PN-ACT-990

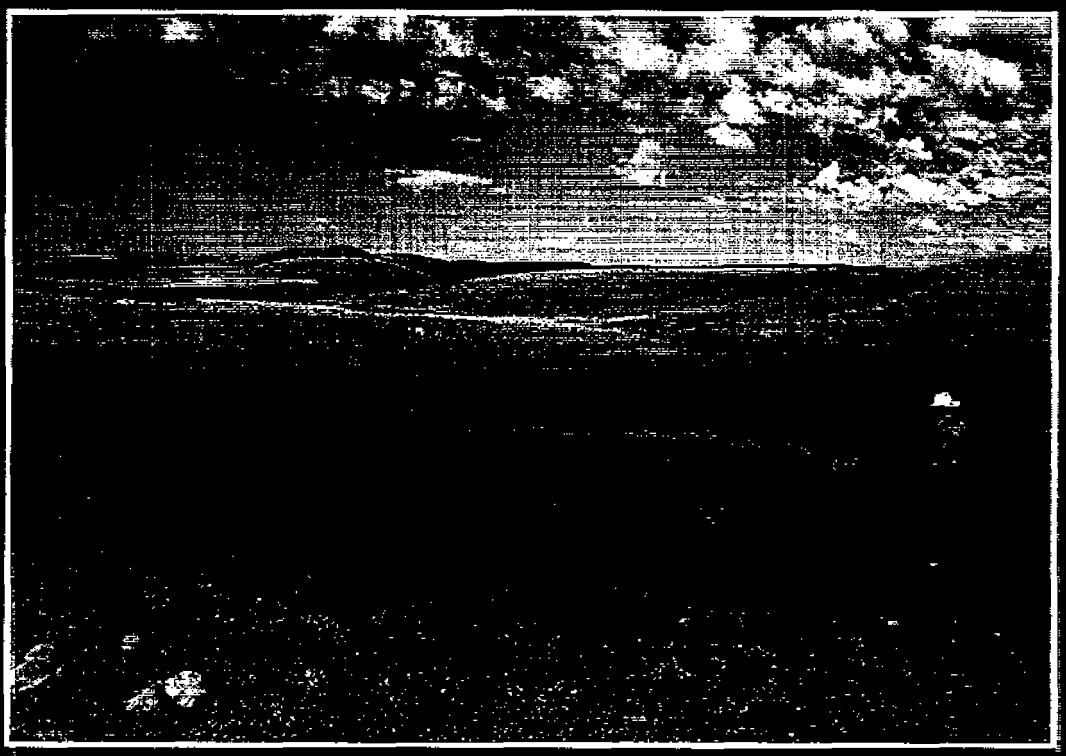
Woodrow Wilson International Center for Scholars

Environmental Change and Security Project

University of Michigan
Population Fellows Program

Finding the Source

The Linkages Between Population and Water



An ECSP Publication
Spring 2002

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THE ENVIRONMENTAL CHANGE AND SECURITY PROJECT (ECSP)

Population growth. Water scarcity. Degraded ecosystems. Resource depletion. Forced migration. Pandemic disease. Since 1994, the Environmental Change and Security Project has explored the connections among these major challenges as well as their links to conflict, human insecurity, and foreign policy. Through its meetings, its publications, its comprehensive Web site, and the original research carried out by its staff and scholars, ECSP serves as an information clearinghouse on these issues. ECSP creates special programming and publications to encourage dialogue among scholars, policymakers, and nongovernmental organizations. Its two annual journals, *The Environmental Change and Security Project Report* and *The China Environment Series*, are read by over 7,000 policymakers, practitioners, journalists, scholars, and interested citizens. ECSP is directed by Geoffrey D. Dabelko and is housed in the Wilson Center's Division of International Studies, headed by Robert S. Litwak.

ECSP is supported by the U.S. Agency for International Development Office of Population through a cooperative agreement with the University of Michigan Population Fellows Programs. ECSP also receives support from the W. Alton Jones Foundation, the David and Lucile Packard Foundation, the U.S. Institute of Peace, the U.S. Environmental Protection Agency, and the National Oceanic and Atmospheric Administration for its Asia Environment Forum and Working Group on Environment in U.S.-China Relations.

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Foreword

Geoffrey D. Dabelko, Director
Environmental Change and Security Project

Population and fresh water are widely recognized as two of the most important issues facing humanity. Yet too few policymakers are aware of the close links between these two phenomena as well as their ramifications for livelihoods, economic productivity, and political and regional stability.

Rapidly growing populations are placing an ever-increasing demand on finite water resources—a demand that contributes to widespread scarcity, massive pollution, and endemic health problems. Urbanization trends of the last half of the 20th century have also exacerbated tensions over allocating water among agricultural, industrial, and domestic sectors. And water quality and quantity challenges, made more severe by population growth, place tremendous stress on local, national, and regional institutions in developed and developing countries. The strain on these capacities to provide clean and safe water to multiple and competing users promises to increase dramatically as 54 countries are expected to reach levels of water stress or scarcity by 2050.

Finding the Source: The Linkages Between Population and Water takes an important step towards increasing knowledge about these interconnections. These three articles highlight some of the most critical issues facing environment and development policy today. In "The Coming Freshwater Crisis is Already Here," Don Hinrichsen and Henrylito Tacio outline how population growth has accelerated the threats to global freshwater resources. Next, Ruth Meinzen-Dick and Paul Appasamy detail how, in the absence of sustainable water policies, urbanization has led to intersectoral competition for both water quantity and quality. Finally, Anthony Turton and Jeroen Warner analyze the role of state and societal adaptability in meeting the challenges of population growth and water scarcity. The common message is unmistakable: global water problems are still soluble—but only with concerted international action that includes efforts to address population growth.

