

WATER SECURITY

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Abstract—Water security is critical for the survival of communities and nations. It represents a major challenge, especially in parts of the world facing increasing water scarcity, such as arid and semi-arid regions or densely populated areas. Water security also directly affects food security, as most of the world's water is used in agriculture for food production. The water/food/energy security nexus was recently identified as one of three important risk clusters that may threaten economic growth and political and social stability in the future.

Water security hinges on balancing water supply with water demand, both of which are subject to change over time. Since there are limits to augmenting the water supply, demand management through economic, administrative, and technical measures is essential for achieving water security. Water management should aim at the sustainable use of renewable water resources and the planned depletion of nonrenewable water resources within well-defined timeframes. Where possible, this should be supplemented by the use of unconventional water sources such as treated wastewater and desalination. Serious threats to water security include population growth (which intensifies water scarcity), pollution (which renders some water resources unusable), and climate change (which may alter the amount and time distribution of precipitation in some parts of the world and increase the water requirements for food production due to higher temperatures).

Two powerful concepts—virtual water and the water footprint—make it easier to grasp the global nature of water security and the need for global initiatives to ensure it. These concepts can also help the public understand the impact of their everyday choices on water availability while offering policy and decision makers new ways of viewing water security and how to improve it.

Water security is critical for most industries and businesses because many processes and supplies depend directly or indirectly on water. Systematic accounting of the quantities involved can help businesses identify opportunities for more-efficient water use and understand the water-related risks that they may face. The development of strategies for dealing with such risks can help achieve water security.

Keywords—virtual water, water footprint, water management, water scarcity, water security

INTRODUCTION

The term *water security* is often used to describe the condition of an uninterrupted water supply of sufficient quantity and adequate quality to meet the domestic water needs of a country or region and support its economic activities that depend on water. A broader definition of water security involves the sustainable development of water resources, protection of water systems, protection of water supply from hazards associated with extreme hydrologic events (such as floods and droughts), and safeguarding of access to water and services for people and the environment. [1] According to the Global Water Partnership,

“the term ‘water security’ aims to capture the complex concept of holistic water management and the balance between resource protection and resource use.” [2] Over the last few years, the term has been increasingly used, even in countries not characterized by water scarcity, like Canada [3] and the United Kingdom [4].

Depending on the prevailing actual or perceived threats to the water supply, water security at times becomes synonymous with a single aspect of the overall problem. For example, in the United States after 9/11, the Environmental Protection Agency used the term almost exclusively to indicate the measures required to protect against terrorist acts that may contaminate or disrupt

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ABBREVIATIONS, ACRONYMS, AND TERMS

CDP	Carbon Disclosure Project
FTSE	global company jointly owned by The Financial Times and the London Stock Exchange
GDP	gross domestic product
GEMI	Global Environmental Management Initiative

Water scarcity is a relative concept that depends on the combination of the available supply and the level of demand for water. In most arid and semi-arid areas, water scarcity has intensified over time due to population and economic growth.

the water supply. On the other hand, in Egypt, where practically all water comes from the Nile River, water security is synonymous with the continuation of past agreements regarding allocation of the river's water resources among the countries sharing its basin. For many industries, water security means the protection against operation disruptions due to water shortages.

On March 22, 2000, at the Second World Water Forum, the main challenges to achieving water security were set forth in the Ministerial Declaration of The Hague on Water Security in the 21st Century. As agreed on by 114 ministers and officials from 130 countries, the listed challenges included: (a) meeting the needs of all people to have access to safe and sufficient water and sanitation; (b) equitably allocating water resources to secure food production; (c) protecting ecosystems; (d) engendering peaceful cooperation in sharing water resources; (e) managing risk in dealing with floods, droughts, and pollution; and (f) managing water in a manner that reflects its economic, social, environmental, and cultural values for all its uses and that accounts for the need for equity. [5]

WATER SCARCITY

Water scarcity is a relative concept that depends on the combination of available supply and level of demand for water. Fresh water is inherently scarce in many parts of the world because of its uneven distribution around the globe. In most arid and semi-arid areas, water scarcity has intensified over time due to population and economic growth. Many parts of the world face physical water scarcity due to the lack of adequate water resources, while parts of the developing world face economic water scarcity because they do not possess the economic means to develop their water resources.

Although the accuracy of global statistics may sometimes be questionable and their use has been criticized by some experts (see [6], for example), data compiled by international organizations at least give an indication of the order of magnitude of the problem. According to the most recent global annual assessment of sanitation and drinking water by the World Health Organization, in 2008, nearly 900 million people did not have access to an improved drinking water source, and over 2.6 billion people did not use improved sanitation facilities. [7] Improved drinking water sources are considered those that provide safe water and include household connections, rainwater collections, public standpipes, boreholes, protected dug wells, and protected springs within 1 kilometer of the household. [8] Use of unsafe drinking water causes the death of 1.8 million people every year from diarrheal diseases such as cholera, with 90% of them being children under 5, mostly in developing countries. [9] Improved sanitation is important because unsanitary practices and discharge of untreated wastewater in nearby water bodies or the ground directly affect drinking water resources.

According to one estimate, the water required for the drinking, cooking, sanitation, and bathing needs of an individual is between 27 and 200 liters per day. Based on this estimate, a minimum standard requirement for basic human needs of 50 liters per person per day has been proposed. [10] Actual domestic water use varies from place to place above and below this proposed minimum because of differences in climate, standard of living, individual lifestyle, water use efficiency, etc. For example, based on data from the US Geological Survey, average domestic water use in the United States was 135 m³/yr per capita in 2005 and varied between approximately 75 and 263 m³/yr per capita in Maine and Nevada, respectively. [11] In the Middle East, a somewhat earlier per capita domestic water use figure varied between approximately 66 m³/yr in Egypt and approximately 23 m³/yr in Yemen. [12]

Total water use is much higher than domestic use due to water needs for agriculture, industry, urban uses, etc. The largest water user is irrigated agriculture. More than three-quarters of all water used around the world is for food production. It is estimated that producing food for the average US diet, which is rich in meat, requires about 5.4 m³/day, or 1,971 m³/yr per person, while an equivalent vegetarian diet requires only 2.6 m³/day per person, less than half that amount. [13]

A widely accepted minimum level of renewable water resources for satisfying the needs of a country with self-sufficient food production is 1,700 m³/yr per person. [14] Countries or regions with fewer water resources are said to be under water stress. If the available renewable water resources are less than 1,000 m³/yr per person, then the country or region is said to be characterized by water scarcity; if they fall below 500 m³/yr per person, the condition is described as absolute water scarcity. Based on population growth rates around 2005, it was estimated that by 2025, 1.8 billion people would be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be under water stress conditions. [15] Water-scarce regions include most arid and semi-arid areas in the American Southwest, Australia, North Africa, Middle East, Northern China, parts of India and South Africa, and densely populated cities and parts of Asia, such as Singapore.

