270 | Daule and Vines        | 41,993.5    | 2,730.9 | 4,080.6 | 5,260.2 | 4,696.3  | 2,419.3 | 1,482.0  | 915.4    | 644.8   | 472.3   | 447.2   | 458.1   | 400.9   | 2,000.7 |
| 251 | Davo                   | 8,460.3     | 133.7   | 0.2     | 0.2     | 2.0      | 9.6     | 542.8    | 283.0    | 126.7   | 238.1   | 288.6   | 192.8   | 89.5    | 158.9   |
| 397 | Dead Sea               | 35,444.0    | 605.0   | 681.7   | 454.0   | 289.3    | 257.0   | 203.5    | 196.8    | 168.4   | 96.6    | 58.6    | 31.9    | 117.9   | 263.4   |
| 147 | Delaware               | 26,713.4    | 1,640.3 | 801.3   | 4,062.4 | 2,255.7  | 1,789.8 | 1,043.1  | 712.5    | 568.2   | 587.3   | 762.0   | 1,406.7 | 1,294.0 | 1,410.3 |
| 96  | Dniepr                 | 510,661.3   | 849.5   | 45.1    | 9,860.5 | 20,513.6 | 7,860.1 | 4,484.4  | 2,811.4  | 1,783.2 | 1,063.7 | 891.9   | 1,449.4 | 588.9   | 4,350.1 |
| 120 | Dniestr                | 72,108.2    | 407.9   | 13.3    | 3,147.7 | 2,602.1  | 1,528.5 | 1,130.4  | 792.2    | 626.7   | 510.8   | 629.4   | 702.3   | 272.1   | 1,030.3 |
| 99  | Don                    | 425,629.6   | 308.1   | 29.4    | 4,138.3 | 14,368.8 | 5,709.0 | 3,280.6  | 2,272.7  | 1,517.1 | 801.0   | 444.2   | 431.0   | 212.1   | 2,792.7 |
| 204 | Dong Jiang             | 32,102.9    | 861.2   | 105.2   | 1,116.0 | 3,077.8  | 5,758.0 | 6,467.3  | 4,881.8  | 4,699.8 | 3,338.0 | 1,558.5 | 934.6   | 567.8   | 2,780.5 |
| 368 | Doring                 | 48,855.5    | 44.0    | 20.3    | 25.5    | 14.8     | 4.2     | 92.2     | 148.6    | 176.0   | 136.2   | 105.1   | 61.5    | 43.1    | 72.6    |
| 142 | Douro                  | 96,125.4    | 3,913.4 | 3,031.8 | 4,104.3 | 2,983.9  | 2,057.4 | 1,252.2  | 1,050.6  | 820.4   | 404.1   | 215.0   | 539.3   | 1,650.2 | 1,835.2 |
| 65  | Dramselv               | 17,364.0    | 259.8   | 0.5     | 97.0    | 1,233.4  | 1,458.1 | 1,401.1  | 734.0    | 665.9   | 720.2   | 633.0   | 304.9   | 170.5   | 639.9   |
| 301 | Drysdale               | 26,015.9    | 26.2    | 283.6   | 270.5   | 96.7     | 58.3    | 35.2     | 21.3     | 12.8    | 7.8     | 4.7     | 2.8     | 1.7     | 68.5    |
| 303 | Durack                 | 29,363.2    | 0.0     | 1.9     | 1.6     | 0.6      | 0.4     | 0.2      | 0.1      | 0.1     | 0.1     | 0.0     | 0.0     | 0.0     | 0.4     |
| 105 | Eastmain               | 48,837.5    | 1,182.9 | 0.0     | 0.0     | 2,558.1  | 9,188.6 | 4,899.7  | 2,922.3  | 2,536.0 | 2,987.8 | 3,379.4 | 1,284.2 | 775.6   | 2,642.9 |
| 140 | Ebro                   | 85,158.6    | 4,220.1 | 2,820.2 | 2,785.8 | 2,876.1  | 2,619.8 | 1,631.9  | 1,192.1  | 853.9   | 509.9   | 561.7   | 873.7   | 2,424.5 | 1,947.5 |
| 154 | Eel (California)       | 7,449.9     | 1,366.1 | 1,258.1 | 927.1   | 540.6    | 304.0   | 173.7    | 105.4    | 63.9    | 38.7    | 23.2    | 15.6    | 579.5   | 449.6   |
| 382 | Eilanden               | 20,077.5    | 5,431.2 | 3,334.4 | 3,835.7 | 3,751.0  | 3,567.3 | 3,244.7  | 3,235.3  | 3,090.1 | 3,371.3 | 2,701.3 | 2,824.9 | 3,278.9 | 3,472.2 |
| 101 | Elbe                   | 139,347.6   | 2,858.7 | 2,594.5 | 4,899.4 | 3,701.9  | 2,272.5 | 1,577.0  | 1,147.9  | 892.7   | 725.8   | 865.4   | 1,454.7 | 1,857.4 | 2,070.7 |
| 26  | Ellice                 | 12,599.6    | 30.5    | -       | -       | -        | -       | 958.3    | 248.8    | 150.3   | 90.8    | 54.8    | 33.1    | 20.0    | 132.2   |
| 391 | Escaut (Schelde)       | 21,498.7    | 1,351.5 | 705.9   | 604.0   | 472.4    | 284.9   | 168.8    | 111.6    | 79.8    | 54.8    | 63.7    | 373.3   | 746.1   | 418.1   |
| 268 | Esmeraldas             | 19,796.2    | 2,922.0 | 4,238.0 | 5,676.0 | 6,743.2  | 4,668.6 | 2,504.1  | 1,398.8  | 876.1   | 589.2   | 579.1   | 755.5   | 966.5   | 2,659.8 |
| 252 | Essequibo              | 68,788.3    | 5,069.1 | 1,976.6 | 2,110.6 | 2,932.1  | 7,163.7 | 13,057.2 | 11,720.0 | 7,957.4 | 3,936.3 | 2,438.8 | 1,874.9 | 3,105.6 | 5,278.5 |
| 394 | Eyre Lake              | 1,188,841.3 | 0.2     | 0.3     | 0.6     | 0.5      | 0.5     | 0.4      | 0.4      | 0.6     | 0.7     | 0.7     | 0.5     | 0.4     | 0.5     |
| 57  | Ferguson               | 15,200.4    | 40.3    | 0.0     | 0.0     | 0.0      | 0.0     | 1,053.5  | 296.1    | 171.1   | 142.1   | 72.5    | 43.8    | 26.4    | 153.8   |
| 73  | Feuilles (Rivière Aux) | 37,425.3    | 673.6   | -       | -       | -        | 2,539.5 | 5,199.5  | 2,051.0  | 1,757.3 | 1,931.8 | 1,773.6 | 731.3   | 441.7   | 1,424.9 |
| 325 | Fitzroy                | 142,915.3   | 72.4    | 1,909.6 | 2,134.9 | 885.3    | 493.9   | 300.8    | 192.9    | 132.5   | 101.8   | 79.8    | 54.4    | 35.2    | 532.8   |
| 311 | Fitzroy                | 94,043.9    | 5.5     | 446.6   | 490.3   | 167.3    | 101.0   | 61.0     | 36.9     | 22.3    | 13.5    | 8.1     | 4.9     | 3.0     | 113.4   |

*continues*

**DATA TABLE 8** *continued*

| Natural runoff (Mm <sup>3</sup> /month) |                              |                         |          |          |          |          |          |          |          |           |          |          |          |          |          |
|---|------------------------------|-------------------------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|
| Basin ID                                | Basin Name                   | Area (km <sup>2</sup> ) | Jan      | Feb      | Mar      | Apr      | May      | Jun      | Jul      | Aug       | Sep      | Oct      | Nov      | Dec      | Average  |
| 389                                     | Flinders                     | 110,041.3               | 0.4      | 89.8     | 28.2     | 15.5     | 9.4      | 5.7      | 3.5      | 2.2       | 1.4      | 0.9      | 0.6      | 0.4      | 13.2     |
| 88                                      | Fraser                       | 239,678.4               | 3,955.1  | 1,048.3  | 2,360.7  | 15,356.9 | 26,897.1 | 15,496.8 | 7,432.2  | 4,439.9   | 3,254.0  | 3,618.6  | 3,140.5  | 2,506.4  | 7,458.9  |
| 377                                     | Fuchun Jiang                 | 37,697.9                | 1,253.4  | 1,966.9  | 3,249.4  | 3,037.5  | 4,025.8  | 5,573.0  | 2,420.0  | 1,437.2   | 1,282.3  | 886.7    | 707.7    | 572.7    | 2,201.1  |
| 200                                     | Fuerte                       | 36,419.8                | 340.7    | 90.6     | 48.7     | 39.8     | 35.5     | 39.1     | 166.0    | 764.0     | 806.9    | 406.5    | 207.8    | 249.3    | 266.2    |
| 374                                     | Galana                       | 51,921.7                | 187.2    | 7.8      | 34.8     | 597.5    | 654.3    | 327.5    | 177.5    | 104.7     | 64.5     | 40.0     | 203.0    | 196.1    | 216.2    |
| 229                                     | Gambia                       | 69,874.3                | 750.8    | 0.3      | 0.3      | 0.3      | 0.3      | 145.1    | 922.2    | 3,078.2   | 3,466.5  | 1,537.8  | 816.1    | 492.4    | 934.2    |
| 369                                     | Gamka                        | 45,676.2                | 65.3     | 14.4     | 28.8     | 40.5     | 41.1     | 51.1     | 45.0     | 62.9      | 111.5    | 105.9    | 87.0     | 55.8     | 59.1     |
| 353                                     | Ganges                       | 1,024,462.6             | 32,182.1 | 10,981.6 | 16,447.4 | 12,896.7 | 12,922.0 | 27,823.6 | 78,624.5 | 128,519.9 | 96,972.9 | 47,842.1 | 32,621.7 | 19,626.1 | 43,121.7 |
| 134                                     | Garonne                      | 55,807.2                | 3,122.4  | 1,918.1  | 2,169.4  | 2,289.6  | 1,911.6  | 1,113.4  | 759.2    | 594.0     | 474.6    | 657.6    | 1,074.9  | 1,915.8  | 1,500.0  |
| 233                                     | Geba                         | 12,774.4                | 537.0    | 3.5      | 4.3      | 4.3      | 3.5      | 79.2     | 413.4    | 1,814.0   | 2,305.1  | 1,207.1  | 582.6    | 353.4    | 608.9    |
| 74                                      | George                       | 39,054.1                | 758.1    | 0.0      | 0.0      | 0.0      | 4,958.0  | 5,039.7  | 3,961.6  | 2,616.4   | 2,618.4  | 1,701.2  | 823.0    | 497.1    | 1,914.5  |
| 312                                     | Gilbert                      | 46,429.1                | 183.1    | 1,374.9  | 1,126.1  | 428.1    | 256.1    | 154.7    | 93.5     | 56.5      | 34.2     | 20.8     | 12.5     | 7.6      | 312.4    |
| 59                                      | Gloma                        | 42,862.7                | 563.2    | 1.3      | 12.0     | 3,439.3  | 3,368.1  | 3,615.4  | 2,048.4  | 1,487.9   | 1,400.5  | 1,344.1  | 677.6    | 369.7    | 1,527.3  |
| 213                                     | Godavari                     | 311,698.7               | 6,805.4  | 626.4    | 1,240.0  | 1,477.3  | 1,571.4  | 891.7    | 13,461.6 | 27,528.4  | 26,621.8 | 12,095.3 | 7,347.2  | 4,834.4  | 8,708.4  |
| 182                                     | Gono (Go)                    | 3,949.5                 | 457.3    | 244.7    | 265.1    | 275.8    | 218.2    | 354.0    | 370.2    | 191.3     | 273.3    | 275.9    | 229.3    | 269.2    | 285.4    |
| 230                                     | Grande De Matagalpa          | 17,991.9                | 1,788.5  | 87.6     | 46.4     | 30.2     | 37.4     | 1,350.9  | 2,694.3  | 2,443.9   | 2,701.8  | 2,950.2  | 1,748.2  | 1,248.2  | 1,427.3  |
| 93                                      | Grande Rivière               | 111,718.4               | 2,729.2  | 0.9      | 0.5      | 0.3      | 20,738.4 | 10,192.2 | 6,544.7  | 6,144.0   | 7,187.4  | 7,682.4  | 2,959.2  | 1,787.3  | 5,497.2  |
| 92                                      | Grande Rivière De La Baleine | 24,256.7                | 482.1    | 0.0      | 0.0      | 0.0      | 3,057.6  | 1,978.3  | 1,140.9  | 1,097.4   | 1,241.0  | 1,368.9  | 523.3    | 316.1    | 933.8    |
| 401                                     | Great Salt Lake              | 74,114.4                | 65.3     | 237.4    | 354.3    | 782.1    | 915.8    | 634.2    | 481.7    | 350.5     | 213.3    | 121.5    | 68.5     | 66.7     | 357.6    |
| 222                                     | Grisalva                     | 127,675.5               | 11,859.4 | 1,204.2  | 664.4    | 610.2    | 1,646.9  | 8,622.6  | 11,809.7 | 13,230.5  | 20,505.5 | 19,300.8 | 10,998.3 | 7,877.1  | 9,027.5  |
| 370                                     | Groot-Kei                    | 18,678.3                | 2.7      | 6.5      | 16.9     | 12.9     | 8.5      | 5.9      | 5.6      | 6.2       | 7.9      | 8.3      | 6.0      | 4.4      | 7.6      |
| 341                                     | Groot-Vis                    | 30,441.2                | 10.7     | 24.1     | 23.0     | 13.9     | 11.7     | 9.5      | 9.9      | 13.2      | 21.7     | 27.3     | 18.9     | 18.9     | 16.9     |
| 161                                     | Guadalquivir                 | 56,954.8                | 677.2    | 1,306.6  | 3,139.9  | 1,977.6  | 1,055.0  | 1,003.9  | 1,110.6  | 955.3     | 481.2    | 185.6    | 65.2     | 160.4    | 1,009.9  |
| 157                                     | Guadiana                     | 66,020.0                | 246.7    | 715.8    | 1,619.0  | 1,022.7  | 571.6    | 571.0    | 703.0    | 614.9     | 301.8    | 105.4    | 30.3     | 15.9     | 543.2    |

|     |                               |             |          |         |          |          |          |          |          |           |          |          |          |          |          |
|-----|-------------------------------|-------------|----------|---------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|
| 85  | Gudena                        | 2,860.9     | 259.3    | 115.5   | 103.3    | 77.1     | 41.9     | 24.7     | 16.2     | 10.7      | 14.8     | 58.0     | 124.8    | 157.3    | 83.6     |
| 379 | Han Jiang                     | 30,741.5    | 429.5    | 189.6   | 1,241.1  | 2,010.5  | 3,792.4  | 4,718.0  | 2,447.5  | 2,125.6   | 1,654.9  | 782.8    | 466.3    | 283.9    | 1,678.5  |
| 160 | Han-Gang<br>(Han River)       | 24,771.5    | 814.3    | 12.5    | 1,372.3  | 1,838.7  | 1,166.9  | 1,200.5  | 4,312.9  | 3,914.3   | 2,697.0  | 1,388.7  | 1,010.5  | 540.7    | 1,689.1  |
| 30  | Hayes (Trib.<br>Arctic Ocean) | 22,992.8    | 27.0     | -       | -        | -        | -        | 834.5    | 225.2    | 133.1     | 80.4     | 48.5     | 29.3     | 17.7     | 116.3    |
| 84  | Hayes (Trib.<br>Hudson Bay)   | 105,371.9   | 339.8    | 7.0     | 4.3      | 2.6      | 7,011.9  | 3,778.4  | 2,054.7  | 1,111.5   | 798.0    | 731.1    | 339.8    | 205.3    | 1,365.4  |
| 355 | Hong<br>(Red River)           | 157,656.9   | 4,779.9  | 80.7    | 104.5    | 254.5    | 1,566.3  | 7,439.6  | 18,447.1 | 22,644.5  | 16,383.8 | 9,602.6  | 5,433.7  | 3,149.0  | 7,490.5  |
| 360 | Hornaday                      | 14,778.0    | 12.4     | 0.0     | 0.0      | 0.0      | 0.0      | 181.3    | 145.7    | 70.2      | 37.1     | 22.3     | 13.5     | 8.1      | 40.9     |
| 359 | Horton                        | 23,926.2    | 12.4     | 0.3     | 0.2      | 0.1      | 78.8     | 314.9    | 93.6     | 54.9      | 33.2     | 20.0     | 12.1     | 7.3      | 52.3     |
| 183 | Huai He                       | 174,309.9   | 1,271.4  | 1,031.3 | 2,377.3  | 4,348.7  | 4,430.9  | 4,375.0  | 4,755.1  | 3,800.5   | 3,689.6  | 1,900.5  | 1,153.0  | 823.3    | 2,829.7  |
| 149 | Huang He<br>(Yellow River)    | 988,062.6   | 2,702.4  | 608.3   | 2,320.1  | 5,166.0  | 8,177.4  | 9,102.2  | 10,309.3 | 9,805.2   | 9,930.4  | 5,872.9  | 3,052.0  | 1,802.8  | 5,737.4  |
| 338 | Huasco                        | 9,871.6     | 92.1     | 16.5    | 10.1     | 6.1      | 3.7      | 2.4      | 1.6      | 1.4       | 1.6      | 1.5      | 0.6      | 46.0     | 15.3     |
| 137 | Hudson                        | 36,892.8    | 1,000.4  | 26.3    | 4,477.0  | 4,970.6  | 2,745.5  | 1,656.2  | 1,063.5  | 725.6     | 742.5    | 1,044.8  | 1,764.9  | 728.3    | 1,745.5  |
| 40  | Iijoki                        | 16,163.3    | 94.2     | 0.1     | 0.1      | 1,326.2  | 997.0    | 396.0    | 232.9    | 151.1     | 155.9    | 299.9    | 102.3    | 61.8     | 318.1    |
| 330 | Incomati                      | 46,295.7    | 1,039.9  | 1,118.5 | 1,027.4  | 517.1    | 276.9    | 173.5    | 113.5    | 83.8      | 67.7     | 43.3     | 129.4    | 456.6    | 420.6    |
| 6   | Indigirka                     | 341,227.8   | 1,902.5  | 179.7   | 108.5    | 65.6     | 450.9    | 16,809.8 | 14,507.5 | 6,786.0   | 3,631.1  | 2,176.2  | 1,314.4  | 793.9    | 4,060.5  |
| 168 | Indus                         | 1,139,075.4 | 11,918.9 | 9,642.7 | 18,198.4 | 21,870.2 | 18,514.4 | 18,264.8 | 32,379.1 | 40,736.0  | 31,344.3 | 19,300.0 | 10,858.9 | 6,757.3  | 19,982.1 |
| 199 | Irawaddy                      | 411,516.3   | 26,908.9 | 342.4   | 994.5    | 4,301.3  | 10,976.0 | 59,825.7 | 98,546.8 | 111,837.4 | 93,122.6 | 59,380.0 | 30,238.9 | 17,673.9 | 42,845.7 |
| 135 | Ishikari                      | 13,783.3    | 859.4    | 2.4     | 2.4      | 4,390.2  | 1,918.3  | 1,080.5  | 793.8    | 776.5     | 1,178.1  | 1,434.9  | 1,481.8  | 564.3    | 1,206.9  |
| 392 | Issyk-Kul                     | 191,032.5   | 300.5    | 48.6    | 2,132.1  | 3,385.1  | 4,295.9  | 3,990.2  | 3,002.3  | 1,671.5   | 1,072.0  | 585.2    | 384.5    | 205.0    | 1,756.1  |
| 163 | James                         | 23,528.4    | 1,600.5  | 1,239.3 | 1,248.0  | 954.0    | 670.9    | 429.1    | 258.7    | 169.2     | 122.7    | 160.2    | 381.4    | 857.5    | 674.3    |
| 309 | Jequitinhonha                 | 68,548.9    | 4,207.8  | 1,648.8 | 1,430.8  | 860.3    | 471.5    | 297.0    | 203.6    | 126.2     | 74.1     | 60.4     | 675.7    | 3,152.4  | 1,100.7  |
| 41  | Joekulsa A<br>Fjoellum        | 7,311.0     | 75.0     | 0.0     | 0.0      | 5.7      | 754.0    | 592.9    | 236.8    | 148.0     | 147.0    | 221.4    | 82.3     | 49.2     | 192.7    |
| 24  | Kalixaelven                   | 17,157.6    | 78.3     | 6.6     | 4.0      | 388.6    | 1,237.8  | 757.3    | 351.5    | 203.1     | 137.7    | 118.6    | 57.6     | 34.8     | 281.3    |
| 80  | Kamchatka                     | 54,103.9    | 689.9    | 0.0     | 0.0      | 0.0      | 9,603.9  | 7,199.7  | 5,399.2  | 2,604.2   | 1,918.9  | 1,546.8  | 749.0    | 452.4    | 2,513.7  |
| 253 | Kelantan                      | 14,419.9    | 3,574.8  | 439.2   | 342.5    | 417.5    | 434.1    | 481.7    | 494.1    | 561.2     | 1,352.9  | 2,084.8  | 2,431.3  | 2,719.0  | 1,277.8  |

*continues*

**DATA TABLE 8** *continued*

| Basin ID | Basin Name    | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |         |         |         |          |          |          |          |          |          |         |         | Average |
|----------|---------------|-------------------------|---|---------|---------|---------|----------|----------|----------|----------|----------|----------|---------|---------|---------|
|          |               |                         | Jan                                     | Feb     | Mar     | Apr     | May      | Jun      | Jul      | Aug      | Sep      | Oct      | Nov     | Dec     |         |
| 36       | Kem           | 42,080.8                | 235.3                                   | 0.5     | 0.4     | 2,642.5 | 3,902.2  | 1,352.6  | 781.6    | 490.1    | 429.8    | 696.2    | 253.6   | 153.2   | 911.5   |
| 18       | Kemijoki      | 55,824.7                | 487.2                                   | 3.2     | 2.0     | 594.1   | 8,987.0  | 2,448.1  | 1,458.1  | 934.7    | 1,082.1  | 1,366.4  | 516.4   | 312.0   | 1,515.9 |
| 1        | Khatanga      | 294,907.5               | 1,571.7                                 | 58.7    | 35.4    | 21.4    | 221.2    | 25,398.5 | 12,884.8 | 6,944.9  | 4,357.0  | 2,419.0  | 1,461.0 | 882.4   | 4,688.0 |
| 256      | Kinabatangan  | 14,101.7                | 2,820.1                                 | 862.7   | 675.4   | 672.8   | 675.3    | 1,148.9  | 787.8    | 1,142.6  | 1,468.5  | 1,388.6  | 1,249.3 | 1,909.0 | 1,233.4 |
| 176      | Kiso          | 5,419.1                 | 652.3                                   | 218.1   | 352.4   | 848.3   | 836.4    | 896.9    | 961.9    | 750.1    | 967.8    | 780.0    | 608.0   | 420.8   | 691.1   |
| 158      | Kitakami      | 9,652.4                 | 690.1                                   | 172.5   | 1,357.6 | 1,082.6 | 802.0    | 551.9    | 581.1    | 590.1    | 631.9    | 775.8    | 828.3   | 528.7   | 716.1   |
| 150      | Kizilirmak    | 77,873.6                | 199.1                                   | 836.5   | 1,201.8 | 2,397.1 | 1,578.7  | 804.4    | 537.4    | 393.4    | 241.0    | 132.0    | 83.4    | 128.5   | 711.1   |
| 139      | Klamath       | 40,040.1                | 3,010.5                                 | 3,574.1 | 3,546.4 | 3,046.4 | 2,001.6  | 1,051.5  | 698.7    | 455.6    | 276.0    | 146.5    | 394.9   | 1,495.2 | 1,641.5 |
| 28       | Kobuk         | 30,242.4                | 211.1                                   | 31.8    | 19.2    | 11.6    | 2,063.7  | 1,100.6  | 619.7    | 373.5    | 338.6    | 159.6    | 96.4    | 58.2    | 423.7   |
| 60       | Kokemaenjoki  | 26,615.9                | 236.7                                   | 1.6     | 1.5     | 3,662.2 | 1,092.9  | 616.1    | 371.5    | 225.5    | 147.2    | 152.9    | 501.9   | 154.8   | 597.1   |
| 13       | Kolyma        | 652,850.5               | 3,721.1                                 | 160.9   | 97.2    | 58.8    | 5,342.4  | 25,441.2 | 35,941.4 | 16,207.8 | 10,517.4 | 5,575.9  | 3,367.8 | 2,034.2 | 9,038.8 |
| 274      | Kouliou       | 60,000.0                | 4,007.3                                 | 2,400.3 | 3,950.9 | 5,306.6 | 3,068.4  | 1,426.7  | 862.7    | 522.5    | 316.7    | 191.7    | 1,130.5 | 3,001.1 | 2,182.1 |
| 34       | Kovda         | 10,227.6                | 30.6                                    | 0.0     | 0.0     | 0.0     | 881.9    | 280.3    | 152.3    | 92.5     | 71.2     | 78.0     | 33.2    | 20.1    | 136.7   |
| 219      | Krishna       | 269,869.0               | 4,249.9                                 | 610.7   | 1,255.2 | 1,355.6 | 1,400.2  | 3,256.5  | 16,600.9 | 15,185.1 | 11,795.9 | 6,710.3  | 4,670.2 | 3,427.8 | 5,876.5 |
| 131      | Kuban         | 58,935.7                | 1,008.9                                 | 1,275.5 | 1,664.7 | 2,123.9 | 1,943.7  | 1,594.5  | 1,393.7  | 826.2    | 621.9    | 471.0    | 528.0   | 626.0   | 1,173.2 |
| 145      | Kura          | 182,283.3               | 559.4                                   | 187.2   | 708.9   | 3,035.7 | 4,111.4  | 2,768.8  | 1,901.8  | 1,396.6  | 913.7    | 766.2    | 692.7   | 413.7   | 1,454.7 |
| 51       | Kuskokwim     | 118,114.0               | 1,269.5                                 | 1.4     | 0.9     | 0.5     | 16,620.3 | 7,998.3  | 5,470.1  | 5,473.3  | 5,291.7  | 2,398.6  | 1,372.5 | 829.0   | 3,893.8 |
| 55       | Kymijoki      | 33,623.1                | 186.3                                   | 1.0     | 1.0     | 4,570.7 | 1,319.9  | 758.1    | 456.3    | 277.2    | 216.4    | 308.4    | 311.4   | 122.5   | 710.7   |
| 44       | Lagarfljot    | 3,285.3                 | 112.9                                   | 0.0     | 0.0     | 22.3    | 1,190.7  | 742.9    | 324.1    | 231.6    | 257.6    | 309.8    | 128.1   | 74.0    | 282.9   |
| 356      | Lake Chad     | 2,391,218.9             | 6,870.6                                 | 135.4   | 144.7   | 180.2   | 263.0    | 1,227.0  | 7,989.1  | 36,416.6 | 27,951.2 | 14,050.2 | 7,408.8 | 4,490.9 | 8,927.3 |
| 395      | Lake Mar      | 154,330.1               | 490.2                                   | 594.7   | 1,026.2 | 504.2   | 261.0    | 162.6    | 112.7    | 87.1     | 80.9     | 85.5     | 95.2    | 137.7   | 303.2   |
|          | Chiquita      |                         |   |         |         |         |          |          |          |          |          |          |         |         |         |
| 402      | Lake Taymur   | 138,782.9               | 723.7                                   | 0.0     | 0.0     | 0.0     | 0.0      | 14,735.9 | 6,387.8  | 3,298.4  | 2,513.9  | 1,300.5  | 785.5   | 474.4   | 2,518.3 |
| 399      | Lake Titicaca | 107,215.3               | 7,124.5                                 | 5,963.3 | 4,974.8 | 2,951.8 | 1,893.3  | 1,052.7  | 658.3    | 552.1    | 469.3    | 688.1    | 678.7   | 2,594.8 | 2,466.8 |
| 396      | Lake Turkana  | 181,536.0               | 2,082.5                                 | 9.0     | 100.4   | 1,988.3 | 3,300.7  | 4,415.2  | 6,718.5  | 7,827.8  | 6,549.2  | 4,135.2  | 2,501.6 | 1,394.5 | 3,418.6 |
| 400      | Lake Vattern  | 11,336.5                | 109.1                                   | 0.5     | 645.9   | 535.8   | 246.0    | 136.0    | 81.3     | 60.0     | 40.2     | 82.5     | 196.1   | 85.7    | 184.9   |



|     |                          |             |          |         |          |          |          |           |          |           |           |          |          |          |          |
|-----|--------------------------|-------------|----------|---------|----------|----------|----------|-----------|----------|-----------|-----------|----------|----------|----------|----------|
| 390 | Leichhardt               | 33,399.2    | 31.9     | 34.8    | 11.9     | 7.2      | 4.4      | 2.6       | 1.6      | 1.0       | 0.6       | 0.4      | 0.2      | 0.1      | 8.1      |
| 228 | Lempa                    | 18,088.5    | 888.1    | 2.9     | 7.6      | 10.3     | 11.7     | 547.6     | 1,582.1  | 1,968.2   | 3,042.2   | 2,295.6  | 976.3    | 585.2    | 993.2    |
| 7   | Lena                     | 2,425,551.1 | 15,771.8 | 655.1   | 396.4    | 361.9    | 87,091.9 | 124,907.8 | 84,650.4 | 63,046.2  | 53,636.1  | 23,839.3 | 14,390.4 | 8,692.2  | 39,786.6 |
| 133 | Liao He                  | 194,436.5   | 678.2    | 20.4    | 220.6    | 1,657.1  | 2,266.7  | 2,171.0   | 2,661.2  | 3,988.1   | 2,606.5   | 1,383.3  | 782.0    | 454.6    | 1,574.1  |
| 339 | Limari                   | 11,780.3    | 118.1    | 101.5   | 40.8     | 21.1     | 12.6     | 27.9      | 18.7     | 17.6      | 14.6      | 15.5     | 11.4     | 31.8     | 36.0     |
| 320 | Limpopo                  | 415,623.1   | 1,880.1  | 3,058.9 | 2,803.2  | 1,433.2  | 767.0    | 501.7     | 359.2    | 334.0     | 330.6     | 246.8    | 159.6    | 308.4    | 1,015.2  |
| 108 | Little Mecatina          | 17,902.9    | 444.5    | 0.0     | 0.0      | 0.0      | 6,156.3  | 2,178.5   | 1,505.7  | 1,078.9   | 1,004.0   | 1,263.0  | 482.6    | 291.5    | 1,200.4  |
| 319 | Loa                      | 50,206.4    | 0.3      | 0.4     | 0.3      | 0.3      | 0.3      | 0.3       | 0.3      | 0.3       | 0.3       | 0.3      | 0.3      | 0.3      | 0.3      |
| 125 | Loire                    | 115,943.6   | 5,691.9  | 3,966.2 | 3,912.1  | 3,192.9  | 2,280.7  | 1,475.0   | 937.1    | 710.2     | 546.1     | 804.6    | 1,839.3  | 3,262.7  | 2,384.9  |
| 381 | Lorentz                  | 4,299.3     | 493.1    | 445.0   | 515.7    | 475.1    | 346.5    | 253.8     | 280.8    | 253.8     | 345.8     | 199.3    | 277.0    | 262.3    | 345.7    |
| 144 | Luan He                  | 71,071.5    | 174.3    | 47.2    | 147.9    | 279.9    | 408.1    | 214.3     | 964.0    | 1,219.0   | 725.2     | 357.8    | 190.0    | 115.8    | 403.6    |
| 23  | Lule                     | 25,127.6    | 313.1    | 1.0     | 0.6      | 1,119.1  | 3,851.3  | 3,784.3   | 1,895.4  | 1,112.2   | 951.7     | 683.0    | 335.9    | 202.9    | 1,187.5  |
| 371 | Lurio                    | 61,172.2    | 4,604.7  | 6,185.0 | 6,089.2  | 2,522.2  | 1,435.2  | 866.8     | 523.5    | 316.3     | 191.1     | 115.4    | 69.7     | 468.0    | 1,948.9  |
| 310 | Macarthur                | 19,673.6    | 0.4      | 1.1     | 55.6     | 14.5     | 8.8      | 5.3       | 3.2      | 1.9       | 1.2       | 0.7      | 0.4      | 0.3      | 7.8      |
| 19  | Mackenzie                | 1,752,001.5 | 5,637.8  | 86.9    | 53.5     | 9,063.7  | 79,403.5 | 79,172.3  | 46,002.0 | 24,877.4  | 15,732.9  | 10,447.5 | 5,767.0  | 3,484.1  | 23,310.7 |
| 224 | Mae Klong                | 28,004.2    | 1,554.4  | 20.9    | 34.2     | 33.5     | 1,076.4  | 3,580.0   | 5,254.6  | 5,831.8   | 5,582.5   | 3,551.6  | 1,715.1  | 1,031.1  | 2,438.9  |
| 235 | Magdalena                | 261,204.9   | 27,118.0 | 3,452.3 | 6,430.2  | 14,175.3 | 21,211.1 | 18,633.1  | 15,055.6 | 15,479.8  | 18,291.2  | 31,846.5 | 31,789.4 | 20,916.3 | 18,699.9 |
| 210 | Mahanadi<br>(Mahahadi)   | 135,061.1   | 3,751.2  | 108.6   | 158.0    | 151.1    | 158.2    | 157.6     | 5,209.0  | 21,461.7  | 14,877.9  | 6,698.9  | 4,119.4  | 2,571.8  | 4,951.9  |
| 205 | Mahi                     | 36,237.7    | 884.2    | 157.9   | 246.0    | 223.2    | 137.5    | 37.8      | 2,640.9  | 4,426.7   | 3,152.3   | 1,389.2  | 865.8    | 573.5    | 1,227.9  |
| 307 | Majes                    | 18,612.1    | 893.9    | 994.8   | 875.9    | 436.0    | 232.5    | 139.9     | 84.7     | 52.7      | 34.4      | 31.7     | 29.3     | 363.0    | 347.4    |
| 380 | Mamberamo                | 75,416.0    | 15,446.4 | 9,453.9 | 12,610.4 | 11,467.8 | 9,723.6  | 7,842.7   | 8,385.4  | 7,964.6   | 8,697.3   | 6,547.6  | 7,173.3  | 8,630.9  | 9,495.3  |
| 324 | Mangoky                  | 43,141.1    | 1,857.9  | 2,203.9 | 1,852.5  | 898.9    | 518.2    | 330.4     | 220.7    | 136.7     | 83.0      | 50.1     | 56.6     | 333.7    | 711.9    |
| 106 | Manicouagan<br>(Rivière) | 54,205.4    | 1,252.8  | 0.3     | 0.2      | 524.6    | 8,666.6  | 6,924.6   | 3,691.1  | 2,983.3   | 3,220.2   | 3,479.9  | 1,358.9  | 820.8    | 2,743.6  |
| 333 | Maputo                   | 30,937.8    | 924.9    | 719.0   | 618.4    | 324.5    | 179.7    | 114.6     | 75.2     | 58.1      | 46.2      | 33.2     | 112.3    | 467.1    | 306.1    |
| 257 | Maroni                   | 65,944.9    | 3,849.5  | 4,583.6 | 5,326.3  | 7,656.9  | 11,080.5 | 10,145.5  | 7,092.8  | 4,342.7   | 2,242.1   | 1,349.5  | 815.1    | 565.6    | 4,920.8  |
| 187 | Mekong                   | 787,256.9   | 30,683.5 | 405.8   | 584.3    | 939.8    | 5,846.3  | 34,283.6  | 85,153.9 | 107,075.0 | 107,961.6 | 64,294.1 | 35,434.1 | 20,497.8 | 41,096.7 |
| 136 | Merrimack                | 12,645.1    | 381.1    | 8.4     | 3,157.8  | 1,789.4  | 1,035.9  | 634.7     | 377.8    | 233.8     | 212.7     | 361.4    | 783.0    | 252.8    | 769.1    |
| 372 | Messalo                  | 24,810.9    | 941.3    | 1,818.6 | 2,197.0  | 1,098.8  | 548.0    | 330.8     | 199.8    | 120.7     | 72.9      | 44.1     | 26.6     | 16.1     | 617.9    |
| 39  | Mezen                    | 76,715.3    | 372.9    | 4.5     | 2.7      | 3,916.9  | 10,521.7 | 3,855.7   | 2,081.0  | 1,250.6   | 799.5     | 867.4    | 386.3    | 233.3    | 2,024.4  |

*continues*

DATA TABLE 8 *continued*

| Basin ID | Basin Name                  | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |           |           |          |          |          |          |          |          |          |          |          |
|----------|-----------------------------|-------------------------|---|----------|-----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|          |                             |                         | Jan                                     | Feb      | Mar       | Apr       | May      | Jun      | Jul      | Aug      | Sep      | Oct      | Nov      | Dec      | Average  |
| 378      | Min Jiang                   | 60,039.7                | 1,710.0                                 | 2,261.2  | 6,444.7   | 6,263.4   | 9,721.2  | 10,643.9 | 4,850.2  | 3,725.5  | 2,882.6  | 2,049.4  | 1,340.9  | 880.7    | 4,397.8  |
| 267      | Mira                        | 13,264.8                | 2,073.0                                 | 1,259.4  | 1,291.0   | 1,430.0   | 2,032.3  | 1,959.3  | 1,248.7  | 1,229.1  | 1,355.3  | 1,165.3  | 1,283.2  | 912.8    | 1,436.6  |
| 122      | Mississippi                 | 3,196,605.4             | 79,924.0                                | 66,571.6 | 111,936.2 | 102,147.6 | 83,552.9 | 56,877.9 | 36,359.7 | 27,329.8 | 18,097.4 | 12,199.9 | 20,013.0 | 38,932.9 | 54,495.2 |
| 306      | Mitchell<br>(N. Au)         | 71,725.2                | 1,080.2                                 | 6,217.0  | 5,876.8   | 2,616.6   | 1,435.1  | 859.9    | 521.2    | 317.3    | 194.5    | 119.8    | 72.3     | 43.0     | 1,612.8  |
| 159      | Mogami                      | 6,853.1                 | 969.3                                   | 827.6    | 1,039.4   | 774.9     | 556.2    | 376.7    | 392.9    | 356.7    | 430.5    | 519.9    | 740.8    | 1,023.9  | 667.4    |
| 242      | Mono                        | 23,899.0                | 122.1                                   | 0.3      | 14.5      | 50.7      | 126.1    | 330.7    | 356.9    | 319.3    | 472.0    | 289.3    | 132.5    | 80.1     | 191.2    |
| 116      | Moose (Trib.<br>Hudson Bay) | 105,615.2               | 1,000.2                                 | 0.6      | 0.6       | 11,334.0  | 9,979.0  | 4,300.8  | 2,527.6  | 1,594.4  | 2,136.5  | 3,024.6  | 1,085.8  | 656.0    | 3,136.7  |
| 313      | Mucuri                      | 16,732.2                | 1,331.8                                 | 412.5    | 315.0     | 254.2     | 167.2    | 113.9    | 88.6     | 50.0     | 28.9     | 21.6     | 212.3    | 1,046.2  | 336.8    |
| 15       | Muonio                      | 37,346.5                | 143.9                                   | 13.1     | 8.0       | 213.9     | 2,005.5  | 1,110.4  | 750.1    | 388.4    | 294.9    | 187.3    | 101.6    | 61.4     | 439.9    |
| 331      | Murray                      | 1,059,507.7             | 2,868.3                                 | 1,379.7  | 1,501.2   | 1,110.5   | 1,279.6  | 2,153.4  | 2,511.6  | 3,164.9  | 3,371.2  | 3,337.6  | 2,314.5  | 2,000.4  | 2,249.4  |
| 37       | Nadym                       | 54,624.7                | 383.2                                   | 0.2      | 0.1       | 0.1       | 4,504.7  | 7,346.2  | 2,354.4  | 1,461.2  | 1,502.8  | 687.7    | 415.4    | 250.9    | 1,575.6  |
| 167      | Naktong                     | 23,325.2                | 508.2                                   | 274.7    | 755.4     | 983.6     | 697.6    | 959.3    | 1,987.4  | 1,879.2  | 1,673.3  | 882.4    | 545.1    | 344.9    | 957.6    |
| 208      | Narmada                     | 95,818.2                | 2,407.1                                 | 430.8    | 900.5     | 1,131.7   | 1,138.1  | 445.1    | 7,352.7  | 11,663.1 | 8,745.2  | 3,757.6  | 2,295.3  | 1,586.4  | 3,487.8  |
| 70       | Narva                       | 58,147.0                | 710.7                                   | 1.2      | 1.2       | 6,018.5   | 1,937.0  | 1,079.4  | 639.7    | 420.0    | 372.9    | 731.8    | 1,459.3  | 466.4    | 1,153.2  |
| 81       | Nass                        | 21,211.7                | 1,054.0                                 | 0.0      | 810.7     | 3,441.7   | 6,020.4  | 4,634.1  | 2,047.3  | 1,515.8  | 1,839.7  | 2,607.5  | 1,420.3  | 691.1    | 2,173.5  |
| 109      | Natashquan<br>(Rivière)     | 16,948.2                | 291.0                                   | 0.0      | 0.0       | 156.2     | 3,726.8  | 1,620.1  | 1,208.4  | 808.1    | 691.2    | 792.3    | 315.9    | 190.8    | 816.7    |
| 345      | Negro<br>(Argentina)        | 130,062.1               | 2,461.3                                 | 98.8     | 347.1     | 1,009.8   | 4,025.3  | 5,859.2  | 6,210.5  | 6,075.1  | 5,030.4  | 4,368.0  | 3,162.3  | 1,740.6  | 3,365.7  |
| 340      | Negro<br>(Uruguay)          | 70,756.4                | 1,301.6                                 | 86.9     | 492.1     | 1,499.0   | 2,274.1  | 3,311.9  | 3,222.8  | 3,290.1  | 3,379.1  | 2,823.2  | 1,553.8  | 846.5    | 2,006.8  |
| 83       | Nelson                      | 1,099,380.3             | 1,698.4                                 | 40.6     | 35.8      | 29,311.7  | 20,864.5 | 15,143.9 | 8,074.5  | 5,014.9  | 4,579.4  | 4,110.0  | 1,799.8  | 1,090.5  | 7,647.0  |
| 87       | Neman                       | 97,299.9                | 740.2                                   | 3.4      | 2,540.2   | 8,813.4   | 3,141.2  | 1,745.1  | 1,037.9  | 641.8    | 406.1    | 467.3    | 1,597.2  | 486.5    | 1,801.7  |
| 56       | Neva                        | 223,309.5               | 1,195.2                                 | 10.6     | 8.8       | 32,169.2  | 9,560.0  | 5,468.9  | 3,272.4  | 1,984.2  | 1,703.3  | 2,586.4  | 1,686.6  | 773.9    | 5,034.9  |

|     |   |             |          |         |          |          |           |           |           |           |           |           |          |          |          |
|-----|---|-------------|----------|---------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|----------|
| 207 | Niger                                     | 2,117,888.7 | 21,778.0 | 99.0    | 256.2    | 1,297.8  | 4,833.0   | 14,794.5  | 38,348.0  | 80,634.7  | 90,704.8  | 47,626.3  | 23,829.5 | 14,278.6 | 28,206.7 |
| 194 | Nile                                      | 3,078,088.1 | 20,724.2 | 2,310.3 | 6,660.0  | 16,300.5 | 18,779.0  | 21,757.3  | 48,384.2  | 80,541.4  | 66,624.1  | 36,444.6  | 22,470.9 | 14,322.2 | 29,609.9 |
| 50  | Nizhny Vyg<br>(Soroka)                    | 31,334.1    | 206.5    | 0.1     | 0.1      | 5,451.2  | 1,622.9   | 926.7     | 553.6     | 334.4     | 420.4     | 626.2     | 224.2    | 135.5    | 875.1    |
| 20  | Noatak                                    | 32,319.5    | 156.5    | 0.8     | 0.5      | 0.3      | 401.9     | 1,980.3   | 1,099.7   | 624.3     | 629.7     | 275.6     | 166.5    | 100.6    | 453.1    |
| 48  | Northern<br>Dvina<br>(Severnaya<br>Dvina) | 323,573.1   | 1,021.4  | 35.1    | 22.2     | 44,567.2 | 19,378.9  | 9,541.8   | 5,592.3   | 3,376.1   | 2,058.6   | 2,097.6   | 971.8    | 587.9    | 7,437.6  |
| 114 | Nottaway                                  | 118,709.0   | 2,188.3  | 0.2     | 0.2      | 13,451.3 | 15,987.7  | 7,640.1   | 5,188.1   | 4,271.3   | 5,083.6   | 6,291.3   | 2,438.0  | 1,434.9  | 5,331.3  |
| 264 | Ntem                                      | 33,526.9    | 2,055.6  | 8.3     | 442.8    | 1,623.3  | 2,595.7   | 1,808.1   | 791.1     | 470.6     | 1,558.6   | 4,430.8   | 3,192.8  | 1,428.3  | 1,700.5  |
| 197 | Nueces                                    | 43,877.9    | 4.2      | 8.4     | 21.4     | 28.3     | 35.8      | 41.5      | 66.6      | 49.3      | 24.4      | 10.5      | 5.4      | 3.8      | 25.0     |
| 67  | Nushagak                                  | 29,513.6    | 517.3    | 0.0     | 0.0      | 1,308.4  | 4,936.8   | 1,770.2   | 1,042.6   | 1,293.2   | 1,548.5   | 1,382.8   | 561.6    | 339.2    | 1,225.1  |
| 275 | Nyanga                                    | 12,369.1    | 1,159.8  | 691.5   | 941.1    | 1,044.4  | 523.6     | 267.4     | 161.5     | 97.5      | 58.9      | 35.6      | 692.8    | 805.1    | 539.9    |
| 261 | Nyong                                     | 34,626.2    | 1,269.1  | 0.1     | 386.2    | 1,153.1  | 1,817.1   | 1,504.5   | 698.1     | 677.8     | 2,434.6   | 3,389.9   | 1,699.9  | 832.3    | 1,321.9  |
| 25  | Ob  | 2,701,040.7 | 6,930.1  | 198.1   | 135.9    | 80,842.2 | 148,619.4 | 68,228.3  | 36,839.8  | 23,540.4  | 18,275.7  | 14,074.8  | 6,865.0  | 4,161.9  | 34,059.3 |
| 365 | Ocona                                     | 16,063.9    | 539.4    | 582.1   | 517.1    | 245.1    | 134.9     | 80.9      | 48.8      | 30.6      | 19.9      | 49.2      | 71.2     | 235.0    | 212.9    |
| 100 | Oder                                      | 116,536.3   | 1,032.5  | 1,852.6 | 5,896.3  | 3,319.4  | 2,160.7   | 1,462.2   | 947.3     | 682.0     | 505.5     | 478.7     | 627.0    | 1,046.2  | 1,667.5  |
| 49  | Oelfusa                                   | 5,678.3     | 378.5    | 0.0     | 323.1    | 1,726.6  | 690.3     | 685.2     | 565.6     | 398.0     | 471.2     | 658.7     | 434.6    | 320.1    | 554.3    |
| 265 | Ogooué                                    | 222,662.7   | 22,726.7 | 7,569.4 | 15,733.8 | 20,776.5 | 19,147.2  | 7,950.2   | 4,618.0   | 2,791.3   | 2,505.1   | 8,651.3   | 23,592.1 | 17,443.6 | 12,792.1 |
| 357 | Okavango                                  | 705,055.7   | 4,075.2  | 6,488.8 | 8,619.1  | 3,971.7  | 2,041.0   | 1,233.1   | 745.9     | 452.1     | 274.8     | 167.1     | 100.7    | 882.0    | 2,421.0  |
| 2   | Olenek                                    | 208,522.0   | 1,231.0  | 159.8   | 96.5     | 58.3     | 658.3     | 16,431.9  | 5,510.3   | 3,070.3   | 1,870.4   | 1,106.6   | 668.3    | 403.7    | 2,605.5  |
| 8   | Omoloy                                    | 38,871.3    | 26.9     | 0.7     | 0.4      | 0.2      | 0.2       | 426.1     | 277.1     | 128.9     | 73.6      | 43.7      | 26.4     | 15.9     | 85.0     |
| 53  | Omega                                     | 65,894.0    | 224.9    | 2.8     | 1.8      | 10,633.8 | 3,402.5   | 1,902.0   | 1,125.9   | 680.1     | 436.9     | 556.4     | 234.8    | 141.1    | 1,611.9  |
| 326 | Orange                                    | 972,388.4   | 1,857.2  | 2,095.4 | 2,246.2  | 1,402.3  | 807.0     | 489.5     | 342.5     | 319.8     | 311.7     | 362.3     | 534.8    | 884.1    | 971.1    |
| 308 | Ord                                       | 55,686.1    | 0.0      | 3.9     | 1.5      | 2.7      | 4.2       | 5.2       | 6.4       | 7.5       | 8.1       | 6.6       | 3.6      | 0.2      | 4.2      |
| 237 | Orinoco                                   | 952,173.4   | 73,559.9 | 9,908.6 | 16,110.2 | 48,197.5 | 96,502.6  | 137,370.7 | 156,922.8 | 139,130.4 | 112,036.3 | 103,445.6 | 77,389.5 | 46,830.9 | 84,783.7 |
| 239 | Oueme                                     | 59,842.6    | 458.8    | 1.0     | 1.1      | 6.9      | 240.8     | 976.7     | 1,265.1   | 1,320.9   | 1,893.3   | 1,037.9   | 499.0    | 301.2    | 666.9    |
| 43  | Oulujoki                                  | 30,554.5    | 230.9    | 1.1     | 0.8      | 5,398.3  | 1,702.8   | 939.7     | 562.7     | 373.1     | 416.6     | 710.7     | 247.3    | 149.5    | 894.5    |
| 262 | Oyapock                                   | 27,075.7    | 4,282.0  | 4,043.5 | 4,817.3  | 6,249.8  | 6,602.9   | 5,755.6   | 3,526.6   | 2,069.9   | 1,131.7   | 683.3     | 412.7    | 586.7    | 3,346.8  |
| 405 | Ozero Sevan                               | 4,765.3     | 8.6      | 0.7     | 3.8      | 76.9     | 106.9     | 55.9      | 31.2      | 21.0      | 12.9      | 13.1      | 13.9     | 5.9      | 29.2     |

