



WORLD  
GLOBAL  
Water

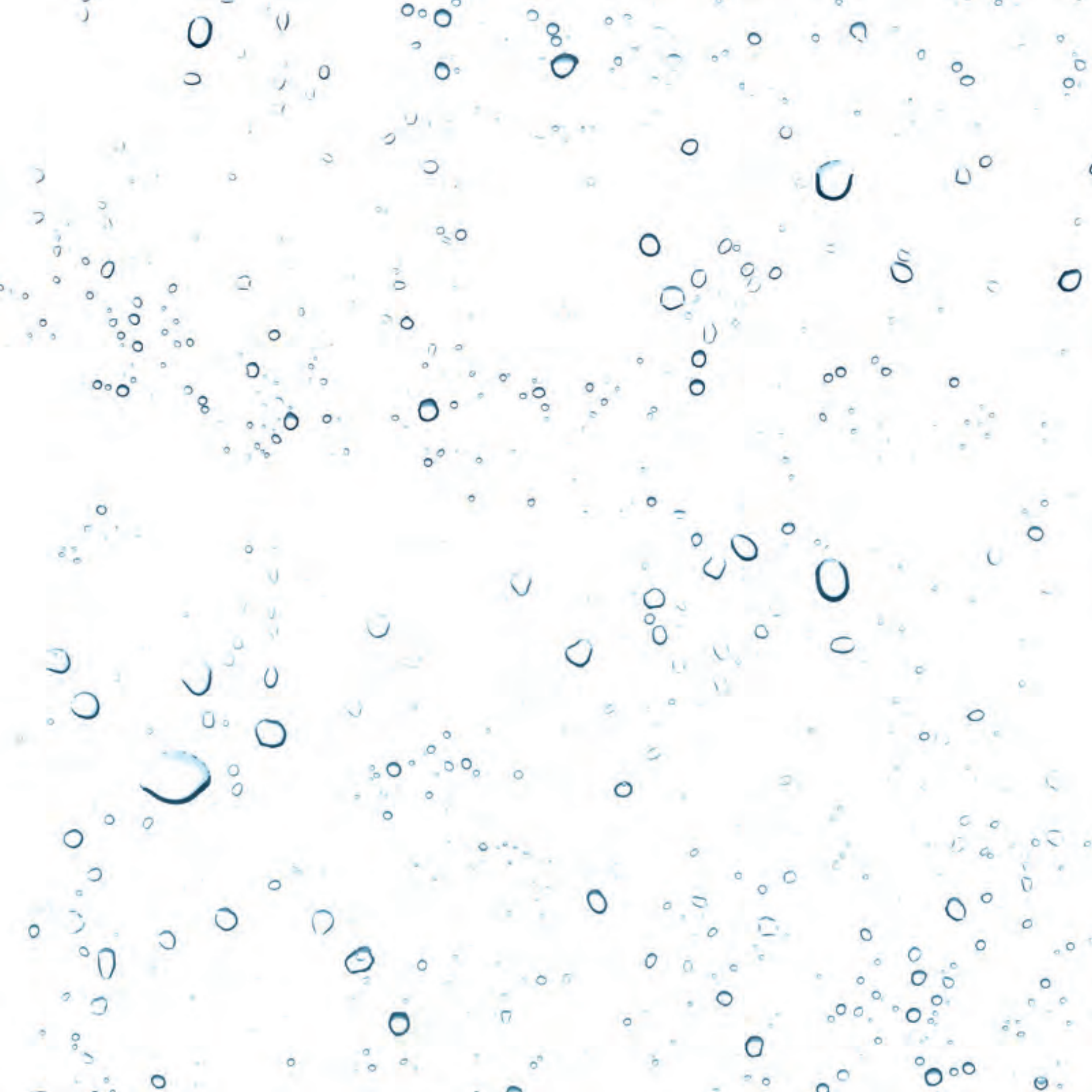
ISSUES




J A B O L G



S E U S S I





...Water, water, everywhere, And all the boards did shrink;  
Water, water, everywhere, Nor any drop to drink...

Samuel Taylor Coleridge ~ "The Rime of the Ancient Mariner" ~ 1798

# **GLOBAL WATER ISSUES**

*A Compendium of Articles*

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*A Compendium of Articles*

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A large, jagged iceberg with a complex, crystalline structure of sharp peaks and deep crevasses. The ice is a deep, vibrant blue, and the background shows a dark, overcast sky with some light breaking through the clouds. The iceberg is the central focus of the image, with its base meeting the dark water of the ocean.

Nothing on Earth is so weak and yielding as water,  
but for breaking down the firm and strong it has no equal...

Lao-Tsze ~ Chinese philosopher ~ ca. 6th Century B.C.



“Water is the only substance on Earth  
that is naturally present in three different forms—  
as a liquid, a solid, and as a gas...”

~ Author Unknown ~



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CARLYN REICHEL

An aerial photograph of a river delta, showing a network of channels and a large body of water. The water is a deep blue, and the surrounding land is a mix of brown and tan, with intricate patterns of pale silt and sediment. The text is overlaid on the image in a white, serif font.

Eventually, all things merge into one,  
and a river runs through it.

The river was cut by the world's great flood  
and runs over rocks from the basement of time.

On some of the rocks are timeless raindrops.

Under the rocks are the words,  
and some of the words are theirs.

I am haunted by waters.

Norman Maclean ~ *A River Runs Through It* ~ 1992

An aerial photograph of a river delta, showing a complex network of blue water channels winding through brownish, textured land. The water channels are prominent, with some being wide and others narrow, creating a maze-like pattern. The land appears to be a mix of soil and vegetation, with some areas looking more eroded or sandy. The overall scene is a natural, intricate landscape.

# Water: “Sine Qua Non”

AN INDISPENSABLE RESOURCE

“If the millions of women  
who haul water long distances had a faucet by their door,  
whole societies could be transformed.”

Tina Rosenberg ~ “The Burden of Thirst” ~ *National Geographic Magazine*, April 2010



# IMAGINING A TOMORROW...

## Foreword

MARIA OTERO—UNDER SECRETARY FOR DEMOCRACY AND GLOBAL AFFAIRS

**I**magine for a moment being on your childhood playground. Relieved to be out of the classroom, you run with friends, climb the jungle gym, and maybe pause for a drink of water from a silver fountain next to the swings.

As a 9-year-old girl growing up in Bolivia, my playground was likewise a happy place—until one day when I innocently drank from the school tap. It wasn't long before the contaminated water took its effect: I contracted a serious bout of hepatitis, missing three months of school—and playtime.

Unfortunately, I share my playground memory with far too many children around the world. Millions of people suffer from lack of potable water, and more than 4,300 children die each day from water-related diseases. This reality is simply unacceptable.

Water is crucial to nearly every aspect of human activity. Besides being key to human survival and growth, water is the fuel that drives economic and political stability. From withstanding drought to controlling floods, achieving water security is one of the great diplomatic and development challenges—and opportunities—of our time. And that's why Secretary Clinton, along with President Obama, recognizes the need to make water security a global imperative, and they have asked USAID Administrator Raj Shah and me to lead our efforts.

The United States is striving to offer assistance for the many international organizations, governments and agencies involved in facing the diverse, complex and urgent challenges associated with water security—many of which are outlined in this book. As water becomes



increasingly scarce, our success is contingent on our mutual dialogue, discipline and cooperation.

This book demonstrates the United States' continued commitment to this issue and our unrelenting pursuit of effective solutions. In its chapters, we see firsthand accounts of the vast impact that fresh water has on the world's population. The articles touch on global health and food security, but they also highlight the personal and human dimension with poignant water stories such as that of Hadiza Ali, a mother from the Zinder region of Niger who lacks access to a clean source of drinking water. The result is an illustration of the depths of the challenges we all face and the multiple obstacles encountered when confronting ineffective water management situations.

But the book also offers hope for a water-secure future. Just as a pebble thrown in a pond creates huge ripples, small modifications in policy, infrastructure and behavior can have a tremendous impact.

I would like to thank the many water scholars and practitioners who devoted their time and their knowledge to this book. I am convinced that within these pages, you will arrive at the same sense of hope: Together, we can achieve a world in which no wars are fought over water, clean water is no longer a luxury but a standard, and playgrounds remain scenes for happy memories.



The frog does not drink up the pond in which he lives.

~ American Indian proverb ~

**Above:** The aqueducts of Machu Picchu, the ancient Inca city built on a mountain ridge in the Andes of Peru, remain a marvel of hydraulic engineering. The extensive water delivery system once supported up to 1,000 residents. © Shutterstock / Thomas Barrat (inset) © Thinkstock / Getty Images / Jupiterimages

# WHEN THE WELL IS DRY...

## Water Scarcity Requires Drastic Solutions

STEVEN SOLOMON

“**W**hen the well is dry, we learn the worth of water,” observed Benjamin Franklin, one of America’s founding fathers, more than two centuries ago, long before anyone imagined the need to sustain water ecosystems or that fresh water could become scarce across the planet. Today, for the first time in human history, the “global well” is starting to go dry—and we are all about to learn the painful lessons of what happens when societies run short of history’s most indispensable resource.

Just as oil transformed the world order and history of the 20th century, a global crisis of freshwater scarcity is starting to reshape the geopolitics, economics, environment, national security, daily living conditions and destiny of human civilization in the 21st century. Even more so because water, unlike oil, is irreplaceable: We can’t drink oil or grow food with it.

What is happening, essentially, is that under the duress of the unquenchable demand of our modern global society—which is using fresh water at *twice* the population growth rate—we are running short of the sustainable, accessible supply required to meet the food, energy, manufacturing and domestic water needs of our present 6.9 billion and far less than what we’ll need, with current trends and practices, for the 9 billion we’re becoming by 2050. The crisis is further exacerbated by the enormous inefficiencies and waste that characterize water management almost everywhere.



Mounting water scarcity presents mankind with a formidable dual challenge—one part environmental and the other political. Due to the uneven global distribution of freshwater resources and population pressures, an alarming fault line is widening across world society between water “haves” and “have-nots”—internationally among states, but also within nations among interest groups, sectors and economic classes that have long competed over equitable access to water resources.

### Water and the Rise of Civilizations

Management of water resources has always been a pivotal axis of power, prosperity and human achievement. Over the centuries societies have struggled politically, militarily, economically and technologically to control the world’s water wealth. We’ve endeavored to erect cities around it, to transport goods on it, to harness its latent energy in various forms, to utilize it as a vital input of agriculture,

industry and domestic well-being, and to an extract ever greater supply of it from nature while erecting protections against its destructive manifestations, such as floods and droughts.

Invariably, epic waterworks have been associated with turning points of civilization and the rise and decline of great states. The agricultural revolution that launched civilization about 5,000 years ago was built on the mastery of large-scale irrigation in the semi-arid flood plains of rivers in Egypt, Mesopotamia and the Indus Valley. Ancient Rome developed the flourishing urban civilization of 1 million residents at the heart of its empire on the flow of abundant, wholesome fresh water brought by its stupendous network of 11 aqueducts.

The takeoff event and vital artery of China's medieval golden age was the completion of its 1,100-mile (1,770-kilometer) Grand Canal linking the resources of its wet, rice-growing southerly Yangtze with its fertile, dry, resource-rich and defensively challenged Yellow River northlands. Islam's brilliant heyday arose on the long-distance trading

wealth carried across its once-impenetrable, waterless deserts from oasis to oasis by long caravans of water-efficient camels.

Heavy ploughs, waterwheel power and finally open oceanic sailing were the West's initial routes to world leadership. The seminal invention of the Industrial Revolution a quarter millennium ago was James Watt's improved steam engine. The demographic transformations fomented by the sanitary and public health revolutions from the late 19th century sprang from efforts to protect increasingly dense urban clusters from the multitude of diseases transmitted through water.

The rise of the United States, similarly, was fostered by its mastering and marrying three diverse hydrological environments:

- Its temperate eastern half, rich in rain-fed agriculture, small rivers for industrial waterpower and transportation, and catalytically unified by the breakthrough Erie Canal.
- The naval linkage and domination of its two ocean frontiers with the building of the epic Panama Canal.



**Above:** In this photograph, taken between 1910 and 1920, a ship moves through the western chamber of the Gatun Locks in the Panama Canal. The channel, which opened in 1914, links the Atlantic and the Pacific oceans. **Courtesy of Library of Congress**





- The innovative triumph over its arid far west with the irrigation, hydropower and flood control provided by the giant, multi-purpose dams pioneered by its Depression-era Hoover Dam.

The worldwide diffusion of giant dams, in turn, was one of the key driving forces of the epoch-defining Green Revolution which fed the unprecedented quadrupling of the 20th-century world population and the emergence of today's global integrated economy.

Every era has been shaped by its response to the great water challenges of its time. And so it is again today. To appreciate water's importance in modern society, it is important to be mindful of just how very much we need to sustain our living standards: A typical, well-nourished meat eater, for instance, consumes more than 3.7 tons, or 3,800 liters, each day through the water that goes into growing the food he or she eats. A single portion of hamburger from grain-fed livestock alone accounts for 60 percent of that total.

A simple cotton T-shirt requires 2,850 liters, or 2.7 tons, to grow. From hat to leather shoes, an average middle-class American wears clothes requiring about 23 tons of water to produce. Making chemicals, steel, processed foods and mining resources are also hugely water-intensive enterprises. Producing a single computer semiconductor chip requires no less than 7,600 liters of ultra-purified water—7.7 tons—while fabricating an automobile demands almost 151,000 liters, or 155 tons of water. In industrialized nations, the largest volumes of water are used not for agriculture but for energy—more than two-fifths of all U.S. water usage goes to energy production, mostly for cooling thermoelectric power plants.

Pumping, transporting and treating such enormous quantities of water—which, at about one kilogram a liter, weighs 20 percent more than oil—is one of the greatest energy and engineering challenges facing advanced societies. By contrast, throughout the world's

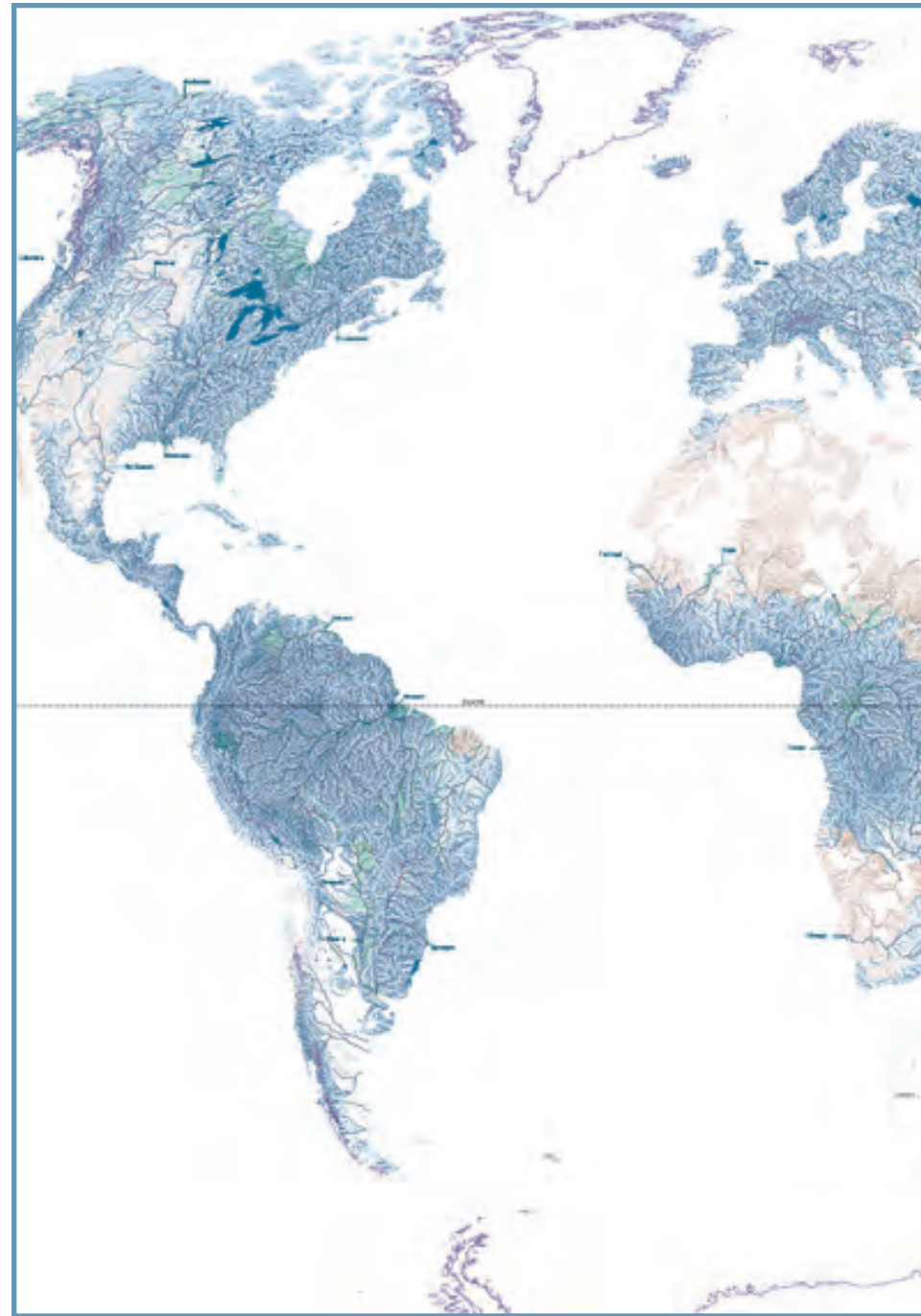


poorest regions, where there are few pipes and pumps, the burden of providing water is borne day after day overwhelmingly by back-breaking human labor. In rural Kenya, where I helped connect two miles of water pipes for a waterless village in 2004, women and children routinely spend three hours each day walking to fetch their minimal domestic clean water needs—about three toilet flushes per person, but nonetheless totaling about 91 kilograms for a family of five. That their time for productive work and school is lost is a heartbreaking illustration—if any is needed—of how indispensable water is for even elemental economic development.

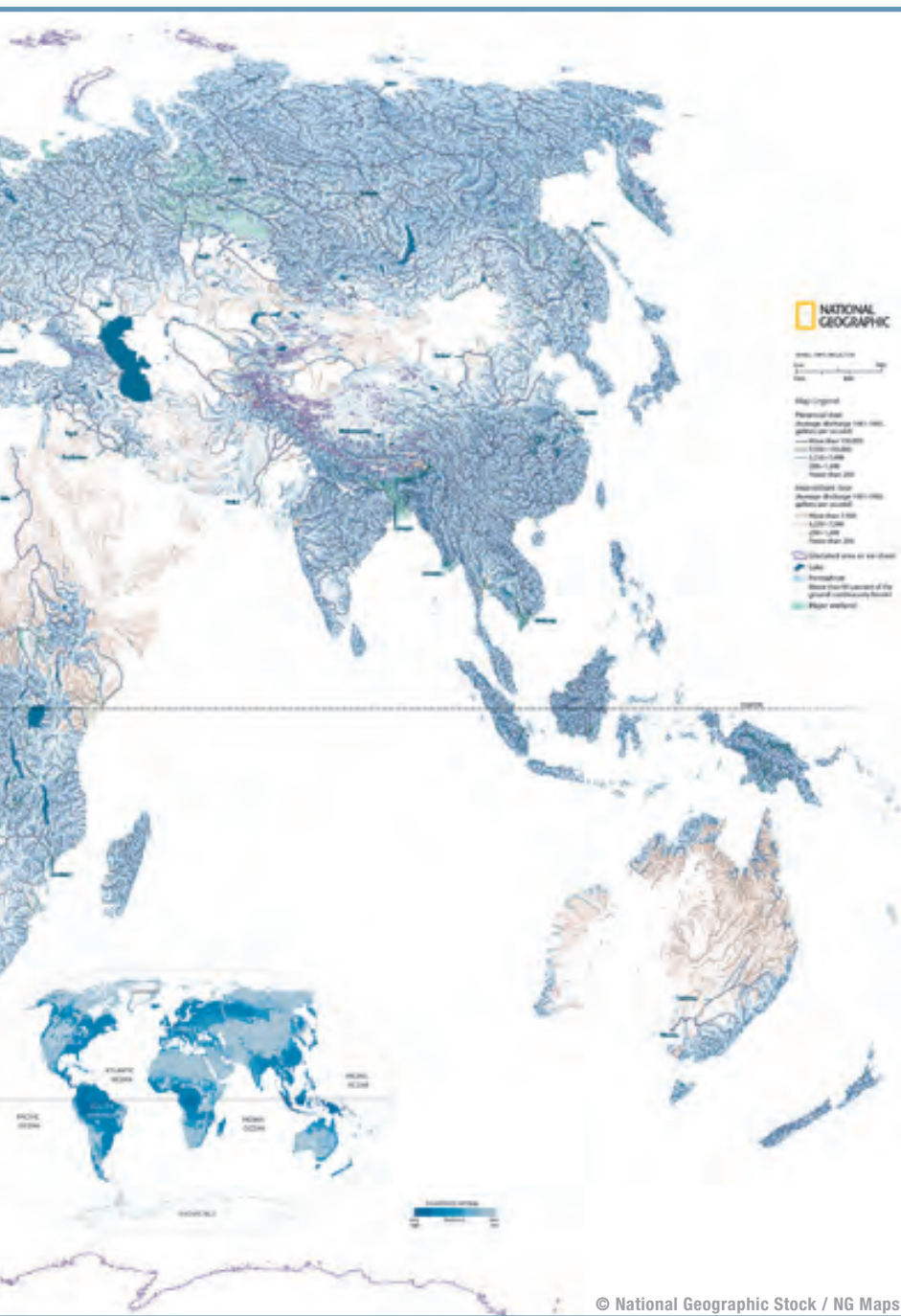
### The Global Water Challenge

Coping with today's growing global water scarcity crisis requires both environmental and political solutions. By drawing more water from the environment than is replenished through the natural water cycle, and through pollution of existing resources, mankind is degrading global freshwater ecosystems to an unprecedented extent. As a result, for the first time since the dawn of civilization, we must now consciously allocate enough water to sustain the health of the ecosystems that are the wellsprings for all society's vital economic and human uses. This was warned by the first comprehensive environmental audit of the planet's environmental health, the Millennium Ecosystem Assessment, in 2005.

So much water is withdrawn from more than 70 major rivers, including the Nile, Indus, Yellow, Euphrates and Colorado, that their flows no longer reach their once-fertile deltas and the seas. Half the world's wetlands have vanished. Agrochemical and industrial pollution



is devastating fish life, contaminating drinking supplies and entering the human food chain. Mountain glaciers from the Himalayas to the Andes are melting at rates never before seen in history, drying up the sources of mighty rivers and threatening the stability of the nations that depend upon their waters. As the environmental crisis worsens, the political perils become more explosive.



The Indus River, vital water lifeline of irrigation-challenged Pakistan, is expected to lose 30 percent of its crucial dry season flow as its Himalayan source glacier vanishes, even as Pakistan's population relentlessly increases by a third over the next generation. Upriver, India has begun aggressively to dam tributaries in hotly contested Kashmir in its own search for more electric power, elevating bilateral tensions over



the nations' uneasy river-sharing treaty. To make up for freshwater shortfalls, irrigation farmers in India, Pakistan, northern China, California's central valley and elsewhere are mining deep groundwater beyond natural replenishment rates to maintain their crop production. Crops dependent upon draining groundwater constitute unsustainable "food bubbles" that are now starting to burst as more and more pumps hit more aquifer bottoms.

Freshwater scarcity is a key reason that a projected 3.5 billion people will live in countries that will not be able to feed themselves by 2025, the Millennium Ecosystem Assessment concluded. They will depend increasingly on imported grain and stable international markets. How well India, Pakistan and China meet their impending national food security challenges will strongly affect total food availability and price volatility from Africa to South Asia, including the already heavily import-dependent, politically combustible Middle East. Humanitarian and health crises are likely to emanate from the 2.6 billion people without adequate sanitation and the 1 billion who lack safe, accessible drinking water.

The water crisis is inseparably linked to climate change, which wreaks its damage through greater variability and extremity of water-related events such as droughts, floods, mudslides, rising sea levels and glacier-melts that overwhelm water infrastructures built for traditional weather patterns. As a result, some foresee that within a decade there may be 150 million environmental refugees wandering within and across borders seeking new livelihoods and homes.

Because energy production is also water-intensive, water-scarce nations are constrained to meet their future energy needs. China's



ability to maintain its rapid economic growth hinges partly on whether it can overcome water scarcity challenges. With only one-fifth the amount of water per person as the United States, it has had to idle factories and abandon major energy projects, and it faces water pollution so severe that its waters often can't be used for agriculture.

### Sharing the Water Wealth

One of the great diplomatic challenges of the dawning age of fresh water scarcity is whether nations will be able to amicably share the 263 river basins, invisible groundwater systems and countless mountain glaciers that cross international borders. Iraq's state-rebuilding effort, for instance, is seriously handicapped by shortages of electric power and irrigation water due to diminished flows in the Euphrates, whose waters are siphoned upstream by Turkey and Syria. In aggregate, the three nations' water projects are predicated on drawing 1.5 times the Euphrates' entire flow—a physical impossibility. The uppermost riparian, Turkey, is in the commanding geopolitical position to decide how much to leave for its neighbors. A similar dynamic is developing in South Asia, where China's hold of the Tibetan plateau gives it ultimate control over the source spigots of most of the region's great rivers, on which 2 billion people depend.

Throughout history, power has migrated upriver as states have gained greater technological capabilities to manage water flows. Such a situation is starting to play out on the Nile. For millennia, downriver Egypt consumed the lion's share of the river, even though 85 percent of its waters originate in impoverished Ethiopia, which until recently barely sipped any for its own development. Over the past decade, the

Nile basin states have labored to negotiate an agreement for cooperative river development and water sharing in a region that is desperately poor, young and projected to swell in population by 50 percent to half a billion by 2025.

Former United Nations Secretary-General Boutros Boutros-Ghali famously predicted a quarter century ago that the “wars of the 21st century will be fought over water.” While nations so far have found more reasons to cooperate than go to war over water, pressures are mounting rapidly with rising populations, absolute scarcity levels and accelerated adjustments wrought by climate change. Water-scarce states that can't produce enough food, energy and goods are more prone to fail. Failing states become breeding grounds for regional instabilities, wars, genocides, international terrorism, piracy, epidemic diseases, famines, mass migrations and other tragedies whose consequences reverberate across borders.

### Global Choices

History teaches that a difficult adjustment lies ahead, as it always has whenever population levels and key resources have gotten unsustainably out of balance. The chief questions are the severity and burden-sharing loads of the adjustment—and which societies will make the nimblest adaptations and emerge as world leaders, and which will not and decline.

We have two basic choices:

- Boost the productivity and environmental sustainability of existing water resources through difficult political changes that improve organization, technology and allocation efficiency.

- Try to buy time by mining groundwater or erecting long pipelines that transfer water from regions with temporary surpluses to those with current scarcity in hope that a new silver-bullet technology, akin to the 20th century's giant dams, will emerge to save the day.

While there have been some promising developments toward improved, sustainable efficiencies, societies so far have mainly followed the path of least political resistance and tried to buy time. But the savior technologies—desalination and genetically modified, low-water-using crops are most often mentioned—are not likely to arrive in time and in sufficient scale to cover the growing global shortfalls.

How effectively the world's water-have nations manage their increasingly precious water resources will also play a major role in shaping global outcomes. With a large competitive advantage as one of the world's water-rich and economically powerful nations, the United States in particular has a golden opportunity. It can simultaneously grow its economy, enhance its international influence and help avert the worst consequences for the planet's water have-nots by stepping up to produce the water-intensive food and goods, viable water management models and multifaceted international assistance required by an increasingly thirsty world. But to do so effectively requires transforming its domestic water economy: Currently an undervalued, archaically managed and often inefficiently allocated resource, water must be treated as a prized economic asset flowing to its most productive and ecosystem-sustainable uses.

In the international arena, the Obama administration in March 2010 took the first step by announcing a five-stream approach integrating the global freshwater crisis into America's priority national security and diplomatic challenges. Secretary of State Hillary Clinton emphasized both the risks and opportunities inherent in water's pervasive importance to society: "Water represents one of the great diplomatic and development opportunities of our time. It's not every day you find an issue where effective diplomacy and development will allow you to save millions of lives, feed the hungry, empower women, advance our national security interests, protect the environment and demonstrate to billions of people that the United States cares, cares about you and your welfare. Water is that issue."


There is yet one further special attribute about water that must inform any profound understanding of the importance of freshwater scarcity—the inextricable affinity between water and our essential humanity, not merely for human life but for a dignified human life. From hand-built mud barrages and man-powered water-lifting treadle pumps in rural Africa to colossal dams and powerful mechanical water-moving pumps in the industrial democracies, water history is



everywhere an unevenly layered history, with ancient, medieval and modern methods coexisting simultaneously, imparting enormous—and easily overlooked—advantages to the comfortable water haves and crippling disadvantages, starting with lives and human capital handicapped by malnutrition, ill health and sacrifice of education to the daily forage for water, to the water have-nots. The need for water trumps every human principle, social bond and ideology. It is literally indispensable. With extreme water scarcity showing through as a root cause of much of the world's poverty, sickness, humanitarian crises, failing states and conflicts, if there can be a meaningful human right to any material thing surely it starts with access to minimum clean, fresh water.

How each member of the world community acts in response to the global freshwater crisis is, at the end of the day, a judgment on our own humanity—and the ultimate fate of human civilization. After all, as science, custom and our own intuition teach, we are water.

*Steven Solomon is author of Water: The Epic Struggle of Wealth, Power, and Civilization, HarperCollins 2010, and he also writes at <http://thewaterblog.wordpress.com>.*



Anyone who can solve the  
problems of water will be worthy of  
two Nobel prizes—one for peace  
and one for science.

John F. Kennedy ~ President, United States of America ~ b.1917–d.1963



# Water and Food Security

# Water flows uphill to money.

Marc Reisner ~ American author ~ *Cadillac Desert*, 1986



**Above:** The Los Angeles Aqueduct system draws water from Owens River in the eastern Sierra Nevada Mountains and from the Colorado River. The 233-mile Owens River aqueduct was a major engineering accomplishment, but it has depleted the river valley. © Shutterstock / iofoto



# ONE LITER = ONE CALORIE

## A Critical Link That Equals Water Scarcity

FRANK RIJSBERMAN

To produce a calorie of food, it takes a liter of water or at least several thousands of liters of water for every person every day. The water required to grow the food we eat is some 70 times greater than the water we need to drink, bathe and wash. Over the next 40 years the global demand for food is expected to double, and that implies that the amount of water used to achieve global food security would also have to double.