Figure 1 shows the per capita renewable water resources for countries with less than 2,500 m³/yr per capita plotted against their per capita gross domestic products (GDPs) and population growth rates. As illustrated, many very poor countries face severe water

scarcity, which is intensified by rapid population growth. It should be noted that per capita renewable water resources is a valid indicator only for relatively small countries or when applied to regions with a relatively uniform climate. The average per capita resources for large countries like the United States or China can be misleading because average values mask significant differences within these countries. For example, the per capita available water resources in the southwestern United States or Western China are far less than the corresponding national average.

Increasing water scarcity can create tensions and become a destabilizing factor in international relationships, as pointed out in a recent report by the US Senate Foreign Relations Committee that examined water issues in Central and South Asia. [16] The report presented an analysis of how foreign assistance could be used for strategic investments to promote water security in the region. In the words of the committee's chairman, Senator John Kerry, "Water security is vital in achieving our foreign policy and national security goals by recognizing the duality of water—as a tool for development or a means to exacerbate conflict." [17]

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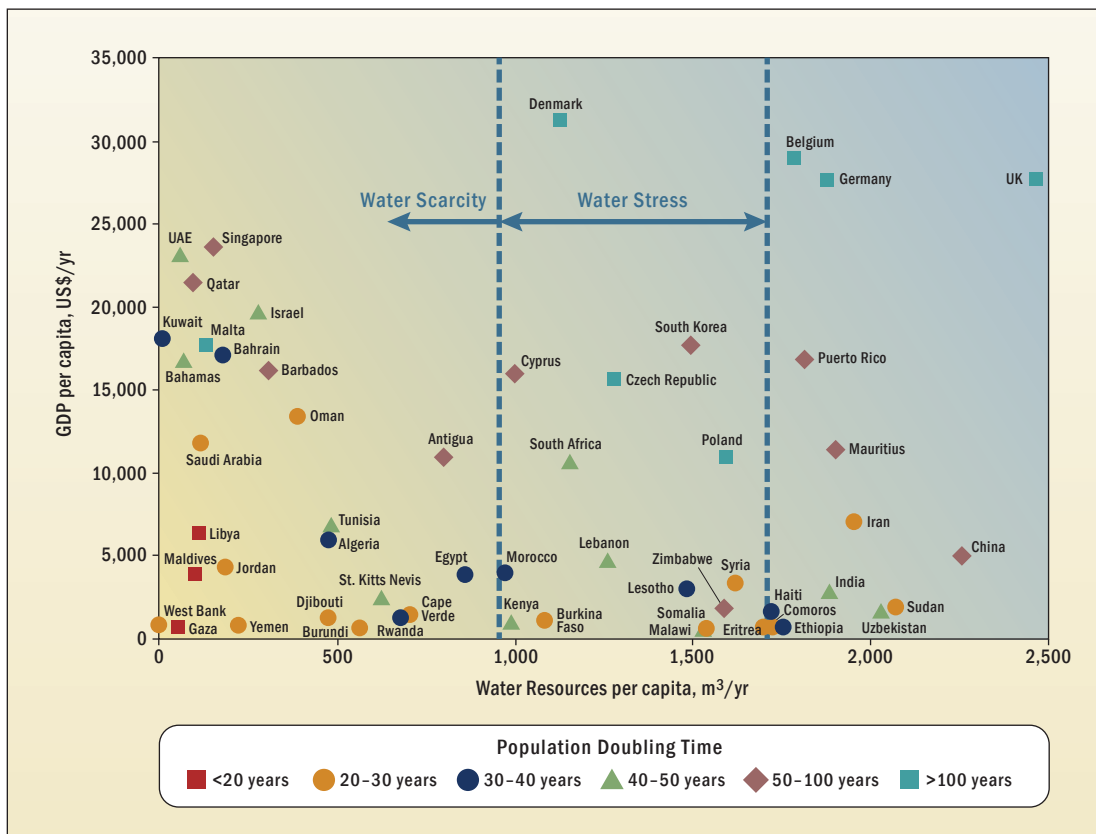


Figure 1. Total Renewable Water Resources Versus Per Capita GDP (per capita renewable water resources from [18]; per capita GDP data for 2003 from [19])

THE WATER/FOOD/ENERGY SECURITY NEXUS

Food security is achieved when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. [20] At a national level, food security can be achieved through internal food production, food imports, or a combination of the two. Many countries pursue policies aimed at self-sufficiency in food production. Besides affirming a country's independence, such policies are justified based on socio-economic considerations because farming is the only employment opportunity in many areas (especially in developing countries). In this case, food security depends on the availability of water and becomes closely tied to water security.

Food and water security are also related to energy security. Water used for food production is obtained by either extracting groundwater or by operating surface water collection, storage, and distribution systems, both of which require energy. Finally, energy generation requires water, primarily for cooling. In the most recent annual meeting of the World Economic Forum in Davos, the water/food/energy security nexus was discussed as one of three important clusters of risks that may threaten economic growth and political and social stability in the future. [21]

WATER MANAGEMENT

Water security hinges on balancing water supply with water demand, both of which change over time. Water supply can decrease due to the depletion of nonrenewable water resources or due to changes in the availability of renewable water resources caused by degradation of quality, climate change, or various human activities that affect the hydrologic cycle, such as land use changes. Water supply can increase through the development of new water resources. Water demand increases as the result of population and economic growth but can be managed through conservation, more efficient water use, economic measures, and agricultural and trade policies. The essence of water management is finding and achieving the optimal equilibrium between water supply and water demand without compromising future water security.