Finding the Source is also a step towards amplifying Southern voices in these policy discussions. Northern perspectives have long dominated debates over not only traditional foreign policy but also the place of environment, population, and health dynamics in national security formulation. By design, the author-team for each of these papers includes one Southern and one Northern writer. Each paper also features substantial treatment of developing-country cases: the Philippines, India, and sub-Saharan Africa, respectively. We hope that this collaboration can serve as a model for future research into these crucial questions. All of us at ECSP are very thankful to the six authors who committed tremendous time and attention to these joint efforts.

This publication is the most recent product of the fruitful, ongoing collaboration between ECSP and the University of Michigan Population Fellows Programs, directed by Frank Zinn. Frank and his colleagues Jane MacKie, Mita Sengupta Gibson, F.J. Cava, and Aimee Balfe have been invaluable partners exploring population and water linkages. Previous efforts include "The Future of the U.S.-Mexico Border: Population, Water, and Development," a policy report from a May 2001 conference in Tijuana, Mexico (available

(continued on page b)

(continued from page a)

at http://ecsp.si.edu/tijuana.htm). These publications and the meetings associated with them have been made possible through the generous support of the U.S. Agency for International Development's Office of Population.

Within ECSP, I want to recognize the hard work of a number of colleagues who made this publication possible. Shanda Leather shaped the topics and worked closely with the authors to foster the North-South dialogue that is at the heart of the project. With her departure from ECSP last year, Robert Lalasz, Jennifer Kaczor, Richard Thomas, Ariel Mendez, and Naomi Greengrass stepped in seamlessly to complete the effort and produce this publication. We hope you find *Finding the Source* a valuable contribution to your thinking on both population and water, and we welcome your comments.

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The Coming Freshwater Crisis is Already Here

Don Hinrichsen and Henrylito Tacio

Don Hinrichsen is an award-winning writer and former journalist who is based in Europe and the United States. He currently works as a writer/media consultant for the UN system. He has also written five books over the past decade on topics ranging from coastal resources to an atlas of the environment. Henrylito D. Tacio is a multi-awarded Filipino journalist who specializes on reporting on science and technology, environment, and agriculture. Tacio currently works as information officer of the Asian Rural Life Development Foundation.

Introduction

Fresh Water Is A Critical Resource Issue

Fresh water is emerging as the most critical resource issue facing humanity. While the supply of fresh water is limited, both the world's population and demand for the resource continues to expand rapidly. As Janet Abramovitz has written: "Today, we withdraw water far faster than it can be recharged—unsustainably mining what was once a renewable resource" (Abramovitz, 1996). Abramovitz estimates that the amount of fresh water withdrawn for human uses has risen nearly 40-fold in the past 300 years, with over half of the increase coming since 1950 (Abramovitz, 1996).

The world's rapid population growth over the last century has been a major factor in increasing global water usage. But demand for water is also rising because of urbanization, economic development, and improved living standards. Between 1900 and 1995, for example, global water withdrawals increased by over six times—more than double the rate of population growth (Gleick, 1998). In developing countries, water withdrawals are rising more rapidly—by four percent to eight percent a year for the past decade—also because of rapid population growth and increasing demand per capita (Marcoux, 1994). Moreover, increasing pollution is shrinking the supply of fresh water even further. In many countries, lakes and rivers are used as receptacles for an assortment of wastes—including untreated or partially treated municipal sewage, industrial poisons, and harmful chemicals that leach into surface and ground water during agricultural activities.

Caught between (a) finite and increasingly polluted water supplies, and (b) rapidly rising demand from population growth and development, many developing countries face difficult and uneasy choices. As the World Bank has warned, lack of water is likely to be the major factor limiting economic development in the decades to come (Serageldin, 1995).

Population and Fresh Water

Population and water resources are closely connected. The availability of fresh water limits how many people an area can support, while population growth, urbanization, and migration all affect the availability and quality of water resources. Population growth increases demand for water for food production, household consumption, and industrial uses. At some point, however, this increased demand becomes overuse, leading to depletion and pollution of surface and groundwater supplies that can cause chronic water shortages. Scarce and degraded water supplies also often cause critical health problems. Polluted water, water shortages, and unsanitary living conditions kill over 12 million people a year (WHO, 1997) and cause a great deal of illness such as cholera, hepatitis A, amoebic dysentery, schistosomiasis, and dengue and malaria fevers. And this increasing competition for limited water supplies also causes social and political tensions. River basins and other

water bodies do not respect national borders: one country's use of upstream water often removes that water from use by downstream countries. There remains a real risk across the globe of escalating tension and perhaps conflict over access to freshwater supplies.

Slowing population growth, conserving water. In less than 30 years, 50 countries could face serious water shortages, affecting more than 3.3 billion people—40 percent of the projected global population (Gardner-Outlaw & Engleman, 1997). The world, especially water-scarce countries (those with less than 1,000 cubic meters per person per year) that are afflicted with rapid population growth, must slow the growth in demand for water by slowing population growth as soon as possible. Family-planning services will empower millions of couples to space and limit their births if they so desire.