Already today a third of the world population is affected by water scarcity. Climate change is expected to worsen this by increasing the frequency and severity of floods and droughts.

That, in a nutshell, paints the grim reality of water and food security. It has led to predictions that future wars will be fought over water and that water will become the blue oil of the 21st century.

What are the water and food challenges faced by the world? Why are they so poorly understood? How did we end up in such a dire situation? Are there solutions to alleviate the world water crisis? These are the questions this article will address.

### Hydrocivilizations

In some parts of the world, such as Western Europe and the U.S. Midwest, it is possible to grow high-yielding crops with the moisture provided by rainfall alone. In many others, however, it is either too dry, such as in the Middle East, North Africa or much of California, or rain falls in just a few big storms every year, such as in monsoon Asia. Civilizations that flourished under these conditions all



depended heavily on their ability to manage water for agriculture. Irrigation on the banks of the river Nile was the source of wealth in ancient Egypt. Roman aqueducts and underground water tunnels were widespread masterpieces of engineering, some of which have survived until today. Famous kings and maharajahs in southern India and Sri Lanka are remembered as much or more for their dam-building feats as their prowess on the battlefield. Food security has been closely intertwined with water management for millennia, but the speed at which water resources have been developed in recent history has been unprecedented.

During the 20th century, the world population tripled, but the total amount of water extracted from rivers and groundwater aquifers for human use has increased sixfold. By the middle of the last century the global stock of large dams, defined as dams higher than 15 meters, numbered 9,000, three-quarters of which were located in industrialized nations. Today there are some 49,000 large dams in the world, two-thirds in developing countries, particularly in Asia. At the same time, the development





**Above right:** The Three Gorges Dam in China crosses the third-longest river in the world and is one of only a few man-made structures visible from space. The dam created a 644-kilometer reservoir on the Yangtze River. © AP Images



of affordable small diesel and electric water pumps led to a boom in groundwater development. In India alone more than 20 million boreholes were drilled and pumped, primarily for irrigation. At the end of the 20th century, global food production was ample to feed the world population (if only the poor could afford it) and food prices were at historic lows, in no small way thanks to a massive global investment in water resources development for food security, hydropower and flood control.

### **The Green Revolution**

In the 1960s and 1970s, rapidly increasing populations in the Southern Hemisphere and dramatic famines in the Indian subcontinent and sub-Saharan Africa led to widespread fears that the Earth would not be able to support a then-projected population of 6 billion. The Ford and Rockefeller foundations took the lead in initiating major international efforts to boost global food production. These collectively have become known as the “Green Revolution.” The best-known element of this revolution was the much-improved varieties of food crops such as rice, wheat and maize. This effort also yielded the only Nobel Peace Prize ever awarded an agricultural scientist, Norman Borlaug, in 1970 for his development of “famine-busting” semi-dwarf, high-yield, disease-resistant wheat varieties.

This boost in agricultural production required fertilizers and irrigation. The assumption was that making water available cheaply to farmers was part of the core infrastructure, along with roads for example, necessary to boost development and achieve food security. Supported by the World Bank and many bilateral donors such as the United States Agency for International Development, governments throughout Asia and to some extent Africa followed in the footsteps of the massive dam and irrigation canal-building programs in places like the western U.S. and Australia’s Murray-Darling basin. Farmers invested simultaneously in wells and pumps for groundwater development. By the start of the 21st century, 17 percent of agricultural land was irrigated and it produced some 40 percent of the world’s food. Countries such as Thailand, India, Vietnam and Mexico became food exporters, despite their population increases.

### **The Value of Water**

Water resource development efforts historically focused on diverting water in rivers and aquifers for use by agriculture, cities or industry. Large wetlands such as the Florida Everglades were seen as wasteland and a source of diseases such as malaria. Assuming that water had zero value in nature, any value produced through irrigation was seen as a



contribution to society. The dominant policy around the world was for governments to bear the cost of investment in water infrastructure and to provide the resulting irrigation water to farmers free of charge—at prices below the cost of operation and maintenance.

This policy had unanticipated consequences. Farmers receiving free or near-free water had no incentive to use it wisely or to invest in water conservation technology. Another consequence was that the massive government bureaucracies created to provide the water to farmers depended for their existence on government budgets rather than revenues from farmers. The bureaucrats had no incentive to be accountable to farmers or to provide high-quality service. In many places irrigation officials devised ingenious ways informally to extract personal revenue—from bribes on construction or maintenance contracts to providing privileged, secure access to farmers willing and able to pay extra. Better-off landowners and irrigation officials all had reason to hide, protect and perpetuate these informal arrangements. Poor farmers got less than their fair share, however, and society as a whole paid the price of a low-performing system. The water used generated a much lower value than it could.

Over time, societies gradually have recognized that “undeveloped” water does have great value. A river and the wetlands, deltas and coastal mangroves that depend on it support a number of vital functions:

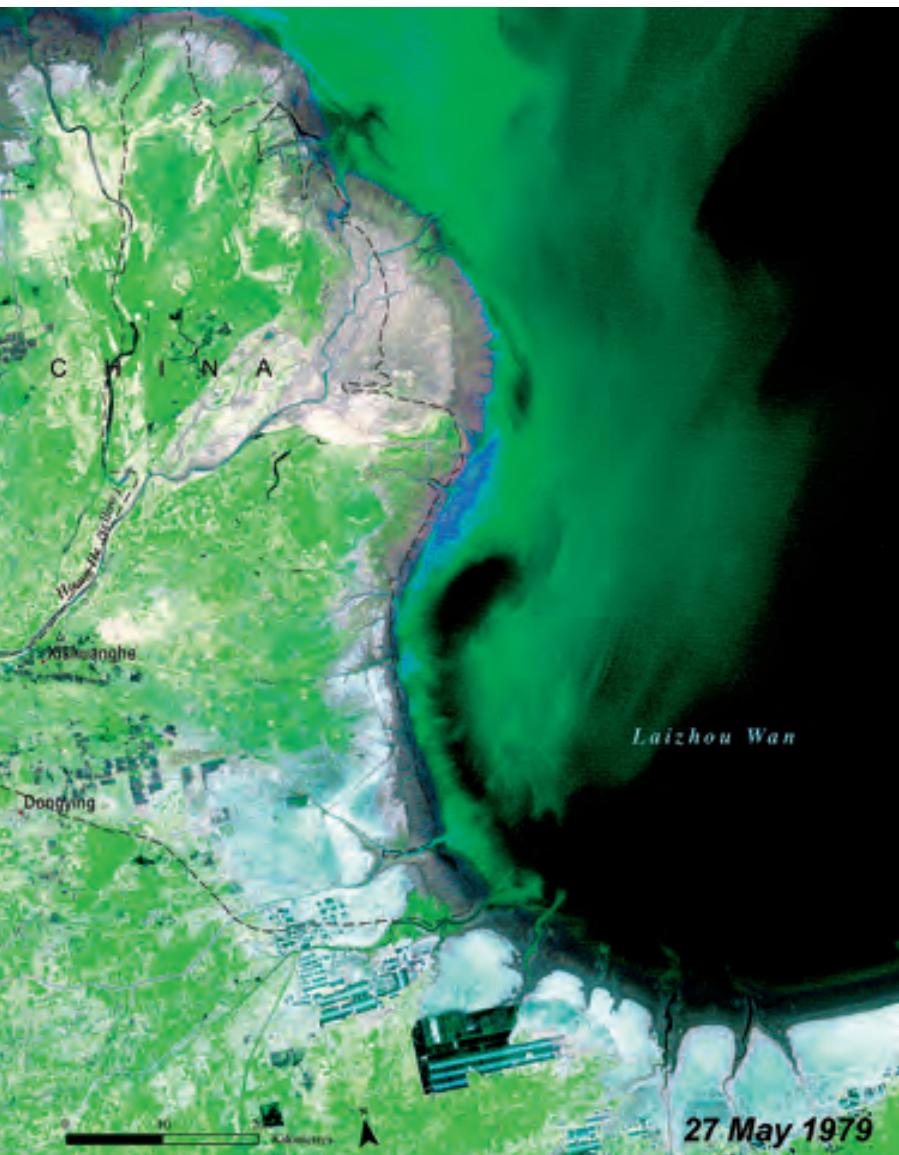
- Fisheries.
- Flood plain uses such as recession agriculture, herding, and flood plain forestry.
- Flood protection.
- Carrying nutrients to flood plains.
- Maintaining deltas and coastlines that erode without sediment.

In short, wetlands and coastal zones are now valued for the ecosystem services they produce.

The lesson is that all water already serves a purpose—and it all has a value. Some irrigation projects have generated less value for society than the ecosystems they replaced.

### Running Out

The old approach to water resources development has reached its limits. Projected population increases require additional food production even as growing wealth in countries such as China and India increases



per capita food consumption. The trends together suggest a doubling of world food demand between now and 2050. Business as usual would then require doubling the amount of water used in agriculture as well. That could in theory be done by increasing the land under cultivation, but there is simply not enough left. Another strategy might be to draw more water from nature, but the easiest rivers to tap and the best sites for dams have already been taken. In fact, there are many signs that too much has already been taken:

- Once-mighty rivers such as the Yellow, Colorado and Jordan no longer reach the sea during critical periods.
- The Aral Sea has dried to a shadow of its former self and has become one of the worst environmental disasters in the world.

- Groundwater levels in many parts of Asia, such as the Indian state of Gujarat, have fallen by more than 150 meters in 25 to 30 years; thousands of wells and whole villages have been abandoned—the aquifer was developed and used up in just one generation.
- A prolonged multiyear drought in Australia recently ravaged irrigated agriculture and has led to a 10-year peak in global wheat prices.
- California courts have limited the diversion of water for irrigation from Northern California and cities in the southern part of the state to protect endangered species in the San Joaquin-Sacramento river delta, causing a crisis for irrigated

agriculture in one of the world's most productive agricultural systems.

- Egypt's Nile, breadbasket since the time of the pharaohs, no longer has enough water to provide more than half the food needed for the country; the remainder has to be imported.

The only realistic option is to increase the productivity of water already in use, producing more crop per drop and more value per drop—for food, for jobs, for health and for the environment. That is a major challenge, particularly where subsidized water prices do not provide incentives to increase productivity, but it can be done.

### **Climate Change**

Just as food security depends on access to food rather than total food production alone, vulnerability to climate change depends on the capacity to adapt rather than climate risk alone. With respect to water, the key both to attaining food security and to managing climate risk is

the ability to manage the daily and interannual variation in rainfall (for rain-fed agriculture) and river runoff (for irrigated agriculture).

The day-to-day variability of rainfall is the major risk factor for most forms of agriculture. Changes in rainfall patterns (in both space and time) will therefore be the most important aspect of climate change in terms of food security. Many adaptation options are variations of existing climate risk management, particularly irrigation systems. Irrigation systems offer an ability to manage water and thus to increase resilience in the face of climate change. On the other hand, river basins that are already “running out” have high climate vulnerability.

### **Poor People Pay the Price**

The world produces enough food to feed everybody, an estimated 17 percent more than the recommended 2,700 calories per person per day. And yet the United Nations Food and Agriculture Organization (FAO) estimates indicate that a huge portion of the world's population



**Above:** A grounded ship rests at the old seaport in Aralsk, Kazakhstan. For years, rivers that fed into the Aral Sea were diverted to irrigate cotton fields. Only 10 percent of the former sea remains, in what is now an environmental disaster. © AP Images



goes hungry. The most recent figure puts the number of malnourished at 925 million, 13 percent of the Earth's total population, and up from 824 million in 1990. Poverty is the main cause of hunger. Hungry people either do not have enough land to grow their own food, or enough cash income to buy it. That implies that simply producing more food is unlikely to cut the number of hungry people, unless it is done in a way that provides jobs and incomes for the hungry.

### **Managing Our Way Out of the Crisis**

Can we increase the productivity of water enough to support a doubling of food production by 2050? Can we do so in a manner that cuts the number of malnourished and maintains or improves ecosystem services? The good news is that water productivity is currently low in most places. That means there is scope for improvement. The value

of water in irrigation can range from 1 to 2 U.S. cents per cubic meter when used to produce grains, to 5 to 10 cents for cash crops such as sugarcane, and up to 50 cents for fruits and vegetables. But this figure depends not only on the crop, but also on location, agricultural practices and water conservation techniques. While most farmers need 1 to 2 cubic meters of water to produce a kilogram of grain, others manage with less than half a cubic meter. There is thus significant potential for farmers to produce more crop per drop. It will not be achieved easily, however. It is a problem many have tried to solve, and few have succeeded.

Silver bullets, such as the high-yielding varieties that boosted crop yields by as much as 50 percent in just five years in India and Pakistan in the 1970s, are not available. Some solutions are not expensive, but they require large-scale institutional change both in water management



and in accountability to users. Both are tough to achieve. Some solutions may be found in technological breakthroughs, such as the drip irrigation systems developed in Israel that can double water productivity, but adopting new technology often requires capital investments beyond the means of most small farmers.

Managing water to achieve food security for all and a healthy environment will require massive efforts. Governments everywhere will have to phase out subsidies, recognize environmental values and stop the race to the bottom where those with means out-compete their neighbors with ever deeper wells. Adapting to climate change will become a priority everywhere. Industrialized nations will emphasize

- Curbing the spread of complex chemicals such as pesticides, drugs and medications.
- Reviving ailing ecosystems, e.g., by decommissioning dams.
- Enabling water to move to its highest-value use.

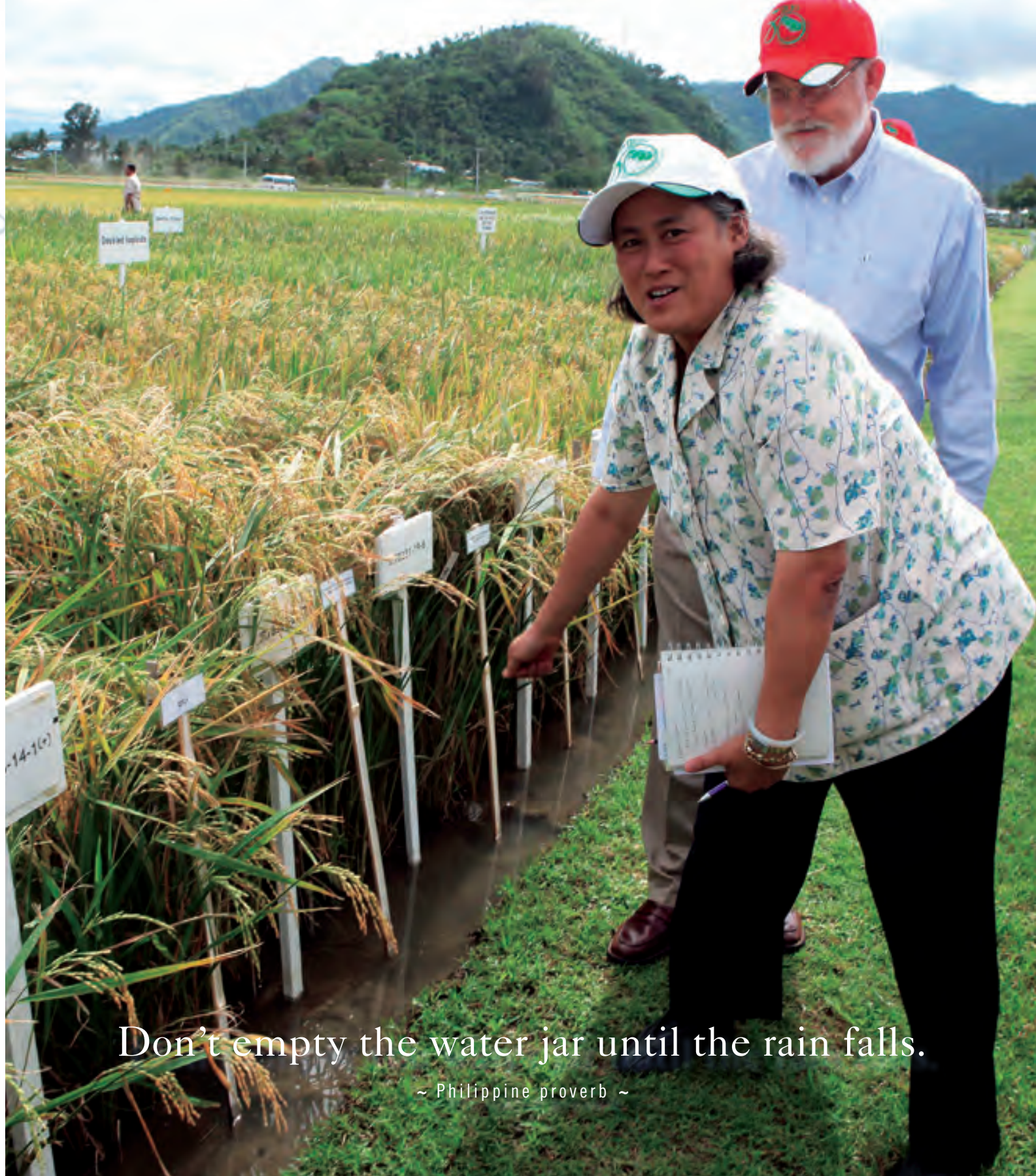
In developing nations, food security for all requires a focus on opportunities for the poor. Particularly helpful will be initiatives that help the needy grow food and generate income. These might involve low-cost drip irrigation, rainwater harvesting or multiple-use water projects that afford households water to drink and bathe, water backyard gardens, tend livestock or support cottage industries.

In short, while food security in the 20th century was achieved by rapidly increasing the amount of water extracted from nature, the challenge for water managers now is to double the productivity of the water already used in the next 40 years.

*Frank Rijsberman, former manager of environmental and health programs for Google.org, a philanthropic organization of Google Inc., now leads the Water, Sanitation and Hygiene program at the Bill & Melinda Gates Foundation. He is former director of the International Water Management Institute in Sri Lanka.*



**Above:** Deltas, coastal mangroves and other “undeveloped” water resources play a critical role worldwide. Even though the Mogtedo irrigation system in Burkina Faso is almost depleted, it continues to support local fishermen. © AP Images



Don't empty the water jar until the rain falls.

~ Philippine proverb ~

**Above:** Princess Maha Chakri Sirindhorn of Thailand and Robert Ziegler, director of the International Rice Research Institute, inspect an experimental rice farm in the Philippines. Growing rice in fields enclosed by stone or earth walls prevents erosion. © AP Images

# DOWNSTREAM DANGERS

## Managing the Impact of Farming

INTERNATIONAL WATER MANAGEMENT INSTITUTE

**A**gricultural activities influence water quality in two ways. First, unsustainable farming practices in upland areas cause soil erosion. Particles wash downstream when it rains, causing downstream lakes, rivers and other bodies of water to fill with silt. This can cause flooding and prevent dams from working. Over time, nutrients become depleted and the upland soil structure damaged.

In a vicious cycle, the land becomes less productive and more soil washes away. If the erosion continues, the soil becomes unusable. This problem is growing as the world's uplands are being cleared and intensively farmed. Population pressures, government policies, market demands and the spiral of land degradation are forcing farmers to move to ever higher lands.

The second impact of farming on water quality is from the use of fertilizers and pesticides. These chemicals can run off with rainwater and flow downstream via rivers into lakes and oceans. In Africa, where fertilizer is less often used, the additional nutrients are sometimes beneficial to farmers downstream. In Asia, however, where agrochemicals are subsidized, rivers can become overloaded with chemicals. This can lead to eutrophication: Algae or other plants grow excessively and disrupt ecosystems, depleting oxygen and killing fish. If fertilizers and pesticides enter groundwater used for drinking, human health problems can result.

The Management of Soil Erosion Consortium (MSEC), founded in the 1990s to address the lack of river catchment data across Southeast



Asia, conducts research in this area. The consortium includes Indonesia, Laos, the Philippines, Thailand and Vietnam, along with the IWMI and the French Institut de Recherche pour le Développement (IRD). During a five-year project, MSEC assessed runoff and sediment from farming practices in 27 catchments (drainage basins) and subcatchments in the five countries. Findings show that sustainable land-use practices can help prevent negative impacts on downstream communities.

### Scientific Solutions

The analysis demonstrated that rapid land use changes were having an impact on catchments. For example, when farmers sought to increase earnings by intercropping rambutan plantations with cassava in one Indonesian catchment, the sediment increased from 2.9 megagrams (Mg) per hectare per year to 13.1 Mg.

The scientists identified farming practices that were causing erosion (for example, higher cropping intensity of growing maize instead of rice). They then identified practices that could help prevent erosion,



such as planting fruit trees or sowing strips of native grass along land contours of the cultivated land.

Notable improvements in sediment amounts were seen when farmers adopted certain conservation practices. For example, when the Indonesian rambutan plantation that had been intercropped with cassava was replaced with grass for livestock, the annual sediment dropped from 13.1 Mg per hectare per year to 2.7 Mg. Similarly, farmers in Laos reduced sediment from 5.9 Mg per hectare per year to 0.1 Mg using a fallow system that increased the land's recovery time.

#### Incentive to Change

Globally, farmers have been slow to adopt erosion reduction techniques. IWMI scientists believe farmers lack sufficient incentive. Scientists are assessing a plan to apportion benefits between upland farmers and hydropower companies operating downstream dams. The idea is that hydropower companies, which have a vested interest in maintaining silt-free reservoirs, would pay farmers to minimize soil erosion.


"This region has very high topography and, given the economic boom, they need power," says Pay Drechsel, theme leader for water quality, health and environment, IWMI. "Many hundreds of dams are being planned."

Using incentives to help reduce pollution from fertilizers and pesticides does not mean paying farmers to use fewer agrochemicals; it requires targeting subsidies more precisely. For example, if dangerous levels of phosphorus were found in an area, it would make sense to remove subsidies on phosphorus-containing chemicals or make them expensive, encouraging farmers to use them sparingly.

*The International Water Management Institute is a nonprofit scientific organization and one of 15 research centers supported by the Consultative Group on International Agricultural Research (CGIAR). IWMI's mission is "improving the management of land and water resources for food, livelihoods and the environment." The Institute is working with overseas partners to help find ways to reduce the negative impacts of inappropriate land use and enhance water quality and livelihoods.*



**Above:** Terracing, the practice of farming on graduated steps, is an effective way to prevent soil erosion and surface runoff on sloped terrain. These terraced rice fields are in Bali, Indonesia. © AP Images (3)



Water is the principle,  
or the element, of things.  
All things are water.

Plutarch ~ Greek philosopher ~ ca. b.45–d.120 A.D.

# Water and Climate



Climate is what you expect, weather is what you get.

Robert A. Heinlein ~ American author ~ b.1907–d.1988



# WATER IN A CHANGING CLIMATE

## The First Effects Are Showing

MIKE MULLER

Climate change has people hot under the collar or waking in a cold sweat. The world's governments now accept that climate change poses a serious long-term threat to their nations' economic and social health. But who caused the problem? Who should address it, and how? And who should pay for the measures required both to limit climate change and to help people adapt to its impact?

### From Controversy to Consensus

On one issue almost everyone at the Copenhagen COP-15 climate summit in December 2009 agreed: The impacts of climate change will be felt through water.

◆ During the opening ceremony, the Danish hosts showed an emotional video of a young girl experiencing some climate change impacts: floods, glacier melt, hurricanes and drought.

◆ Yvo de Boer, then-executive secretary of the United Nations Framework Convention on Climate Change (UNFCCC), movingly recalled the testimony of Nyi Lay, a 6-year-old boy who lost his parents and younger brother, washed away when a devastating cyclone hit Burma in May 2008.

◆ Rajendra Pachauri, chairman of the U.N. Intergovernmental Panel on Climate Change (IPCC), warned that “in Africa, by 2020, between 75 and 250 million people are projected to be exposed to water stress due to climate change, and in some countries on that continent, yields from rain-fed agriculture could be reduced by up to 50 percent.”



◆ As U.N. Secretary-General Ban Ki-moon summarized, “The evidence assaults us: melting ice caps, advancing deserts, rising sea levels.”

The message is clear. The way we use energy may cause climate change, but the world will experience the results through water. The way we manage water will shape profoundly how we adapt to climate change. We gain much practical knowledge by studying the perspective of those who work with water and who engage daily with the vagaries of climate.

### A History of Managing Uncertainty

The adage “climate is what you expect, weather is what you get,” often attributed to weather scientists, was coined by American science fiction writer Robert Heinlein in 1973. We worry about weather every day—Do I need a coat? Should I take an umbrella? Must the fields be irrigated this week? But

climate defines our expectations—Should we install central heating? Is this valley a safe place to build houses? Will the country be able to feed itself?



Science fact has now outrun science fiction, and climate change is undermining our confidence in those expectations. Forget the weather; we are no longer sure what climate to expect.

Water, however, has always been a good indicator of the state of both weather and climate. In Pharaonic Egypt, the priests monitored the levels of the Nile not just to predict whether there would be a good harvest but also for the very practical purpose of setting taxes.

Their records, amongst the longest sustained measurements of a natural phenomenon anywhere in the world, are a valuable source of climatic history. They show that variation has been the one constant factor—no season was ever like the last one; no sequence of floods and droughts matched another. Indeed, mathematicians analyze apparently random behavior with techniques they derived from the records of Nile flows.

With their long experience of monitoring weather patterns and river flows, water managers have developed a good understanding of how to work with climate. But climate change forces them to rethink their approaches.

### **Global Warming Amplified in the Water Cycle**

Predicted levels of global warming, 2 to 4 degrees Celsius by year 2100, do not sound very great. But warming's impact will be amplified in the water cycle in a number of ways. The Earth's average temperature (15 C) allows different forms of water—solid ice, liquid or vapor—to coexist. The extra energy causing the temperature rise will disturb that balance.

Weather events, such as tropical storms, will become more frequent while rainfall is expected to become more intense, even as some places receive less on average. Future floods likely will be larger, more destructive and more frequent than today.

As temperatures rise, evaporation will increase. If it exceeds rain, the Earth will grow drier. In arid areas, more rainwater will be absorbed



by dry land, instead of “running off” to fill streams and rivers. Drier soils will soak up the water as it infiltrates downward, reducing the recharge of aquifers—nature's underground water stores—and the flow of the natural springs that they feed.

Changes in vegetation cover in a warmer climate will divert rainwater from rivers and other vital aquifers. Evapotranspiration (the total water loss from the soil, including both direct evaporation and the giving off of moisture from leaves and other plant surfaces) from the denser, more luxuriant vegetation may draw still more water up from the soil and into the atmosphere.

These effects of temperature changes will have huge impacts on communities worldwide.



- Although more carbon dioxide should boost plant growth, food production will fall in many places as rainfall lessens and becomes more sporadic. Lower river flows will mean less water available for irrigation. In most of Mexico, for example, river flow is expected to decline; by 2080, key irrigation districts could see reductions between 25 and 50 percent. In many countries, hunger and poverty will follow close behind drought.
- Health will also be affected. As water from heavier-than-usual rainfall stagnates in warmer temperatures, malaria-carrying mosquitoes will thrive in new places. Meanwhile, waterborne illnesses will spread as it becomes more difficult and costly to



ensure adequate drinking water supplies and sanitation in poor countries.

- Flooding disasters will increase, harming the many hundreds of millions of people who live close to vulnerable rivers, on flood plains or on river deltas: “Two billion people will live in areas where river flood potential could increase by the 2080s,” warns Pachauri of the IPCC. Coastal flooding will be exacerbated by sea level rise as the world’s polar stores of snow and ice melt. Salt water from the seas will mix with both surface and underground freshwater supplies, rendering them unusable.
- Warming will also reduce the amount of water stored in the snowfields and glaciers of the Himalayas, Andes and other mountain chains. More flooding is expected as ice and snow in mountain catchments melt. But once the reserves have disappeared, the steady, regular flows of the past will be supplanted by less predictable wet-season flash floods as water increasingly falls as rain rather than snow. Downstream communities will have to find new ways to store the water that was previously released more gradually throughout the dry season.

Increased pollution impacts are less obvious. Sanitary engineers say that “the solution to pollution is dilution,” since much waste from cities and industries is removed by rivers and need not damage rivers’ ecologies if there is sufficient flow. But reduced river flows will no longer be able to perform this function; communities will either have to pay more to treat their wastes or suffer the consequences of increased pollution.

### More Pressing Water Challenges?

Despite this litany of problems, the world’s water managers and experts did not initially give them very high priority. In 2003, the U.N. World Water Development Report concluded that “climate change will account for about 20 percent of the increase in global water scarcity.”

Anyone familiar with the 80/20 rule of management will get the message: Tackling climate change was not at the top of the water managers' "to-do" lists. The reason was that they faced many more immediate problems. In much of the world, water use increases at faster-than-sustainable levels, driven by population growth and economic development. Meanwhile, water pollution limits the usability of what we have.

Where water is taken directly from rivers, shortages quickly become evident as downstream users complain that they no longer have enough. But where water is drawn from underground, users may not realize that they are drawing down their water "bank balance." From the western United States to India and the Middle East, water tables are falling far faster than they can be recharged.

Urbanization is another threat, and not just because residents of rapidly growing cities want more water for their households. Often, particularly in developing countries, urban wastes pollute water at the expense of downstream users who must either spend large amounts of money to treat it, find other sources or risk using it.

Economic growth brings further challenges. Prosperity changes diets, requiring both more food and more water to produce it. And new technologies generate new kinds of pollution.

### **The Future Is Not What It Used to Be**

Water managers have reconsidered their priorities. One reason is that some actions to mitigate climate change were themselves threatening the water cycle and water users. The expansion of biofuel production is a good example. Already, water experts had identified finding enough "water for food" as a key 21st-century challenge. Now, suddenly, food would have to compete with energy crops for scarce water.

Hydropower similarly offers real benefits but increases competition for water resources. As an invaluable source of renewable energy, channeling water through turbines and then back to the sea can help in the fight against climate change. But uncertain river flows threaten hydropower's reliability even as the premium prices renewable energy commands divert limited water resources away from other uses.