In general, augmenting the supply is problematic. Most countries and regions facing water scarcity have already fully developed their water resources beyond sustainable levels, resulting in rivers that run out of water by the time they reach the sea, lakes that shrink, and groundwater

wells that run dry. Use of nonrenewable water resources is only a short-term solution because, by definition, their use leads to their depletion. Large water transfer schemes, like the south-to-north water transfer under construction in China, are usually prohibitively expensive and have many negative environmental impacts. Nonconventional ways to augment the water supply include using treated wastewater, desalination, and, on a smaller scale, water harvesting. Theoretically, desalination offers the potential of unlimited water supply to areas near the ocean or other saline water bodies, but its feasibility depends on the availability and cost of energy. Technological developments in membrane technologies based on reverse osmosis have lowered the energy requirements for desalination, though they still remain quite high.

In view of these limitations, Gleick introduced the concept of peak water analogously with the concept of peak oil and described the implications of reaching peak water use and what would need to be done to avoid irreversible ecological damage to the environment. [22] In this respect, nonrenewable water resources, such as the fossil groundwater in the aquifers of North Africa and the Middle East, are very similar to oil, following a similar production curve over time with a distinct peak at some point, followed by declining production. On the other hand, renewable water resources are limited by the rate of their replenishment. They can be used indefinitely at their peak limit, but obviously not beyond that limit.

Where supply-side augmentation is not an option, demand management offers the only viable solution for survival and sustainable development. Demand management aims at influencing attitudes and consumption patterns toward more efficient and cost-effective water use and is often practiced through a combination of economic, technical, and administrative measures. Economic measures often include pricing mechanisms and other incentives for reducing water use. Technical measures include conservation, more-efficient water use, and water reuse. Adopting such measures is critical to the viability and acceptability of new community projects built in parts of the world where water is scarce.

In the past, water management was viewed as a technical subject in the domain of engineering. Today, the many complex factors affecting water supply and demand require water management

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to integrate input from multiple disciplines and be practiced in the context of a water strategy consistent with, and supported by, government policies and planning in critical sectors. These sectors include demographic growth, agriculture, industry, trade, and environmental protection.

To a great extent, successful water resources management depends on the existence of the proper political, institutional, and legal frameworks and organizational structures that form the foundation of water governance. In many parts of the world, reform and improvement of water governance are essential to achieving water security.

THREATS TO WATER SECURITY

A recent study concluded that “80% of the world’s population is exposed to high levels of threat to water security.” [23] Overall, the greatest of these threats is population growth because it increases the demand for water. With the available renewable water resources remaining the same (at best) and nonrenewable water resources being depleted, more people will have to share the same or a smaller amount of water in the future. As can be seen in Figure 1, some countries with very limited renewable water resources have very high birth rates, their populations doubling in less than 30 years. Also, in some areas with very limited water resources, internal migration (the result of policies that encourage the expansion of cities and other developments in desert environments) has resulted in rapid population growth, seriously undermining the water security of these areas. In addition, economic growth and higher standards of living over time increase water use per capita due to changing diets and greater consumption of goods—many of which need water for their production.

Another common threat to water security is pollution, which may render entire water bodies unsuitable for specific uses. Multiple sources of chemical and biological contamination are among the common causes of water quality degradation. Such contamination arises both from discrete point sources (such as industrial facilities and the discharge of untreated municipal waste) and from nonpoint pollution resulting from the application of excess fertilizers, herbicides, and livestock waste. China today is a great example of a country where these problems are a major source of concern for water security.

Water security also includes protecting the water supply from terrorist acts intended to cause harm. Besides measures for physically protecting the water infrastructure, advanced methods and technologies for the early detection of harmful agents within the water distribution network have been developed in response to this threat.

A factor that complicates the assessment of future water resources availability is climate change. It is predicted that climate change will alter precipitation patterns around the world, making many areas more prone to drought and increasing water scarcity. Global atmospheric circulation models suggest that increased emissions of carbon dioxide and other greenhouse gases contribute to global warming. It is predicted that higher temperatures will increase evapotranspiration, leading to an increase in precipitation in latitudes greater than 30° North and 30° South, while less and more erratic precipitation is expected in many tropical and subtropical regions. [24] This will change streamflow patterns, affecting the distribution of water resources in both space and time.

Despite significant progress in global atmospheric modeling, it is still difficult to predict the impact of climate change on smaller scales, such as the scale of a river basin. There seems to be agreement, though, that changes in precipitation distribution in space and time are likely to produce greater extremes—more severe floods and droughts. Besides their impact on surface water resources, these precipitation and temperature changes will affect groundwater resources by modifying the recharge rate of different aquifers.

Global warming will also affect demand by increasing water requirements for agriculture due to increased evapotranspiration at higher temperatures. Water stress in many arid and semi-arid areas is likely to increase, so countries like Pakistan, India, Mexico, and northern China, and the countries of the Middle East and sub-Saharan Africa, are likely to be affected significantly. The effects on some water systems may be quite dramatic. For example, according to Barnett and Pierce [25], there is a 50% probability that Lakes Mead and Powell, the two largest reservoirs on the Colorado River and the major sources of water for the southwestern United States, will go dry by the year 2021. Besides their effect on water resources, higher temperatures are also likely to raise sea levels, causing the inundation of low-lying coastal areas and increasing saltwater intrusion into coastal aquifers.

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THE SCALE OF WATER SECURITY AND VIRTUAL WATER TRADE

Through most of history, water security was sought at a local scale, with people choosing to live near a water source, a river, a lake, or an aquifer. Early civilizations in Egypt, Mesopotamia, and India flourished along rivers where water was readily available. Over time, advances in engineering made possible the construction of large dams to store water and aqueducts to transfer water over long distances. This allowed the water resources of a river basin to be shared throughout the entire basin and even benefit people in nearby basins. As engineering became more ambitious, water transfer schemes made it possible to bring water to arid or semi-arid areas across long distances, expanding the scale of water security to the regional or national level. Examples of such large-scale projects are the water transfer scheme from northern to southern California and the south-to-north water transfer under construction in China.