At the same time, the world's "water profligacy" must end as soon as possible. Throughout the world, enormous amounts of water are wasted due to inappropriate agricultural subsidies, inefficient irrigation systems, imprudent pricing of municipal water, poor watershed management, pollution, and other practices. The world can no longer afford to waste its precious supplies of fresh water.

Freshwater Availability and Us

While 70 percent of the earth's surface is water, only three percent of it is fresh water—and almost all of that three percent is inaccessible for human use (Lean & Hinrichsen, 1994; Lefort, 1996). About three-quarters of all fresh water on earth is locked away in the form of ice caps and glaciers located in polar areas far from most human habitation. In all, only about 0.01 percent of the world's total water supply is considered available for human use on a regular basis. If the world's freshwater supply amounted to the contents of a bathtub, the amount easily accessible to humanity would fill a thimble.

Nevertheless, even this thimble full of water is, in theory, enough to sustain an estimated 20 billion people. But in reality, only a small amount of the freshwater supply is reliable enough to be considered accessible year after year. Globally, 505,000 cubic kilometers of renewable fresh water shifts from the sea to the land every year as rain or snow via the hydrological cycle; but only 47,000 cubic kilometers per year can be considered accessible for human use (Gleick, 2000).

Freshwater Distribution

The world's available fresh water supply is also distributed extremely unevenly around the globe. About three-quarters of global annual rainfall comes down in areas containing less than one-third of the world's population. More than half the global runoff occurs in Asia (31 percent) and South America (25 percent). *Runoff* is defined as water originating as precipitation on land that then runs off the land into rivers, streams, and lakes, eventually reaching the ocean, inland seas, or aquifers. That portion of the runoff that can be used year after year by human beings is known as *stable runoff* (Hinrichsen, Robey & Upadhyay, 1998). While North America has the most fresh water available (at over 19,000 cubic meters per capita as estimated in 1990), Asia has only 4,700 cubic meters of fresh water per capita (Population Reference Bureau, 1998). This disparity is a function both of differences in population density and available water resources.

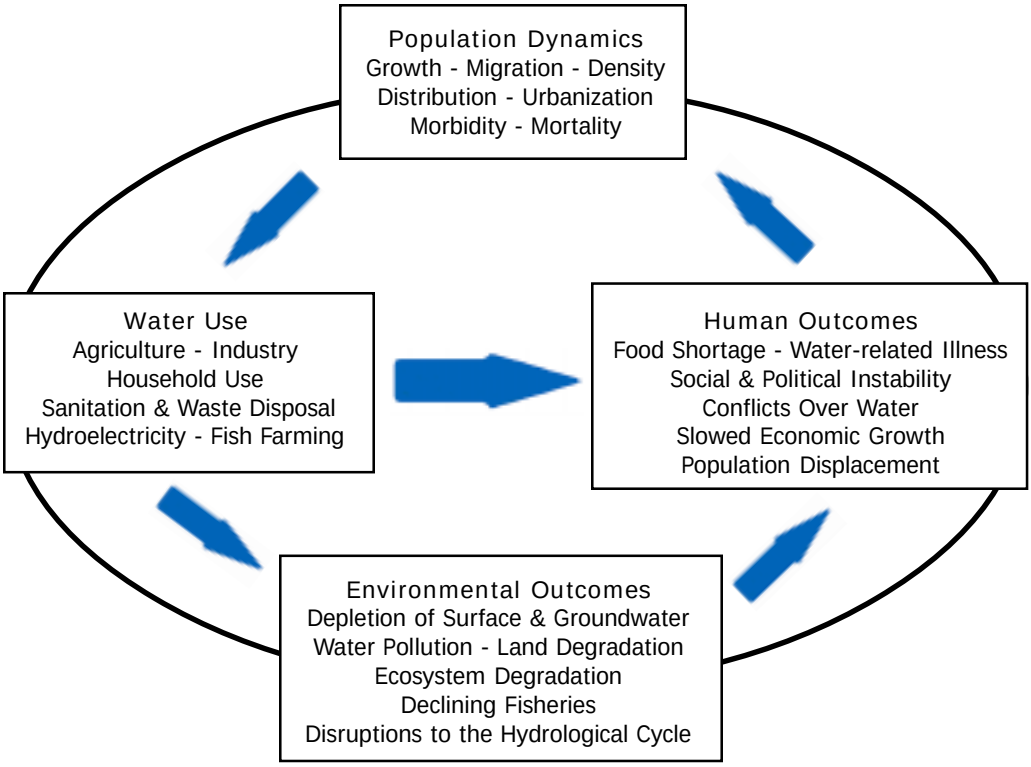
About 80 percent of the world's water runoff is concentrated in northern and equatorial zones, which have relatively small populations. The Amazon Basin alone, a vast region with less than 10 million people, accounts for 20 percent of the global average runoff each year. In Africa, the Congo River and its tributaries account for 30 percent of the entire continent's annual runoff; but the Congo's area contains only 10 percent of Africa's population. Even more dramatic water disparities hold at the country level—ranging from 46,000 cubic meters per person in Brazil (much of it accounted for by the sparsely-

populated Amazon River Basin) to only 75 cubic meters per person in Kuwait (Gardner-Outlaw & Engelman, 1997). There are also striking differences in water availability within countries. In Mexico, for instance, less than 10 percent of the land area provides more than half of the national rainwater runoff every year. Despite the fact that 90 percent of Mexico is chronically water-short and arid, its total per capita water availability in 1990 was over 4,000 cubic meters. Such a figure is grossly misleading as a measure of actual

Map 1. The Philippines

Source: *The Times Atlas of the World* (1999)

Figure 1. Links Between Population and Fresh Water



Source: IUCN et al. (1996)

water availability for most Mexicans.