*continues*

DATA TABLE 8 *continued*

| Basin ID | Basin Name     | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |          |          |          |          |          |          |          |          |          |          | Average  |
|----------|----------------|-------------------------|---|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|          |                |                         | Jan                                     | Feb      | Mar      | Apr      | May      | Jun      | Jul      | Aug      | Sep      | Oct      | Nov      | Dec      |          |
| 260      | Pahang         | 28,436.7                | 5,776.0                                 | 1,292.5  | 1,416.5  | 1,962.1  | 1,937.4  | 1,260.3  | 863.4    | 823.6    | 1,395.6  | 2,714.8  | 3,612.5  | 4,175.9  | 2,269.2  |
| 17       | Palyavaam      | 31,112.8                | 106.3                                   | 0.0      | 0.0      | 0.0      | 0.0      | 1,878.7  | 1,036.4  | 526.4    | 355.2    | 191.1    | 115.4    | 69.7     | 356.6    |
| 279      | Pangani        | 50,364.8                | 34.7                                    | 22.7     | 34.9     | 203.1    | 493.3    | 239.9    | 152.6    | 87.1     | 59.8     | 38.7     | 28.7     | 27.5     | 118.6    |
| 212      | Panuco         | 82,929.1                | 1,540.6                                 | 95.9     | 186.5    | 197.5    | 137.9    | 362.8    | 2,013.6  | 2,491.4  | 6,156.6  | 3,524.7  | 1,770.8  | 1,046.5  | 1,627.1  |
| 221      | Papaloapan     | 39,885.1                | 1,877.2                                 | 12.4     | 16.0     | 15.8     | 11.5     | 477.3    | 2,373.0  | 4,411.2  | 5,780.4  | 4,426.4  | 2,194.2  | 1,261.7  | 1,904.8  |
| 322      | Paraiba Do Sul | 58,027.2                | 7,384.0                                 | 4,105.7  | 3,823.9  | 2,180.1  | 1,239.1  | 759.3    | 470.0    | 308.5    | 264.6    | 590.0    | 1,633.4  | 4,400.3  | 2,263.2  |
| 302      | Paraná         | 2,640,486.1             | 105,979.7                               | 72,853.1 | 68,346.4 | 50,136.2 | 39,988.6 | 34,546.3 | 22,504.9 | 18,037.0 | 19,546.7 | 24,410.8 | 32,882.5 | 57,492.3 | 45,560.4 |
| 363      | Patacua        | 24,232.4                | 1,710.9                                 | 118.6    | 53.8     | 32.7     | 19.7     | 70.9     | 693.4    | 892.9    | 1,438.3  | 2,176.2  | 1,802.4  | 1,293.7  | 858.6    |
| 190      | Pearl          | 22,423.0                | 1,984.2                                 | 2,012.8  | 2,131.6  | 1,713.4  | 1,094.2  | 598.0    | 392.6    | 256.9    | 162.9    | 99.8     | 148.7    | 752.9    | 945.7    |
| 22       | Pechora        | 312,763.3               | 2,459.1                                 | 31.2     | 19.2     | 1,449.0  | 58,305.9 | 38,794.9 | 16,270.2 | 9,630.9  | 7,855.7  | 4,450.1  | 2,542.8  | 1,536.1  | 11,945.4 |
| 171      | Pee Dee        | 46,531.3                | 2,824.5                                 | 2,381.4  | 2,346.1  | 1,609.2  | 944.6    | 589.6    | 563.3    | 455.2    | 460.3    | 379.9    | 545.7    | 1,384.2  | 1,207.0  |
| 226      | Penner         | 54,976.4                | 568.7                                   | 34.4     | 52.1     | 45.1     | 43.8     | 41.5     | 158.5    | 151.2    | 182.9    | 360.5    | 1,017.5  | 485.3    | 261.8    |
| 129      | Penobscot      | 21,168.9                | 655.1                                   | 0.6      | 482.1    | 5,554.7  | 1,878.0  | 1,224.9  | 733.4    | 451.5    | 421.6    | 684.5    | 1,327.0  | 429.8    | 1,153.6  |
| 128      | Po             | 73,066.6                | 4,276.6                                 | 2,000.0  | 3,536.1  | 5,530.3  | 6,397.4  | 4,452.6  | 2,941.3  | 2,394.4  | 2,314.0  | 2,947.8  | 3,482.3  | 2,857.2  | 3,594.2  |
| 33       | Ponoy          | 13,186.0                | 127.2                                   | 0.0      | 0.0      | 0.0      | 1,585.1  | 438.1    | 255.8    | 178.3    | 268.5    | 394.1    | 138.1    | 83.4     | 289.1    |
| 376      | Popigay        | 48,954.2                | 84.9                                    | 0.8      | 0.5      | 0.3      | 0.2      | 2,052.3  | 754.1    | 410.5    | 251.2    | 146.9    | 88.7     | 53.6     | 320.3    |
| 156      | Potomac        | 32,380.6                | 1,355.9                                 | 1,163.5  | 1,705.2  | 1,374.1  | 948.5    | 624.9    | 370.6    | 255.1    | 188.4    | 213.6    | 392.6    | 752.3    | 778.7    |
| 250      | Pra            | 23,479.8                | 378.6                                   | 3.2      | 102.6    | 282.2    | 657.8    | 1,316.6  | 691.0    | 327.9    | 645.8    | 1,039.5  | 483.0    | 247.6    | 514.6    |
| 31       | Pur            | 111,351.3               | 740.7                                   | 0.3      | 0.3      | 0.3      | 7,186.7  | 15,161.5 | 4,615.2  | 2,795.1  | 2,896.5  | 1,331.2  | 804.1    | 485.8    | 3,001.5  |
| 286      | Purari         | 32,139.9                | 7,089.0                                 | 4,200.2  | 5,204.7  | 5,335.2  | 4,459.8  | 3,535.0  | 2,952.7  | 3,064.9  | 3,853.1  | 3,615.9  | 3,635.9  | 4,215.8  | 4,263.5  |
| 375      | Pyasina        | 63,888.8                | 470.7                                   | 4.9      | 3.1      | 2.0      | 1.3      | 8,582.4  | 2,828.9  | 1,874.0  | 1,803.8  | 814.2    | 491.9    | 297.2    | 1,431.2  |
| 38       | Quoich         | 28,217.6                | 41.6                                    | -        | -        | -        | -        | 1,216.3  | 349.6    | 199.5    | 128.2    | 74.8     | 45.2     | 27.3     | 173.5    |
| 263      | Rajang         | 49,943.5                | 20,497.2                                | 8,513.0  | 9,657.7  | 10,211.2 | 9,935.6  | 7,769.6  | 6,882.1  | 6,855.9  | 9,242.6  | 11,129.0 | 11,855.9 | 12,276.9 | 10,402.2 |
| 344      | Rapel          | 15,689.5                | 1,119.4                                 | 178.1    | 113.7    | 66.3     | 510.5    | 1,373.7  | 1,356.5  | 1,185.4  | 876.8    | 701.4    | 412.7    | 681.5    | 714.7    |
| 110      | Rhine          | 190,522.1               | 13,179.1                                | 7,657.6  | 8,094.3  | 9,602.3  | 8,013.0  | 6,055.1  | 4,779.6  | 4,183.7  | 3,971.9  | 4,514.6  | 6,546.6  | 8,363.7  | 7,080.1  |
| 126      | Rhone          | 97,485.2                | 7,316.8                                 | 3,365.1  | 5,895.8  | 6,325.3  | 5,588.7  | 4,446.6  | 2,690.2  | 2,212.7  | 2,277.1  | 3,477.1  | 5,232.4  | 5,154.7  | 4,498.5  |

|     |                       |           |          |          |          |          |          |         |         |         |         |         |         |         |         |
|-----|-----------------------|-----------|----------|----------|----------|----------|----------|---------|---------|---------|---------|---------|---------|---------|---------|
| 278 | Rio Acarau            | 14,472.9  | 22.3     | 31.8     | 810.4    | 1,076.9  | 646.7    | 301.3   | 179.6   | 110.0   | 67.9    | 42.1    | 26.2    | 16.4    | 277.6   |
| 266 | Rio Araguari          | 33,771.5  | 4,727.0  | 5,377.5  | 6,935.9  | 8,461.5  | 8,118.0  | 7,123.8 | 4,272.9 | 2,486.6 | 1,376.3 | 831.0   | 501.9   | 398.5   | 4,217.6 |
| 272 | Rio Capim             | 54,888.3  | 1,537.9  | 5,606.4  | 8,799.8  | 7,926.1  | 5,924.9  | 3,782.3 | 2,616.7 | 1,569.4 | 878.6   | 525.8   | 317.7   | 205.5   | 3,307.6 |
| 298 | Rio De Contas         | 56,526.5  | 297.0    | 120.1    | 258.0    | 556.9    | 550.1    | 447.9   | 457.9   | 292.5   | 179.2   | 110.9   | 165.1   | 224.8   | 305.0   |
| 314 | Rio Doce              | 86,085.9  | 12,563.7 | 5,298.4  | 4,242.2  | 2,461.5  | 1,301.4  | 784.3   | 483.1   | 302.0   | 187.0   | 117.8   | 2,334.5 | 9,099.0 | 3,264.6 |
| 271 | Rio Gurupi            | 32,335.3  | 491.7    | 2,048.7  | 4,647.2  | 4,513.5  | 3,426.0  | 2,151.5 | 1,412.8 | 764.6   | 450.8   | 272.3   | 164.5   | 103.1   | 1,703.9 |
| 277 | Rio Itapecuru         | 52,672.0  | 84.3     | 1,224.8  | 3,260.0  | 3,253.3  | 1,651.3  | 883.6   | 520.8   | 314.3   | 190.4   | 115.4   | 69.7    | 42.3    | 967.5   |
| 295 | Rio Itapicuru         | 37,593.4  | 56.5     | 2.3      | 2.1      | 7.2      | 99.2     | 263.0   | 645.3   | 362.8   | 169.7   | 102.3   | 62.2    | 38.4    | 150.9   |
| 337 | Rio Jacuí             | 70,798.0  | 5,005.1  | 2,492.1  | 2,901.2  | 3,920.9  | 4,897.0  | 5,793.0 | 5,339.7 | 5,145.1 | 5,743.1 | 5,136.4 | 3,405.9 | 2,794.2 | 4,381.1 |
| 285 | Rio Jaguaribe         | 72,804.3  | 64.1     | 11.7     | 1,619.3  | 2,744.3  | 1,562.6  | 861.9   | 515.6   | 319.8   | 213.3   | 142.0   | 92.4    | 60.4    | 683.9   |
| 282 | Rio Mearim            | 56,687.0  | 356.4    | 2,713.7  | 5,445.6  | 4,657.5  | 2,321.9  | 1,253.1 | 745.7   | 450.8   | 272.8   | 165.1   | 99.9    | 61.7    | 1,545.3 |
| 296 | Rio Pataguacu         | 54,607.1  | 274.1    | 185.7    | 300.7    | 705.2    | 1,494.5  | 1,165.9 | 1,466.7 | 878.0   | 455.0   | 267.7   | 194.3   | 163.9   | 629.3   |
| 288 | Rio Paraiba           | 18,969.1  | 37.7     | 2.0      | 3.5      | 89.5     | 253.8    | 514.2   | 396.9   | 208.3   | 115.4   | 73.2    | 46.6    | 29.6    | 147.6   |
| 276 | Rio Parnaíba          | 336,584.2 | 2,039.6  | 3,746.9  | 7,333.0  | 6,991.8  | 3,124.0  | 1,723.6 | 1,047.6 | 641.5   | 394.0   | 242.4   | 157.1   | 558.8   | 2,333.4 |
| 280 | Rio Pindare           | 39,112.0  | 253.4    | 2,304.7  | 4,716.9  | 4,525.5  | 2,674.7  | 1,415.4 | 814.8   | 488.9   | 295.4   | 178.6   | 108.0   | 65.3    | 1,486.8 |
| 304 | Rio Prado             | 31,673.7  | 696.0    | 283.3    | 357.3    | 417.6    | 243.4    | 187.0   | 168.8   | 106.4   | 58.7    | 36.6    | 137.5   | 549.1   | 270.1   |
| 329 | Rio Ribeira           | 25,697.5  | 2,174.8  | 1,657.5  | 1,425.9  | 887.3    | 735.4    | 782.1   | 538.1   | 442.8   | 601.1   | 860.6   | 773.8   | 987.3   | 988.9   |
|     | Do Iguape             |           |          |          |          |          |          |         |         |         |         |         |         |         |         |
| 294 | Rio Vaza-Barris       | 15,314.2  | 17.1     | 1.4      | 1.7      | 1.6      | 61.4     | 151.1   | 177.6   | 102.7   | 49.8    | 30.8    | 18.8    | 11.8    | 52.2    |
| 166 | Roanoke               | 26,801.0  | 1,844.9  | 1,467.9  | 1,460.0  | 1,085.8  | 725.1    | 448.3   | 316.0   | 238.3   | 184.2   | 159.1   | 332.5   | 853.9   | 759.7   |
| 141 | Rogue                 | 14,526.6  | 1,090.2  | 1,088.4  | 909.0    | 858.5    | 622.6    | 302.4   | 190.5   | 120.0   | 73.0    | 41.5    | 212.2   | 514.3   | 501.9   |
| 299 | Roper                 | 79,907.5  | 434.9    | 1,537.1  | 1,682.2  | 599.2    | 358.4    | 216.7   | 131.2   | 79.7    | 48.5    | 29.6    | 17.7    | 10.5    | 428.8   |
| 373 | Rovuma                | 151,948.6 | 9,106.2  | 15,265.1 | 18,092.1 | 9,319.0  | 4,605.3  | 2,779.5 | 1,678.9 | 1,014.2 | 612.7   | 370.2   | 223.6   | 516.4   | 5,298.6 |
| 284 | Rufiji                | 204,638.8 | 1,836.2  | 3,827.1  | 7,683.8  | 8,804.4  | 4,027.1  | 2,129.0 | 1,285.4 | 779.2   | 473.6   | 288.1   | 176.3   | 418.8   | 2,644.1 |
| 115 | Rupert                | 16,063.4  | 311.4    | 0.0      | 0.0      | 794.7    | 3,201.0  | 1,189.1 | 796.1   | 677.5   | 758.7   | 894.3   | 338.0   | 204.2   | 763.8   |
| 287 | Ruvu                  | 17,541.2  | 121.7    | 122.6    | 361.9    | 952.4    | 722.0    | 287.6   | 174.0   | 106.2   | 64.9    | 39.6    | 23.9    | 73.4    | 254.2   |
| 191 | Sabine                | 25,611.8  | 1,109.9  | 1,334.8  | 1,286.5  | 1,307.3  | 936.9    | 456.1   | 276.7   | 165.9   | 101.9   | 62.1    | 86.8    | 295.2   | 618.3   |
| 148 | Sacramento            | 77,208.9  | 5,375.8  | 6,127.3  | 6,249.1  | 5,067.8  | 3,136.9  | 2,369.0 | 2,064.4 | 1,708.0 | 1,170.4 | 511.3   | 343.5   | 1,439.3 | 2,963.6 |
| 112 | Saguenay<br>(Rivière) | 91,366.9  | 1,984.2  | 1.5      | 1.5      | 11,245.1 | 11,251.7 | 8,137.7 | 5,058.6 | 4,100.4 | 4,665.6 | 5,748.5 | 2,173.4 | 1,301.6 | 4,639.2 |
| 127 | Saint John            | 55,151.8  | 1,543.0  | 1.9      | 1.9      | 13,364.2 | 4,478.5  | 3,060.9 | 1,929.0 | 1,260.9 | 1,384.3 | 2,179.7 | 2,871.4 | 1,012.4 | 2,757.4 |

*continues*

DATA TABLE 8 *continued*

| Basin ID | Basin Name                     | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |          |          |         |          |          |          |          |          |         |          |          |
|----------|--------------------------------|-------------------------|---|----------|----------|----------|---------|----------|----------|----------|----------|----------|---------|----------|----------|
|          |                                |                         | Jan                                     | Feb      | Mar      | Apr      | May     | Jun      | Jul      | Aug      | Sep      | Oct      | Nov     | Dec      | Average  |
| 153      | Sakarya                        | 62,482.7                | 348.5                                   | 1,016.9  | 1,126.0  | 888.3    | 508.1   | 345.2    | 273.7    | 242.4    | 156.9    | 68.9     | 26.5    | 75.1     | 423.0    |
| 342      | Salado                         | 266,263.9               | 1,011.5                                 | 24.7     | 73.2     | 787.5    | 1,228.1 | 1,234.8  | 1,105.6  | 959.3    | 1,261.2  | 1,567.9  | 1,418.0 | 767.6    | 953.3    |
| 170      | Salinas                        | 12,654.6                | 11.8                                    | 34.5     | 58.5     | 36.9     | 36.9    | 47.2     | 66.4     | 68.2     | 42.9     | 9.6      | 2.7     | 1.6      | 34.4     |
| 354      | Salween                        | 258,475.2               | 8,366.0                                 | 95.5     | 592.3    | 1,511.4  | 2,846.6 | 12,055.4 | 24,649.1 | 32,068.1 | 27,586.6 | 18,159.4 | 9,737.1 | 5,522.3  | 11,932.5 |
| 198      | San Antonio                    | 10,952.4                | 12.3                                    | 13.2     | 14.4     | 23.4     | 25.7    | 19.4     | 25.1     | 18.3     | 9.9      | 5.7      | 4.2     | 8.8      | 15.0     |
| 162      | San Joaquin                    | 34,365.6                | 707.1                                   | 829.3    | 1,285.7  | 1,335.3  | 1,136.9 | 1,098.6  | 1,267.9  | 1,193.7  | 818.4    | 322.2    | 74.9    | 102.3    | 847.7    |
| 232      | San Juan                       | 41,659.4                | 5,223.3                                 | 533.6    | 282.7    | 261.5    | 1,036.0 | 3,952.8  | 4,778.7  | 4,793.9  | 6,119.6  | 7,350.0  | 4,839.9 | 3,921.9  | 3,591.2  |
| 258      | San Juan<br>(Columbia-Pacific) | 13,898.0                | 6,064.5                                 | 2,203.5  | 2,616.1  | 3,456.3  | 4,124.0 | 3,912.7  | 3,904.9  | 3,971.2  | 4,103.4  | 4,529.7  | 4,529.1 | 3,905.9  | 3,943.4  |
| 203      | San Pedro                      | 29,358.8                | 192.9                                   | 2.6      | 4.4      | 6.2      | 7.1     | 3.4      | 137.0    | 732.2    | 987.8    | 369.0    | 206.3   | 130.3    | 231.6    |
| 249      | Sanaga                         | 134,252.0               | 4,812.3                                 | 3.0      | 236.5    | 2,004.2  | 4,068.5 | 5,840.0  | 7,929.0  | 9,616.8  | 13,725.9 | 13,358.0 | 5,383.1 | 3,156.1  | 5,844.5  |
| 292      | Santa                          | 11,882.5                | 455.4                                   | 563.1    | 650.9    | 399.4    | 210.8   | 125.2    | 78.5     | 57.1     | 44.0     | 79.5     | 128.6   | 132.8    | 243.8    |
| 352      | Santa Cruz                     | 30,599.9                | 1,652.2                                 | 385.0    | 560.0    | 1,181.8  | 1,590.7 | 1,850.7  | 1,577.2  | 2,464.8  | 3,221.0  | 3,226.9  | 1,605.8 | 1,042.5  | 1,696.6  |
| 175      | Santee                         | 40,035.3                | 804.8                                   | 794.4    | 752.0    | 496.5    | 298.4   | 193.4    | 174.2    | 169.8    | 140.6    | 124.1    | 150.6   | 395.6    | 374.5    |
| 211      | Santiago                       | 126,222.3               | 681.2                                   | 116.1    | 243.6    | 265.3    | 168.1   | 205.1    | 1,027.8  | 2,651.8  | 3,112.7  | 1,413.6  | 791.4   | 492.4    | 930.8    |
| 290      | São Francisco                  | 628,629.1               | 27,716.3                                | 15,251.7 | 13,981.8 | 7,511.4  | 4,656.8 | 5,028.4  | 4,947.7  | 3,343.7  | 1,665.4  | 1,268.7  | 4,929.8 | 18,730.9 | 9,086.0  |
| 240      | Sassandra                      | 68,097.5                | 2,261.5                                 | 1.4      | 3.2      | 129.1    | 309.3   | 2,250.3  | 3,322.8  | 4,638.5  | 8,322.9  | 5,416.1  | 2,603.4 | 1,487.3  | 2,562.2  |
| 181      | Savannah                       | 27,740.4                | 1,501.0                                 | 1,570.4  | 1,658.6  | 1,058.3  | 583.9   | 360.8    | 272.1    | 190.7    | 187.5    | 165.1    | 238.5   | 572.9    | 696.6    |
| 315      | Save                           | 114,957.8               | 2,203.3                                 | 3,356.1  | 2,440.7  | 1,065.6  | 627.7   | 386.7    | 242.8    | 173.8    | 130.9    | 85.0     | 41.4    | 348.7    | 925.2    |
| 68       | Seal                           | 53,439.9                | 126.4                                   | 1.6      | 1.0      | 0.6      | 3,534.7 | 1,434.9  | 728.5    | 432.3    | 415.7    | 241.7    | 130.6   | 78.9     | 593.9    |
| 179      | Sebou                          | 36,201.3                | 1,058.8                                 | 1,081.1  | 1,248.4  | 934.9    | 533.2   | 346.0    | 284.6    | 201.0    | 141.9    | 76.4     | 197.1   | 563.6    | 555.6    |
| 119      | Seine                          | 74,227.9                | 3,426.9                                 | 2,491.0  | 2,183.7  | 1,663.9  | 1,005.1 | 594.9    | 402.4    | 304.5    | 202.7    | 234.2    | 696.1   | 1,700.9  | 1,242.2  |
| 220      | Senegal                        | 436,981.1               | 1,629.1                                 | 10.0     | 15.2     | 11.7     | 12.0    | 447.8    | 3,062.5  | 8,464.3  | 6,863.4  | 3,270.9  | 1,792.3 | 1,076.7  | 2,221.3  |
| 281      | Sepik                          | 81,119.7                | 15,375.9                                | 9,555.7  | 12,665.7 | 12,180.9 | 9,397.5 | 7,423.9  | 6,795.9  | 6,812.5  | 7,707.7  | 8,100.4  | 8,084.8 | 9,182.5  | 9,440.3  |
| 89       | Seyvern (Trib.<br>Hudson Bay)  | 98,590.5                | 593.2                                   | 0.0      | 0.0      | 969.8    | 7,964.8 | 3,325.3  | 1,813.8  | 1,158.6  | 1,429.9  | 1,689.2  | 644.0   | 388.9    | 1,664.8  |

|     |                           |             |          |          |          |           |          |          |          |          |          |          |          |          |          |
|-----|---------------------------|-------------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 241 | Shebelle                  | 805,077.0   | 1,126.2  | 49.5     | 54.4     | 2,532.2   | 1,755.0  | 1,025.3  | 1,594.0  | 2,005.1  | 1,944.7  | 1,681.9  | 1,610.5  | 791.5    | 1,347.5  |
| 165 | Shinano,<br>Chikuma       | 11,158.8    | 1,100.6  | 807.7    | 800.2    | 1,837.3   | 1,864.2  | 1,290.9  | 1,242.1  | 1,006.9  | 1,172.1  | 1,174.8  | 1,150.4  | 1,044.7  | 1,207.7  |
| 215 | Sittang                   | 34,265.3    | 2,254.3  | 3.3      | 6.3      | 6.6       | 16.9     | 3,852.3  | 7,852.6  | 10,043.8 | 8,332.3  | 4,900.8  | 2,492.4  | 1,478.4  | 3,436.7  |
| 123 | Skagit                    | 7,961.0     | 951.3    | 342.8    | 1,452.8  | 1,747.8   | 975.0    | 491.1    | 287.0    | 173.6    | 108.5    | 409.0    | 751.3    | 600.5    | 690.9    |
| 82  | Skeena                    | 42,944.4    | 1,078.2  | 0.2      | 1,041.9  | 4,491.6   | 8,819.6  | 7,160.8  | 3,082.5  | 2,010.7  | 1,937.6  | 2,313.5  | 1,518.6  | 707.1    | 2,846.9  |
| 86  | Skjern A                  | 2,817.6     | 351.5    | 132.9    | 121.1    | 89.0      | 50.8     | 28.9     | 18.4     | 22.4     | 70.4     | 165.2    | 192.5    | 228.6    | 122.6    |
| 289 | Solo (Benga-<br>wan Solo) | 15,146.1    | 2,855.5  | 2,415.3  | 2,433.6  | 1,722.1   | 949.3    | 531.7    | 332.1    | 222.4    | 171.0    | 106.2    | 250.0    | 1,099.8  | 1,090.8  |
| 348 | South Esk                 | 10,842.5    | 186.5    | 8.9      | 10.5     | 32.6      | 76.3     | 208.6    | 392.9    | 471.5    | 403.2    | 358.1    | 217.0    | 135.7    | 208.5    |
| 121 | Southern Bug              | 60,121.0    | 38.8     | 7.9      | 1,840.9  | 967.0     | 519.4    | 311.3    | 205.6    | 138.9    | 77.0     | 43.3     | 27.5     | 18.1     | 349.6    |
| 79  | Spey                      | 2,942.2     | 478.1    | 203.5    | 174.9    | 136.5     | 98.8     | 58.1     | 43.8     | 52.5     | 81.3     | 157.4    | 246.1    | 292.1    | 168.6    |
| 130 | St. Croix                 | 4,638.6     | 170.5    | 0.1      | 0.1      | 1,441.8   | 475.5    | 301.5    | 171.5    | 101.8    | 88.6     | 166.9    | 352.7    | 111.8    | 281.9    |
| 196 | St. Johns                 | 22,489.2    | 379.1    | 187.4    | 226.0    | 126.3     | 72.7     | 67.3     | 331.1    | 475.2    | 796.6    | 731.2    | 335.3    | 225.9    | 329.5    |
| 117 | St. Lawrence              | 1,055,021.5 | 13,835.1 | 351.1    | 29,605.6 | 132,375.7 | 51,230.9 | 31,947.4 | 19,602.9 | 13,031.9 | 15,304.9 | 21,038.1 | 22,898.9 | 9,715.3  | 30,078.1 |
| 71  | Stikine                   | 51,147.5    | 1,826.9  | 603.3    | 508.0    | 1,656.9   | 9,699.8  | 11,933.0 | 5,766.5  | 3,728.6  | 3,815.5  | 3,379.2  | 1,948.6  | 1,370.5  | 3,853.1  |
| 384 | Sungai Kajan              | 33,171.8    | 10,769.4 | 4,092.4  | 5,488.6  | 6,619.3   | 6,870.7  | 5,795.5  | 5,104.8  | 4,917.8  | 6,431.1  | 6,999.8  | 7,819.9  | 6,829.4  | 6,478.2  |
| 386 | Sungai Kapuas             | 84,902.3    | 29,491.3 | 13,356.0 | 15,227.7 | 15,516.0  | 13,513.3 | 10,291.5 | 7,393.4  | 6,608.1  | 8,936.3  | 13,775.6 | 17,293.6 | 17,622.4 | 14,085.4 |
| 385 | Sungai<br>Mahakam         | 75,822.7    | 18,606.0 | 7,876.5  | 10,134.8 | 13,756.5  | 12,600.1 | 9,668.4  | 6,831.4  | 5,649.9  | 5,951.6  | 7,402.7  | 11,152.8 | 12,616.4 | 10,187.3 |
| 398 | Suriname                  | 24,867.7    | 2,186.8  | 1,915.0  | 2,088.7  | 2,922.6   | 4,729.6  | 5,013.8  | 3,973.9  | 2,420.7  | 1,213.0  | 729.1    | 440.4    | 526.6    | 2,346.7  |
| 54  | Susitna                   | 49,470.3    | 1,270.7  | 2.2      | 1.4      | 3,654.1   | 8,319.0  | 8,905.7  | 5,269.7  | 4,095.0  | 4,842.3  | 2,738.5  | 1,370.5  | 827.8    | 3,441.4  |
| 143 | Susquehanna               | 69,080.1    | 2,091.9  | 1,240.2  | 8,814.7  | 5,917.2   | 3,887.6  | 2,447.9  | 1,522.7  | 1,002.4  | 867.5    | 1,337.0  | 2,499.4  | 1,658.8  | 2,774.0  |
| 192 | Suwannee                  | 26,400.9    | 1,043.0  | 1,262.4  | 1,316.2  | 797.7     | 415.7    | 300.4    | 613.1    | 756.9    | 714.7    | 385.8    | 211.7    | 527.5    | 695.4    |
| 42  | Svarta,<br>Skagafiroi     | 3,429.6     | 54.9     | 0.0      | 29.3     | 123.6     | 363.8    | 392.6    | 148.0    | 89.0     | 76.1     | 152.2    | 68.9     | 36.0     | 127.9    |
| 69  | Taku                      | 17,967.6    | 430.1    | 0.0      | 0.0      | 806.8     | 2,508.0  | 2,296.9  | 1,033.2  | 783.7    | 1,027.7  | 1,263.6  | 467.0    | 282.0    | 908.3    |
| 269 | Tana                      | 95,715.0    | 290.5    | 14.7     | 38.9     | 512.9     | 706.1    | 333.2    | 183.6    | 113.4    | 69.9     | 103.6    | 260.5    | 305.1    | 244.4    |
| 9   | Tana (NO, FI)             | 14,518.1    | 71.8     | 0.0      | 0.0      | 0.0       | 2,851.4  | 778.3    | 457.0    | 276.1    | 217.4    | 149.0    | 77.9     | 47.1     | 410.5    |
| 247 | Tano                      | 15,656.1    | 321.4    | 0.2      | 32.5     | 186.6     | 547.1    | 1,356.6  | 700.0    | 337.1    | 480.9    | 810.9    | 421.8    | 218.4    | 451.1    |
| 214 | Tapti                     | 65,096.3    | 1,243.3  | 168.4    | 306.4    | 365.6     | 395.0    | 149.1    | 3,365.4  | 5,169.5  | 5,115.9  | 2,124.1  | 1,333.7  | 886.1    | 1,718.5  |

*continues*



DATA TABLE 8 continued

| Basin ID | Basin Name           | Area (km <sup>2</sup> ) | Natural runoff (Mm <sup>3</sup> /month) |          |          |          |          |          |          |          |          |          |          |          | Average  |
|----------|----------------------|-------------------------|---|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|          |                      |                         | Jan                                     | Feb      | Mar      | Apr      | May      | Jun      | Jul      | Aug      | Sep      | Oct      | Nov      | Dec      |          |
| 358      | Tarim                | 1,051,731.4             | 241.9                                   | 77.0     | 269.6    | 593.6    | 1,657.0  | 2,845.3  | 3,326.7  | 2,360.3  | 1,351.4  | 540.9    | 295.2    | 164.1    | 1,143.6  |
| 27       | Taz                  | 152,086.0               | 989.9                                   | 6.0      | 3.6      | 2.2      | 12,922.1 | 23,163.4 | 7,321.6  | 4,370.1  | 3,193.2  | 1,738.0  | 1,049.7  | 634.0    | 4,616.2  |
| 152      | Tejo                 | 70,351.7                | 2,713.3                                 | 2,202.2  | 3,261.5  | 2,062.1  | 1,343.3  | 834.4    | 721.8    | 559.4    | 292.8    | 124.7    | 136.5    | 1,182.1  | 1,286.2  |
| 174      | Tenryu               | 5,769.0                 | 584.8                                   | 291.0    | 511.3    | 839.0    | 748.4    | 861.4    | 816.6    | 724.3    | 1,026.6  | 888.4    | 635.8    | 438.9    | 697.2    |
| 113      | Thames               | 12,358.9                | 726.2                                   | 447.7    | 361.1    | 237.6    | 136.9    | 78.4     | 49.7     | 32.4     | 21.8     | 18.4     | 131.8    | 395.2    | 219.8    |
| 45       | Thelon               | 238,839.0               | 478.4                                   | 0.1      | 0.0      | 0.0      | 6,190.9  | 10,749.7 | 3,370.2  | 2,026.8  | 1,686.6  | 859.5    | 519.1    | 313.5    | 2,182.9  |
| 47       | Tjorsa               | 7,527.1                 | 422.1                                   | 33.1     | 91.6     | 1,123.0  | 1,723.6  | 1,322.4  | 662.2    | 584.0    | 668.7    | 840.8    | 478.5    | 288.8    | 686.6    |
| 62       | Thlewiaza            | 64,399.6                | 91.9                                    | 10.3     | 6.2      | 3.7      | 1,834.1  | 666.0    | 339.5    | 204.2    | 198.6    | 94.1     | 56.8     | 34.3     | 295.0    |
| 155      | Tigris and Euphrates | 832,578.6               | 15,514.6                                | 16,609.9 | 22,140.0 | 25,647.8 | 18,735.0 | 10,281.7 | 7,368.3  | 5,738.1  | 3,544.0  | 2,291.3  | 3,575.7  | 7,623.3  | 11,589.1 |
| 273      | Tocantins            | 774,718.3               | 82,937.0                                | 65,826.8 | 71,926.3 | 45,721.6 | 24,110.4 | 14,567.5 | 8,930.8  | 5,585.4  | 3,923.1  | 3,979.0  | 16,536.2 | 44,543.4 | 32,382.3 |
| 169      | Tone                 | 15,739.3                | 936.2                                   | 260.8    | 691.8    | 1,057.7  | 983.0    | 973.7    | 1,058.8  | 1,240.9  | 1,561.5  | 1,541.0  | 979.8    | 683.0    | 997.3    |
| 225      | Tranh (Nr Thu Bon)   | 9,459.9                 | 2,007.0                                 | 45.2     | 24.6     | 16.4     | 71.3     | 290.8    | 883.2    | 1,278.8  | 1,770.6  | 2,724.1  | 2,418.9  | 1,615.2  | 1,095.5  |
| 102      | Trent                | 9,052.9                 | 691.4                                   | 368.2    | 303.2    | 213.3    | 137.6    | 80.5     | 56.5     | 51.0     | 49.0     | 67.1     | 198.0    | 402.5    | 218.2    |
| 189      | Trinity (Texas)      | 46,168.2                | 588.6                                   | 822.5    | 766.2    | 973.4    | 839.8    | 365.7    | 234.6    | 152.1    | 98.0     | 66.6     | 52.7     | 255.9    | 434.7    |
| 317      | Tsribihina           | 61,991.9                | 9,631.8                                 | 9,804.7  | 9,049.7  | 4,154.5  | 2,354.3  | 1,436.8  | 893.2    | 545.1    | 328.9    | 198.3    | 299.2    | 2,841.4  | 3,461.5  |
| 335      | Tugela               | 30,079.3                | 758.7                                   | 786.8    | 752.8    | 372.3    | 204.5    | 126.4    | 86.3     | 74.3     | 66.9     | 64.9     | 86.0     | 376.1    | 313.0    |
| 14       | Tuloma               | 26,057.7                | 94.6                                    | 11.6     | 7.1      | 4.4      | 1,732.1  | 547.3    | 300.0    | 180.4    | 119.2    | 121.3    | 55.2     | 33.5     | 267.2    |
| 91       | Tweed                | 4,770.9                 | 575.8                                   | 239.8    | 225.1    | 158.2    | 110.7    | 72.3     | 54.4     | 61.3     | 91.1     | 172.0    | 311.6    | 366.0    | 203.2    |
| 362      | Ulua                 | 26,392.0                | 1,735.8                                 | 77.7     | 42.4     | 31.4     | 19.3     | 510.5    | 1,791.6  | 1,997.4  | 3,135.9  | 2,748.5  | 1,916.8  | 1,262.0  | 1,272.4  |
| 97       | Ural                 | 339,084.2               | 324.2                                   | 5.7      | 165.2    | 10,759.3 | 3,817.4  | 2,162.0  | 1,470.8  | 948.2    | 527.8    | 322.1    | 587.8    | 214.5    | 1,775.4  |
| 334      | Uruguay              | 265,504.6               | 15,702.5                                | 5,633.7  | 8,112.2  | 13,990.4 | 16,949.4 | 19,158.1 | 16,344.5 | 15,620.3 | 18,876.7 | 20,160.7 | 12,864.3 | 9,587.2  | 14,416.7 |
| 383      | Uwimbu               | 29,373.9                | 8,952.7                                 | 5,395.2  | 6,379.0  | 5,992.2  | 6,010.0  | 5,432.3  | 5,263.6  | 5,126.4  | 5,387.6  | 4,552.8  | 4,357.4  | 5,401.7  | 5,687.6  |
| 61       | Vaern-Goeta          | 51,791.5                | 1,198.3                                 | 3.2      | 2,259.8  | 5,377.8  | 2,297.5  | 1,379.5  | 819.2    | 707.0    | 791.8    | 1,475.7  | 1,616.9  | 1,037.2  | 1,580.3  |
| 404      | Van Goltu            | 17,736.8                | 117.9                                   | 0.6      | 127.0    | 1,118.2  | 1,378.3  | 489.2    | 294.9    | 184.2    | 112.7    | 115.2    | 230.6    | 77.6     | 353.9    |

|     |                            |             |          |          |          |           |           |           |           |           |           |          |          |          |
|-----|----------------------------|-------------|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|----------|
| 32  | Varzuga                    | 8,182.2     | 47.2     | 0.0      | 0.0      | 683.9     | 188.7     | 110.1     | 66.6      | 112.4     | 140.1     | 51.2     | 30.9     | 119.3    |
| 223 | Verde                      | 18,342.8    | 378.7    | 2.9      | 6.5      | 6.9       | 10.1      | 365.4     | 850.4     | 1,648.0   | 893.8     | 414.1    | 250.8    | 402.7    |
| 305 | Victoria                   | 78,462.4    | 0.1      | 20.4     | 14.0     | 5.5       | 3.3       | 1.2       | 0.7       | 0.4       | 0.3       | 0.2      | 0.1      | 4.0      |
| 64  | Volga                      | 1,408,278.9 | 3,091.7  | 147.2    | 747.6    | 140,132.1 | 51,088.9  | 17,230.0  | 10,747.1  | 6,887.4   | 6,486.8   | 3,165.6  | 1,902.0  | 22,517.4 |
| 227 | Volta                      | 414,004.1   | 2,522.1  | 7.7      | 80.1     | 291.8     | 828.4     | 2,616.6   | 8,402.5   | 11,296.3  | 5,427.0   | 2,744.7  | 1,654.9  | 3,286.9  |
| 52  | Vuoksi                     | 62,707.4    | 334.8    | 1.2      | 1.2      | 10,528.9  | 2,968.3   | 1,039.2   | 643.3     | 560.3     | 960.4     | 387.0    | 220.0    | 1,614.4  |
| 347 | Waikato                    | 15,358.7    | 1,209.9  | 436.0    | 382.1    | 601.3     | 1,271.4   | 1,642.5   | 1,551.8   | 1,388.8   | 1,356.2   | 1,080.3  | 781.6    | 1,109.9  |
| 103 | Weser                      | 43,140.2    | 3,511.3  | 2,008.3  | 1,895.7  | 1,397.8   | 902.7     | 504.3     | 484.0     | 501.8     | 819.6     | 1,601.5  | 2,294.1  | 1,378.2  |
| 76  | Western Dvina<br>(Daugava) | 89,340.3    | 772.7    | 2.1      | 2.1      | 9,180.8   | 2,977.1   | 1,713.6   | 619.6     | 425.3     | 849.3     | 1,548.2  | 507.4    | 1,634.5  |
| 94  | Wimisk                     | 106,470.3   | 890.2    | 2.1      | 1.3      | 3,470.5   | 10,190.2  | 4,433.5   | 1,479.2   | 2,350.9   | 2,486.7   | 957.9    | 578.6    | 2,440.9  |
| 98  | Wisla                      | 193,764.0   | 947.0    | 37.8     | 12,812.8 | 6,810.9   | 4,190.9   | 1,781.3   | 1,243.2   | 858.0     | 779.6     | 1,157.5  | 847.9    | 2,837.0  |
| 201 | Xi Jiang                   | 362,894.3   | 8,372.9  | 2,682.6  | 4,932.3  | 10,762.2  | 25,796.8  | 44,596.4  | 41,263.7  | 25,138.3  | 14,767.9  | 8,958.4  | 5,447.9  | 19,593.0 |
| 4   | Yana                       | 233,479.4   | 896.1    | 72.8     | 44.0     | 26.6      | 159.2     | 7,535.9   | 6,820.7   | 3,807.3   | 1,106.8   | 668.5    | 403.8    | 1,947.9  |
| 177 | Yangtze<br>(Chang Jiang)   | 1,745,094.4 | 40,746.3 | 20,673.1 | 48,340.7 | 86,583.8  | 114,954.9 | 136,756.4 | 119,291.0 | 113,382.9 | 101,024.6 | 41,278.9 | 25,519.8 | 76,365.2 |
| 193 | Yaqui                      | 76,181.7    | 15.8     | 30.2     | 63.2     | 72.9      | 36.0      | 24.2      | 49.0      | 61.5      | 29.0      | 14.8     | 15.8     | 38.1     |
| 5   | Yenisei                    | 2,558,237.3 | 16,135.2 | 742.2    | 452.4    | 7,752.7   | 162,714.9 | 162,047.8 | 97,190.0  | 64,240.9  | 24,440.8  | 14,455.9 | 8,735.1  | 50,583.3 |
| 178 | Yodo                       | 8,424.2     | 1,063.4  | 536.0    | 654.4    | 713.4     | 583.0     | 743.8     | 675.6     | 510.1     | 820.6     | 652.7    | 632.7    | 696.1    |
| 151 | Yongding He                | 214,406.5   | 174.7    | 403.8    | 1,472.8  | 2,529.4   | 2,501.8   | 1,275.4   | 1,729.3   | 2,397.6   | 1,071.8   | 442.9    | 137.8    | 1,193.5  |
| 16  | Yukon                      | 829,632.3   | 4,850.3  | 252.5    | 152.7    | 943.7     | 53,166.5  | 48,766.9  | 29,776.4  | 16,607.0  | 12,906.1  | 4,212.2  | 2,544.3  | 15,152.2 |
| 293 | Zambezi                    | 1,388,572.2 | 73,279.9 | 82,019.0 | 68,514.8 | 32,327.8  | 18,268.1  | 10,936.3  | 6,663.6   | 4,203.7   | 2,618.2   | 1,305.4  | 21,500.8 | 26,938.3 |

# Area Equipped for Irrigation Actually Irrigated

## Description

The area equipped for agricultural irrigation that is actually irrigated is listed here by major country, in thousands of hectares (1,000 ha), for different five-year periods. The periods are 1988–1992, 1993–1997, 1998–2002, 2003–2007, and 2008–2012. Within each of these periods, data are typically available for only a single year, listed in the column labeled “Actual Year of Data.” Thus, for Afghanistan (the first entry), three data points are available, for the years 1990, 2002, and 2011, as noted.

The area actually irrigated is typically less than the area capable of being irrigated (or equipped for irrigation), since actual water availability, climatic conditions, economic factors, and decisions about cropping and fallowing patterns vary annually.

Countries not included on this list either have no irrigation or no reported data—their absence from the list is not an indication of which condition applies.

## Limitations

Data are collected by the Food and Agriculture Organization of the United Nations (FAO), usually through country reports and information about crop production. Different methods of collecting these data are used in different regions. All of the data are made available through the FAO’s AQUASTAT database, as noted below. For some countries, data are available for only a single year.

## Sources

UN FAO. 2013. AQUASTAT database. Rome, Italy: Food and Agriculture Organization of the United Nations. <http://www.fao.org> (accessed February 6, 2013).