The introduction of the virtual water concept makes it possible to consider water security on a global scale by examining trade among nations. The term *virtual water* is used to describe the amount of water required to produce food or other products. [26] The virtual water contents of various food products differ significantly. For example, the production of 1 kilogram of wheat requires a little more than 1 cubic meter of water, while the production of 1 kilogram of beef requires more than 10 times as much. The trade of goods among countries or regions creates a flow of virtual water from the commodity-exporting regions to the commodity-importing regions. The concept of virtual water shows how water-scarce countries or regions can benefit by importing agricultural products that require large amounts of water, saving the water that would have been required to produce those products locally. This way, water-scarce countries or regions can increase their water security by reserving part of their limited water resources for other uses.

As noted by Hoekstra, “export of water-intensive commodities implies that the domestic water resources are more intensively used than they would have been in the case without such export. As a result, the pressure on, and the scarcity of, the domestic water resources will be increased. In reverse, countries that import water-intensive commodities relieve the pressure on their domestic water resource.” [27] Virtual water becomes, in essence, an alternative source of water.

The volumes of traded virtual water represent a significant percentage of the total water consumed. Estimates of total virtual water traded among nations in 1995–2000 are in the range of 1,040 to 1,340 km³ [28], which is about 50% to 64% of the 2,100 km³ estimated total volume of fresh water consumed in 2000. [29]

GREEN, BLUE, AND GRAY WATER

To better appreciate the implications of virtual water trade, it is instructive to understand the source of the water content of different products. In this context, researchers use the terms *green*, *blue*, and *gray* water. “Green” water is defined as the rainwater stored in soil as soil moisture. The water content of the products of rain-fed agriculture is classified as 100% green water. “Blue” water is the water that runs off to rivers or percolates deep into the ground to become groundwater. Irrigated agriculture depends on blue water. The “gray” virtual water content of products assesses the water pollution caused by their production. Gray water is the estimated volume of water required to dilute the effluents from the production of a product and bring the quality of the receiving water body to acceptable standards.

An important difference between green and blue water in the context of the virtual water discussion is that blue water has alternative uses, while green water does not. For example, if blue water is not used in agriculture, it can be used for domestic or industrial supply, to enhance environmental flows, etc. On the other hand, green water can be used only by vegetation; its use is limited by the variety of plants that can be grown in a given area. For example, the moisture in the soil (green water) could support a forest, a pasture, or agricultural crops. As countries trade goods that require the use of water for their production, there is a flow of virtual water among them. Strictly speaking, this may not necessarily constitute “virtual water trade” because it may not be the result of conscious water policy decisions. A report by the World Water Council noted that “one can only speak of virtual water trade if conscious choices are made in water and environmental management policies whether or not to make water available or to release pressure on the domestic water resources by importing goods that else would have consumed much of the domestic water resources available.” [30] However, the flow of virtual water among countries or regions is a reality, whether it is the result of conscious water trade or not.

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THE WATER FOOTPRINT AS A TOOL FOR RAISING AWARENESS ABOUT WATER SECURITY

Hoekstra introduced the concept of the *water footprint* to account for all direct and indirect water use by a nation. [31] It is calculated as the sum of all direct water use within a nation and the net virtual water import. The estimated global average per capita water footprint from 1997-2001 was 1,243 m³/yr; for the United States, the average was 2,483 m³/yr; for the United Kingdom, 1,245 m³/yr; and for China, 702 m³/yr. [32] **Figure 2** shows the water footprints of different countries as estimated by Hoekstra and Chapagain [32] versus their per capita GDPs. This concept can be equally applied to an individual, a community, or a business. The water footprint of an individual or a community is defined as the sum of the volume of fresh water used and the virtual water content of all services used and goods consumed by that individual or community. The water footprint of a business is defined as the volume of fresh water used to make the products produced by the business, plus the virtual water content of all the supplies, parts, and all other services.

The virtual water content of specific products and the water footprint are powerful tools for raising awareness about the implications of specific consumption patterns for water security. For example, the total water needed to produce

a cup of coffee (125 mL) is 0.14 m³, equal to 1,120 cups of the same size. To produce a hamburger (150 g), 2.4 m³ of water is required; a cotton T-shirt weighing 200 g requires 2 m³ of water. [32] It is also important to know whether the virtual water content of a product is green, blue, or gray water. For example, most of the virtual water content of coffee is the water for growing the coffee plants. Because these plants are grown in areas with high rainfall, the virtual water content of coffee is mostly green water. On the other hand, cotton production in some areas is supported by rainwater, while in other areas it relies totally on irrigation, or blue water. For instance, it has been estimated that the virtual blue water content of 1 kg of final cotton textile (the weight of a pair of jeans) in Turkmenistan is 14.122 m³; in Uzbekistan, 11.140 m³; in Egypt, 10.787 m³; in Pakistan, 9.884 m³; in India, 5.726 m³; in China, 2.345 m³; and in the United States, 1.897 m³. [33]

In some cases, irrigated cotton production has led to wasteful use of water, with significant negative impacts. A prime example of this is the expansion of cotton production in Central Asia, which led to one of the greatest environmental catastrophes of the 20th century: the destruction of the Aral Sea. It all started with the Soviet government's plan in the 1950s to boost cotton production using the waters of the Amu Darya