In addition, freshwater supplies throughout much of the developing world comes in the form of seasonal rains. Because rains often run off too quickly for efficient use (as during Asia's monsoons), some developing countries can use no more than 20 percent of their potentially available water resources. India, for instance, gets 90 percent of its rainfall during the summer monsoon season.

Altering Natural Supply Systems

Dams. As water-short societies have done for centuries, many countries attempt (a) to move water from where it occurs in nature to where people want it, and (b) to store water for future use. Dams have emerged over the last 50 years as the major strategy for such alteration. There are some 40,000 dams worldwide that are higher than 15 meters. India, for example, has come to rely increasingly on dams and impoundments to meet its water needs. By the year 2000, the Indian government had built over 4,000 large dams to store water from the monsoon season for use during the dry season (World Commission on Dams, 2000). But although dams insure a steady water supply, they often imperil aquatic ecosystems by disrupting flood cycles, blocking river channels, and altering water flows in rivers, floodplains, deltas, and other natural wetlands. In India, deforestation in watersheds has caused massive siltation of water reservoirs and reduced the lifespan of many hydroelectric dams and irrigation schemes.

Desalination. Some countries have so little fresh water available that they must resort to the costly conversion of sea water into fresh water. Without desalination, the Arab states of the Persian Gulf could not support a number anywhere close to their current populations. Without desalination, 40 Saudis would have to share the same amount

of water that is available to one Malaysian (about 14,000 cubic meters per year) (Gardner-Outlaw & Engelman, 1997). And Bahrain has virtually no fresh water at all; its population depends completely on desalination of seawater from the Gulf.

At present, desalination is far too expensive and impractical for widespread use. Despite falling prices—the costs of desalination are down to US$1.00-to-$1.60 per cubic meter—the technology is highly energy intensive and beyond the reach of most poor water-short countries, not to mention land-locked countries. Three oil-rich Arab states—Saudi Arabia, Kuwait, and the United Arab Emirates—accounted for close to half the world's 1993 desalination capacity (Gleick, 2000). These countries are, in effect, turning oil into water.

How Water is Used

People use water for agriculture, industry, and domestic (municipal) purposes. As population grows, requirements for basic personal use rise proportionately. Rising living standards, which bring such amenities as running water to homes, dramatically increase per capita water consumption. Increasing agricultural and industrial water consumption also reflects changing living standards. Agriculture dominates global water use, accounting for 69 percent of all annual withdrawals. Industry accounts for about 23 percent, followed by municipal (domestic) consumption at 8 percent (Engelman & LeRoy, 1993; European Schoolbooks, 1994).

But global averages conceal important regional and national differences in the way water is used. In Asia, for example, a higher percentage of water withdrawal (86 percent) goes for agriculture, while industry accounts for 8 percent and domestic use just 6 percent. (India uses 90 percent of all water withdrawals for agricultural purposes). In Africa, 88 percent of water withdrawals go for agriculture, 7 percent for domestic purposes, and 5 percent for industry. In contrast, most of Europe's water use (54 percent) is for industry, while agriculture accounts for 33 percent and domestic use 13 percent (European Schoolbooks, 1994). As these regional statistics suggest, developing countries devote most of their water supplies to agriculture.

A Future of Scarcity

Years of rapid population growth and increasing per capita consumption have squeezed the world's freshwater resources. As global population has grown to nearly 6.1 billion today (and continues to grow by about 78 million people each year), the demand for fresh water in some areas exceeds nature's capacity to provide it. A growing number of countries are expected to face water shortages in the near future—shortages that will be fueled by problems both on the demand side (notably rapid population growth) and on the supply side (mainly inadequate water supplies and poor policies).

Declining Water Availability Per Capita

There is no more water on earth now than there was 2,000 years ago, when the population was less than 3 percent of its current size. Fresh water's per capita availability, which has been falling for centuries, has been dropping more precipitously in recent years as the globe's population growth has exploded. Unsurprisingly, the availability of fresh water has also fallen, from 17,000 cubic meters per person in 1950 to 7,044 cubic meters in 2000 (World Resources, 2000). The supply of fresh water per capita is one-third lower now than it was as recently as 1970, a direct result of the nearly 2 billion people added to the planet since.

While population growth rates are slowing in most developing countries, absolute numbers of people added each year remain near historic highs. As a result of projected

population growth, global per capita availability of fresh water is likely to be no more than 5,100 cubic meters in the year 2025 (Gardner-Outlaw & Engelman, 1997). China and India, the world's first and second most populous countries, respectively, provide examples of how even modest population growth rates can translate into large absolute numbers because of an already-enormous population base. China's population growth rate in 2000 was only 0.9 percent—but, with China's total population at over 1.2 billion, even this small growth rate translates into an additional 12 million people each year. Similarly, India's population growth rate of about 1.8 percent means that about 18 million people a year will be added to its current population of one billion. The world's annual population growth of 78 million a year (as of 2000) implies an increased demand for fresh water on the order of 64 billion cubic meters a year—an amount equivalent to the entire annual flow rate of the Rhine River, assuming countries continue to withdraw water at current rates (Clarke, 1991). And, as noted above, rapid population growth not only makes it increasingly difficult to provide adequate supplies of fresh water; it can also strain resources for proper sanitation, housing, health care, education, employment, and food supplies.