**DATA TABLE 9** Area Equipped for Irrigation Actually Irrigated (1,000 ha)

| Country                          | Actual Year<br>of Data | Period<br>1988-1992 | Actual Year<br>of Data | Period<br>1993-1997 | Actual Year<br>of Data | Period<br>1998-2002 | Actual Year<br>of Data | Period<br>2003-2007 | Actual Year<br>of Data | Period<br>2008-2012 |
|----------------------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| Afghanistan                      | 1990                   | 2,660               |                        | 2002                | 1,732                  |                     |                        |                     | 2011                   | 1,896               |
| Albania                          |                        |                     |                        |                     |                        |                     | 2007                   | 107                 | 2009                   | 205                 |
| Algeria                          | 1992                   | 366                 |                        | 2001                | 453                    |                     |                        |                     |                        |                     |
| Angola                           |                        |                     | 1996                   | 35                  |                        |                     |                        |                     |                        |                     |
| Antigua and Barbuda              |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Argentina                        |                        |                     |                        |                     | 2002                   | 1,356               |                        |                     |                        |                     |
| Armenia                          |                        |                     | 1995                   | 173                 |                        |                     | 2006                   | 176                 |                        |                     |
| Australia                        |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Austria                          |                        |                     | 1995                   | 46                  |                        |                     | 2007                   | 43                  |                        |                     |
| Azerbaijan                       | 1992                   | 1,340               |                        | 2002                | 1,352                  |                     | 2004                   | 1,356               | 2010                   | 1,358               |
| Bahamas                          |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Bahrain                          |                        |                     | 1994                   | 3                   |                        |                     |                        |                     |                        |                     |
| Bangladesh                       | 1989                   | 2,738               |                        |                     |                        |                     |                        |                     |                        |                     |
| Barbados                         |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Belarus                          |                        |                     |                        |                     |                        |                     |                        |                     | 2011                   | 31                  |
| Belgium                          |                        |                     |                        |                     |                        |                     | 2007                   | 6                   |                        |                     |
| Belize                           |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Benin                            |                        |                     |                        |                     | 2002                   | 9                   |                        |                     | 2008                   | 17                  |
| Bhutan                           |                        |                     | 1995                   | 27                  |                        |                     | 2007                   | 28                  |                        |                     |
| Bolivia (Plurinational State of) |                        |                     |                        |                     | 1999                   | 128                 |                        |                     |                        |                     |
| Bosnia and Herzegovina           | 1992                   | 1                   |                        |                     |                        |                     |                        |                     |                        |                     |
| Botswana                         | 1989                   | 2,700               |                        |                     |                        |                     | 2006                   | 4,454               |                        |                     |
| Brazil                           |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Brunei Darussalam                |                        |                     | 1995                   | 1                   |                        |                     |                        |                     |                        |                     |
| Bulgaria                         |                        |                     | 1997                   | 43                  |                        |                     | 2007                   | 73                  | 2011                   | 41                  |
| Burkina Faso                     | 1992                   | 24                  |                        |                     |                        |                     |                        |                     |                        |                     |

*continues*

DATA TABLE 9 *continued*

| Country                          | Actual Year<br>of Data | Period<br>1988-1992 | Actual Year<br>of Data | Period<br>1993-1997 | Actual Year<br>of Data | Period<br>1998-2002 | Actual Year<br>of Data | Period<br>2003-2007 | Actual Year<br>of Data | Period<br>2008-2012 |
|----------------------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| Burundi                          |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Cambodia                         |                        |                     | 1993                   | 242                 | 2001                   | 255                 | 2006                   | 317                 |                        |                     |
| Cameroon                         |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Canada                           |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Cape Verde                       | 1988                   | 2                   | 1997                   | 2                   |                        |                     |                        |                     |                        |                     |
| Central African Republic         |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Chad                             | 1988                   | 13                  |                        |                     | 2002                   | 26                  |                        |                     |                        |                     |
| Chile                            |                        |                     |                        |                     |                        |                     | 2007                   | 1,094               |                        |                     |
| China                            | 1992                   | 44,418              | 1995                   | 45,017              |                        |                     | 2006                   | 54,219              |                        |                     |
| Colombia                         |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Comoros                          |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Congo                            |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Costa Rica                       |                        |                     | 1997                   | 103                 |                        |                     | 2006                   | 102                 |                        |                     |
| Côte d'Ivoire                    |                        |                     | 1994                   | 67                  |                        |                     |                        |                     |                        |                     |
| Cuba                             |                        |                     | 1997                   | 738                 |                        |                     |                        |                     |                        |                     |
| Cyprus                           |                        |                     | 1994                   | 33                  |                        |                     | 2007                   | 31                  |                        |                     |
| Czech Republic                   |                        |                     |                        |                     |                        |                     | 2007                   | 20                  |                        |                     |
| Democratic Republic of the Congo |                        |                     | 1995                   | 8                   | 2000                   | 7                   |                        |                     |                        |                     |
| Denmark                          |                        |                     |                        |                     |                        |                     | 2007                   | 254                 |                        |                     |
| Djibouti                         | 1989                   | 0                   |                        |                     | 1999                   | 0                   |                        |                     |                        |                     |
| Dominican Republic               |                        |                     |                        |                     | 1999                   | 270                 |                        |                     |                        |                     |
| Ecuador                          |                        |                     | 1997                   | 613                 | 2000                   | 620                 |                        |                     |                        |                     |
| Egypt                            | 1990                   | 2,585               | 1993                   | 3,246               | 2002                   | 3,422               |                        |                     |                        |                     |
| El Salvador                      |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Equatorial Guinea                |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Eritrea                          |                        |                     | 1993                   | 13                  |                        |                     |                        |                     |                        |                     |
| Estonia                          |                        |                     | 1995                   | 2                   |                        |                     |                        |                     | 2010                   | 0                   |



DATA TABLE 9 *continued*

| Country     | Actual Year<br>of Data | Period<br>1988-1992 | Actual Year<br>of Data | Period<br>1993-1997 | Actual Year<br>of Data | Period<br>1998-2002 | Actual Year<br>of Data | Period<br>2003-2007 | Actual Year<br>of Data | Period<br>2008-2012 |
|-------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| Latvia      |                        |                     |                        |                     | 2007                   | 1                   |                        |                     |                        |                     |
| Lebanon     |                        |                     | 1998                   | 90                  |                        |                     |                        |                     |                        |                     |
| Lesotho     |                        |                     | 1994                   | 0                   | 1999                   | 0                   |                        |                     |                        |                     |
| Liberia     |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| Libya       | 1990                   | 240                 |                        |                     | 2000                   | 316                 |                        |                     |                        |                     |
| Lithuania   |                        |                     |                        |                     |                        |                     | 2007                   | 1                   |                        |                     |
| Madagascar  | 1992                   | 895                 |                        |                     | 2000                   | 550                 |                        |                     |                        |                     |
| Malawi      | 1992                   | 27                  |                        |                     |                        |                     |                        |                     |                        |                     |
| Mali        |                        |                     |                        |                     | 2000                   | 176                 |                        |                     |                        |                     |
| Malta       | 1990                   | 1                   |                        |                     |                        |                     | 2007                   | 3                   |                        |                     |
| Mauritania  |                        |                     | 1994                   | 27                  |                        |                     | 2004                   | 23                  |                        |                     |
| Mauritius   |                        |                     |                        |                     | 2002                   | 21                  |                        |                     |                        |                     |
| Mexico      | 1989                   | 5,150               | 1997                   | 5,505               |                        |                     | 2007                   | 5,439               |                        |                     |
| Mongolia    |                        |                     | 1993                   | 63                  |                        |                     |                        |                     |                        |                     |
| Morocco     |                        |                     |                        |                     | 2000                   | 1,407               | 2004                   | 1,448               |                        |                     |
| Mozambique  |                        |                     | 1995                   | 45                  | 2001                   | 40                  |                        |                     |                        |                     |
| Myanmar     | 1990                   | 1,056               | 1995                   | 1,582               |                        |                     | 2004                   | 2,110               |                        |                     |
| Namibia     | 1992                   | 6                   |                        |                     |                        |                     |                        |                     |                        |                     |
| Netherlands |                        |                     |                        |                     |                        |                     | 2007                   | 202                 |                        |                     |
| New Zealand |                        |                     |                        |                     | 2002                   | 384                 | 2007                   | 509                 |                        |                     |
| Nicaragua   |                        |                     | 1997                   | 51                  |                        |                     |                        |                     |                        |                     |
| Niger       |                        |                     |                        |                     | 2000                   | 65                  | 2005                   | 66                  |                        |                     |
| Nigeria     | 1991                   | 172                 |                        |                     | 2000                   | 222                 | 2004                   | 219                 |                        |                     |
| Norway      |                        |                     |                        |                     |                        |                     | 2007                   | 55                  |                        |                     |
| Oman        |                        |                     | 1993                   | 62                  |                        |                     |                        |                     |                        |                     |
| Panama      |                        |                     | 1997                   | 28                  | 2000                   | 27                  |                        |                     |                        |                     |
| Peru        |                        |                     | 1994                   | 1,109               |                        |                     |                        |                     |                        |                     |



|                       |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
|-----------------------|------|-------|-------|------|--|------|-------|--|--|--|------|-------|--|--|------|-------|--|--|
| Philippines           |      |       | 1,471 | 1993 |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Poland                |      |       |       |      |  |      |       |  |  |  | 2007 | 72    |  |  |      |       |  |  |
| Portugal              | 1990 | 631   |       |      |  |      |       |  |  |  | 2007 | 422   |  |  |      |       |  |  |
| Puerto Rico           |      |       |       |      |  |      |       |  |  |  | 2007 | 16    |  |  |      |       |  |  |
| Qatar                 | 1990 | 6     | 8     | 1993 |  | 2001 | 6     |  |  |  | 2004 | 6     |  |  |      |       |  |  |
| Republic of Moldova   | 1992 | 225   | 210   | 1994 |  |      |       |  |  |  | 2007 | 32    |  |  |      |       |  |  |
| Romania               |      |       |       |      |  |      |       |  |  |  | 2007 | 173   |  |  |      |       |  |  |
| Russian Federation    |      |       | 4,095 | 1994 |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Rwanda                |      |       |       |      |  |      |       |  |  |  |      |       |  |  | 2008 | 8     |  |  |
| Saudi Arabia          | 1992 | 1,608 |       |      |  | 1999 | 1,191 |  |  |  |      |       |  |  |      |       |  |  |
| Senegal               |      |       | 69    | 1997 |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Serbia                |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Seychelles            |      |       |       |      |  |      |       |  |  |  | 2003 | 0     |  |  | 2011 | 34    |  |  |
| Slovakia              |      |       |       |      |  | 2000 | 111   |  |  |  | 2007 | 39    |  |  |      |       |  |  |
| Somalia               |      |       |       |      |  | 2000 | 65    |  |  |  |      |       |  |  |      |       |  |  |
| South Africa          |      |       |       |      |  | 2000 | 1,498 |  |  |  |      |       |  |  | 2011 | 1,601 |  |  |
| Spain                 |      |       |       |      |  |      |       |  |  |  |      |       |  |  | 2009 | 3,093 |  |  |
| Sri Lanka             |      |       |       |      |  |      |       |  |  |  | 2006 | 463   |  |  |      |       |  |  |
| Sudan and South Sudan |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Suriname              |      |       | 1,197 | 1995 |  | 2000 | 800   |  |  |  |      |       |  |  |      |       |  |  |
| Swaziland             |      |       |       |      |  | 1998 | 51    |  |  |  |      |       |  |  |      |       |  |  |
| Sweden                |      |       |       |      |  | 2002 | 45    |  |  |  |      |       |  |  |      |       |  |  |
| Switzerland           |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Syrian Arab Republic  |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Tajikistan            |      |       | 719   | 1994 |  | 2000 | 1,210 |  |  |  |      |       |  |  | 2010 | 36    |  |  |
| Thailand              |      |       |       |      |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Timor-Leste           |      |       |       |      |  |      |       |  |  |  | 2007 | 5,060 |  |  |      |       |  |  |
| Togo                  | 1990 | 2     | 6     | 1996 |  | 2002 | 29    |  |  |  |      |       |  |  |      |       |  |  |
| Trinidad and Tobago   |      |       | 3     | 1997 |  |      |       |  |  |  |      |       |  |  |      |       |  |  |
| Tunisia               | 1991 | 322   |       |      |  | 2000 | 393   |  |  |  |      |       |  |  |      |       |  |  |
| Turkey                |      |       | 3,098 | 1994 |  |      |       |  |  |  | 2006 | 4,320 |  |  | 2008 | 5,280 |  |  |

*continues*

**DATA TABLE 9** *continued*

| Country                            | Actual Year<br>of Data | Period<br>1988-1992 | Actual Year<br>of Data | Period<br>1993-1997 | Actual Year<br>of Data | Period<br>1998-2002 | Actual Year<br>of Data | Period<br>2003-2007 | Actual Year<br>of Data | Period<br>2008-2012 |
|------------------------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|---------------------|
| Turkmenistan                       |                        |                     | 1994                   | 1,744               |                        |                     | 2006                   | 1,991               |                        |                     |
| Uganda                             |                        |                     |                        |                     | 1998                   | 6                   |                        |                     | 2010                   | 12                  |
| Ukraine                            |                        |                     | 1995                   | 1,845               | 2002                   | 730                 |                        |                     |                        |                     |
| United Arab Emirates               |                        |                     | 1993                   | 54                  |                        |                     |                        |                     | 2010                   | 76                  |
| United Kingdom                     |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| United Republic of Tanzania        |                        |                     |                        |                     |                        |                     |                        |                     |                        |                     |
| United States of America           |                        |                     | 1997                   | 22,779              | 2002                   | 22,384              | 2007                   | 22,905              | 2008                   | 22,229              |
| Uruguay                            |                        |                     |                        |                     | 1998                   | 181                 |                        |                     |                        |                     |
| Uzbekistan                         |                        |                     | 1994                   | 4,202               |                        |                     |                        |                     | 2005                   | 3,700               |
| Venezuela (Bolivarian Republic of) |                        |                     |                        |                     | 1998                   | 308                 |                        |                     |                        |                     |
| Vietnam                            | 1990                   | 2,100               | 1994                   | 2,100               |                        |                     |                        |                     | 2005                   | 4,585               |
| Zambia                             | 1992                   | 46                  |                        |                     | 2002                   | 156                 |                        |                     |                        |                     |
| Zimbabwe                           |                        |                     |                        |                     | 1999                   | 124                 |                        |                     |                        |                     |

# Overseas Development Assistance for Water Supply and Sanitation, by Donating Country, 2004–2011

## Description

The annual overseas development assistance, or official development assistance (ODA), for water supply and sanitation is listed here, by donating country (and European Union institutions), for the years 2004 through 2011. Shown are the total amounts committed, in current US dollars in millions.

“ODA” is the term given to funding that flows from governments or multilateral institutions for the purpose of providing aid to countries. This funding is usually provided for the purpose of promoting economic development and welfare and is “concessional in character and conveys a grant element of at least 25 percent.” ODA can take a number of forms, including technical assistance, investment projects, debt forgiveness or rescheduling, equity investments, and other assistance. The Organisation for Economic Co-operation and Development’s (OECD’s) Development Assistance Committee (DAC) identifies eleven subsectors in the “water supply and sanitation” category:

- Water resources policy and administrative management
- Water resources protection
- Water supply and sanitation—large systems
- Water supply—large systems
- Sanitation—large systems
- Basic drinking water supply and basic sanitation
- Basic drinking water supply
- Basic sanitation
- River development
- Waste management and disposal
- Education and training in water supply and sanitation

Data table 11 provides a breakdown of ODA for water supply and sanitation by these subsectors.

## Limitations

ODA does not constitute all the funding that flows to developing countries, such as other public sector or private sector flows; hence, these numbers do not reflect all funding for water projects. In addition, not all ODA described as related to “water supply and sanitation” may flow to purely water projects.

## Source

Organisation for Economic Co-operation and Development (OECD). 2013. Query Wizard for International Development Statistics. <http://stats.oecd.org/qwids/>.

**DATA TABLE 10** Overseas Development Assistance for Water Supply and Sanitation, by Donating Country, 2004–2011

| Country/Agency      | Current (Millions US\$) |          |          |          |          |          |          |          |
|---------------------|-------------------------|----------|----------|----------|----------|----------|----------|----------|
|                     | 2004                    | 2005     | 2006     | 2007     | 2008     | 2009     | 2010     | 2011     |
| Australia           | 30.19                   | 34.50    | 6.43     | 15.01    | 13.90    | 44.68    | 171.38   | 230.33   |
| Austria             | 20.08                   | 16.77    | 20.40    | 24.15    | 36.58    | 23.16    | 17.99    | 26.57    |
| Belgium             | 24.70                   | 37.79    | 55.16    | 47.98    | 102.96   | 61.33    | 48.93    | 69.84    |
| Canada              | 79.76                   | 41.09    | 18.54    | 24.33    | 46.96    | 73.85    | 19.47    | 44.99    |
| Denmark             | 245.43                  | 98.90    | 144.62   | 31.66    | 19.01    | 164.95   | 140.81   | 88.07    |
| Finland             | 6.05                    | 43.34    | 44.17    | 30.59    | 51.18    | 54.32    | 99.35    | 122.20   |
| France              | 175.50                  | 114.85   | 237.42   | 391.23   | 359.65   | 802.77   | 495.60   | 323.02   |
| Germany             | 435.75                  | 382.26   | 497.14   | 593.96   | 906.44   | 820.47   | 750.81   | 1,040.71 |
| Greece              | 1.39                    | 0.52     | 1.03     | 2.78     | 0.76     | 2.99     | 0.12     | —        |
| Iceland             | —                       | —        | —        | —        | —        | —        | —        | 0.39     |
| Ireland             | 19.15                   | 16.83    | 16.91    | 22.80    | 28.15    | 17.47    | 9.97     | 10.70    |
| Italy               | 5.89                    | 69.00    | 54.50    | 59.69    | 163.41   | 55.94    | 63.29    | 13.92    |
| Japan               | 709.47                  | 2,128.66 | 1,250.89 | 1,930.07 | 1,668.24 | 2,786.04 | 1,933.26 | 1,711.10 |
| Korea               | 78.31                   | 101.56   | 80.76    | 74.52    | 269.70   | 70.71    | 283.15   | 172.13   |
| Luxembourg          | 14.38                   | 12.43    | 10.27    | 12.95    | 19.02    | 22.29    | 20.30    | 21.54    |
| Netherlands         | 146.50                  | 191.69   | 455.15   | 359.27   | 373.08   | 196.51   | 69.28    | 129.53   |
| New Zealand         | 1.76                    | 2.16     | 2.77     | 3.58     | 3.21     | 2.58     | 1.53     | 5.83     |
| Norway              | 32.26                   | 42.53    | 28.02    | 46.60    | 44.65    | 40.66    | 50.86    | 17.76    |
| Portugal            | 2.17                    | 2.48     | 0.63     | 1.57     | 0.32     | 0.42     | 0.99     | 0.63     |
| Spain               | 78.47                   | 58.02    | 69.03    | 121.45   | 577.07   | 577.77   | 308.44   | 155.11   |
| Sweden              | 43.77                   | 68.73    | 64.32    | 46.72    | 76.90    | 75.37    | 45.31    | 66.30    |
| Switzerland         | 31.57                   | 35.77    | 31.74    | 34.31    | 49.28    | 43.06    | 49.26    | 331.51   |
| United Kingdom      | 29.46                   | 44.26    | 51.16    | 104.88   | 160.66   | 114.32   | 156.94   | 170.45   |
| United States       | 954.69                  | 1,023.27 | 817.79   | 432.14   | 846.78   | 461.91   | 431.34   | 465.40   |
| EU Institutions     | 413.17                  | 687.16   | 726.55   | 490.50   | 170.28   | 528.11   | 678.11   | 603.69   |
| Kuwait (KFAED)      | —                       | —        | —        | —        | —        | —        | 43.27    | 40.22    |
| Multilateral, Total | 1,476.04                | 1,346.75 | 1,807.02 | 1,955.88 | 1,676.51 | 1,682.27 | 2,326.53 | 3,141.53 |
| All Donors Total    | 5,055.91                | 6,601.32 | 6,492.42 | 6,858.62 | 7,664.70 | 8,723.95 | 8,216.29 | 9,003.47 |

# Overseas Development Assistance for Water Supply and Sanitation, by Subsector, 2007-2011 (Total of All Donating Countries)

## Description

The allocation of total overseas development assistance (ODA) commitments for water supply and sanitation by all donating countries is provided in this table, from 2007 to 2011, in millions of dollars. The Organisation for Economic Co-operation and Development's (OECD's) Development Assistance Committee (DAC) recently expanded the categories from previous years, and it now identifies the following eleven subsectors in the "water supply and sanitation" category:

Water resources policy and administrative management

Water resources protection

Water supply and sanitation—large systems

Water supply—large systems

Sanitation—large systems

Basic drinking water supply and basic sanitation

Basic drinking water supply

Basic sanitation

River development

Waste management and disposal

Education and training in water supply and sanitation

By far the largest expenditure is for large-scale water supply and sanitation projects; basic water supply and sanitation projects generally receive less than half as much funding as large-scale projects. One concern of many analysts is that much ODA is directed to serving wealthier populations, or to improving services to populations that are already at least partly served by existing systems, and hence does not contribute to meeting the water- and sanitation-related Millennium Development Goals.

## Limitations

ODA does not constitute all of the funding that flows to developing countries, such as other public sector or private sector flows; hence, these numbers do not reflect all funding for water projects. These data do not readily compare with those published in the previous volume of *The World's Water* as a result of changes in categorizations by the OECD. The development statistics provided by the OECD do not clearly differentiate where there might be double-counting of assistance in multiple categories.

## Source

Organisation for Economic Co-operation and Development (OECD). 2013. Query Wizard for International Development Statistics. <http://stats.oecd.org/qwids/>.



**DATA TABLE 11** Overseas Development Assistance for Water Supply and Sanitation, by Subsector, 2007 to 2011 (Total of All Donating Countries)

| Water Sector(s)                                       | Amount Committed in Millions of Dollars |          |          |          |          |
|---|---|----------|----------|----------|----------|
|   | 2007                                    | 2008     | 2009     | 2010     | 2011     |
| Water resources policy and administrative management  | 762.04                                  | 927.19   | 795.70   | 980.29   | 842.79   |
| Water resources protection                            | 128.65                                  | 247.58   | 172.47   | 69.95    | 193.92   |
| Water supply and sanitation—large systems             | 3,980.24                                | 4,555.75 | 4,163.96 | 2,146.08 | 1,417.39 |
| Water supply—large systems                            | —                                       | —        | —        | 1,333.36 | 1,504.10 |
| Sanitation—large systems                              | —                                       | —        | —        | 639.25   | 1,506.55 |
| Basic drinking water supply and basic sanitation      | 978.62                                  | 1,170.90 | 3,027.27 | 962.34   | 1,067.98 |
| Basic drinking water supply                           | —                                       | —        | —        | 664.46   | 402.73   |
| Basic sanitation                                      | —                                       | —        | —        | 409.87   | 160.46   |
| River development                                     | 282.18                                  | 411.89   | 219.74   | 234.88   | 377.62   |
| Waste management and disposal                         | 414.94                                  | 155.04   | 255.07   | 270.26   | 373.46   |
| Education and training in water supply and sanitation | 16.17                                   | 67.02    | 16.70    | 69.35    | 76.82    |
| Water Supply and Sanitation Total                     | 6,562.82                                | 7,535.37 | 8,650.92 | 7,780.09 | 7,923.82 |

# Per Capita Water Footprint of National Consumption, by Country, 1996–2005

## Description

Conventional estimates of national water use have historically been restricted to statistics on water withdrawals within national boundaries. In recent years, a new approach has been developed and applied to calculate water “footprints,” which include water use (typically withdrawals and consumption, estimated separately), the use of “green water” and “grey water,” and information about water used in other countries to produce imported products. Quantifying these national water footprints is an evolving field.

The data here include the per capita water footprint for internal and external water consumption by country, measured in cubic meters per person per year ( $\text{m}^3/\text{cap}/\text{yr}$ ), averaged over the decade 1996–2005. Data on population assumptions are also shown. A distinction is made between “green” and “blue” water. In addition, the authors include the grey water footprint in the estimation of the water footprint in each sector, an estimate of the footprint of farm animal products, and details on the water footprints of national imports and exports.

Freshwater footprints are reported in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time. A water footprint has three components: green, blue, and grey. The “blue water” footprint refers to use of surface water and groundwater. The “green water” footprint is the volume of rainwater consumed, which is particularly relevant in agricultural production. The “grey water” footprint is a measure of freshwater pollution and is defined as the volume of freshwater required to assimilate a load of pollutants.

## Limitations

While the concept of the water footprint is an extremely valuable one, the process for computing footprints continues to evolve, and data sets continue to improve. For example, water withdrawal numbers are often not accurately or consistently reported (see, e.g., the description of data table 2). Estimates of agricultural water use depend on a mix of implicit and explicit assumptions about actual irrigation levels, climatic data for certain crop types, and irrigation technologies. Some consumer categories are not included

or accurately estimated. Estimates of the water footprint of imported goods are produced using global averages because of constraints on information of the location of exported goods. The grey water footprint estimates are based on a limited set of pollutants—leaching and runoff of nitrogen fertilizers—and exclude the potential effects of other agricultural chemicals, including pesticides.

See the original source for far more detail on the fundamental assumptions and limitations of the footprint approach.

## Source

Mekonnen, M. M., and A. Y. Hoekstra. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Value of Water Research Report Series No. 50. Delft, Netherlands: UNESCO-IHE Institute for Water Education. <http://www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Voll.pdf>.

**DATA TABLE 12 Per Capita Water Footprint of National Consumption, by Country, 1996–2005 (m<sup>3</sup>/cap/yr)**

| Country                | Water Footprint of National Consumption |          |       |       |          |       |         |         |       |         |         |      |
|------------------------|---|----------|-------|-------|----------|-------|---------|---------|-------|---------|---------|------|
|                        | Total Population (Thousands)            | Internal |       |       | External |       |         | Total   |       |         |         |      |
|                        |   | Green    | Blue  | Grey  | Green    | Blue  | Grey    | Green   | Blue  | Grey    | Blue    | Grey |
| Albania                | 3,084.9                                 | 602.2    | 106.4 | 218.9 | 492.7    | 78.7  | 56.4    | 1,094.9 | 185.0 | 275.3   | 1,555.2 |      |
| Algeria                | 30,767.4                                | 634.6    | 93.8  | 43.6  | 700.6    | 51.2  | 65.7    | 1,335.2 | 145.0 | 109.4   | 1,589.5 |      |
| Angola                 | 14,609.8                                | 798.4    | 14.2  | 8.2   | 108.4    | 14.7  | 14.3    | 906.8   | 28.9  | 22.6    | 958.3   |      |
| Antigua and Barbuda    | 77.4                                    | 391.2    | 5.3   | 44.0  | 828.0    | 100.9 | 198.5   | 1,219.2 | 106.2 | 242.6   | 1,567.9 |      |
| Argentina              | 37,060.0                                | 1,288.3  | 104.3 | 152.8 | 35.0     | 5.6   | 20.7    | 1,323.4 | 109.9 | 173.5   | 1,606.8 |      |
| Armenia                | 3,089.5                                 | 516.3    | 134.6 | 237.1 | 450.2    | 41.8  | 58.8    | 966.5   | 176.4 | 295.8   | 1,438.8 |      |
| Australia              | 19,320.0                                | 1,716.9  | 194.9 | 130.7 | 136.3    | 21.5  | 114.3   | 1,853.3 | 216.3 | 245.0   | 2,314.6 |      |
| Austria                | 8,057.3                                 | 396.3    | 16.2  | 92.9  | 738.1    | 82.5  | 271.5   | 1,134.4 | 98.7  | 364.4   | 1,597.5 |      |
| Azerbaijan             | 8,155.3                                 | 510.0    | 176.6 | 198.3 | 310.6    | 26.0  | 23.3    | 820.6   | 202.6 | 221.6   | 1,244.9 |      |
| Bahamas                | 306.3                                   | 200.8    | —     | —     | 1,348.9  | 167.4 | 415.8   | 1,549.7 | 167.4 | 415.8   | 2,132.9 |      |
| Bangladesh             | 141,966.7                               | 477.9    | 57.3  | 99.8  | 98.1     | 22.5  | 13.0    | 576.0   | 79.8  | 112.8   | 768.6   |      |
| Barbados               | 253.0                                   | 553.0    | 19.9  | 255.5 | 941.3    | 117.3 | 202.9   | 1,494.2 | 137.2 | 458.4   | 2,089.9 |      |
| Belarus                | 10,030.1                                | 1,091.2  | 19.3  | 223.4 | 215.8    | 44.2  | 123.8   | 1,306.9 | 63.5  | 347.2   | 1,717.6 |      |
| Belgium                | 10,401.0                                | 34.5     | 21.7  | 148.9 | 1,181.2  | 120.5 | 380.7   | 1,215.7 | 142.2 | 529.6   | 1,887.5 |      |
| Belize                 | 254.6                                   | 1,154.7  | 39.2  | 585.9 | 120.9    | 38.5  | 71.0    | 1,275.7 | 77.8  | 656.9   | 2,010.4 |      |
| Benin                  | 6,820.0                                 | 1,020.2  | 1.9   | 14.5  | 67.3     | 20.3  | 11.9    | 1,087.5 | 22.1  | 26.5    | 1,136.1 |      |
| Bermuda                | 63.0                                    | 6.8      | 2.0   | 4.8   | 1,706.9  | 230.2 | 1,044.7 | 1,713.7 | 232.1 | 1,049.5 | 2,995.3 |      |
| Bolivia                | 8,408.8                                 | 3,063.9  | 47.4  | 29.2  | 295.9    | 15.3  | 16.2    | 3,359.9 | 62.7  | 45.3    | 3,467.9 |      |
| Bosnia and Herzegovina | 3,631.7                                 | 659.0    | 4.7   | 33.2  | 408.2    | 28.8  | 122.2   | 1,067.3 | 33.4  | 155.5   | 1,256.1 |      |
| Botswana               | 1,725.8                                 | 1,202.0  | 13.9  | 54.9  | 561.7    | 179.8 | 38.9    | 1,763.7 | 193.7 | 93.8    | 2,051.2 |      |
| Brazil                 | 175,307.6                               | 1,644.8  | 57.7  | 137.5 | 159.6    | 12.7  | 14.8    | 1,804.4 | 70.4  | 152.3   | 2,027.1 |      |
| Brunei Darussalam      | 336.8                                   | 25.5     | 0.0   | 0.0   | 2,796.4  | 334.1 | 264.5   | 2,821.9 | 334.1 | 264.5   | 3,420.6 |      |
| Bulgaria               | 7,988.3                                 | 1,478.9  | 35.1  | 352.7 | 330.3    | 47.6  | 52.2    | 1,809.2 | 82.6  | 405.0   | 2,296.8 |      |
| Burkina Faso           | 11,950.2                                | 1,600.1  | 16.7  | 28.5  | 37.4     | 14.6  | 5.7     | 1,637.5 | 31.2  | 34.2    | 1,702.9 |      |

*continues*

**DATA TABLE 12** *continued*

| Country                    | Total Population (Thousands) | Water Footprint of National Consumption |       |       |          |       |       |         |       |       |         |       |      |
|----------------------------|------------------------------|---|-------|-------|----------|-------|-------|---------|-------|-------|---------|-------|------|
|                            |                              | Internal                                |       |       | External |       |       | Total   |       |       |         |       |      |
|                            |                              | Green                                   | Blue  | Grey  | Green    | Blue  | Grey  | Green   | Blue  | Grey  | Blue    | Green | Grey |
| Burundi                    | 6,651.7                      | 677.3                                   | 15.0  | 9.8   | 13.2     | 1.3   | 2.0   | 690.5   | 16.3  | 11.8  | 718.6   |       |      |
| Cambodia                   | 12,834.1                     | 955.7                                   | 54.1  | 6.5   | 47.7     | 8.3   | 5.6   | 1,003.5 | 62.4  | 12.1  | 1,077.9 |       |      |
| Cameroon                   | 16,080.9                     | 1,144.8                                 | 10.5  | 21.9  | 37.5     | 21.2  | 9.1   | 1,182.3 | 31.7  | 31.0  | 1,245.0 |       |      |
| Canada                     | 30,889.0                     | 1,345.1                                 | 79.7  | 426.1 | 254.9    | 73.8  | 153.6 | 1,600.0 | 153.6 | 579.7 | 2,333.3 |       |      |
| Cape Verde                 | 442.6                        | 599.3                                   | 22.9  | 4.1   | 495.1    | 65.0  | 57.8  | 1,094.4 | 87.9  | 61.8  | 1,244.1 |       |      |
| Central African Republic   | 3,772.3                      | 1,147.8                                 | 19.3  | 5.3   | 14.4     | 2.9   | 3.3   | 1,162.3 | 22.2  | 8.6   | 1,193.1 |       |      |
| Chad                       | 8,614.3                      | 1,425.0                                 | 20.3  | 4.2   | 7.7      | 2.6   | 1.9   | 1,432.7 | 23.0  | 6.1   | 1,461.7 |       |      |
| Chile                      | 15,492.1                     | 451.5                                   | 150.8 | 166.5 | 327.3    | 20.0  | 38.5  | 778.8   | 170.8 | 205.0 | 1,154.6 |       |      |
| China                      | 1,277,208.3                  | 614.3                                   | 106.3 | 243.7 | 86.2     | 11.2  | 9.4   | 700.5   | 117.5 | 253.1 | 1,071.1 |       |      |
| Colombia                   | 40,093.6                     | 894.5                                   | 48.0  | 158.8 | 227.0    | 18.7  | 28.0  | 1,121.5 | 66.6  | 186.8 | 1,374.9 |       |      |
| Comoros                    | 710.2                        | 1,107.4                                 | 2.9   | 6.7   | 102.1    | 84.9  | 21.1  | 1,209.5 | 87.9  | 27.8  | 1,325.2 |       |      |
| Congo, Democratic Republic | 52,052.6                     | 529.8                                   | 2.1   | 4.0   | 10.2     | 3.4   | 2.7   | 540.0   | 5.4   | 6.6   | 552.1   |       |      |
| Congo, Republic            | 3,096.2                      | 506.6                                   | 7.5   | 10.6  | 191.3    | 47.9  | 22.3  | 697.9   | 55.4  | 32.9  | 786.2   |       |      |
| Costa Rica                 | 3,962.9                      | 687.7                                   | 60.5  | 277.0 | 348.5    | 49.8  | 66.9  | 1,036.2 | 110.3 | 343.9 | 1,490.4 |       |      |
| Côte d'Ivoire              | 17,422.3                     | 1,158.5                                 | 8.2   | 31.1  | 45.5     | 36.6  | 15.6  | 1,204.0 | 44.8  | 46.7  | 1,295.5 |       |      |
| Croatia                    | 4,520.8                      | 892.7                                   | 1.1   | 143.0 | 462.3    | 36.6  | 152.1 | 1,355.0 | 37.7  | 295.0 | 1,687.8 |       |      |
| Cuba                       | 11,090.9                     | 1,189.6                                 | 93.1  | 179.6 | 175.2    | 12.6  | 37.0  | 1,364.9 | 105.7 | 216.6 | 1,687.2 |       |      |
| Cyprus                     | 790.9                        | 364.4                                   | 229.3 | 91.0  | 1,317.9  | 120.0 | 262.8 | 1,682.3 | 349.3 | 353.8 | 2,385.4 |       |      |
| Czech Republic             | 10,228.3                     | 818.6                                   | 15.2  | 203.2 | 418.2    | 64.5  | 130.9 | 1,236.7 | 79.7  | 334.2 | 1,650.6 |       |      |
| Denmark                    | 5,339.5                      | 512.7                                   | 13.3  | 97.1  | 709.4    | 82.2  | 219.9 | 1,222.1 | 95.5  | 317.0 | 1,634.6 |       |      |
| Dominica                   | 68.1                         | 2,169.8                                 | —     | 23.9  | 361.8    | 83.5  | 77.4  | 2,531.7 | 83.5  | 101.3 | 2,716.5 |       |      |
| Dominican Republic         | 8,900.7                      | 740.4                                   | 105.3 | 105.9 | 366.6    | 25.2  | 57.9  | 1,107.0 | 130.5 | 163.8 | 1,401.3 |       |      |
| East Timor                 | 868.1                        | 1,748.0                                 | 43.0  | —     | 48.1     | 10.6  | 13.6  | 1,796.1 | 53.6  | 13.6  | 1,863.2 |       |      |
| Ecuador                    | 12,367.9                     | 1,388.6                                 | 136.3 | 244.8 | 199.2    | 11.8  | 26.0  | 1,587.9 | 148.0 | 270.9 | 2,006.8 |       |      |

|                  |             |         |       |       |         |       |       |         |       |       |         |
|------------------|-------------|---------|-------|-------|---------|-------|-------|---------|-------|-------|---------|
| Egypt            | 70,957.6    | 150.8   | 506.6 | 301.3 | 333.8   | 20.1  | 28.5  | 484.5   | 526.7 | 329.8 | 1,341.0 |
| El Salvador      | 5,944.5     | 578.9   | 13.6  | 115.4 | 249.3   | 37.4  | 37.9  | 828.2   | 51.0  | 153.3 | 1,032.5 |
| Eritrea          | 3,786.8     | 533.1   | 2.7   | 8.1   | 494.1   | 27.1  | 23.8  | 1,027.2 | 29.8  | 31.9  | 1,088.9 |
| Estonia          | 1,372.7     | 712.5   | 8.0   | 110.4 | 601.9   | 148.5 | 138.4 | 1,314.4 | 156.5 | 248.8 | 1,719.7 |
| Ethiopia         | 66,511.7    | 1,107.7 | 23.3  | 9.8   | 20.4    | 1.8   | 4.2   | 1,128.1 | 25.1  | 14.0  | 1,167.2 |
| Fiji Islands     | 803.6       | 1,195.0 | 2.8   | 51.0  | 415.6   | 59.1  | 43.8  | 1,610.6 | 61.9  | 94.7  | 1,767.3 |
| Finland          | 5,181.9     | 651.0   | 18.0  | 79.4  | 406.2   | 61.5  | 197.7 | 1,057.2 | 79.5  | 277.2 | 1,413.9 |
| France           | 59,435.5    | 735.3   | 48.4  | 156.4 | 618.1   | 86.8  | 140.6 | 1,353.4 | 135.2 | 297.0 | 1,785.7 |
| French Polynesia | 237.9       | 907.3   | 2.6   | 6.2   | 630.6   | 146.9 | 182.8 | 1,537.9 | 149.5 | 189.0 | 1,876.4 |
| Gabon            | 1,245.3     | 1,020.4 | 15.0  | 52.9  | 271.1   | 55.2  | 36.2  | 1,291.5 | 70.2  | 89.1  | 1,450.8 |
| Gambia           | 1,324.9     | 541.9   | 1.8   | 12.2  | 246.4   | 52.4  | 32.2  | 788.2   | 54.2  | 44.4  | 886.9   |
| Georgia          | 4,719.9     | 1,219.7 | 97.0  | 282.3 | 587.4   | 35.3  | 45.7  | 1,807.1 | 132.3 | 328.0 | 2,267.5 |
| Germany          | 82,138.8    | 311.4   | 18.0  | 116.2 | 741.9   | 67.2  | 171.6 | 1,053.3 | 85.1  | 287.8 | 1,426.3 |
| Ghana            | 19,784.5    | 1,091.4 | 3.3   | 19.3  | 57.7    | 21.0  | 14.2  | 1,149.0 | 24.3  | 33.5  | 1,206.9 |
| Greece           | 10,937.4    | 890.9   | 218.6 | 142.1 | 761.1   | 107.4 | 218.0 | 1,652.0 | 326.0 | 360.1 | 2,338.1 |
| Grenada          | 101.5       | 1,267.2 | 2.2   | —     | 636.9   | 94.5  | 153.3 | 1,904.1 | 96.7  | 153.3 | 2,154.0 |
| Guatemala        | 11,412.4    | 713.0   | 15.0  | 68.8  | 136.1   | 18.8  | 31.0  | 849.0   | 33.8  | 99.8  | 982.7   |
| Guinea           | 8,463.3     | 1,492.1 | 6.6   | 16.3  | 52.7    | 26.4  | 11.4  | 1,544.9 | 33.0  | 27.7  | 1,605.6 |
| Guinea-Bissau    | 1,325.7     | 1,028.8 | 65.0  | 19.7  | 31.2    | 40.2  | 12.7  | 1,060.0 | 105.2 | 32.4  | 1,197.6 |
| Guyana           | 759.1       | 1,046.5 | 101.0 | 159.6 | 165.2   | 23.4  | 52.7  | 1,211.7 | 124.5 | 212.2 | 1,548.4 |
| Haiti            | 8,719.4     | 780.9   | 26.4  | 6.0   | 141.0   | 49.9  | 25.6  | 921.9   | 76.3  | 31.6  | 1,029.8 |
| Honduras         | 6,299.4     | 913.5   | 19.4  | 71.4  | 123.3   | 28.0  | 21.9  | 1,036.7 | 47.4  | 93.3  | 1,177.5 |
| Hungary          | 10,199.8    | 1,547.2 | 24.5  | 303.5 | 369.2   | 41.2  | 98.4  | 1,916.3 | 65.7  | 401.8 | 2,383.9 |
| Iceland          | 282.2       | 14.5    | 31.7  | 195.9 | 1,468.9 | 102.3 | 295.5 | 1,483.4 | 133.9 | 491.4 | 2,108.7 |
| India            | 1,051,289.5 | 685.5   | 216.7 | 159.0 | 22.4    | 2.2   | 3.0   | 707.9   | 218.9 | 162.0 | 1,088.8 |
| Indonesia        | 206,706.2   | 854.8   | 48.8  | 107.0 | 77.8    | 24.3  | 10.8  | 932.7   | 73.1  | 117.7 | 1,123.5 |
| Iran             | 67,157.7    | 749.4   | 568.1 | 215.6 | 289.5   | 20.7  | 23.2  | 1,038.9 | 588.8 | 238.7 | 1,866.5 |
| Ireland          | 3,868.6     | 278.8   | 9.7   | 79.9  | 660.8   | 99.0  | 173.2 | 939.6   | 108.7 | 253.2 | 1,301.4 |
| Israel           | 6,134.0     | 207.4   | 145.2 | 72.9  | 1,583.1 | 108.1 | 186.1 | 1,790.5 | 253.3 | 259.0 | 2,302.7 |
| Italy            | 57,520.5    | 629.3   | 66.7  | 209.5 | 1,091.2 | 126.1 | 180.3 | 1,720.5 | 192.7 | 389.8 | 2,302.9 |

*continues*

**DATA TABLE 12** *continued*

| Country                        | Total Population (Thousands) | Water Footprint of National Consumption |       |       |         |          |       |         |       |       |         |      |       |
|--------------------------------|------------------------------|---|-------|-------|---------|----------|-------|---------|-------|-------|---------|------|-------|
|                                |                              | Internal                                |       |       |         | External |       |         |       | Total |         |      |       |
|                                |                              | Green                                   | Blue  | Grey  | Grey    | Green    | Blue  | Grey    | Grey  | Green | Blue    | Grey | Total |
| Jamaica                        | 2,578.4                      | 838.5                                   | 23.8  | 83.9  | 585.7   | 66.2     | 98.0  | 1,424.2 | 90.0  | 181.9 | 1,696.2 |      |       |
| Japan                          | 126,741.3                    | 176.6                                   | 29.3  | 112.9 | 832.8   | 61.7     | 165.8 | 1,009.4 | 91.0  | 278.7 | 1,379.0 |      |       |
| Jordan                         | 4,956.1                      | 112.5                                   | 82.0  | 43.8  | 1,126.3 | 167.3    | 146.2 | 1,238.8 | 249.3 | 189.9 | 1,678.0 |      |       |
| Kazakhstan                     | 15,160.4                     | 1,710.6                                 | 355.5 | 175.7 | 81.1    | 17.9     | 35.6  | 1,791.7 | 373.4 | 211.3 | 2,376.4 |      |       |
| Kenya                          | 31,935.3                     | 875.1                                   | 10.9  | 24.1  | 155.8   | 23.6     | 11.9  | 1,031.0 | 34.4  | 35.9  | 1,101.3 |      |       |
| Kiribati                       | 85.0                         | 2,341.6                                 | —     | —     | 314.7   | 148.8    | 54.1  | 2,656.3 | 148.8 | 54.1  | 2,859.2 |      |       |
| Korea, Democratic People's Rep | 22,867.1                     | 542.5                                   | 70.1  | 149.6 | 91.0    | 17.0     | 18.2  | 633.4   | 87.1  | 167.9 | 888.4   |      |       |
| Korea, Republic                | 46,443.0                     | 252.4                                   | 25.9  | 78.6  | 1,032.7 | 85.4     | 154.2 | 1,285.2 | 111.3 | 232.8 | 1,629.3 |      |       |
| Kuwait                         | 2,251.5                      | 6.6                                     | 40.9  | 170.8 | 1,412.9 | 251.0    | 190.2 | 1,419.5 | 291.9 | 361.0 | 2,072.4 |      |       |
| Kyrgyzstan                     | 4,961.6                      | 495.4                                   | 249.7 | 99.1  | 593.5   | 27.9     | 33.8  | 1,088.9 | 277.6 | 132.9 | 1,499.4 |      |       |
| Laos                           | 5,431.9                      | 891.0                                   | 67.8  | 43.2  | 27.3    | 4.3      | 7.9   | 918.3   | 72.1  | 51.1  | 1,041.4 |      |       |
| Latvia                         | 2,368.7                      | 1,036.6                                 | 8.6   | 150.2 | 289.9   | 55.5     | 256.0 | 1,326.5 | 64.1  | 406.2 | 1,796.8 |      |       |
| Lebanon                        | 3,816.5                      | 303.4                                   | 186.6 | 82.3  | 1,245.0 | 148.0    | 146.2 | 1,548.4 | 334.7 | 228.5 | 2,111.5 |      |       |
| Lesotho                        | 1,890.3                      | 1,533.5                                 | 4.2   | 15.5  | 40.2    | 33.0     | 13.1  | 1,573.7 | 37.2  | 28.7  | 1,639.5 |      |       |
| Liberia                        | 2,790.3                      | 1,064.7                                 | 2.6   | 15.4  | 64.8    | 33.2     | 53.8  | 1,129.5 | 35.8  | 69.3  | 1,234.6 |      |       |
| Libya                          | 5,411.9                      | 301.2                                   | 283.6 | 129.0 | 981.3   | 227.7    | 115.6 | 1,282.5 | 511.3 | 244.5 | 2,038.3 |      |       |
| Lithuania                      | 3,501.4                      | 1,048.4                                 | 6.7   | 58.9  | 218.3   | 47.7     | 135.9 | 1,266.7 | 54.4  | 194.8 | 1,516.0 |      |       |
| Luxembourg                     | 450.5                        | 508.9                                   | 7.2   | 110.2 | 1,432.2 | 96.3     | 359.5 | 1,941.2 | 103.5 | 469.6 | 2,514.3 |      |       |
| Macedonia                      | 2,010.5                      | 602.2                                   | 49.6  | 182.4 | 382.7   | 43.0     | 88.0  | 984.8   | 92.6  | 270.4 | 1,347.8 |      |       |
| Madagascar                     | 15,529.4                     | 1,329.4                                 | 148.4 | 38.7  | 36.2    | 16.2     | 7.2   | 1,365.6 | 164.6 | 45.9  | 1,576.1 |      |       |
| Malawi                         | 12,005.8                     | 804.1                                   | 13.8  | 59.9  | 48.4    | 3.1      | 6.9   | 852.6   | 17.0  | 66.8  | 936.3   |      |       |
| Malaysia                       | 23,458.2                     | 1,240.6                                 | 56.5  | 128.6 | 503.3   | 96.3     | 78.1  | 1,743.9 | 152.8 | 206.7 | 2,103.3 |      |       |
| Maldives                       | 273.5                        | 221.8                                   | 5.3   | 15.6  | 813.5   | 164.2    | 140.6 | 1,035.3 | 169.5 | 156.2 | 1,361.1 |      |       |
| Mali                           | 10,701.0                     | 1,769.6                                 | 145.6 | 54.5  | 54.8    | 11.1     | 8.2   | 1,824.4 | 156.7 | 62.7  | 2,043.8 |      |       |



|                                |           |         |       |       |         |       |       |         |       |       |         |
|--------------------------------|-----------|---------|-------|-------|---------|-------|-------|---------|-------|-------|---------|
| Malta                          | 391.0     | 74.1    | 20.1  | 88.6  | 1,600.7 | 186.6 | 245.7 | 1,674.8 | 206.7 | 334.3 | 2,215.8 |
| Mauritania                     | 2,648.1   | 1,262.0 | 84.4  | 62.1  | 1,036.8 | 85.0  | 34.9  | 2,298.8 | 169.4 | 96.9  | 2,565.1 |
| Mauritius                      | 1,199.6   | 371.9   | 26.8  | 153.6 | 1,238.9 | 219.2 | 150.3 | 1,610.8 | 246.0 | 303.9 | 2,160.6 |
| Mexico                         | 99,810.4  | 840.0   | 101.7 | 195.3 | 661.1   | 88.5  | 91.4  | 1,501.1 | 190.2 | 286.7 | 1,978.0 |
| Moldova                        | 4,051.3   | 983.2   | 105.9 | 138.3 | 55.7    | 14.8  | 29.0  | 1,038.9 | 120.7 | 167.2 | 1,326.8 |
| Mongolia                       | 2,409.3   | 1,316.3 | 40.7  | 87.0  | 2,207.8 | 54.6  | 68.1  | 3,524.1 | 95.3  | 155.2 | 3,774.6 |
| Morocco                        | 28,961.9  | 981.3   | 171.1 | 69.2  | 424.2   | 37.7  | 41.2  | 1,405.5 | 208.8 | 110.4 | 1,724.8 |
| Mozambique                     | 18,560.9  | 1,022.6 | 8.3   | 9.9   | 61.8    | 9.3   | 7.2   | 1,084.4 | 17.6  | 17.2  | 1,119.2 |
| Myanmar                        | 46,626.5  | 1,124.8 | 42.2  | 27.7  | 18.0    | 1.3   | 3.0   | 1,142.8 | 43.5  | 30.7  | 1,217.0 |
| Namibia                        | 1,839.1   | 1,169.4 | 22.9  | 53.1  | 339.6   | 68.4  | 28.9  | 1,509.0 | 91.3  | 82.0  | 1,682.2 |
| Nepal                          | 24,707.0  | 944.6   | 115.1 | 20.9  | 94.9    | 9.9   | 15.2  | 1,039.5 | 125.0 | 36.1  | 1,200.6 |
| Netherlands                    | 15,946.9  | 43.6    | 12.7  | 22.9  | 1,012.3 | 116.2 | 258.0 | 1,055.9 | 128.9 | 280.9 | 1,465.7 |
| New Caledonia                  | 216.8     | 550.6   | 0.2   | 35.8  | 1,100.4 | 128.2 | 179.6 | 1,651.0 | 128.4 | 215.4 | 1,994.7 |
| New Zealand                    | 3,905.5   | 477.3   | 90.3  | 104.9 | 720.0   | 58.4  | 137.8 | 1,197.3 | 148.7 | 242.7 | 1,588.8 |
| Nicaragua                      | 5,125.0   | 682.6   | 30.2  | 53.8  | 104.6   | 20.2  | 20.8  | 787.2   | 50.4  | 74.6  | 912.1   |
| Niger                          | 11,272.1  | 3,351.9 | 64.5  | 12.6  | 59.1    | 22.6  | 7.9   | 3,411.0 | 87.1  | 20.5  | 3,518.7 |
| Nigeria                        | 126,648.8 | 1,147.3 | 12.3  | 19.1  | 43.9    | 11.6  | 8.1   | 1,191.2 | 23.9  | 27.2  | 1,242.3 |
| Norway                         | 4,501.6   | 344.7   | 21.6  | 86.3  | 678.8   | 100.9 | 190.5 | 1,023.5 | 122.5 | 276.8 | 1,422.8 |
| Occupied Palestinian Territory | 3,221.2   | 788.8   | 120.4 | 68.1  | 30.1    | 6.7   | 40.5  | 819.0   | 127.1 | 108.6 | 1,054.6 |
| Pakistan                       | 149,801.8 | 535.5   | 406.6 | 172.3 | 191.7   | 15.2  | 10.0  | 727.2   | 421.8 | 182.2 | 1,331.3 |
| Panama                         | 2,979.1   | 747.2   | 37.2  | 162.5 | 311.5   | 34.6  | 70.7  | 1,058.7 | 71.8  | 233.2 | 1,363.7 |
| Paraguay                       | 5,406.5   | 1,789.1 | 41.9  | 66.6  | 26.1    | 12.2  | 18.3  | 1,815.2 | 54.1  | 84.9  | 1,954.1 |
| Peru                           | 26,157.7  | 502.4   | 135.4 | 97.2  | 307.8   | 16.1  | 29.2  | 810.2   | 151.5 | 126.3 | 1,088.0 |
| Philippines                    | 78,472.9  | 994.4   | 51.9  | 145.2 | 133.0   | 26.2  | 27.1  | 1,127.3 | 78.1  | 172.2 | 1,377.7 |
| Poland                         | 38,408.0  | 778.0   | 18.6  | 262.4 | 232.6   | 40.2  | 73.6  | 1,010.6 | 58.8  | 336.0 | 1,405.4 |
| Portugal                       | 10,278.4  | 696.3   | 161.9 | 146.1 | 1,157.9 | 201.3 | 141.9 | 1,854.2 | 363.2 | 288.1 | 2,505.5 |
| Romania                        | 22,089.3  | 1,183.2 | 39.4  | 217.0 | 161.5   | 37.3  | 50.3  | 1,344.8 | 76.7  | 267.3 | 1,688.8 |
| Russian Federation             | 146,082.3 | 1,374.8 | 55.9  | 191.7 | 174.1   | 39.1  | 16.1  | 1,548.9 | 95.0  | 207.8 | 1,851.6 |
| Rwanda                         | 7,735.9   | 775.2   | 3.0   | 6.0   | 24.4    | 5.4   | 7.0   | 799.6   | 8.4   | 13.0  | 821.0   |
| Saint Kitts and Nevis          | 46.4      | 593.4   | 0.2   | 1.2   | 706.7   | 127.9 | 202.3 | 1,300.1 | 128.1 | 203.5 | 1,631.6 |