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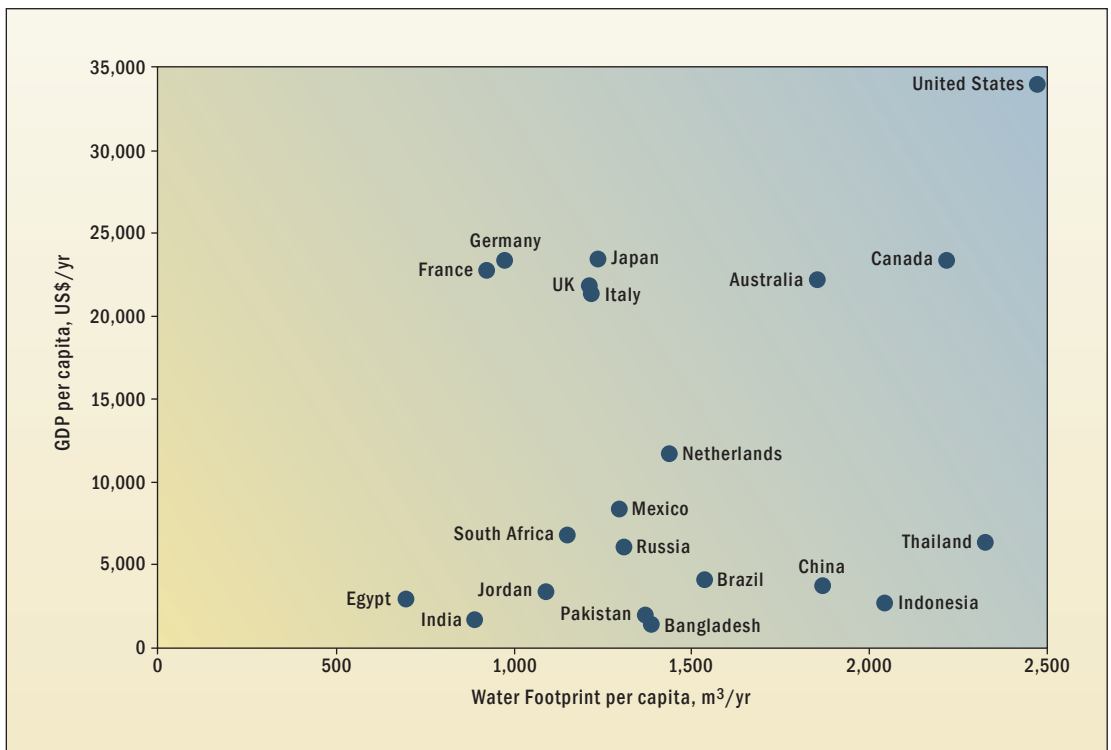


Figure 2. Water Footprint of Different Countries Versus the Per Capita GDPs (water footprint values from [32], based on data for 1997-2001; per capita GDP for 1999 from [34])

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and the Syr Darya rivers, the main sources of water for the Aral Sea. To implement this plan, several new reservoirs and canals were constructed in the area. These projects diverted large volumes of water for irrigation and, at the same time, introduced significant water loss through evaporation from the reservoirs and seepage through the canals, most of which, like the 1,375 km long Karakum Canal through the desert, were unlined. This cut off practically all flow into the Aral Sea, which started shrinking. Its volume was reduced by 90% over the last 50 years. Between 1950 and 2009, its volume decreased from 1,058 km³ to 105 km³, its area decreased from 65,607 km² to 13,500 km², and its salinity increased tenfold from 10.17 g/L to 102 g/L. [35]

As argued in a recent column [36], publicizing the virtual water content of different products, such as that of a T-shirt, can help raise awareness about the dwindling water resources in arid regions that sometimes are the source of the materials for manufacturing those products. This can help consumers understand the impact of their choices on the water resources of distant places. By supporting products from areas using sustainable water management practices, consumers can influence farmers and authorities to adopt such practices and improve water use efficiency. Among the suggestions to this end are labeling water-intensive products and certifying industries or retailers that meet specific criteria of efficient, sustainable, and fair water use. [27]

BUSINESS WATER SECURITY

Water security for individual businesses implies the avoidance of water-related risks that may disrupt operations, affect profitability, or both. Business water security assessments are based on analyzing the vulnerability of a business to disruptions in its water supply, as well as its resilience. An indication of increased concern and awareness about these risks can be found in a recent guidance by the Securities and Exchange Commission, which referred explicitly to “changes in the availability or quality of water” in the context of climate-related risks and opportunities that public companies need to disclose to their investors. [37] A recent study that evaluated the quality, depth, and clarity of water risk disclosure of 100 of the largest publicly traded companies from eight different sectors concluded that most of these companies failed to reference specific at-risk operations or supply chains and did not attempt to quantify or monetize such risks. [38] It also found that

even though many companies face exposure to water-related risks, only one-quarter of them detail specific policies, standards, or management systems to reduce these risks and associated costs, and only one-fifth disclose quantified targets to reduce water use.

Another survey aimed at collecting critical water-related data from several large corporations was recently undertaken by the Carbon Disclosure Project (CDP). As part of this initiative—the CDP Water Disclosure project—the CDP sent a questionnaire to 302 of the world’s 500 largest companies in the FTSE Global Equity Index Series, focusing on sectors that are water intensive or particularly exposed to water-related risks. Feedback from the 150 companies that responded showed that in two-thirds of them, responsibility for water-related issues lies at the Board or Executive Committee level; 89% have developed specific water policies, strategies, and plans; and 60% have set water-related performance targets. [39]

Assessing water security and related risks for a business requires thorough quantitative and qualitative analysis of water use in the business itself and its suppliers and an understanding of how water affects its customers. The analysis of water use in the business itself accounts for all inflows, outflows, and internal flows of water through the different processes of the business. These data are then used to develop the water budget for the full business cycle. The recording and analysis of these external and internal flows of a business is sometimes referred to as water auditing. A goal of water auditing is to identify potential losses as well as opportunities for more-efficient water use. Metrics can be very useful for assessing progress toward the goal of improved water security and can also be used to compare various designs and concepts in terms of sustainability. Examples of such metrics are the volume of water used per unit output, the wastewater produced/discharged per unit output, and the ratio of fresh water usage to recycled water usage. It is also essential to assess the sustainability of the water supply that supports the business, understand present and future potential competing uses for that water, and foresee potential regulatory changes that may impose constraints on its use.

Recognizing the significance of water-related risks, several think tanks and institutes serving the business community and different nonprofit organizations have worked on this subject over the last few years to prepare tools and

methods to help businesses improve their water security. An overview of major business-relevant initiatives that provide guidance on sustainable water management and tools, measurement methodologies, standards, and reporting indicators has been prepared by the World Business Council for Sustainable Development and the International Union for Conservation of Nature. [40]

For example, the Global Environmental Management Initiative (GEMI), a nonprofit organization of several major companies focusing on environmental, health, and safety issues, produced the Water Sustainability Tool, designed to help individual companies build a business water strategy. [41] Similarly, the Water Sustainability Planner was designed to help convert the corporate sustainability strategy into a site or unit strategy for water and assist in understanding water use and impacts and water risk assessment [42].