Rising Demand for Fresh Water

But as rapid population growth shrinks per-capita water availability, per-capita water demand is rising as countries develop economically. Global withdrawals of water have grown dramatically because of factors such as (a) the growth of industrial uses, (b) rising demand for domestic purposes, and (c) increasing reliance on irrigation to produce food.

As countries develop, water use soars. Consider the United States: while the average American in 1900 withdrew just 10 cubic meters of water a year for personal and household use, that figure had jumped by 1994 to an average of over 200 cubic meters a year (European Schoolbooks, 1994). Why? A century ago, most Americans used well water or public standpipes. Running water was largely unavailable to households except in big cities, while most people lived in rural areas. Today, of course, virtually every American—rural or urban—has running water.

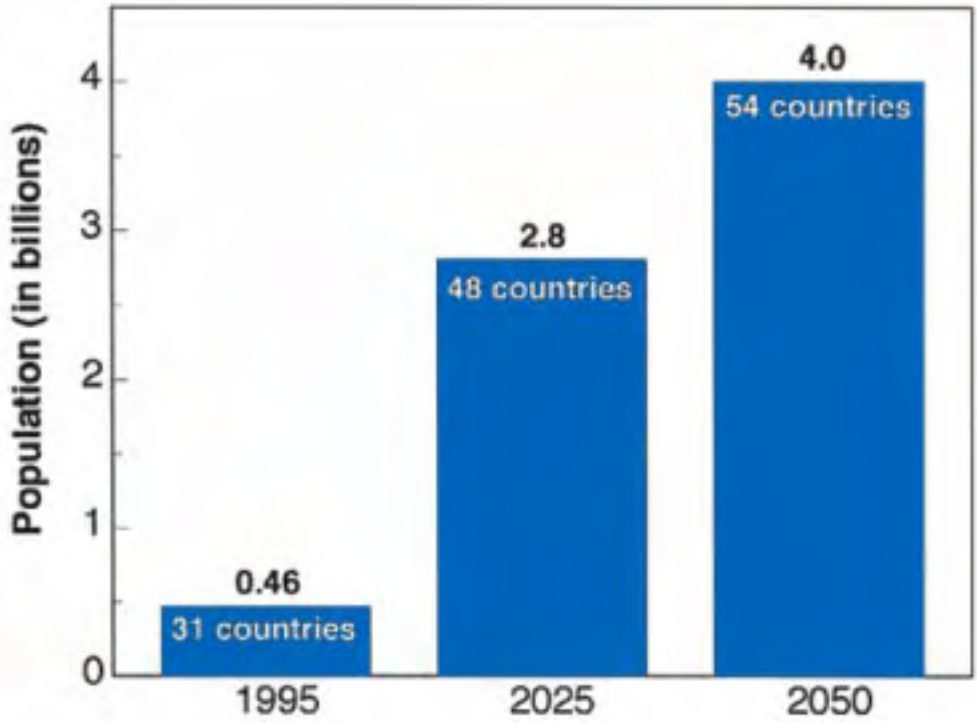
But developing regions today still use far less water per capita than do developed regions. In Africa, for example, annual water withdrawals average only 17 cubic meters of water per capita; in Asia, the figure is 31 cubic meters (Clarke, 1991). Household use in developing countries is especially scarce. Water use by either developing-country agriculture or developed-country households far exceeds household water use in many developing countries—reflecting the difficulty many people have in obtaining clean water for personal use. Most people in developing countries get their water from a public standpipe, a community well, rivers and lakes, or rain collected from roof runoff. Running water is still a rare commodity in developing rural areas.

This pattern is changing dramatically, however, as developing countries become predominately urban and individual households gain access to piped water through city water systems. As cities grow ever larger, their demand for water increases substantially. Such demand growth is putting tremendous pressure on urban water supply systems, most of which are totally inadequate to meet such demand.

Between 1950 and 1980, for instance, Latin American cities such as Bogota, Mexico City, Sao Paulo, and Managua tripled and even quadrupled their populations. Some African cities (such as Nairobi, Dar es Salaam, Lagos, and Kinshasa) grew sevenfold. This explosive growth, the result of a rural exodus, is making the world predominately urban. In the 1990s, Third World cities have had to cope with around 60 million new arrivals every year (UNCHS, 2001).

Figure 2. Water Scarcity and Stress

Population in Water-Scarce and Water-Stressed Countries, 1995-2050



Source: Abramovitz (1996)

The Era of Water Shortages

Hydrologists consider a country to be under *water stress* when its annual water supplies drop to between 1,000 and 1,700 cubic meters per person. In turn, countries face *water scarcity* when their annual water supplies drop below 1,000 cubic meters per person. Once a country enters the water-scarce category, it faces severe constraints on food production, economic development, and protection of natural ecosystems.

More and more countries are facing water stress and scarcity as their populations grow, urbanization accelerates, and water consumption increases. Thirty-one countries (with a combined population of close to half a billion) faced water stress or scarcity as of 1995. The number of people estimated to live in water-short countries increased by nearly 125 million between 1990 and 1995 (see Table 1).