The most serious challenge is the loss of climate predictability. Water managers can no longer use the past to forecast the future. This is crucial, because water management historically requires long-term decisions about major infrastructure typically built for a life of 50 or even 100 years. Past designs assumed that climates were constant, that storms would occur with similar frequencies and intensities and cause the same kinds of floods. Droughts were projected to follow similar patterns. All sorts of infrastructure—from large dams, hydropower plants and water supply systems to airport runways and the gutters in city streets—were designed on these assumptions.



The designs aimed to achieve risk levels acceptable for their users. Farmers growing annual crops might live with failure once in five years, but perennial orchards need greater reliability. Domestic users in well-off communities may accept restrictions on using water for gardening but not for their basic household supplies. For strategic industries such as power supplies to a national grid, failures more often than every 200 years are unacceptable.

Engineers and hydrologists helped determine, for instance, how strong a levee was required to withstand all but a "100-year" storm by developing sophisticated prediction models grounded in historic records of rainfall and river flows. But these techniques will not work if future weather does not follow past patterns. Design for "nonstationary" climates requires new techniques, new scenario planning, asking "what if" questions and building resilient systems that can cope with unexpected variations.

### **In Practice, the Future Is Already Arriving**

The IPCC has predicted with high confidence that "many arid and semi-arid areas (e.g., the Mediterranean basin, western United States, southern Africa and northeastern Brazil)...are projected to suffer a decrease of water resources due to climate change."

Maarten de Wit and Jacek Stankiewicz, scientists at the Africa Earth Observatory Network in Cape Town, explain that if the expected rainfall reductions occur, perennial rivers will stop flowing for part of the year across 25 percent of Africa.

In some places, these futures have already arrived.

- UN-Water, a consortium of 26 international agencies involved with water issues, recently concluded that “already, water-related climate change impacts are being experienced in the form of more severe and more frequent droughts and floods.”
- Along the Andes in South America and the Himalayas in Asia, the behavior of rivers fed by snowfields and glaciers has changed. Downstream countries like Bangladesh report a combination of both floods and droughts that destabilizes their economies.
- Meanwhile, California’s state government has warned: “Climate change is already affecting California. Sea levels have risen by as much as seven inches along the California coast over the last century, increasing erosion and pressure on the state’s infrastructure, water supplies and natural resources. The state has also seen increased average temperatures, more extreme hot days, fewer cold nights, a lengthening of the growing season, shifts in the water cycle with less winter precipitation falling as snow, and both snowmelt and rainwater running off sooner in the year.”

### Practical Perspectives and Innovative Responses

Water resources and water use differ greatly between and even within countries. No single quick-fix approach can help each adapt to the future. However, an encouraging pattern of local and regional innovation is emerging.

- Australia, recently devastated by droughts, wildfires and climate-related floods and facing critical urban water shortages, is an example. The city of Perth is augmenting supplies using wind-powered desalination plants, while federal government water reform seeks to change habits and bring water use in line with the country’s decreasing water availability.
- Industries from food and beverages to power and mining are finding ways to reduce water use and vulnerability to climate change. South Africa’s new thermal power stations are dry cooled, using only 0.1 liter per kilowatt-hour of electricity, compared with 1.9 liters for wet-cooled stations.
- The insurance industry is also working to understand climate futures: “For companies that position themselves skillfully, the effects of climate change may also present new opportunities because the demand for new natural hazard covers will increase,” writes Thomas Loster of the Munich Re Geo Risks Department. Meanwhile, poor countries such as Ethiopia are testing drought insurance plans to ensure that communities can feed themselves during major droughts.

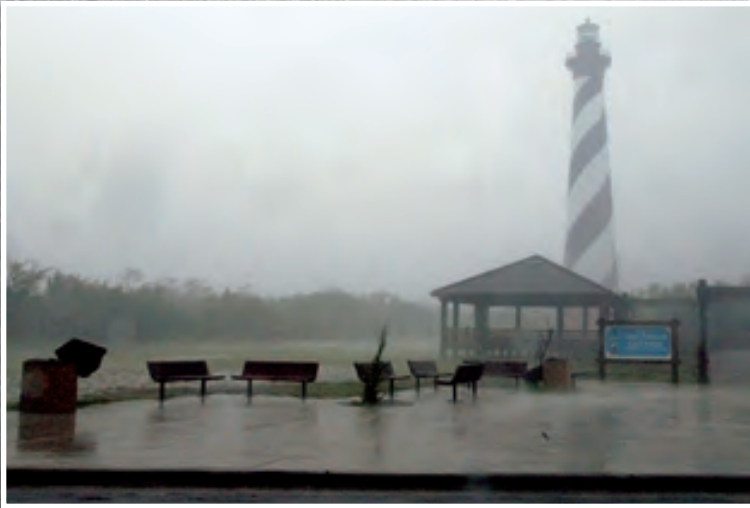
- The United States demonstrates how responses must come from all levels and interest groups.
  1. A work group within the federal government’s inter-agency Climate Change Adaptation Task Force develops recommendations for planning and implementation of adaptation actions to address climate effects on water resources. A second work group focuses on “international resilience” and how the United States government can support international adaptation efforts.
  2. In California, environmental regulators have set specific water targets in the state’s 2009 climate adaptation strategy: “California must change its water management and uses because climate change will likely create greater competition for limited water supplies needed by the environment, agriculture and cities...state agencies must implement strategies to achieve a statewide 20-percent reduction in per capita water use by 2020, expand surface and groundwater storage [and] support agricultural water use efficiency.”
  3. The American Waterworks Association, representing U.S. water utilities, also supports “the development of more refined global climate models and associated tools to better understand and address these impacts at a water utility-relevant scale, and the development of water footprints to help utilities prioritize climate change-related adaptation and mitigation decisions.”

### Conclusion: No Regrets

The emerging consensus among water managers and experts is that while we cannot predict today the effects climate change will have over the next century, we are sure that many will flow through the water cycle. So water must be better managed and water systems made more resilient.

The Global Water Partnership, an international network of people and organizations working to improve water resource management, sums it up: “Better water management today will build a more resilient world tomorrow. Today’s investments in water security should be seen as an explicit part of a longer-term strategy for adaptation.”

*Mike Muller co-chairs the United Nations–Water World Water Assessment Programme’s Expert Group on Indicators, Monitoring and Databases and is a member of the Global Water Partnership’s Technical Advisory Committee. A registered professional engineer, he recently co-edited Integrated Water Resources Management in Practice: Better Water Management for Development (Earthscan 2009).*



## hur·ri·cane

/ 'hæ·rə,keɪn, Brit 'hɪrəkən /

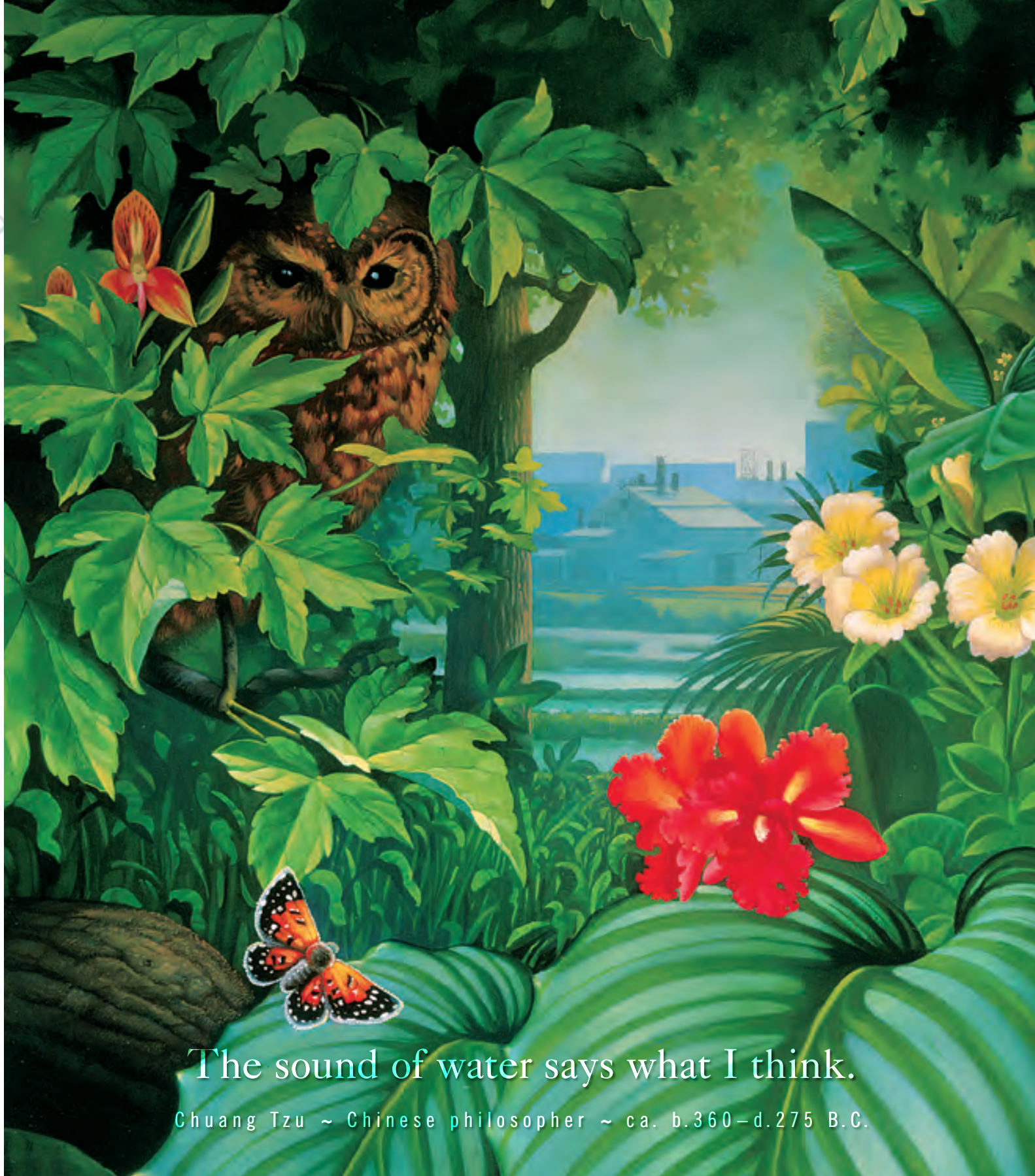
*noun* [plural hur·ri·cane]:

an extremely large, powerful and destructive storm with very strong winds that occurs especially in the western part of the Atlantic Ocean

© Getty Images / Time Life Pictures / Steve Liss



**Above right:** (top) A cyclist in Cuba fights the wind and rain during Hurricane Lili in 2002. (center) Nearly half a million people in Texas and Louisiana were ordered to leave their homes to avoid the 225-kilometer-per-hour winds of Hurricane Lili, shown by satellite. (bottom) Hurricane Dennis escalated erosion and caused \$10 billion in damages in Florida in 2005. © AP Images (3)



The sound of water says what I think.

Chuang Tzu ~ Chinese philosopher ~ ca. b.360–d.275 B.C.

**Above:** Tropical environments are feeling the effects of climate change due not only to nature, but also to increased emissions of greenhouse gases such as carbon dioxide, methane and nitrous oxide from nearby nontropical areas. Scientists have detected warming of the Caribbean region, as well as drying conditions and rising sea levels. Islanders in the high tropics can expect drier conditions because moisture will be transported to the equator, which will become wetter. © Brian Leicester



# THE VIEW FROM JAMAICA

## An Island Perspective

ANTHONY CHEN

**I**magine yourself 10,000 years ago, when the Earth started warming after the last ice age, on an island in higher tropical latitudes, such as Jamaica. Without modern thermometers and tidal gauges, you would probably not have perceived the gradual rise in temperature or sea level.

You would not have seen the need to adapt to prevent the growing changes our world now experiences.

Compare that with yourself as a modern islander. Over a lifetime you will experience a warming climate. You will feel the need to install air-conditioning or cooling fans in your home. You will notice that periods of drought and flooding are more frequent, storm surges more destructive. You probably will be forced to take temporary measures to react to some of these changes, such as storing water in droughts or securing your home during a hurricane, but nothing on a planned basis.

What is the difference between 10,000 years ago and now? The former warming took place over thousands of years and was due to natural variations, such as in solar radiation, volcanic eruptions and vegetation. The present warming has taken place over only a century and a half, and it is due not only to nature but also to increased emissions of greenhouse gases, such as carbon dioxide, methane and nitrous oxide, since the Industrial Revolution. Estimated and actual data measurements have shown an exponential increase in these gases over the period, according to the Intergovernmental Panel on Climate Change (IPCC).



With the benefit of measuring instruments, scientists have been able to detect warming of the Caribbean region, as well as drying conditions and rising sea levels.

Now, fast-forward to 2100. While we can envisage many scenarios, climate scientists are coming to a consensus that focuses on two: one in which temperature increases are kept below 2 C, and the other, above 2 C. Under the latter, the effects of climate change will be more severe, perhaps reaching a point of no return. Two of the impacts of greatest concern are in the water and health sectors.

### Possible Consequences

Islanders in the high tropics can expect much drier conditions. This is because much of the moisture in high tropics will be transported to the equator, which will become wetter, according to the IPCC.

One recent study suggests that some watershed areas will become deficient. The watershed area serving the Kingston Metropolitan Area will be in surplus but severely strained. Communities supplied by a single spring or river will be increasingly vulnerable. Non-irrigated



local crops and foodstuffs important to the local Jamaican market will be threatened.

Rainfall associated with storms, even though less frequent, is expected to be more intense or heavier. Flooding, landslides and soil erosion, especially in mountainous regions, as well as sediment transport and high turbidity in the water supply will produce devastating results. Given the coastal location of many of Jamaica's wells for agriculture, public water and industry, a significant rise in sea level will make them vulnerable to salt water intrusion and reduced water quality.

Among other effects:

- The probability of more intense hurricanes, the intensity of which is naturally cyclical, but investigation shows that increased intensity can be caused by the rise in sea surface temperatures in the Atlantic.
- Endangered human settlement due to sea level rise and storm surges.
- Bleaching and possible death of coral reefs.
- Depletion of coastal resources, including the death and migration of fishes to cooler waters.
- Possible extinction of some plant species.

Compounded by associated conditions that could lead to a reduction in tourism, all the above except the last would lead to human suffering and pose serious challenges to social peace and economic progress.

In addition, many health issues will arise, including dengue fever. Temperature increases above 2 C can lead to a threefold rise in the transmission of dengue, research at the University of the West Indies shows. A direct link between temperature and dengue in the Caribbean has been reported. The transmission of dengue can be expected to increase in line with increased temperatures, along with increases in its more deadly form, dengue hemorrhagic fever.

#### Immediate Action Needed

The severity of these challenges means reactive responses are no longer possible. Planned adaptive strategies and actions must be put in place, either at the national or international level. On the national level, recommendations for the water sector, based on a 2008 study by ESL Management Solutions Ltd., have been presented to the Jamaican Ministry of Water. For possible increased dengue transmission, several strategies, including an early-warning system, have been suggested to the Ministry of Health.

Other possible sources of assistance include the United Nations-sponsored Community-Based Adaptation program, which helps selected communities adapt to climate change. A local agency, the Environmental Foundation of Jamaica, also helps nongovernmental organizations and other institutions pay for mitigation and adaptation projects.

Regionally, several initiatives are being undertaken. The Belize-based Caribbean Community Climate Change Centre coordinates much of the Caribbean region's response to climate change. The center is a key node for information on climate change issues and on the region's response to climate change. The Caribbean Disaster Emergency Response Agency, a Barbados-based interregional network for countries within the Caribbean Community, has included climate change response as part of its mission.




At the national level, however, a commitment to responding to the threats of climate change generally has not been reflected among the region's policymakers. (Guyana is the notable exception.) Given the severity of the threats and the global and all-encompassing nature of climate change, some suggest that the Jamaican government should ensure that response to climate change is integrated and coordinated through foreign and domestic policies and programs at all levels of the political system. The roles of national meteorological agencies need to be strengthened and their expertise tapped in policymaking.

On the international level, the most pressing issue is climate change mitigation. Developed and developing countries alike must cut greenhouse gas emissions to prevent the consequences of a temperature increase of more than 2 C. The Alliance of Small Island States, an intergovernmental organization consolidating the voices of 43 small-island developing states—37 of which are United Nations members—is working on ways to cut emissions. The alliance represents 28 percent of developing

countries—20 percent of total U.N. membership and 5 percent of world population. In addition to emission cuts, AOSIS seeks commitments from developed countries to fund adaptation in small islands.

Our scenarios of past, present and future islanders have taken us from a scene in which little impact of climate was noted and little needed to be done about climate change to one in which the effects of climate change will be severely felt. Small islanders have done the least to contribute to climate change but will be among those suffering the worst impacts. From the perspective of small islanders, it is imperative for all to act to mitigate and adapt to climate change.

*Anthony Chen is professor emeritus of atmospheric physics at the University of the West Indies, Mona, Jamaica, where he headed the Climate Studies Group. He is a member of the Intergovernmental Panel on Climate Change (IPCC), which shared the 2007 Nobel Peace Prize with former U.S. Vice President Al Gore.*



*In aqua sanitas*  
(In water there is health)

Pliny the Elder ~ Roman author, naturalist and philosopher ~ b.23–d.79 A.D.



# Water and Health



Filthy water cannot be washed.

~ West African proverb ~

*Above:* Peul villagers near Wassadou, Senegal, extract water from a well. Contact with unsanitary water while swimming, working or gathering water can lead to parasitic infection. © Shutterstock / Hector Conesa

# WATER + HEALTH = LIFE

## Savvy Water Management Saves Lives

JAMIE BARTRAM • BARBARA WALLACE

# W

ater's importance for health has been recognized across cultures and millennia and remains as relevant in the 21st century as it was in ancient Rome, when Pliny the Elder observed: *In aqua sanitas* (In water there is health). According to the World Health Organization, if humankind would manage its water resources properly, ensure everyone has reliable access to safe drinking water and basic sanitation, and make basic hygiene practices the norm, we could save around 1.8 million lives yearly—mainly the lives of young children.

The list of diseases that we could prevent makes for impressive reading. Some of the world's greatest ills are on the list, headed by diarrheal disease that kills more children than HIV/AIDS, tuberculosis and malaria combined. Diarrheal diseases include the killer outbreak diseases like cholera, typhoid and dysentery. Diarrhea acts in a vicious circle with malnutrition, which leads to the deaths of many children already weakened by repeated episodes of diarrhea.

Other diseases on the list do not spring so readily to mind. Trachoma is the world's leading cause of preventable blindness. It can be prevented through a simple regime of face washing and use of latrines, since the flies that transmit the *Chlamydia trachomatis* bacteria that cause the disease breed in human waste. Schistosomiasis, or bilharzia, is a parasitic disease that affects 200 million people worldwide, half of them in Africa. It is the second most socio-economically devastating parasitic disease after malaria, but the schistosome parasite that transmits the disease requires human waste to pass into lakes (preventable through better sanitation), infection of certain



species of snail (controllable by improved water resource management) and human infection by parasite larvae that burrow through immersed skin (preventable by minimizing contact with infected water when swimming, working in water or collecting water to take home).

*In aqua sanitas* also faces some very 21st-century challenges. Warm buildings and modern materials allow some types of bacteria to grow in water systems. Normally these natural inhabitants of water environments get little attention from health specialists, but some are big news. In July 1976, deaths among a group of retired U.S. Legionnaires were traced back to a previously unknown species of bacteria that was later named *Legionella pneumophila*. Since then, hundreds of outbreaks of Legionnaires' disease have been recognized, affecting up to 18,000 people annually in the U.S. alone. Other hazards from bugs that grow in water are increasingly being recognized as well. Some come from ingestion, some from contact and others through inhalation—for example, breathing in contaminated water vapor from showers.



Courtesy of USAID / Academy for Educational Development / Crystal Thompson

As we use ever-more-complex and sophisticated ways to manage water—things like water-cooled air conditioners, water-sprayed displays, plumbed-in devices and massive water systems in large buildings—the potential for things to go wrong increases. Even the sophisticated ways in which we now treat water to ensure its safety are not without risk. Treatment processes like desalination strip out micro-organisms and toxic chemicals, but also remove almost all minerals. One intriguing line of research explores whether reducing these minerals in our diet may be bad for us—with most concern around possible impacts on cardiovascular (heart) health.

Achieving *In aqua sanitas* sounds like a very basic goal. Surely countries just need to properly manage their water resources and ensure that everyone has reliable access to safe drinking water, basic sanitation and hand washing. Some countries have dealt effectively with this challenge for decades. So why is water still such a crucial health problem across the globe? The statistics are stark: In round numbers, only about half the world's households have either piped water or a simple latrine or toilet. It is hard to envision real progress without these two basic amenities. And the future does not look rosy. At the current rates of progress, in 2015 there will be more than 1.5 billion people living in households without piped water or a safe latrine.

### More of the Same Is Not the Answer

So is the solution simply more of the same—but faster? Drilling wells and constructing latrines; building piped water supplies and sanitary sewers? Likely not.

Experience shows that people do not value what they do not have a stake in—which leads to early breakdown and failure. So the efforts of many charities and foundations to drill communal wells in rural villages,



© AP Images

for example, do not help as much as they should—around 48 percent of wells in sub-Saharan Africa are out of action at any one time. In fact, it costs less and is more effective to improve simple operation and maintenance of existing infrastructure than to build more of it, although it's a far less spectacular task with fewer photo opportunities than inaugurating a new facility. What's more, the real benefit to households of an improved community well may not add up to much. If a new well is not much closer to home than the traditional water source, it may still mean a lengthy walk many times a day to collect water, taking time away from





work or school for (typically) women and children. Even if the well is properly constructed, evidence shows that the water is usually contaminated by the time it is consumed.

The sanitation problem is no more easily solved than the drinking water conundrum. For many people who live in developed nations, the flush toilet is so familiar that an alternative form of sanitation is hard to imagine. But it is an accident of history—born of the particular circumstances surrounding the sanitary revolution that occurred more than 100 years ago in what are now some of today’s industrialized countries.



Courtesy of USAID / Ika Francisca

And it’s not necessarily a good idea everywhere. The simple act of flushing a toilet means taking scarce water that could be used for other purposes, then treating and pumping it at great cost in order to flush away waste that then either requires treatment or goes on to pollute the environment. And sewers and flush toilets are expensive to install and to operate—so it is unlikely that they will be affordable or sustainable, at least today, in many parts of the world.

So what is the answer? Should we aim to develop the kinds of reliable piped water and sanitary sewerage services found in the urban areas of many emerging economies and across much of the developed world? For some areas, certainly, yes. But these solutions will not work everywhere and they are unlikely to be quick or sustainable fixes for many parts of the developing world.

Fortunately, there are some encouraging signs of new, innovative and exciting ways to respond to these challenges.

During the past 15 years, groups of researchers and practitioners in international agencies, academia and the private and nonprofit sectors have explored ways in which water can be treated at home and made safe to drink at very low cost. The solutions vary hugely:

- Disinfection of water in used bottles using sunlight.
- Disinfection with chemicals like chlorine from solutions or tablets.
- Filtration through sand beds, ceramic materials or sophisticated modern materials.
- Sacheted water treatment mixtures to deal with water one bucket at a time.

All these empower households that access water through wells or traditional unimproved sources such as rivers and streams (or even unsafe piped systems) to take control of their own health rather than—literally



Courtesy of World Water Corps / Water for the People / Jody Camp



© AP Images



Courtesy of World Water Corps / Action Against Hunger

# The Cost of Water

HOW DOES YOUR WATER COSTS COMPARE?



© National Geographic Stock / NG Maps

**Above left:** (top) Children are most vulnerable to water-transmitted diarrheal disease. (center) Entrepreneurial water salesmen like this Nigerian man help solve water sanitation problems in many parts of the world. (bottom) Children in Liberia show how they use a water pump.

### Water Cost to a Consumer by Municipality

Per 100 gallons, based on roughly 4,000 gallons a month usage, U.S. dollars, 2009

Kuala Lumpur MALAYSIA - \$0.10	Gaborone BOTSWANA - \$0.25	Tijuana MEXICO - \$0.26 to \$0.75	Perth AUSTRALIA - \$0.76 to \$1.75	Gent BELGIUM - \$1.76 to \$3.50
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**Tallinn**  
ESTONIA - \$0.11

**Moscow**  
RUSSIA - \$0.25

**Odesa**  
UKRAINE - \$0.17

**Yerevan**  
ARMENIA - \$0.30

**Damascus**  
SYRIA - \$0.01

**Ramallah**  
WEST BANK - \$0.50

**Cairo**  
EGYPT - \$0.03

**Dubai**  
U.A.E. - \$0.02

**Riyadh**  
SAUDI ARABIA - \$0.01

**Muscat**  
OMAN - \$0.05

**Addis Ababa**  
ETHIOPIA - \$0.09

**Nairobi**  
KENYA - \$0.20

**Kigali**  
RWANDA - \$0.01

**Lusaka**  
ZAMBIA - \$0.07

**Gaborone**  
BOTSWANA - \$0.25

**Johannesburg**  
SOUTH AFRICA - \$0.15

**Ulaanbaatar**  
MONGOLIA - \$0.05

**Beijing**  
CHINA - \$0.20

**Seoul**  
SOUTH KOREA - \$0.22

**Tokyo**  
JAPAN - \$0.74

**Tashkent**  
UZBEKISTAN - \$0.03

**Ashgabat**  
TURKMENISTAN - \$0.00

**Chongqing**  
CHINA - \$0.15

**Shanghai**  
CHINA - \$0.12

**Hiroshima**  
JAPAN - \$0.69

**Kumamoto**  
JAPAN - \$1.04

**New Delhi**  
INDIA - \$0.03

**Karachi**  
PAKISTAN - \$0.01

**Kolkata  
(Calcutta)**  
INDIA - \$0.00

**Hong Kong**  
CHINA - \$0.21

**Taipei**  
TAIWAN - \$0.11

**Hanoi**  
VIETNAM - \$0.06

**Bangalore**  
INDIA - \$0.05

**Ho Chi Minh City**  
VIETNAM - \$0.13

**Colombo**  
SRI LANKA - \$0.04

**Kuala Lumpur**  
MALAYSIA - \$0.09

**Manila**  
PHILIPPINES - \$0.16

**Singapore**  
SINGAPORE - \$0.01

**Jakarta**  
INDONESIA - \$0.26

**Perth**  
AUSTRALIA - \$1.59

**Brisbane**  
AUSTRALIA - \$1.80

**Sydney**  
AUSTRALIA - \$1.61

**Melbourne**  
AUSTRALIA - \$1.30

**Auckland**  
NEW ZEALAND - \$1.46

### Free Drinks

Politics often determine water fees. Regimes in Turkmenistan and Libya charge zero (and Cuba bills next to nothing) to burnish the leaders' power.

### Heading Up

Despite water shortages, China had kept fees low to stall inflation. Rates are now rising to promote conservation.

### New Delhi's Dilemma

Low prices aim to help the poor. But the perpetually broke water utility can't afford to service the slums, whose residents then pay inflated fees to private vendors.



© AP Images



© AP Images



Courtesy of World Water Corps / Water for the People / John Kayster

**Above right:** (top) Children play near stagnant, polluted water in Harare, Zimbabwe. (center) An economic crisis in recent years led to a cholera outbreak in Zimbabwe, where this boy is collecting water. (bottom) Children enjoying clean water.



Courtesy of World Water Corps / International Water Association / Brian Reed

and metaphorically—asking them to “wait in line” for an improved water supply to be offered at some distant future date. Some studies report dramatic health improvements—as much as a 60-percent reduction in diarrheal disease when these methods are used in disaster situations.

While the good news is that half the world’s population already has piped water at home, the bad news is that only a fraction of those water supplies are safe and reliable. Improving the way systems are managed to ensure water arrives safely and predictably 24 hours a day, seven days a week is a real challenge. Over the past two decades, an international group coordinated by the World Health Organization has combined managerial and scientific insights into the way water systems work. The result is a comprehensive management approach called “water safety planning.” Water Safety Plans adopt a preventive approach, so that problems are averted rather than detected and fixed only after contaminated water is distributed and consumed, as is the case with conventional monitoring. This approach has the potential to significantly reduce the costs of monitoring and analyzing water in laboratories—a savings useful worldwide and particularly in developing countries and remote settings, where these costs can be prohibitive.

### **A Role for Entrepreneurs**

More recently, commercial ingenuity and business entrepreneurship are coming to bear on otherwise intractable water and sanitation problems. For example, as the world becomes increasingly urbanized, supplying reliably accessible safe water is a growing challenge in the extensive shantytowns that surround many large cities. In the world’s slums, technical challenges often combine with economic constraints



and political tensions to confound development efforts. In several countries, water kiosks run by local entrepreneurs have started to emerge as a response. Selling safe water through kiosks has a dual benefit—shanty dwellers can access clean water close to home, and the entrepreneur can make a living. Less common, but perhaps even more exciting, some entrepreneurs are moving into piped water delivery—sometimes running small networks of hoses that provide water to nearby houses for a fee, in areas where these houses would have no prospect of securing piped water from the local utility.



© AP Images

Water and health combine historical and contemporary challenges and add future challenges to the mix. Greater demand for food and hence for irrigation places water resources under greater pressure than ever before. More and different industrial activity will introduce new pollutants into water. These and the uncertainty introduced by projected climate change will render the task of guaranteeing adequate water supply and sanitation ever more costly and complex. Ancient diseases such as cholera may re-emerge with new intensity if modern problems of pollution, population growth, urbanization and climate change make



Courtesy of World Water Corps / Water Aid / Brent Stirling

clean water an ever-scarcer resource. As we introduce new ways to manage water for health, these methods may themselves pose new challenges and create unanticipated effects.

Water is a precious resource, fundamental for life and health. The rich history of efforts to provide people with water and sanitation provides us with only limited guidance for the 21st century. A Korean proverb says *The water downstream will not be clear if the water upstream is muddied*. Those who work upstream—in policy, government, media and program development—must make water and sanitation a priority, and seek new and innovative solutions in partnership with the billions living downstream, to make *In aqua sanitas* a reality in our lifetimes.