*continues*

DATA TABLE 12 continued

| Country                  | Total Population (Thousands) | Water Footprint of National Consumption |       |       |          |       |       |         |       |       |         |      |       |
|--------------------------|------------------------------|---|-------|-------|----------|-------|-------|---------|-------|-------|---------|------|-------|
|                          |                              | Internal                                |       |       | External |       |       | Total   |       |       |         |      |       |
|                          |                              | Green                                   | Blue  | Grey  | Green    | Blue  | Grey  | Green   | Blue  | Grey  | Blue    | Grey | Total |
| Saint Lucia              | 157.5                        | 56.4                                    | 8.0   | 71.4  | 1,145.2  | 115.1 | 162.9 | 1,201.6 | 123.2 | 234.4 | 1,559.1 |      |       |
| Saint Vincent/Grenadines | 108.2                        | 878.8                                   | —     | —     | 594.5    | 96.9  | 119.1 | 1,473.3 | 96.9  | 119.1 | 1,689.3 |      |       |
| Samoa                    | 176.1                        | 1,811.4                                 | —     | 0.5   | 168.3    | 64.3  | 37.9  | 1,979.7 | 64.3  | 38.4  | 2,082.4 |      |       |
| São Tomé and Príncipe    | 141.5                        | 1,459.9                                 | 0.7   | —     | 155.8    | 59.5  | 52.0  | 1,615.8 | 60.2  | 52.0  | 1,728.0 |      |       |
| Saudi Arabia             | 21,114.2                     | 126.3                                   | 343.4 | 157.9 | 1,004.9  | 104.1 | 112.7 | 1,131.2 | 447.5 | 270.6 | 1,849.3 |      |       |
| Senegal                  | 10,055.0                     | 757.9                                   | 33.2  | 16.5  | 264.7    | 53.9  | 24.9  | 1,022.6 | 87.1  | 41.3  | 1,151.1 |      |       |
| Serbia and Montenegro    | 10,729.5                     | 1,224.5                                 | 58.5  | 928.1 | 107.5    | 27.9  | 43.3  | 1,332.1 | 86.3  | 971.3 | 2,389.7 |      |       |
| Seychelles               | 80.6                         | 657.7                                   | 50.8  | 126.6 | 1,010.5  | 155.1 | 191.0 | 1,668.1 | 205.9 | 317.6 | 2,191.6 |      |       |
| Sierra Leone             | 4,408.0                      | 1,132.2                                 | 11.5  | 5.5   | 248.5    | 22.9  | 16.9  | 1,380.7 | 34.4  | 22.5  | 1,437.6 |      |       |
| Slovakia                 | 5,377.2                      | 704.2                                   | 21.8  | 141.3 | 310.0    | 51.6  | 106.4 | 1,014.3 | 73.4  | 247.7 | 1,335.4 |      |       |
| Slovenia                 | 1,986.5                      | 373.8                                   | 20.0  | 351.8 | 971.8    | 77.2  | 217.7 | 1,345.6 | 97.2  | 569.5 | 2,012.4 |      |       |
| Solomon Islands          | 421.9                        | 530.2                                   | —     | —     | 138.8    | 22.0  | 31.8  | 668.9   | 22.0  | 31.8  | 722.7   |      |       |
| South Africa             | 45,183.8                     | 786.8                                   | 85.8  | 106.3 | 240.5    | 11.8  | 24.1  | 1,027.3 | 97.6  | 130.4 | 1,255.4 |      |       |
| Spain                    | 40,840.6                     | 1,004.9                                 | 232.2 | 167.1 | 797.3    | 88.9  | 170.8 | 1,802.1 | 321.2 | 338.0 | 2,461.3 |      |       |
| Sri Lanka                | 18,883.5                     | 771.5                                   | 107.7 | 78.4  | 207.7    | 54.5  | 35.9  | 979.3   | 162.2 | 114.2 | 1,255.7 |      |       |
| Sudan                    | 35,224.9                     | 1,428.1                                 | 199.4 | 40.4  | 56.4     | 4.8   | 6.7   | 1,484.5 | 204.1 | 47.1  | 1,735.7 |      |       |
| Suriname                 | 470.8                        | 749.1                                   | 122.1 | 155.4 | 260.3    | 18.5  | 41.6  | 1,009.4 | 140.6 | 196.9 | 1,346.9 |      |       |
| Swaziland                | 1,073.1                      | 491.4                                   | 49.1  | 28.7  | 655.7    | 146.4 | 26.4  | 1,147.0 | 195.5 | 55.0  | 1,397.5 |      |       |
| Sweden                   | 8,911.5                      | 535.5                                   | 18.2  | 129.5 | 502.7    | 61.9  | 180.1 | 1,038.1 | 80.0  | 309.6 | 1,427.8 |      |       |
| Switzerland              | 7,232.5                      | 183.6                                   | 15.5  | 71.9  | 851.4    | 98.8  | 307.1 | 1,035.0 | 114.4 | 379.0 | 1,528.4 |      |       |
| Syria                    | 16,859.5                     | 1,187.6                                 | 348.4 | 236.4 | 270.8    | 38.7  | 25.3  | 1,458.5 | 387.0 | 261.7 | 2,107.2 |      |       |
| Tajikistan               | 6,201.4                      | 647.8                                   | 458.6 | 177.7 | 1,069.1  | 15.4  | 18.6  | 1,716.8 | 474.0 | 196.2 | 2,387.1 |      |       |
| Tanzania                 | 34,719.2                     | 913.4                                   | 24.6  | 18.5  | 52.9     | 10.0  | 6.7   | 966.3   | 34.6  | 25.3  | 1,026.2 |      |       |
| Thailand                 | 62,968.7                     | 939.0                                   | 140.1 | 123.7 | 148.8    | 25.1  | 30.7  | 1,087.8 | 165.2 | 154.4 | 1,407.4 |      |       |

|                      |             |         |       |       |         |       |       |         |       |       |         |
|----------------------|-------------|---------|-------|-------|---------|-------|-------|---------|-------|-------|---------|
| Togo                 | 5,303.9     | 845.6   | 2.9   | 20.7  | 94.5    | 15.2  | 11.3  | 940.0   | 18.0  | 32.0  | 990.1   |
| Trinidad and Tobago  | 1,296.6     | 83.4    | 17.6  | 159.0 | 1,224.9 | 92.4  | 138.7 | 1,308.3 | 110.0 | 297.7 | 1,716.0 |
| Tunisia              | 9,482.7     | 1,299.7 | 130.9 | 68.7  | 504.7   | 137.3 | 75.7  | 1,804.4 | 268.2 | 144.4 | 2,217.0 |
| Turkey               | 66,848.5    | 933.8   | 178.6 | 182.3 | 216.0   | 74.2  | 57.0  | 1,149.9 | 252.8 | 239.3 | 1,641.9 |
| Turkmenistan         | 4,544.7     | 1,239.2 | 729.3 | 90.7  | 185.2   | 10.3  | 18.9  | 1,424.4 | 739.6 | 109.6 | 2,273.6 |
| Uganda               | 24,961.9    | 1,019.2 | 1.0   | 7.7   | 35.9    | 10.0  | 5.2   | 1,055.1 | 11.0  | 12.9  | 1,079.0 |
| UK                   | 59,334.4    | 243.5   | 8.6   | 59.3  | 672.0   | 84.1  | 190.5 | 915.5   | 92.7  | 249.8 | 1,258.1 |
| Ukraine              | 48,737.6    | 1,117.6 | 46.3  | 305.9 | 55.9    | 9.7   | 39.2  | 1,173.6 | 56.0  | 345.1 | 1,574.6 |
| United Arab Emirates | 3,329.8     | 412.7   | 159.3 | 188.7 | 1,508.5 | 411.3 | 455.5 | 1,921.2 | 570.6 | 644.2 | 3,136.0 |
| Uruguay              | 3,307.1     | 1,567.4 | 56.4  | 70.6  | 388.7   | 6.5   | 43.0  | 1,956.2 | 62.9  | 113.6 | 2,132.6 |
| USA                  | 288,958.2   | 1,600.4 | 190.0 | 476.6 | 367.9   | 48.9  | 158.7 | 1,968.3 | 238.9 | 635.3 | 2,842.5 |
| Uzbekistan           | 24,895.6    | 509.9   | 359.7 | 135.7 | 255.6   | 3.6   | 13.9  | 765.5   | 363.3 | 149.5 | 1,278.3 |
| Vanuatu              | 193.8       | 1,264.0 | —     | —     | 45.5    | 75.0  | 46.6  | 1,309.5 | 75.0  | 46.6  | 1,431.2 |
| Venezuela            | 24,640.2    | 874.6   | 64.6  | 184.5 | 527.0   | 23.1  | 36.6  | 1,401.6 | 87.7  | 221.1 | 1,710.3 |
| Vietnam              | 79,188.2    | 637.7   | 81.0  | 271.0 | 52.4    | 6.8   | 9.6   | 690.0   | 87.8  | 280.6 | 1,058.5 |
| Yemen                | 18,502.1    | 71.4    | 127.8 | 20.1  | 551.2   | 90.4  | 40.4  | 622.6   | 218.2 | 60.5  | 901.3   |
| Zambia               | 10,573.6    | 754.0   | 30.8  | 45.7  | 76.2    | 8.0   | 6.5   | 830.2   | 38.9  | 52.2  | 921.3   |
| Zimbabwe             | 12,357.4    | 958.7   | 63.3  | 92.7  | 81.1    | 6.8   | 7.7   | 1,039.7 | 70.1  | 100.4 | 1,210.2 |
| World                | 6,154,564.2 | 796.6   | 117.8 | 170.5 | 218.8   | 35.5  | 46.0  | 1,015.4 | 153.3 | 216.5 | 1,385.2 |

# Per Capita Water Footprint of National Consumption, by Sector and Country, 1996–2005

## Description

Like data table 12, this table includes estimates of water footprints by country, but here they are split into sectoral data on agricultural, industrial, and domestic uses, for “blue,” “green,” and “grey” water, in cubic meters per person per year ( $\text{m}^3/\text{cap}/\text{yr}$ ).

Conventional estimates of national water use have historically been restricted to statistics on water withdrawals within national boundaries. In recent years, a new approach has been developed and applied to calculate water “footprints,” which include water use (typically withdrawals and consumption, estimated separately), the use of “green water” and “grey water,” and information about water used in other countries to produce imported products. Quantifying these national water footprints is an evolving field.

The data here include the water footprints for crop production, industrial production, and domestic water supply, with a distinction made between green and blue water. In addition, the authors include the grey water footprint in the estimation of the water footprint in each sector, an estimate of the footprint of farm animal products, and details on the water footprints of national imports and exports. The data are reported as per capita water consumption, measured in cubic meters per person per year and averaged over the decade 1996–2005. Data on population assumptions are also shown.

Freshwater footprints are reported in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time. A water footprint has three components: green, blue, and grey. The “blue water” footprint refers to use of surface water and groundwater. The “green water” footprint is the volume of rainwater consumed, which is particularly relevant in agricultural production. The “grey water” footprint is a measure of freshwater pollution and is defined as the volume of freshwater required to assimilate a load of pollutants.

## Limitations

While the concept of the water footprint is an extremely valuable one, the process for computing footprints continues to evolve, and data sets continue to improve. For example, water withdrawal numbers are often not accurately or consistently reported (see,

e.g., the description of data table 2). Estimates of agricultural water use depend on a mix of implicit and explicit assumptions about actual irrigation levels, climatic data for certain crop types, and irrigation technologies. Some consumer categories are not included or accurately estimated. Estimates of the water footprint of imported goods are produced using global averages because of constraints on information of the location of exported goods. The grey water footprint estimates are based on a limited set of pollutants—leaching and runoff of nitrogen fertilizers—and exclude the potential effects of other agricultural chemicals, including pesticides.

See the original source for far more detail on the fundamental assumptions and limitations of the footprint approach.

## Source

Mekonnen, M. M., and A. Y. Hoekstra. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Value of Water Research Report Series No. 50. Delft, Netherlands: UNESCO-IHE Institute for Water Education. <http://www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Voll.pdf>.

**DATA TABLE 13** Per Capita Water Footprint of National Consumption, by Sector and Country, 1996–2005 (m<sup>3</sup>/cap/yr)

| Country                | Population<br>(Thousands) | Water Footprint of Consumption<br>of Agricultural Products |       |       |          |       |       | Water Footprint of Consumption<br>of Industrial Products |       |      |          |      |       | Water Footprint<br>of Domestic |      |
|------------------------|---------------------------|--|-------|-------|----------|-------|-------|--|-------|------|----------|------|-------|--------------------------------|------|
|                        |                           | Internal   |       |       | External |       |       | Internal   |       |      | External |      |       | Blue                           | Grey |
|                        |                           | Green  | Blue  | Grey  | Green    | Blue  | Grey  | Blue   | Grey  | Blue | Grey     | Blue | Grey  | Blue                           | Grey |
| Albania                | 3,084.9                   | 602.2  | 88.9  | 36.5  | 492.7    | 77.4  | 39.5  | 2.6  | 48.2  | 1.3  | 17.0     | 14.9 | 134.2 |                                |      |
| Algeria                | 30,767.4                  | 634.6  | 88.8  | 9.6   | 700.6    | 50.6  | 59.7  | 0.7  | 6.4   | 0.6  | 6.1      | 4.3  | 27.7  |                                |      |
| Angola                 | 14,609.8                  | 798.4  | 13.6  | 2.4   | 108.4    | 14.6  | 13.1  | 0.1  | 0.9   | 0.1  | 1.2      | 0.5  | 4.9   |                                |      |
| Antigua and Barbuda    | 77.4                      | 391.2  | 1.0   | —     | 828.0    | 87.8  | 74.8  | 0.5  | 9.2   | 13.1 | 123.7    | 3.9  | 34.9  |                                |      |
| Argentina              | 37,060.0                  | 1,288.3  | 87.9  | 45.4  | 35.0     | 3.9   | 3.0   | 3.1  | 33.9  | 1.7  | 17.7     | 13.2 | 73.5  |                                |      |
| Armenia                | 3,089.5                   | 516.3  | 105.6 | 26.7  | 450.2    | 40.7  | 41.0  | 1.6  | 19.4  | 1.1  | 17.8     | 27.3 | 191.0 |                                |      |
| Australia              | 19,320.0                  | 1,716.9  | 172.0 | 80.9  | 136.3    | 12.0  | 10.1  | 4.6  | 10.4  | 9.4  | 104.2    | 18.2 | 39.5  |                                |      |
| Austria                | 8,057.3                   | 396.3  | 2.0   | 52.4  | 738.1    | 64.2  | 81.0  | 5.1  | 8.0   | 18.3 | 190.5    | 9.2  | 32.5  |                                |      |
| Azerbaijan             | 8,155.3                   | 510.0  | 160.2 | 17.5  | 310.6    | 25.1  | 9.1   | 10.1   | 132.1 | 0.9  | 14.2     | 6.4  | 48.6  |                                |      |
| Bahamas                | 306.3                     | 200.8  | —     | —     | 1,348.9  | 140.1 | 136.7 | —  | —     | 27.3 | 279.2    | —    | —     |                                |      |
| Bangladesh             | 141,966.7                 | 477.9  | 54.4  | 72.9  | 98.1     | 22.4  | 11.2  | 0.1  | 1.4   | 0.1  | 1.8      | 2.8  | 25.5  |                                |      |
| Barbados               | 253.0                     | 553.0  | 1.4   | 24.9  | 941.3    | 108.3 | 120.5 | 6.6  | 123.8 | 9.0  | 82.4     | 11.9 | 106.7 |                                |      |
| Belarus                | 10,030.1                  | 1,091.2  | 7.5   | 199.3 | 215.8    | 37.4  | 10.8  | 5.3  | 4.6   | 6.8  | 113.1    | 6.5  | 19.5  |                                |      |
| Belgium                | 10,401.0                  | 34.5   | 0.1   | 10.0  | 1,181.2  | 92.6  | 97.3  | 14.4   | 112.1 | 27.9 | 283.4    | 7.1  | 26.9  |                                |      |
| Belize                 | 254.6                     | 1,154.7  | 16.3  | 246.6 | 120.9    | 34.2  | 25.7  | 19.1   | 306.5 | 4.3  | 45.3     | 3.9  | 32.8  |                                |      |
| Benin                  | 6,820.0                   | 1,020.2  | 1.0   | 5.2   | 67.3     | 20.0  | 8.6   | 0.2  | 3.9   | 0.3  | 3.3      | 0.6  | 5.4   |                                |      |
| Bermuda                | 63.0                      | 6.8  | 2.0   | 4.8   | 1,706.9  | 150.1 | 128.5 | —  | —     | 80.1 | 916.2    | —    | —     |                                |      |
| Bolivia                | 8,408.8                   | 3,063.9  | 44.8  | 7.9   | 295.9    | 14.8  | 11.6  | 0.5  | 5.8   | 0.5  | 4.6      | 2.1  | 15.4  |                                |      |
| Bosnia and Herzegovina | 3,631.7                   | 659.0  | 4.7   | 33.2  | 408.2    | 24.3  | 63.0  | —  | —     | 4.5  | 59.3     | —    | —     |                                |      |
| Botswana               | 1,725.8                   | 1,202.0  | 8.5   | —     | 561.7    | 179.4 | 34.3  | 0.7  | 13.7  | 0.4  | 4.6      | 4.6  | 41.2  |                                |      |
| Brazil                 | 175,307.6                 | 1,644.8  | 48.5  | 55.4  | 159.6    | 11.8  | 6.1   | 2.4  | 33.5  | 0.8  | 8.7      | 6.9  | 48.6  |                                |      |
| Brunei Darussalam      | 336.8                     | 25.5   | 0.0   | 0.0   | 2,796.4  | 327.3 | 169.2 | —  | —     | 6.8  | 95.3     | —    | —     |                                |      |
| Bulgaria               | 7,988.3                   | 1,478.9  | 7.5   | 124.7 | 330.3    | 45.2  | 19.7  | 13.7   | 139.6 | 2.3  | 32.5     | 13.8 | 88.5  |                                |      |
| Burkina Faso           | 11,950.2                  | 1,600.1  | 15.8  | 20.2  | 37.4     | 14.4  | 4.0   | 0.0  | 0.5   | 0.1  | 1.7      | 0.9  | 7.8   |                                |      |

|                            |             |         |       |       |         |       |      |      |       |      |       |      |       |
|----------------------------|-------------|---------|-------|-------|---------|-------|------|------|-------|------|-------|------|-------|
| Burundi                    | 6,651.7     | 677.3   | 14.1  | 0.8   | 13.2    | 1.2   | 1.3  | 0.1  | 2.4   | 0.1  | 0.7   | 0.7  | 6.6   |
| Cambodia                   | 12,834.1    | 955.7   | 53.6  | 2.1   | 47.7    | 8.0   | 4.2  | 0.0  | 0.2   | 0.2  | 1.4   | 0.5  | 4.2   |
| Cameroon                   | 16,080.9    | 1,144.8 | 9.2   | 8.5   | 37.5    | 21.0  | 6.8  | 0.2  | 3.3   | 0.2  | 2.2   | 1.1  | 10.1  |
| Canada                     | 30,889.0    | 1,345.1 | 24.9  | 172.4 | 254.9   | 60.5  | 30.8 | 25.7 | 140.8 | 13.3 | 122.8 | 29.1 | 112.9 |
| Cape Verde                 | 442.6       | 599.3   | 22.5  | —     | 495.1   | 63.8  | 46.6 | 0.0  | 0.8   | 1.2  | 11.2  | 0.4  | 3.3   |
| Central African Republic   | 3,772.3     | 1,147.8 | 18.8  | 0.0   | 14.4    | 2.9   | 3.0  | 0.0  | 0.5   | 0.0  | 0.2   | 0.5  | 4.8   |
| Chad                       | 8,614.3     | 1,425.0 | 19.9  | 0.0   | 7.7     | 2.6   | 1.4  | —    | —     | 0.1  | 0.5   | 0.5  | 4.2   |
| Chile                      | 15,492.1    | 451.5   | 135.6 | 122.3 | 327.3   | 18.0  | 16.9 | 6.0  | 20.1  | 2.1  | 21.6  | 9.2  | 24.1  |
| China                      | 1,277,208.3 | 614.3   | 98.5  | 170.0 | 86.2    | 10.9  | 5.3  | 2.5  | 31.7  | 0.3  | 4.2   | 5.3  | 41.9  |
| Colombia                   | 40,093.6    | 894.5   | 34.1  | 30.5  | 227.0   | 17.8  | 19.9 | 0.4  | 7.3   | 0.8  | 8.1   | 13.4 | 121.0 |
| Comoros                    | 710.2       | 1,107.4 | 2.2   | —     | 102.1   | 84.6  | 18.2 | 0.0  | 0.6   | 0.3  | 2.9   | 0.7  | 6.1   |
| Congo, Democratic Republic | 52,052.6    | 529.8   | 1.7   | 0.3   | 10.2    | 3.4   | 2.6  | 0.0  | 0.4   | 0.0  | 0.1   | 0.4  | 3.3   |
| Congo, Republic            | 3,096.2     | 506.6   | 6.5   | 1.0   | 191.3   | 47.7  | 21.4 | 0.0  | 0.3   | 0.1  | 0.9   | 1.0  | 9.3   |
| Costa Rica                 | 3,962.9     | 687.7   | 37.4  | 43.1  | 348.5   | 47.1  | 42.6 | 3.1  | 57.0  | 2.7  | 24.3  | 19.9 | 176.9 |
| Côte d'Ivoire              | 17,422.3    | 1,158.5 | 6.7   | 15.0  | 45.5    | 36.3  | 12.1 | 0.3  | 4.8   | 0.3  | 3.5   | 1.3  | 11.4  |
| Croatia                    | 4,520.8     | 892.7   | 0.6   | 136.0 | 462.3   | 28.6  | 49.7 | 0.5  | 6.9   | 8.1  | 102.4 | —    | —     |
| Cuba                       | 11,090.9    | 1,189.6 | 74.9  | 41.4  | 175.2   | 11.7  | 26.7 | 4.2  | 48.6  | 0.8  | 10.3  | 14.1 | 89.6  |
| Cyprus                     | 790.9       | 364.4   | 220.6 | 27.6  | 1,317.9 | 106.7 | 96.7 | 0.2  | 2.4   | 13.3 | 166.1 | 8.5  | 61.0  |
| Czech Republic             | 10,228.3    | 818.6   | 1.0   | 149.2 | 418.2   | 56.2  | 40.8 | 3.9  | 15.0  | 8.3  | 90.1  | 10.3 | 39.1  |
| Denmark                    | 5,339.5     | 512.7   | 3.7   | 75.3  | 709.4   | 66.4  | 58.9 | 1.9  | 4.6   | 15.8 | 161.0 | 7.7  | 17.3  |
| Dominica                   | 68.1        | 2,169.8 | —     | 23.9  | 361.8   | 80.1  | 45.6 | —    | —     | 3.5  | 31.8  | —    | —     |
| Dominican Republic         | 8,900.7     | 740.4   | 92.8  | —     | 366.6   | 23.7  | 44.2 | 0.2  | 4.0   | 1.5  | 13.8  | 12.2 | 101.9 |
| East Timor                 | 868.1       | 1,748.0 | 43.0  | —     | 48.1    | 10.6  | 13.6 | —    | —     | —    | —     | —    | —     |
| Ecuador                    | 12,367.9    | 1,388.6 | 116.4 | 40.3  | 199.2   | 10.8  | 16.1 | 2.7  | 50.3  | 1.0  | 9.9   | 17.1 | 154.3 |
| Egypt                      | 70,957.6    | 150.8   | 496.7 | 189.5 | 333.8   | 19.6  | 22.7 | 2.4  | 44.6  | 0.5  | 5.8   | 7.5  | 67.2  |
| El Salvador                | 5,944.5     | 578.9   | 7.1   | 45.5  | 249.3   | 36.1  | 25.2 | 1.2  | 21.4  | 1.2  | 12.7  | 5.4  | 48.4  |
| Eritrea                    | 3,786.8     | 533.1   | 1.9   | 0.5   | 494.1   | 27.0  | 22.0 | 0.0  | 0.2   | 0.2  | 1.9   | 0.8  | 7.4   |
| Estonia                    | 1,372.7     | 712.5   | 0.2   | 77.8  | 601.9   | 139.0 | 35.0 | 1.2  | 4.3   | 9.5  | 103.4 | 6.6  | 28.2  |
| Ethiopia                   | 66,511.7    | 1,107.7 | 22.7  | 5.0   | 20.4    | 1.8   | 3.1  | 0.0  | 0.3   | 0.1  | 1.0   | 0.5  | 4.5   |
| Fiji Islands               | 803.6       | 1,195.0 | 1.0   | 29.6  | 415.6   | 57.1  | 18.0 | 0.5  | 10.2  | 2.1  | 25.8  | 1.2  | 11.2  |

*continues*



**DATA TABLE 13** *continued*

| Country          | Population<br>(Thousands) | Water Footprint of Consumption<br>of Agricultural Products |       |       |          |       |       | Water Footprint of Consumption<br>of Industrial Products |       |      |          |      |       | Water Footprint<br>of Domestic |      |
|------------------|---------------------------|--|-------|-------|----------|-------|-------|--|-------|------|----------|------|-------|--------------------------------|------|
|                  |                           | Internal   |       |       | External |       |       | Internal   |       |      | External |      |       | Blue                           | Grey |
|                  |                           | Green  | Blue  | Grey  | Green    | Blue  | Grey  | Blue   | Grey  | Blue | Grey     | Blue | Grey  | Blue                           | Grey |
| Finland          | 5,181.9                   | 651.0  | 1.2   | 17.5  | 406.2    | 47.9  | 40.3  | 10.2   | 32.3  | 13.6 | 157.4    | 6.6  | 29.6  |                                |      |
| France           | 59,435.5                  | 735.3  | 23.1  | 63.2  | 618.1    | 77.0  | 35.0  | 14.7   | 55.9  | 9.8  | 105.7    | 10.6 | 37.4  |                                |      |
| French Polynesia | 237.9                     | 907.3  | 2.6   | 6.2   | 630.6    | 135.7 | 82.7  | —  | —     | 11.2 | 100.2    | —    | —     |                                |      |
| Gabon            | 1,245.3                   | 1,020.4  | 10.1  | 6.7   | 271.1    | 54.6  | 30.2  | 0.1  | 2.9   | 0.6  | 6.1      | 4.8  | 43.4  |                                |      |
| Gambia           | 1,324.9                   | 541.9  | 1.2   | 5.4   | 246.4    | 52.2  | 29.4  | 0.1  | 2.0   | 0.2  | 2.8      | 0.5  | 4.8   |                                |      |
| Georgia          | 4,719.9                   | 1,219.7  | 76.2  | 42.6  | 587.4    | 34.2  | 29.4  | 5.6  | 102.5 | 1.1  | 16.3     | 15.3 | 137.3 |                                |      |
| Germany          | 82,138.8                  | 311.4  | 1.0   | 85.9  | 741.9    | 56.9  | 62.3  | 9.9  | 10.4  | 10.3 | 109.4    | 7.1  | 19.9  |                                |      |
| Ghana            | 19,784.5                  | 1,091.4  | 1.9   | 4.8   | 57.7     | 20.6  | 9.7   | 0.2  | 3.8   | 0.4  | 4.6      | 1.2  | 10.7  |                                |      |
| Greece           | 10,937.4                  | 890.9  | 206.0 | 88.0  | 761.1    | 96.4  | 78.2  | 1.0  | 2.7   | 11.0 | 139.9    | 11.6 | 51.4  |                                |      |
| Grenada          | 101.5                     | 1,267.2  | 2.2   | —     | 636.9    | 90.1  | 113.7 | —  | —     | 4.4  | 39.6     | —    | —     |                                |      |
| Guatemala        | 11,412.4                  | 713.0  | 13.0  | 50.3  | 136.1    | 17.7  | 19.8  | 0.9  | 10.1  | 1.1  | 11.2     | 1.1  | 8.4   |                                |      |
| Guinea           | 8,463.3                   | 1,492.1  | 5.1   | 2.5   | 52.7     | 26.3  | 10.2  | 0.1  | 1.4   | 0.1  | 1.3      | 1.4  | 12.4  |                                |      |
| Guinea-Bissau    | 1,325.7                   | 1,028.8  | 63.1  | —     | 31.2     | 40.0  | 11.1  | 0.2  | 4.1   | 0.1  | 1.6      | 1.7  | 15.6  |                                |      |
| Guyana           | 759.1                     | 1,046.5  | 96.6  | 114.9 | 165.2    | 22.1  | 39.6  | 0.5  | 9.1   | 1.3  | 13.1     | 4.0  | 35.6  |                                |      |
| Haiti            | 8,719.4                   | 780.9  | 25.8  | —     | 141.0    | 49.8  | 23.9  | 0.0  | 0.8   | 0.2  | 1.7      | 0.6  | 5.2   |                                |      |
| Honduras         | 6,299.4                   | 913.5  | 18.0  | 55.6  | 123.3    | 27.4  | 16.1  | 0.3  | 5.8   | 0.7  | 5.8      | 1.1  | 10.0  |                                |      |
| Hungary          | 10,199.8                  | 1,547.2  | 7.2   | 200.0 | 369.2    | 34.6  | 24.5  | 10.3   | 66.2  | 6.6  | 73.9     | 7.0  | 37.3  |                                |      |
| Iceland          | 282.2                     | 14.5   | —     | 5.8   | 1,468.9  | 82.3  | 88.1  | 14.0   | 114.3 | 20.0 | 207.4    | 17.7 | 75.7  |                                |      |
| India            | 1,051,289.5               | 685.5  | 210.5 | 91.6  | 22.4     | 2.1   | 1.8   | 1.2  | 22.7  | 0.1  | 1.2      | 5.0  | 44.7  |                                |      |
| Indonesia        | 206,706.2                 | 854.8  | 45.5  | 77.1  | 77.8     | 24.0  | 7.5   | 0.1  | 1.4   | 0.3  | 3.3      | 3.2  | 28.5  |                                |      |
| Iran             | 67,157.7                  | 749.4  | 558.3 | 122.9 | 289.5    | 20.1  | 14.9  | 0.6  | 9.6   | 0.6  | 8.2      | 9.2  | 83.1  |                                |      |
| Ireland          | 3,868.6                   | 278.8  | 0.1   | 37.7  | 660.8    | 90.9  | 65.5  | 2.9  | 11.9  | 8.1  | 107.7    | 6.7  | 30.3  |                                |      |
| Israel           | 6,134.0                   | 207.4  | 134.2 | 54.3  | 1,583.1  | 98.9  | 89.1  | 0.6  | 1.3   | 9.3  | 97.0     | 10.3 | 17.2  |                                |      |
| Italy            | 57,520.5                  | 629.3  | 43.9  | 94.2  | 1,091.2  | 117.0 | 82.4  | 8.7  | 47.7  | 9.1  | 97.8     | 14.0 | 67.7  |                                |      |

|                                     |           |         |       |       |         |       |       |      |       |      |       |      |       |
|-------------------------------------|-----------|---------|-------|-------|---------|-------|-------|------|-------|------|-------|------|-------|
| Jamaica                             | 2,578.4   | 838.5   | 17.3  | 16.2  | 585.7   | 63.8  | 75.7  | 1.0  | 18.8  | 2.5  | 22.3  | 5.4  | 48.9  |
| Japan                               | 126,741.3 | 176.6   | 11.0  | 16.6  | 832.8   | 54.7  | 83.0  | 4.6  | 26.8  | 7.0  | 82.9  | 13.7 | 69.5  |
| Jordan                              | 4,956.1   | 112.5   | 75.8  | 10.1  | 1,126.3 | 163.8 | 103.7 | 0.3  | 2.3   | 3.5  | 42.4  | 5.9  | 31.4  |
| Kazakhstan                          | 15,160.4  | 1,710.6 | 344.2 | 16.5  | 81.1    | 16.4  | 13.0  | 7.4  | 124.1 | 1.5  | 22.6  | 3.9  | 35.0  |
| Kenya                               | 31,935.3  | 875.1   | 9.3   | 8.5   | 155.8   | 23.3  | 8.7   | 0.1  | 2.4   | 0.2  | 3.2   | 1.5  | 13.1  |
| Kiribati                            | 85.0      | 2,341.6 | —     | —     | 314.7   | 148.2 | 48.0  | —    | —     | 0.5  | 6.2   | —    | —     |
| Korea, Democratic People's Republic | 22,867.1  | 542.5   | 58.1  | —     | 91.0    | 16.7  | 14.6  | 4.2  | 79.2  | 0.2  | 3.7   | 7.8  | 70.5  |
| Korea, Republic                     | 46,443.0  | 252.4   | 9.8   | 24.3  | 1,032.7 | 79.7  | 91.9  | 1.9  | 6.6   | 5.7  | 62.4  | 14.3 | 47.7  |
| Kuwait                              | 2,251.5   | 6.6     | 22.9  | 6.4   | 1,412.9 | 246.0 | 138.2 | 0.2  | 4.3   | 4.9  | 51.9  | 17.8 | 160.1 |
| Kyrgyzstan                          | 4,961.6   | 495.4   | 240.8 | 14.4  | 593.5   | 26.9  | 16.8  | 2.4  | 32.3  | 1.0  | 17.0  | 6.4  | 52.5  |
| Laos                                | 5,431.9   | 891.0   | 64.2  | 0.2   | 27.3    | 3.9   | 2.4   | 1.2  | 21.5  | 0.3  | 5.4   | 2.4  | 21.5  |
| Latvia                              | 2,368.7   | 1,036.6 | 0.2   | 107.3 | 289.9   | 39.6  | 24.5  | 1.7  | 9.8   | 15.9 | 231.5 | 6.8  | 33.0  |
| Lebanon                             | 3,816.5   | 303.4   | 174.8 | 33.7  | 1,245.0 | 142.7 | 76.7  | 1.8  | 11.0  | 5.4  | 69.4  | 10.0 | 37.7  |
| Lesotho                             | 1,890.3   | 1,533.5 | 2.9   | 0.7   | 40.2    | 32.8  | 11.0  | 0.3  | 5.3   | 0.2  | 2.1   | 1.1  | 9.5   |
| Liberia                             | 2,790.3   | 1,064.7 | 1.2   | —     | 64.8    | 30.5  | 22.6  | 0.3  | 5.8   | 2.7  | 31.2  | 1.1  | 9.7   |
| Libya                               | 5,411.9   | 301.2   | 271.7 | 16.1  | 981.3   | 226.7 | 105.1 | 0.6  | 11.4  | 1.0  | 10.5  | 11.3 | 101.4 |
| Lithuania                           | 3,501.4   | 1,048.4 | 0.3   | 28.5  | 218.3   | 39.2  | 27.5  | 0.4  | 1.8   | 8.5  | 108.4 | 6.0  | 28.7  |
| Luxembourg                          | 450.5     | 508.9   | 0.0   | 101.1 | 1,432.2 | 68.0  | 87.3  | 1.6  | 1.7   | 28.3 | 272.2 | 5.6  | 7.3   |
| Macedonia                           | 2,010.5   | 602.2   | 35.5  | 42.4  | 382.7   | 38.5  | 30.7  | 3.4  | 46.8  | 4.5  | 57.3  | 10.7 | 93.2  |
| Madagascar                          | 15,529.4  | 1,329.4 | 145.1 | 2.7   | 36.2    | 16.0  | 4.8   | 0.6  | 11.7  | 0.2  | 2.4   | 2.7  | 24.3  |
| Malawi                              | 12,005.8  | 804.1   | 12.4  | 45.0  | 48.4    | 3.0   | 5.2   | 0.2  | 3.7   | 0.1  | 1.7   | 1.2  | 11.2  |
| Malaysia                            | 23,458.2  | 1,240.6 | 49.0  | 57.1  | 503.3   | 93.9  | 56.7  | 1.0  | 13.2  | 2.4  | 21.4  | 6.5  | 58.3  |
| Maldives                            | 273.5     | 221.8   | 4.2   | 8.7   | 813.5   | 160.8 | 89.0  | 0.0  | —     | 3.4  | 51.6  | 1.1  | 6.9   |
| Mali                                | 10,701.0  | 1,769.6 | 139.8 | 0.0   | 54.8    | 10.9  | 5.7   | 0.3  | 4.8   | 0.2  | 2.5   | 5.5  | 49.6  |
| Malta                               | 391.0     | 74.1    | 9.8   | 7.0   | 1,600.7 | 176.4 | 130.0 | 0.0  | 0.6   | 10.2 | 115.7 | 10.2 | 81.0  |
| Mauritania                          | 2,648.1   | 1,262.0 | 78.1  | 0.0   | 1,036.8 | 84.6  | 30.4  | 0.6  | 11.1  | 0.4  | 4.5   | 5.7  | 51.0  |
| Mauritius                           | 1,199.6   | 371.9   | 8.4   | 3.3   | 1,238.9 | 215.3 | 103.8 | 0.6  | 6.9   | 3.9  | 46.5  | 17.8 | 143.4 |
| Mexico                              | 99,810.4  | 840.0   | 86.7  | 88.1  | 661.1   | 84.9  | 59.6  | 1.3  | 16.8  | 3.6  | 31.8  | 13.6 | 90.4  |
| Moldova                             | 4,051.3   | 983.2   | 90.0  | 29.6  | 55.7    | 13.2  | 4.7   | 10.5 | 72.9  | 1.5  | 24.3  | 5.4  | 35.8  |

*continues*

**DATA TABLE 13** *continued*

| Country                           | Population<br>(Thousands) | Water Footprint of Consumption<br>of Agricultural Products |       |       |          |       |      | Water Footprint of Consumption<br>of Industrial Products |      |      |          |      |       | Water Footprint<br>of Domestic |      |
|-----------------------------------|---------------------------|--|-------|-------|----------|-------|------|--|------|------|----------|------|-------|--------------------------------|------|
|                                   |                           | Internal   |       |       | External |       |      | Internal   |      |      | External |      |       | Blue                           | Grey |
|                                   |                           | Green  | Blue  | Grey  | Green    | Blue  | Grey | Blue   | Grey | Blue | Grey     | Blue | Grey  | Blue                           | Grey |
| Mongolia                          | 2,409.3                   | 1,316.3  | 35.5  | 30.2  | 2,207.8  | 53.6  | 52.7 | 1.4  | 23.2 | 1.1  | 15.4     | 3.7  | 33.6  |                                |      |
| Morocco                           | 28,961.9                  | 981.3  | 166.4 | 45.8  | 424.2    | 36.7  | 29.6 | 0.4  | 1.6  | 1.0  | 11.5     | 4.2  | 21.9  |                                |      |
| Mozambique                        | 18,560.9                  | 1,022.6  | 7.9   | 6.2   | 61.8     | 9.3   | 6.6  | 0.0  | 0.3  | 0.1  | 0.7      | 0.4  | 3.4   |                                |      |
| Myanmar                           | 46,626.5                  | 1,124.8  | 41.2  | 17.5  | 18.0     | 1.1   | 1.2  | 0.1  | 2.3  | 0.1  | 1.8      | 0.9  | 7.9   |                                |      |
| Namibia                           | 1,839.1                   | 1,169.4  | 18.7  | 11.8  | 339.6    | 67.9  | 24.0 | 0.3  | 5.6  | 0.5  | 4.9      | 4.0  | 35.7  |                                |      |
| Nepal                             | 24,707.0                  | 944.6  | 113.8 | 8.3   | 94.9     | 9.8   | 12.3 | 0.1  | 1.6  | 0.2  | 2.9      | 1.2  | 10.9  |                                |      |
| Netherlands                       | 15,946.9                  | 43.6   | 2.8   | 15.1  | 1,012.3  | 99.5  | 85.3 | 6.9  | 1.2  | 16.7 | 172.8    | 3.1  | 6.5   |                                |      |
| New Caledonia                     | 216.8                     | 550.6  | 0.2   | 35.8  | 1,100.4  | 118.1 | 79.5 | —  | —    | 10.1 | 100.1    | —    | —     |                                |      |
| New Zealand                       | 3,905.5                   | 477.3  | 62.1  | 23.0  | 720.0    | 49.1  | 35.3 | 2.1  | 8.1  | 9.3  | 102.5    | 26.1 | 73.8  |                                |      |
| Nicaragua                         | 5,125.0                   | 682.6  | 26.2  | 16.0  | 104.6    | 19.4  | 12.2 | 0.2  | 4.4  | 0.8  | 8.6      | 3.7  | 33.4  |                                |      |
| Niger                             | 11,272.1                  | 3,351.9  | 63.7  | 4.9   | 59.1     | 22.6  | 7.4  | 0.0  | 0.4  | 0.1  | 0.5      | 0.8  | 7.2   |                                |      |
| Nigeria                           | 126,648.8                 | 1,147.3  | 10.9  | 5.5   | 43.9     | 11.5  | 7.4  | 0.1  | 1.6  | 0.1  | 0.7      | 1.3  | 12.0  |                                |      |
| Norway                            | 4,501.6                   | 344.7  | 2.0   | 12.1  | 678.8    | 87.7  | 55.8 | 8.5  | 33.5 | 13.2 | 134.7    | 11.1 | 40.7  |                                |      |
| Occupied Palestinian<br>Territory | 3,221.2                   | 788.8  | 114.0 | —     | 30.1     | 6.6   | 39.7 | 1.1  | 20.1 | 0.1  | 0.8      | 5.3  | 48.0  |                                |      |
| Pakistan                          | 149,801.8                 | 535.5  | 403.6 | 136.7 | 191.7    | 15.0  | 8.1  | 0.8  | 15.9 | 0.1  | 1.8      | 2.2  | 19.6  |                                |      |
| Panama                            | 2,979.1                   | 747.2  | 18.2  | 53.3  | 311.5    | 32.1  | 44.1 | 0.5  | 3.7  | 2.5  | 26.6     | 18.5 | 105.5 |                                |      |
| Paraguay                          | 5,406.5                   | 1,789.1  | 39.7  | 45.9  | 26.1     | 11.0  | 4.4  | 0.3  | 5.4  | 1.2  | 13.9     | 1.8  | 15.3  |                                |      |
| Peru                              | 26,157.7                  | 502.4  | 126.1 | 55.8  | 307.8    | 15.4  | 21.7 | 2.8  | 13.9 | 0.7  | 7.5      | 6.4  | 27.5  |                                |      |
| Philippines                       | 78,472.9                  | 994.4  | 42.8  | 47.4  | 133.0    | 25.7  | 21.7 | 1.7  | 30.7 | 0.4  | 5.3      | 7.5  | 67.1  |                                |      |
| Poland                            | 38,408.0                  | 778.0  | 1.7   | 151.8 | 232.6    | 36.2  | 23.6 | 11.4   | 80.2 | 4.0  | 50.0     | 5.5  | 30.4  |                                |      |
| Portugal                          | 10,278.4                  | 696.3  | 147.2 | 61.0  | 1,157.9  | 196.9 | 95.6 | 4.2  | 25.7 | 4.4  | 46.4     | 10.5 | 59.4  |                                |      |
| Romania                           | 22,089.3                  | 1,183.2  | 24.0  | 58.6  | 161.5    | 34.9  | 17.5 | 7.7  | 99.8 | 2.5  | 32.8     | 7.7  | 58.5  |                                |      |
| Russian Federation                | 146,082.3                 | 1,374.8  | 43.1  | 49.7  | 174.1    | 38.7  | 10.5 | 3.6  | 59.4 | 0.4  | 5.6      | 9.2  | 82.6  |                                |      |

|                          |          |         |       |       |         |       |       |      |       |      |       |      |       |
|--------------------------|----------|---------|-------|-------|---------|-------|-------|------|-------|------|-------|------|-------|
| Rwanda                   | 7,735.9  | 775.2   | 2.5   | 0.5   | 24.4    | 5.3   | 6.1   | 0.1  | 1.3   | 0.1  | 0.9   | 0.5  | 4.2   |
| Saint Kitts and Nevis    | 46.4     | 593.4   | 0.2   | 1.2   | 706.7   | 116.7 | 86.4  | —    | —     | 11.2 | 115.9 | —    | —     |
| Saint Lucia              | 157.5    | 56.4    | 0.1   | —     | 1,145.2 | 110.7 | 122.8 | —    | —     | 4.4  | 40.1  | 7.9  | 71.4  |
| Saint Vincent/Grenadines | 108.2    | 878.8   | —     | —     | 594.5   | 94.1  | 92.5  | —    | —     | 2.8  | 26.7  | —    | —     |
| Samoa                    | 176.1    | 1,811.4 | —     | 0.5   | 168.3   | 63.2  | 24.9  | —    | —     | 1.2  | 13.1  | —    | —     |
| São Tomé and Príncipe    | 141.5    | 1,459.9 | 0.7   | —     | 155.8   | 59.0  | 48.0  | —    | —     | 0.4  | 3.9   | —    | —     |
| Saudi Arabia             | 21,114.2 | 126.3   | 332.4 | 52.8  | 1,004.9 | 101.8 | 89.7  | 0.8  | 14.3  | 2.3  | 23.0  | 10.1 | 90.8  |
| Senegal                  | 10,055.0 | 757.9   | 32.0  | 4.9   | 264.7   | 53.5  | 19.9  | 0.3  | 3.6   | 0.4  | 5.0   | 1.0  | 7.9   |
| Serbia and Montenegro    | 10,729.5 | 1,224.5 | 10.8  | 98.4  | 107.5   | 25.7  | 10.7  | 40.4 | 764.3 | 2.2  | 32.6  | 7.3  | 65.4  |
| Seychelles               | 80.6     | 657.7   | 39.0  | 0.2   | 1,010.5 | 146.8 | 91.1  | 2.0  | 37.1  | 8.3  | 99.9  | 9.9  | 89.3  |
| Sierra Leone             | 4,408.0  | 1,132.2 | 11.0  | —     | 248.5   | 22.8  | 15.4  | 0.1  | 1.5   | 0.1  | 1.5   | 0.5  | 4.1   |
| Slovakia                 | 5,377.2  | 704.2   | 11.0  | 75.7  | 310.0   | 44.4  | 32.8  | 2.8  | 17.0  | 7.2  | 73.6  | 8.0  | 48.7  |
| Slovenia                 | 1,986.5  | 373.8   | 0.5   | 205.2 | 971.8   | 65.8  | 93.6  | 9.4  | 79.1  | 11.5 | 124.2 | 10.1 | 67.5  |
| Solomon Islands          | 421.9    | 530.2   | —     | —     | 138.8   | 21.5  | 26.0  | —    | —     | 0.4  | 5.8   | —    | —     |
| South Africa             | 45,183.8 | 786.8   | 76.7  | 49.9  | 240.5   | 10.7  | 12.5  | 0.5  | 4.1   | 1.1  | 11.6  | 8.6  | 52.4  |
| Spain                    | 40,840.6 | 1,004.9 | 214.5 | 142.2 | 797.3   | 79.3  | 68.1  | 6.0  | —     | 9.7  | 102.7 | 11.7 | 25.0  |
| Sri Lanka                | 18,883.5 | 771.5   | 105.6 | 54.9  | 207.7   | 53.8  | 26.7  | 0.5  | 9.2   | 0.6  | 9.2   | 1.6  | 14.3  |
| Sudan                    | 35,224.9 | 1,428.1 | 196.3 | 10.2  | 56.4    | 4.6   | 4.4   | 0.3  | 5.0   | 0.2  | 2.3   | 2.8  | 25.3  |
| Suriname                 | 470.8    | 749.1   | 114.7 | 79.1  | 260.3   | 17.0  | 27.8  | 1.0  | 18.9  | 1.4  | 13.8  | 6.4  | 57.3  |
| Swaziland                | 1,073.1  | 491.4   | 46.4  | —     | 655.7   | 146.0 | 21.5  | 0.5  | 8.6   | 0.4  | 4.8   | 2.2  | 20.1  |
| Sweden                   | 8,911.5  | 535.5   | 1.5   | 85.7  | 502.7   | 50.9  | 53.5  | 4.4  | 13.3  | 11.0 | 126.6 | 12.2 | 30.5  |
| Switzerland              | 7,232.5  | 183.6   | 0.1   | 45.2  | 851.4   | 78.8  | 82.6  | 6.9  | 4.4   | 20.1 | 224.6 | 8.6  | 22.3  |
| Syria                    | 16,859.5 | 1,187.6 | 338.9 | 148.7 | 270.8   | 38.1  | 17.4  | 1.0  | 15.5  | 0.6  | 7.9   | 8.5  | 72.2  |
| Tajikistan               | 6,201.4  | 647.8   | 447.7 | 47.8  | 1,069.1 | 14.8  | 9.2   | 3.8  | 66.0  | 0.6  | 9.4   | 7.1  | 63.9  |
| Tanzania                 | 34,719.2 | 913.4   | 23.0  | 4.3   | 52.9    | 9.9   | 5.0   | 0.0  | 0.6   | 0.1  | 1.7   | 1.5  | 13.7  |
| Thailand                 | 62,968.7 | 939.0   | 134.5 | 64.3  | 148.8   | 23.5  | 10.9  | 1.2  | 20.3  | 1.7  | 19.8  | 4.3  | 39.1  |
| Togo                     | 5,303.9  | 845.6   | 1.1   | 5.1   | 94.5    | 15.0  | 8.9   | 0.0  | 0.4   | 0.2  | 2.4   | 1.7  | 15.1  |
| Trinidad and Tobago      | 1,296.6  | 83.4    | 0.1   | 0.4   | 1,224.9 | 89.0  | 108.5 | 1.3  | 16.9  | 3.4  | 30.1  | 16.2 | 141.7 |
| Tunisia                  | 9,482.7  | 1,299.7 | 126.7 | 42.3  | 504.7   | 135.5 | 57.8  | 0.3  | 3.2   | 1.8  | 17.9  | 3.8  | 23.2  |
| Turkey                   | 66,848.5 | 933.8   | 167.9 | 103.3 | 216.0   | 71.2  | 17.4  | 2.4  | 24.6  | 3.0  | 39.5  | 8.3  | 54.4  |

*continues*

**DATA TABLE 13** *continued*

| Country              | Population<br>(Thousands) | Water Footprint of Consumption<br>of Agricultural Products |       |       |          |       |       | Water Footprint of Consumption<br>of Industrial Products |       |      |          |      |       | Water Footprint<br>of Domestic<br>Water Consumption |      |
|----------------------|---------------------------|--|-------|-------|----------|-------|-------|--|-------|------|----------|------|-------|---|------|
|                      |                           | Internal   |       |       | External |       |       | Internal   |       |      | External |      |       | Blue  | Grey |
|                      |                           | Green  | Blue  | Grey  | Green    | Blue  | Grey  | Blue   | Grey  | Blue | Grey     | Blue | Grey  | Blue  | Grey |
| Turkmenistan         | 4,544.7                   | 1,239.2  | 719.3 | 0.1   | 185.2    | 9.4   | 11.6  | 0.8  | 7.4   | 0.9  | 7.3      | 9.2  | 83.2  |   |      |
| Uganda               | 24,961.9                  | 1,019.2  | 0.4   | 1.1   | 35.9     | 9.8   | 3.4   | 0.1  | 1.9   | 0.1  | 1.8      | 0.5  | 4.7   |   |      |
| UK                   | 59,334.4                  | 243.5  | 0.9   | 53.3  | 672.0    | 71.9  | 61.0  | 4.1  | 2.0   | 12.2 | 129.6    | 3.5  | 4.1   |   |      |
| Ukraine              | 48,737.6                  | 1,117.6  | 28.2  | 62.0  | 55.9     | 7.7   | 4.4   | 8.8  | 159.7 | 2.0  | 34.8     | 9.4  | 84.2  |   |      |
| United Arab Emirates | 3,329.8                   | 412.7  | 140.1 | 12.3  | 1,508.5  | 386.2 | 185.3 | 0.6  | 9.7   | 25.1 | 270.2    | 18.5 | 166.8 |   |      |
| Uruguay              | 3,307.1                   | 1,567.4  | 53.4  | 39.1  | 388.7    | 4.0   | 11.9  | 0.5  | 9.7   | 2.5  | 31.0     | 2.4  | 21.8  |   |      |
| USA                  | 288,958.2                 | 1,600.4  | 136.5 | 223.5 | 367.9    | 37.5  | 31.7  | 30.9   | 164.7 | 11.3 | 127.0    | 22.6 | 88.4  |   |      |
| Uzbekistan           | 24,895.6                  | 509.9  | 346.7 | 0.0   | 255.6    | 3.1   | 5.8   | 1.9  | 35.5  | 0.5  | 8.1      | 11.1 | 100.1 |   |      |
| Vanuatu              | 193.8                     | 1,264.0  | —     | —     | 45.5     | 73.9  | 33.5  | —  | —     | 1.1  | 13.2     | —    | —     |   |      |
| Venezuela            | 24,640.2                  | 874.6  | 48.5  | 33.2  | 527.0    | 22.2  | 28.7  | 0.7  | 12.2  | 0.9  | 7.9      | 15.5 | 139.2 |   |      |
| Vietnam              | 79,188.2                  | 637.7  | 68.0  | 94.2  | 52.4     | 6.4   | 4.2   | 6.1  | 113.8 | 0.4  | 5.4      | 7.0  | 63.0  |   |      |
| Yemen                | 18,502.1                  | 71.4   | 126.2 | 5.1   | 551.2    | 90.2  | 38.4  | 0.1  | 1.8   | 0.2  | 2.0      | 1.5  | 13.1  |   |      |
| Zambia               | 10,573.6                  | 754.0  | 27.8  | 16.0  | 76.2     | 7.9   | 4.9   | 0.3  | 5.1   | 0.1  | 1.5      | 2.7  | 24.7  |   |      |
| Zimbabwe             | 12,357.4                  | 958.7  | 57.7  | 34.5  | 81.1     | 6.6   | 5.5   | 0.8  | 15.3  | 0.2  | 2.2      | 4.8  | 42.9  |   |      |
| World                | 6,154,564.2               | 796.6  | 107.1 | 90.3  | 218.8    | 33.2  | 21.4  | 3.8  | 34.3  | 2.3  | 24.6     | 6.8  | 45.8  |   |      |

# Total Water Footprint of National Consumption, by Country, 1996–2005

## Description

The data in this table are similar to those in data table 12 on both internal production and external imports, but on a total (rather than a per capita) basis. Conventional estimates of national water use have historically been restricted to statistics on water withdrawals within national boundaries. In recent years, a new approach has been developed and applied to calculate water “footprints,” which include water use (typically withdrawals and consumption, estimated separately), the use of “green water” and “grey water,” and information about water used in other countries to produce imported products. Quantifying these national water footprints is an evolving field.