The World Business Council for Sustainable Development developed the Global Water Tool to help companies and organizations map their water use and assess risks relative to their global operations and supply chains. [43]

Berger and Finkbeiner recently discussed how to address water use in the lifecycle assessment methodology, which measures the environmental impacts of individual products from cradle to grave. [44]

Another tool available to a business is its water footprint, defined as the total volume of fresh water used directly or indirectly to run and support the business. The Water Footprint Network, established in 2008 to coordinate efforts to further develop and disseminate knowledge on water footprint concepts, methods, and tools, has recently prepared a new global water footprint standard. [45]

Morrison and Schulte evaluated these four tools and methodologies (GEMI tools, Global Water Tool, lifecycle assessment, and water footprint) and their use. [46] Based on this evaluation, they made specific recommendations on how to advance corporate water accounting practices, such as placing greater emphasis on assessing the local water resource context, supply chain, and water quality; improving data collection; developing consistent reporting criteria across the industry; and encouraging greater cooperation among companies in this area.

Another ongoing project related to business water security is the effort under way by

Goldman Sachs, General Electric, and the World Resources Institute to develop a water index to measure water-related risks and opportunities for companies and their investors. [47] This effort began with a pilot project focused on the thermal power industry in the Yellow River basin in China, a water-stressed region due to its rapid economic growth.

Finally, some corporations have developed their own corporate water strategies to assess their water use, analyze water-related risks and vulnerabilities, identify opportunities to use water more efficiently, set specific water use targets, and employ metrics to assess progress in reaching these targets. For example, Nestlé published a water management report presenting year-to-year data on water use and wastewater generated as well as data on specific indicators, such as the amount of water used and wastewater generated per unit of product. [48]

CONCLUSIONS

Because growing populations have to share limited water resources in many parts of the world, water security is recognized as an essential factor for the sustainability of communities, cities, and countries and critical for the success of most businesses. Uncertainty about the impact of climate change on water resources adds to the urgency of improving water security. To achieve water security, a sustainable equilibrium between water supply and demand must be sought by augmenting supply and managing demand. In general, the options for augmenting supply are limited, because most conventional water resources are already being used. Unconventional water sources, such as the reuse of treated wastewater and desalination, can supplement available water resources in water-scarce areas. Water savings through conservation, more-efficient water use, and elimination of leaks and other losses in water distribution systems can contribute to the water supply. Managing demand through economic measures and well-thought-out development, agricultural, trade, and other policies should be an essential part of any strategy for achieving water security. Good governance of the water sector and adaptation of policies that discourage wasteful and inefficient water use are also essential preconditions for water security.

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Raising public awareness about water's increasing scarcity can help influence politicians to adopt agricultural, economic, and other sustainable development policies that do not promote growth at the expense of security, because any threat to water security is also a threat to growth.

options for improving water security in front of policy and decision makers. These concepts make it easier to realize the global nature of water security and the need for global initiatives to ensure it.

Achieving water security for industries and other businesses requires a thorough understanding of the myriad processes and supplies dependent on water, along with a systematic accounting of the quantities involved to identify opportunities for more-efficient water use. Water-security-related risks must be identified and a strategy developed for dealing with such risks. Use of the proper metrics can help assess progress toward the goals of the water strategy.

Achieving water security also requires action at all levels, from individual choices to the development and implementation of appropriate policies at local, regional, and national levels. International coordination and collaboration in water governance reform can help ease the threats to global water security. Raising public awareness about water's increasing scarcity can help influence politicians to adopt agricultural, economic, and other sustainable development policies that do not promote growth at the expense of security, because any threat to water security is also a threat to growth. ■

REFERENCES

- [1] B. Schultz and S. Uhlenbrook, "Water Security: What Does it Mean, What May it Imply?" in "Water for a Changing World - Developing Local Knowledge and Capacity," G.J. Alaerts and N.L. Dickinson eds., *Proceedings of the International Symposium*, June 13-15 2007, UNESCO-IHE Delft, the Netherlands, CRC Press, Taylor and Francis Group, London, UK, 2009, see <http://www.unesco-ihe.org/Users/Prof.-S.-Uhlenbrook-PhD-MSc/Publications>.
- [2] "Towards Water Security: A Framework for Action," Global Water Partnership, Stockholm, Sweden, and London, United Kingdom, 2000, http://www.gwpsudamerica.org/docs/publicacoes/doc_78_en.pdf.
- [3] E. Norman, K. Bakker, C. Cook, G. Dunn, and D. Allen, "Water Security: A Primer - 2010," policy report for "Developing a Canadian Water Security Framework as a Tool for Improved Water Governance for Watersheds (2008-2012)," Program on Water Governance, University of British Columbia, Vancouver, Canada, 2010, <http://www.watergovernance.ca/wp-content/uploads/2010/04/WaterSecurityPrimer20101.pdf>.
- [4] "Global Water Security - An Engineering Perspective," The Royal Academy of Engineering, London, UK, April 2010, http://www.raeng.org.uk/news/publications/list/reports/Global_Water_Security_report.pdf.
- [5] "Ministerial Declaration of The Hague on Water Security in the 21st Century," agreed to March 22, 2000, in The Hague, the Netherlands, http://www.worldwatercouncil.org/fileadmin/www/Library/Official_Declarations/The_Hague_Declaration.pdf.
- [6] A.K. Biswas, "Water: Crisis Due to Scarcity or Poor Governance?," closing keynote address, Global Water Conference, Frankfurt, Germany, May 20, 2010, http://www.malekigroup.com/images/fgbw/h2o/Biswas-Asit-K_Global-H20-Conference_20%20May-2010.pdf.
- [7] "UN-Water Global Annual Assessment of Sanitation and Drinking-Water (GLAAS) 2010: Targeting Resources for Better Results," World Health Organization, 2010, http://whqlibdoc.who.int/publications/2010/9789241599351_eng.pdf.
- [8] "Health through Safe Drinking Water and Basic Sanitation," World Health Organization website, accessed on February 15, 2011, http://www.who.int/water_sanitation_health/mdg1/en/index.html.
- [9] "Facts and Figures: Water, Sanitation and Hygiene Links to Health," World Health Organization website, accessed on February 15, 2011, http://www.who.int/water_sanitation_health/publications/factsfigures04/en/.
- [10] P.H. Gleick, "Basic Water Requirements for Human Activities: Meeting Basic Needs," *Water International*, Vol. 21, No. 2, pp. 83-92, http://www.bvsde.paho.org/bvsacd/cd17/basic_wate.pdf.
- [11] J.F. Kenny, N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin, "Estimated Use of Water in the United States in 2005," U.S. Geological Survey Circular 1344, USGS, Reston, VA, 2009, <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.
- [12] P. Magiera, S. Taha, and L. Nolte, "Water Demand Management in the Middle East and North Africa," presented at the International Water Demand Management Conference, Dead Sea, Jordan, May 30-June 3, 2004.
- [13] S. Postel and A. Vickers, "Boosting Water Productivity," Chapter 3, State of the World 2004, Special Focus: The Consumer Society, The Worldwatch Institute, Washington, DC, 2004, <http://www.globalwaterpolicy.org/pubs/SOW04water.pdf>.
- [14] F.R. Rijsberman, "Water Scarcity: Fact or Fiction?," *Proceedings of the 4th International Crop Science Congress - New Directions for a Diverse Planet*, September 26 - October 1, 2004, Brisbane, Australia, http://www.cropsociety.org.au/icsc2004/plenary/1/1994_rijsbermanf.htm.
- [15] "Coping with Water Scarcity," UN-Water Thematic Initiatives, United Nations, August 2006, <http://www.unwater.org/downloads/waterscarcity.pdf>.
- [16] "Avoiding Water Wars: Water Scarcity and Central Asia's Growing Importance for Stability in Afghanistan and Pakistan," A Majority Staff Report prepared for the use of the Committee on Foreign Relations, United States Senate, One Hundred Twelfth Congress, First Session, February 22, 2011, <http://foreign.senate.gov/download/?id=738A9FCF-FA1B-4ECD-9814-A1F6C5BE04D2>.