*Jamie Bartram, Ph.D., is a public health professor at the University of North Carolina at Chapel Hill and director of the Water Institute at UNC. He spent 10 years with the World Health Organization in areas related to water and health and has more than 20 years of public policy experience working in more than 30 countries. In 2004, Bartram received the International Water Association's Grand Award for his achievements.*

*Barbara Wallace, MPH, is director of corporate and foundation relations for the School of Public Health at the University of North Carolina at Chapel Hill. She has directed and advised HIV/AIDS initiatives for CARE USA, the state of Georgia and the Federation of Red Cross and Red Crescent Societies in Geneva, and she was a deputy director in the British National Health Service.*



Nothing is hopeless, we must hope for everything.

Euripides ~ Greek philosopher ~ ca. b.480=d.406 B.C.

# THE MOST INDECENT WORK

## Unsanitary Occupation Called Disgraceful

HARRIETTE NAA LAMILEY BENTIL • DICK DE JONG

**S**eventeen years later after their country passed a law making the health-threatening occupation illegal, some 1.3 million Indians still earn a living by performing the degrading and dangerous job of cleaning up human excrement by hand. Manual scavenging entails cleaning latrines and carcasses of humans and animals with bare hands. The United Nations Commission on Human Rights has described it as the most indecent form of work.

Without any protective clothing—such as boots, masks or gloves—manual scavengers clean toilets and clogged sewer lines. They collect fecal matter in baskets lined with leaves, and many are left sick.

About 80 percent of these workers are women, and the majority are Dalits, a collection of communities that were denied any caste status in India's traditional social hierarchy. They are paid roughly 900 rupees (\$19.32 USD) a month and can afford only cheap drugs to treat their illnesses.

According to WaterAid America, a U.S.-based nongovernmental organization (NGO), India's teeming cities lack the infrastructure for sewage removal, but a recent report from the organization points to caste prejudice as the reason that little progress has been made in stopping manual scavenging.

### Like a Priest Predestined to Preach

In modern India, manual scavengers are still cleaning the waste of people who “discriminate against and look down on the scavengers,” according to Wilson Bezwada, founder of a program aimed at ending



the practice. Bezwada, who comes from a family who worked as scavengers, started Safai Karmachari Andolan, a national campaign aimed at challenging the links between caste and occupation. “Through eradicating manual scavenging,” he says, “we will break the link imposed by the caste system between birth and dehumanizing occupations. It is a matter of human dignity.”

His movement is working in 18 Indian states. “No human being should carry someone else’s shit,” Bezwada said at the 2009 Stockholm Water Forum.

Since 1986, the movement has engaged in protracted struggles. One is to change the mindset of scavengers, many of whom believe that, in the words of Bezwada, “like a priest who is predestined to preach, we are predestined to do this work.”

But for most of the scavengers, the work is hideous. “We have not yet told our children what we do.

They won’t understand; there is no pride in it,” a female scavenger said.

In September 2008, women from scavenging communities in Madhya Pradesh and Gujarat states met with the National Human Rights



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© Getty Images / AFP / Douglas E. Curran

Commission (NHRC) in Delhi to demand dignity for their labor. They asked for a revision of existing laws and policies to counter manual scavenging.

#### **Lack of Government Support**

Bezwada believes the Indian government has not demonstrated enough commitment to liberating those who perform a job that does not legally exist.

Ashif Shaikh of Rashtriya Garima Abhiyan, an NGO working with scavenger communities, says that existing surveys of the practice have provided an incorrect and misleading picture of the numbers of people involved, and that most states have underreported them.

But the situation is not all gloomy. Bezwada said Safai Karmachari Andolan has helped a number of manual scavengers obtain alternative livelihoods, and the collective efforts of NGOs in the country have reduced the number of scavengers from 2 million to 1.3 million.

Bezwada has become an icon of hope for the hopeless as he strives to create alternatives for manual scavengers. For him, the struggle will not end until every single person is liberated from working as a scavenger. “This is not a fight for power, wealth nor fame, but for human dignity and respect,” he said.

*Harriette Naa Lamiley Bentil is a senior environmental reporter with the Daily Graphic newspaper in Accra and a member of the Ghana Wat-san Journalists Network (GWJN). Dick de Jong is an information and communication officer with the IRC International Water and Sanitation Centre, and is chief editor of Source Bulletin.*





**Above:** In polluted water, garbage dumps and open streets, India's scavengers engage in what the United Nations Human Rights Commission has called "the most indecent form of work." Thanks to the collective efforts of organizations across India, hundreds of thousands have found alternative livelihoods, including the women pictured at the bottom left.



No one can see their reflection in running water.  
It is only in still water that we can see.

~ Taoist proverb ~

# BETTER SANITATION LEADS TO NEW CAREER

## Success Making Toilets in Vietnam

DICK DE JONG

**T**he story below was excerpted from a study conducted 2½ years after a pilot project had been implemented to encourage rural residents in Thanh Hoa and Quang Nam provinces, Vietnam, to improve sanitation. The IRC International Water and Sanitation Centre from the Netherlands and ADCOM Consultants in Hanoi conducted the study. Dr. Christine Sijbesma of IRC and Dr. Truong Xuan Truong of ADCOM were the team leaders.

Thuy Thanh Ky is a mason in the Quang Nam province of Vietnam. He is 43 years old and has completed secondary school education. He has a wife and four children. Thuy, from Binh Trieu Commune in the Thang Binh District, was a poor farmer until he took up part-time masonry in 1996 to make some extra money. His business went well, and after two years he became a full-time mason. Until 2001, he worked with a group of seven or eight other masons, mostly close friends and relatives.

They started with some small contracts to build houses, and at the beginning, most of the houses did not include toilets. In 2003, the demand for sanitary toilets in the home began to increase, so Thuy decided to concentrate on building them.

Thuy and his fellow masons learned their trade through the Rural Sanitation Marketing Project and International Development Enterprises (IDE), the nongovernmental organization



that ran the project. Even though Thuy did not participate directly in the program, he benefited indirectly from its existence.

Thuy obtained a copy of the project's manual and studied the recommended models. He also learned from masons who had received training. As his contacts in the commune and his technique improved, he got more contracts for building toilets, not only in his own commune, but also in others.

### Success after the Program

Customers choose Thuy because his skills are good and he offers a good mix of price and quality. He has built a business network and can draw on other area masons if he needs to share work.

He also is part of a working group of about 20 masons who build about eight toilets per month, working in pairs. His family income has increased and his life is better. Some customers are



**Above:** This is a brochure (*front side*) for potential participants in a rural sanitation program of the IRC International Water and Sanitation Centre from the Netherlands and ADCOM Consultants in Hanoi. Text translation—(*right panel*) Under symbol (boy with toilet)—“Sanitation; Civilization; Health” (*center panel*) Main heading: “Sanitary toilet: fellow traveler of families’ future happiness”; “For further information, please contact the following address” (*lines to write in address*). (*left panel*) “Choose for your family one prototype of these toilets: Double vault composting toilet: • without water • feces can be used • low construction costs; Single vault pour flush toilet: • can be constructed close to or inside the house • needs a sufficient supply of water • reasonable construction costs; Septic tank toilet: • can be constructed close to or inside the house • needs a sufficient supply of water • high construction costs **Courtesy of RWSSP**

**Below:** A resident in the Quang Nam province of Vietnam discusses his new toilet with an inspector. Demand for toilets grew in the early 2000s, offering local masons new business opportunities. **Courtesy of RWSSP**



**Above:** Same brochure (*opposite side*). Text translation—(*right panel*) Toilets are sanitary only when you know how to maintain them: Clean the toilet often, Put water and soap near toilets for hand washing, Build or upgrade toilets to protect health and happiness for you and the people. (*center panel*) Sanitation/Health: • Save time and money from buying medicines • Children’s feces are as dangerous as adults’ feces. Civilization/Privacy: • Convenience when guests are coming over • No smell for your family and neighbor. Convenience/Safety: • Can use at any time • Safe fertilizer storage • No pollution to water sources and the environment. Be A Model Family In A Cultured Village (*left panel*) Diagram showing: • People’s feces contain very dangerous germs • Diarrhea, dysentery, typhoid, hepatitis, parasitic worms • Sickiness, labor force reduction • Money wasted to buy medicine and for health treatment • Poverty **Courtesy of RWSSP**

**Below:** Researchers with IRC International Water and Sanitation Centre and ADCOM Consultants interviewed sanitation promoters such as this plumber in Hanoi. **Courtesy of RWSSP**





late in paying, but as they are people from his own commune, he is not worried. To his great happiness, his oldest son is following in his footsteps and has also become a mason.

*The World Bank Water and Sanitation Program and the Rural Water Supply and Sanitation Partnership in the Vietnamese Ministry of Agriculture and Rural Development sponsored the pilot project. International Development Enterprises ran the project between January 2003 and December 2006. Dick de Jong is an information and communication officer with the IRC International Water and Sanitation Centre.*

**Left and Below:** Access to sanitary water is only part of the solution to health problems in countries such as Vietnam. Good hygiene practices—including bathing and washing clothes—are also needed. **Courtesy of RWSSP**





*Il n'y a rien au-dessus qui ne soit des cieux!*

*[There is nothing above that is not heaven!]*

© iStockphoto.com / d.1813



# Alexandra Cousteau

“TO LEAVE A BLUE LEGACY”



The noblest of the elements is water.

Pindar ~ Greek poet ~ ca. b.522–d.433 B.C.

*Above:* In 2008, Alexandra Cousteau founded Blue Legacy, a nonprofit organization dedicated to making water one of the defining issues of the century. Capitalizing on the expansion of interactive media, the Expedition Blue Planet voyages seek to illustrate the connectedness of water by bringing to life stories and places that many people never have experienced. © Shutterstock / Danychenko Laroslav



# EXPEDITION BLUE PLANET

## Environmental Storytelling

ALEXANDRA COUSTEAU

Water is Earth's great storyteller.

It is a barometer of sustainability and the canvas on which our struggle to maintain balance traces shaky arcs that ripple throughout our systems. And it is within these telling ripples—the shrinking surfaces of our ice stores, the fluctuating flows of our rivers, the shifting patterns of precipitation, and the rising of our seas—that we are discerning the effects of climate change first.

In the face of such a challenge, we can't afford to continue dealing with water issues in isolation. We can't continue to make the focus of our conversation on water just about the fragility of coral reefs, the scarcity of free-flowing river habitats or the depletion of fish stocks. We can't continue to separate protecting fresh water of a single region from protecting the world's oceans. We have to return to the simple truth so many of us learned in grade school earth science courses: Our planet's hydrosphere is a single, interconnected system.

For the first time in history, humans have the ability to reach far beyond their local environs to consume and affect water in places their eyes will never see and their feet will never touch. We have expanded our consumption to the farthest points of the Earth and plumbed the depths of our oceans. Carefully crafted, that reach can end the ancient scourges of hunger, thirst and abject poverty, as resources and technology from one region provide sustenance for another, and the exchange generates opportunity for progress.

But when our reach is out of balance, our nearly insatiable quest for profit and resources drains ancient water reserves to irrigate industrial



crops. It scrapes the oceans bare to gather a few marketable species. And it propagates a willful ignorance to the impact of our waste, as if science ends at the exhaust pipe or does not reach into the watershed or past the boundaries of property lines or arbitrary jurisdictions. Out of balance, our thirst exhausts our ability to reason. Out of balance, our reach exhausts our resources. And we are out of balance.

### The New Perspective on Global Water

Nearly every system that shapes the availability and quality of water on our planet is dramatically and historically out of balance. From the phosphorous and nitrogen cycles, to the carbon cycle, to local ecosystems and more, our century of progress has largely ignored the simple principles of basic grade school science: Our interconnected hydrosphere puts us each quite literally downstream from one another.

The view my grandfather commanded from the deck of the *Calypso* for a good deal of the past century and the images Neil Armstrong brought us from space helped put our water planet into perspective. Indeed, 70 percent of Earth is covered by water. But only a tiny percentage



of that water is available for human consumption. In fact, if you could fit all the water in the world into a gallon jug, less than a teaspoon of that would be available for our use. Our actions throughout the water cycle dramatically affect that tiny teaspoon. And with climate change escalating and water cycles out of balance, that teaspoon is shrinking.

Our water crisis is a global issue—a human issue. It isn't going to be fixed by scientists or policymakers alone. It's up to each of us...to all of us. This realization was the beginning of a new era in my work.

### **The Blue Planet Expeditions**

Called to this legacy, I have dedicated my life to continuing the environmental storytelling tradition of my father and grandfather. My work took a decidedly global scope when Blue Legacy, the nonprofit I founded in 2008, secured funding to launch our first expedition in February of 2009.

Traveling from the oceans that in so many ways have defined much of my family's history, I made my way to the roof of the world—to the Himalayas, where the tallest mountains on Earth rise and seven great rivers begin—to explore the global interconnectivity of water. Fed by the snow and ice blanketing these stunning peaks, the Ganges, Mekong,

Yangtze and their four sister rivers support a stunning 2 billion people—nearly one out of every three people in the world.

Our yearly expeditions take us on the road more than 100 days at a time. We tell stories from the field and produce multimedia content that is distributed through a network of 30,000 media partners, including small blogs, websites such as Mother Nature Network and major outlets such as National Geographic.

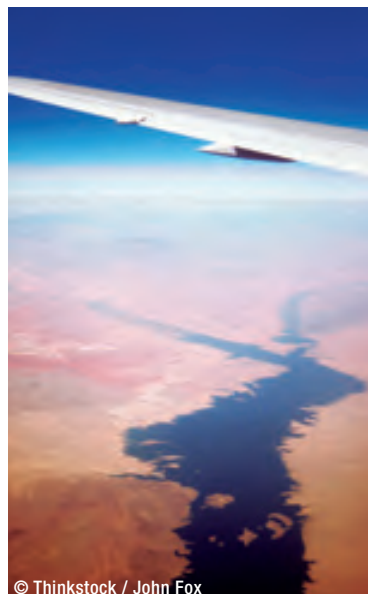
Capitalizing on the expanse of interactive media technology, Expedition Blue Planet seeks to illustrate the connectivity of water by taking the audience into the field. Blending new media, social media and traditional media allows our team to bring to life stories and places that many have never experienced. As the expedition unfolds, our team develops a library of daily content in front of our audience.

Our second journey, Expedition Blue Planet 2010, focused attention back home, on the status of water in North America. My team of environmental filmmakers, photographers and editors and I set out on a 138-day, 23,000-kilometer journey across the United States and Canada to explore water issues in our own backyard and to highlight successful local efforts to restore watersheds and protect our most precious resource.

Traveling from the northern stretches of the Colorado River, across canyons, deserts, mountains and prairies to the coral reefs of



© Thinkstock / John Fox



© Thinkstock / John Fox

Florida, our team experienced more than six distinct ecosystems and worked in urban, wilderness and ocean environments.

In our 14-meter custom biodiesel bus—which served as headquarters, high-tech editing lab and broadcast suite—my team and I also explored the Tennessee River Valley, the Great Lakes region and the Chesapeake Bay. We teamed with local organizations to host working days of awareness and action, listening to stories and experiencing the lifestyles of local people who know these water systems intimately.

In this way, Expedition Blue Planet 2010 engaged people in environmentalism and exploration as few have done. When we were not filming and editing, artists, musicians, writers and celebrities joined us in 10 to 15 cities for the watershed awareness and action days, and we joined residents to highlight their work on local restoration projects. All too often, we as Americans are inclined to think the water crisis is happening to “them,” “over there,” “far away,” when in fact we are all affected.

Region by region, my crew reached out to communities to experience and document peoples’ relationships with water. Region by region, we posted interactive media to a broad range of online sites, mapping our expedition, quite literally, to tell the stories that were so strikingly told to us, ultimately producing an elaborate and eclectic patchwork quilt of water experiences.

With a map of our travels, our stories and our work, it’s easy to recognize the intricately interlaced connections we share worldwide—connections that pay no heed to the undeniable and seemingly significant differences in our cities, seasons and local climates. Stepping back and looking at the map of our travels, one thing is explicitly clear: We are all connected by water, and by the health of water.



Courtesy of Blue Legacy International

So it could be said that the challenge for my generation is largely about establishing a new water perspective and ethos recognizing that the regionalized and “compartmentalized” understanding of water has led to many of the poor management practices we have as a society. Our insistence on confining water policies and water rights into the autonomous circles of “agriculture,” “energy,” “industrial use,” “human consumption,” “rivers and streams,” “oceans” and so on has led to wholly independent and often entirely incongruent systems of standards, measurements and practices.

Confined to neat bubbles of discussion and management, we’ve failed to build and maintain intelligent infrastructure, and too often, in our pursuit of progress, we’ve completely destroyed the water-shaping ecosystems that could have provided sustainable solutions. It truly is time for us to redefine what it means to live sustainably on a water planet.

*Alexandra Cousteau, member of a family with a tradition of seafaring and water conservation, founded Blue Legacy International in 2008 to “tell the story of our Water Planet by focusing on the interconnectivity of water issues.” The organization develops and distributes traditional and new media projects to inspire audiences everywhere to take action on critical water issues.*



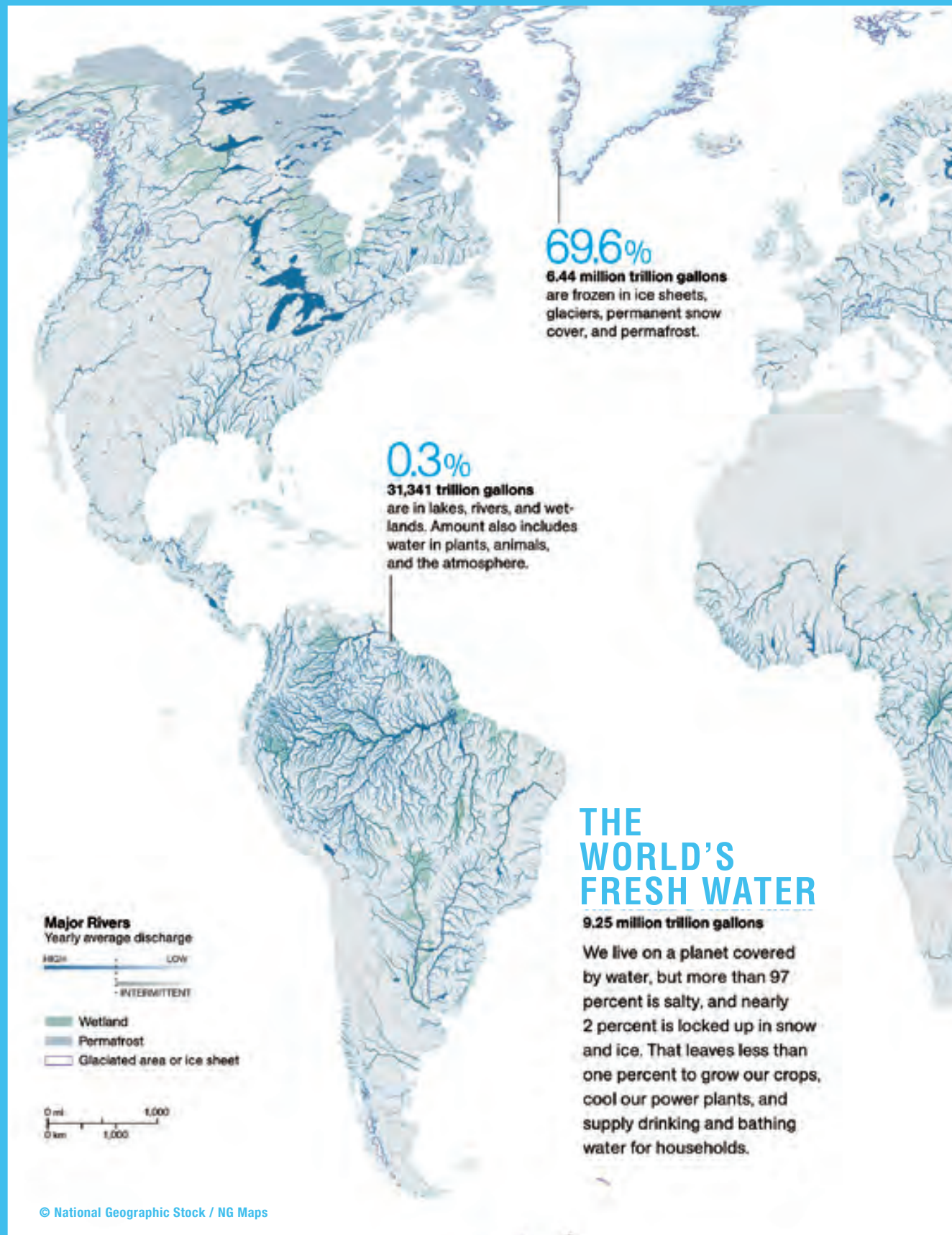
Courtesy of USAID / Mahabat Alymkulova

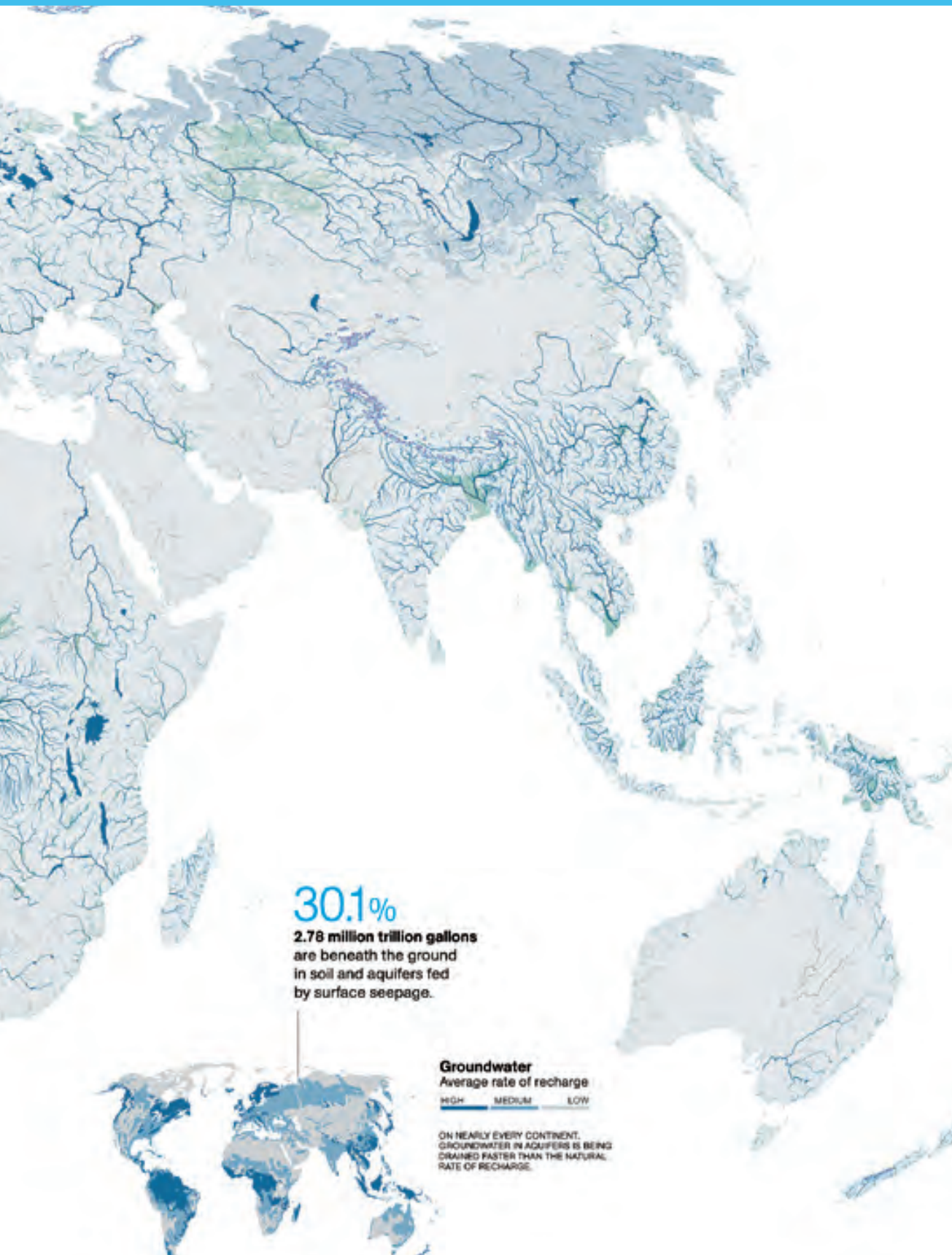


Courtesy of USAID / ADRA / Tereza Byrne



© AP Images





**Above right:** Better access to sanitary water is improving the lives of families in Nepal (*top*), Senegal (*center*) and Kazakhstan (*bottom*).



## Water sustains all.

Thales of Miletus ~ Greek philosopher ~ ca. b.624–d.546 B.C.

**Above:** Water streams over the face of Pronh Kin as she receives a blessing the same way kings and commoners of Angkor's glory days did. © Corbis / Fritz Hoffman

# WRIT IN STONE

## Adapting to Climate Change

ALEXANDRA COUSTEAU

When we think about the future we all too often forget to look at our past. When my mind wanders down muddy pathways into the jungle that reclaims the ruins of the once majestic Angkor Empire, I am poignantly reminded that there's a lesson in those fallen temples we should hear today.



**Above:** Storm clouds hover above the ancient ruins of Angkor. The Khmer capital, once the largest city on Earth, crumbled when drought caused the city's water supply to dwindle. © Shutterstock / seanyuan



### From Metropolis to Village

The metropolis of nearly 1 million people was, in its day, the largest city on the planet. Khmer rulers engineered an ingenious system of canals and reservoirs to store water from the rainy season. With a predictable climate and reliable water infrastructure, the empire became a dominant agricultural producer and built wealth that drew ambassadors from China and, as recent excavations by French archaeologists seem to indicate, trade from as far away as modern-day Iran.

And then everything changed. Tree ring studies, along with pollen and plant specimens preserved in the mud of the once great reservoirs, paint a picture—the dependable patterns of rainfall shifted sometime around 1350 due to climate change. Evidence indicates at least four efforts to alter the system to make up for what was no doubt thought of as a simple pattern of dry years.

Without sophisticated means of predicting an event like climate change and a water system quite literally set in stone, there was little the people of Angkor could do to alter their infrastructure fast enough



to keep pace with the city's thirst. It was chilling to walk down dry riverbeds and see falling ancient arches made of intricately carved stones stripped from once-sacred temples in a futile attempt to keep pace with the changes. In fewer than 100 years, only small villages remained as citizens fled the golden spires of their great city in pursuit of water.





### Water and Climate Change Today

Global climate change is an absolute reality. Fueled by a century of carbon, our current climate change is already ahead of models and picking up speed at a dramatic pace. As in Angkor, its effects will be felt first in water. And while global consumption increases and politics



debate, the global community races down a collision course with history—possibly doomed to be remembered by the same epitaph that marks the ghostly ruins of the once great Angkor Empire: Unsustainable consumption of resources, mismanagement of critical infrastructure and destruction of water-shaping ecosystems during a period of climate change lead to collapse.

The Khmer people may not have understood what they were risking, but we do. Water is the defining challenge of our century, and unless we commit as consumers and speak out as citizens, those who will someday examine our collapse will not marvel at the grandeur of our cities but at the foolishness of our choices. I challenge you to join me in not only embracing new habits and technology to conserve water, but in also insisting governmental leaders commit to meaningful climate policy.

*Alexandra Cousteau, member of a family with a tradition of seafaring and water conservation, founded Blue Legacy International in 2008 to “tell the story of our Water Planet by focusing on the interconnectivity of water issues.” The organization develops and distributes traditional and new media projects to inspire audiences everywhere to take action on critical water issues.*

# IMPERIAL ANGKOR

ITS VAST WATER SYSTEM WAS A MARVEL OF ENGINEERING—AND A CAUTIONARY TALE OF TECHNOLOGICAL OVERREACH.

At its height in the 13th century (depicted in this reconstruction), the capital of the Khmer Empire was the most extensive urban complex in the world. Using imaging radar and other tools, researchers have learned that Greater Angkor covered almost 400 square miles, roughly the area of the five boroughs of New York City, with as many as 750,000 inhabitants. Most were rice farmers and laborers who worked the giant jigsaw of fields. In the city center, perhaps 40,000 people—elites and farmers alike—lived within the walls of Angkor Thom, a 3.5-square-mile enclosure with temples and a royal palace. Though the rainy season usually brought ample water, the ability to store water in great reservoirs called barays and control its flow gave Angkor an edge in times of drought or flood. But this engineered landscape required constant maintenance. When the water system faltered, so did Angkor's power.

## ANGKOR'S COMPLEX PLUMBING

In Southeast Asia, months of monsoon rains are followed by months of near drought. To ensure a steady water supply, stabilize rice production, and control flooding, Khmer engineers built a network of canals, moats, ponds, and reservoirs. Massive earthworks slowed the wet-season deluge flowing from the Kulen Hills, directing it into canals that fed the barays and temple moats. Spreading across the gently sloping land, the water drained finally into the Tonle Sap, the largest freshwater lake in Southeast Asia.

ART BY STEVE CONDEN. INSET ART BY TOM CHANDLER AND MICHAEL BROOY DITTMORE AND LISA R. WITTEK. NG STAFF. BASE MAP OF SYDNEY AND CHRISTOPHE POTTER, FRENCH SCHOOL OF ASIEN CONSULTANT; ROLAND FLETCHER, UNIVERSITY OF SYDNEY. SOURCES: EFO; GREATER ANGKOR PROJECT, A COLLABORATION OF UNIVERSITY OF SYDNEY. SCALE: VARIOUS IN THIS PERSPECTIVE. LENGTH OF EAST BARAY IS 4





### SACRED SOURCE

The Kulen Hills sheltered the headwaters of the Siem Reap River and were quarried for rock to build Angkor's temples. The hills were logged for timber and firewood and to clear land for farming; deforestation may have caused floods that choked some of Angkor's canals with sand and silt.



### LIFE IN A SEA OF RICE

On raised ground between fields, Angkor residents built timber houses on stilts. They planted palms and other trees to provide shade, fruit, and fronds for annual roof replacement. Ponds collected water during the wet season; during dry months water from the main canals fed the fields. Each community had a shrine (at bottom left), where priests may have helped mediate water use.