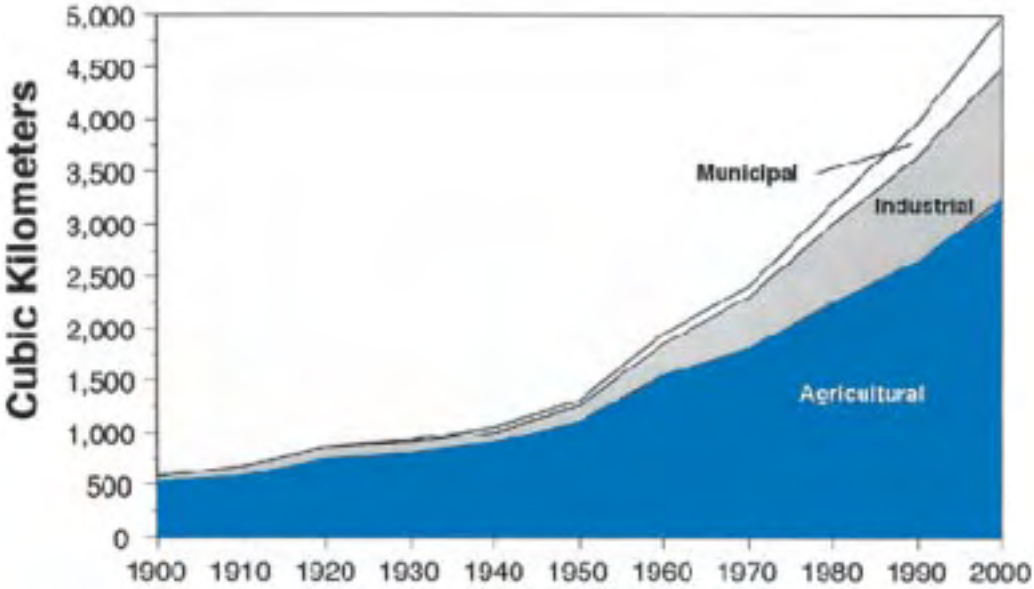
By 2025, 50 countries and more than 3.3 billion people will face water stress or scarcity. By 2050, the number of countries afflicted with water stress or scarcity will rise to 54, and their populations to 4 billion people—40 percent of the projected global population of 9.4 billion. The majority of these countries—40 of them—are in the Near East, North Africa, and sub-Saharan Africa (see Figure 3) (Gardner-Outlaw & Engelman, 1997; UNFPA, 1997).

It is no coincidence that nearly all countries with looming water shortages also suffer from rapid population growth rates. The population in sub-Saharan Africa is growing, on average, by 2.5 percent a year. Populations in the Near East and North Africa are expanding by two percent a year.

The Near East and North Africa. The 20 countries of the Near East and North Africa region face the worst prospects. Annual per-capita water availability in the region already has fallen to only 1,250 cubic meters—60 percent less water per-capita than in

Figure 3. Rising Water Use

Global Annual Water Withdrawal by Sector, 1900-2000



Source: Abramovitz (1996)

1960. By 2025, per-capita supplies in this region are projected to fall almost 50 percent to 650 cubic meters (Gardner-Outlaw & Engelman, 1997).

According to Tony Allan of the University of London, in 1972 the entire Near East "ran out of water" (i.e., the region was using more water than could be replenished every year from rainfall, in effect mining its aquifers down). At the time, the region's total population was only 122 million (Mitchell, 1998). Since then, the Near East has continued to withdraw more water from its rivers and aquifers every year than it replenishes (Mitchell, 1998). Jordan and Yemen currently withdraw 30 percent more water from ground water aquifers every year than they replenish. Israel's annual water use already exceeds its renewable supply by 15 percent, or some 300 million cubic meters. And Saudi Arabia represents one of the worst cases of unsustainable water use in the world. This extremely arid country, squeezed between the Red Sea and the Arabian Gulf, now mines a non-renewable resource (fossil ground water) for three-quarters of its water needs. It takes tens of thousands of years for these deep aquifers to replenish themselves, while ground water depletion currently averages around 5.2 billion cubic meters a year and is expected to keep on increasing well into this century.

Nine out of 14 countries in the Near East also already confront water scarcity, making the Near East the most water-short region in the world. Worse, populations in six Near Eastern countries are expected to double within two decades. Water is one of the major political issues confronting the region's leaders. Since virtually all rivers in the Near East are shared by several nations, current tensions over water rights could escalate into outright conflicts.

Sub-Saharan Africa. Much of Africa also faces serious water constraints. In 2000, 250 million people in Africa were living in water-stressed countries—150 million of them in water-scarce countries. And because of rapid population growth, this problem will worsen over the next two decades. By the year 2025, as many as 1.1 billion people—two-thirds of the region's projected population—will live under conditions of water scarcity (Falkenmark, 1994).

Southeast Asia. In densely populated Asia, home to 60 percent of the world's people, water resources are in critical shape—especially in Southeast Asia. As elsewhere,

the booming population has intensified water usage. In Vietnam, for instance, increasing population has reduced per capita water volume: from 14,520 cubic meters in 1945 to only 4,840 cubic meters in 2000. Experts contend that, although Asia is relatively well-endowed with water resources, many of the continent's countries will in the near future experience water shortages for all or part of the year (Asian Development Bank, 1999). Currently, Asia's per capita water resources are only slightly above half the world's average. In terms of water resources per person, the groups of the Indian subcontinent, Eastern Asia, and the Far East have the lowest figures, while Southeast Asia has much more water per person than the world average (see Table 2) (Facon, 2000).