The data here include the total water footprint for internal and external water consumption by country, measured in millions of cubic meters per year ( $\text{Mm}^3/\text{yr}$ ) and averaged over the decade 1996–2005. Data on population assumptions are also provided. A distinction is made between green water and blue water. In addition, the authors include the grey water footprint in the estimation of the water footprint in each sector, an estimate of the footprint of farm animal products, and details on the water footprints of national imports and exports. The final column presents the external water footprint as a fraction of the total national water footprint.

Freshwater footprints are reported in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time. A water footprint has three components: green, blue, and grey. The “blue water” footprint refers to use of surface water and groundwater. The “green water” footprint is the volume of rainwater consumed, which is particularly relevant in agricultural production. The “grey water” footprint is a measure of freshwater pollution and is defined as the volume of freshwater required to assimilate a load of pollutants.

## Limitations

While the concept of the water footprint is an extremely valuable one, the process for computing footprints continues to evolve, and data sets continue to improve. For example, water withdrawal numbers are often not accurately or consistently reported (see,

e.g., the description of data table 2). Estimates of agricultural water use depend on a mix of implicit and explicit assumptions about actual irrigation levels, climatic data for certain crop types, and irrigation technologies. Some consumer categories are not included or accurately estimated. Estimates of the water footprint of imported goods are produced using global averages because of constraints on information of the location of exported goods. The grey water footprint estimates are based on a limited set of pollutants—leaching and runoff of nitrogen fertilizers—and exclude the potential effects of other agricultural chemicals, including pesticides.

See the original source for more detail on the fundamental assumptions and limitations of the footprint approach.

## Source

Mekonnen, M. M., and A. Y. Hoekstra. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Value of Water Research Report Series No. 50. Delft, Netherlands: UNESCO-IHE Institute for Water Education. <http://www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Voll.pdf>.



**DATA TABLE 14** Total Water Footprint of National Consumption, by Country, 1996–2005 (Mm<sup>3</sup>/yr)

| Country                | Total Water Footprint of National Consumption |          |          |                             |         |         |                     |          |          |      |       |      | Ratio of External/ Total Water Footprint (%) |
|------------------------|---|----------|----------|-----------------------------|---------|---------|---------------------|----------|----------|------|-------|------|--|
|                        | Internal (WFcons, nat, int)                   |          |          | External (WFcons, nat, ext) |         |         | Total (WFcons, nat) |          |          | Blue | Green | Grey |  |
|                        | Green   | Blue     | Grey     | Green                       | Blue    | Grey    | Green               | Blue     | Grey     |      |       |      |  |
| Albania                | 1,857.8                                       | 328.1    | 675.2    | 1,519.8                     | 242.7   | 174.1   | 3,377.6             | 570.8    | 849.3    | 40.4 |       |      |  |
| Algeria                | 19,523.7                                      | 2,886.1  | 1,342.2  | 21,555.6                    | 1,573.9 | 2,022.6 | 41,079.4            | 4,459.9  | 3,364.9  | 51.4 |       |      |  |
| Angola                 | 11,663.8                                      | 207.7    | 120.1    | 1,584.0                     | 215.2   | 209.6   | 13,247.8            | 422.9    | 329.7    | 14.3 |       |      |  |
| Antigua and Barbuda    | 30.3  | 0.4      | 3.4      | 64.1                        | 7.8     | 15.4    | 94.4                | 8.2      | 18.8     | 71.9 |       |      |  |
| Argentina              | 47,746.2                                      | 3,864.9  | 5,661.8  | 1,298.1                     | 207.5   | 767.8   | 49,044.3            | 4,072.3  | 6,429.6  | 3.8  |       |      |  |
| Armenia                | 1,595.1                                       | 415.7    | 732.5    | 1,391.0                     | 129.3   | 181.5   | 2,986.0             | 545.0    | 914.0    | 38.3 |       |      |  |
| Australia              | 33,170.9                                      | 3,764.5  | 2,525.7  | 2,634.0                     | 414.9   | 2,208.2 | 35,804.9            | 4,179.4  | 4,733.9  | 11.8 |       |      |  |
| Austria                | 3,192.9                                       | 130.7    | 748.7    | 5,947.3                     | 664.6   | 2,187.5 | 9,140.2             | 795.3    | 2,936.2  | 68.4 |       |      |  |
| Azerbaijan             | 4,158.9                                       | 1,440.6  | 1,617.2  | 2,533.4                     | 212.0   | 190.2   | 6,692.3             | 1,652.6  | 1,807.4  | 28.9 |       |      |  |
| Bahamas                | 61.5  | —        | —        | 413.2                       | 51.3    | 127.4   | 474.7               | 51.3     | 127.4    | 90.6 |       |      |  |
| Bangladesh             | 67,849.0                                      | 8,130.3  | 14,168.5 | 13,923.7                    | 3,196.3 | 1,848.8 | 81,772.7            | 11,326.6 | 16,017.3 | 17.4 |       |      |  |
| Barbados               | 139.9   | 5.0      | 64.6     | 238.1                       | 29.7    | 51.3    | 378.0               | 34.7     | 116.0    | 60.4 |       |      |  |
| Belarus                | 10,944.5                                      | 193.6    | 2,240.4  | 2,164.1                     | 443.6   | 1,241.9 | 13,108.5            | 637.2    | 3,482.3  | 22.3 |       |      |  |
| Belgium                | 359.2   | 225.6    | 1,549.2  | 12,285.4                    | 1,253.6 | 3,959.4 | 12,644.6            | 1,479.2  | 5,508.6  | 89.1 |       |      |  |
| Belize                 | 294.0   | 10.0     | 149.2    | 30.8                        | 9.8     | 18.1    | 324.8               | 19.8     | 167.3    | 11.5 |       |      |  |
| Benin                  | 6,957.5                                       | 12.6     | 99.1     | 458.9                       | 138.4   | 81.4    | 7,416.4             | 151.0    | 180.4    | 8.8  |       |      |  |
| Bermuda                | 0.4   | 0.1      | 0.3      | 107.5                       | 14.5    | 65.8    | 108.0               | 14.6     | 66.1     | 99.5 |       |      |  |
| Bolivia                | 25,764.0                                      | 398.7    | 245.3    | 2,488.5                     | 128.4   | 136.0   | 28,252.5            | 527.1    | 381.3    | 9.4  |       |      |  |
| Bosnia and Herzegovina | 2,393.3                                       | 17.0     | 120.6    | 1,482.6                     | 104.5   | 444.0   | 3,876.0             | 121.4    | 564.6    | 44.5 |       |      |  |
| Botswana               | 2,074.4                                       | 23.9     | 94.8     | 969.4                       | 310.3   | 67.1    | 3,043.8             | 334.2    | 161.9    | 38.0 |       |      |  |
| Brazil                 | 288,345.2                                     | 10,119.8 | 24,109.3 | 27,980.8                    | 2,222.0 | 2,596.5 | 316,326.0           | 12,341.8 | 26,705.8 | 9.2  |       |      |  |
| Brunei Darussalam      | 8.6   | 0.0      | 0.0      | 941.8                       | 112.5   | 89.1    | 950.4               | 112.5    | 89.1     | 99.3 |       |      |  |
| Bulgaria               | 11,814.2                                      | 280.2    | 2,817.7  | 2,638.3                     | 379.9   | 417.2   | 14,452.5            | 660.1    | 3,234.9  | 18.7 |       |      |  |
| Burkina Faso           | 19,121.3                                      | 199.1    | 340.2    | 447.0                       | 174.1   | 68.5    | 19,568.3            | 373.2    | 408.7    | 3.4  |       |      |  |
| Burundi                | 4,505.5                                       | 99.6     | 65.4     | 87.5                        | 8.6     | 13.2    | 4,593.0             | 108.2    | 78.6     | 2.3  |       |      |  |

*continues*

DATA TABLE 14 continued

| Country                    | Total Water Footprint of National Consumption |           |           |           |                             |          |           |           |                     |      |      |      | Ratio of External/ Total Water Footprint (%) |
|----------------------------|---|-----------|-----------|-----------|-----------------------------|----------|-----------|-----------|---------------------|------|------|------|--|
|                            | Internal (Wfcons, nat, int)                   |           |           |           | External (Wfcons, nat, ext) |          |           |           | Total (Wfcons, nat) |      |      |      |  |
|                            | Green   | Blue      | Grey      | Grey      | Green                       | Blue     | Grey      | Grey      | Green               | Blue | Grey | Grey |  |
| Cambodia                   | 12,266.0                                      | 694.5     | 84.0      | 612.6     | 105.9                       | 71.3     | 12,878.6  | 800.4     | 155.3               | 5.7  |      |      |  |
| Cameroon                   | 18,409.0                                      | 169.0     | 352.7     | 603.7     | 340.9                       | 145.5    | 19,012.7  | 509.9     | 498.2               | 5.4  |      |      |  |
| Canada                     | 41,548.5                                      | 2,463.0   | 13,161.6  | 7,874.8   | 2,280.4                     | 4,746.0  | 49,423.3  | 4,743.4   | 17,907.6            | 20.7 |      |      |  |
| Cape Verde                 | 265.2   | 10.1      | 1.8       | 219.1     | 28.8                        | 25.6     | 484.4     | 38.9      | 27.4                | 49.7 |      |      |  |
| Central African Republic   | 4,329.9                                       | 72.9      | 20.2      | 54.5      | 11.0                        | 12.4     | 4,384.4   | 83.9      | 32.6                | 1.7  |      |      |  |
| Chad                       | 12,275.2                                      | 175.2     | 36.0      | 66.2      | 22.5                        | 16.1     | 12,341.4  | 197.7     | 52.1                | 0.8  |      |      |  |
| Chile                      | 6,994.0                                       | 2,336.0   | 2,579.5   | 5,070.5   | 310.4                       | 597.1    | 12,064.5  | 2,646.4   | 3,176.6             | 33.4 |      |      |  |
| China                      | 784,627.8                                     | 135,713.2 | 311,238.1 | 110,077.5 | 14,298.3                    | 12,048.7 | 894,705.3 | 150,011.5 | 323,286.9           | 10.0 |      |      |  |
| Colombia                   | 35,863.2                                      | 1,922.5   | 6,365.5   | 9,100.9   | 748.7                       | 1,122.2  | 44,964.1  | 2,671.2   | 7,487.7             | 19.9 |      |      |  |
| Comoros                    | 786.5   | 2.1       | 4.8       | 72.5      | 60.3                        | 15.0     | 859.0     | 62.4      | 19.8                | 15.7 |      |      |  |
| Congo, Democratic Republic | 27,577.5                                      | 108.6     | 206.1     | 530.4     | 175.0                       | 139.6    | 28,107.9  | 283.6     | 345.8               | 2.9  |      |      |  |
| Congo, Republic            | 1,568.7                                       | 23.3      | 32.7      | 592.2     | 148.2                       | 69.1     | 2,160.9   | 171.5     | 101.8               | 33.3 |      |      |  |
| Costa Rica                 | 2,725.2                                       | 239.8     | 1,097.8   | 1,381.0   | 197.4                       | 265.0    | 4,106.2   | 437.2     | 1,362.8             | 31.2 |      |      |  |
| Côte d'Ivoire              | 20,184.3                                      | 142.7     | 542.5     | 792.2     | 637.2                       | 271.6    | 20,976.5  | 779.9     | 814.1               | 7.5  |      |      |  |
| Croatia                    | 4,035.7                                       | 5.0       | 646.4     | 2,089.9   | 165.6                       | 687.4    | 6,125.6   | 170.6     | 1,333.8             | 38.6 |      |      |  |
| Cuba                       | 13,194.0                                      | 1,033.0   | 1,991.4   | 1,943.7   | 139.4                       | 410.5    | 15,137.7  | 1,172.4   | 2,401.9             | 13.3 |      |      |  |
| Cyprus                     | 288.2   | 181.4     | 72.0      | 1,042.3   | 94.9                        | 207.8    | 1,330.5   | 276.3     | 279.8               | 71.3 |      |      |  |
| Czech Republic             | 8,372.5                                       | 155.4     | 2,078.7   | 4,277.0   | 660.1                       | 1,339.2  | 12,649.6  | 815.5     | 3,417.9             | 37.2 |      |      |  |
| Denmark                    | 2,737.5                                       | 71.0      | 518.7     | 3,787.8   | 438.8                       | 1,174.1  | 6,525.3   | 509.8     | 1,692.7             | 61.9 |      |      |  |
| Dominica                   | 147.8   | —         | 1.6       | 24.6      | 5.7                         | 5.3      | 172.4     | 5.7       | 6.9                 | 19.2 |      |      |  |
| Dominican Republic         | 6,589.8                                       | 937.2     | 942.3     | 3,263.2   | 224.0                       | 515.7    | 9,853.0   | 1,161.3   | 1,458.0             | 32.1 |      |      |  |
| East Timor                 | 1,517.4                                       | 37.3      | —         | 41.8      | 9.2                         | 11.8     | 1,559.2   | 46.5      | 11.8                | 3.9  |      |      |  |
| Ecuador                    | 17,174.5                                      | 1,685.4   | 3,028.1   | 2,464.1   | 145.6                       | 321.9    | 19,638.6  | 1,831.0   | 3,350.0             | 11.8 |      |      |  |
| Egypt                      | 10,697.6                                      | 35,944.2  | 21,381.6  | 23,682.2  | 1,426.2                     | 2,023.7  | 34,379.8  | 37,370.4  | 23,405.3            | 28.5 |      |      |  |
| El Salvador                | 3,441.3                                       | 81.1      | 685.9     | 1,482.0   | 222.1                       | 225.3    | 4,923.3   | 303.2     | 911.2               | 31.4 |      |      |  |

|                  |           |           |           |           |         |          |           |           |           |      |
|------------------|-----------|-----------|-----------|-----------|---------|----------|-----------|-----------|-----------|------|
| Eritrea          | 2,018.6   | 10.2      | 30.7      | 1,871.0   | 102.7   | 90.2     | 3,889.7   | 112.9     | 120.9     | 50.1 |
| Estonia          | 978.1     | 11.0      | 151.5     | 826.2     | 203.8   | 190.0    | 1,804.3   | 214.8     | 341.5     | 51.7 |
| Ethiopia         | 73,675.2  | 1,546.7   | 654.5     | 1,357.8   | 121.9   | 276.2    | 75,033.0  | 1,668.6   | 930.7     | 2.3  |
| Fiji Islands     | 960.3     | 2.3       | 41.0      | 334.0     | 47.5    | 35.2     | 1,294.3   | 49.8      | 76.1      | 29.3 |
| Finland          | 3,373.3   | 93.1      | 411.6     | 2,105.0   | 318.7   | 1,024.7  | 5,478.3   | 411.8     | 1,436.3   | 47.1 |
| France           | 43,704.2  | 2,879.3   | 9,295.2   | 36,738.7  | 5,156.5 | 8,358.0  | 80,443.0  | 8,035.8   | 17,653.1  | 47.3 |
| French Polynesia | 215.8     | 0.6       | 1.5       | 150.0     | 34.9    | 43.5     | 365.9     | 35.6      | 45.0      | 51.2 |
| Gabon            | 1,270.7   | 18.7      | 65.8      | 337.6     | 68.8    | 45.1     | 1,608.3   | 87.4      | 111.0     | 25.0 |
| Gambia           | 717.9     | 2.4       | 16.2      | 326.4     | 69.5    | 42.7     | 1,044.3   | 71.9      | 58.9      | 37.3 |
| Georgia          | 5,756.9   | 457.8     | 1,332.6   | 2,772.6   | 166.7   | 215.7    | 8,529.5   | 624.5     | 1,548.3   | 29.5 |
| Germany          | 25,576.8  | 1,474.5   | 9,542.0   | 60,940.9  | 5,518.2 | 14,099.1 | 86,517.7  | 6,992.7   | 23,641.1  | 68.8 |
| Ghana            | 21,592.2  | 65.3      | 381.7     | 1,140.8   | 416.1   | 281.2    | 22,733.0  | 481.4     | 662.9     | 7.7  |
| Greece           | 9,744.3   | 2,391.0   | 1,553.7   | 8,324.7   | 1,174.3 | 2,384.6  | 18,069.0  | 3,565.2   | 3,938.4   | 46.5 |
| Grenada          | 128.6     | 0.2       | —         | 64.6      | 9.6     | 15.6     | 193.3     | 9.8       | 15.6      | 41.1 |
| Guatemala        | 8,136.5   | 171.7     | 785.0     | 1,552.9   | 214.6   | 354.0    | 9,689.4   | 386.3     | 1,139.0   | 18.9 |
| Guinea           | 12,628.3  | 55.7      | 137.7     | 446.4     | 223.6   | 96.8     | 13,074.7  | 279.4     | 234.5     | 5.6  |
| Guinea-Bissau    | 1,363.8   | 86.2      | 26.2      | 41.4      | 53.3    | 16.8     | 1,405.2   | 139.5     | 43.0      | 7.0  |
| Guyana           | 794.4     | 76.7      | 121.1     | 125.4     | 17.8    | 40.0     | 919.8     | 94.5      | 161.1     | 15.6 |
| Haiti            | 6,808.8   | 230.0     | 52.4      | 1,229.8   | 435.5   | 222.9    | 8,038.5   | 665.5     | 275.3     | 21.0 |
| Honduras         | 5,754.3   | 122.3     | 449.8     | 776.5     | 176.4   | 137.9    | 6,530.8   | 298.8     | 587.7     | 14.7 |
| Hungary          | 15,780.8  | 249.4     | 3,095.4   | 3,765.5   | 420.4   | 1,003.4  | 19,546.4  | 669.8     | 4,098.8   | 21.3 |
| Iceland          | 4.1       | 8.9       | 55.3      | 414.5     | 28.9    | 83.4     | 418.6     | 37.8      | 138.7     | 88.5 |
| India            | 720,644.0 | 227,832.7 | 167,199.4 | 23,546.0  | 2,277.7 | 3,105.3  | 744,190.0 | 230,110.4 | 170,304.7 | 2.5  |
| Indonesia        | 176,695.4 | 10,092.3  | 22,107.9  | 16,089.3  | 5,026.9 | 2,226.8  | 192,784.7 | 15,119.2  | 24,334.7  | 10.1 |
| Iran             | 50,325.3  | 38,153.7  | 14,477.1  | 19,445.0  | 1,391.1 | 1,556.1  | 69,770.3  | 39,544.8  | 16,033.2  | 17.9 |
| Ireland          | 1,078.6   | 37.3      | 309.2     | 2,556.3   | 383.0   | 670.1    | 3,634.9   | 420.4     | 979.4     | 71.7 |
| Israel           | 1,272.1   | 890.4     | 447.1     | 9,710.6   | 663.2   | 1,141.4  | 10,982.7  | 1,553.6   | 1,588.4   | 81.5 |
| Italy            | 36,197.9  | 3,834.6   | 12,049.7  | 62,764.0  | 7,251.0 | 10,369.2 | 98,961.9  | 11,085.6  | 22,418.9  | 60.7 |
| Jamaica          | 2,162.1   | 61.3      | 216.4     | 1,510.2   | 170.8   | 252.8    | 3,672.3   | 232.1     | 469.1     | 44.2 |
| Japan            | 22,377.2  | 3,711.7   | 14,306.8  | 105,550.2 | 7,819.5 | 21,013.9 | 127,927.4 | 11,531.1  | 35,320.7  | 76.9 |

*continues*

DATA TABLE 14 continued

| Country                             | Total Water Footprint of National Consumption |         |         |      |                             |         |         |      |                     |         |          |      | Ratio of External/ Total Water Footprint (%) |
|-------------------------------------|---|---------|---------|------|-----------------------------|---------|---------|------|---------------------|---------|----------|------|--|
|                                     | Internal (Wfcons, nat, int)                   |         |         |      | External (Wfcons, nat, ext) |         |         |      | Total (Wfcons, nat) |         |          |      |  |
|                                     | Green   | Blue    | Grey    | Grey | Green                       | Blue    | Grey    | Grey | Green               | Blue    | Grey     | Grey |  |
| Jordan                              | 557.6   | 406.2   | 217.0   | —    | 5,582.1                     | 829.2   | 724.4   | —    | 6,139.7             | 1,235.4 | 941.4    | —    | 85.8   |
| Kazakhstan                          | 25,933.0                                      | 5,389.4 | 2,663.2 | —    | 1,229.6                     | 271.5   | 539.8   | —    | 27,162.6            | 5,660.9 | 3,203.0  | —    | 5.7  |
| Kenya                               | 27,947.7                                      | 346.8   | 768.4   | —    | 4,976.8                     | 752.8   | 378.8   | —    | 32,924.5            | 1,099.6 | 1,147.2  | —    | 17.4   |
| Kiribati                            | 199.0   | —       | —       | —    | 26.8                        | 12.6    | 4.6     | —    | 225.8               | 12.6    | 4.6      | —    | 18.1   |
| Korea, Democratic People's Republic | 12,405.1                                      | 1,603.0 | 3,421.6 | —    | 2,080.0                     | 387.7   | 417.2   | —    | 14,485.0            | 1,990.8 | 3,838.8  | —    | 14.2   |
| Korea, Republic                     | 11,724.0                                      | 1,202.9 | 3,650.6 | —    | 47,962.4                    | 3,967.4 | 7,162.4 | —    | 59,686.4            | 5,170.3 | 10,813.1 | —    | 78.1   |
| Kuwait                              | 14.9  | 92.2    | 384.6   | —    | 3,181.1                     | 565.0   | 428.1   | —    | 3,196.0             | 657.2   | 812.8    | —    | 89.5   |
| Kyrgyzstan                          | 2,458.1                                       | 1,238.9 | 491.9   | —    | 2,944.6                     | 138.4   | 167.7   | —    | 5,402.7             | 1,377.3 | 659.6    | —    | 43.7   |
| Laos                                | 4,839.6                                       | 368.2   | 234.8   | —    | 148.4                       | 23.3    | 42.7    | —    | 4,988.0             | 391.5   | 277.6    | —    | 3.8  |
| Latvia                              | 2,455.4                                       | 20.5    | 355.7   | —    | 686.6                       | 131.4   | 606.3   | —    | 3,142.0             | 151.9   | 962.1    | —    | 33.5   |
| Lebanon                             | 1,158.0                                       | 712.2   | 314.2   | —    | 4,751.5                     | 565.0   | 557.8   | —    | 5,909.5             | 1,277.2 | 872.0    | —    | 72.9   |
| Lesotho                             | 2,898.7                                       | 8.0     | 29.3    | —    | 76.0                        | 62.3    | 24.8    | —    | 2,974.7             | 70.3    | 54.2     | —    | 5.3  |
| Liberia                             | 2,970.9                                       | 7.2     | 43.1    | —    | 180.7                       | 92.7    | 150.2   | —    | 3,151.6             | 99.9    | 193.3    | —    | 12.3   |
| Libya                               | 1,630.0                                       | 1,534.6 | 697.9   | —    | 5,310.9                     | 1,232.4 | 625.5   | —    | 6,940.9             | 2,767.1 | 1,323.4  | —    | 65.0   |
| Lithuania                           | 3,670.9                                       | 23.5    | 206.4   | —    | 764.3                       | 167.1   | 475.8   | —    | 4,435.2             | 190.6   | 682.2    | —    | 26.5   |
| Luxembourg                          | 229.3   | 3.2     | 49.6    | —    | 645.2                       | 43.4    | 161.9   | —    | 874.5               | 46.6    | 211.6    | —    | 75.1   |
| Macedonia                           | 1,210.6                                       | 99.7    | 366.7   | —    | 769.4                       | 86.5    | 176.9   | —    | 1,980.0             | 186.2   | 543.6    | —    | 38.1   |
| Madagascar                          | 20,644.5                                      | 2,305.2 | 601.3   | —    | 562.6                       | 251.1   | 111.5   | —    | 21,207.1            | 2,556.3 | 712.7    | —    | 3.8  |
| Malawi                              | 9,654.3                                       | 166.1   | 719.5   | —    | 581.6                       | 37.5    | 82.3    | —    | 10,235.8            | 203.6   | 801.8    | —    | 6.2  |
| Malaysia                            | 29,102.0                                      | 1,324.2 | 3,016.9 | —    | 11,805.6                    | 2,259.8 | 1,831.4 | —    | 40,907.6            | 3,584.0 | 4,848.3  | —    | 32.2   |
| Maldives                            | 60.7  | 1.5     | 4.3     | —    | 222.5                       | 44.9    | 38.5    | —    | 283.2               | 46.4    | 42.7     | —    | 82.2   |
| Mali                                | 18,936.7                                      | 1,557.7 | 583.0   | —    | 586.4                       | 119.1   | 87.9    | —    | 19,523.1            | 1,676.8 | 670.9    | —    | 3.6  |
| Malta                               | 29.0  | 7.9     | 34.6    | —    | 625.9                       | 72.9    | 96.1    | —    | 654.9               | 80.8    | 130.7    | —    | 91.7   |
| Mauritania                          | 3,341.8                                       | 223.4   | 164.3   | —    | 2,745.6                     | 225.0   | 92.4    | —    | 6,087.4             | 448.5   | 256.7    | —    | 45.1   |
| Mauritius                           | 446.1   | 32.1    | 184.3   | —    | 1,486.1                     | 263.0   | 180.3   | —    | 1,932.3             | 295.1   | 364.6    | —    | 74.4   |

|                                |           |          |          |          |         |         |           |          |          |      |
|--------------------------------|-----------|----------|----------|----------|---------|---------|-----------|----------|----------|------|
| Mexico                         | 83,840.7  | 10,147.9 | 19,492.1 | 65,986.0 | 8,833.4 | 9,124.9 | 149,826.7 | 18,981.3 | 28,617.1 | 42.5 |
| Moldova                        | 3,983.3   | 429.1    | 560.3    | 225.6    | 59.8    | 117.3   | 4,208.9   | 488.9    | 677.6    | 7.5  |
| Mongolia                       | 3,171.4   | 98.0     | 209.6    | 5,319.3  | 131.6   | 164.2   | 8,490.7   | 229.7    | 373.8    | 61.7 |
| Morocco                        | 28,420.2  | 4,955.5  | 2,005.4  | 12,286.8 | 1,092.0 | 1,192.7 | 40,707.0  | 6,047.5  | 3,198.1  | 29.2 |
| Mozambique                     | 18,980.3  | 153.1    | 183.8    | 1,147.6  | 173.0   | 134.5   | 20,128.0  | 326.1    | 318.4    | 7.0  |
| Myanmar                        | 52,447.8  | 1,968.7  | 1,291.8  | 837.9    | 58.6    | 140.7   | 53,285.7  | 2,027.3  | 1,432.5  | 1.8  |
| Namibia                        | 2,150.6   | 42.2     | 97.6     | 624.5    | 125.7   | 53.1    | 2,775.1   | 168.0    | 150.7    | 26.0 |
| Nepal                          | 23,338.5  | 2,843.7  | 515.9    | 2,344.9  | 245.8   | 374.8   | 25,683.4  | 3,089.5  | 890.7    | 10.0 |
| Netherlands                    | 695.2     | 202.6    | 365.0    | 16,142.5 | 1,852.5 | 4,115.1 | 16,837.7  | 2,055.1  | 4,480.1  | 94.6 |
| New Caledonia                  | 119.4     | 0.0      | 7.8      | 238.6    | 27.8    | 38.9    | 357.9     | 27.8     | 46.7     | 70.6 |
| New Zealand                    | 1,864.3   | 352.8    | 409.6    | 2,811.9  | 228.0   | 538.3   | 4,676.2   | 580.8    | 947.9    | 57.7 |
| Nicaragua                      | 3,498.2   | 154.6    | 275.5    | 536.3    | 103.5   | 106.6   | 4,034.5   | 258.1    | 382.1    | 16.0 |
| Niger                          | 37,783.4  | 727.5    | 141.7    | 666.2    | 254.8   | 89.5    | 38,449.6  | 982.3    | 231.2    | 2.5  |
| Nigeria                        | 145,305.7 | 1,557.3  | 2,417.6  | 5,557.1  | 1,468.0 | 1,030.0 | 150,862.8 | 3,025.3  | 3,447.6  | 5.1  |
| Norway                         | 1,551.9   | 97.2     | 388.6    | 3,055.6  | 454.2   | 857.5   | 4,607.5   | 551.4    | 1,246.1  | 68.2 |
| Occupied Palestinian Territory | 2,540.9   | 387.9    | 219.4    | 97.1     | 21.4    | 130.4   | 2,638.0   | 409.3    | 349.8    | 7.3  |
| Pakistan                       | 80,221.9  | 60,913.3 | 25,806.7 | 28,718.7 | 2,274.2 | 1,494.2 | 108,940.6 | 63,187.5 | 27,300.9 | 16.3 |
| Panama                         | 2,226.0   | 110.7    | 484.1    | 928.0    | 103.1   | 210.7   | 3,154.0   | 213.8    | 694.7    | 30.6 |
| Paraguay                       | 9,672.6   | 226.3    | 360.3    | 141.1    | 65.9    | 98.7    | 9,813.7   | 292.2    | 459.0    | 2.9  |
| Peru                           | 13,141.8  | 3,541.9  | 2,541.3  | 8,050.4  | 421.8   | 763.0   | 21,192.2  | 3,963.7  | 3,304.3  | 32.4 |
| Philippines                    | 78,032.3  | 4,074.0  | 11,392.0 | 10,433.7 | 2,054.9 | 2,123.4 | 88,466.0  | 6,128.9  | 13,515.4 | 13.5 |
| Poland                         | 29,880.5  | 713.8    | 10,078.3 | 8,934.8  | 1,544.9 | 2,827.6 | 38,815.3  | 2,258.8  | 12,905.9 | 24.7 |
| Portugal                       | 7,156.9   | 1,664.0  | 1,502.1  | 11,901.3 | 2,069.1 | 1,458.9 | 19,058.2  | 3,733.1  | 2,960.9  | 59.9 |
| Romania                        | 26,137.0  | 869.6    | 4,793.2  | 3,567.9  | 824.9   | 1,111.8 | 29,704.8  | 1,694.5  | 5,905.0  | 14.8 |
| Russian Federation             | 200,827.8 | 8,160.5  | 28,000.3 | 25,437.2 | 5,711.1 | 2,353.6 | 226,265.0 | 13,871.5 | 30,353.9 | 12.4 |
| Rwanda                         | 5,996.7   | 23.1     | 46.4     | 189.1    | 41.8    | 53.9    | 6,185.8   | 64.9     | 100.3    | 4.5  |
| Saint Kitts and Nevis          | 27.5      | 0.0      | 0.1      | 32.8     | 5.9     | 9.4     | 60.3      | 5.9      | 9.4      | 63.5 |
| Saint Lucia                    | 8.9       | 1.3      | 11.3     | 180.4    | 18.1    | 25.7    | 189.3     | 19.4     | 36.9     | 91.3 |
| Saint Vincent/Grenadines       | 95.1      | —        | —        | 64.3     | 10.5    | 12.9    | 159.4     | 10.5     | 12.9     | 48.0 |
| Samoa                          | 319.0     | —        | 0.1      | 29.6     | 11.3    | 6.7     | 348.6     | 11.3     | 6.8      | 13.0 |

*continues*

**DATA TABLE 14** *continued*

| Country               | Total Water Footprint of National Consumption |          |          |          |                             |         |         |         |                     |          |          |          | Ratio of External/ Total Water Footprint (%) |
|-----------------------|---|----------|----------|----------|-----------------------------|---------|---------|---------|---------------------|----------|----------|----------|--|
|                       | Internal (Wfcons, nat, int)                   |          |          |          | External (Wfcons, nat, ext) |         |         |         | Total (Wfcons, nat) |          |          |          |  |
|                       | Green   | Blue     | Grey     | —        | Green                       | Blue    | Grey    | —       | Green               | Blue     | Grey     | —        |  |
| São Tomé and Príncipe | 206.6   | 0.1      | —        | —        | 22.1                        | 8.4     | 7.4     | —       | 228.6               | 8.5      | 7.4      | —        | 15.5   |
| Saudi Arabia          | 2,667.5                                       | 7,250.0  | 3,334.7  | 3,334.7  | 21,217.6                    | 2,198.0 | 2,378.7 | 2,378.7 | 23,885.1            | 9,448.1  | 5,713.4  | 5,713.4  | 66.1   |
| Senegal               | 7,620.5                                       | 333.8    | 165.5    | 165.5    | 2,662.0                     | 542.4   | 250.2   | 250.2   | 10,282.4            | 876.1    | 415.6    | 415.6    | 29.8   |
| Serbia and Montenegro | 13,138.5                                      | 627.2    | 9,957.7  | 9,957.7  | 1,153.9                     | 299.3   | 464.2   | 464.2   | 14,292.3            | 926.5    | 10,421.8 | 10,421.8 | 7.5  |
| Seychelles            | 53.0  | 4.1      | 10.2     | 10.2     | 81.4                        | 12.5    | 15.4    | 15.4    | 134.5               | 16.6     | 25.6     | 25.6     | 61.9   |
| Sierra Leone          | 4,990.7                                       | 50.7     | 24.4     | 24.4     | 1,095.2                     | 101.0   | 74.7    | 74.7    | 6,085.9             | 151.7    | 99.1     | 99.1     | 20.1   |
| Slovakia              | 3,786.8                                       | 117.1    | 759.9    | 759.9    | 1,667.2                     | 277.7   | 572.1   | 572.1   | 5,454.0             | 394.8    | 1,332.0  | 1,332.0  | 35.1   |
| Slovenia              | 742.6   | 39.7     | 698.8    | 698.8    | 1,930.4                     | 153.5   | 432.5   | 432.5   | 2,673.1             | 193.2    | 1,131.3  | 1,131.3  | 62.9   |
| Solomon Islands       | 223.7   | —        | —        | —        | 58.5                        | 9.3     | 13.4    | 13.4    | 282.2               | 9.3      | 13.4     | 13.4     | 26.6   |
| South Africa          | 35,551.6                                      | 3,879.0  | 4,804.7  | 4,804.7  | 10,867.1                    | 532.1   | 1,089.1 | 1,089.1 | 46,418.8            | 4,411.1  | 5,893.8  | 5,893.8  | 22.0   |
| Spain                 | 41,038.9                                      | 9,484.6  | 6,826.5  | 6,826.5  | 32,561.5                    | 3,631.8 | 6,976.7 | 6,976.7 | 73,600.4            | 13,116.4 | 13,803.2 | 13,803.2 | 42.9   |
| Sri Lanka             | 14,569.5                                      | 2,033.7  | 1,479.7  | 1,479.7  | 3,922.7                     | 1,028.5 | 677.6   | 677.6   | 18,492.2            | 3,062.2  | 2,157.3  | 2,157.3  | 23.7   |
| Sudan                 | 50,305.0                                      | 7,022.6  | 1,424.7  | 1,424.7  | 1,985.8                     | 168.4   | 234.3   | 234.3   | 52,290.8            | 7,191.1  | 1,659.0  | 1,659.0  | 3.9  |
| Suriname              | 352.7   | 57.5     | 73.1     | 73.1     | 122.5                       | 8.7     | 19.6    | 19.6    | 475.2               | 66.2     | 92.7     | 92.7     | 23.8   |
| Swaziland             | 527.3   | 52.7     | 30.8     | 30.8     | 703.6                       | 157.1   | 28.3    | 28.3    | 1,230.9             | 209.8    | 59.1     | 59.1     | 59.3   |
| Sweden                | 4,772.0                                       | 161.8    | 1,154.2  | 1,154.2  | 4,479.4                     | 551.5   | 1,605.3 | 1,605.3 | 9,251.4             | 713.3    | 2,759.4  | 2,759.4  | 52.2   |
| Switzerland           | 1,328.1                                       | 112.5    | 519.9    | 519.9    | 6,157.6                     | 714.9   | 2,221.3 | 2,221.3 | 7,485.7             | 827.3    | 2,741.2  | 2,741.2  | 82.3   |
| Syria                 | 20,023.1                                      | 5,873.0  | 3,984.9  | 3,984.9  | 4,566.1                     | 652.3   | 426.9   | 426.9   | 24,589.2            | 6,525.3  | 4,411.8  | 4,411.8  | 15.9   |
| Tajikistan            | 4,017.0                                       | 2,844.1  | 1,101.7  | 1,101.7  | 6,629.8                     | 95.7    | 115.2   | 115.2   | 10,646.9            | 2,939.8  | 1,216.9  | 1,216.9  | 46.2   |
| Tanzania              | 31,712.9                                      | 853.0    | 644.0    | 644.0    | 1,836.6                     | 348.4   | 233.1   | 233.1   | 33,549.5            | 1,201.4  | 877.1    | 877.1    | 6.8  |
| Thailand              | 59,129.4                                      | 8,821.3  | 7,791.3  | 7,791.3  | 9,367.2                     | 1,582.5 | 1,931.9 | 1,931.9 | 68,496.6            | 10,403.7 | 9,723.2  | 9,723.2  | 14.5   |
| Togo                  | 4,484.9                                       | 15.1     | 109.7    | 109.7    | 501.0                       | 80.5    | 60.1    | 60.1    | 4,985.9             | 95.7     | 169.8    | 169.8    | 12.2   |
| Trinidad and Tobago   | 108.2   | 22.8     | 206.2    | 206.2    | 1,588.2                     | 119.8   | 179.8   | 179.8   | 1,696.4             | 142.6    | 386.0    | 386.0    | 84.8   |
| Tunisia               | 12,324.7                                      | 1,241.4  | 651.2    | 651.2    | 4,785.7                     | 1,302.0 | 718.2   | 718.2   | 17,110.5            | 2,543.4  | 1,369.4  | 1,369.4  | 32.4   |
| Turkey                | 62,426.0                                      | 11,937.3 | 12,186.7 | 12,186.7 | 14,441.1                    | 4,959.3 | 3,807.2 | 3,807.2 | 76,867.2            | 16,896.7 | 15,994.0 | 15,994.0 | 21.1   |

|                      |             |           |             |             |           |           |             |           |             |      |
|----------------------|-------------|-----------|-------------|-------------|-----------|-----------|-------------|-----------|-------------|------|
| Turkmenistan         | 5,631.8     | 3,314.7   | 412.3       | 841.6       | 46.7      | 85.9      | 6,473.3     | 3,361.3   | 498.2       | 9.4  |
| Uganda               | 25,440.5    | 26.2      | 191.9       | 897.1       | 248.5     | 129.9     | 26,337.5    | 274.7     | 321.8       | 4.7  |
| UK                   | 14,449.5    | 508.6     | 3,519.8     | 39,873.5    | 4,989.5   | 11,304.8  | 54,323.0    | 5,498.1   | 14,824.6    | 75.2 |
| Ukraine              | 54,470.5    | 2,255.0   | 14,907.4    | 2,726.0     | 474.5     | 1,911.0   | 57,196.5    | 2,729.5   | 16,818.4    | 6.7  |
| United Arab Emirates | 1,374.4     | 530.3     | 628.3       | 5,023.0     | 1,369.5   | 1,516.8   | 6,397.3     | 1,899.8   | 2,145.1     | 75.7 |
| Uruguay              | 5,183.7     | 186.4     | 233.4       | 1,285.6     | 21.5      | 142.1     | 6,469.3     | 207.9     | 375.5       | 20.5 |
| USA                  | 462,444.5   | 54,907.2  | 137,709.8   | 106,318.7   | 14,116.8  | 45,856.7  | 568,763.2   | 69,024.0  | 183,566.5   | 20.2 |
| Uzbekistan           | 12,695.0    | 8,954.8   | 3,377.1     | 6,362.5     | 88.8      | 345.9     | 19,057.5    | 9,043.6   | 3,723.0     | 21.4 |
| Vanuatu              | 245.0       | —         | —           | 8.8         | 14.5      | 9.0       | 253.8       | 14.5      | 9.0         | 11.7 |
| Venezuela            | 21,550.6    | 1,591.2   | 4,545.8     | 12,984.8    | 568.6     | 901.0     | 34,535.4    | 2,159.8   | 5,446.9     | 34.3 |
| Vietnam              | 50,495.0    | 6,415.2   | 21,459.5    | 4,146.3     | 537.6     | 764.1     | 54,641.2    | 6,952.8   | 22,223.6    | 6.5  |
| Yemen                | 1,320.7     | 2,364.8   | 371.0       | 10,199.2    | 1,672.5   | 747.6     | 11,520.0    | 4,037.3   | 1,118.5     | 75.7 |
| Zambia               | 7,972.4     | 326.2     | 483.6       | 805.8       | 85.0      | 68.3      | 8,778.1     | 411.1     | 551.8       | 9.8  |
| Zimbabwe             | 11,846.5    | 782.2     | 1,145.2     | 1,002.0     | 84.2      | 95.3      | 12,848.5    | 866.4     | 1,240.5     | 7.9  |
| World                | 4,902,626.4 | 724,848.3 | 1,049,238.3 | 1,346,910.7 | 218,476.3 | 282,963.7 | 6,249,537.1 | 943,324.6 | 1,332,202.1 | 21.7 |



# Total Water Footprint of National Consumption, by Sector and Country, 1996–2005

## Description

The data in this table are similar to those for data table 14 on both internal production and external imports by economic sector. Conventional estimates of national water use have historically been restricted to statistics on water withdrawals within national boundaries. In recent years, a new approach has been developed and applied to calculate water “footprints,” which include water use (typically withdrawals and consumption, estimated separately), the use of “green water” and “grey water,” and information on water used in other countries to produce imported products. Quantifying these national water footprints is an evolving field.

The data here include the total water footprint for internal and external water consumption by country and sector (agricultural, industrial, domestic), measured in millions of cubic meters per year ( $\text{Mm}^3/\text{yr}$ ) and averaged over the decade 1996–2005. Data on population assumptions are also provided. A distinction is made between green water and blue water. In addition, the authors include the grey water footprint in the estimation of the water footprint in each sector, an estimate of the footprint of farm animal products, and details on the water footprints of national imports and exports.

Freshwater footprints are reported in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time. A water footprint has three components: green, blue, and grey. The “blue water” footprint refers to use of surface water and groundwater. The “green water” footprint is the volume of rainwater consumed, which is particularly relevant in agricultural production. The “grey water” footprint is a measure of freshwater pollution and is defined as the volume of freshwater required to assimilate a load of pollutants.

## Limitations

While the concept of the water footprint is an extremely valuable one, the process for computing footprints continues to evolve, and data sets continue to improve. For example, water withdrawal numbers are often not accurately or consistently reported (see, e.g., the description of data table 2). Estimates of agricultural water use depend on a mix

of implicit and explicit assumptions about actual irrigation levels, climatic data for certain crop types, and irrigation technologies. Some consumer categories are not included or accurately estimated. Estimates of the water footprint of imported goods are produced using global averages because of constraints on information of the location of exported goods. The grey water footprint estimates are based on a limited set of pollutants—leaching and runoff of nitrogen fertilizers—and exclude the potential effects of other agricultural chemicals, including pesticides.

See the original source for far more detail on the fundamental assumptions and limitations of the footprint approach.

## Source

Mekonnen, M. M., and A. Y. Hoekstra. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Value of Water Research Report Series No. 50. Delft, Netherlands: UNESCO-IHE Institute for Water Education. <http://www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Voll.pdf>.