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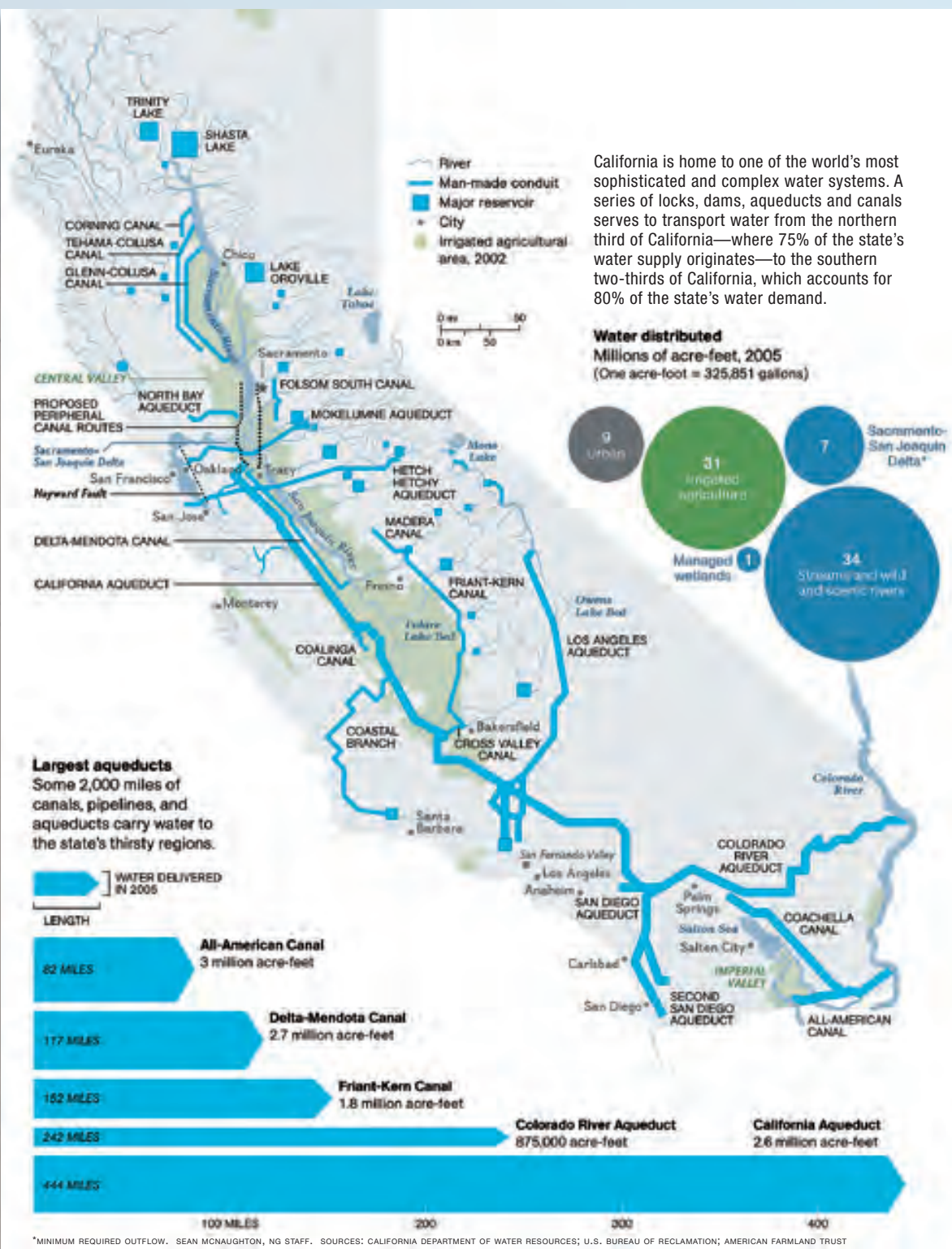


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California is home to one of the world's most sophisticated and complex water systems. A series of locks, dams, aqueducts and canals serves to transport water from the northern third of California—where 75% of the state's water supply originates—to the southern two-thirds of California, which accounts for 80% of the state's water demand.



# REPLUMBING CALIFORNIA

## A Modern Day Wonder of the World

© National Geographic Stock / NG Maps

**Above: (left)** The diagram and map show the massive amounts of water transported across great distances in California. **(center top)** The Glen Canyon Dam on the Colorado River is only one piece of California's water puzzle. **(center middle)** Much of the state's agricultural irrigation depends on water from the canals, including this field of poppies. **(center bottom)** The state has built a water system that uses waterways, such as the canal that runs along portions of Interstate 8, to bring water to where it is needed.



© Shutterstock / Michael Woodruff

**Above right:** Water pumped from local rivers and streams protects California's vineyards from frost, but the practice has diminished water wildlife. In a state where water demand often outstrips supply, a delicate balance must be struck between agriculture and environment.



# It's all about water.... Water is life!

Onkokame Kitso Mokaila ~ Minister of Environment, Wildlife and Tourism / Botswana ~ 2009

# THE OKAVANGO DELTA

## A Model for Water Resource Management

ALEXANDRA COUSTEAU

# W

riting about the Okavango Delta in Botswana, it is tempting to present a package of clichés wrapped in hyperbole and tied up with a bow of abundant adjectives: The most magnificent place on Earth! A pristine wilderness, such as hardly exists anymore on our planet! A journey back to the dawn of time!

Yet all these remarks are true. In fact, anything one might say about the Okavango would seem an understatement. No amount of reading about this natural wonder or gazing longingly at photography books could have prepared me for what I experienced when I visited the Okavango for Expedition Blue Planet in 2009.

The miracle of the Okavango is water, an oasis in a country that is 85 percent covered by the Kalahari thirst land—the largest continuous stretch of sand on Earth, where 9,000 million cubic meters of water flow annually from the rainy highlands of Angola through Namibia. When it hits a depression between two fault lines in northern Botswana, the water spreads like the fingers of a hand, forming an alluvial fan. What makes the Okavango unique is that instead of emptying into an ocean or lake as other deltas do, the water nourishes a wide range of plant life and evaporates, fading into the bone-dry reaches of the Kalahari.

Okavango has remained one of the most pristine wetlands on Earth. Wildlife freely roams the largely undeveloped delta. One might imagine that in Botswana, a country the size of France with a population of just 2 million, competition for the water of the delta is not that



fierce. But such is not the case. The Okavango River basin extends some 700,000 square kilometers across three countries: Angola, Namibia and Botswana. Not only does the delta face threats from humans for agricultural interests, but the water flow is threatened by river diversion for dams and freshwater supplies by neighboring countries to the north.

### A Collaborative Effort

Fortunately, the people of this region understand the importance of protecting the delta, and they work together to ensure its costs and benefits are shared equally. An agreement signed in 1994 committed Angola, Namibia and Botswana to coordinating environmentally sustainable water resources development, while also addressing the socio-economic needs of each country. In fact, one of the reasons I wanted to come to the Okavango Delta was to explore the rare and admirable cooperation between these nations.

One morning my crew and I had a meeting with members of the Permanent Okavango River Basin Water Commission (OKACOM). Portia Segomelo, who represents Botswana on the commission, explained, “The thing that brought us together is the principle that



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water is life. Regardless of where you are sitting, or the boundaries of countries, there will always be a need for water.... In Botswana, we have the benefit of the tourism industry because Angola and Namibia allow water to flow here. So we share those benefits, investing in research and management of the water resources.”

The process has been long and expensive, she said. It has been challenging to ensure that everyone’s views are represented, but the advantages have been immeasurable. “We have not fought over water yet,” she said. “We see water as a source of cooperation.”

### Maintaining Balance

The delta is a place where the indigenous people known as San live in much the same way as their ancestors. They historically have made a life for themselves in the grassy, undulating desert part of Botswana.

The delta also is a place where some of the Earth’s largest herds of elephant roam, where hyenas slink while lions roar, and where thousands of migrating egrets, herons and storks raise a constant din in their breeding grounds. It is a place in balance.

As with all watery places on this blue planet, that balance is delicate. A growing population and agricultural interests thirst for the water—as do the neighboring countries where the delta’s water originates. Thankfully, Botswana is blessed with a stable government that works to protect the delta and maintain its balance. The government is considered a model for careful management of the environment, which is valued as a precious resource as well as a major source of tourism-generated income.

During our expedition, Onkokame Kitso Mokaila, Botswana’s minister of environment, wildlife and tourism, discussed the importance of involving all stakeholders, including representatives of agriculture, fisheries, tourism, wildlife, cattle ranchers and the people of all three countries. He expressed pride in his country and its president, Lieutenant General Seretse Khama Ian Khama, whom he said “is a conservationist through and through.”

“We have a saying,” Mokaila said. “Every river has its people.... It’s all about water. It’s all about water. Maybe in some countries water is taken for granted. For us it’s not because it’s not readily available. It’s like gold to us. Water is life!”

*Alexandra Cousteau, member of a family with a tradition of seafaring and water conservation, founded Blue Legacy International in 2008 to “tell the story of our Water Planet by focusing on the interconnectivity of water issues.” The organization develops and distributes traditional and new media projects to inspire audiences everywhere to take action on critical water issues.*





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Courtesy of Blue Legacy International



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**Above:** The Okavango Delta teems with African wildlife. (clockwise from top left) Elephants bathe and drink; Cousteau takes a tour with local expert Map Ives; African buffalo splash; blue wildebeest graze; hippos head to shore; red lechwe dash through shallow water; a lion couple rests; a yellow-billed stork hunts; a saddle-billed stork forages for food; and zebra remain alert. (center) A baboon enjoys a taste of vegetation.

Berlin 1995



Plans to protect air and water, wilderness  
and wildlife are in fact plans to protect man.

Stewart L. Udall ~ U.S. Secretary of Interior ~ b.1920–d.2010

**Above:** Representatives from more than 130 countries gathered in the Berlin Congress Center for the opening session of the 1995 U.N. Convention on Climate Change. Delegates agreed on the dangers of inaction, but were unable to reach a binding agreement to reduce global greenhouse gas emissions. The challenges of climate change are not only economic and structural, but political. © AP Images / Jan Bauer

# Conference of the Parties



## The Politics of Water





Water links us to our neighbor in a way  
more profound and complex than any other.

John E. Thorson ~ Administrative Law Judge ~ California Public Utilities Commission

# TRANSBOUNDARY WATER

## The Geopolitical Struggles for Control

FRED PEARCE

Water will be one of the crucial issues of the 21st century. Once, we took water for granted. Increasingly however, water is not available where we need it or when we need it, and in a growing number of regions, scarce water supplies are limiting development and threatening food security.

Some of the world's largest and best-known rivers no longer reach the sea in significant volume for part of the year.

Many rivers—the Indus in Pakistan and the Nile in Egypt, the Yellow River in China and the Ganges in South Asia, even the Colorado and the Rio Grande in North America—are being exhausted by water-hungry crops and taps in burgeoning cities. Two-thirds of the water used worldwide irrigates crops. The United Nations Food and Agriculture Organization concludes that “water rather than land is the binding constraint” on crop production in at least a third of the world. Climate change is almost certain to worsen what is fast emerging as a world water crisis.

The International Water Management Institute, a World Bank-supported research agency in Sri Lanka, estimates that 25 percent of the world's river systems run dry before they reach the sea, causing negative impacts on human livelihoods and ecosystems. Perhaps the most egregious example is the drying of the Aral Sea in Central Asia. Large-scale irrigation systems set up during the Soviet era to grow cotton in Uzbekistan, Turkmenistan and Kazakhstan have virtually halted the flow of water to what was until a half century ago the world's



fourth-largest inland sea. Fish can no longer survive in the remaining saline sump, and former coastal fishing ports like Muynak in Uzbekistan are now 100 kilometers from shore. Left behind is largely uncharted desert. Without the moderating influence of the sea, local climates are more extreme, and dust storms from the dry seabed blow salt and chemical residue from farms across surrounding countries.

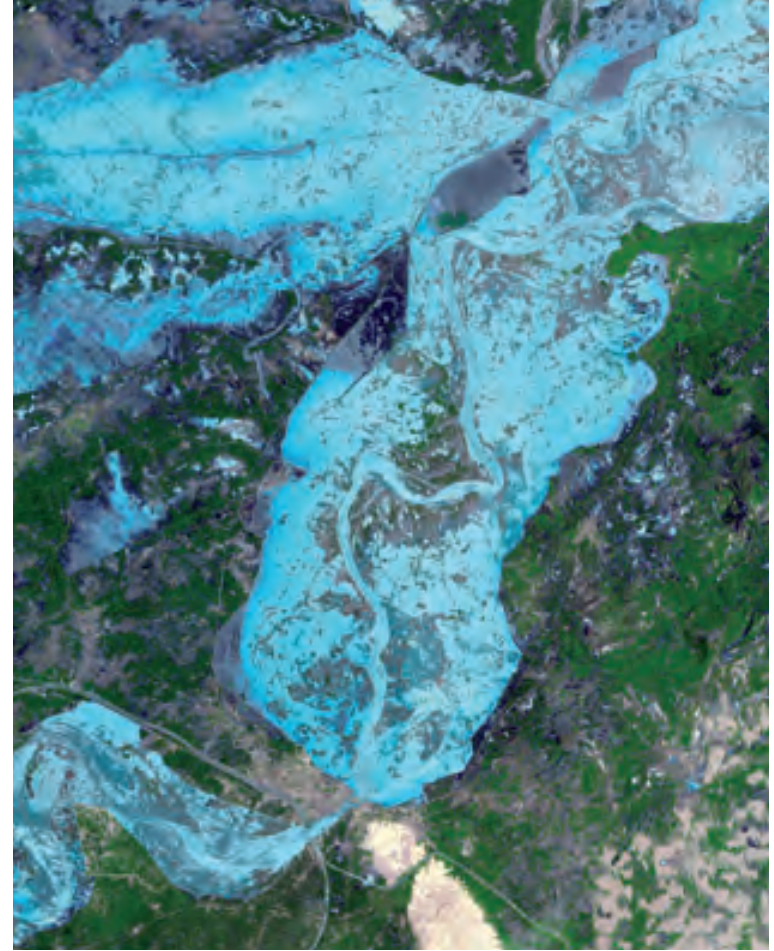
Until recently, water management was seen as a supply-side endeavor: Building dams, treatment works and irrigation ditches provided more water and solved water shortages. But where urgent water shortages are emerging, supply-side solutions are no longer possible. One way to make better use of variable natural water supplies is to store water, typically behind large dams on major rivers. Storage capacity varies around the world. The Murray-Darling river basin in Australia has dams capable of holding 500 days of river flow. But the Indus in Pakistan—a similar-size river basin in a similarly arid environment—has a storage capacity of just 40 days.



### THE THIRD POLE

No single landscape defines the Tibetan Plateau region, a tangle of mountains, rivers, forests, lakes, and high plains. Sometimes called the Third Pole, it is a lockbox of snow and glacial ice that supplies fresh water to nearly a third of the world's people.

**Above:** Climate change may cause snowfields and glaciers to melt faster, decreasing reserves of water. This means that people who live downstream will need to conserve and store water for dry seasons. The high altitudes and low latitudes of the Tibetan Plateau make it especially sensitive to climate shifts. © National Geographic Stock / Allan Cartography Inc. and Jerome N. Cookson, NG Staff



Not all regions have the potential and technology to increase storage capacity. Where rivers are running dry, new dams will only take water from one set of users and give it to another. And in many river systems, the best sites for dams (generally in steep river valleys) are already being used.

The World Bank estimates that Africa has only 20 to 25 percent of the water storage capacity it needs, making countries like Kenya vulnerable to drought. This can have a devastating effect on a country's economy. In 2005, for example, drought reduced Kenya's gross domestic product by 16 percent.

### Sharing Water across National Borders

Water shortages also create international tensions. Almost half the world's population lives in river basins that straddle borders. For instance, there is no agreement on sharing the waters of the Tigris and the Euphrates, which flow out of the mountains of Turkey—where dams are being built—and into arid Iraq. An international treaty signed at the United Nations a decade ago set a framework for resolving disputes over shared water resources, but it has not been ratified by enough nations to come into force.



© AP Images



© AP Images

Africa has 80 transboundary rivers. Two-thirds of the world's transboundary rivers are not covered by water-sharing treaties. In Africa, the existing agreement on sharing the waters of the Nile, which runs through 10 countries, is more than a half century old. The agreement favors downstream Egypt and Sudan and is widely regarded as illegitimate by upstream countries. Long-running talks aimed at developing a new agreement have achieved no success.

As rivers run dry, the world is increasingly relying on underground water reserves, some of which are thousands of years old. In densely populated Asia, these reserves are being overpumped, thereby threatening future supplies. Worldwide, we are “mining” some 200 cubic kilometers of water a year. Half a billion people are consuming wheat, rice and other crops irrigated with water reserves that are not being replenished.

India faces particular problems. With surface water supplies failing, farmers have sunk more than 20 million tube wells beneath their fields in the past 15 years. They pump an estimated 100 cubic kilometers a year more water than the rains replace. Water tables are falling fast. An estimated quarter of India's food crops are grown using water from overpumped aquifers.

Like rivers, some critical underground water reserves in arid regions straddle international boundaries. Jordan and Saudi Arabia, for example, share the Disi aquifer. The vast Nubian basin reserve beneath the Sahara desert lies below parts of Libya, Egypt, Sudan and Chad. Man-

agement of the water stored in rock pores beneath the West Bank is another source of tension between Israeli and Palestinian authorities—just as access to the River Jordan is disputed among Israel, Jordan and Syria.

### Moving Water and “Virtual Water”

Water is heavy to lift, so most water is managed within river basins, where it can be moved largely by gravity, but interbasin transfers can offer a solution to local shortages. For instance, China is building a network of canals and pipes to take water from the Yangtze River system in the wet south to arid regions in the north, where the Yellow River is fully used and underground reserves are overpumped. The project will cost tens of billions of dollars. Similarly, the Indian government has proposed an even larger project to move water from the monsoon rivers of northern India to the arid south and west. Other ideas have been under discussion to divert water from the Congo River into the Sahara and from Australia's northern tropical rivers into its desert interior.

Such plans are costly. It is cheaper to move crops than to move the water to grow them. So the world increasingly is relieving local water crises by “moving” water in the form of food. Economists call this the “virtual water” trade. About 15 percent of the water consumed by humans around the world is exported in the form of virtual water. This trade is essential for the survival of countries in the Middle East, such as Egypt, Algeria and Jordan. More virtual water is imported into the

**Above:** (left) Women collect water from a pit in the small village of Dan Mallam in Niger. Women there spend most of their time meeting basic household needs. (right) A man walks on a dike in Kazakhstan that protects the Aral Sea. Large Soviet-era irrigation systems used to grow cotton allow virtually no water to reach what was once the world's fourth-largest inland sea.



Middle East each year than flows down the River Nile. Without it, there would likely have been water wars.

Some countries are major exporters of virtual water, notably the United States, Australia and Canada. Others, including most European nations, are major importers. The United Kingdom, for instance, imports an estimated 40 cubic kilometers of virtual water each year, mostly in food crops.

While the virtual water trade is vital for feeding the world, it creates vulnerabilities that are likely to intensify as concerns about food security mount. Will countries like Australia and the United States remain willing to grow thirsty crops for export?

The virtual water trade has the potential to turn local water shortages into global food crises. One important cause of the spike in world food prices in 2007 and 2008 was drought in Australia, formerly the world's largest net exporter of virtual water. The absence of rainfall in its main agricultural region, the Murray-Darling River basin, reduced its exports of thirsty food crops—including rice, sugar and wheat—by more than 50 percent.

Climate change could make matters worse by increasing demand and reducing supply of virtual water. Scientists predict that it will result in the world's wet places getting wetter, while the dry places become drier. It is in dry countries that water demand, mainly to irrigate crops, is greatest.

### Advances in Water Technology

Technology could come to the world's aid. There is plenty of water in the oceans. Desalination of seawater is the main source of drinking water in oil- and gas-rich states in the Middle East, where the large amounts of energy required for the process are available locally and cheaply. Technical advances are reducing the cost of desalination. As prices fall, the technology is being adopted elsewhere, notably in Israel. But it is unlikely to supply the large amounts of cheap water required for irrigating crops or to serve areas away from coasts.

It is more likely that technical breakthroughs will come through greater water efficiency. Many modern high-yielding crop varieties are thirsty. Seed companies are working to develop crops that require less water. Equally important is more efficient irrigation technology. Most systems lose the majority of water to evaporation and seepage. Drip irrigation can deliver water in smaller quantities and close to plant roots. It has the potential to cut water demand for irrigation by 50 percent or more.

A second major development will be the recycling of water—especially the reuse of cleaned urban wastewater to irrigate crops. Pioneers in this field include Israel, Tunisia and Mexico. For example, Mexico



cleans sewage from Ciudad Juarez to irrigate crops downstream along a dry portion of the Rio Grande.

Economics can help drive these changes. In parts of the Middle East, water continues to be supplied for free, even when it is expensively manufactured with desalination. As a result, some of the driest places in the world have some of the highest per-capita rates of water consumption. There is resistance to realistic water pricing. Water is a "human right," an essential for survival. But many countries are confronting the issue. China, for example, has a national plan to raise water prices to curb demand.

Water, some say, is the new oil, set to dominate global geopolitics in the 21st century. It will never become a global commodity like oil, but as the world faces real limits to supplies, and as climate change alters the geography of its availability, water will become an increasingly political issue, both within and between countries. We will no longer be able to take water for granted.

*Fred Pearce is an environmental writer and the author of a number of books, including When the Rivers Run Dry, What Happens When Our Water Runs Out? and The Coming Population Crash: and Our Planet's Surprising Future.*

And so never ending, but always descending.

Robert Southey ~ British poet ~ "The Cataract of Lodore," 1820



# WATER KNOWS NO BOUNDARIES

## Pact with India Assists Pakistan

SARDAR MUHAMMAD TARIQ

**P**akistan faces great challenges in supplying its people, farms and industries with sufficient water. The nation has responded by investing significantly in infrastructure and has achieved an allocation agreement with its major regional neighbor.

Even so, a number of problems remain, including the prospect of climate change. Pakistanis must redouble their efforts.

### Water Resources

Pakistan is among the world's most arid countries. Its average rainfall is only 240 millimeters a year. (By contrast, among nations of similar area, Nigeria receives more than 1,500 millimeters, Venezuela more than 900, Turkey nearly 700.) Pakistan's population and economy heavily depend on water from two sources:

- ◆ The annual influx into the Indus system of about 190 billion cubic meters (BCM) of water, mostly derived from snowmelt in the Himalayas. The Indus system includes the Indus, Jhelum, Chenab and Kabul rivers and also some flows not captured by India of the Ravi, Sutlej and Beas rivers. Seventy-seven percent of Pakistan's population is located in the Indus basin.

- ◆ Pakistan's 16 million hectares of underground aquifers have a total potential of 68 BCM of groundwater, recharged mostly through its network of canals and partially through some limited structural



arrangements such as village ponds, and small, medium and large dams.

Eighty-one percent of the surface water is available in the wet season (Kharif), which runs from April to September, but shortages during the long dry season, particularly late Kharif and early Rabbi (October to March) seasons, are common, and this is likely to be aggravated by climate change.

### Infrastructure Development

Pakistan has a long history of developing the infrastructure needed by its agricultural, domestic, industrial and environmental sectors. The first well-managed canal system was introduced in 1840. Since then, many hydraulic structures have been constructed to expand the irrigated area.

The Indus Waters Treaty of 1960 between India and Pakistan shaped profoundly the pattern of subsequent development. Under this treaty, the two nations divided the six rivers of the Indus basin.

India received exclusive water rights to the three eastern rivers (the Ravi, Sutlej and Beas) and water from the three western rivers



(the Indus, Jhelum and Chenab) was allotted to Pakistan. Because Pakistan's primary agricultural food basket was in the east, and historically had been irrigated by the rivers now allotted to India, massive infrastructure then was needed to transfer the waters of western rivers to the irrigated area in the east.

Pakistan responded by constructing major barrages and inter-river canals to transfer these waters eastward. The results were impressive. Two major storage dams—one on the Jhelum River, the other on the Indus—eight barrages, 61,000 kilometers of main canals and 1.6 million kilometers of secondary and tertiary canals together form the largest contiguous irrigated area in the world, spread over some 16 million hectares. The Tarbela Dam, constructed on the River Indus in

the 1960s, remains among the world's largest in volume. Some of the link canals constructed are larger than the river Thames.

### Water Distribution and Future Challenges

The Indus Waters Treaty established transboundary water rights between India and Pakistan. In 1991, the Inter-Provincial Water Apportionment Accord resolved differences among Pakistan's four provinces. In the irrigated area water rights have been allocated to "canal commands," which means the area is irrigated by a single canal. Within each canal command, water is distributed on a rotational system. Provinces share surpluses and shortages of water according to a defined formula in the accord. As a consequence, the availability of water affects usage of



**Above:** (top left) Niaz Khan crouches in a slum near Karachi, Pakistan, to collect tap water from a government-funded water supply. (top right) Villagers cultivate rice in Mahar, Pakistan. (bottom) Following the Indus Waters Treaty of 1960, massive infrastructure was needed to transfer water from the Indus River to Pakistan's agricultural food basket in the east. © AP Images (3)

the canals. Irrigation canals are exclusively meant for providing irrigation water to the crops. Industrial uses from canal waters are not allowed.

In the irrigated area, people use both canal water and groundwater for their domestic needs. Because of extreme variation in the availability of surface water, farmers have installed extensive vertical wells to supplement their requirements with groundwater. The resulting overmining of the aquifer, in turn, has caused intrusion of salt water into wells and degraded water quality.

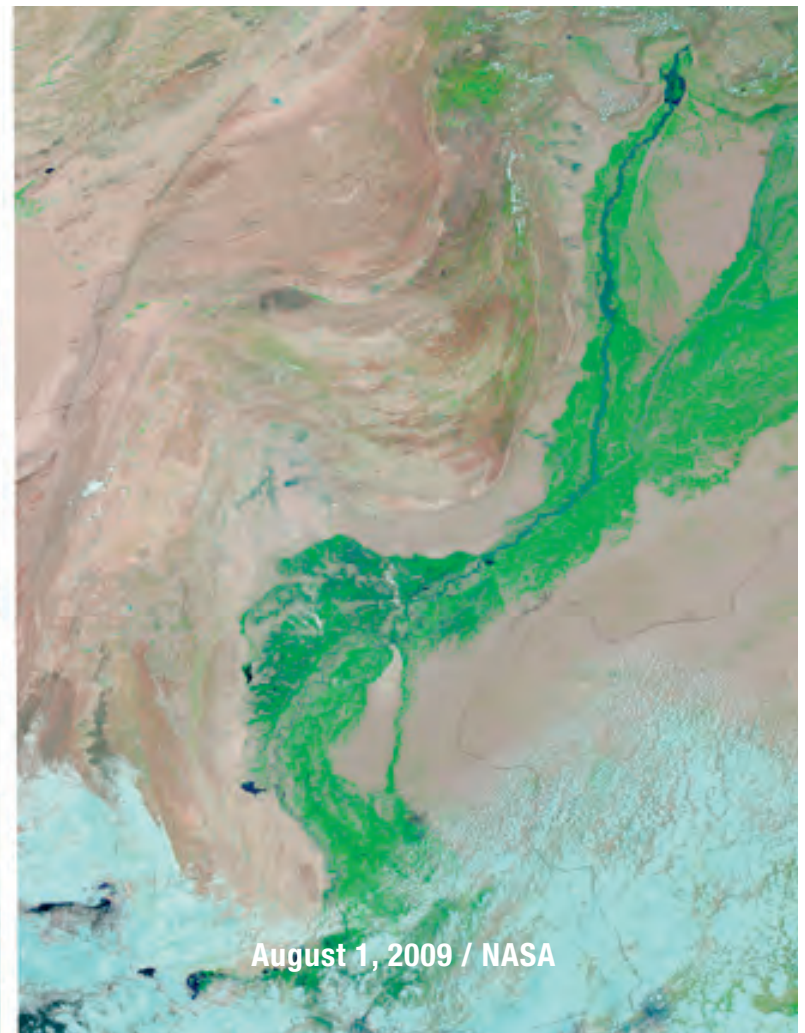
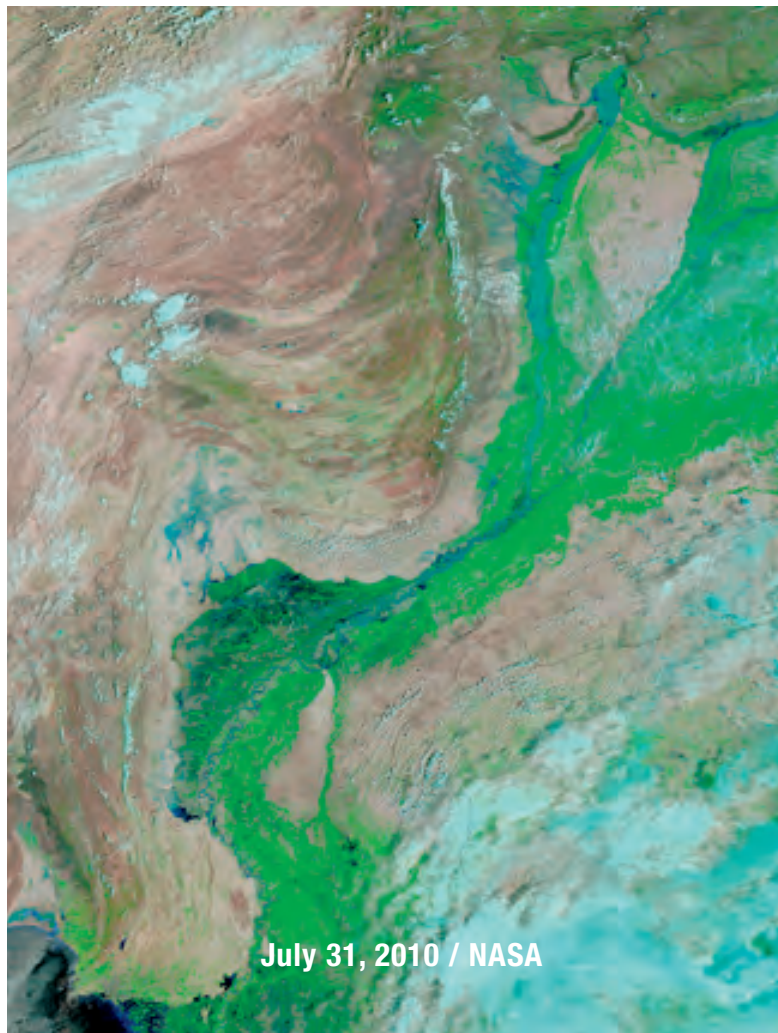
The urban and outlying suburban areas of Pakistan mostly depend on groundwater for their water supply and sanitation. With growing urbanization, the groundwater table is declining fast. Recycling of city effluent and the desalinization of salt water are being gradually introduced to overcome acute water shortages.