- [17] "Senate Foreign Relations Committee Report Warns Water Security in Central and South Asia May Jeopardize Long-Term Regional Stability," US Senate Committee on Foreign Relations press release, February 22, 2011, <http://foreign.senate.gov/press/chair/release/?id=0b32e452-9c4c-4417-82ee-d201bcfc8ae>.
- [18] "Review of World Water Resources by Country, Water Reports 23," Food and Agriculture Organization of the United Nations, Rome, Italy, 2003, <ftp://ftp.fao.org/agl/aglw/docs/wr23e.pdf>.
- [19] "The World Factbook 2004," Central Intelligence Agency, access via <https://www.cia.gov/library/publications/download/download-2004/index.html>.
- [20] "Rome Declaration on World Food Security," World Food Summit, November 13-17, 1996, Rome, Italy, see <http://www.fas.usda.gov/icd/summit/1997/romefinal.html>.
- [21] "Global Risks 2011," Sixth Edition, An Initiative of the Risk Response Network, World Economic Forum, January 2011, http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2011.pdf.
- [22] P.H. Gleick and M. Palaniappan, "Peak Water Limits to Freshwater Withdrawal and Use," *Proceedings of the National Academy of Sciences*, Vol. 107, No. 25, pp. 11155-11162, <http://www.pnas.org/content/107/25/11155.full.pdf+html> and http://www.pacinst.org/press_center/press_releases/peak_water_pnas.pdf.
- [23] C.J. Vörösmarty, P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S.E. Bunn, C.A. Sullivan, C. Reidy Liermann, and P.M. Davies, "Global Threats to Human Water Security and River Biodiversity," *Nature*, Vol. 467, Issue 7315, September 30, 2010, pp. 555-561, <http://www.nature.com/nature/journal/v467/n7315/full/nature09440.html>.
- [24] "The 1st UN World Water Development Report: Water for People, Water for Life," UNESCO, 2003, <http://www.unesco.org/water/wwap/wwdr/wwdr1>.
- [25] T.P. Barnett and D.W. Pierce, "When Will Lake Mead Go Dry?" *Water Resources Research*, Vol. 44, W03201, March 29, 2008, access via <http://www.agu.org/pubs/crossref/2008/2007WR006704.shtml>.
- [26] J.A. Allan, "Fortunately There Are Substitutes for Water Otherwise Our Hydro-Political Futures Would Be Impossible," *Priorities for Water Resources Allocation and Management, Overseas Development Administration (ODA)*, London, UK, 1993, pp. 13-26.
- [27] A.Y. Hoekstra, "The Global Dimension of Water Governance: Why the River Basin Approach Is No Longer Sufficient and Why Cooperative Action at Global Level Is Needed," *Water*, Vol. 3, No. 1, December 2010, pp. 21-46, <http://www.mdpi.com/2073-4441/3/1/21/pdf>.
- [28] A.Y. Hoekstra, "Virtual Water: An Introduction," *Proceedings of the International Expert Meeting on Virtual Water Trade*, Value of Water Research Report Series No. 12, IHE Delft, the Netherlands, December 12-13, 2002, (published February 2003), Part 1, Chapter 1, pp. 13-23, <http://www.waterfootprint.org/Reports/Report12.pdf>.
- [29] W.J. Cosgrove and F. Rijsberman, "World Water Vision: Making Water Everybody's Business," World Water Council, World Water Vision, Earthscan Ltd., London, UK, March 2000, see <http://www.earthscan.co.uk/?tabid=433>.
- [30] "E-Conference Synthesis: Virtual Water Trade - Conscious Choices," WWC Publication No. 2, World Water Council, March 2004, http://www.worldwatercouncil.org/fileadmin/wwc/Library/Publications_and_reports/virtual_water_final_synthesis.pdf.
- [31] A.Y. Hoekstra and P.Q. Hung, "Virtual Water Trade: A Quantification of Virtual Water Flows Between Nations in Relation to International Crop Trade," *Proceedings of the International Expert Meeting on Virtual Water Trade*, Value of Water Research Report Series No. 12, Part 1, Chapter 2, pp. 25-47, IHE Delft, the Netherlands, December 12-13, 2002 (published February 2003), <http://www.waterfootprint.org/Reports/Report12.pdf>.
- [32] A.Y. Hoekstra and A.K. Chapagain, "Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern," *Water Resources Management*, Vol. 21, No. 1, 2007, pp. 35-48, http://www.waterfootprint.org/Reports/Hoekstra_and_Chapagain_2007.pdf.
- [33] A.K. Chapagain, A.Y. Hoekstra, H.H.G. Savenije, and R. Gautam, "The Water Footprint of Cotton Consumption," Value of Water Research Report Series No. 18, UNESCO-IHE Delft, the Netherlands, September 2005, <http://www.waterfootprint.org/Reports/Report18.pdf>.
- [34] "The World Factbook 2000," Central Intelligence Agency, 2000, access via <https://www.cia.gov/library/publications/download/download-2000/index.html>.
- [35] "Database of the Aral Sea, Bathymetric Characteristics," CAWATERinfo, Portal of Knowledge for Water and Environmental Issues in Central Asia, funded by the Swiss Agency for Development and Cooperation, accessed on February 20, 2011, http://www.cawater-info.net/arak/data/tabs_e.htm.
- [36] I. Rudenko and J.P.A. Lamers, "Virtual Water Saves Prized Liquid Asset - Concept Raises Awareness About Dwindling Resource in Arid Region," VOICES UNESCO in the Asia-Pacific, No. 23, July-September 2010, p. 18, http://www.cawater-info.net/library/eng/rudenko_lamers_e.pdf and <http://unesdoc.unesco.org/images/0018/001888/188813E.pdf>.
- [37] "Commission Guidance Regarding Disclosure Related to Climate Change," Securities and Exchange Commission 17 CFR PARTS 211, 231, and 241 [Release Nos. 33-9106; 34-61469; FR-82], February 2, 2010, <http://www.sec.gov/rules/interp/2010/33-9106.pdf>.
- [38] B. Barton, "Murky Waters? Corporate Reporting on Water Risk - A Benchmarking Study of 100 Companies," A Ceres Report, Boston, MA, February 2010, http://www.waterfootprint.org/Reports/Barton_2010.pdf.
- [39] "CDP Water Disclosure 2010, Global Report," 2010 Carbon Disclosure Project, <https://www.cdproject.net/CDPResults/CDP-2010-Water-Disclosure-Global-Report.pdf>.