**DATA TABLE 15** Total Water Footprint of National Consumption, by Sector and Country, 1996–2005 (Mm<sup>3</sup>/yr)

| Country                | Water Footprint of Consumption of Agricultural Products |         |          |                                  |         |         | Water Footprint of Consumption of Industrial Products |         |       |                                  |         |         | Water Footprint of Domestic Water Consumption |      |      |
|------------------------|---|---------|----------|----------------------------------|---------|---------|---|---------|-------|----------------------------------|---------|---------|---|------|------|
|                        | Internal (WFcons, nat, int, agr)                        |         |          | External (WFcons, nat, ext, agr) |         |         | Internal (WFcons, nat, int, ind)                      |         |       | External (WFcons, nat, ext, ind) |         |         | Blue  | Grey | Grey |
|                        | Green   | Blue    | Grey     | Green                            | Blue    | Grey    | Blue  | Grey    | Blue  | Grey                             | Blue    | Grey    | Blue  | Grey | Grey |
| Albania                | 1,857.8   | 274.1   | 112.5    | 1,519.8                          | 238.8   | 121.7   | 7.9   | 148.6   | 3.9   | 52.4                             | 46.0    | 414.0   |   |      |      |
| Algeria                | 19,523.7  | 2,731.4 | 294.4    | 21,555.6                         | 1,555.6 | 1,835.6 | 21.7  | 196.8   | 18.3  | 187.1                            | 133.0   | 851.1   |   |      |      |
| Angola                 | 11,663.8  | 198.9   | 34.9     | 1,584.0                          | 213.1   | 192.0   | 0.9   | 13.2    | 2.0   | 17.6                             | 8.0     | 72.0    |   |      |      |
| Antigua and Barbuda    | 30.3  | 0.1     | —        | 64.1                             | 6.8     | 5.8     | 0.0   | 0.7     | 1.0   | 9.6                              | 0.3     | 2.7     |   |      |      |
| Argentina              | 47,746.2  | 3,258.0 | 1,682.4  | 1,298.1                          | 146.0   | 111.2   | 115.9   | 1,255.5 | 61.5  | 656.5                            | 491.0   | 2,724.0 |   |      |      |
| Armenia                | 1,595.1   | 326.4   | 82.4     | 1,391.0                          | 125.8   | 126.6   | 5.0   | 60.0    | 3.5   | 54.9                             | 84.3    | 590.0   |   |      |      |
| Australia              | 33,170.9  | 3,323.8 | 1,562.8  | 2,634.0                          | 232.4   | 195.2   | 88.7  | 200.5   | 182.4 | 2,013.0                          | 352.0   | 762.5   |   |      |      |
| Austria                | 3,192.9   | 16.0    | 422.4    | 5,947.3                          | 517.2   | 652.8   | 40.8  | 64.6    | 147.4 | 1,534.7                          | 74.0    | 261.7   |   |      |      |
| Azerbaijan             | 4,158.9   | 1,306.1 | 143.1    | 2,533.4                          | 205.1   | 74.2    | 82.4  | 1,077.5 | 6.9   | 116.1                            | 52.1    | 396.6   |   |      |      |
| Bahamas                | 61.5  | —       | —        | 413.2                            | 42.9    | 41.9    | —   | —       | 8.4   | 85.5                             | —       | —       |   |      |      |
| Bangladesh             | 67,849.0  | 7,717.2 | 10,353.4 | 13,923.7                         | 3,177.6 | 1,587.5 | 11.6  | 200.8   | 18.6  | 261.2                            | 401.6   | 3,614.4 |   |      |      |
| Barbados               | 139.9   | 0.4     | 6.3      | 238.1                            | 27.4    | 30.5    | 1.7   | 31.3    | 2.3   | 20.8                             | 3.0     | 27.0    |   |      |      |
| Belarus                | 10,944.5  | 75.5    | 1,998.8  | 2,164.1                          | 375.3   | 108.0   | 53.0  | 46.2    | 68.3  | 1,133.9                          | 65.0    | 195.5   |   |      |      |
| Belgium                | 359.2   | 1.2     | 103.6    | 12,285.4                         | 963.5   | 1,012.3 | 150.1   | 1,165.5 | 290.0 | 2,947.2                          | 74.3    | 280.0   |   |      |      |
| Belize                 | 294.0   | 4.1     | 62.8     | 30.8                             | 8.7     | 6.6     | 4.9   | 78.0    | 1.1   | 11.5                             | 1.0     | 8.3     |   |      |      |
| Benin                  | 6,957.5   | 7.1     | 35.3     | 458.9                            | 136.5   | 58.7    | 1.4   | 26.8    | 1.9   | 22.7                             | 4.1     | 36.9    |   |      |      |
| Bermuda                | 0.4   | 0.1     | 0.3      | 107.5                            | 9.5     | 8.1     | —   | —       | 5.0   | 57.7                             | —       | —       |   |      |      |
| Bolivia                | 25,764.0  | 376.8   | 66.4     | 2,488.5                          | 124.4   | 97.3    | 3.8   | 49.0    | 4.0   | 38.7                             | 18.0    | 129.9   |   |      |      |
| Bosnia and Herzegovina | 2,393.3   | 17.0    | 120.6    | 1,482.6                          | 88.3    | 228.7   | —   | —       | 16.2  | 215.3                            | —       | —       |   |      |      |
| Botswana               | 2,074.4   | 14.7    | —        | 969.4                            | 309.6   | 59.3    | 1.3   | 23.7    | 0.7   | 7.9                              | 7.9     | 71.1    |   |      |      |
| Brazil                 | 288,345.2   | 8,497.8 | 9,704.9  | 27,980.8                         | 2,074.9 | 1,074.5 | 420.1   | 5,878.7 | 147.1 | 1,522.0                          | 1,202.0 | 8,525.7 |   |      |      |
| Brunei Darussalam      | 8.6   | 0.0     | 0.0      | 941.8                            | 110.2   | 57.0    | —   | —       | 2.3   | 32.1                             | —       | —       |   |      |      |
| Bulgaria               | 11,814.2  | 60.1    | 995.8    | 2,638.3                          | 361.3   | 157.2   | 109.6   | 1,115.3 | 18.6  | 260.0                            | 110.6   | 706.6   |   |      |      |

|                            |           |           |           |           |          |         |         |          |       |         |         |          |
|----------------------------|-----------|-----------|-----------|-----------|----------|---------|---------|----------|-------|---------|---------|----------|
| Burkina Faso               | 19,121.3  | 188.4     | 241.1     | 447.0     | 172.3    | 47.7    | 0.3     | 5.5      | 1.8   | 20.8    | 10.4    | 93.6     |
| Burundi                    | 4,505.5   | 93.8      | 5.6       | 87.5      | 8.3      | 8.6     | 0.8     | 15.7     | 0.4   | 4.6     | 4.9     | 44.1     |
| Cambodia                   | 12,266.0  | 688.1     | 26.9      | 612.6     | 103.3    | 53.8    | 0.4     | 3.1      | 2.6   | 17.5    | 6.0     | 54.0     |
| Cameroon                   | 18,409.0  | 148.1     | 137.4     | 603.7     | 337.6    | 109.9   | 2.9     | 53.3     | 3.3   | 35.6    | 18.0    | 162.0    |
| Canada                     | 41,548.5  | 769.7     | 5,326.5   | 7,874.8   | 1,868.5  | 952.3   | 794.3   | 4,348.1  | 411.9 | 3,793.7 | 899.0   | 3,487.0  |
| Cape Verde                 | 265.2     | 9.9       | —         | 219.1     | 28.2     | 20.6    | 0.0     | 0.4      | 0.5   | 5.0     | 0.2     | 1.4      |
| Central African Republic   | 4,329.9   | 70.8      | 0.1       | 54.5      | 10.9     | 11.5    | 0.1     | 2.0      | 0.1   | 0.9     | 2.0     | 18.0     |
| Chad                       | 12,275.2  | 171.2     | 0.0       | 66.2      | 22.0     | 11.9    | —       | —        | 0.5   | 4.2     | 4.0     | 36.0     |
| Chile                      | 6,994.0   | 2,100.8   | 1,895.0   | 5,070.5   | 278.1    | 261.8   | 93.2    | 311.5    | 32.3  | 335.3   | 142.0   | 373.0    |
| China                      | 784,627.8 | 125,741.5 | 217,182.4 | 110,077.5 | 13,906.1 | 6,719.4 | 3,218.7 | 40,523.2 | 392.2 | 5,329.3 | 6,753.0 | 53,532.5 |
| Colombia                   | 35,863.2  | 1,367.9   | 1,223.2   | 9,100.9   | 715.6    | 798.6   | 15.7    | 291.3    | 33.1  | 323.6   | 539.0   | 4,851.0  |
| Comoros                    | 786.5     | 1.6       | —         | 72.5      | 60.1     | 12.9    | 0.0     | 0.4      | 0.2   | 2.1     | 0.5     | 4.3      |
| Congo, Democratic Republic | 27,577.5  | 88.6      | 15.5      | 530.4     | 174.4    | 133.3   | 1.1     | 19.6     | 0.6   | 6.3     | 19.0    | 171.0    |
| Congo, Republic            | 1,568.7   | 20.0      | 3.1       | 592.2     | 147.8    | 66.4    | 0.1     | 0.8      | 0.4   | 2.7     | 3.2     | 28.8     |
| Costa Rica                 | 2,725.2   | 148.3     | 170.9     | 1,381.0   | 186.7    | 168.8   | 12.4    | 226.1    | 10.6  | 96.2    | 79.0    | 700.9    |
| Côte d'Ivoire              | 20,184.3  | 116.2     | 260.9     | 792.2     | 631.8    | 211.4   | 4.5     | 83.6     | 5.5   | 60.2    | 22.0    | 198.0    |
| Croatia                    | 4,035.7   | 2.6       | 615.0     | 2,089.9   | 129.1    | 224.6   | 2.5     | 31.4     | 36.4  | 462.9   | —       | —        |
| Cuba                       | 13,194.0  | 830.5     | 458.9     | 1,943.7   | 130.0    | 296.2   | 46.5    | 539.1    | 9.4   | 114.3   | 156.0   | 993.4    |
| Cyprus                     | 288.2     | 174.5     | 21.8      | 1,042.3   | 84.4     | 76.5    | 0.1     | 1.9      | 10.5  | 131.3   | 6.8     | 48.2     |
| Czech Republic             | 8,372.5   | 10.2      | 1,525.8   | 4,277.0   | 574.8    | 417.3   | 40.2    | 153.1    | 85.3  | 921.9   | 105.0   | 399.8    |
| Denmark                    | 2,737.5   | 19.6      | 401.8     | 3,787.8   | 354.6    | 314.6   | 10.4    | 24.3     | 84.2  | 859.5   | 41.0    | 92.5     |
| Dominica                   | 147.8     | —         | 1.6       | 24.6      | 5.5      | 3.1     | —       | —        | 0.2   | 2.2     | —       | —        |
| Dominican Republic         | 6,589.8   | 826.1     | —         | 3,263.2   | 210.5    | 393.1   | 2.1     | 35.4     | 13.5  | 122.6   | 109.0   | 906.9    |
| East Timor                 | 1,517.4   | 37.3      | —         | 41.8      | 9.2      | 11.8    | —       | —        | —     | —       | —       | —        |
| Ecuador                    | 17,174.5  | 1,440.2   | 498.3     | 2,464.1   | 133.9    | 198.9   | 33.3    | 621.8    | 11.8  | 123.0   | 212.0   | 1,908.0  |
| Egypt                      | 10,697.6  | 35,246.2  | 13,446.0  | 23,682.2  | 1,394.1  | 1,609.1 | 168.0   | 3,165.7  | 32.2  | 414.6   | 530.0   | 4,770.0  |
| El Salvador                | 3,441.3   | 42.1      | 270.5     | 1,482.0   | 214.7    | 150.0   | 7.0     | 127.4    | 7.4   | 75.3    | 32.0    | 288.0    |
| Eritrea                    | 2,018.6   | 7.1       | 1.9       | 1,871.0   | 102.1    | 83.2    | 0.0     | 0.9      | 0.6   | 7.1     | 3.1     | 27.9     |

*continues*

DATA TABLE 15 *continued*

| Country          | Water Footprint of Consumption of Agricultural Products |           |          |                                  |         |         | Water Footprint of Consumption of Industrial Products |          |       |                                  |         |          | Water Footprint of Domestic Water Consumption |          |
|------------------|---|-----------|----------|----------------------------------|---------|---------|---|----------|-------|----------------------------------|---------|----------|---|----------|
|                  | Internal (WFcons, nat, int, agr)                        |           |          | External (WFcons, nat, ext, agr) |         |         | Internal (WFcons, nat, int, ind)                      |          |       | External (WFcons, nat, ext, ind) |         |          | Blue  | Grey     |
|                  | Green   | Blue      | Grey     | Green                            | Blue    | Grey    | Blue  | Grey     | Blue  | Grey                             | Blue    | Grey     | Blue  | Grey     |
| Estonia          | 978.1   | 0.3       | 106.9    | 826.2                            | 190.8   | 48.0    | 1.7   | 5.9      | 13.0  | 142.0                            | 9.0     | 38.8     | 9.0   | 38.8     |
| Ethiopia         | 73,675.2  | 1,512.4   | 335.5    | 1,357.8                          | 116.8   | 209.2   | 1.0   | 19.2     | 5.1   | 67.0                             | 33.3    | 299.7    | 33.3  | 299.7    |
| Fiji Islands     | 960.3   | 0.8       | 23.8     | 334.0                            | 45.8    | 14.4    | 0.4   | 8.2      | 1.7   | 20.7                             | 1.0     | 9.0      | 1.0   | 9.0      |
| Finland          | 3,373.3   | 6.2       | 90.8     | 2,105.0                          | 248.4   | 208.9   | 52.9  | 167.3    | 70.3  | 815.8                            | 34.0    | 153.5    | 34.0  | 153.5    |
| France           | 43,704.2  | 1,375.0   | 3,753.5  | 36,738.7                         | 4,576.9 | 2,077.9 | 876.3   | 3,320.4  | 579.5 | 6,280.1                          | 628.0   | 2,221.3  | 628.0   | 2,221.3  |
| French Polynesia | 215.8   | 0.6       | 1.5      | 150.0                            | 32.3    | 19.7    | —   | —        | 2.7   | 23.8                             | —       | —        | —   | —        |
| Gabon            | 1,270.7   | 12.5      | 8.3      | 337.6                            | 68.0    | 37.6    | 0.2   | 3.6      | 0.7   | 7.5                              | 6.0     | 54.0     | 6.0   | 54.0     |
| Gambia           | 717.9   | 1.6       | 7.2      | 326.4                            | 69.1    | 39.0    | 0.1   | 2.7      | 0.3   | 3.7                              | 0.7     | 6.3      | 0.7   | 6.3      |
| Georgia          | 5,756.9   | 359.4     | 200.9    | 2,772.6                          | 161.5   | 138.7   | 26.4  | 483.7    | 5.2   | 77.0                             | 72.0    | 648.0    | 72.0  | 648.0    |
| Germany          | 25,576.8  | 83.9      | 7,055.1  | 60,940.9                         | 4,672.9 | 5,116.2 | 809.5   | 854.9    | 845.4 | 8,982.9                          | 581.0   | 1,632.0  | 581.0   | 1,632.0  |
| Ghana            | 21,592.2  | 37.7      | 94.8     | 1,140.8                          | 408.5   | 191.2   | 4.1   | 75.4     | 7.6   | 90.0                             | 23.5    | 211.5    | 23.5  | 211.5    |
| Greece           | 9,744.3   | 2,253.0   | 962.0    | 8,324.7                          | 1,053.9 | 854.9   | 11.0  | 29.9     | 120.3 | 1,529.7                          | 127.0   | 561.8    | 127.0   | 561.8    |
| Grenada          | 128.6   | 0.2       | —        | 64.6                             | 9.1     | 11.5    | —   | —        | 0.4   | 4.0                              | —       | —        | —   | —        |
| Guatemala        | 8,136.5   | 148.6     | 573.9    | 1,552.9                          | 201.8   | 226.0   | 10.1  | 114.8    | 12.9  | 128.0                            | 13.0    | 96.3     | 13.0  | 96.3     |
| Guinea           | 12,628.3  | 43.0      | 21.4     | 446.4                            | 222.7   | 86.3    | 0.8   | 11.7     | 1.0   | 10.6                             | 12.0    | 104.6    | 12.0  | 104.6    |
| Guinea-Bissau    | 1,363.8   | 83.6      | —        | 41.4                             | 53.1    | 14.7    | 0.3   | 5.5      | 0.2   | 2.1                              | 2.3     | 20.7     | 2.3   | 20.7     |
| Guyana           | 794.4   | 73.3      | 87.2     | 125.4                            | 16.8    | 30.1    | 0.4   | 6.9      | 1.0   | 9.9                              | 3.0     | 27.0     | 3.0   | 27.0     |
| Haiti            | 6,808.8   | 224.6     | —        | 1,229.8                          | 433.9   | 208.3   | 0.4   | 7.4      | 1.6   | 14.6                             | 5.0     | 45.0     | 5.0   | 45.0     |
| Honduras         | 5,754.3   | 113.2     | 350.1    | 776.5                            | 172.3   | 101.2   | 2.2   | 36.7     | 4.1   | 36.7                             | 7.0     | 63.0     | 7.0   | 63.0     |
| Hungary          | 15,780.8  | 73.7      | 2,039.6  | 3,765.5                          | 353.3   | 249.8   | 104.7   | 674.9    | 67.1  | 753.6                            | 71.0    | 380.9    | 71.0  | 380.9    |
| Iceland          | 4.1   | —         | 1.6      | 414.5                            | 23.2    | 24.9    | 3.9   | 32.3     | 5.6   | 58.5                             | 5.0     | 21.4     | 5.0   | 21.4     |
| India            | 720,644.0   | 221,346.8 | 96,332.9 | 23,546.0                         | 2,179.1 | 1,885.5 | 1,261.9   | 23,850.5 | 98.5  | 1,219.8                          | 5,224.0 | 47,016.0 | 5,224.0                                       | 47,016.0 |
| Indonesia        | 176,695.4   | 9,413.1   | 15,941.2 | 16,089.3                         | 4,969.0 | 1,553.2 | 17.2  | 280.0    | 57.9  | 673.6                            | 662.0   | 5,886.7  | 662.0   | 5,886.7  |
| Iran             | 50,325.3  | 37,496.5  | 8,253.6  | 19,445.0                         | 1,347.5 | 1,002.6 | 37.1  | 643.5    | 43.6  | 553.4                            | 620.0   | 5,580.0  | 620.0   | 5,580.0  |

|                   |          |         |         |           |         |          |       |         |       |          |         |         |
|-------------------|----------|---------|---------|-----------|---------|----------|-------|---------|-------|----------|---------|---------|
| Ireland           | 1,078.6  | 0.2     | 145.7   | 2,556.3   | 351.6   | 253.5    | 11.1  | 46.1    | 31.4  | 416.6    | 26.0    | 117.4   |
| Israel            | 1,272.1  | 823.4   | 333.3   | 9,710.6   | 606.4   | 546.4    | 4.0   | 8.1     | 56.8  | 595.0    | 63.0    | 105.7   |
| Italy             | 36,197.9 | 2,526.9 | 5,416.4 | 62,764.0  | 6,727.6 | 4,740.8  | 500.7 | 2,741.5 | 523.4 | 5,628.4  | 807.0   | 3,891.9 |
| Jamaica           | 2,162.1  | 44.7    | 41.8    | 1,510.2   | 164.5   | 195.2    | 2.6   | 48.6    | 6.3   | 57.5     | 14.0    | 126.0   |
| Japan             | 22,377.2 | 1,388.0 | 2,109.0 | 105,550.2 | 6,930.0 | 10,513.4 | 583.7 | 3,392.7 | 889.4 | 10,500.5 | 1,740.0 | 8,805.1 |
| Jordan            | 557.6    | 375.7   | 50.0    | 5,582.1   | 812.0   | 514.0    | 1.4   | 11.5    | 17.2  | 210.4    | 29.1    | 155.5   |
| Kazakhstan        | 25,933.0 | 5,218.5 | 250.7   | 1,229.6   | 249.1   | 197.6    | 111.9 | 1,881.6 | 22.4  | 342.2    | 59.0    | 531.0   |
| Kenya             | 27,947.7 | 295.5   | 273.0   | 4,976.8   | 744.8   | 277.2    | 4.3   | 76.5    | 8.0   | 101.6    | 47.0    | 418.9   |
| Kiribati          | 199.0    | —       | —       | 26.8      | 12.6    | 4.1      | —     | —       | 0.0   | 0.5      | —       | —       |
| Korea, Democratic | 12,405.1 | 1,328.4 | —       | 2,080.0   | 382.1   | 333.3    | 95.7  | 1,810.6 | 5.7   | 83.9     | 179.0   | 1,611.0 |
| People's Republic |          |         |         |           |         |          |       |         |       |          |         |         |
| Korea, Republic   | 11,724.0 | 454.3   | 1,130.6 | 47,962.4  | 3,700.9 | 4,266.6  | 86.6  | 306.0   | 266.5 | 2,895.8  | 662.0   | 2,214.1 |
| Kuwait            | 14.9     | 51.6    | 14.4    | 3,181.1   | 553.9   | 311.3    | 0.5   | 9.8     | 11.1  | 116.9    | 40.1    | 360.5   |
| Kyrgyzstan        | 2,458.1  | 1,194.9 | 71.3    | 2,944.6   | 133.6   | 83.5     | 12.1  | 160.2   | 4.8   | 84.2     | 32.0    | 260.3   |
| Laos              | 4,839.6  | 348.8   | 0.8     | 148.4     | 21.4    | 13.2     | 6.4   | 117.0   | 1.8   | 29.6     | 13.0    | 117.0   |
| Latvia            | 2,455.4  | 0.5     | 254.2   | 686.6     | 93.9    | 58.0     | 4.0   | 23.3    | 37.5  | 548.3    | 16.0    | 78.2    |
| Lebanon           | 1,158.0  | 667.3   | 128.7   | 4,751.5   | 544.5   | 292.8    | 6.9   | 41.8    | 20.5  | 265.1    | 38.0    | 143.7   |
| Lesotho           | 2,898.7  | 5.4     | 1.3     | 76.0      | 62.0    | 20.9     | 0.6   | 10.0    | 0.3   | 4.0      | 2.0     | 18.0    |
| Liberia           | 2,970.9  | 3.3     | —       | 180.7     | 85.2    | 63.2     | 0.8   | 16.1    | 7.5   | 87.1     | 3.0     | 27.0    |
| Libya             | 1,630.0  | 1,470.3 | 87.3    | 5,310.9   | 1,226.9 | 568.8    | 3.4   | 61.6    | 5.5   | 56.7     | 61.0    | 549.0   |
| Lithuania         | 3,670.9  | 1.1     | 99.6    | 764.3     | 137.3   | 96.3     | 1.4   | 6.3     | 29.8  | 379.4    | 21.0    | 100.5   |
| Luxembourg        | 229.3    | 0.0     | 45.6    | 645.2     | 30.7    | 39.3     | 0.7   | 0.8     | 12.7  | 122.6    | 2.5     | 3.3     |
| Macedonia         | 1,210.6  | 71.4    | 85.3    | 769.4     | 77.4    | 61.7     | 6.8   | 94.1    | 9.0   | 115.1    | 21.5    | 187.4   |
| Madagascar        | 20,644.5 | 2,253.5 | 41.5    | 562.6     | 247.9   | 74.4     | 9.6   | 181.8   | 3.2   | 37.1     | 42.0    | 378.0   |
| Malawi            | 9,654.3  | 148.7   | 539.9   | 581.6     | 36.0    | 62.4     | 2.4   | 44.6    | 1.5   | 19.9     | 15.0    | 135.0   |
| Malaysia          | 29,102.0 | 1,148.7 | 1,338.6 | 11,805.6  | 2,202.7 | 1,329.5  | 23.6  | 310.3   | 57.1  | 502.0    | 152.0   | 1,368.0 |
| Maldives          | 60.7     | 1.2     | 2.4     | 222.5     | 44.0    | 24.3     | 0.0   | —       | 0.9   | 14.1     | 0.3     | 1.9     |
| Mali              | 18,936.7 | 1,496.0 | 0.3     | 586.4     | 116.8   | 60.7     | 2.7   | 51.7    | 2.3   | 27.2     | 59.0    | 531.0   |
| Malta             | 29.0     | 3.8     | 2.7     | 625.9     | 69.0    | 50.8     | 0.0   | 0.2     | 4.0   | 45.2     | 4.0     | 31.7    |
| Mauritania        | 3,341.8  | 206.8   | 0.0     | 2,745.6   | 224.0   | 80.6     | 1.6   | 29.3    | 1.1   | 11.8     | 15.0    | 135.0   |

*continues*

DATA TABLE 15 *continued*

| Country                        | Water Footprint of Consumption of Agricultural Products |          |          |                                  |         |         | Water Footprint of Consumption of Industrial Products |         |       |                                  |         |         | Water Footprint of Domestic Water Consumption |      |
|--------------------------------|---|----------|----------|----------------------------------|---------|---------|---|---------|-------|----------------------------------|---------|---------|---|------|
|                                | Internal (WFcons, nat, int, agr)                        |          |          | External (WFcons, nat, ext, agr) |         |         | Internal (WFcons, nat, int, ind)                      |         |       | External (WFcons, nat, ext, ind) |         |         | Blue  | Grey |
|                                | Green   | Blue     | Grey     | Green                            | Blue    | Grey    | Blue  | Grey    | Blue  | Grey                             | Blue    | Grey    | Blue  | Grey |
| Mauritius                      | 446.1   | 10.0     | 4.0      | 1,486.1                          | 258.2   | 124.5   | 0.7   | 8.3     | 4.7   | 55.7                             | 21.4    | 172.1   |   |      |
| Mexico                         | 83,840.7  | 8,654.2  | 8,796.4  | 65,986.0                         | 8,475.0 | 5,950.0 | 134.6   | 1,674.0 | 358.5 | 3,174.9                          | 1,359.0 | 9,021.8 |   |      |
| Moldova                        | 3,983.3   | 364.6    | 119.8    | 225.6                            | 53.6    | 18.9    | 42.5  | 295.3   | 6.3   | 98.4                             | 22.0    | 145.2   |   |      |
| Mongolia                       | 3,171.4   | 85.6     | 72.8     | 5,319.3                          | 129.0   | 127.0   | 3.5   | 55.8    | 2.6   | 37.2                             | 9.0     | 81.0    |   |      |
| Morocco                        | 28,420.2  | 4,819.7  | 1,326.6  | 12,286.8                         | 1,062.2 | 858.5   | 12.8  | 45.9    | 29.8  | 334.2                            | 123.0   | 632.9   |   |      |
| Mozambique                     | 18,980.3  | 145.8    | 115.9    | 1,147.6                          | 171.8   | 122.4   | 0.3   | 4.9     | 1.2   | 12.1                             | 7.0     | 63.0    |   |      |
| Myanmar                        | 52,447.8  | 1,921.6  | 815.6    | 837.9                            | 52.5    | 57.8    | 6.1   | 107.2   | 6.1   | 82.9                             | 41.0    | 369.0   |   |      |
| Namibia                        | 2,150.6   | 34.3     | 21.7     | 624.5                            | 124.9   | 44.1    | 0.6   | 10.2    | 0.9   | 8.9                              | 7.3     | 65.7    |   |      |
| Nepal                          | 23,338.5  | 2,811.3  | 206.1    | 2,344.9                          | 241.2   | 302.9   | 2.3   | 39.9    | 4.6   | 71.9                             | 30.0    | 270.0   |   |      |
| Netherlands                    | 695.2   | 44.0     | 241.5    | 16,142.5                         | 1,586.3 | 1,359.8 | 109.7   | 19.2    | 266.2 | 2,755.3                          | 49.0    | 104.4   |   |      |
| New Caledonia                  | 119.4   | 0.0      | 7.8      | 238.6                            | 25.6    | 17.2    | —   | —       | 2.2   | 21.7                             | —       | —       |   |      |
| New Zealand                    | 1,864.3   | 242.4    | 89.9     | 2,811.9                          | 191.6   | 137.8   | 8.4   | 31.6    | 36.4  | 400.5                            | 102.0   | 288.0   |   |      |
| Nicaragua                      | 3,498.2   | 134.4    | 82.2     | 536.3                            | 99.5    | 62.8    | 1.2   | 22.3    | 4.0   | 43.9                             | 19.0    | 171.0   |   |      |
| Niger                          | 37,783.4  | 718.2    | 55.8     | 666.2                            | 254.3   | 83.3    | 0.3   | 5.0     | 0.6   | 6.2                              | 9.0     | 81.0    |   |      |
| Nigeria                        | 145,305.7   | 1,375.3  | 699.1    | 5,557.1                          | 1,459.0 | 941.5   | 13.0  | 197.6   | 9.0   | 88.5                             | 169.0   | 1,521.0 |   |      |
| Norway                         | 1,551.9   | 8.8      | 54.3     | 3,055.6                          | 394.7   | 251.0   | 38.3  | 150.9   | 59.5  | 606.5                            | 50.0    | 183.4   |   |      |
| Occupied Palestinian Territory | 2,540.9   | 367.3    | —        | 97.1                             | 21.3    | 127.8   | 3.4   | 64.7    | 0.2   | 2.6                              | 17.2    | 154.7   |   |      |
| Pakistan                       | 80,221.9  | 60,459.4 | 20,480.7 | 28,718.7                         | 2,252.7 | 1,220.2 | 126.9   | 2,383.0 | 21.5  | 274.0                            | 327.0   | 2,943.0 |   |      |
| Panama                         | 2,226.0   | 54.4     | 158.8    | 928.0                            | 95.5    | 131.4   | 1.4   | 10.9    | 7.6   | 79.2                             | 55.0    | 314.4   |   |      |
| Paraguay                       | 9,672.6   | 214.5    | 248.3    | 141.1                            | 59.5    | 23.6    | 1.8   | 29.4    | 6.5   | 75.1                             | 10.0    | 82.6    |   |      |
| Peru                           | 13,141.8  | 3,299.5  | 1,458.4  | 8,050.4                          | 404.0   | 567.8   | 74.5  | 362.4   | 17.8  | 195.1                            | 168.0   | 720.5   |   |      |
| Philippines                    | 78,032.3  | 3,356.3  | 3,722.9  | 10,433.7                         | 2,020.2 | 1,704.4 | 132.9   | 2,405.8 | 34.7  | 419.0                            | 584.8   | 5,263.2 |   |      |
| Poland                         | 29,880.5  | 65.3     | 5,829.9  | 8,934.8                          | 1,391.5 | 906.6   | 438.5   | 3,080.7 | 153.4 | 1,921.1                          | 210.0   | 1,167.7 |   |      |



|                              |           |         |         |          |         |         |       |         |       |         |         |          |
|------------------------------|-----------|---------|---------|----------|---------|---------|-------|---------|-------|---------|---------|----------|
| Portugal                     | 7,156.9   | 1,513.3 | 627.4   | 11,901.3 | 2,023.9 | 982.3   | 42.7  | 264.4   | 45.3  | 476.5   | 108.0   | 610.2    |
| Romania                      | 26,137.0  | 529.9   | 1,295.1 | 3,567.9  | 770.2   | 387.0   | 170.7 | 2,205.2 | 54.7  | 724.8   | 169.0   | 1,292.9  |
| Russian Federation           | 200,827.8 | 6,300.2 | 7,257.7 | 25,437.2 | 5,649.8 | 1,528.4 | 520.3 | 8,682.6 | 61.3  | 825.2   | 1,340.0 | 12,060.0 |
| Rwanda                       | 5,996.7   | 19.0    | 4.0     | 189.1    | 41.3    | 47.2    | 0.5   | 10.0    | 0.5   | 6.7     | 3.6     | 32.4     |
| Saint Kitts and Nevis        | 27.5      | 0.0     | 0.1     | 32.8     | 5.4     | 4.0     | —     | —       | 0.5   | 5.4     | —       | —        |
| Saint Lucia                  | 8.9       | 0.0     | —       | 180.4    | 17.4    | 19.3    | —     | —       | 0.7   | 6.3     | 1.3     | 11.3     |
| Saint Vincent/<br>Grenadines | 95.1      | —       | —       | 64.3     | 10.2    | 10.0    | —     | —       | 0.3   | 2.9     | —       | —        |
| Samoa                        | 319.0     | —       | 0.1     | 29.6     | 11.1    | 4.4     | —     | —       | 0.2   | 2.3     | —       | —        |
| São Tomé and<br>Príncipe     | 206.6     | 0.1     | —       | 22.1     | 8.4     | 6.8     | —     | —       | 0.1   | 0.6     | —       | —        |
| Saudi Arabia                 | 2,667.5   | 7,019.4 | 1,115.7 | 21,217.6 | 2,149.9 | 1,893.1 | 17.7  | 302.0   | 48.1  | 485.6   | 213.0   | 1,917.0  |
| Senegal                      | 7,620.5   | 321.4   | 49.5    | 2,662.0  | 538.0   | 200.0   | 2.5   | 36.1    | 4.4   | 50.1    | 9.8     | 79.9     |
| Serbia and<br>Montenegro     | 13,138.5  | 116.0   | 1,055.6 | 1,153.9  | 275.5   | 114.6   | 433.1 | 8,200.1 | 23.8  | 349.5   | 78.0    | 702.0    |
| Seychelles                   | 53.0      | 3.1     | 0.0     | 81.4     | 11.8    | 7.3     | 0.2   | 3.0     | 0.7   | 8.1     | 0.8     | 7.2      |
| Sierra Leone                 | 4,990.7   | 48.3    | —       | 1,095.2  | 100.4   | 68.0    | 0.4   | 6.4     | 0.6   | 6.6     | 2.0     | 18.0     |
| Slovakia                     | 3,786.8   | 59.2    | 406.8   | 1,667.2  | 238.8   | 176.5   | 15.1  | 91.4    | 38.8  | 395.5   | 42.8    | 261.7    |
| Slovenia                     | 742.6     | 1.1     | 407.6   | 1,930.4  | 130.7   | 185.9   | 18.6  | 157.1   | 22.8  | 246.6   | 20.1    | 134.1    |
| Solomon Islands              | 223.7     | —       | —       | 58.5     | 9.1     | 11.0    | —     | —       | 0.2   | 2.4     | —       | —        |
| South Africa                 | 35,551.6  | 3,466.1 | 2,253.2 | 10,867.1 | 483.9   | 566.2   | 22.6  | 183.2   | 48.3  | 522.9   | 390.4   | 2,368.3  |
| Spain                        | 41,038.9  | 8,759.6 | 5,805.6 | 32,561.5 | 3,237.5 | 2,782.2 | 246.0 | —       | 394.3 | 4,194.6 | 479.0   | 1,020.9  |
| Sri Lanka                    | 14,569.5  | 1,993.7 | 1,036.6 | 3,922.7  | 1,016.3 | 504.2   | 10.0  | 173.1   | 12.3  | 173.4   | 30.0    | 270.0    |
| Sudan                        | 50,305.0  | 6,914.0 | 358.3   | 1,985.8  | 162.6   | 155.0   | 9.6   | 175.4   | 5.8   | 79.3    | 99.0    | 891.0    |
| Suriname                     | 352.7     | 54.0    | 37.2    | 122.5    | 8.0     | 13.1    | 0.5   | 8.9     | 0.7   | 6.5     | 3.0     | 27.0     |
| Swaziland                    | 527.3     | 49.8    | —       | 703.6    | 156.6   | 23.1    | 0.5   | 9.2     | 0.4   | 5.2     | 2.4     | 21.6     |
| Sweden                       | 4,772.0   | 13.8    | 764.1   | 4,479.4  | 453.9   | 477.2   | 39.1  | 118.5   | 97.6  | 1,128.1 | 109.0   | 271.6    |
| Switzerland                  | 1,328.1   | 0.7     | 326.8   | 6,157.6  | 569.7   | 597.2   | 49.8  | 32.1    | 145.2 | 1,624.1 | 62.0    | 161.0    |
| Syria                        | 20,023.1  | 5,713.0 | 2,506.6 | 4,566.1  | 642.1   | 293.0   | 17.4  | 261.5   | 10.2  | 133.9   | 142.6   | 1,216.9  |
| Tajikistan                   | 4,017.0   | 2,776.2 | 296.5   | 6,629.8  | 92.0    | 56.9    | 23.9  | 409.3   | 3.6   | 58.2    | 44.0    | 396.0    |

*continues*

DATA TABLE 15 *continued*

| Country              | Water Footprint of Consumption of Agricultural Products |           |           |                                  |           |           | Water Footprint of Consumption of Industrial Products |           |          |                                  |          |           | Water Footprint of Domestic Water Consumption |      |      |
|----------------------|---|-----------|-----------|----------------------------------|-----------|-----------|---|-----------|----------|----------------------------------|----------|-----------|---|------|------|
|                      | Internal (WFcons, nat, int, agr)                        |           |           | External (WFcons, nat, ext, agr) |           |           | Internal (WFcons, nat, int, ind)                      |           |          | External (WFcons, nat, ext, ind) |          |           | Blue  | Grey | Grey |
|                      | Green   | Blue      | Grey      | Green                            | Blue      | Grey      | Blue  | Grey      | Blue     | Grey                             | Blue     | Grey      | Blue  | Grey | Grey |
| Tanzania             | 31,712.9  | 799.1     | 147.6     | 1,836.6                          | 344.1     | 174.9     | 1.2   | 22.1      | 4.3      | 58.2                             | 52.7     | 474.3     |   |      |      |
| Thailand             | 59,129.4  | 8,471.4   | 4,050.3   | 9,367.2                          | 1,477.0   | 683.8     | 76.0  | 1,275.9   | 105.5    | 1,248.1                          | 273.9    | 2,465.1   |   |      |      |
| Togo                 | 4,484.9   | 6.1       | 27.3      | 501.0                            | 79.4      | 47.4      | 0.1   | 2.3       | 1.1      | 12.7                             | 8.9      | 80.1      |   |      |      |
| Trinidad and Tobago  | 108.2   | 0.1       | 0.5       | 1,588.2                          | 115.5     | 140.7     | 1.7   | 21.9      | 4.4      | 39.1                             | 21.0     | 183.8     |   |      |      |
| Tunisia              | 12,324.7  | 1,201.5   | 400.8     | 4,785.7                          | 1,285.0   | 548.3     | 3.3   | 30.2      | 17.0     | 169.9                            | 36.5     | 220.2     |   |      |      |
| Turkey               | 62,426.0  | 11,221.3  | 6,903.6   | 14,441.1                         | 4,756.7   | 1,165.3   | 160.1   | 1,646.4   | 202.6    | 2,642.0                          | 556.0    | 3,636.7   |   |      |      |
| Turkmenistan         | 5,631.8   | 3,269.1   | 0.7       | 841.6                            | 42.7      | 52.8      | 3.6   | 33.6      | 4.0      | 33.1                             | 42.0     | 378.0     |   |      |      |
| Uganda               | 25,440.5  | 10.7      | 28.4      | 897.1                            | 245.5     | 85.9      | 2.5   | 46.5      | 3.0      | 44.1                             | 13.0     | 117.0     |   |      |      |
| UK                   | 14,449.5  | 56.0      | 3,160.0   | 39,873.5                         | 4,264.0   | 3,617.4   | 245.6   | 117.0     | 725.5    | 7,687.4                          | 207.0    | 242.8     |   |      |      |
| Ukraine              | 54,470.5  | 1,372.2   | 3,022.2   | 2,726.0                          | 375.2     | 214.9     | 426.7   | 7,781.3   | 99.4     | 1,696.1                          | 456.0    | 4,104.0   |   |      |      |
| United Arab Emirates | 1,374.4   | 466.5     | 40.9      | 5,023.0                          | 1,285.9   | 617.1     | 2.1   | 32.2      | 83.6     | 899.7                            | 61.7     | 555.3     |   |      |      |
| Uruguay              | 5,183.7   | 176.6     | 129.4     | 1,285.6                          | 13.1      | 39.5      | 1.7   | 32.0      | 8.4      | 102.6                            | 8.0      | 72.0      |   |      |      |
| USA                  | 462,444.5   | 39,447.3  | 64,568.7  | 106,318.7                        | 10,839.9  | 9,160.3   | 8,915.9   | 47,583.7  | 3,276.9  | 36,696.4                         | 6,544.0  | 25,557.4  |   |      |      |
| Uzbekistan           | 12,695.0  | 8,630.3   | 0.3       | 6,362.5                          | 76.8      | 145.3     | 47.5  | 883.8     | 12.1     | 200.6                            | 277.0    | 2,493.0   |   |      |      |
| Vanuatu              | 245.0   | —         | —         | 8.8                              | 14.3      | 6.5       | —   | —         | 0.2      | 2.6                              | —        | —         |   |      |      |
| Venezuela            | 21,550.6  | 1,194.1   | 817.3     | 12,984.8                         | 547.2     | 706.6     | 16.1  | 299.5     | 21.4     | 194.4                            | 381.0    | 3,429.0   |   |      |      |
| Vietnam              | 50,495.0  | 5,381.6   | 7,459.0   | 4,146.3                          | 507.5     | 334.6     | 479.7   | 9,014.5   | 30.1     | 429.5                            | 554.0    | 4,986.0   |   |      |      |
| Yemen                | 1,320.7   | 2,335.5   | 94.1      | 10,199.2                         | 1,669.4   | 709.8     | 2.0   | 34.2      | 3.1      | 37.8                             | 27.2     | 242.6     |   |      |      |
| Zambia               | 7,972.4   | 294.1     | 169.0     | 805.8                            | 83.6      | 52.0      | 3.0   | 53.6      | 1.4      | 16.2                             | 29.0     | 261.0     |   |      |      |
| Zimbabwe             | 11,846.5  | 713.2     | 426.4     | 1,002.0                          | 81.7      | 68.6      | 10.1  | 188.7     | 2.5      | 26.7                             | 58.9     | 530.1     |   |      |      |
| World                | 4,902,626.4   | 659,210.5 | 555,954.8 | 1,346,910.7                      | 204,557.4 | 131,506.6 | 23,614.9  | 211,278.3 | 13,918.9 | 151,457.2                        | 42,022.9 | 282,005.3 |   |      |      |

# Global Cholera Cases Reported to the World Health Organization, by Country, 1949-2011

## Description

Annual cases of cholera are shown here for all reporting countries. Cholera is one of many waterborne diseases that are a consequence of the lack of sanitation services and access to clean drinking water. Some data on cholera cases and deaths are available as early as 1922 from reports to the League of Nations, but consistent reports are available from the World Health Organization only since 1949. The data here are given annually from 1949 to 2011.

In 2011, a total of fifty-eight countries from all continents reported approximately 590,000 cases of cholera to the World Health Organization, of which 32 percent were in Africa and 61.2 percent were in the Americas (defined as North, Central, and South America and the Caribbean). These data reflect a massive upsurge in the Americas from previous years. A particularly severe outbreak started in Haiti at the end of October 2010 and also affected the Dominican Republic.

These data also show the rapid and severe spread of cholera in Latin America during the seventh pandemic, starting with the appearance of cholera in Peru in 1991 and spreading rapidly. That sharp spike in cholera was the first manifestation of the seventh pandemic in the Americas and was the first time that the Americas had seen more than a handful of indigenous cases in over a century.

## Limitations

There are serious problems with the reporting of cholera. In particular, the data here represent only the cases identified and reported to the World Health Organization and do not include undiagnosed or unreported cases. The true number of cholera cases is known to be much higher than reported here. Many countries refuse to report cholera cases, or define many severe diarrheal diseases as something other than cholera, often as “acute watery diarrhea.” As many as 500,000 to 700,000 cases of acute watery diarrhea occur annually in areas of Central and Southeast Asia and in some African countries.

As a result, the totals shown in the table are likely to seriously underrepresent total cholera cases.

## Sources

- World Health Organization (WHO). 2011. Number of Reported Cholera Cases. Global Health Observatory. [http://www.who.int/gho/epidemic\\_diseases/cholera/cases\\_text/en/index.html](http://www.who.int/gho/epidemic_diseases/cholera/cases_text/en/index.html) (accessed June 1, 2013).
- . 2013. Cholera Data Portal. <http://apps.who.int/gho/data/node.main.175>.

**DATA TABLE 16A** Global Cholera Cases Reported to the World Health Organization, by Country, 1949-1979

| Country                          | 1949   | 1950   | 1951   | 1952   | 1953   | 1954   | 1955   | 1956  | 1957   | 1958   | 1959   | 1960  | 1961  | 1962  | 1963  | 1964  | 1965  | 1966 | 1967  | 1968  | 1969  | 1970  | 1971  | 1972  | 1973  | 1974  | 1975  | 1976 | 1977   | 1978  | 1979  |  |  |  |  |  |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|-------|-------|-------|-------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|--------|-------|-------|--|--|--|--|--|
| Afghanistan                      |        |        |        |        |        |        |        |       |        |        |        | 887   |       |       |       |       | 218   |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Albania                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Algeria                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       | 1,332 | 646   | 605   | 738   | 1,165 | 286  | 262    | 220   | 2,513 |  |  |  |  |  |
| Angola                           |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       | 1    | 268   | 934   | 88    | 726   |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Argentina                        |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Armenia                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Australia                        |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       | 40    |       |       |       |      | 2      | 1     | 1     |  |  |  |  |  |
| Austria                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Azerbaijan                       |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Bahamas                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Bahrain                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       | 1    |       |       |       |       |       | 74    | 37    |       |       |      |        | 906   | 39    |  |  |  |  |  |
| Bangladesh                       | 29,809 | 20,894 | 21,154 | 27,631 | 15,617 | 16,642 | 23,699 | 8,054 | 15,631 | 16,915 | 15,618 | 2,663 | 2,524 | 3,975 | 3,333 | 1,123 | 3,154 | 664  | 3,156 | 7,411 | 7,411 | 7,419 | 2,342 | 1,059 | 1,969 | 5,614 | 4,888 | 957  | 10,403 | 5,576 | 2,154 |  |  |  |  |  |
| Belarus                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Belgium                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Belize                           |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Benin                            |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       | 175   | 2,133 | 250   | 3     | 73    | 45    | 146  | 2      | 27    |       |  |  |  |  |  |
| Bhutan                           |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Bolivia (Plurinational State of) |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Botswana                         |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Brazil                           |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Brunei Darussalam                |        |        |        |        |        |        | 1      |       |        |        |        |       |       |       |       |       | 198   |      |       |       |       | 24    |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Burkina Faso                     |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       | 1    | 1,761 | 1     | 1,118 | 632   | 3     |       |       |       |       |      |        | 1     |       |  |  |  |  |  |
| Burundi                          |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Cambodia                         | 10     | 57     | 24     | 11     | 2      |        | 1      | 6     | 3      |        |        |       |       |       |       |       |       |      |       |       |       |       |       |       |       |       |       |      |        |       |       |  |  |  |  |  |
| Cameroon                         |        |        |        |        |        |        |        |       |        |        |        |       |       |       |       |       |       |      |       |       |       |       | 2,167 | 362   | 206   | 83    | 3     | 135  |        |       |       |  |  |  |  |  |

*continues*







DATA TABLE 16A continued

| Country                          | 1949  | 1950  | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957  | 1958 | 1959 | 1960 | 1961  | 1962   | 1963  | 1964   | 1965  | 1966  | 1967  | 1968  | 1969  | 1970  | 1971  | 1972  | 1973  | 1974  | 1975  | 1976  | 1977  | 1978  | 1979   |     |  |       |    |    |  |
|----------------------------------|-------|-------|------|------|------|------|------|------|-------|------|------|------|-------|--------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-----|--|-------|----|----|--|
| Malawi                           |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       | 371   |       |       | 19    | 577   | 263   |        |     |  |       |    |    |  |
| Malaysia                         |       |       |      |      |      | 1    |      |      |       |      |      |      |       |        | 349   | 512    | 16    | 5     |       |       | 15    | 70    | 106   | 53    | 864   | 369   | 349   | 110   | 246   | 444   | 1,635  | 502 |  |       |    |    |  |
| Maldives                         |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       | 11,336 |     |  |       |    |    |  |
| Mali                             |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       | 2,665 | 4,792 | 2     | 219   | 130   |       |       |       |       |        |     |  |       |    |    |  |
| Marshall Islands                 |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Mauritania                       |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       | 1,139 | 148   | 150   |       |       |       |       |       |        |     |  |       |    |    |  |
| Mauritius                        |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Mexico                           |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Micronesia (Federated States of) |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Mongolia                         |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Morocco                          |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       | 56    | 7     |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Mozambique                       |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       | 453   | 1,018 | 11    | 3     | 18    |       |        |     |  | 4,564 |    |    |  |
| Myanmar                          | 4,212 | 6,753 | 347  | 22   | 35   | 42   | 13   | 10   | 7     | 3    | 259  | 1    | 1     | 3,019  | 922   | 207    | 263   | 9     | 3     | 205   | 911   | 378   | 180   | 386   | 2,363 | 2,942 | 1,519 |       | 3,551 | 874   |        |     |  |       |    |    |  |
| Namibia                          |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Nauru                            |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       | 38 | 50 |  |
| Nepal                            |       |       |      |      |      |      |      |      | 2,706 |      |      |      |       |        |       |        | 727   | 2     |       |       | 34    | 226   | 391   | 4     | 1     | 7     | 8     | 260   | 185   | 428   | 1,662  | 22  |  |       |    |    |  |
| Netherlands                      |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| New Zealand                      |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Nicaragua                        |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Niger                            |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Nigeria                          |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Norway                           |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Oman                             |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Pakistan                         |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Panama                           |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Papua New Guinea                 |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Paraguay                         |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Peru                             |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |
| Philippines                      |       |       |      |      |      |      |      |      |       |      |      |      | 9,923 | 13,015 | 3,979 | 16,464 | 4,581 | 5,261 | 1,629 | 2,787 | 1,541 | 1,095 | 3,585 | 5,601 | 2,840 | 1,730 | 680   | 1,258 | 1,363 | 1,408 | 1,268  |     |  |       |    |    |  |
| Poland                           |       |       |      |      |      |      |      |      |       |      |      |      |       |        |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |        |     |  |       |    |    |  |



**DATA TABLE 16A** *continued*

| Country                            | 1949 | 1950   | 1951    | 1952    | 1953    | 1954   | 1955   | 1956   | 1957   | 1958   | 1959   | 1960   | 1961   | 1962   | 1963   | 1964   | 1965   | 1966   | 1967   | 1968   | 1969   | 1970   | 1971    | 1972   | 1973    | 1974   | 1975   | 1976   | 1977   | 1978   | 1979   |  |  |
|------------------------------------|------|--------|---------|---------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|--------|---------|--------|--------|--------|--------|--------|--------|--|--|
| Tunisia                            |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        | 27     |        |        |        |        | 27     | 4       | 656    |         |        |        |        |        |        |        |  |  |
| Turkey                             |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        | 384    |        |        |        |        |        |         |        |         |        |        | 17     |        |        |        |  |  |
| Turkmenistan                       |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Tuvalu                             |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Uganda                             |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        | 757    |        |        |        |        |        |         |        |         |        | 3      |        |        | 1,120  | 940    |  |  |
| Ukraine                            |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| United Arab Emirates               |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | 2       |        |         |        |        |        |        |        |        |  |  |
| United Kingdom                     |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | 1      | 3       | 2      | 5       | 3      | 1      | 1      | 2      |        |        |  |  |
| United Republic of Tanzania        |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        | 10      |        |        | 297    | 6,608  | 2,559  |        |  |  |
| United States of America           |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Uzbekistan                         |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Venezuela (Bolivarian Republic of) |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Vietnam                            |      | 9      | 26      | 7       | 7       | 3      |        |        |        |        |        |        |        |        |        | 20,186 | 1,738  | 8,353  | 7,664  | 1,097  | 2,573  | 82     | 270     | 146    | 1,495   | 139    | 5      | 1,068  | 32     | 2      | 365    |  |  |
| Yemen                              |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | 190     | 1,064  | 215     | 6      | 1      |        |        | 414    | 1,953  |  |  |
| Zambia                             |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Zimbabwe                           |      |        |         |         |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |         |        |         |        |        |        |        |        |        |  |  |
| Global Total                       | 17   | 34,665 | 114,518 | 123,025 | 240,927 | 37,804 | 40,218 | 63,542 | 63,031 | 95,763 | 36,138 | 38,130 | 61,966 | 68,727 | 59,437 | 95,938 | 56,609 | 31,146 | 24,748 | 34,164 | 36,173 | 63,994 | 176,068 | 80,248 | 108,788 | 97,635 | 93,055 | 68,622 | 63,276 | 77,678 | 57,645 |  |  |