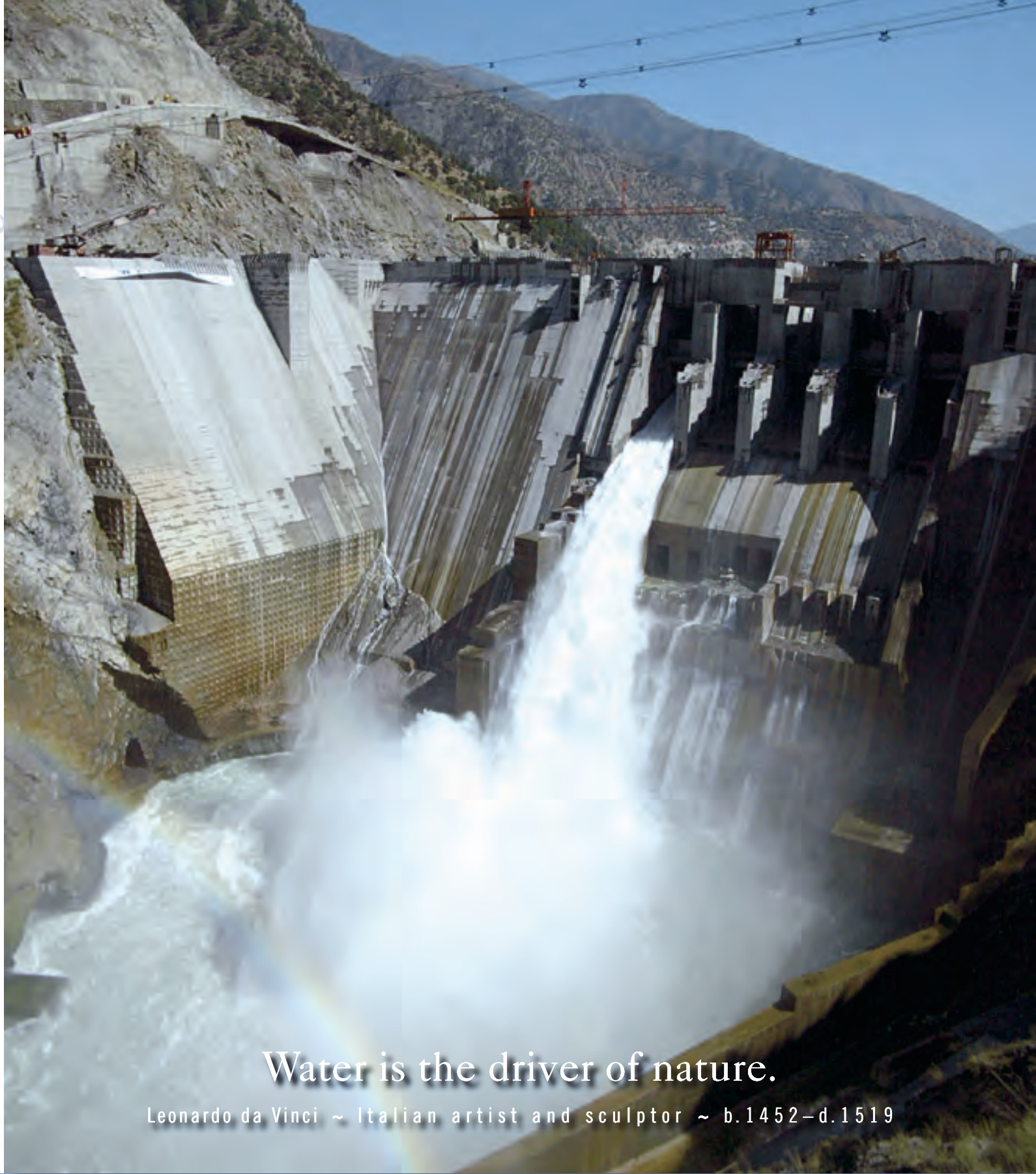
Pakistan highly depends on its single basin. Unfortunately, there is no additional basin from which additional supplies can be transferred to the water-stressed region. The nation possesses no additional water resources. Pakistan therefore must better manage the supplies it does have.

The challenges are real. Pakistan is a water-scarce country with high precipitation variation, high water stress indicators (imbalance between water use and water resources) and high ecosystem deterioration. Transboundary aquifer mining and transboundary surface water pollution complicate the dilemma. Climate change threatens to make it more acute.

To meet these challenges, Pakistan must respond in a number of ways. Areas for improvement include efficiency of water use, access to clean drinking water and sanitation, and maintenance of existing water infrastructure. Pakistan's present water storage capacity must be increased. Prudent water management also will require new infrastructure to augment Pakistani hydropower energy and increase agricultural productivity.

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Water is the driver of nature.

Leonardo da Vinci ~ Italian artist and sculptor ~ b.1452–d.1519

# GENDER AND IRRIGATION IN SOUTH ASIA

## Including Women in Water Management

SEEMA KULKARNI

South Asia has recently made unprecedented investments in the infrastructure required to meet its domestic water, irrigation, industrial and hydropower needs. But the emphasis on large-scale irrigation has posed a particular burden upon the rural poor and upon women. The investments, which have focused mostly on large dams, storage structures and canal networks, undoubtedly have brought real benefits.

However, this irrigation expansion also has led to unsustainable and inequitable uses of water. For example, overemphasis on large storage has led to population displacement and environmental sustainability problems such as submergence of forests and loss of flora and fauna. Failure to regulate groundwater has exacerbated the water crisis in rural areas, and the impact is largely borne by women in poor rural families. These inequities, particularly those related to gender, have been largely ignored by policymakers and researchers. This article examines the dimensions of gender inequities related to irrigation and suggests a way forward.

### Women and Water Collection

Water and gender are often seen to be linked because of the important role that women have in water collection and water management. According to a study commissioned by UNICEF and carried out by the Rajiv Gandhi National Drinking Water Mission in 1990, the principal collectors of water in Indian households are women, usually between the ages of 15 and 25.



They collect about 192 liters of water a day for an average household of seven members. The breakdown of age and sex in household water collection<sup>1</sup> is as follows:

- Women of ages 15–35 —63.6 percent
- Women of ages 36–50 —16.2 percent
- Women of ages >50 —2.0 percent
- Women of ages <15 —4.0 percent
- Men —14.0 percent

These figures show that women are crucial in meeting domestic water needs and also underscore the importance of incorporating women into water-management decisionmaking. The time and energy that go into water collection are shown to have considerable health and social impacts on women.

Women normally spend a significant portion of their time meeting basic household needs for water. This leaves them with very little time to engage in any productive activity outside of the home and forces them to remain in subsistence. Additionally, young girls are often forced to stay out of school to collect water, stifling the opportunities available for the following



generation of women in many parts of India and of other developing countries in South Asia.

### **Factors that Determine Women's Access to Irrigation**

Many social, cultural and economic factors determine a person's access to water. Issues of caste, class, color, gender and ethnicity, among others, manifest in every aspect of social life, and water is no exception. Ownership of property and technology, access to knowledge and information, and access to decisionmaking processes are contributing factors.

#### *Land and Capital Ownership*

Ownership of land and of the technology to extract and use water determines access to water. In South Asia, only 11 percent of women own land, so men typically control their access to water. The landless, regardless of gender, also lack access to water for their means of livelihood. Class and gender therefore intersect to mediate access to water. In addition, class intersects with caste or other forms of social discrimination when it comes to ownership of productive resources such as land and water, statistics show. Without state regulation, class, caste and gender factors will persist and perpetuate inequities in access to water.

### *Notions around Gender*

Ideas about women's proper role contribute to the lack of female influence in these institutions. Women typically are viewed as nurturers and caretakers involved in the welfare of the family. It is assumed their roles are static and confined to the domestic or the reproductive sphere, leaving the productive sphere for the men. Women are also seen as a homogenous group, undifferentiated by education, class or other social factors, and they are seen as members of a household, not as individuals in their own right. Because water is allocated by household, the male head of the household is the only recipient, or mediator, of all water benefits.

### **Women and Water Rights**

There is little documentation of the traditional rights of women over water sources. Formal rights are often vested in men as farmers and as heads of the household. Women therefore have little or no access to irrigation in their own capacity, and access is usually mediated through a male member of the household. Few women use water as individual farmers to irrigate crops on individually owned land. Most women draw canal water for homestead plots or for domestic use in informal arrangements. This water is used for purposes other than





irrigation: for drinking, domestic use, for small vegetable gardens, for livestock and microenterprises such as fisheries. Giving women a voice in setting water priorities requires an enabling environment recognizing that the right to water is embedded in the larger canvas of gender rights, livelihood sustainability and human security.

These inequities reveal themselves in policy decisions governing access to and control of water, as well as access to technical knowledge about managing water. In South Asia, women are extensively involved in irrigating agriculture. About 40 percent of women are involved in various kinds of agricultural activities as managers and laborers. Despite this, women rarely occupy key decisionmaking positions within the institutions that determine how water will be used. Those with technical and institutional management skills—mainly men—make the important decisions, while the knowledge and needs of the poor and of many water consumers often are not considered important.

### **Women's Role in Water Management: The Way Forward**

In light of women's prominent role in collecting household water—combined with the opportunity costs for women when they spend much of their day looking for water—women should exert more influence in water management and irrigation policy.

Women's presence in irrigation management and independent access to water are important for two reasons. First, women's contribution in terms of time and energy in subsistence agriculture has been proven to be significant. Improving their access to water and decisions related to water is critical for better livelihood outcomes. Second, such changes have the potential to challenge the existing property regime and its gender-specific tasks. It is assumed that because most women do not own land, they will not use water entitlements if given any. However, if access to water is given, women may demand land, trade that water, or use water for microenterprises. Incorporating women as stakeholders in decisions about irrigation and water will make irrigation and water management more equitable.

For women, water can never be a fragmented resource available to meet only a single need. It must be available for multiple uses, including domestic needs, agriculture, fishing and small enterprises, as well as for cultural and ecosystem needs. The new way forward must be one that captures the perceptions and voices of women concerning the management and uses of water.

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This article draws on these sources:

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# How does the water come down at Lodore?

Robert Southey ~ British poet ~ “The Cataract of Lodore,” 1820



# IRRIGATING INDIA

## Water Policy on the Subcontinent

INTERNATIONAL WATER MANAGEMENT INSTITUTE

India has a lengthy history of artificial irrigation. The traditional Indian agricultural practice had emphasized small-scale, community-managed irrigation projects. However, when the East India Company began governing India in the 1800s, it introduced large-scale, basinwide irrigation—an irrigation technique intended to conduct revenue-driven agriculture and counter the effects of drought.

This foreign irrigation technique set the course for irrigation practices on the Indian subcontinent for the next 200 years.

### Rise of Groundwater Use

In the past 40 years, however, groundwater has emerged as the primary source for irrigation.

As the infrastructure and management of large-scale irrigation programs deteriorated, farmers began extracting groundwater, which has become the mainstay of agriculture in 85 percent of India's farming areas outside large canal commands. Many farmers are growing a wider range of crops than the staples of rice and wheat and require a water supply that is more flexible than supply-driven programs. However, with millions of farmers sucking water from tube wells whenever they choose, groundwater supplies are dwindling.

By 2000, Indian institutions had gathered considerable data related to irrigation, but they knew little about how to use the information to influence policy. A team of about 30 social scientists



and management graduates started looking for ways to integrate centrally managed irrigation systems with the trend toward intensive groundwater use.

The International Water Management Institute (IWMI) has helped Indian policymakers learn lessons from efforts to overhaul irrigation projects in China, Mexico and Africa. It also brought the topic of groundwater use in India to the forefront of the irrigation debate.

“Until 2000 most Indian discussions on irrigation were centered on large-scale irrigation projects and surface water in irrigation,” said Tushaar Shah, a senior fellow at IWMI India. “There was little in the literature about the increasingly important role that groundwater is playing and how this resource might be managed.”

Current efforts focus on addressing groundwater depletion by refilling aquifers with rainwater that would otherwise run off and be wasted. In 2006, IWMI recommended a program of refilling groundwater across the 65 percent of India that has hard-rock aquifers, and it was incorporated in India's 2008 budget.

## From Research to Reality

One challenge is restoring and maintaining the rainwater supply in areas with hard-rock aquifers. These geological formations can store less rainwater than areas with porous sand or clay rocks. The Indian government has allocated \$400 million (USD) to fund dug-well recharge projects in areas where hard-rock aquifers have been overused. A dug-well is a wide, shallow well often lined with concrete. The money will pay for 7 million dug-well structures to divert monsoon runoff.

Each includes a desiltation chamber, plus pipes to collect surplus rainwater and divert desilted water from the chamber to the well. Small and midsized farms receive 100 percent of equipment costs in subsidies; others receive 50 percent. So far, the states of Tamil Nadu, Maharashtra and Gujarat have begun using this funding for groundwater recharge programs.

Gujarat is finalizing its managed aquifer recharge plan. The state's 191 dams contain more than 20,000 million cubic meters (MCM) of water but suffer high losses from evaporation in dams and open canals. An additional 16,600 MCM are available but wasted through runoff. The plan aims to store 11,000 MCM in the proposed Kalpasar Lake in the Gulf of Khambhat, while the remaining 5,600 MCM will be diverted underground as part of the recharge program. Gujarat will use the funding to install 21,200 percolation tanks (used to impound runoff water), 22,400 recharge wells (enabling water to be pumped into an aquifer) and 23,600 check dams (small dams that store runoff and recharge aquifers).

## Gujarat: A Leading Example

Sometimes sound water policy clashes with established interests. This was the case in Gujarat after the state introduced electricity subsidies to farmers around 1970. The subsidies enabled farmers to easily pump groundwater from ever-increasing depths, and the state eventually faced the dual problem of bankrupt electricity utilities and depleted groundwater storage.

The Asian Development Bank and World Bank suggested that governments cut the electricity subsidies and charge farmers based on metered consumption of power. However, when some states tried to do so, farmers formed powerful lobbies and several chief ministers lost their seats. A different solution was required.

IWMI suggested that governments propose “intelligent rationing” of farm power by separating the cables carrying electricity to farmers from those supplying other rural users, such as domestic households and industries. They should then provide farmers with high-quality power for a specified number of hours each day at a price they could afford.

Eventually Gujarat adopted these recommendations in a larger program to reform the electricity utility. After the cables were separated,



© Shutterstock / Paul Prescott

rural households, schools and industries had a much higher-quality power supply, which boosted well-being.

IWMI also works with policy managers in the Indus-Gangetic and Yellow River basins to analyze groundwater issues from physical, socio-economic, governance and policy perspectives. The work helps decisionmakers think about using groundwater productively and sustainably and craft effective groundwater management policies.

*The International Water Management Institute (IWMI) is a nonprofit scientific organization and one of 15 research centers supported by the Consultative Group on International Agricultural Research (CGIAR). IWMI's mission is “improving the management of land and water resources for food, livelihoods and the environment.” During the past decade, IWMI has helped put groundwater on the political agenda in India and has influenced initiatives to recharge dwindling aquifers at the national level.*

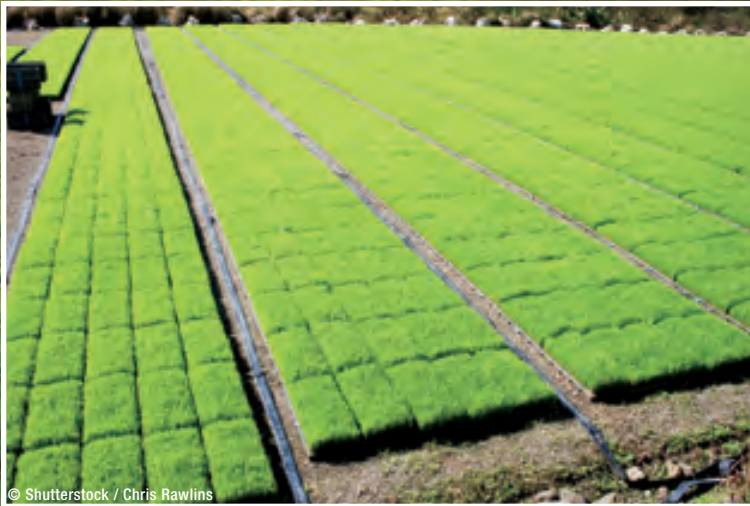


© AP Images

**Above: (bottom)** A watchman outside Rajkot, India, surveys a holding tank as water from an underground aquifer spills from 25 pipes. The water is distributed to nearby villages and farms such as the banana plantation in the top photo.



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**Above:** Artificial irrigation supports Indian agriculture. **(background)** A tea plantation weaves through rolling hills. **(insets)** Workers build an irrigation furrow in Alleppey, India, to nourish the paddy fields shown.



A river is more than an amenity,  
it is a treasure.

Oliver Wendell Holmes ~ U.S. Supreme Court Justice ~ b.1841–d.1935

# THE WATER AND ENERGY LINK

## Some Outcomes Are Unintended

FRANK RIJSBERMAN

**W**ater and energy are linked in many ways—the most obvious being that roughly 20 percent of the world’s energy is produced from hydropower. About half of all hydropower is generated in just six countries: Canada, China, Brazil, the United States, Russia and Norway. In Norway, hydropower generates almost all energy; in Brazil it is 80 percent and in Canada more than half.

In Ghana, more than 60 percent of the electricity generated comes from the Akosombo Dam, which created Lake Volta, the largest man-made lake in the world, covering 3.6 percent of the country.

Hydropower is renewable energy and is environmentally friendly because it does not generate greenhouse gas emissions, but it is not without shortcomings. Some dams and reservoirs that generate hydropower required the resettlement of millions of people, and some have flooded spectacular gorges and canyons. They also have affected downstream uses and are at risk of failure. In the United States alone, hundreds of dam failures have cost thousands of lives. The Banqiao Dam failure in China in 1975 killed 170,000 people.

Opposition to dams led the World Bank to stop funding dam construction for a period, though such funding has resumed. In the United States and Europe, most sites suitable for large hydropower dams have already been used. The debate in these regions now focuses on decommissioning



dams—destroying them to return water to rivers. While big dams have been subject to controversy, around 1,700 dams are under construction, particularly in China and India. Canada, Brazil and a number of other countries, including several in Africa, have considerable potential for large hydropower dams.

Not all hydropower comes from large dams. In-stream waterwheels have powered mills for millennia, and modern microhydro plants use similar principles to generate electricity. Many sites are available for microhydro plants, but the amount of power generated is likely to remain small compared with the output of large dams. Climate-change concerns have revived research on tidal and wave energy, and while this is a potentially large energy source, the technology is still being developed.

### The Energy Cost of Water

Pumping groundwater, pumping water over distances and treating water to remove pollutants or salt require large amounts of energy. As



groundwater levels fall, pumping for irrigation takes even more energy. In Gujarat, India, in the 1970s, oxen were used to pump water from depths less than 10 meters, but as more was pumped and water levels fell, farmers drilled deeper wells and installed larger pumps. Farmers who can afford 55-horsepower pumps use them to drill more than 200 meters. As these wells are depleted, farmers quit and move to the city.

Thousands of villages in India have been abandoned for this reason. While precise numbers are hard to find, one estimate indicates the amount of electricity used to pump groundwater is nearly equal to all the hydropower produced in the country. Local governments have subsidized electricity for farmers until, in some cases, they ran out of money. The nexus of groundwater and energy has led to government crises in some Indian states such as Gujarat.

Water treatment, particularly desalination, is very energy-intensive. The cost of modern desalination—moving water through ultrafine membranes at high pressures—has dropped from several U.S. dollars to a range of 50 cents to \$1 per cubic meter, depending on the salt content of the water and the local price of energy. More than 80 percent of the cost is for the required energy.

Cost projections indicate that in coming decades desalination will be commonly used on islands, in coastal cities in arid areas and in luxury hotels in isolated places. The same membrane technology—combined with UV disinfection—is the basis for an exploding industry in the Philippines and Indonesia of shops that sell bottled water treated on site at prices affordable to low-income groups. Thus, desalination can play a role both in development and in the fight against poverty.



## Biofuels

Energy security, trade balances and greenhouse gas concerns have stirred interest in replacing gasoline with plant ethanol. More than 70 percent of the world's biofuel production is in Brazil (from sugarcane) and the United States (primarily from corn). Biofuel crops cover about 5 percent of the agricultural land in both countries. In Europe, rapeseed is the primary biofuel crop.


One concern is that biofuel production competes with food cultivation for land and water resources. Economists predict that the prices of cassava, sugar, oil crops and grains will increase as a result of biofuel production, which will directly affect food security of the poor. In China and India, already facing water scarcity, targets set a few years ago for increased biofuel production are unlikely to be met, as the water required cannot be made available without affecting food production.

Corn production for ethanol has increased dramatically in the United States. The share of corn for ethanol has gone from less than 10 percent to more than 20 percent from 2003 to 2008. In 2008, a combination of bad weather and high biofuel demand more than doubled the price of corn from the previous year. High corn prices led to higher food prices around the world—prices that were felt particularly in Mexico, where corn is the staple food.

*Frank Rijsberman, former manager of environmental and health programs for Google.org, a philanthropic organization of Google Inc., now leads the Water, Sanitation and Hygiene program at the Bill and Melinda Gates Foundation. He is former director of the International Water Management Institute in Sri Lanka and former professor at the International Institute for Water Education.*



**Above:** In Batatais, Brazil, a machine cuts sugarcane for biofuel. Brazil is the second-largest biofuel producer in the world after the United States. Sugarcane requires less water than corn, but competition over whether to use water to cultivate biofuel or food remains a concern. © AP Images




We think of our land and water and human resources  
not as static and sterile possessions  
but as life-giving assets to be directed  
by wise provisions for future days.

Franklin D. Roosevelt ~ President, United States of America ~ b.1882–d.1945

*Above:* The Iguazu Falls on the border of Brazil and Argentina are the widest in the world. The Iguazu River pours an estimated 6 million liters of water per second over wide cliffs flanked by lush tropical rainforest. The national parks in Brazil and Argentina bordering the waterfall are World Heritage sites. © National Geographic Stock / Frans Lanting

# Water Management



An aerial photograph of the Okavango River, showing its characteristic meandering path through a vast, flat landscape. The river is a dark blue-grey color, contrasting with the surrounding green and yellowish-brown vegetation. The river's path is highly irregular, with many loops and curves. The landscape appears to be a mix of grasslands and wetlands, with some areas showing signs of waterlogging or marshiness. The overall scene is one of a large, natural, and somewhat untamed river system.

The care of rivers is not a question of rivers  
but of the human heart.

Tanaka Shozo ~ Japanese statesman and conservationist ~ b.1841–d.1913

**Above:** The Okavango River, source of the largest and most biologically diverse delta in the world, is under pressure from three nations: Angola, Namibia and Botswana. To balance development needs with environmental concerns for this largely undeveloped river, the three countries formed the Permanent Okavango River Basin Water Commission in 1994. © National Geographic Stock / Frans Lanting

# A KEY STRATEGY

## Successful Integrated Water Management

MIKE MULLER

**F**rom Egypt and Mesopotamia to India, China and Central America, ancient civilizations thrived when they successfully managed water and coped with its natural cycles of flood and drought. Today, under different pressures, civilizations threaten the very water resources that sustain them.

According to the United Nations World Water Development Report in 2009, “Alongside natural causes, new and continuing human activities have become primary drivers of the pressures affecting our planet’s water systems.

“These pressures are most often related to human development and economic growth.” The report added that the consequences of increased use, pollution and human-induced climate change are potentially disastrous. “Unless resolved, they may lead to increasing political insecurity and conflict at local and national levels.”

Many nations already understood this. Participating nations at the 1992 Earth Summit in Rio de Janeiro agreed that countries and communities should adopt an integrated approach to water resource management. But what does that mean in practice? Can any single prescription solve water problems that vary so much across the world?

### A History of Interdependence

Life was simpler when there was just one village on the banks of a stream. Villagers collected drinking water upstream, washing was done in front of the village, and animals drank downstream. Even as the village grew into a town and the community’s



wastewater flowed back into the stream, those basic rules still held.

But as populations grew and became wealthier, connections between communities multiplied. The stream’s flow was depleted by upstream farmers; pollution from the city affected villages downstream; a hydropower dam changed river flow patterns and reduced the catch of fishing communities at the river estuary. Growing populations, economic prosperity, new technologies and social priorities all require that water resources, once taken for granted, be actively managed.

### Scale and Scope of Water Management

This is easier said than done. In every part of the world, water users tend to focus first on meeting their immediate needs. China built many dams to generate power. Along the Mississippi River in the United States, thousands of kilometers of levees were erected to protect communities from floods. In India, farmers drilled millions of wells to reach underground water



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© AP Images



© Corbis / G.J. McCarthy

sources. Across southern Africa, foresters have established plantations across wide swaths of highlands.

But the water cycle is interconnected and knows no national boundaries. Water evaporates from the sea, falls over land and returns to the sea via rivers and underground pathways. This “renewable cycle” regulates itself until human activities reach critical levels; then water must be managed as a common resource.

The scope of that management depends on the nature of the interactions. Along the stream, water shortages can be resolved if the farmers and villagers agree who can take water, and when, or perhaps build a reservoir to collect water for the dry season. Where settlements pollute a river, rules are needed to balance competing needs and to protect people and their environment. Initially, traditional custom and practice may suffice. But, as situations become more complex, they may need to be underpinned by formal knowledge, organizations, bylaws and regulations.

### Integrated Water Management

Water resource management may involve:

- Monitoring the quantity and quality of water and who is using (and abusing) it.

- Allocating water by deciding who gets what share of what is available.
- Protecting water by setting (and enforcing) rules about waste disposal.
- Developing infrastructure to store, transport and treat water and wastewater.
- Establishing organizations in which different communities and different nations can agree upon and implement common water management rules and needed programs.

Integrated management is important because the actions of one community or nation affect others. China’s dams displaced many farmers from their lands; levees along U.S. rivers shifted flooding from one community to another; Indian water tables have dropped dramatically, rendering farmers’ supplies less reliable and more expensive; the trees planted in Southern Africa have sucked up groundwater and dried up mountain springs and streams.

Today, the need for stronger cooperative action and the role of integrated water management increasingly are clear. The 1992 Rio Summit adopted Agenda 21, a comprehensive plan of action for “every area in which humans impact the environment.” Chapter 18 covered freshwater resources. It identified a number of key areas for an integrated approach:

**Above:** (left) Pollution from cities upstream, such as in Guanabara Bay from Rio de Janeiro’s Manguinhos slum, affects those downstream who use the water to cook and clean. (right top) Women wash their clothes in the Ayeyarwady River in Bagan, Burma. (right bottom) Without integrated water management, local solutions such as the Trinity River levees in Dallas, Texas, merely shift water problems from one community to another.



Courtesy of Mike Muller

- Recognition that water is integral to the natural environment of the Earth is necessary.
- Users and the different uses they make of water need to be considered together.
- Land uses that have significant impact on water should be managed accordingly.
- Surface and groundwater must be managed together since they are closely linked.
- Water quantity and quality need to be managed together because “pollution needs dilution.”
- Finally, water management should be coordinated with general development planning at the local, regional and national levels, so development decisions reflect water constraints.

### **Institutions for Integrated Water Management**

At its simplest, integrated water resource management requires different water users to meet and discuss their common problems, that they possess adequate information to allow them to make decisions and that they share a commitment to find solutions acceptable to all.


In many countries, water user associations or catchment agencies allow farmers, city dwellers and other users to do just that. The same prescription applies to more complicated water challenges. Whether it is about use of water from North America’s Great Lakes or the floods on South Asia’s great river Ganges, which flows from Nepal through India into Bangladesh, the first step is getting the interested parties together to discuss their concerns.

Sometimes the challenge is to sort out which problems are local and which require a larger view. Sometimes local issues grow into larger ones. In South Australia, a thriving wine industry emerged, using water from a small river, the Langhorne Creek. Its success was attributed to strong community organization. However, when more water was needed to expand, that community began taking water from the nearby Murray-Darling, Australia’s most important river. Overnight, it became dependent on cooperation between four state governments, guided from Canberra, the federal capital, a thousand miles away.

Many technical instruments can be deployed to help solve problems. Legal systems can establish clear rights to use water, pricing systems may discourage waste, education programs encourage communities to reduce pollution.

But the fundamental challenge is to provide the fora within which diverse water consumers can better share information, understand the constraints and opportunities their common resource offers and decide together how to manage it. Applied in many different ways on many different scales, the integrated approach to water resource management remains a key strategy for a world that must learn to nurture its scarce water resources.

*Mike Muller co-chairs the U.N.-Water World Water Assessment Programme’s Expert Group on Indicators, Monitoring and Databases and is a member of the Global Water Partnership’s Technical Advisory Committee. A registered professional engineer, he recently co-edited Integrated Water Resources Management in Practice: Better Water Management for Development (Earthscan 2009).*



The cure for anything is salt water—  
sweat, tears, or the sea.

Isak Dinesen ~ Danish author ~ b.1885–d.1962

**Above:** The Dead Sea, which is 8.6 times more salty than the ocean, is really a huge lake bordering Jordan to the east and Israel and the West Bank to the west. The salt, which clusters in crystalline deposits along the coast, creates a harsh environment where animals and plants cannot flourish, but the Dead Sea is rich in minerals that are healthy for humans. Desalination is one of several projects proposed to address damage to the lake caused by a decrease in water from the Jordan River. © Shutterstock / AlexGul



# WATER, WATER EVERYWHERE...

## Is Desalination a Solution?

EMILIO GABRIELLI

**D**esalination, also referred to as “desalinization” and “desalting,” is the process of removing dissolved salts from water to produce fresh water from water too salty for human consumption, agriculture or industry. Approximately 300 million people around the world rely on desalinated water for some or all their daily needs.

New technologies, especially the development of reverse osmosis technology, have rendered desalted water increasingly economical, and increasingly important to people nearly everywhere.