But total water availability is a grossly misleading statistic, and some Asian countries are already feeling the thirst. In Malaysia, for instance, rapid population growth and a better standard of living over the last three decades have resulted in a heavy demand for water (Malaysian Water Partnership, 2000). The problem of population growth is felt particularly in urban areas because of rural-urban migration and the rapid urbanization of surrounding countrysides. The exponential growth in the world's urban population has stretched many governments' ability to provide the infrastructure and service needs as well as the necessary environmental conditions for a better living.

The Kuala Lumpur-based Malaysian Water Partnership asserts that the increased demand for a limited and diminishing supply of clean water in Malaysia has led to competition for water there—and that the country's continued economic growth will magnify this problem even more acutely (Malaysian Water Partnership, 2000). In addition, as the readily-available portion of Malaysia's water resources has already been developed for use in practically all regions of the country experiencing high-water demand, future water-resources development there will require the construction of more storage dams. Such dams are costly, both financially and environmentally.

This recent development worries Singapore, which imports water from neighboring countries (particularly Malaysia). Since attaining its independence in 1963, Singapore has seen its water consumption increased 10-fold. The Philippines is also a major consumer of water (see Box 1). Faucet water flows from the Philippine city of Cebu average 19 hours daily, and Metro Manila average 17—high numbers compared with six hours in Indonesia's Bandung or New Dehli's mere four hours. Region-wide, the average number of hours of water supplied per day is only 11.4 hours.

In Asia as a whole, competition among water users is also increasing. Almost 84 percent of the water withdrawal in the region is used for agricultural purposes, compared to 71 percent for the world. The Indian subcontinent (92 percent) and Eastern Asia (77 percent) have the world's highest level of regional water withdrawal for agriculture (World Resources Report, 1998). The two regions together represent about 82 percent of the total irrigated area in Asia.

More and more water is demanded from all sectors. In Malaysia, for instance, the annual water demand for the domestic and industrial sectors has been expanding at the rate of 12 percent due to the rapid population increase and the rapid growth of industries. By 2020, the domestic and industrial sectors are expected to be the main water users in the country (Malaysian Water Partnership, 2000). This is also true in Thailand, the Philippines, and other Asian countries.

As noted above, global water demand is increasing for various reasons such as population growth and expansion of industrial and municipal services. At the same time, in recent years, many areas face water shortage for some economic activities (especially agriculture) as well as domestic water during their dry season.

Water problems within countries. Regions and states of many large countries (such as India, China, and the United States) could also join the water-stressed category. Already, 19 major Indian cities face chronic water shortages, and India as a whole is

expected to enter the water-stressed category by 2030 (Gardner-Outlaw & Engelman, 1997). China, which has 22 percent of the world's population but only seven percent of all freshwater runoff, will be just above the 1,700 cubic meters per capita line that designates "water-stress." And United States groundwater reserves are also being depleted in many areas. According to researchers David and Marcia Pimentel, the United States' "mammoth groundwater aquifers are being mined at an alarming rate" (Pimentel et al., 1997). The amount of ground water withdrawn in the United States is currently 25 percent greater than its replenishment rate. The western half of the country is depleting groundwater aquifers at even faster rates in some areas (such as parts of the huge Ogalalla aquifer that lies under parts of six states).

Box 1. Water Crisis: The Case of the Philippines

The Philippines is a country where diarrhea remains a leading killer of children, where water-borne diseases are more common than sanitary toilets, and where farmers cannot water their own crops. Experts prescribed one possible solution to these problems: access to potable water for all 80 million residents of the country. If the Philippine government could only supply its population with sufficient and clean water, it could trigger a chain reaction of major successes in improving the country's health and well-being (Gorecho, 1998, p. 21).

But the stark reality is that clean and accessible water remains an elusive commodity for the Philippines. In the 1950s, according to Dr. Rafael D. Guerrero III, executive director of the Philippine Council for Aquatic and Marine Research and Development, the Philippines had as much as 9,600 cubic meters of clean water per person. Four decades later, the citizens must make do with little more than a third of that volume—3,300 cubic meters of water per capita (Rafael Guerrero, personal communication, 2000). "The image of a water-rich Philippines is a mirage," declares Gregory C. Ira, former head of the Water Equity in the Lifescape and Landscape Study (WELLS) of the International Institute of Rural Reconstruction (Gregory C. Ira, personal communication, 2000). "There is a water crisis in the Philippines, one of the wettest countries of Southeast Asia."

The water crisis is more transparent in metro Manila, home to more than 10 million people. Residents of the middle-class Better Living Subdivision on the southern flank of the metropolis consider themselves lucky to have water from the Metropolitan Waterworks and Sewerage System (MWSS), touted as the "first modern water system in Asia." No matter that the water flows from their faucets for just a few hours per day, and only every other day (Maniquis, 1996). Up until the mid-1980s, residents had to make do with water from pump wells and delivery services. The water still had to be boiled for drinking. Residents often drove to work with car trunks full of water containers to be filled.

For people in the lower-income neighborhoods around the subdivision who do not have service from MWSS, pushcart vendors are still the main source of water. And they pay the vendors much more for water than their neighbors in Better Living pay for water from the faucet. The situation is even worse in Manila's poor Tondo district, where residents in one area have to take a boat ride just to get water (Maniquis, 1996).