**DATA TABLE 16B** Global Cholera Cases Reported to the World Health Organization, by Country, 1980–2011

| Country                          | 1980  | 1981 | 1982 | 1983 | 1984 | 1985  | 1986   | 1987   | 1988   | 1989  | 1990  | 1991  | 1992   | 1993   | 1994   | 1995   | 1996  | 1997  | 1998   | 1999   | 2000  | 2001  | 2002  | 2003 | 2004   | 2005  | 2006    | 2007   | 2008   | 2009  | 2010   | 2011  |       |        |        |     |   |  |    |  |
|----------------------------------|-------|------|------|------|------|-------|--------|--------|--------|-------|-------|-------|--------|--------|--------|--------|-------|-------|--------|--------|-------|-------|-------|------|--------|-------|---------|--------|--------|-------|--------|-------|-------|--------|--------|-----|---|--|----|--|
| Afghanistan                      |       |      |      |      |      |       |        |        |        |       |       |       |        | 37,046 | 39,735 | 19,903 |       | 8,340 | 20,000 | 49,278 | 8,660 | 8,998 | 6     | 82   |        | 66    |         |        |        |       | 13,152 | 1,324 | 2,369 | 3,753  |        |     |   |  |    |  |
| Albania                          |       |      |      |      |      |       |        |        |        |       |       |       |        |        | 626    |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Algeria                          | 614   |      |      | 218  | 45   |       |        | 1,507  | 699    | 393   | 1,299 |       | 69     |        | 118    |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Angola                           |       |      |      |      |      |       | 16,222 | 15,500 | 17,601 | 9,527 | 8,590 | 3,608 |        |        | 3,443  | 3,295  | 1,306 |       |        |        |       |       |       |      |        |       | 134,514 | 36,844 | 31,533 | 4,038 | 1,484  | 1,810 |       |        |        |     |   |  |    |  |
| Argentina                        |       |      |      |      |      |       |        |        |        |       |       |       |        | 2,350  | 889    | 188    | 474   | 1,274 | 12     |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Armenia                          |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        |        |       |       | 25     |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Australia                        | 2     | 2    | 1    | 4    | 1    | 2     |        | 1      | 1      |       |       |       | 3      | 5      | 3      | 5      | 2     | 4     | 10     | 8      | 2     | 4     | 10    | 4    | 4      | 4     | 6       | 6      |        |       |        |       |       |        |        | 3   | 6 |  |    |  |
| Austria                          |       |      |      |      |      |       |        |        |        |       | 2     |       |        | 1      | 1      | 1      | 1     | 1     | 2      | 2      |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Azerbaijan                       |       |      |      |      |      |       |        |        |        |       |       |       |        |        | 18     |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Bahamas                          |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Bahrain                          |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Bangladesh                       |       |      |      |      |      |       | 523    | 571    | 94     | 82    | 8     | 479   | 78     | 562    | 2,297  | 418    | 3,918 | 2,134 | 6,880  | 1,021  |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Belarus                          |       |      |      |      |      |       |        |        |        |       |       |       |        |        | 3      | 3      |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Belgium                          | 1     |      |      | 1    | 1    | 1     |        |        |        |       |       | 1     | 1      | 1      | 1      |        |       |       |        |        |       |       |       |      | 2      |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Belize                           |       |      |      |      |      |       |        |        |        |       |       | 159   | 135    | 6      | 19     | 26     | 4     | 56    | 12     |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Benin                            | 3     | 2    | 3    | 1    | 1    | 243   |        |        |        |       |       | 7,474 | 413    | 10     | 187    | 203    | 6,190 | 1,592 | 412    | 1,710  | 936   | 7,886 | 540   | 868  | 1,284  | 1,498 | 182     |        |        |       |        |       | 2,955 | 148    | 983    | 755 |   |  |    |  |
| Bhutan                           |       |      |      |      |      |       |        |        |        |       |       | 422   | 494    |        |        | 25     |       |       | 19     |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Bolivia (Plurinational State of) |       |      |      |      |      |       |        |        |        |       |       | 206   | 22,260 | 10,134 | 2,710  | 2,293  | 2,847 | 3,264 | 466    |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Botswana                         |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        |        |       |       |        |        |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Brazil                           |       |      |      |      |      |       |        |        |        |       |       | 2,103 | 30,317 | 59,212 | 49,455 | 15,915 | 5,522 | 5,762 | 5,142  | 8,990  | 1,430 | 14    |       |      | 42     | 5     |         |        |        |       |        |       |       |        |        |     |   |  | 1  |  |
| Brunei Darussalam                |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        |        |       |       |        | 93     |       |       |       |      |        |       |         |        |        |       |        |       |       |        |        |     |   |  | 3  |  |
| Burkina Faso                     |       |      |      |      |      |       |        |        |        |       |       |       |        |        |        | 1,451  | 425   |       | 2,072  | 186    | 1,234 | 954   |       | 2    |        |       |         |        |        |       |        |       |       |        |        |     |   |  | 20 |  |
| Burundi                          | 2,039 | 582  | 415  | 512  | 180  | 259   |        |        |        |       | 82    | 3     | 479    | 78     | 562    | 2,297  | 418   | 3,918 | 2,134  | 6,880  | 2,042 | 2,006 | 1,154 | 864  | 1,638  | 2,618 | 1,772   | 730    | 702    | 710   | 333    | 1,072 |       |        |        |     |   |  |    |  |
| Cambodia                         |       |      |      |      |      |       |        | 474    | 56     | 47    | 5     | 770   | 1,229  | 2,252  | 3,065  | 4,190  | 740   | 310   | 2,394  | 3,422  |       |       |       |      | 114    |       |         |        |        |       |        |       |       |        |        |     |   |  |    |  |
| Cameroon                         | 229   | 243  | 5    | 55   | 392  | 1,158 | 165    | 94     | 4      | 4     | 16    | 4,026 | 1,288  | 648    | 527    | 615    | 5,796 | 3,418 | 9,206  | 3,168  | 246   | 518   | 132   | 414  | 16,010 | 5,694 | 1,844   | 20     |        |       |        |       | 1,608 | 10,759 | 22,433 |     |   |  |    |  |

*continues*

DATA TABLE 16B *continued*

| Country                               | 1980  | 1981  | 1982   | 1983  | 1984 | 1985 | 1986  | 1987  | 1988  | 1989  | 1990   | 1991   | 1992   | 1993   | 1994   | 1995   | 1996  | 1997   | 1998   | 1999   | 2000   | 2001   | 2002   | 2003   | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   |     |  |   |  |  |
|---------------------------------------|-------|-------|--------|-------|------|------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-----|--|---|--|--|
| Canada                                |       |       |        |       |      |      |       |       |       | 1     |        | 2      | 5      |        |        |        |       | 2      | 4      |        | 10     | 12     | 8      | 10     | 6      | 14     | 4      | 2      | 3      | 4      | 2      |        |     |  |   |  |  |
| Cape Verde                            |       |       |        |       |      |      |       |       |       |       |        |        |        |        | 128    | 12,913 | 428   |        | 266    |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Central African Republic              |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        | 886   | 44     |        |        |        |        | 640    |        |        |        |        |        |        |        |        |        | 117 |  |   |  |  |
| Chad                                  |       |       |        |       |      |      |       |       |       |       |        | 13,915 |        |        | 1,094  |        | 7,830 | 17,602 | 8,190  | 434    |        | 10,488 |        | 110    | 11,062 | 180    | 3,336  |        |        | 67     | 6,395  | 17,267 |     |  |   |  |  |
| Chile                                 |       |       |        |       |      |      |       |       |       |       | 41     | 73     | 32     | 1      |        |        | 1     | 8      | 24     |        |        |        |        |        |        |        |        |        |        |        |        |        | 1   |  |   |  |  |
| China                                 | 88    |       |        |       |      |      |       | 4     | 7,267 | 5,628 | 644    | 210    | 583    | 11,673 | 34,677 | 10,337 | 316   | 2,354  | 9,294  | 9,178  | 3,692  | 280    | 446    | 488    | 1,960  | 322    | 336    | 522    | 170    | 157    | 26     |        |     |  |   |  |  |
| Colombia                              |       |       |        |       |      |      |       |       |       |       | 11,979 | 15,129 |        |        | 230    | 996    | 1,922 | 4,428  | 3,016  | 884    | 84     |        |        |        | 2      |        |        |        |        |        |        |        |     |  |   |  |  |
| Comoros                               |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       | 14,600 | 2,360  | 6,594  | 452    | 3,134  | 112    | 2      | 2      |        |        | 3,110  | 4      |        |        |        |     |  |   |  |  |
| Congo                                 |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        | 550   | 6,444  | 9,626  | 18     |        |        |        |        |        |        | 350    | 15,570 | 468    | 93     |        |        |     |  |   |  |  |
| Costa Rica                            |       |       |        |       |      |      |       |       |       |       |        |        | 12     | 14     | 38     | 24     | 19    | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Côte d'Ivoire                         |       |       | 34     |       |      |      |       |       |       |       | 604    | 37     | 724    | 1,108  | 4,993  | 1,345  |       |        |        |        |        | 11,824 | 8,376  | 2,068  | 210    | 78     | 828    | 16     | 21     | 10     | 32     | 1,261  |     |  |   |  |  |
| Czech Republic                        |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       | 7      |        |        |        |        | 2      |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Democratic People's Republic of Korea | 170   |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Democratic Republic of the Congo      | 1,051 | 2,379 | 10,328 | 2,977 | 162  | 740  | 1,059 | 1,150 | 295   | 99    | 468    | 4,066  | 1,949  | 986    | 58,057 | 553    | 7,886 | 4,842  | 69,798 | 25,422 | 29,990 | 11,456 | 63,316 | 54,544 | 15,330 | 26,860 | 41,284 | 56,538 | 90,450 | 45,798 | 13,884 | 21,700 |     |  |   |  |  |
| Denmark                               |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Djibouti                              |       |       |        |       |      | 115  |       |       |       |       |        |        |        |        | 10,655 | 1,122  |       | 4,848  | 328    |        |        |        |        |        |        |        | 2,174  |        |        |        |        | 2,047  | 127 |  |   |  |  |
| Dominican Republic                    |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Ecuador                               |       |       |        |       |      |      |       |       |       |       |        | 46,320 | 31,870 |        | 6,833  | 1,785  | 2,160 | 1,059  | 130    | 7,448  | 180    | 54     | 18     | 50     | 5      |        |        |        |        |        |        |        |     |  |   |  |  |
| El Salvador                           |       |       |        |       |      |      |       |       |       |       | 947    | 8,717  | 6,573  |        | 11,745 | 2,923  | 182   |        | 16     | 268    | 631    |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Equatorial Guinea                     |       |       |        |       |      | 404  | 108   |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        | 118    | 12,762 |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Eritrea                               |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Estonia                               |       |       |        |       |      |      |       |       |       |       |        |        |        |        | 2      |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Ethiopia                              |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Finland                               |       | 1     |        |       |      |      |       |       |       |       |        |        |        |        |        | 2      | 1     |        | 2      |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| France                                | 1     | 20    | 18     | 3     | 1    |      | 37    | 7     |       | 1     | 6      | 7      |        | 5      | 4      | 6      | 8     | 6      | 4      |        | 10     | 4      | 2      |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Gabon                                 |       | 7     |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        | 12     | 1,258  |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Gambia                                |       |       |        |       |      | 2    |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Georgia                               |       |       |        |       |      |      |       |       |       |       |        |        |        |        |        |        |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |     |  |   |  |  |
| Germany                               | 4     | 4     | 1      |       |      |      | 2     |       | 2     | 1     | 1      | 1      | 1      | 1      | 5      | 1      |       | 4      | 10     | 6      | 4      | 2      | 2      | 2      | 6      |        | 2      | 4      |        |        |        |        |     |  | 4 |  |  |



DATA TABLE 16B continued

| Country                          | 1980  | 1981  | 1982  | 1983   | 1984  | 1985  | 1986  | 1987  | 1988  | 1989  | 1990   | 1991    | 1992    | 1993   | 1994   | 1995   | 1996   | 1997  | 1998   | 1999   | 2000   | 2001   | 2002   | 2003   | 2004   | 2005   | 2006  | 2007   | 2008   | 2009   | 2010   | 2011   |       |     |     |  |
|----------------------------------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|--------|---------|---------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|-------|-----|-----|--|
| Malawi                           | 261   | 487   |       |        |       |       |       |       | 6     | 8,351 | 13,457 | 8,088   | 298     | 25,193 | 107    | 1      | 1      | 260   | 3,490  | 53,016 | 4,782  | 4,790  | 65,236 | 5,472  | 1,350  | 2,210  | 8,296 | 950    | 1,662  | 1,502  | 1,155  | 120    |       |     |     |  |
| Malaysia                         | 97    | 469   | 516   | 2,195  | 67    | 52    | 55    | 1,168 | 1,324 | 393   | 2,071  | 506     | 474     | 995    | 534    | 2,209  | 1,486  | 778   | 2,608  | 1,070  | 248    | 1,114  |        |        | 32     | 474    | —     | 374    | 443    | 586    |        |        |       |     |     |  |
| Maldives                         |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Mali                             |       |       |       |        | 1,795 | 3,759 | 1,916 | 352   |       |       |        |         |         |        |        | 2,191  | 5,723  | 12    | 12     | 3,770  | 134    | 36     | 2,910  | 5,678  | 2,356  | 14     | 153   |        |        |        |        | 2,220  |       |     |     |  |
| Marshall Islands                 |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        | 300    |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Mauritania                       |       |       |       |        | 166   | 259   | 3,734 | 1,578 | 575   | 700   |        |         |         |        |        |        |        | 4,534 | 924    |        |        | 160    | 68     |        |        | 8,264  | 50    | 3      |        |        |        |        | 46    |     |     |  |
| Mauritius                        |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Mexico                           |       |       |       |        |       |       |       |       |       |       |        | 2,680   | 8,162   | 10,712 | 4,059  | 16,430 | 1,088  | 4,712 | 142    |        |        | 10     | 2      |        |        |        |       |        |        |        | 2      |        | 1     | 1   |     |  |
| Micronesia (Federated States of) |       |       |       |        |       |       |       |       |       |       | 34     |         |         |        |        |        |        |       |        |        |        | 6,904  | 28     |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Mongolia                         |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Morocco                          |       |       |       |        |       |       |       |       |       |       | 4,573  |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Mozambique                       | 1,212 | 1,753 | 2,301 | 10,745 | 521   | 3     | 1     |       |       | 371   | 4,152  | 7,847   | 30,802  | 19,803 | 692    |        |        | —     | 17,478 | 85,344 | 88,658 | 35,298 | 17,898 | 48,750 | 27,516 | 40,160 | 4,452 | 12,612 | 5,244  | 18,174 | 39,358 | 7,430  | 1,279 |     |     |  |
| Myanmar                          | 1,018 | 28    |       | 989    |       |       |       |       |       | 597   |        | 924     | 826     | 1,758  | 421    | 1,296  |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       | 16  |     |  |
| Namibia                          |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Nauru                            |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Nepal                            | 1     | 24    |       |        |       |       |       |       |       | 141   | 23,888 | 30,648  | 798     | 31     | 32     | 157    | 274    | 490   | 3,490  |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Netherlands                      | 2     |       | 2     |        |       |       |       |       | 1     |       | 3      |         |         | 3      | 1      | 9      | 3      | 4     | 8      | 4      | 2      | 2      | 2      | 2      | 2      | 2      | 8     | 6      |        |        |        | 5      |       |     |     |  |
| New Zealand                      |       |       |       |        |       |       |       | 2     |       |       | 5      |         |         |        | 2      | 2      |        |       |        |        |        | 2      |        |        |        |        | 1     |        |        |        |        |        |       |     |     |  |
| Nicaragua                        |       |       |       |        |       |       |       |       |       |       |        | 1       | 3,067   | 6,631  | 7,821  | 8,825  | 2,813  | 2,566 | 2,874  | 1,104  | 12     |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Niger                            | 7     |       |       |        | 3,788 |       |       |       |       | 166   |        | 3,238   |         |        | 732    | 264    | 3,957  | 518   |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Nigeria                          | 138   | 107   | 248   | 178    | 1,667 | 30    | 91    | 1,290 | 137   | 1,078 |        | 59,478  | 8,687   | 4,160  | 2,859  | 1,059  | 12,374 | 2,644 | 6,928  | 52,716 | 5,598  | 4,624  | 10,658 | 3,866  | 6,372  | 8,954  | 4,056 | 3,322  | 10,820 | 27,382 | 44,456 | 23,377 |       |     |     |  |
| Norway                           |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        | 1      |       | 4      |        |        |        |        |        |        |        | 2     | 2      | 1      |        |        |        |       |     |     |  |
| Oman                             |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        | 14     | 1      |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Pakistan                         |       | 4     |       |        |       |       |       |       |       |       |        |         |         | 12,062 |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       | 164 | 527 |  |
| Panama                           |       |       |       |        |       |       |       |       |       |       |        | 1,178   | 2,416   | 42     |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Papua New Guinea                 |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Paraguay                         |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        | 4      |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Peru                             |       |       |       |        |       |       |       |       |       |       |        | 322,562 | 242,237 | 72,404 | 23,887 | 22,397 | 4,518  | 6,966 | 83,434 | 3,092  | 1,868  | 988    | 16     |        |        |        |       |        |        |        |        |        |       |     |     |  |
| Philippines                      | 836   | 864   | 930   |        |       | 10    |       |       |       |       |        | 345     | 708     | 3,340  | 847    | 1,402  | 1,210  | 1,458 | 660    | 550    | 348    |        |        | 1,066  | 278    | 132    | —     |        |        |        |        |        | 33    | 120 |     |  |
| Poland                           |       |       |       |        |       |       |       |       |       |       |        |         |         |        |        |        |        |       |        |        |        |        |        |        |        |        |       |        |        |        |        |        |       |     |     |  |





DATA TABLE 16B *continued*

| Country                            | 1980   | 1981   | 1982   | 1983   | 1984   | 1985   | 1986   | 1987   | 1988   | 1989   | 1990   | 1991   | 1992    | 1993    | 1994    | 1995    | 1996    | 1997    | 1998    | 1999    | 2000    | 2001    | 2002    | 2003    | 2004    | 2005    | 2006    | 2007    | 2008    | 2009    | 2010    | 2011  |    |        |  |
|------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-------|----|--------|--|
| Tonga                              |        |        |        |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |         |         |         | 145     |         |         |         |         |         |         |         |         |         |       |    |        |  |
| Tunisia                            |        |        |        |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |       |    |        |  |
| Turkey                             |        |        |        |        |        |        |        |        |        |        |        |        |         |         | 1       |         |         | 110     |         |         |         | 1,122   | 30      |         |         |         |         |         |         |         |         |       |    |        |  |
| Turkmenistan                       |        |        |        |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |       |    |        |  |
| Tuvalu                             |        |        |        |        |        | 42     |        |        |        |        |        |        | 293     |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |       |    |        |  |
| Uganda                             | 1,539  |        | 190    |        |        |        | 140    | 140    |        |        |        | 279    | 5,072   |         | 704     | 538     | 291     | 5,220   | 99,028  | 10,358  | 5,614   | 494     | 4,548   | 8,754   | 6,760   | 9,848   | 10,388  | 552     | 7,452   | 2,190   | 2,341   |       |    |        |  |
| Ukraine                            |        |        |        |        |        |        |        |        |        |        |        | 75     |         |         | 813     | 525     |         |         |         | 4       |         |         |         |         |         |         |         |         |         |         |         |       | 33 |        |  |
| United Arab Emirates               |        |        |        |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |         |         |         |         | 3       |         |         |         |         |         |         |         |         |       |    |        |  |
| United Kingdom                     | 6      | 12     | 1      | 4      | 5      | 4      | 11     | 2      | 10     | 1      | 6      | 8      | 5       | 13      | 18      | 10      | 13      | 12      | 36      |         |         | 66      |         | 18      | 26      |         | 98      | 64      | 16      | 32      | 8       | 32    |    |        |  |
| United Republic of Tanzania        | 5,196  | 4,241  | 4,071  | 1,816  | 2,600  | 1,984  | 1,231  | 1,892  | 5,267  | 2,150  | 2,230  | 5,676  | 18,526  | 792     | 2,240   | 2,957   | 1,464   | 80,498  | 28,976  | 24,532  | 9,274   | 2,600   | 23,840  | 1,420   | 20,638  | 5,890   | 28,594  | 3,218   | 5,822   | 15,400  | 4,469   | 942   |    |        |  |
| United States of America           |        |        |        |        |        |        |        | 6      | 9      |        | 7      | 26     | 103     | 19      | 47      | 19      | 3       | 8       | 34      | 12      | 8       | 8       | 4       | 4       | 10      | 24      | 16      | 14      | 10      | 20      | 15      | 42    |    |        |  |
| Uzbekistan                         |        |        |        |        |        |        |        |        |        |        |        |        |         |         | 1       |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |       |    |        |  |
| Venezuela (Bolivarian Republic of) |        |        |        |        |        |        |        |        |        |        |        | 15     | 2,842   | 409     |         |         | 269     | 5,102   | 626     | 752     | 141     |         |         |         |         |         |         |         |         |         |         |       |    | 49     |  |
| Vietnam                            | 978    | 157    | 57     | 392    | 22     | 502    | 525    | 216    | 343    | 143    | 358    | 52     | 4,260   | 3,361   | 5,776   | 6,088   | 566     | 8       | 26      | 338     |         |         |         |         |         |         |         |         |         |         |         |       |    | 3      |  |
| Yemen                              | 720    |        |        |        |        |        |        |        |        |        |        |        | 4       |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |       |    | 31,789 |  |
| Zambia                             | 57     | 14     | 1,403  | 233    |        |        |        |        |        | 44     | 3,717  | 13,154 | 11,659  | 6,766   |         |         | 2,172   | 72      | 342     | 27,022  | 9,008   | 6,218   | 678     | 2,098   | 24,298  | 3,006   | 10,720  | 4,572   | 4,122   | 9,424   | 6,794   | 330   |    |        |  |
| Zimbabwe                           |        |        |        |        |        | 144    | 2      |        |        |        |        |        | 2,048   | 5,385   |         |         |         |         | 1,990   | 11,274  | 3,350   | 1,300   | 6,250   | 2,018   | 238     | 1,032   | 1,578   | 130     | 120,110 | 198,086 | 951     | 1,220 |    |        |  |
| Global Total                       | 42,776 | 51,633 | 64,925 | 65,251 | 29,324 | 45,279 | 52,738 | 56,105 | 53,920 | 54,108 | 74,764 | 99,534 | 492,984 | 380,714 | 365,488 | 214,802 | 144,727 | 280,629 | 596,882 | 526,065 | 285,518 | 372,077 | 284,513 | 223,137 | 202,744 | 283,745 | 473,544 | 438,891 | 417,778 | 317,528 | 378,104 |       |    |        |  |

# Global Cholera Deaths Reported to the World Health Organization, by Country, 1949-2011

## Description

Annual deaths from cholera are shown here for all reporting countries. Cholera is one of many waterborne diseases that are a consequence of the lack of sanitation services and access to clean drinking water. Some data on cholera cases and deaths are available as early as 1922 from reports to the League of Nations, but consistent reports are available from the World Health Organization only since 1949. The data here are given annually from 1949 to 2011.

Since 2006, between 7,500 and 15,000 people have died each year from cholera, not counting unreported or misreported data. Particularly hard hit in 2011 were Haiti and Somalia.

In 2011, a total of fifty-eight countries from all continents reported approximately 590,000 cases of cholera to the World Health Organization, of which 32 percent were in Africa and 61.2 percent were in the Americas (defined as North, Central, and South America and the Caribbean). These data reflect a massive upsurge in the Americas from previous years. A particularly severe outbreak started in Haiti at the end of October 2010 and also affected the Dominican Republic.

These data also show the rapid and severe spread of cholera in Latin America during the seventh pandemic, starting with the appearance of cholera in Peru in 1991 and spreading rapidly. That sharp spike in cholera was the first manifestation of the seventh pandemic in the Americas and was the first time that the Americas had seen more than a handful of indigenous cases in over a century.

## Limitations

There are serious problems with the reporting of cholera. In particular, the data here include only the deaths identified and reported to the World Health Organization and do not include undiagnosed or unreported cases. The true number of cholera deaths is known to be much higher than reported here. Many countries refuse to report cholera as such, or define many severe diarrheal diseases as something other than cholera, often as “acute watery diarrhea.” As many as 500,000 to 700,000 cases and an unknown number of deaths from acute watery diarrhea occur annually in vast areas of Central and South-east Asia and in some African countries.

As a result, the totals shown in the table are likely to seriously underrepresent total cholera deaths.

## Sources

- World Health Organization (WHO). 2011. Number of Reported Cholera Cases. Global Health Observatory. [http://www.who.int/gho/epidemic\\_diseases/cholera/cases\\_text/en/index.html](http://www.who.int/gho/epidemic_diseases/cholera/cases_text/en/index.html) (accessed June 1, 2013).
- . 2013. Cholera Data Portal. <http://apps.who.int/gho/data/node.main.175>.

**DATA TABLE 17A** Global Cholera Deaths Reported to the World Health Organization, by Country, 1948–1979

| Country                          | 1949   | 1950   | 1951   | 1952   | 1953  | 1954  | 1955   | 1956  | 1957   | 1958   | 1959  | 1960  | 1961  | 1962  | 1963  | 1964 | 1965  | 1966 | 1967 | 1968  | 1969  | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |   |     |    |  |  |
|----------------------------------|--------|--------|--------|--------|-------|-------|--------|-------|--------|--------|-------|-------|-------|-------|-------|------|-------|------|------|-------|-------|------|------|------|------|------|------|------|------|------|------|---|-----|----|--|--|
| Afghanistan                      |        |        |        |        |       |       |        |       |        |        |       | 199   |       |       |       |      | 55    |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Albania                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Algeria                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      | 110  | 71   | 74   | 50   | 118  | 30   | 9    | 13   | 94   |   |     |    |  |  |
| Andorra                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      | 24   | 9    | 34   | 4    |      |      |      |      |   |     |    |  |  |
| Angola                           |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Argentina                        |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Armenia                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Australia                        |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       | 0    |      | 0    |      |      |      |      |      |      |      | 0 | 0   | 0  |  |  |
| Austria                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Azerbaijan                       |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Bahrain                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       | 0    |      |       |       |      |      | 4    | 0    |      |      |      |      |      |      | 2 | 0   |    |  |  |
| Bangladesh                       | 12,947 | 12,372 | 12,684 | 16,904 | 9,443 | 9,802 | 15,310 | 5,134 | 10,119 | 11,066 | 6,272 | 1,703 | 1,304 | 1,248 | 2,419 | 683  | 1,234 | 369  | 614  | 1,556 | 1,889 | 386  | 201  | 369  | 173  | 117  | 62   | 354  | 81   | 21   |      |   |     |    |  |  |
| Belarus                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Belgium                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Belize                           |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Benin                            |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      | 37   | 274  | 29   | 2    | 4    | 1    | 14   | 0    | 0    |   |     |    |  |  |
| Bhutan                           |        |        |        |        |       |       |        |       | 0      |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Bolivia (Plurinational State of) |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Botswana                         |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Brazil                           |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Brunei Darussalam                |        |        |        |        |       |       | 0      |       |        |        |       |       |       |       |       |      | 6     |      |      |       |       | 0    |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Burkina Faso                     |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       | 1    | 495  | 0    | 249  | 66   | 3    |      |      | 0    |      |   |     |    |  |  |
| Burundi                          |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      |      |      |      |      |      |      |      |      |      |   |     |    |  |  |
| Cambodia                         | 1      | 40     | 10     | 8      | 2     |       | 1      | 1     | 0      |        |       |       |       |       | 13    | 27   |       | 5    | 0    | 1     |       |      |      | 14   | 1    | 0    |      |      |      |      |      |   | 248 | 31 |  |  |
| Cameroon                         |        |        |        |        |       |       |        |       |        |        |       |       |       |       |       |      |       |      |      |       |       |      | 336  | 27   | 16   | 16   | 0    | 27   |      | 0    | 4    |   |     |    |  |  |

*continues*

DATA TABLE 17A continued

| Country                               | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972  | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |  |   |  |  |   |         |             |
|---------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|------|------|------|------|------|------|------|--|---|--|--|---|---------|-------------|
| Canada                                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Cape Verde                            |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      | 8    | 3    | 17   |      |      |      |  |   |  |  |   |         |             |
| Central African Republic              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Chad                                  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2,411 | 3    | 87   |      |      |      |      |      |  |   |  |  |   |         |             |
| Chile                                 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| China                                 | 1    |      |      |      |      |      |      |      |      |      |      |      |      | 24   | 0    |      |      |      | 0    |      |      |      |      |       |      |      |      |      |      |      |      |  | 2 |  |  |   |         |             |
| Colombia                              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Comoros                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      | 238  | 1    |      |      |  |   |  |  |   |         |             |
| Congo                                 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Costa Rica                            |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Côte d'Ivoire                         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 39    | 9    |      |      |      |      |      |      |  |   |  |  | 0 |         |             |
| Czech Republic                        |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1     |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Democratic People's Republic of Korea |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Democratic Republic of the Congo      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   | 183 511 |             |
| Denmark                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Djibouti                              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3     | 81   | 3    |      |      |      |      |      |  |   |  |  |   | 0 0 2   |             |
| Dominican Republic                    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Ecuador                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| El Salvador                           |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Equatorial Guinea                     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Eritrea                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Estonia                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Ethiopia                              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         | 0           |
| Finland                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| France                                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         | 0           |
| Gabon                                 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         | 2           |
| Gambia                                |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Georgia                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         |             |
| Germany                               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |      |      |      |      |      |      |      |  |   |  |  |   |         | 0 0 0 0 0 0 |

|                                  |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
|----------------------------------|-----|--------|--------|--------|-------|--------|--------|--------|-------|--------|--------|--------|--------|--------|-------|----|-----|----|-----|-------|-------|-------|-------|-------|-------|-------|-------|-----|-----|-----|-----|----|--|----|---|---|---|----|
| Ghana                            |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       | 180   | 641   | 32    | 39    | 37    | 10    | 0   | 353 | 120 | 113 |    |  |    |   |   |   |    |
| Greece                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Guatemala                        |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Guinea                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       | 60    |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Guinea-Bissau                    |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Guyana                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Haiti                            |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Honduras                         |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Hungary                          |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| India                            | 396 | 41,543 | 58,252 | 19,368 | 7,662 | 17,206 | 49,715 | 49,818 | 7,696 | 26,946 | 27,141 | 16,357 | 17,035 | 12,664 | 2,799 | 36 | 139 | 22 | 262 | 1,257 | 3,607 | 6,956 | 5,406 | 2,289 | 2,330 | 3,715 | 2,665 | 289 | 246 | 113 |     |    |  |    |   |   |   |    |
| Indonesia                        |     |        |        |        |       |        |        |        |       | 22     | 474    | 80     | 83     | 69     |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Iran (Islamic Republic of)       |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     | 56 |  |    |   |   |   |    |
| Iraq                             |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       | 20 |     |    |     |       |       |       |       |       |       |       |       |     |     |     | 1   | 0  |  |    |   |   |   |    |
| Israel                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Italy                            |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    | 23  |       |       |       |       |       |       |       |       |     |     |     |     | 0  |  |    |   |   |   |    |
| Japan                            |     |        |        |        |       |        |        |        |       |        |        |        | 0      | 1      |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     | 0   | 0  |  |    |   |   |   |    |
| Jordan                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     | 0  |  |    |   |   |   |    |
| Kazakhstan                       |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Kenya                            |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Kiribati                         |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Kuwait                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Kyrgyzstan                       |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Lao People's Democratic Republic |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Lebanon                          |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Lesotho                          |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  | 0  |   |   |   |    |
| Liberia                          |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Libya                            |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Madagascar                       |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
| Malawi                           |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  |    |   |   |   |    |
|                                  |     |        |        |        |       |        |        |        |       |        |        |        |        |        |       |    |     |    |     |       |       |       |       |       |       |       |       |     |     |     |     |    |  | 20 | 0 | 0 | 0 | 24 |

continues







DATA TABLE 17A continued

| Country                            | 1949 | 1950   | 1951   | 1952   | 1953    | 1954   | 1955   | 1956   | 1957   | 1958   | 1959   | 1960  | 1961   | 1962   | 1963   | 1964   | 1965   | 1966  | 1967 | 1968 | 1969  | 1970  | 1971   | 1972   | 1973   | 1974  | 1975  | 1976  | 1977  | 1978  | 1979  |    |     |     |
|------------------------------------|------|--------|--------|--------|---------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|-------|------|------|-------|-------|--------|--------|--------|-------|-------|-------|-------|-------|-------|----|-----|-----|
| Turkey                             |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        | 52     |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Turkmenistan                       |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Tuvalu                             |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Uganda                             |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        | 30     |       |      |      |       |       |        |        |        |       |       | 0     |       |       | 110   | 60 |     |     |
| Ukraine                            |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| United Arab Emirates               |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        | 0      |        |       |       |       |       |       |       |    |     |     |
| United Kingdom                     |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       | 0      | 0      | 0      | 0     | 0     | 0     | 0     | 0     | 0     | 0  | 0   |     |
| United Republic of Tanzania        |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       | 26 | 733 | 305 |
| United States of America           |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Uzbekistan                         |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Venezuela (Bolivarian Republic of) |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Vietnam                            |      | 4      | 21     | 6      | 7       | 3      |        |        |        |        |        |       |        |        |        | 872    | 29     | 167   | 71   | 8    | 26    | 1     | 1      | 1      | 18     | 2     | 0     | 0     | 0     | 0     | 0     | 0  | 28  |     |
| Yemen                              |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        | 26     | 140    | 23    | 1     | 0     |       |       |       |    | 12  | 45  |
| Zambia                             |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    | 36  | 11  |
| Zimbabwe                           |      |        |        |        |         |        |        |        |        |        |        |       |        |        |        |        |        |       |      |      |       |       |        |        |        |       |       |       |       |       |       |    |     |     |
| Total                              | 3    | 16,133 | 58,661 | 71,397 | 141,173 | 28,835 | 17,476 | 32,523 | 54,853 | 61,836 | 19,367 | 7,800 | 30,528 | 30,695 | 19,137 | 22,289 | 13,996 | 4,572 | 637  | 830  | 2,209 | 7,533 | 26,132 | 10,658 | 10,081 | 7,649 | 7,079 | 3,950 | 2,177 | 3,354 | 3,478 |    |     |     |

**DATA TABLE 17B** Global Cholera Deaths Reported to the World Health Organization, by Country, 1980–2011

| Country                          | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987  | 1988  | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006  | 2007  | 2008 | 2009 | 2010  | 2011 |   |   |   |  |  |
|----------------------------------|------|------|------|------|------|------|------|-------|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|------|------|-------|------|---|---|---|--|--|
| Afghanistan                      |      |      |      |      |      |      |      |       |       |      |      |      |      | 931  | 118  | 624  |      | 250  | 0    | 304  | 396  | 228  |      | 14   |      | 0    |       |       | 44   | 22   | 20    | 44   |   |   |   |  |  |
| Albania                          |      |      |      |      |      |      |      |       |       |      |      |      |      |      | 25   |      |      |      |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Algeria                          | 18   |      |      | 9    | 0    |      |      | 0     | 30    | 0    | 20   |      | 0    |      | 4    |      |      |      |      |      |      |      |      |      |      | 0    | 0     |       |      |      |       |      |   |   |   |  |  |
| Andorra                          |      |      |      |      |      |      |      |       |       |      |      |      |      | 0    |      |      |      |      |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Angola                           |      |      |      |      |      |      |      | 1,403 | 1,542 | 925  | 809  | 582  | 184  |      | 187  | 248  | 42   |      |      |      |      |      |      |      |      | 0    | 5,444 | 1,026 | 486  | 176  | 60    | 110  |   |   |   |  |  |
| Argentina                        |      |      |      |      |      |      |      |       |       |      |      | 15   | 34   | 15   | 1    | 5    | 24   | 0    |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Armenia                          |      |      |      |      |      |      |      |       |       |      |      |      |      |      |      |      |      | 0    |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Australia                        | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0     | 0     | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0     | 0     | 0    | 0    | 0     | 0    | 0 | 0 | 0 |  |  |
| Austria                          |      |      |      |      |      |      |      |       |       |      | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |      |      |      |      |      |      |      |      | 0     |       |      |      |       |      |   |   |   |  |  |
| Azerbaijan                       |      |      |      |      |      |      |      |       |       |      |      |      |      |      | 0    |      |      |      |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Bahrain                          |      |      |      |      |      |      |      |       |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Bangladesh                       |      |      |      |      |      |      | 23   | 43    | 2     | 4    | 0    | 29   | 0    | 41   | 61   | 0    | 190  | 52   | 126  | 32   |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Belarus                          |      |      |      |      |      |      |      |       |       |      |      |      |      |      | 0    | 0    |      |      |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Belgium                          | 0    | 0    |      | 0    | 0    | 0    |      |       |       |      |      |      |      | 0    | 0    |      |      |      |      |      |      |      |      |      | 0    | 0    |       |       |      |      |       |      |   |   |   |  |  |
| Belize                           |      |      |      |      |      |      |      |       |       |      |      |      | 4    | 3    | 1    | 1    | 0    | 0    | 2    | 0    |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Benin                            | 0    | 0    | 0    | 0    | 0    |      | 13   |       |       |      |      | 259  | 17   | 2    | 20   | 12   | 203  | 32   | 2    | 50   | 22   | 142  | 26   | 22   | 18   | 22   | 2     |       |      |      |       |      |   |   |   |  |  |
| Bhutan                           |      |      |      |      |      |      |      |       |       |      |      | 19   | 6    |      |      | 0    |      | 0    |      |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Bolivia (Plurinational State of) |      |      |      |      |      |      |      |       |       |      |      | 12   | 395  | 254  | 46   | 54   | 68   | 36   | 14   |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Botswana                         |      |      |      |      |      |      |      |       |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0     | 0     |      |      |       |      |   |   |   |  |  |
| Brazil                           |      |      |      |      |      |      |      |       |       |      |      | 33   | 363  | 644  | 452  | 85   | 33   | 74   | 54   | 166  | 34   | 0    |      |      | 0    | 0    |       |       |      |      |       |      |   |   |   |  |  |
| Brunei Darussalam                |      |      |      |      |      |      |      |       |       |      |      |      |      |      |      |      |      |      | 0    |      |      |      |      |      |      |      |       |       |      |      |       |      |   |   |   |  |  |
| Burkina Faso                     |      |      |      |      |      |      |      |       |       |      |      | 61   |      |      |      | 113  | 58   | 104  | 14   | 28   | 14   |      |      |      |      |      | 32    | 0     |      |      |       |      |   |   |   |  |  |
| Burundi                          | 28   | 11   | 9    | 35   | 10   | 15   |      |       |       |      |      | 29   | 0    | 41   |      |      |      | 190  | 52   | 126  | 32   | 40   | 16   | 36   | 28   | 36   | 14    | 4     | 8    | 0    | 2     | 1    |   |   |   |  |  |
| Cambodia                         |      |      |      |      |      |      |      | 55    | 0     | 2    | 0    | 97   | 120  | 104  | 211  | 123  | 20   | 0    | 132  | 260  |      |      |      |      | 2    |      |       |       |      |      |       |      |   |   |   |  |  |
| Cameroon                         | 23   | 17   | 3    | 18   | 60   | 103  | 12   | 6     | 0     | 2    | 0    | 491  | 66   | 19   | 61   | 21   | 485  | 360  | 632  | 70   | 58   | 14   | 16   | 72   | 274  | 220  | 70    | 2     | 0    | 178  | 1,314 | 783  |   |   |   |  |  |

*continues*

DATA TABLE 17B continued

| Country                               | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991  | 1992 | 1993 | 1994  | 1995 | 1996 | 1997 | 1998  | 1999  | 2000  | 2001 | 2002  | 2003  | 2004 | 2005 | 2006 | 2007  | 2008  | 2009 | 2010 | 2011 |    |   |  |
|---------------------------------------|------|------|------|------|------|------|------|------|------|------|------|-------|------|------|-------|------|------|------|-------|-------|-------|------|-------|-------|------|------|------|-------|-------|------|------|------|----|---|--|
| Canada                                |      |      |      |      |      |      |      |      | 0    | 0    |      |       |      | 0    | 1     | 0    | 0    | 0    | 0     | 0     | 0     |      | 0     |       | 0    | 0    | 0    | 0     | 0     | 0    | 0    | 0    |    |   |  |
| Cape Verde                            |      |      |      |      |      |      |      |      |      |      |      |       |      |      | 12    | 240  | 3    |      | 2     |       |       |      |       |       |      |      | 0    | 0     |       |      |      |      |    |   |  |
| Central African Republic              |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      | 150  | 6     |       |       |      |       | 96    | 0    | 0    |      |       |       |      |      | 15   |    |   |  |
| Chad                                  |      |      |      |      |      |      |      |      |      |      |      | 1,344 |      |      | 43    |      | 448  | 886  | 288   | 36    |       | 452  |       | 14    | 544  | 28   | 142  | 0     |       | 6    | 350  | 458  |    |   |  |
| Chile                                 |      |      |      |      |      |      |      |      |      |      | 2    | 1     | 0    | 0    | 0     | 0    | 0    | 0    | 4     |       |       |      |       |       |      |      |      |       |       |      |      | 0    |    |   |  |
| China                                 | 0    |      |      |      |      |      |      | 0    | 89   | 59   | 5    | 0     | 1    | 94   | 319   | 88   | 4    | 58   | 0     | 0     | 6     | 0    | 2     | 2     | 2    | 8    | 4    | 0     | 0     | 0    | 0    | 0    |    |   |  |
| Colombia                              |      |      |      |      |      |      |      |      |      |      |      | 207   | 158  | 0    | 14    | 35   | 70   | 64   | 14    | 0     |       |      |       |       | 0    |      |      |       |       |      |      |      |    |   |  |
| Comoros                               |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      | 136  | 84    | 182   | 8     | 92   |       |       |      |      | 0    | 0     | 0     | 58   | 0    |      |    |   |  |
| Congo                                 |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      | 120  | 44    | 40    | 4     |      |       |       |      |      | 0    | 20    | 266   | 8    | 0    |      |    |   |  |
| Costa Rica                            |      |      |      |      |      |      |      |      |      |      |      |       | 0    | 0    | 0     | 1    | 0    |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Côte d'Ivoire                         |      |      | 0    |      |      |      |      |      |      |      | 116  | 7     | 42   | 55   | 184   | 22   |      |      |       |       |       | 610  | 286   | 100   | 18   | 12   | 30   | 2     | 2     | 4    | 0    | 24   |    |   |  |
| Czech Republic                        |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Democratic People's Republic of Korea | 0    |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Democratic Republic of the Congo      | 81   | 800  | 693  | 245  | 3    | 30   | 125  | 218  | 32   | 6    | 61   | 294   | 59   | 175  | 4,181 | 22   | 638  | 652  | 5,852 | 1,566 | 1,882 | 780  | 3,958 | 1,978 | 456  | 488  | 852  | 1,200 | 1,096 | 474  | 364  | 584  |    |   |  |
| Denmark                               |      |      |      |      |      |      |      |      |      |      | 0    |       |      | 0    | 0     | 0    |      |      |       |       |       |      |       |       | 0    |      |      |       |       |      |      |      |    |   |  |
| Djibouti                              |      |      |      |      |      | 7    |      |      |      |      |      |       |      | 99   | 15    |      |      | 100  | 6     |       | 64    |      |       |       |      |      |      | 54    |       |      | 38   | 1    |    |   |  |
| Dominican Republic                    |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Ecuador                               |      |      |      |      |      |      |      |      |      |      |      | 697   | 208  | 72   | 16    | 23   | 12   | 6    | 74    | 0     | 2     | 0    |       |       |      | 0    |      |       |       |      |      |      |    |   |  |
| El Salvador                           |      |      |      |      |      |      |      |      |      |      | 34   | 45    | 14   | 38   | 2     | 2    |      |      | 0     | 0     | 4     |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Equatorial Guinea                     |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       | 2    | 66   | 0    |       |       |      |      |      |    |   |  |
| Eritrea                               |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      | 0    | 0     | 18    | 0    |      |      |    |   |  |
| Estonia                               |      |      |      |      |      |      |      |      |      |      |      |       |      | 0    |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Ethiopia                              |      |      |      | 0    |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      | 0    | 0     | 1,150 | 544  | 46   | 868  | 42 |   |  |
| Finland                               |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       | 0    |      |      |       |       |       |      |       |       |      |      | 0    |       |       |      |      |      |    |   |  |
| France                                | 0    |      | 0    | 0    | 0    |      | 0    | 0    |      |      | 1    | 0     |      | 0    | 0     | 0    | 0    | 0    | 0     |       | 0     |      |       |       |      |      | 0    | 0     | 0     | 0    | 0    | 0    | 0  | 0 |  |
| Gabon                                 |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Gambia                                |      | 0    |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       | 0     |      |      | 0    | 0     | 0     | 0    | 0    | 0    | 0  | 0 |  |
| Gambia                                |      |      |      |      |      | 0    |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      | 26   | 0     | 2     | 0    |      |      |    |   |  |
| Georgia                               |      |      |      |      |      |      |      |      |      |      |      |       |      |      |       |      |      |      |       |       |       |      |       |       |      |      |      |       |       |      |      |      |    |   |  |
| Germany                               | 0    | 0    | 0    |      |      |      |      |      |      |      |      |       | 0    | 0    | 0     | 0    | 0    | 0    | 0     | 0     | 0     |      |       |       | 0    |      | 0    | 0     | 0     | 0    | 0    | 2    | 0  | 0 |  |



DATA TABLE 17B continued

| Country                          | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990  | 1991  | 1992 | 1993 | 1994 | 1995 | 1996  | 1997  | 1998 | 1999  | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010  | 2011 |    |     |   |
|----------------------------------|------|------|------|------|------|------|------|------|------|------|-------|-------|------|------|------|------|-------|-------|------|-------|------|------|------|------|------|------|------|------|------|------|-------|------|----|-----|---|
| Malaysia                         | 7    | 14   | 17   | 38   | 1    | 2    | 2    | 18   | 32   | 14   | 38    | 6     | 8    | 13   | 0    | 27   | 0     | 8     | 38   | 0     | 2    | 22   |      |      | 0    | 4    | 0    |      | 2    | 12   | 10    |      |    |     |   |
| Maldives                         |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Mali                             |      |      |      |      | 406  | 838  | 151  | 84   |      |      |       |       |      |      |      | 231  | 761   | 6     | 6    | 102   | 18   | 4    | 238  | 410  | 152  | 0    |      |      |      |      |       | 95   |    |     |   |
| Marshall Islands                 |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      | 12   |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Mauritania                       |      |      |      |      | 15   | 20   | 113  | 101  | 38   | 27   |       |       |      |      |      |      | 148   | 14    |      |       |      | 0    | 16   |      |      | 140  | 0    | 0    |      |      |       | 3    |    |     |   |
| Mauritius                        |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      | 0    | 0    |      |      |      |       |      |    |     |   |
| Mexico                           |      |      |      |      |      |      |      |      |      |      | 34    | 99    | 193  | 56   | 137  | 5    | 2     | 0     | 0    | 0     | 0    | 0    | 0    |      |      |      |      | 0    |      |      | 0     | 0    |    |     |   |
| Micronesia (Federated States of) |      |      |      |      |      |      |      |      |      |      | 1     |       |      |      |      |      | 0     |       |      |       | 40   | 0    |      |      |      | 0    |      |      |      |      |       |      |    |     |   |
| Mongolia                         |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      | 12    |       |      |       |      |      |      |      |      | 0    |      |      |      |      |       |      |    |     |   |
| Morocco                          |      |      |      |      |      |      |      |      |      |      | 137   |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Mozambique                       | 85   | 132  | 199  | 447  | 11   | 0    | 0    |      |      | 12   | 194   | 328   | 727  | 507  | 27   |      |       | 0     | 518  | 2,706 | 476  | 204  | 684  | 204  | 220  | 48   | 58   | 44   | 204  | 310  | 234   | 5    |    |     |   |
| Myanmar                          | 50   | 3    | 29   |      |      |      |      |      |      | 11   |       | 39    | 50   | 52   | 4    | 6    |       |       |      |       |      |      |      |      |      | 0    | 10   | 0    | 76   | 6    |       |      |    |     |   |
| Namibia                          |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Nauru                            |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Nepal                            | 0    | 0    |      |      |      |      |      |      |      | 2    | 495   | 873   | 15   | 0    | 0    | 1    | 0     | 34    |      |       |      |      |      |      |      |      |      | 0    |      | 0    | 18    |      |    |     |   |
| Netherlands                      |      |      |      |      |      |      |      |      |      |      | 0     |       |      |      |      |      |       |       |      |       |      |      |      |      |      | 0    | 0    | 0    | 0    |      |       |      |    |     |   |
| New Zealand                      |      |      |      |      |      |      |      |      |      |      | 0     |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Nicaragua                        |      |      |      |      |      |      |      |      |      |      |       | 0     | 46   | 220  | 134  | 164  | 107   | 72    | 58   | 14    | 0    |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Niger                            | 0    |      |      |      | 308  |      |      |      |      | 22   |       | 367   |      |      | 83   | 15   | 206   | 26    | 170  |       | 76   | 2    | 24   | 22   | 114  | 110  | 162  | 4    | 140  | 132  | 60    |      |    |     |   |
| Nigeria                          | 25   | 18   | 18   | 2    | 185  | 0    | 23   | 111  | 10   | 61   |       | 7,654 | 686  | 266  | 313  | 87   | 1,193 | 268   | 374  | 4,170 | 86   | 238  | 308  | 174  | 370  | 348  | 254  | 96   | 494  | 862  | 3,424 | 742  |    |     |   |
| Norway                           |      |      |      |      |      |      |      |      |      | 0    |       |       |      |      |      |      |       |       | 0    |       |      |      |      |      |      | 0    | 0    | 0    |      |      |       |      |    |     |   |
| Oman                             |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Pakistan                         | 0    |      |      |      |      |      |      |      |      |      |       |       |      |      | 206  |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      | 0     | 219  |    |     |   |
| Panama                           |      |      |      |      |      |      |      |      |      |      |       | 29    | 49   | 4    |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Papua New Guinea                 |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      | 0    |      |      |      |       |      | 90 | 190 | 2 |
| Paraguay                         |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      | 0     |       |      |       |      |      |      |      |      |      |      |      |      |      |       | 0    |    |     |   |
| Peru                             |      |      |      |      |      |      |      |      |      |      | 2,909 | 801   | 575  | 199  | 171  | 21   | 58    | 1,136 | 12   | 12    | 0    | 0    |      |      |      |      |      |      |      |      |       |      |    |     |   |
| Philippines                      | 61   | 51   | 31   |      | 1    |      |      |      |      |      |       | 0     | 10   | 27   | 4    | 14   | 0     | 34    | 0    | 12    |      |      |      | 6    | 4    | 2    | 0    |      |      |      | 4     | 3    |    |     |   |
| Poland                           |      |      |      |      |      |      |      |      |      |      |       | 0     |      |      |      |      |       |       |      |       |      |      |      |      |      |      | 0    |      |      |      |       |      |    |     |   |
| Portugal                         |      |      |      |      |      |      |      |      |      |      |       |       |      |      |      |      |       |       |      |       |      |      |      |      |      |      |      |      |      |      |       |      |    |     |   |