### Growing Use, Shrinking Cost

Desalination has been known for hundreds of years, but only in the middle of the 20th century have more efficient processes rendered it feasible on a larger scale. The last 20 years in particular have seen unprecedented adoption of desalination technology. Today, worldwide cumulative desalting capacity exceeds 60 million cubic meters per day (approximately 16 billion U.S. gallons per day) and is increasing at a fast rate.

Despite its reputation as a costly means of securing fresh water, desalinated water already represents more than 1 percent of worldwide freshwater consumption. By way of comparison, it is more than 10 times the average amount of water that flows through the River Thames in the United Kingdom. Desalination is an important part of global water



management strategies and is no longer viewed as the solution to use only when no other is available.

Decreasing cost has made this possible. The International Desalination Association (IDA) estimates the average cost of desalinated seawater at U.S. 75 cents to \$1.25 per cubic meter for seawater and 25 cents to 60 cents per cubic meter for brackish water, depending on the size of the plant, energy costs and other factors.

### A Brief History of Desalination

Until the middle of the 20th century, only thermal processes were used. Salty water was vaporized in a boiler; the steam was collected and condensed into distilled water.

During the 19th century, this method of desalination saw increased use as the shipboard means of producing drinking water. In the second half of that century, the first large-scale land-based plants were built in desert regions, including northern Chile and Western Australia.



Courtesy of the U.S. Bureau of Reclamation

Larger-scale desalination became viable in 1957, when Professor Robert Silver from Glasgow University in Scotland patented the Multi-Stage Flash (MSF) Evaporator. By recovering condensed heat from vapor and using it to evaporate more water, the MSF Evaporator could produce several tons of distilled water with one ton of steam. In time the ratio reached 10 to 1.

The oil-rich but water-poor nations of the Persian Gulf immediately recognized the opportunity. By the beginning of the 1960s, large MSF seawater desalination plants coupled with power generation plants were changing the socio-economic reality of countries like Saudi Arabia, Kuwait and the United Arab Emirates, where societies for the first time in history relied on artificially produced fresh water as their main supply.



Courtesy of Fisac Italmimpianti

While MSF found many applications in the Gulf area and elsewhere, a new process made it possible to produce fresh water without first evaporating it.

In the 1960s, it was discovered that by applying very high pressure, salty water could be forced through a membrane with tiny, molecule-sized pores. As the water passed through, much of the salt was left behind. Reverse Osmosis (RO) was born. As less salty water required less pressure, and hence less energy, the new technology was especially useful for lower salinity (brackish) waters. By contrast, evaporation requires the same amount of energy no matter how salty the water.

### A New Economic Reality

While RO at first competed with MSF in seawater desalination, by the end of the 1980s RO became the true market leader (the Middle East remaining a partial exception). This was mainly due to the introduction in the RO process of new energy recovery systems, which roughly halved the energy required to desalt water. Now, the required energy can be equal to or less than that required to pump fresh water for long distances.

Desalination already has made a difference in the Middle East and the Caribbean, but its role now is growing nearly everywhere—from Spain to Chile and Peru, from North Africa to Australia and many other regions. The new economics of desalination means that it no longer is just a solution for richer countries. Under the right circumstances, desalination can play a role in development and in the fight against poverty. According to the IDA, desalination now is used in 150 countries. Approximately 300 million people around the world rely on desalinated water for some or all their daily needs.

RO technology has spread to other, complementary areas. New membranes filter larger particles like pathogens and pesticides. Often coupled with RO as a polishing step, these membranes contribute to water resources by allowing use or reuse of polluted water, or safe disposal of that water into the environment.

Desalination and membrane processes should be considered mainstream sources of fresh water for rich and poor nations alike.

*Emilio Gabbrielli has 35 years of experience in water management, especially dealing with such issues as desalination and reuse and in water resources management and services. He is vice president of business development for Toray Membrane USA and has served many times on the board of the International Desalination Association (IDA), including as vice president. Gabbrielli is the director for Latin America and the Caribbean on the present IDA board. From 2003 to 2008 he served as CEO (executive secretary) of the Global Water Partnership (GWP) in Stockholm, Sweden.*



Courtesy of the U.S. Bureau of Reclamation



Courtesy of the U.S. Bureau of Reclamation



Courtesy of Hyflux Ltd.



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**Above:** The desalination plant in Hadera, Israel, is the third of five planned facilities expected to provide one-third of Israel's drinking water. *(inset top and middle)* In Yuma, Arizona, one of the world's largest reverse osmosis plants is used to reduce the salinity of the Colorado River. *(inset bottom)* The SingSpring desalination plant in Singapore is a seawater reverse osmosis plant that produces up to 136 million liters of drinking water per day.



Rivers are roads which move,  
and carry us whither we desire to go.

Blaise Pascal ~ French physicist and philosopher ~ b.1623–d.1662

# URBAN WASTEWATER WOES

## Managing Farm Irrigation to Protect Crops

INTERNATIONAL WATER MANAGEMENT INSTITUTE

**H**alf the world's people live in cities, a figure expected to reach two-thirds by 2050. This expected urban migration has serious implications for future city dwellers and for farmers as they increasingly compete with industrial and residential users for water supplies.

Although farmers near cities, or peri-urban farmers, have greater opportunities to sell produce, many rely on urban wastewater to nurture their crops. This can pose real health risks.

City wastewater contains a mix of pollutants, including wastewater from bathrooms, kitchens and toilets, along with urban runoff. While this water contains more nutrients, it also has salts, antibiotics, endocrine disruptors and pathogens that cause diseases like cholera and diarrhea, which kills 1.1 million people annually and is the second most common cause of infant death worldwide.

In places such as India, where booming industry outstrips sanitation and environmental protection laws, pathogens may be accompanied by heavy metal contamination. Reducing heavy metal contamination of crops may involve identifying the contamination source, such as a factory or mine, then determining which crops are affected and prohibiting consumption of them. Heavy metals are often absorbed by plants, so not eating polluted crops is the only way to prevent health risks. Patho-



gens, by contrast, pollute the surface of crops, so washing fruits and vegetables in clean water or not splashing them when irrigating with wastewater can help reduce contamination. Promoting these actions could save many lives.

### Reducing Disease Risk

Since 2004, the International Water Management Institute has been working in Accra, Ghana, to reduce contamination of wastewater used for crops. Because farmers have to irrigate frequently, sometimes twice a day, crops can be repeatedly contaminated. This prevents the natural death of pathogens that can occur when crops are watered less frequently in hot sunshine. Every day in Accra, 200,000 people eat fried chicken, rice and raw salad bought from street vendors. The salad leaves are invariably irrigated with contaminated water; a single cholera bacterium is enough to infect the consumer.

It is important to identify behavior change that could help reduce contamination of raw salads and to research how best to trigger changes



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that make a difference—a challenging process with poorly educated populations. Another approach is to set up multiple barriers by analyzing the food production process from growing to selling to eating, then determining where it might be possible to create barriers against contamination. Barriers include teaching farmers to irrigate differently or persuading street vendors to wash crops.

“You have to find out the best ways to put across a message,” said Pay Drechsel, theme leader for water quality, health and environment, IWMI. “For example, should it be a pastor or a mother or a white man dressed as a doctor who conveys the message?”

Economic incentives can help change behavior. It is easy, for example, to persuade farmers to switch to organic produce if they can charge a

higher price. People who understand the value of chemical-free, organic produce are willing to pay more. In countries with poorer populations, however, people are unlikely to pay more for uncontaminated crops. A recent hand-washing campaign in Ghana shows the “lateral thinking” required to trigger behavior change in such places. Instead of mentioning germs or bacteria, the campaign posters focused on the “yuk” factor, making people feel uncomfortable that their hands were dirty.

#### A Multiple-barrier Approach to Health

Because people don’t get sick only from raw vegetables—they can also get sick from swimming at polluted beaches or using dirty toilet facilities—IWMI plans a holistic multiple-barrier project that analyzes



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© AP Images

**Above:** Every day in Accra, Ghana, some 200,000 people eat fried chicken, rice and raw salad bought from street vendors. The salad leaves are invariably irrigated with contaminated water; a single cholera bacterium can infect the consumer. *(clockwise from top left)* A vendor sorts tomatoes at the Agbogbloshie food market in Accra. Farmers in central Ghana collect rainwater for crops. Women help each other gather water near Ghana’s Dikunani Dam. The Akosombo Dam created the world’s largest man-made lake, covering 4 percent of Ghana’s territory.

risk from all sectors and the cost-effectiveness of different strategies. Ultimately, the aim is to advise authorities how they can save the most people from dying or becoming sick at the lowest cost. “If a city has \$1 million, we want to tell officials whether they should spend it by banning people from the beach, repairing the drinking water supply or implementing one or more barriers to improve food safety,” Drechsel said. “If at one point—be it on the farm, in the market or at the sales point—we can reduce contamination by 30 percent, every third child remains healthy.”

*The International Water Management Institute (IWMI) is a nonprofit scientific organization and one of 15 research centers supported by the Consultative Group on International Agricultural Research (CGIAR). IWMI’s mission is “to improve the management of land and water resources for food, livelihoods and the environment.” IWMI is working to help reduce the risks of contaminated irrigation water by promoting behavior changes along the supply chain from farm to plate.*



Courtesy of USAID / Louis Stippel



Courtesy of IWMI-Ghana

**Above: (top right)** A farmer in Kuntunso near Techiman, Ghana, inspects a cashew fruit. **(bottom)** Farmers near cities find good opportunities to sell fruits, but many use contaminated water to grow their crops. These fields of lettuce and shallots in Accra, Ghana, were nurtured by contaminated wastewater.



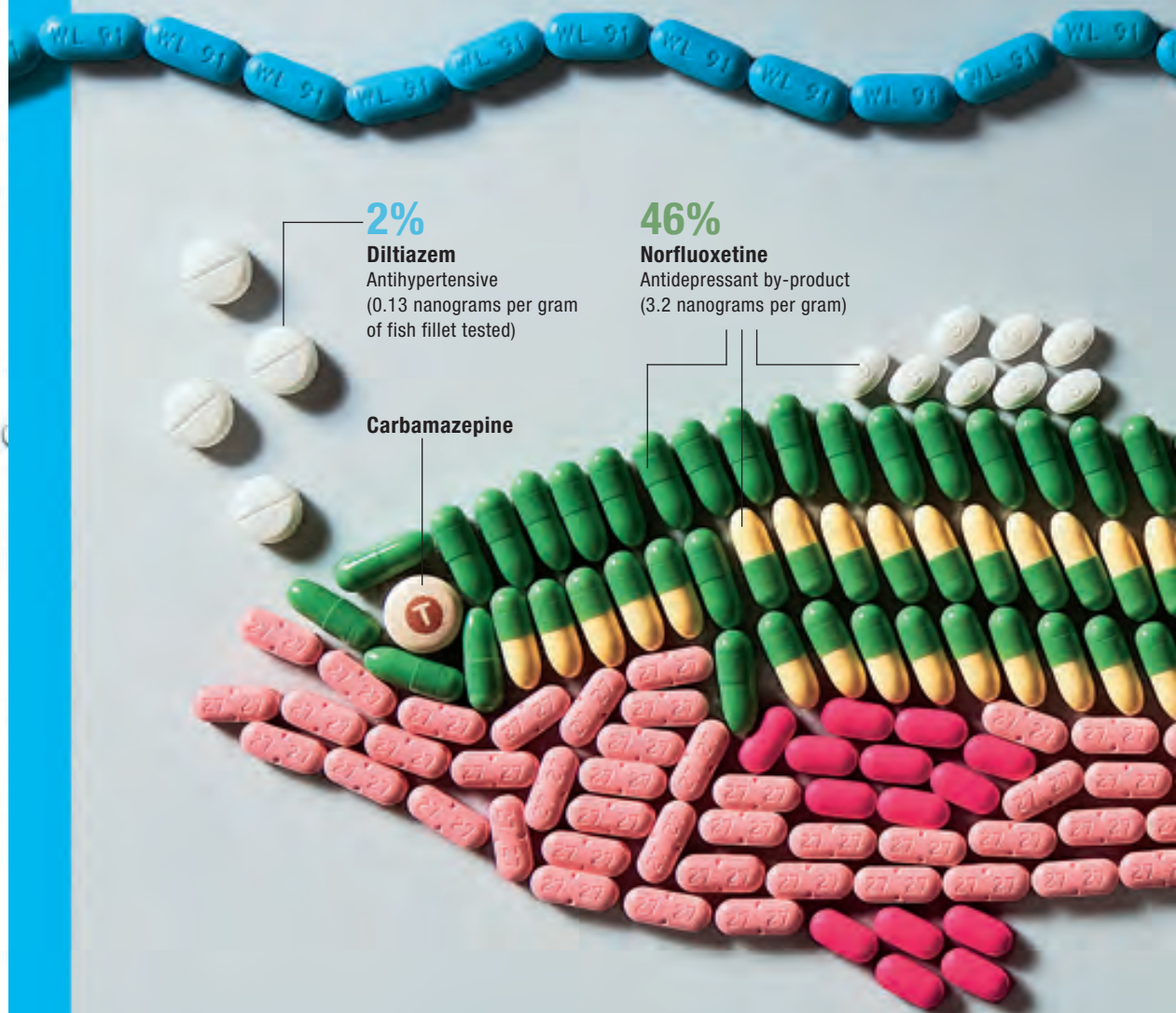
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## FISH PHARM

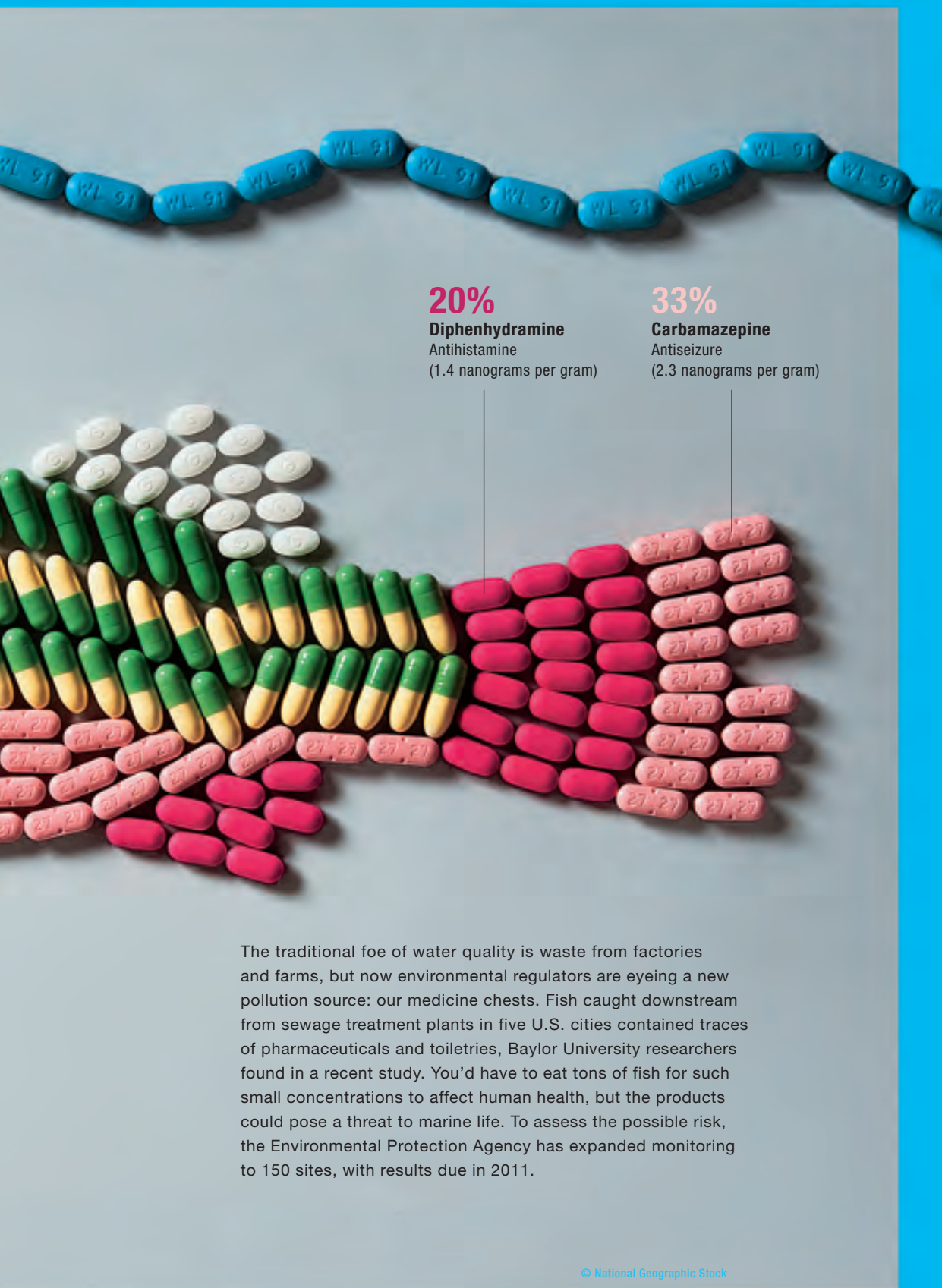
### A New Source of Pollution

These pills represent the relative amount of four pharmaceutical drugs found in fish pulled from the North Shore Channel in Chicago and tested by Baylor University scientists.

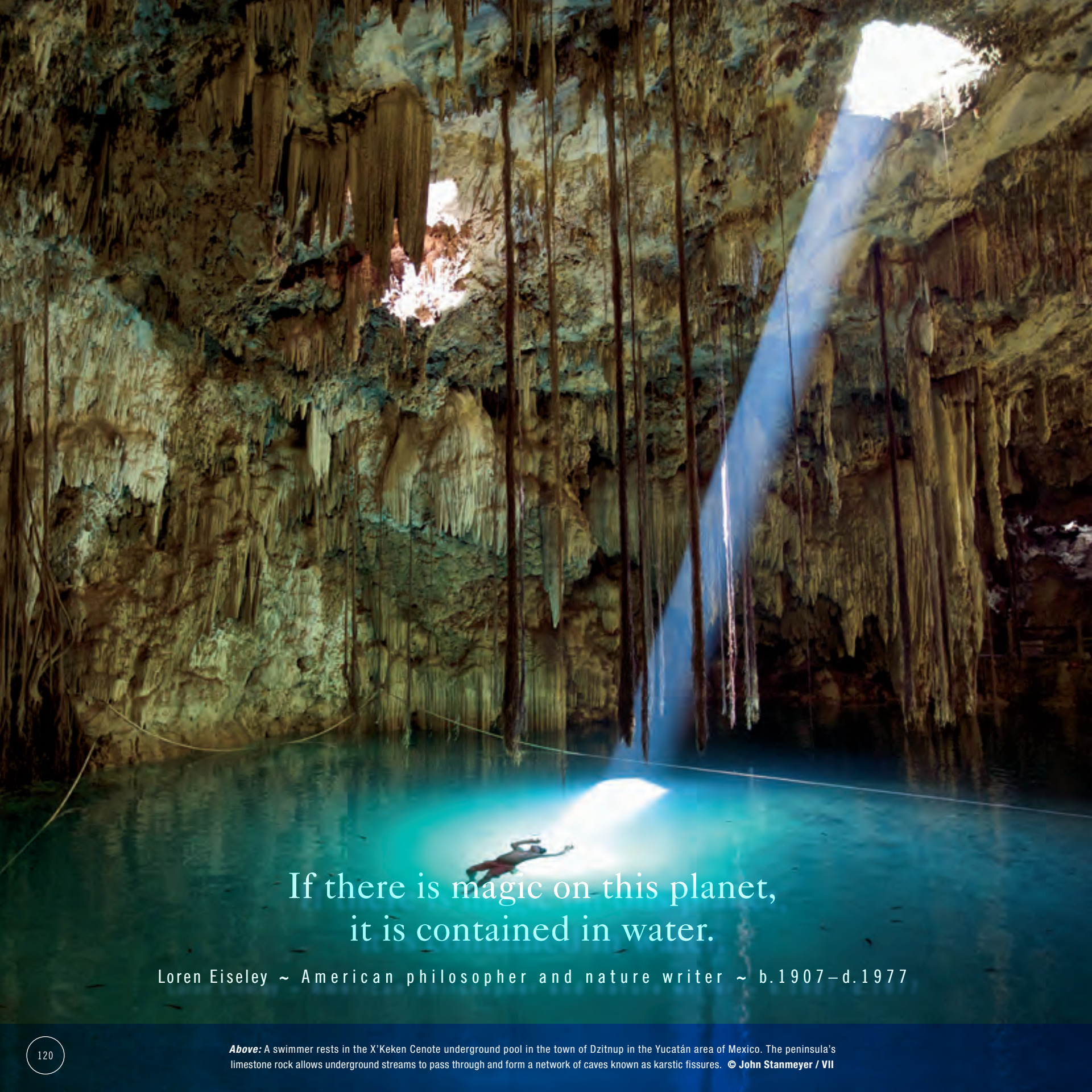
\*PERCENTAGES EXCEED 100 BECAUSE OF ROUNDING  
BLUE ANTIHISTAMINE PILLS (TOP) ARE NOT INCLUDED IN PERCENTAGES

ART: OLIVER UBERTI, NG STAFF; PHOTO: REBECCA HALE, NG STAFF  
SOURCE: ALEJANDRO RAMIREZ, BAYLOR UNIVERSITY





**Above right:** Water scarcity is not only a matter of availability, but also of quality and sanitation. **(top)** People in Mogtedo, Burkina Faso, work on a water management project to improve the town's agriculture. **(center)** Vendors of dried fish in Accra wait patiently for customers. Water scarcity has contributed to higher food prices in Ghana. **(bottom)** Two boys rest atop a donkey cart after collecting water from the Dikunani Dam in Savelugu.



If there is magic on this planet,  
it is contained in water.

Loren Eiseley ~ American philosopher and nature writer ~ b.1907–d.1977

# STILL WATERS RUN DEEP

## Mexico's Groundwater Management

GONZALO MEREDIZ ALONSO • PETER BAUER-GOTTWEIN

BIBI N. GONDWE • ALEJANDRA FREGOSO • ROBERT SUPPER

**T**he only reliable source of fresh water for the Yucatán Peninsula is a large karstic groundwater reservoir. Karstic refers to areas of irregular limestone in which erosion has produced fissures, sinkholes, underground streams and caverns. Limestone allows groundwater to pass through it easily over time, which creates unique and irregular networks of caves. Karst areas often show no surface water.

Humans and ecosystems in the region depend on this resource for water, but massive population growth and economic development, particularly in the Mexican federal state of Quintana Roo, have led to critical pollution problems. Groundwater science can improve understanding of water flow and pollution in this area, while clear political commitments and specific institutional responsibilities are essential for effective groundwater management.

While Mexico has a strong institutional base for managing water policy, including the National Water Commission (CONAGUA) and regional water supply commissions, the Yucatán Peninsula's unique and little known karstic characteristics make current policy insufficient to avoid pollution and degradation from urban and tourism development. A major problem is the lack of a suitable groundwater monitoring network. CONAGUA maintains only about 35 groundwater-level monitoring stations for Quintana Roo, which, with an area of 51,000 square kilometers, is as large as Costa Rica.



Another issue is the need for an appropriate system to enforce groundwater resource protection in Quintana Roo. The results of groundwater research could help encourage two critical policy developments: the designation of protected areas and the design and implementation of an environmental service payment system.

### Groundwater Management Problems

The Yucatán Peninsula includes the Mexican states of Quintana Roo, Yucatán and Campeche as well as portions of Guatemala and Belize. Its groundwater reservoir contains subterranean caves tens of kilometers long and tens of meters in diameter. In these caves, water and pollution travel fast. Moreover, saline seawater intrudes tens of kilometers inland into the aquifer. Groundwater use and wastewater disposal are rapidly increasing in response to the urban development and tourism of the Yucatán Peninsula.



In just 35 years, Cancun has grown from a small fishing village to the largest resort destination in Mexico. As tourism spreads south along Mexico's Caribbean coast, communities like Playa del Carmen and Tulum boast annual growth rates of more than 15 percent. Quintana Roo, which has almost 80,000 hotel rooms, receives about 10 million visitors every year. This influx severely taxes the peninsula's water resources. By federal policy, wastewater is re-injected into the groundwater often without any treatment; only 32 percent of the peninsula's wastewater is treated.

Groundwater is important not only for consumption but for ecology. The region's groundwater supports spectacular wetlands, including the Sian Ka'an Biosphere Reserve on the Caribbean coast, Mexico's first biosphere reserve, which consists of 6,500 square kilometers of tropical forest, marshes, mangroves and coastal habitats. The reserve also protects 120 kilometers of the Mesoamerican Reef, the second-largest coral reef in the world. Its geology generates sinkholes, hummocks, lagoons and freshwater springs. Reconciling human and ecosystem water demands is emerging as a key groundwater management problem in Quintana Roo.

### Groundwater Science Tools

The important question for managing and protecting wells and ecosystems is "Where does the groundwater come from?" While science can provide powerful tools to understand groundwater flow and pollution in karstic areas dominated by submerged caves, a lack of field observations of Yucatán groundwater limits the use of some tools, such as computer modeling. In this case, satellite and aircraft survey data have been helpful. Helicopter-borne sensors that transmit and receive electromagnetic signals have mapped the underground cave systems in

detail, and satellite imagery has shown faults and other regional-scale zones with potential for fast water flow. For example, satellite imagery reveals that about 17 percent of rainfall recharges the groundwater aquifer. And satellite-borne radar sensors, which investigated variations in Sian Ka'an's wetlands, show that wetland flooding peaks three months later than the annual rainfall peak in October, and the wetlands connect to water from an area much larger than the biosphere reserve itself. These results demonstrate a need for land-use regulation to protect key source areas.

### Political and Institutional Requirements

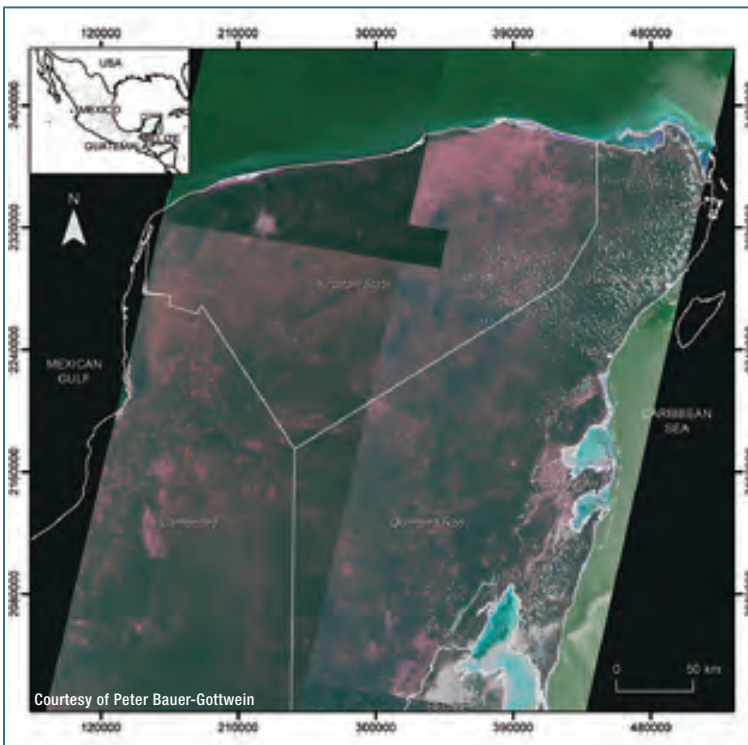
Based on groundwater flow maps, land-use planning at the municipal level can be used to define the human activities and developments



Courtesy of Peter Bauer-Gottwein / photo by Alfredo Medina



© Thinkstock / Hemera



Courtesy of Peter Bauer-Gottwein

that are compatible with the groundwater characteristics. Increasing the awareness of the fragility of local water resources encourages people to connect homes to local sewage systems and to demand higher quality and investment in wastewater treatment from state and federal agencies.

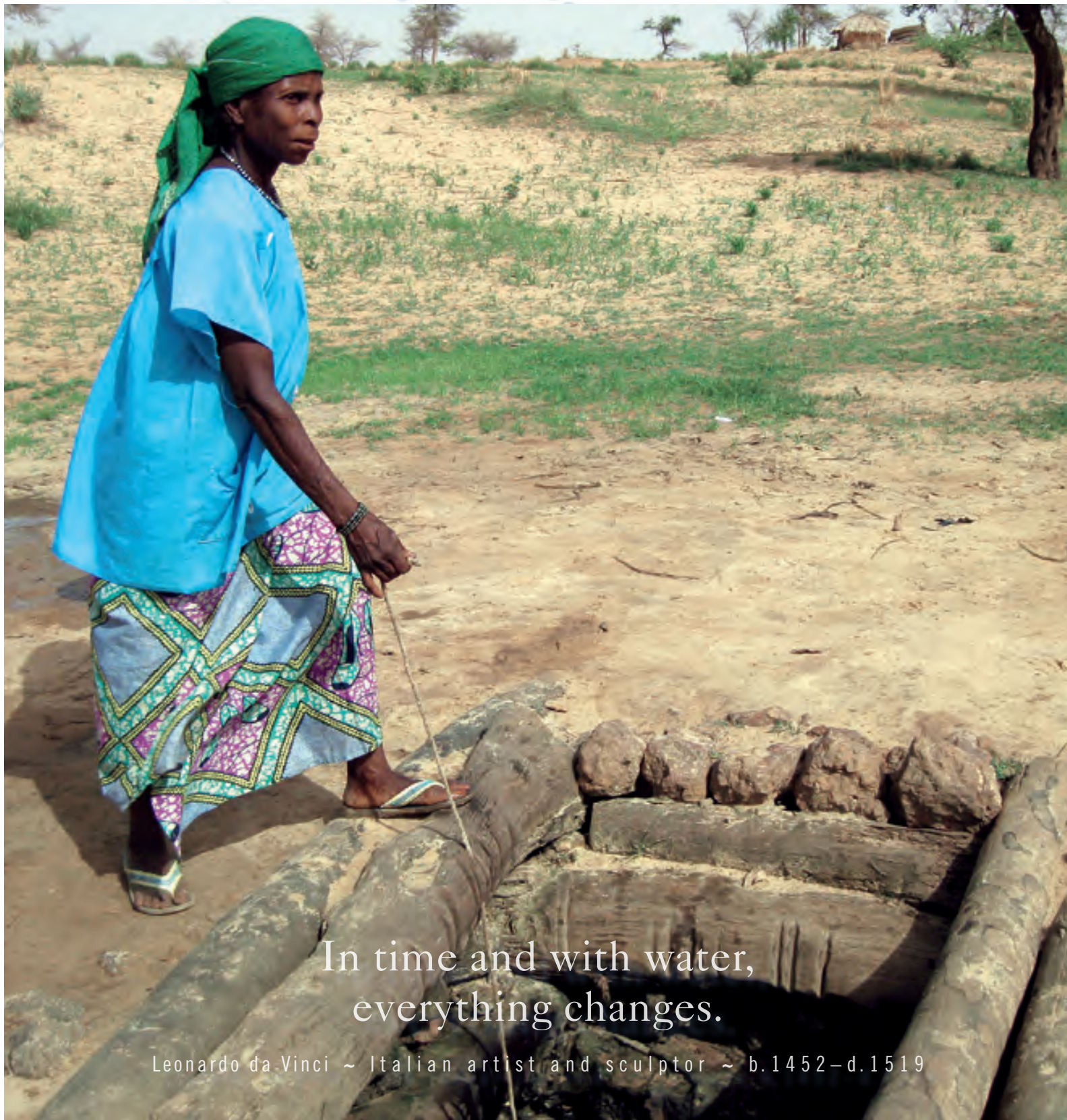
An environmental service payment plan could be set up to require that resorts benefiting from favorable land-use laws pay water fees into a fund that would compensate landowners in critical water source areas. This plan would provide sustainable financial tools to guarantee water availability for the resorts, as well as Quintana Roo's ecosystems.