- [40] "Water For Business – Initiatives Guiding Sustainable Water Management in the Private Sector, Version 2," World Business Council for Sustainable Development (WBCSD) and International Union for Conservation of Nature (IUCN), March 2010, <http://www.wbcd.org/web/water4business.pdf>.
- [41] "Connecting the Drops Toward Creative Water Strategies – A Water Sustainability Tool," Global Environmental Management Initiative (GEMI), June 2002, <http://www.gemi.org/resources/ConnectingTheDrops.pdf>.
- [42] "Collecting the Drops: A Water Sustainability Planner," Global Environmental Management Initiative (GEMI), January 2007, <http://www.gemi.org/resources/CollectingDrops.pdf>.
- [43] "2010 Global Water Tool®: Refreshed for Risk Assessment," World Business Council for Sustainable Development (WBCSD), <http://www.wbcd.org/web/publications/external/GWT/GWT%20brief.pdf>.
- [44] M. Berger and M. Finkbeiner, "Water Footprinting: How to Address Water Use in Life Cycle Assessment?," *Sustainability*, Vol. 2, April 2010, pp. 919-944, <http://www.mdpi.com/2071-1050/2/4/919/pdf>.
- [45] A.Y. Hoekstra, A.K. Chapagain, M.M. Aldaya, and M.M. Mekonnen, "The Water Footprint Assessment Manual – Setting the Global Standard," Earthscan, London, UK, and Washington, DC, 2011, <http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf>.
- [46] J. Morrison and P. Schulte, "Corporate Water Accounting – An Analysis of Methods and Tools for Measuring Water Use and Its Impacts," Pacific Institute, Oakland, CA, 2010, http://www.pacinst.org/reports/corporate_water_accounting_analysis/corporate_water_accounting_analysis.pdf.
- [47] T. Wolstencroft, "Transition to a Low-Carbon Economy – Opportunities and Challenges of the Emerging Clean Energy Industry," The Goldman Sachs Group, Inc., 2010, <http://www2.goldmansachs.com/ideas/environment-and-energy/goldman-sachs/transition-doc.pdf>.
- [48] "The Nestlé Water Management Report," Nestlé S.A., Vevey, Switzerland, March 2007, http://www.nestle.com/Common/NestleDocuments/Documents/Reports/CSV%20reports/Water/Water_management_report_2006_English.pdf.

BIOGRAPHY



Angelos Findikakis, PhD, is a Bechtel Fellow and senior principal engineer with the BSII Geotechnical and Hydraulic Engineering Services group, based in San Francisco. His expertise lies in environmental hydraulics, hydrologic engineering, groundwater, and water

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Since becoming a Bechtel Fellow in 1998, Angelos has worked on various technical excellence activities sponsored by the Fellows. He is the corporate coordinator of the Bechtel Technical Information Program and the Outstanding Technical Paper Awards Program, and he led a Fellows initiative on knowledge management.

Angelos is consulting professor in the Department of Civil and Environmental Engineering at Stanford University, where he teaches a class on water resources management. He is also active in a variety of professional organizations, including the International Association of Hydro-Environment Engineering and Research (IAHR), the American Society of Civil Engineers (ASCE), and the American Geophysical Union (AGU). Over the years, Angelos has served on several professional organization committees and is currently the vice chair of the Innovation and Professional Development Division of IAHR and of the IAHR Task Force on Global Water Security.

The recipient of several awards—including the Straub Award in 1981 (awarded annually for the best doctoral dissertation in hydraulic engineering), the ASCE Hering Medal in 1981, and the ASCE Wesley W. Horner Award in 2000—Angelos recently finished editing a volume on groundwater management practices. He has also authored or coauthored several papers published in peer-reviewed journals and participated in the proceedings of the technical conferences or symposia where they were presented.

Angelos received his PhD and MSc, both in Civil Engineering, from Stanford University in Palo Alto, California. He also holds a Diploma in Civil Engineering from the National Technical University of Athens, Greece. Angelos is a Professional Engineer in California.