DATA TABLE 17B *continued*

| Country                            | 1980  | 1981  | 1982  | 1983  | 1984  | 1985  | 1986  | 1987  | 1988  | 1989  | 1990  | 1991   | 1992  | 1993  | 1994   | 1995  | 1996  | 1997   | 1998   | 1999   | 2000   | 2001  | 2002  | 2003  | 2004  | 2005  | 2006   | 2007  | 2008   | 2009  | 2010   | 2011  |   |   |   |     |
|------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|--------|-------|-------|--------|--------|--------|--------|-------|-------|-------|-------|-------|--------|-------|--------|-------|--------|-------|---|---|---|-----|
| Tunisia                            |       |       |       |       |       |       |       |       |       |       |       |        |       |       |        |       |       |        |        |        |        |       |       |       |       |       |        |       |        |       |        |       |   |   |   |     |
| Turkey                             |       |       |       |       |       |       |       |       |       |       |       |        |       |       |        |       |       |        |        |        |        | 12    | 4     |       |       |       |        |       |        |       |        |       |   |   |   |     |
| Turkmenistan                       |       |       |       |       |       |       |       |       |       |       |       |        | 8     |       |        |       |       |        | 0      |        |        |       |       |       |       |       |        |       |        |       |        |       |   |   |   |     |
| Tuvalu                             |       |       |       |       |       |       |       |       |       |       |       |        |       |       |        |       |       |        |        |        |        |       |       |       |       |       |        |       |        |       |        |       |   |   |   |     |
| Uganda                             | 181   |       | 48    |       |       |       | 50    |       |       |       |       | 28     | 104   |       | 39     | 66    | 40    | 376    | 4,128  | 456    | 344    | 8     | 266   | 258   | 182   | 196   | 212    | 6     | 240    | 46    | 156    |       |   |   |   |     |
| Ukraine                            |       |       |       |       |       |       |       |       |       |       |       | 0      |       |       | 20     | 10    |       |        |        | 0      |        |       |       |       |       |       |        | 0     |        |       |        |       | 0 |   |   |     |
| United Arab Emirates               |       |       |       |       |       |       |       |       |       |       |       |        |       |       |        |       |       |        |        |        |        |       |       |       |       |       |        |       |        |       |        |       |   |   |   |     |
| United Kingdom                     |       | 0     | 0     | 0     | 0     | 1     | 0     | 0     | 0     | 0     | 0     | 0      | 0     | 0     | 0      | 0     | 0     | 0      | 0      | 0      |        |       |       |       | 0     | 0     | 0      | 0     | 0      | 0     | 0      | 0     | 0 | 0 |   |     |
| United Republic of Tanzania        | 587   | 330   | 324   | 127   | 338   | 250   | 215   | 232   | 580   | 232   | 81    | 572    | 2,173 | 74    | 155    | 96    | 36    | 4,462  | 1,216  | 1,168  | 312    | 104   | 594   | 64    | 544   | 188   | 508    | 130   | 176    | 226   | 118    | 11    |   |   |   |     |
| United States of America           |       |       |       |       |       |       |       | 0     | 0     | 0     | 0     | 0      | 1     | 0     | 0      | 0     | 0     | 0      | 0      | 0      | 0      | 0     |       |       | 0     | 0     | 0      | 0     | 0      | 0     | 0      | 0     | 0 | 0 | 0 |     |
| Uzbekistan                         |       |       |       |       |       |       |       |       |       |       |       |        |       |       | 0      |       |       |        |        |        |        |       |       |       |       |       |        |       |        |       |        |       |   | 0 |   |     |
| Venezuela (Bolivarian Republic of) |       |       |       |       |       |       |       |       |       |       |       | 2      | 68    | 10    |        |       | 9     | 118    | 14     | 16     | 0      |       |       |       |       |       |        |       |        |       |        |       |   |   |   |     |
| Vietnam                            | 49    | 8     | 0     | 0     | 0     | 9     | 8     | 5     | 7     | 0     | 4     | 1      | 110   | 9     | 68     | 45    | 2     | 0      | 2      | 0      |        |       |       |       |       | 0     | 0      | 0     | 0      | 0     | 2      | 0     | 0 | 0 |   |     |
| Yemen                              | 20    |       |       |       |       |       |       |       |       |       |       |        | 0     |       |        |       |       |        |        |        |        |       |       |       |       |       |        |       |        |       |        |       |   | 6 | 8 | 134 |
| Zambia                             | 17    | 0     | 131   | 19    |       |       |       |       |       | 44    | 315   | 1,091  | 913   | 426   |        |       | 42    | 0      | 0      | 1,070  | 606    | 330   | 24    | 58    | 746   | 14    | 366    | 70    | 78     | 160   | 124    | 7     |   |   |   |     |
| Zimbabwe                           |       |       |       |       |       | 6     |       |       |       |       |       |        | 105   | 332   |        |       |       |        | 88     | 770    | 446    | 28    | 384   | 70    | 18    | 52    | 122    | 8     | 5,856  | 5,412 | 42     | 2     |   |   |   |     |
| Total                              | 1,954 | 2,441 | 3,821 | 2,668 | 1,830 | 4,114 | 3,966 | 3,009 | 2,855 | 1,711 | 2,802 | 19,302 | 8,214 | 6,761 | 10,750 | 5,045 | 6,418 | 12,742 | 21,664 | 18,442 | 10,538 | 5,794 | 9,128 | 3,788 | 4,690 | 4,544 | 12,600 | 8,066 | 10,286 | 9,886 | 15,086 | 7,781 |   |   |   |     |

# Perceived Satisfaction with Water Quality in Sub-Saharan Africa

## Description

In 2012, the Gallup Organization released the results of a survey on perceived satisfaction with water quality taken in cities and other areas of sub-Saharan Africa (and in other regions; see data table 18B). The question asked was, “In the city or area where you live, are you satisfied or dissatisfied with the quality of water?”

This table summarizes the results of that survey, which may be the first of its kind. The complete survey was done worldwide. The results shown here are only for sub-Saharan Africa. Perceived water quality is generally lowest in this region, the Middle East, and countries that were formerly in the Soviet Union. The summary provided by Gallup notes, “Seven of the 10 countries where residents are least satisfied are in sub-Saharan Africa, where residents sometimes have to walk miles for water, and waterborne and water-related diseases such as cholera are common.”

## Limitations

Like any poll, this one has limitations. As described by Gallup, the results presented here are based on telephone and face-to-face interviews with 1,000 adults, aged fifteen and older, conducted in more than 140 countries in 2011. The maximum margin of sampling error is described as ranging from a low of  $\pm 2$  percentage points to a high of  $\pm 5.1$  percentage points. In addition to sampling error, one challenge with polls such as this involves the wording and interpretation of the questions asked. For example, what does “satisfied” mean?

Moreover, perceived levels of satisfaction say nothing about actual water quality. Many people may perceive problems where none exist and, conversely, may not perceive problems when major contamination exists.

## Source

Gallup. 2012. Air Quality Rated Better Than Water Quality Worldwide: Residents of Sub-Saharan Africa Rate Their Water the Worst. Report by A. Pugliese and J. Ray. May 14. <http://www.gallup.com/poll/154646/Air-Quality-Rated-Better-Water-Quality-Worldwide.aspx> (accessed June 3, 2013).

**DATA TABLE 18A** Perceived Satisfaction with Water Quality in Sub-Saharan Africa

| Country or City (%)      | Satisfied (%) | Dissatisfied (%) |
|--------------------------|---------------|------------------|
| Mauritius                | 88            | 12               |
| Rwanda                   | 70            | 30               |
| Zimbabwe                 | 64            | 36               |
| South Africa             | 62            | 38               |
| Mozambique               | 62            | 38               |
| Botswana                 | 62            | 38               |
| Malawi                   | 62            | 38               |
| Ghana                    | 61            | 39               |
| Kenya                    | 61            | 39               |
| Somaliland region        | 61            | 39               |
| Uganda                   | 61            | 39               |
| Benin                    | 59            | 41               |
| Swaziland                | 58            | 42               |
| Niger                    | 57            | 43               |
| Senegal                  | 56            | 44               |
| Burundi                  | 56            | 44               |
| Madagascar               | 53            | 47               |
| Djibouti                 | 52            | 48               |
| Angola                   | 51            | 49               |
| Mali                     | 50            | 50               |
| Zambia                   | 49            | 51               |
| Guinea                   | 48            | 52               |
| Cameroon                 | 48            | 52               |
| Mauritania               | 47            | 53               |
| Comoros                  | 47            | 53               |
| Liberia                  | 47            | 53               |
| Conga Brazzaville        | 47            | 53               |
| Burkina Faso             | 46            | 54               |
| Chad                     | 46            | 54               |
| Nigeria                  | 43            | 57               |
| Gabon                    | 42            | 58               |
| Central African Republic | 41            | 59               |
| Togo                     | 41            | 59               |
| Lesotho                  | 39            | 61               |
| Tanzania                 | 36            | 64               |
| Sudan                    | 35            | 65               |
| Congo Kinshasa           | 31            | 69               |
| Sierra Leone             | 30            | 70               |

# Regional Assessment of Satisfaction with Water (and Air) Quality

## Description

In 2012, the Gallup Organization released the results of a survey on perceived satisfaction with water quality taken in cities and other areas around the world. The question asked was, “In the city or area where you live, are you satisfied or dissatisfied with the quality of [air or water]?”

This table summarizes the results of that survey for different regions of the world. In general, with the exception of Europe, air quality in all regions was thought to be better than water quality. Ratings of water quality are highest in the richer countries of North America, much of Europe, and developed regions in Asia. Perceived water quality is generally lowest in sub-Saharan Africa (see data table 18A), the Middle East, and countries of the former Soviet Union. The summary provided by Gallup notes, “Seven of the 10 countries where residents are least satisfied are in sub-Saharan Africa, where residents sometimes have to walk miles for water, and waterborne and water-related diseases such as cholera are common.”

## Limitations

Like any poll, this one has limitations. As described by Gallup, the results presented here are based on telephone and face-to-face interviews with 1,000 adults, aged fifteen and older, conducted in more than 140 countries in 2011. The maximum margin of sampling error is described as ranging from a low of  $\pm 2$  percentage points to a high of  $\pm 5.1$  percentage points. In addition to sampling error, one challenge with polls such as this involves the wording and interpretation of the questions asked. For example, what does “satisfied” mean?

Moreover, perceived levels of satisfaction say nothing about actual water quality. Many people may perceive problems where none exist and, conversely, may not perceive problems when major contamination exists.

## Source

Gallup. 2012. Air Quality Rated Better Than Water Quality Worldwide: Residents of Sub-Saharan Africa Rate Their Water the Worst. Report by A. Pugliese and J. Ray. May 14. <http://www.gallup.com/poll/154646/Air-Quality-Rated-Better-Water-Quality-Worldwide.aspx> (accessed May 28, 2013).

**DATA TABLE 18B** Regional Assessment of Satisfaction with Water (and Air) Quality

| Region                       | Satisfied with Air Quality (%) | Satisfied with Water Quality (%) |
|------------------------------|--------------------------------|----------------------------------|
| Global                       | 75                             | 68                               |
| Sub-Saharan Africa           | 78                             | 51                               |
| Americas                     | 78                             | 73                               |
| Asia                         | 84                             | 78                               |
| Europe                       | 75                             | 79                               |
| Former Soviet Union          | 68                             | 61                               |
| Middle East and North Africa | 68                             | 63                               |



# Countries Most and Least Satisfied with Water Quality

## Description

In 2012, the Gallup Organization released the results of a survey on perceived satisfaction with water quality taken in cities and other areas around the world. The question asked was, “In the city or area where you live, are you satisfied or dissatisfied with the quality of [air or water]?”

This table presents the countries “most” and “least” satisfied with water quality. Ratings of water quality are highest in the richer countries of the Americas, much of Europe, and parts of developed regions in Asia. Perceived water quality is generally lowest in sub-Saharan Africa (see data table 18A), the Middle East, and parts of the former Soviet Union.

## Limitations

Like any poll, this one has limitations. As described by Gallup, the results presented here are based on telephone and face-to-face interviews with 1,000 adults, aged fifteen and older, conducted in more than 140 countries in 2011. The maximum margin of sampling error is described as ranging from a low of  $\pm 2$  percentage points to a high of  $\pm 5.1$  percentage points. In addition to sampling error, one challenge with polls such as this involves the wording and interpretation of the questions asked. For example, what does “satisfied” mean?

Moreover, perceived levels of satisfaction say nothing about actual water quality. Many people may perceive problems where none exist and, conversely, may not perceive problems when major contamination exists.

## Source

Gallup. 2012. Air Quality Rated Better Than Water Quality Worldwide: Residents of Sub-Saharan Africa Rate Their Water the Worst. Report by A. Pugliese and J. Ray. May 14. <http://www.gallup.com/poll/154646/Air-Quality-Rated-Better-Water-Quality-Worldwide.aspx> (accessed May 28, 2013).

**DATA TABLE 18c** Countries Most and Least Satisfied with Water Quality

| <b>Most Satisfied with Water Quality</b>  |          |
|---|----------|
| <b>Country</b>                            | <b>%</b> |
| United Kingdom                            | 97       |
| Germany                                   | 96       |
| Sweden                                    | 96       |
| Denmark                                   | 96       |
| Singapore                                 | 95       |
| Finland                                   | 94       |
| Austria                                   | 94       |
| Netherlands                               | 93       |
| Australia                                 | 92       |
| Luxembourg                                | 91       |
| Uruguay                                   | 91       |
| <b>Least Satisfied with Water Quality</b> |          |
| <b>Country</b>                            | <b>%</b> |
| Congo (Kinshasha)                         | 24       |
| Sierra Leone                              | 30       |
| Iraq                                      | 32       |
| Haiti                                     | 32       |
| Lesotho                                   | 39       |
| Central African Republic                  | 41       |
| Togo                                      | 41       |
| Tanzania                                  | 41       |
| Ukraine                                   | 42       |
| Gabon                                     | 42       |

# Water Units, Data Conversions, and Constants

Water experts, managers, scientists, and educators work with a bewildering array of different units and data. These vary with the field of work: engineers may use different water units than hydrologists; urban water agencies may use different units than reservoir operators; academics may use different units than water managers. But they also vary with regions: water agencies in England may use different units than water agencies in France or Africa; hydrologists in the eastern United States often use different units than hydrologists in the western United States. And they vary over time: today's water agency in California may sell water by the acre-foot, but its predecessor a century ago may have sold miner's inches or some other now arcane measure.

These differences are of more than academic interest. Unless a common "language" is used, or a dictionary of translations is available, errors can be made or misunderstandings can ensue. In some disciplines, unit errors can be more than embarrassing; they can be expensive, or deadly. In September 1999, the \$125 million Mars Climate Orbiter spacecraft was sent crashing into the face of Mars instead of into its proper safe orbit above the surface because one of the computer programs controlling a portion of the navigational analysis used English units incompatible with the metric units used in all the other systems. The failure to translate English units into metric units was described in the findings of the preliminary investigation as the principal cause of mission failure.

This table is a comprehensive list of water units, data conversions, and constants related to water volumes, flows, pressures, and much more. Most of these units and conversions were compiled by Kent Anderson and initially published in P. H. Gleick, 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*, Oxford University Press, New York.

## Water Units, Data Conversions, and Constants

| Prefix (Metric) | Abbreviation | Multiple         | Prefix (Metric) | Abbreviation | Multiple          |
|-----------------|--------------|------------------|-----------------|--------------|-------------------|
| deka-           | da           | 10               | deci-           | d            | 0.1               |
| hecto-          | h            | 100              | centi-          | c            | 0.01              |
| kilo-           | k            | 1000             | milli-          | m            | 0.001             |
| mega-           | M            | 10 <sup>6</sup>  | micro-          | μ            | 10 <sup>-6</sup>  |
| giga-           | G            | 10 <sup>9</sup>  | nano-           | n            | 10 <sup>-9</sup>  |
| tera-           | T            | 10 <sup>12</sup> | pico-           | P            | 10 <sup>-12</sup> |
| peta-           | P            | 10 <sup>15</sup> | femto-          | f            | 10 <sup>-15</sup> |
| exa-            | E            | 10 <sup>18</sup> | atto-           | a            | 10 <sup>-18</sup> |

**LENGTH (L)**

|                            |  |                                      |   |
|----------------------------|--|--------------------------------------|---|
| <b>1 micron (μ)</b>        | = 1 × 10 <sup>-3</sup> mm<br>= 1 × 10 <sup>-6</sup> m<br>= 3.937 × 10 <sup>-5</sup> in                                       | <b>10 hectometers</b>                | = 1 kilometer   |
| <b>1 millimeter (mm)</b>   | = 0.1 cm<br>= 1 × 10 <sup>-3</sup> m<br>= 0.03937 in   | <b>1 mil</b>                         | = 0.0254 mm<br>= 1 × 10 <sup>-3</sup> in  |
| <b>1 centimeter (cm)</b>   | = 10 mm<br>= 0.01 m<br>= 1 × 10 <sup>-5</sup> km<br>= 0.3937 in<br>= 0.03281 ft<br>= 0.01094 yd                              | <b>1 inch (in)</b>                   | = 25.4 mm<br>= 2.54 cm<br>= 0.08333 ft<br>= 0.0278 yd   |
| <b>1 meter (m)</b>         | = 1000 mm<br>= 100 cm<br>= 1 × 10 <sup>-3</sup> km<br>= 39.37 in<br>= 3.281 ft<br>= 1.094 yd<br>= 6.21 × 10 <sup>-4</sup> mi | <b>1 foot (ft)</b>                   | = 30.48 cm<br>= 0.3048 m<br>= 3.048 × 10 <sup>-4</sup> km<br>= 12 in<br>= 0.3333 yd<br>= 1.89 × 10 <sup>-4</sup> mi |
| <b>1 kilometer (km)</b>    | = 1 × 10 <sup>5</sup> cm<br>= 1000 m<br>= 3280.8 ft<br>= 1093.6 yd<br>= 0.621 mi   | <b>1 yard (yd)</b>                   | = 91.44 cm<br>= 0.9144 m<br>= 9.144 × 10 <sup>-4</sup> km<br>= 36 in<br>= 3 ft<br>= 5.68 × 10 <sup>-4</sup> mi      |
| <b>10 millimeters</b>      | = 1 centimeter   | <b>1 mile (mi)</b>                   | = 1609.3 m<br>= 1.609 km<br>= 5280 ft<br>= 1760 yd  |
| <b>10 centimeters</b>      | = 1 decimeter  | <b>1 fathom (nautical)</b>           | = 6 ft  |
| <b>10 decimeters (dm)</b>  | = 1 meter  | <b>1 league (nautical)</b>           | = 5.556 km<br>= 3 nautical miles  |
| <b>10 meters</b>           | = 1 dekameter  | <b>1 league (land)</b>               | = 4.828 km<br>= 5280 yd<br>= 3 mi   |
| <b>10 dekameters (dam)</b> | = 1 hectometer   | <b>1 international nautical mile</b> | = 1.852 km<br>= 6076.1 ft<br>= 1.151 mi   |

## Water Units, Data Conversions, and Constants (continued)

AREA (L<sup>2</sup>)

|  |  |                                       |   |
|--|--|---------------------------------------|---|
| <b>1 square centimeter</b><br>(cm <sup>2</sup> ) | = 1 × 10 <sup>-4</sup> m <sup>2</sup><br>= 0.1550 in <sup>2</sup><br>= 1.076 × 10 <sup>-3</sup> ft <sup>2</sup><br>= 1.196 × 10 <sup>-4</sup> yd <sup>2</sup>  | <b>1 square foot (ft<sup>2</sup>)</b> | = 929.0 cm <sup>2</sup><br>= 0.0929 m <sup>2</sup><br>= 144 in <sup>2</sup><br>= 0.1111 yd <sup>2</sup>   |
| <b>1 square meter</b><br>(m <sup>2</sup> )       | = 1 × 10 <sup>-4</sup> hectare<br>= 1 × 10 <sup>-6</sup> km <sup>2</sup><br>= 1 centare<br>(French)<br>= 0.01 are<br>= 1550.0 in <sup>2</sup><br>= 10.76 ft <sup>2</sup><br>= 1.196 yd <sup>2</sup><br>= 2.471 × 10 <sup>-4</sup> acre | <b>1 square yard (yd<sup>2</sup>)</b> | = 2.296 × 10 <sup>-5</sup> acre<br>= 3.587 × 10 <sup>-8</sup> mi <sup>2</sup><br>= 0.8361 m <sup>2</sup><br>= 8.361 × 10 <sup>-5</sup> hectare<br>= 1296 in <sup>2</sup><br>= 9 ft <sup>2</sup><br>= 2.066 × 10 <sup>-4</sup> acres<br>= 3.228 × 10 <sup>-7</sup> mi <sup>2</sup> |
| <b>1 are</b>                                     | = 100 m <sup>2</sup>   | <b>1 acre</b>                         | = 4046.9 m <sup>2</sup><br>= 0.40469 ha<br>= 4.0469 × 10 <sup>-3</sup> km <sup>2</sup><br>= 43,560 ft <sup>2</sup><br>= 4840 yd <sup>2</sup><br>= 1.5625 × 10 <sup>-3</sup> mi <sup>2</sup>   |
| <b>1 hectare (ha)</b>                            | = 1 × 10 <sup>4</sup> m <sup>2</sup><br>= 100 are<br>= 0.01 km <sup>2</sup><br>= 1.076 × 10 <sup>5</sup> ft <sup>2</sup><br>= 1.196 × 10 <sup>4</sup> yd <sup>2</sup><br>= 2.471 acres<br>= 3.861 × 10 <sup>-3</sup> mi <sup>2</sup>   | <b>1 square mile (mi<sup>2</sup>)</b> | = 2.590 × 10 <sup>6</sup> m <sup>2</sup><br>= 259.0 hectares<br>= 2.590 km <sup>2</sup><br>= 2.788 × 10 <sup>7</sup> ft <sup>2</sup><br>= 3.098 × 10 <sup>6</sup> yd <sup>2</sup><br>= 640 acres<br>= 1 section (of land)   |
| <b>1 square kilometer</b><br>(km <sup>2</sup> )  | = 1 × 10 <sup>6</sup> m <sup>2</sup><br>= 100 hectares<br>= 1.076 × 10 <sup>7</sup> ft <sup>2</sup><br>= 1.196 × 10 <sup>6</sup> yd <sup>2</sup><br>= 247.1 acres<br>= 0.3861 mi <sup>2</sup>  | <b>1 feddan (Egyptian)</b>            | = 4200 m <sup>2</sup><br>= 0.42 ha<br>= 1.038 acres   |
| <b>1 square inch (in<sup>2</sup>)</b>            | = 6.452 cm <sup>2</sup><br>= 6.452 × 10 <sup>-4</sup> m <sup>2</sup><br>= 6.944 × 10 <sup>-3</sup> ft <sup>2</sup><br>= 7.716 × 10 <sup>-4</sup> yd <sup>2</sup>   |                                       |   |

(continues)

## Water Units, Data Conversions, and Constants (continued)

VOLUME (L<sup>3</sup>)

|  |  |                                      |  |
|--|--|--------------------------------------|--|
| <b>1 cubic centimeter (cm<sup>3</sup>)</b> | = 1 × 10 <sup>-3</sup> liter<br>= 1 × 10 <sup>-6</sup> m <sup>3</sup><br>= 0.06102 in <sup>3</sup><br>= 2.642 × 10 <sup>-4</sup> gal<br>= 3.531 × 10 <sup>-3</sup> ft <sup>3</sup>   | <b>1 cubic foot (ft<sup>3</sup>)</b> | = 2.832 × 10 <sup>4</sup> cm <sup>3</sup><br>= 28.32 liters<br>= 0.02832 m <sup>3</sup><br>= 1728 in <sup>3</sup><br>= 7.481 gal<br>= 0.03704 yd <sup>3</sup>      |
| <b>1 liter (l)</b>                         | = 1000 cm <sup>3</sup><br>= 1 × 10 <sup>-3</sup> m <sup>3</sup><br>= 61.02 in <sup>3</sup><br>= 0.2642 gal<br>= 0.03531 ft <sup>3</sup>  | <b>1 cubic yard (yd<sup>3</sup>)</b> | = 0.7646 m <sup>3</sup><br>= 6.198 × 10 <sup>-4</sup> acre-ft<br>= 46656 in <sup>3</sup><br>= 27 ft <sup>3</sup>   |
| <b>1 cubic meter (m<sup>3</sup>)</b>       | = 1 × 10 <sup>6</sup> cm <sup>3</sup><br>= 1000 liter<br>= 1 × 10 <sup>-9</sup> km <sup>3</sup><br>= 264.2 gal<br>= 35.31 ft <sup>3</sup><br>= 6.29 bbl<br>= 1.3078 yd <sup>3</sup><br>= 8.107 × 10 <sup>-4</sup> acre-ft  | <b>1 acre-foot (acre-ft or AF)</b>   | = 1233.48 m <sup>3</sup><br>= 3.259 × 10 <sup>5</sup> gal<br>= 43560 ft <sup>3</sup>   |
| <b>1 cubic decameter (dam<sup>3</sup>)</b> | = 1000 m <sup>3</sup><br>= 1 × 10 <sup>6</sup> liter<br>= 1 × 10 <sup>-6</sup> km <sup>3</sup><br>= 2.642 × 10 <sup>5</sup> gal<br>= 3.531 × 10 <sup>4</sup> ft <sup>3</sup><br>= 1.3078 × 10 <sup>3</sup> yd <sup>3</sup><br>= 0.8107 acre-ft   | <b>1 Imperial gallon</b>             | = 4.546 liters<br>= 277.4 in <sup>3</sup><br>= 1.201 gal<br>= 0.16055 ft <sup>3</sup>  |
| <b>1 cubic hectometer (ha<sup>3</sup>)</b> | = 1 × 10 <sup>6</sup> m <sup>3</sup><br>= 1 × 10 <sup>3</sup> dam <sup>3</sup><br>= 1 × 10 <sup>9</sup> liter<br>= 2.642 × 10 <sup>8</sup> gal<br>= 3.531 × 10 <sup>7</sup> ft <sup>3</sup><br>= 1.3078 × 10 <sup>6</sup> yd <sup>3</sup><br>= 810.7 acre-ft                                 | <b>1 cfs-day</b>                     | = 1.98 acre-feet<br>= 0.0372 in-mi <sup>2</sup><br>= 1.738 × 10 <sup>7</sup> gal<br>= 2.323 × 10 <sup>6</sup> ft <sup>3</sup><br>= 53.3 acre-ft<br>= 26.9 cfs-days |
| <b>1 cubic kilometer (km<sup>3</sup>)</b>  | = 1 × 10 <sup>12</sup> liter<br>= 1 × 10 <sup>9</sup> m <sup>3</sup><br>= 1 × 10 <sup>6</sup> dam <sup>3</sup><br>= 1000 ha <sup>3</sup><br>= 8.107 × 10 <sup>5</sup> acre-ft<br>= 0.24 mi <sup>3</sup>  | <b>1 inch-mi<sup>2</sup></b>         | = 1.738 × 10 <sup>7</sup> gal<br>= 2.323 × 10 <sup>6</sup> ft <sup>3</sup><br>= 53.3 acre-ft<br>= 26.9 cfs-days  |
| <b>1 cubic inch (in<sup>3</sup>)</b>       | = 16.39 cm <sup>3</sup><br>= 0.01639 liter<br>= 4.329 × 10 <sup>-3</sup> gal<br>= 5.787 × 10 <sup>-4</sup> ft <sup>3</sup><br>= 3.785 liters<br>= 3.785 × 10 <sup>-3</sup> m <sup>3</sup><br>= 231 in <sup>3</sup><br>= 0.1337 ft <sup>3</sup><br>= 4.951 × 10 <sup>-3</sup> yd <sup>3</sup> | <b>1 barrel (of oil) (bbl)</b>       | = 159 liter<br>= 0.159 m <sup>3</sup><br>= 42 gal<br>= 5.6 ft <sup>3</sup>   |
| <b>1 gallon (gal)</b>                      |  | <b>1 million gallons</b>             | = 3.069 acre-ft<br>= 0.473 liter<br>= 28.875 in <sup>3</sup><br>= 0.5 qt<br>= 16 fluid ounces<br>= 32 tablespoons<br>= 96 teaspoons                                |
|  |  | <b>1 pint (pt)</b>                   | = 0.473 liter<br>= 28.875 in <sup>3</sup><br>= 0.5 qt<br>= 16 fluid ounces<br>= 32 tablespoons<br>= 96 teaspoons   |
|  |  | <b>1 quart (qt)</b>                  | = 0.946 liter<br>= 57.75 in <sup>3</sup><br>= 2 pt<br>= 0.25 gal   |
|  |  | <b>1 morgen-foot (S. Africa)</b>     | = 2610.7 m <sup>3</sup>  |
|  |  | <b>1 board-foot</b>                  | = 2359.8 cm <sup>3</sup><br>= 144 in <sup>3</sup><br>= 0.0833 ft <sup>3</sup>  |
|  |  | <b>1 cord</b>                        | = 128 ft <sup>3</sup><br>= 0.453 m <sup>3</sup>  |

## Water Units, Data Conversions, and Constants (continued)

**VOLUME/AREA (L<sup>3</sup>/L<sup>2</sup>)**

|                       |  |                      |                |
|-----------------------|--|----------------------|----------------|
| <b>1 inch of rain</b> | = 5.610 gal/yd <sup>2</sup><br>= 2.715 × 10 <sup>4</sup><br>gal/acre | <b>1 box of rain</b> | = 3,154.0 lesh |
|-----------------------|--|----------------------|----------------|

**MASS (M)**

|   |   |                          |  |
|---|---|--------------------------|--|
| <b>1 gram (g or gm)</b>                 | = 0.001 kg<br>= 15.43 gr<br>= 0.03527 oz<br>= 2.205 × 10 <sup>-3</sup> lb | <b>1 ounce (oz)</b>      | = 28.35 g<br>= 437.5 gr<br>= 0.0625 lb               |
| <b>1 kilogram (kg)</b>                  | = 1000 g<br>= 0.001 tonne<br>= 35.27 oz<br>= 2.205 lb                     | <b>1 pound (lb)</b>      | = 453.6 g<br>= 0.45359237 kg<br>= 7000 gr<br>= 16 oz |
| <b>1 hectogram (hg)</b>                 | = 100 gm<br>= 0.1 kg  | <b>1 short ton (ton)</b> | = 907.2 kg<br>= 0.9072 tonne<br>= 2000 lb            |
| <b>1 metric ton (tonne or te or MT)</b> | = 1000 kg<br>= 2204.6 lb<br>= 1.102 ton<br>= 0.9842 long ton              | <b>1 long ton</b>        | = 1016.0 kg<br>= 1.016 tonne                         |
| <b>1 dalton (atomic mass unit)</b>      | = 1.6604 × 10 <sup>-24</sup> g  | <b>1 long ton</b>        | = 2240 lb<br>= 1.12 ton                              |
| <b>1 grain (gr)</b>                     | = 2.286 × 10 <sup>-3</sup> oz<br>= 1.429 × 10 <sup>-4</sup> lb            | <b>1 stone (British)</b> | = 6.35 kg<br>= 14 lb                                 |

**TIME (T)**

|                            |   |                         |  |
|----------------------------|---|-------------------------|--|
| <b>1 second (s or sec)</b> | = 0.01667 min<br>= 2.7778 × 10 <sup>-4</sup> hr | <b>1 day (d)</b>        | = 24 hr<br>= 86400 s                               |
| <b>1 minute (min)</b>      | = 60 s<br>= 0.01667 hr                          | <b>1 year (yr or y)</b> | = 365 d<br>= 8760 hr<br>= 3.15 × 10 <sup>7</sup> s |
| <b>1 hour (hr or h)</b>    | = 60 min<br>= 3600 s                            |                         |  |

**DENSITY (M/L<sup>3</sup>)**

|   |  |  |  |
|---|--|--|--|
| <b>1 kilogram per cubic meter (kg/m<sup>3</sup>)</b>  | = 10 <sup>-3</sup> g/cm <sup>3</sup><br>= 0.062 lb/ft <sup>3</sup> | <b>1 metric ton per cubic meter (te/m<sup>3</sup>)</b> | = 1.0 specific gravity<br>= density of H <sub>2</sub> O at 4°C |
| <b>1 gram per cubic centimeter (g/cm<sup>3</sup>)</b> | = 1000 kg/m <sup>3</sup><br>= 62.43 lb/ft <sup>3</sup>             | <b>1 pound per cubic foot (lb/ft<sup>3</sup>)</b>      | = 8.35 lb/gal<br>= 16.02 kg/m <sup>3</sup>                     |

(continues)



## Water Units, Data Conversions, and Constants (continued)

## VELOCITY (L/T)

|   |   |  |   |
|---|---|--|---|
| <b>1 meter per second (m/s)</b>           | = 3.6 km/hr<br>= 2.237 mph<br>= 3.28 ft/s | <b>1 foot per second (ft/s)</b>        | = 0.68 mph<br>= 0.3048 m/s  |
| <b>1 kilometer per hour (km/h or kph)</b> | = 0.62 mph<br>= 0.278 m/s                 | <b>velocity of light in vacuum (c)</b> | = $2.9979 \times 10^8$ m/s<br>= 186,000 mi/s                          |
| <b>1 mile per hour (mph or mi/h)</b>      | = 1.609 km/h<br>= 0.45 m/s<br>= 1.47 ft/s | <b>1 knot</b>                          | = 1.852 km/h<br>= 1 nautical mile/hour<br>= 1.151 mph<br>= 1.688 ft/s |

VELOCITY OF SOUND IN WATER AND SEAWATER  
(assuming atmospheric pressure and sea water salinity of 35,000 ppm)

| Temp, °C | Pure water,<br>(meters/sec) | Sea water,<br>(meters/sec) |
|----------|-----------------------------|----------------------------|
| 0        | 1,400                       | 1,445                      |
| 10       | 1,445                       | 1,485                      |
| 20       | 1,480                       | 1,520                      |
| 30       | 1,505                       | 1,545                      |

FLOW RATE (L<sup>3</sup>/T)

|   |  |   |   |
|---|--|---|---|
| <b>1 liter per second (l/sec)</b>                   | = 0.001 m <sup>3</sup> /sec<br>= 86.4 m <sup>3</sup> /day<br>= 15.9 gpm<br>= 0.0228 mgd<br>= 0.0353 cfs<br>= 0.0700 AF/day   | <b>1 cubic decameters per day (dam<sup>3</sup>/day)</b> | = 11.57 l/sec<br>= $1.157 \times 10^{-2}$ m <sup>3</sup> /sec<br>= 1000 m <sup>3</sup> /day<br>= $1.83 \times 10^6$ gpm<br>= 0.264 mgd<br>= 0.409 cfs<br>= 0.811 AF/day |
| <b>1 cubic meter per second (m<sup>3</sup>/sec)</b> | = 1000 l/sec<br>= $8.64 \times 10^4$ m <sup>3</sup> /day<br>= $1.59 \times 10^4$ gpm<br>= 22.8 mgd<br>= 35.3 cfs<br>= 70.0 AF/day  | <b>1 gallon per minute (gpm)</b>                        | = 0.0631 l/sec<br>= $6.31 \times 10^{-5}$ m <sup>3</sup> /sec<br>= $1.44 \times 10^{-3}$ mgd<br>= $2.23 \times 10^{-3}$ cfs<br>= $4.42 \times 10^{-3}$ AF/day           |
| <b>1 cubic meter per day (m<sup>3</sup>/day)</b>    | = 0.01157 l/sec<br>= $1.157 \times 10^{-5}$ m <sup>3</sup> /sec<br>= 0.183 gpm<br>= $2.64 \times 10^{-4}$ mgd<br>= $4.09 \times 10^{-4}$ cfs<br>= $8.11 \times 10^{-4}$ AF/day | <b>1 million gallons per day (mgd)</b>                  | = 43.8 l/sec<br>= 0.0438 m <sup>3</sup> /sec<br>= 3785 m <sup>3</sup> /day<br>= 694 gpm<br>= 1.55 cfs<br>= 3.07 AF/day  |

## Water Units, Data Conversions, and Constants (continued)

**FLOW RATE (L<sup>3</sup>/T) (continued)**

|                                      |   |   |   |
|--------------------------------------|---|---|---|
| <b>1 cubic foot per second (cfs)</b> | = 28.3 l/sec<br>= 0.0283 m <sup>3</sup> /sec<br>= 2447 m <sup>3</sup> /day<br>= 449 gpm<br>= 0.646 mgd<br>= 1.98 AF/day       | <b>1 miner's inch</b>                             | = 0.02 cfs (in Idaho, Kansas, Nebraska, New Mexico, North Dakota, South Dakota, and Utah)<br>= 0.026 cfs (in Colorado)<br>= 0.028 cfs (in British Columbia) |
| <b>1 acre-foot per day (AF/day)</b>  | = 14.3 l/sec<br>= 0.0143 m <sup>3</sup> /sec<br>= 1233.48 m <sup>3</sup> /day<br>= 226 gpm<br>= 0.326 mgd<br>= 0.504 cfs      | <b>1 weir</b><br><b>1 quinaría (ancient Rome)</b> | = 0.02 garcía<br>= 0.47–0.48 l/sec  |
| <b>1 miner's inch</b>                | = 0.025 cfs (in Arizona, California, Montana, and Oregon: flow of water through 1 in <sup>2</sup> aperture under 6-inch head) |   |   |

**ACCELERATION (L/T<sup>2</sup>)**

|   |  |
|---|--|
| <b>standard acceleration of gravity</b> | = 9.8 m/s <sup>2</sup><br>= 32 ft/s <sup>2</sup> |
|---|--|

**FORCE (ML/T<sup>2</sup> = Mass × Acceleration)**

|                     |  |                      |  |
|---------------------|--|----------------------|--|
| <b>1 newton (N)</b> | = kg·m/s <sup>2</sup><br>= 10 <sup>5</sup> dynes<br>= 0.1020 kg force<br>= 0.2248 lb force | <b>1 dyne</b>        | = g·cm/s <sup>2</sup><br>= 10 <sup>-5</sup> N    |
|                     |  | <b>1 pound force</b> | = lb mass × acceleration of gravity<br>= 4.448 N |

(continues)

## Water Units, Data Conversions, and Constants (continued)

|  |  |  |  |
|--|--|--|--|
| <b>PRESSURE (M/L<sup>2</sup> = Force/Area)</b> |  | <b>1 kilogram per sq. centimeter (kg/cm<sup>2</sup>)</b> | = 14.22 lb/in <sup>2</sup>   |
| <b>1 pascal (Pa)</b>                           | = N/m <sup>2</sup>   | <b>1 inch of water at 62°F</b>                           | = 0.0361 lb/in <sup>2</sup><br>= 5.196 lb/ft <sup>3</sup><br>= 0.0735 inch of mercury at 62°F  |
| <b>1 bar</b>                                   | = 1 × 10 <sup>5</sup> Pa<br>= 1 × 10 <sup>6</sup> dyne/cm <sup>2</sup><br>= 1019.7 g/cm <sup>2</sup><br>= 10.197 te/m <sup>2</sup><br>= 0.9869 atmos-<br>phere<br>= 14.50 lb/in <sup>2</sup><br>= 1000 millibars   | <b>1 foot of water at 62°F</b>                           | = 0.433 lb/in <sup>2</sup><br>= 62.36 lb/ft <sup>2</sup><br>= 0.833 inch of mercury at 62°F<br>= 2.950 × 10 <sup>-2</sup> atmosphere   |
| <b>1 atmosphere (atm)</b>                      | = standard pressure<br>= 760 mm of mercury at 0°C<br>= 1013.25 millibars<br>= 1033 g/cm <sup>2</sup><br>= 1.033 kg/cm <sup>2</sup><br>= 14.7 lb/in <sup>2</sup><br>= 2116 lb/ft <sup>2</sup><br>= 33.95 feet of water at 62°F<br>= 29.92 inches of mercury at 32°F | <b>1 pound per sq. inch (psi or lb/in<sup>2</sup>)</b>   | = 2.309 feet of water at 62°F<br>= 2.036 inches of mercury at 32°F<br>= 0.06804 atmosphere<br>= 0.07031 kg/cm <sup>2</sup><br>= 0.4192 lb/in <sup>2</sup><br>= 1.133 feet of water at 32°F |
| <b>TEMPERATURE</b>                             |  | <b>1 inch of mercury at 32°F</b>                         |  |
| <b>degrees Celsius or Centigrade (°C)</b>      | = (°F-32) × 5/9  | <b>degrees Fahrenheit (°F)</b>                           | = 32 + (°C × 1.8)  |
| <b>Kelvins (K)</b>                             | = K-273.16<br>= 273.16 + °C<br>= 273.16 + ((°F- 32) × 5/9)   |  | = 32 + ((°K-273.16) × 1.8)   |

## Water Units, Data Conversions, and Constants (continued)

**ENERGY (ML<sup>2</sup>/T<sup>2</sup> = Force × Distance)**

|                                     |  |  |   |
|-------------------------------------|--|--|---|
| <b>1 joule (J)</b>                  | = 10 <sup>7</sup> ergs<br>= N·m<br>= W·s<br>= kg·m <sup>2</sup> /s <sup>2</sup><br>= 0.239 calories<br>= 9.48 × 10 <sup>-4</sup> Btu | <b>1 kilowatt-hour (kWh)</b>                 | = 3.6 × 10 <sup>6</sup> J<br>= 3412 Btu<br>= 859.1 kcal   |
| <b>1 calorie (cal)</b>              | = 4.184 J<br>= 3.97 × 10 <sup>-3</sup> Btu<br>(raises 1 g H <sub>2</sub> O 1°C)  | <b>1 quad</b>                                | = 10 <sup>15</sup> Btu<br>= 1.055 × 10 <sup>18</sup> J<br>= 293 × 10 <sup>9</sup> kWh<br>= 0.001 Q<br>= 33.45 GWy |
| <b>1 British thermal unit (Btu)</b> | = 1055 J<br>= 252 cal (raises 1 lb H <sub>2</sub> O 1°F)<br>= 2.93 × 10 <sup>-4</sup> kWh  | <b>1 Q</b>                                   | = 1000 quads<br>≈ 10 <sup>21</sup> J  |
| <b>1 erg</b>                        | = 10 <sup>-7</sup> J<br>= g·cm <sup>2</sup> /s <sup>2</sup><br>= dyne·cm   | <b>1 foot-pound (ft-lb)</b>                  | = 1.356 J<br>= 0.324 cal  |
| <b>1 kilocalorie (kcal)</b>         | = 1000 cal<br>= 1 Calorie (food)   | <b>1 therm</b>                               | = 10 <sup>5</sup> Btu   |
|                                     |  | <b>1 electron-volt (eV)</b>                  | = 1.602 × 10 <sup>-19</sup> J   |
|                                     |  | <b>1 kiloton of TNT</b>                      | = 4.2 × 10 <sup>12</sup> J  |
|                                     |  | <b>1 10<sup>6</sup> te oil equiv. (Mtoe)</b> | = 7.33 × 10 <sup>6</sup> bbl oil<br>= 45 × 10 <sup>15</sup> J<br>= 0.0425 quad                                    |

**POWER (ML<sup>2</sup>/T<sup>3</sup> = rate of flow of energy)**

|   |   |                                  |  |
|---|---|----------------------------------|--|
| <b>1 watt (W)</b>                           | = J/s<br>= 3600 J/hr<br>= 3.412 Btu/hr                              | <b>1 horsepower (H.P. or hp)</b> | = 0.178 kcal/s<br>= 6535 kWh/yr<br>= 33,000 ft-lb/min<br>= 550 ft-lb/sec<br>= 8760 H.P.-hr/yr                                      |
| <b>1 TW</b>                                 | = 10 <sup>12</sup> W<br>= 31.5 × 10 <sup>18</sup> J<br>= 30 quad/yr | <b>H.P. input</b>                | = 1.34 × kW input to motor<br>= horsepower input to motor  |
| <b>1 kilowatt (kW)</b>                      | = 1000W<br>= 1.341 horsepower<br>= 0.239 kcal/s<br>= 3412 Btu/hr    | <b>Water H.P.</b>                | = H.P. required to lift water at a definite rate to a given distance assuming 100% efficiency<br>= gpm × total head (in feet)/3960 |
| <b>10<sup>6</sup> bbl (oil) /day (Mb/d)</b> | ≈ 2 quads/yr<br>≈ 70 GW   |                                  |  |
| <b>1 quad/yr</b>                            | = 33.45 GW<br>≈ 0.5 Mb/d  |                                  |  |
| <b>1 horsepower (H.R or hp)</b>             | = 745.7W<br>= 0.7457 kW   |                                  |  |

(continues)

## Water Units, Data Conversions, and Constants (continued)

**EXPRESSIONS OF HARDNESS<sup>a</sup>**

|  |  |                        |   |
|--|--|------------------------|---|
| <b>1 grain per gallon</b>              | = 1 grain CaCO <sub>3</sub><br>per U.S. gallon             | <b>1 French degree</b> | = 1 part CaCO <sub>3</sub> per<br>100,000 parts water |
| <b>1 part per million</b>              | = 1 part CaCO <sub>3</sub> per<br>1,000,000 parts<br>water | <b>1 German degree</b> | = 1 part CaO per<br>100,000 parts water               |
| <b>1 English, or Clark,<br/>degree</b> | = 1 grain CaCO <sub>3</sub><br>per Imperial<br>gallon      |                        |   |

**CONVERSIONS OF HARDNESS**

|                                    |                                     |                        |                                     |
|------------------------------------|-------------------------------------|------------------------|-------------------------------------|
| <b>1 grain per U.S.<br/>gallon</b> | = 17.1 ppm, as<br>CaCO <sub>3</sub> | <b>1 French degree</b> | = 10 ppm, as<br>CaCO <sub>3</sub>   |
| <b>1 English degree</b>            | = 14.3 ppm, as<br>CaCO <sub>3</sub> | <b>1 German degree</b> | = 17.9 ppm, as<br>CaCO <sub>3</sub> |

**WEIGHT OF WATER**

|                     |             |                          |           |
|---------------------|-------------|--------------------------|-----------|
| <b>1 cubic inch</b> | = 0.0361 lb | <b>1 imperial gallon</b> | = 10.0 lb |
| <b>1 cubic foot</b> | = 62.4 lb   | <b>1 cubic meter</b>     | = 1 tonne |
| <b>1 gallon</b>     | = 8.34 lb   |                          |           |

**DENSITY OF WATER<sup>a</sup>**

| Temperature |      | Density            |
|-------------|------|--------------------|
| °C          | °F   | gm/cm <sup>3</sup> |
| 0           | 32   | 0.99987            |
| 1.667       | 35   | 0.99996            |
| 4.000       | 39.2 | 1.00000            |
| 4.444       | 40   | 0.99999            |
| 10.000      | 50   | 0.99975            |
| 15.556      | 60   | 0.99907            |
| 21.111      | 70   | 0.99802            |
| 26.667      | 80   | 0.99669            |
| 32.222      | 90   | 0.99510            |
| 37.778      | 100  | 0.99318            |
| 48.889      | 120  | 0.98870            |
| 60.000      | 140  | 0.98338            |
| 71.111      | 160  | 0.97729            |
| 82.222      | 180  | 0.97056            |
| 93.333      | 200  | 0.96333            |
| 100.000     | 212  | 0.95865            |

Note: Density of Sea Water: approximately 1.025 gm/cm<sup>3</sup> at 15°C.

<sup>a</sup>Source: van der Leeden, F., Troise, F. L., and Todd, D. K., 1990. *The Water Encyclopedia*, 2d edition. Lewis Publishers, Inc., Chelsea, Michigan.

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