Current state and municipal laws and policies may not suffice to manage water resources in Yucatán. One solution is for local nongovernmental organizations to work with the National Water Commission to create a new legal framework that encompasses management, use and preservation of underground rivers, caves and cenotes (sinkholes).

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*Bibi N. Gondwe and Peter Bauer-Gottwein are from the department of environmental engineering at the Technical University of Denmark in Kongens Lyngby. Gonzalo Merediz Alonso and Alejandra Fregoso represent Amigos de Sian Ka'an in Cancun and Robert Supper is from the Geological Survey of Austria in Vienna.*



In time and with water,  
everything changes.

Leonardo da Vinci ~ Italian artist and sculptor ~ b.1452–d.1519

**Above:** Six times a day, Hadiza Ali in rural Niger walked 40 minutes through sand to bring water from a contaminated traditional well to her home in the village of Kabori. Because the opening of the water hole was at ground level, spilled water and rainwater easily ran back into the well, contaminating it with dirt and animal waste. **Courtesy of Winrock International / Emily Kovich**

# PRIMING THE WATER PUMP

## Multiple-Use Water Services in Niger

MARY RENWICK • EMILY KOVICH

KEES VOGT • MAMAN YACOUBA

**H**adiza Ali's life once revolved around a well. Six times a day, the middle-aged mother walked 20 minutes each way from her village, Kabori, to collect water from a traditional well. The traditional village well in Kabori, like most other wells in the Zinder region of Niger, is the source of drinking water for both humans and livestock.

The traditional well opening is at ground level, so any spilled water and rainwater runs back into the well—carrying with it dirt and animal waste.

Hadiza was among the majority of rural Nigeriens (64 percent) who lack access to safe drinking water. Contaminated drinking water, coupled with poor hygiene and inadequate sanitation, is a major cause of diarrhea and other water- and sanitation-related diseases, particularly among children. Niger has one of the highest child mortality rates in the world—more than 20 percent of children die before the age of 5, primarily from water-related diseases.

Many organizations have attempted to solve this problem by installing hand pumps for drinking water. Hand pumps provide safe water, but they often break down after a few years and are not repaired. There are no official statistics on the number of nonfunctional pumps, but some nongovernmental organizations and government staff speculate that as many as 80 percent of pumps could be nonfunctional.



There are at least three main reasons for this lack of durability: the high cost and scarcity of replacement parts, some of which cost more than \$500 (USD) in a country where 85 percent of the population survives on less than \$2 (USD) per day; overuse (often for watering livestock), which results in frequent breakdowns; and lack of community organization to maintain the pump and resolve any disputes or breakdowns.

### Economic Solutions to Water Scarcity

Winrock International's Multiple-Use Water Services project in Niger has been tackling these obstacles to sustainable safe drinking water in four ways:

- 1 Lowering cost and increasing availability of spare parts by training local metalworkers to make low-cost pumps for both drinking and irrigation—the drinking water pumps are made from completely local materials and the cost of the pump (not including the borehole) for a small community is less than \$175 (USD) and spare parts cost \$3 to \$25.



Courtesy of Winrock International / Emily Kovich

② Increasing communities' earning power by providing access to water for economic uses such as market gardening and aquaculture.

③ Preventing overuse by calculating actual water needs of small livestock, factoring them into the targeted amount of water to be provided and putting in several pumps in the same village when necessary.

④ Providing pump management training to communities and close follow-up over several months by field agents.

Winrock's multiple-use strategy in Niger was the result of a systematic cost-benefit assessment (completed by Winrock and financed by the Bill & Melinda Gates Foundation) of single versus multiple-use water services and their potential applicability in South Asia and sub-Saharan Africa. The results suggest that although multiple-use services cost more than single-use services, they offer significant advantages because

- They generate more income and benefits such as improved health, nutrition, time savings, food security, livelihood diversification and social empowerment and



- They also increase sustainability of services. Productive water use generates income that increases the ability of households to cover ongoing operation, maintenance and replacement costs of multiple-use systems. Because they better meet the water needs of communities, multiple-use services increase returns on community investment and decrease conflict related to water access, as well as damage to infrastructure caused by "illegal" or unplanned uses.





Courtesy of Winrock International / Emily Kovich

Since November 2008, Winrock's Multiple-Use Water Services project in Zinder, Niger, has

- Increased access to water for domestic and productive uses to more than 13,500 people.
- Trained (or provided follow-up training to) three irrigation pump manufacturers and three rope pump manufacturers.
- Sold more than 100 irrigation pumps at full cost.
- Trained 86 gardeners who had underdeveloped gardens.




Courtesy of Winrock International / Mary Renwick

- Installed and provided training for seven experimental aquaculture ponds.
- Provided 17,295 people with hygiene training, leading to 592 hand-washing stations being purchased and installed by households.

### Life after the Well

Hadiza no longer walks to the well, but instead gets her water from the rope pump. She says that she likes the pump because she doesn't have to worry about getting in one more trip to the well before it gets dark and she can collect water without leaving her grandchildren behind. Hadiza adds that she has gotten so used to the clean taste of the pump water she can't imagine drinking the well water again. Winrock will soon install another pump in the village.

*Mary Renwick leads Winrock's Water Innovation Program and is based in Arlington, Virginia. Emily Kovich (project field coordinator), Kees Vogt (project director) and Maman Yacouba (project technical director) are based in Zinder, Niger. For further information, email [mrenwick@winrock.org](mailto:mrenwick@winrock.org).*

An aerial photograph of a Morning Glory roll cloud in Queensland, Australia. The cloud is a massive, white, wave-like structure that stretches across a wide river valley. The valley below is a mix of brown and green, with winding roads and rivers. The sky is a pale blue with some light clouds. The overall scene is dramatic and captures a rare natural phenomenon.

We're coming to the edge, running on the water,  
coming through the fog, your sons and daughters.  
Let the river run, Let all the dreamers wake the nation,...

Carly Simon ~ American singer and songwriter ~ "Let the River Run" ~ 1988

# Catalysts for Change



In today's modern world, water has been taken for granted, and we've lost our respect for it.

Jane Seymour ~ English actress ~ b.1951

**Above:** Actress Jane Seymour, narrator for the documentary film *The American Southwest: Are We Running Dry?*, stands on location in Shiprock, New Mexico. Produced by Jim Thebaut, the film explores drought conditions in the Southwest and their economic toll. © AP Images

# THE GLOBAL CRISIS IN FILM

An Interview with Jim Thebaut

NADIA SHAIRZAY AHMED

Filmmaker Jim Thebaut is the chief executive officer, president and executive producer of the Chronicles Group Inc., a nonprofit organization working to raise awareness of global water issues.

Thebaut has produced and directed a number of documentaries relating to water. They include

*Running Dry*, *Running Dry: Beyond the Brink* and *The American Southwest: Are We Running Dry?*

Interviewed in Washington in 2009, Thebaut explained the urgency of the water issue, how people can overcome shortages, and what he hopes people will learn from his films.

**Question:** Why do you think that global water issues are becoming so important?

**Jim Thebaut:** [Water] is the centerpiece of our existence and it interrelates with everything—agriculture, food supply, energy, public health and all of these issues are really crucial. When you combine these with the problem of population growth—we are now [6.9] billion people going on 9 billion by the year 2050—water is really a major issue.

Australia is the poster child for climate problems and drought, which have affected every facet of their society to the point where the average Australian uses 25 to 50 gallons [95 to 180 liters] of water per day. On the other hand, the



average American uses 200 gallons of water [757 liters] per day, so we have to rethink how we use our water. There are other places across the planet, such as sub-Saharan Africa, China and southern Asia, that are in just dire condition. Over 1 million children die every year from water-related diseases...Water has no political party; it transcends these divisions and affects the whole world.

**Q:** What is the connection between water and international security?

**Thebaut:** If a country is running out of water, then the leadership of that country could do anything, including aggression, to ensure its water supplies, particularly because water affects food security and is necessary to sustain life. Furthermore, a lack of clean water and problems with sanitation create dire situations around the world—compound poverty, people lose hope, and this creates the potential for major conflict. It's all linked together.



### Documentary Films

**Q:** Explain your involvement and the work of the *Running Dry* project and the Chronicles Group.

**Thebaut:** The Chronicles Group was created to present to the world critical global issues of the 21st century through film. The late U.S. Senator Paul Simon wrote an important book called *Tapped Out* about the global water crisis. My background was in environmental planning and I wanted to make a difference in the world. In 2001, I contacted Paul and we decided to implement the *Running Dry* project to educate the world about the water crisis.

In 2004, I produced the documentary *Running Dry*, filmed across the globe in the Middle East, sub-Saharan Africa, India and China. The film has been presented all over the world and was screened in February 2005 on Capitol Hill in Washington. Regrettably, Paul died in December 2003, just before the filming of *Running Dry*, which was personally devastating. However, the film and screening did become the genesis for the Paul Simon Water for the Poor Act.

More recently, I realized that we really need to think about water and international security, so I started the film project *Running Dry: Beyond the Brink*, which shows the connections among drought, public health, energy, agriculture and ultimately, international security. I've

also been working on another project, *Running Dry: South Africa*, which is a comprehensive public education program on water problems and solutions in South Africa. The foundation for dealing with the water crisis is education.

### International Perspective

**Q:** Through your filming, you have traveled all over the world. What are some successful water projects that you have seen?

**Thebaut:** Australia is facing a lot of problems due to drought, but they have rallied as a country and have implemented a national water policy to tackle this issue. The combination of a national water strategy and widespread awareness among the population about conserving water has made Australia's response a model for other countries.

Another example is in the Indian state of Rajasthan, which, during the monsoon season, [has] really wonderful rainfall harvesting programs...[T]hey capture the rain, and it recharges into the groundwater, and it supplies water for many villages and helps agriculture.



They're living within the ecological system. There's no sense to let the rain just roll off; they want to capture it and keep it.

One of the problems we have in the U.S. is [that] we don't capture rainwater, and when there are big rainstorms, the water just runs off. In the U.S. we often take things for granted and only act when there is a crisis, but we could be the leader of innovation and planning when it comes to dealing with water.

**Q:** What are some important measures that are needed to tackle the global water crisis?

**Thebaut:** Countries need to implement strategies and public policies that look at water issues as all-encompassing—water as it relates to energy, public health, food supply and international security. Everything is connected and we need coordination between countries and coordination within individual governments to effectively reverse the water crisis. The understanding should be that every country and every region has different problems and different needs when it comes to water, and [we need] to tailor programs for each particular situation.



With regard to the U.S., the country needs a national water strategy and a White House-level coordinator for water issues, both domestic and international.

We can't replumb the planet; we have to think about the ecology of the Earth when we make decisions. We've spent a lot of our time engineering the planet, but we can't do that anymore. When we think of solutions to the water crisis, we have to be sensitive to the environment, cognizant of the ecological system, and [we have to] think ahead.

We also have to think about how the ecological system is closely tied to population growth. Ultimately, we have to think about birth-rates, which is a sensitive issue, but we have to recognize that population growth contributes to water scarcity, food insecurity and many other negative factors. As a global society, we have to think about the ways in which we can fairly and ethically manage population growth to prevent negative ecological effects.

At the end of the day, it comes down to education and connecting with individuals to get people all around the world to really understand this problem and to work on solutions. We all have to help each other so we don't deplete our global water resources and we, as a global society, have to be serious about this and develop strategies that really work.

*Nadia Shairzay Ahmed is a writer-editor at the Bureau of International Information Programs of the U.S. Department of State.*

Thousands have lived without love,  
not one without water.

W. H. Auden ~ British-American poet ~ b.1907–d.1993



**Above:** Mount Kilimanjaro, the highest peak in Africa, towers over the savannah. Ethiopian-American musician Kenna, whose father suffered from waterborne illness during childhood, wanted to climb Kilimanjaro to raise money and awareness of water issues worldwide. The one-man campaign grew into a 300-person trek. © Shutterstock / enote



# A MOUNTING AWARENESS

## Celebrity Activists Climb Mount Kilimanjaro

CARLYN REICHEL

**T**hrough freezing temperatures, driving snow, sleet and rain—the most inclement weather conditions seen on Mount Kilimanjaro in 15 years—they climbed. In January 2010, 45 hikers, 16 guides and 248 porters embarked on a six-day trek to summit the highest mountain in Africa and raise awareness of the global water crisis.

One billion people lack access to clean drinking water, and diseases caused by poor sanitation and unsafe water are the single largest cause of illness around the world.

Grammy-nominated musician Kenna organized the climb, the “Summit on the Summit,” after learning of his father’s childhood struggle with waterborne illness growing up in Ethiopia. What started as one man’s commitment soon grew into an epic 300-person trek. “The idea was that I was going to climb Mount Kilimanjaro, I was going to do it and raise money and awareness on my own,” said Kenna. “What I was blessed to find out every time I mentioned that I was going to go climb the mountain was that friends would want to go with me.”

The Summit on the Summit initiative brought together actors, musicians and activists, including Jessica Biel, Emile Hirsch, Lupe Fiasco, Santigold and Alexandra Cousteau. It was filmed by MTV for the documentary *Summit on the Summit: Kilimanjaro*. “To have these stubborn, strong-minded, powerful



human beings together in one place, with their own opinions, their own visions, their own ideas, to have them come together in such a synergistic way and believe in each other and back each other and support each other—strangers that they’d never met—it was the most beautiful thing,” said Kenna. “I wanted the climb to be an example of mankind, and it truly was that, but then beyond my imagination...it literally was a summit on the summit.”

### A Physical and Intellectual Challenge

For those involved, the grueling nature of the climb was a fitting metaphor for the global struggle for clean drinking water and sanitation. The hikers were inspired by the real-life struggles of the people who contend with water issues for their survival.

According to Elizabeth Gore, executive director for global partnerships at the United Nations Foundation, “We were carrying packs that maybe were 18 pounds [8 kilograms] and hiking six, seven hours a day, but there are little girls who carry almost 80 kilos



## A GLACIAL LOSS

At a distinctly unglacial rate...

The East Rongbuk Glacier of Mount Everest lost some 350 vertical feet of ice between August 1921 (top) and October 2008.

The Tibetan Plateau as a whole is heating up twice as fast as the global average of 1.3°F over the past century—and in some places faster. These warming rates, unprecedented for at least two millennia, are merciless on the glaciers, whose rare confluence of high altitudes and low latitudes makes them especially sensitive to shifts in climates.

Brook Larmer, "The Big Melt," *National Geographic*, April 2010, p. 66



MOUNT EVEREST—EAST RONGBUK GLACIER  
August 1921



MOUNT EVEREST—EAST RONGBUK GLACIER  
October 2008





sometimes of water, and the average time in Ethiopia, for example, they walk is six hours a day to get water. So I think our climb was nothing compared to what they do every single day.”

The group visited a village in Tanzania before the hike and spent time in a refugee camp in Ethiopia afterward to see firsthand how lack of water affects the lives of real people. The hikers also committed to educating themselves about water along the way. They climbed by day, and at night they held discussion sessions with experts on different aspects of water issues. “We literally would sit at night and talk through, one night how does water affect girls, the next night what’s the peace, security and human rights issue around it, and we did it all the way,” said Gore. “Of course, not on the summit day,” she quickly amended, “because that was unbelievable.”

### Reception in the U.S.

Under Secretary of State for Democracy and Global Affairs Maria Otero commended the group on its commitment to the global water crisis at a U.S. State Department reception to honor the Summit on the Summit hikers and open a photo exhibition of their climb. Otero said



the United States has made water a principal foreign policy commitment, providing more than \$1 billion in support through the U.S. Agency for International Development and the Millennium Challenge Corporation to bring water to people for the first time. In 2009, that support amounted to clean water for 8 million people and sanitation for 6 million people who would otherwise have gone without.

Otero also affirmed that there is much work still to be done. By the year 2025, approximately two-thirds of the world’s population will be living in areas termed “water-stressed,” meaning there are insufficient water resources to meet need. This makes water not only a health



issue, but a peace and security issue. “The lack of sustainable and timely supply of water will undermine food security, it will become a source of tension, and it will create conflict,” said Otero. “We will see the lives of more and more threatened.”

During the hike, the Summit on the Summit was the most popular cause on both Twitter and Facebook, where the hikers posted updates on their status and photos throughout the hike. But Kenna is not satisfied. He is developing a “Blue Education” program that will engage youth and their families with the global water crisis. “I want to build allies to the cause, not just have people watch us climb, or come to a



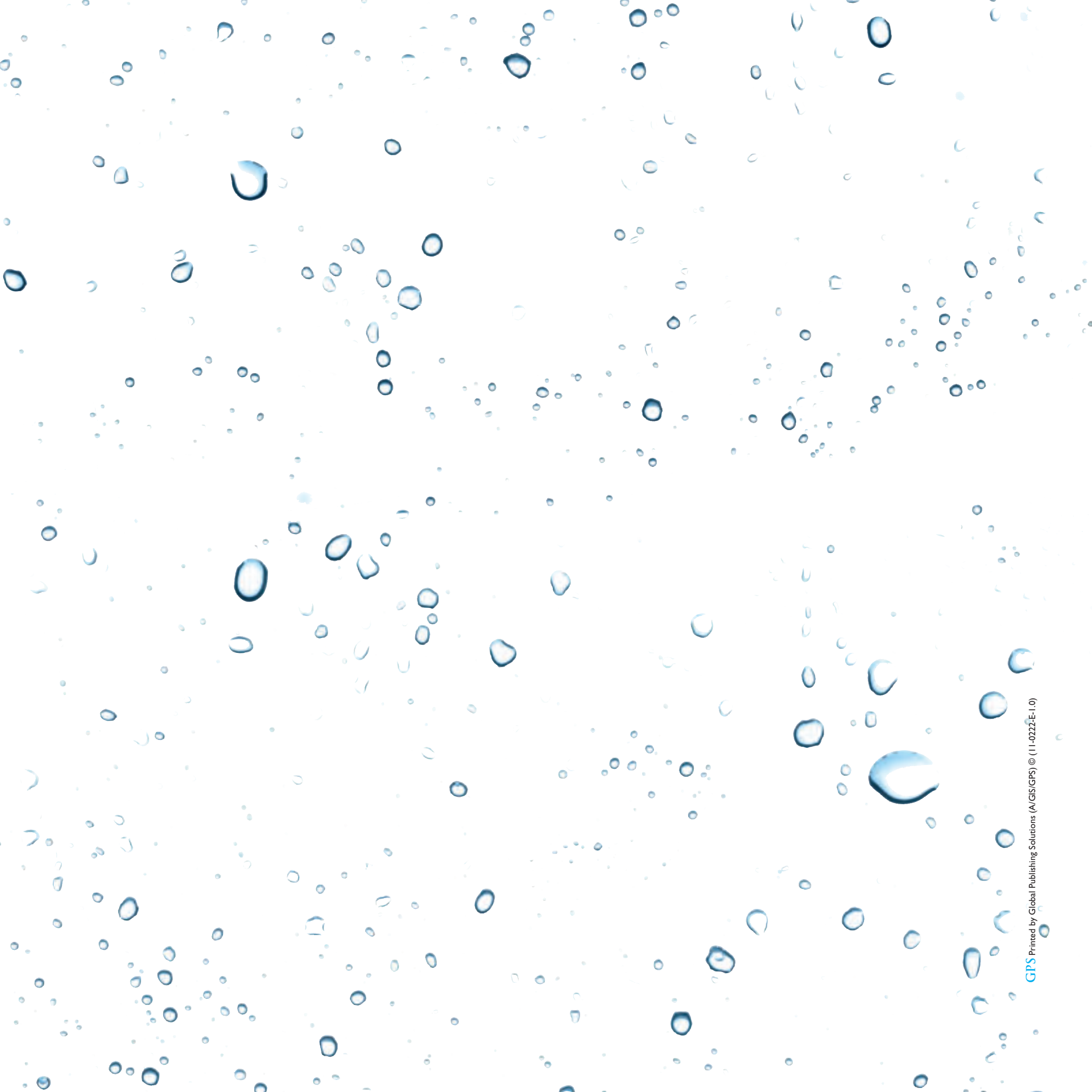
photo exhibit, or see a bunch of pictures of us doing things. I want them to feel like they were there, know why we did it and really activate themselves in the future.”

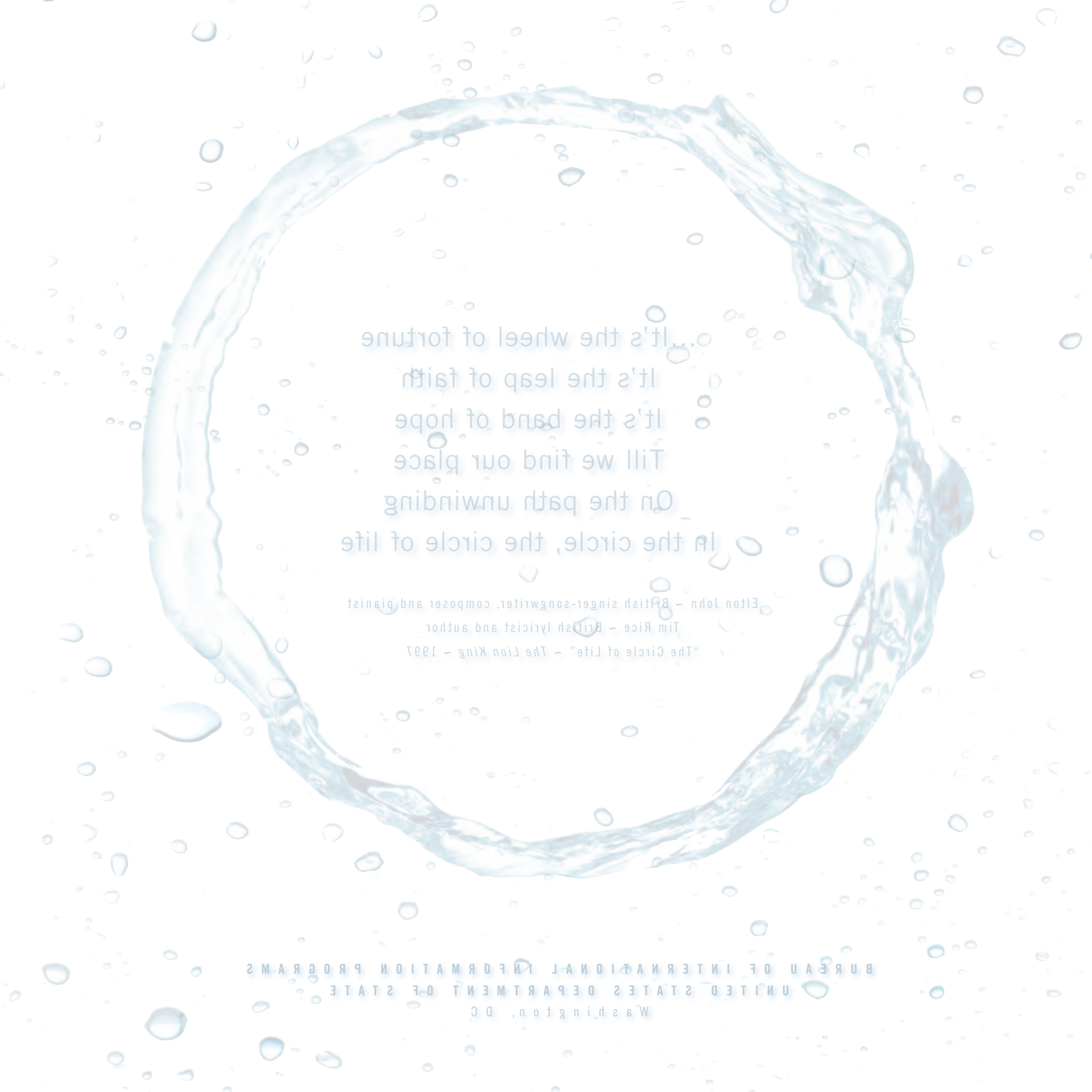
### A Continuing Endeavor

As part of this initiative, the group toured Washington in March 2010—holding meetings with members of Congress and at the State Department to bring water issues to the attention of policymakers. The week of activities culminated with the premiere of the MTV documentary *Summit on the Summit*, which aired on March 14, 2010.

For the hikers and Kenna in particular, the work of the Summit is not yet done. While he has yet to determine the next steps, he is certain of the importance of the work. “Water is a fundamental and physical issue more than it is a charitable one,” he said. “It is the most essential thing to the maintenance of life and to mankind itself. With as many needs as are outlined in the Millennium Development Goals, all are interconnected with water. If water isn’t the first and most important issue, then what is?”

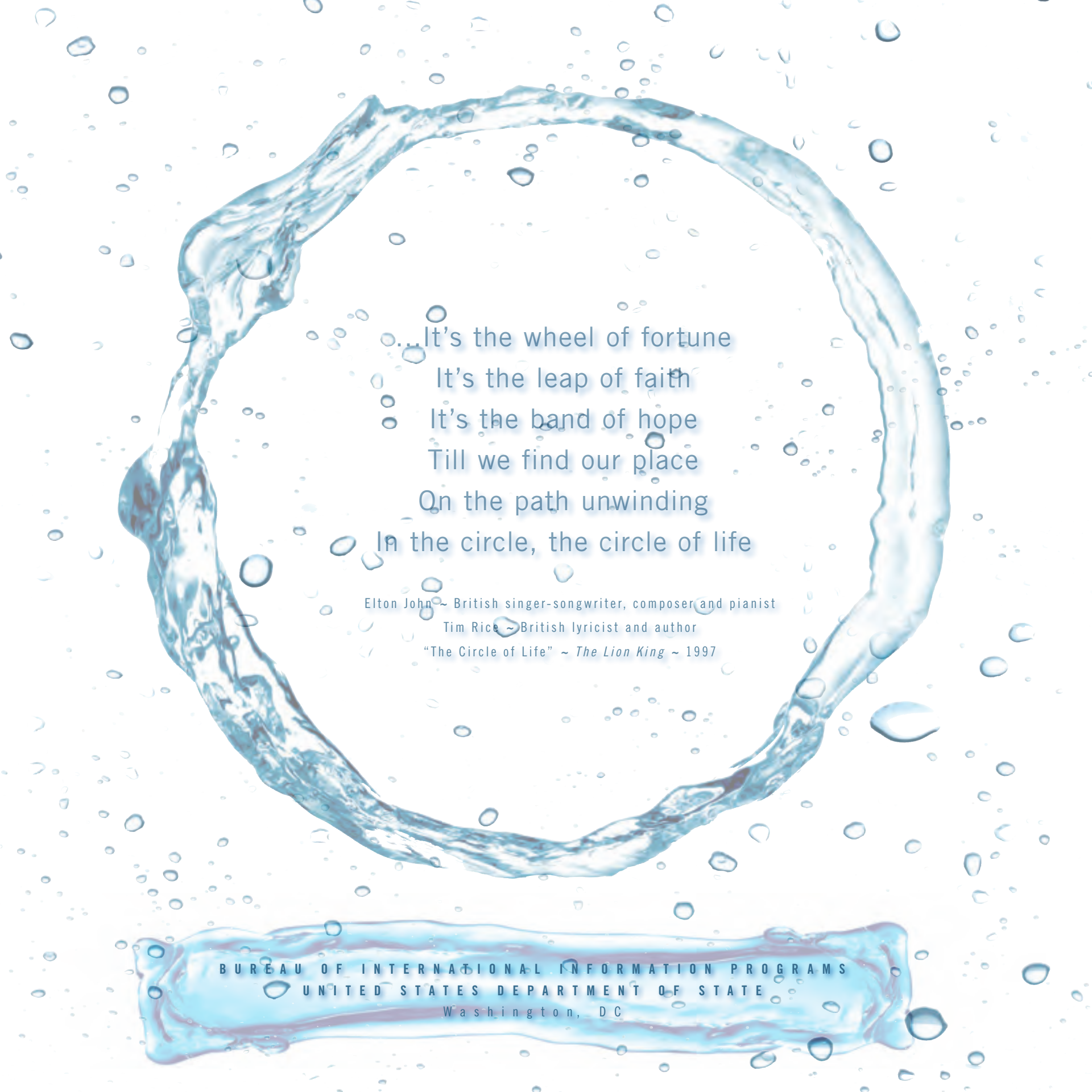
*Carlyn Reichel is a writer-editor at the Bureau of International Information Programs of the U.S. Department of State.*





In the circle, the circle of life  
On the path unwinding  
Till we find our place  
It's the band of hope  
It's the leap of faith  
...It's the wheel of fortune

"The Circle of Life" ~ The Lion King ~ 1997  
Tim Rice ~ British lyricist and author  
Elton John ~ British singer-songwriter, composer and pianist



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