For poor people in Manila, the price of water is exorbitant. For example, water costs the family of Winnie Madera, a resident of Cainta, Metro Manila, US$20 per month—or 7 percent of the couple's total income of US$300 (Asian Development Bank, 1999). Madera used to pay US$12.50 per month for a metered piped supply

from a deep tubewell operated by a private contractor. However, the supply was only for one hour twice a day. She paid another US$7.50 per month for drinking water purchased by the container from another contractor. The source was purported to be from the concessionaire's piped supply. In 1999, however, there was trouble with both sources of water at the same time. The deep tubewell closed down due to pump problems. Diarrhea and typhoid broke out in Madera's neighborhood, and one of her sons had to be hospitalized.

In areas where water still springs in the Philippines, that water is often polluted and contaminated. The country's water is supplied by rainfall along with rivers, lakes, springs, and groundwater. But changing weather patterns worldwide have affected the Philippines as well: rainfall is growing scarcer, and what falls is collected or wasted in watersheds with balding forests. As a result, there has been a dramatic drop of from 30 to 50 percent in the country's available stable water resources in the past three decades (Rafael Guerrero, personal communication, 2000).

A recent report released by the Philippines Department of Environment and Natural Resources (DENR) said that 90 percent of the 99 watershed areas in the country are "hydrologically critical"(Langit, 1996) due to their degraded physical condition. Massive destruction of the once-productive forested watersheds by illegal loggers and uncontrolled land use from mining, overgrazing, agricultural expansion, and industrialization have contributed to water depletion (Environmental Management Bureau, 1996).

Worse, excessive soil erosion is hastening the destruction of watershed areas. The DENR report stated that 36 of the country's 75 provinces are severely affected by soil erosion. Two provinces—Cebu and Batangas—have lost more than 80 percent of their topsoil to erosion. In Luzon, the four major basins (Bicol, Magat, Pampanga, and Agno) are in critical condition due to acute soil erosion and sedimentation (Public Affairs Staff, Manila Department of Environment and Natural Resources, personal communication, 1998).

River pollution also contributes to the country's current water problem. Another DENR report classifies 37 of the 418 rivers in the Philippines as polluted, while the rest are slightly polluted. Eleven rivers are considered "biologically dead." Fifty-two percent of the country's water pollution load is attributable to domestic wastes, while industry accounts for 48 percent.

There is more bad news. Water levels in the Philippines' major freshwater sources have been dropping at the rate of 50 percent over the past 20 years. Excessive pumping of ground water has caused water depletion and consequent decline in water levels (Tacio, 1994). In less than 20 years, water levels in wells have dropped from an average of 20 meters below land surface to more than 120 meters in some areas, particularly in the industrialized areas of Paranaque and Taguig (both in metro Manila). As a result, wells that used to yield one to two cubic meters per minute can now barely produce more than 0.3 cubic meters per minute.

The problem confronting the country's water supply will also dry up agriculture, which accounts for 86 percent of the country's total water use. During the 1997-1998 El Nino climate phenomenon, water ordinarily used to irrigate farmlands in Candaba, Pampanga was diverted for household use, resulting in the destruction of 17,000 hectares of rice land.

The forthcoming water crisis in the Philippines will likewise cause industry to grind to a halt. Commercial and industrial users consume up to eight percent of the

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national water supply. Only the balance of six percent remains for domestic or municipal use. But that relatively smaller portion carries with it heavier implications for the country's health (Department of Environment and Natural Resources, 1998).

Currently, only 63 percent of the country's total population has access to safe water. Almost 30 percent of households in the Philippines do not have sanitary toilets. This gives rise to a host of health problems, from waterborne diseases to the persistence of diarrhea as a leading killer of children in the country (Environmental Management Bureau, 1996). In November 2000, 1,500 people were brought to overflowing hospitals and clinics in Zamboanga City after drinking water contaminated with rota virus and *E. coli*. Two children were reported dead (Agence France Presse, 2000).

What is the government of the Philippines doing to solve the problem of water shortage? In 1974, it created the National Water Resources Board (NWRB), an authoritative national organization that coordinates and integrates all activities in water resources development and management. It has also passed several water laws and regulations and created various organizations to oversee particular bodies of water like the Laguna Lake Development Authority (LLDA) and the Agno River Basin Development Commission. Likewise, the government foresees that, by 2025, "water of sufficient quantity and acceptable quality are in place for all stakeholders with provisions for water-related disasters so as to meet present and future needs" (National Water Resources Board, 2000, page 12). During the national consultation on water-sector mapping and visioning, participants forwarded this vision: "By the year 2025, water resources in the Philippines are being used efficiently, allocated equitably and managed sustainably" (National Water Resources Board, 2000, page 12).

Meanwhile, at the home of Rosa Andal in the poverty-stricken Sapu Masla village in the southern part of Mindanao, there is no water: the tap has long been dry. She must get up in the dark of night and, laden with plastic pails, walk for three kilometers to fetch water from a river. "Nobody does anything," Andal laments. "Politicians come, make promises, take votes and go. What else can the government claim to do when it cannot even provide a glass of clean drinking water for my children?" (Rosa Andal, personal communication, 2000)

Competition for Scarce Water Supplies

In developed and developing countries alike, fierce competition among water users is rising as people demand more and more from limited water resources. Tensions are particularly severe in places that face population pressures, rapid urbanization, and urgent development needs.

A number of developed, water-short countries—including Belgium, the United Kingdom, Poland, and Singapore—have faced tensions over water. The western United States has witnessed tension between (a) farmers with irrigation needs, and (b) urban areas with municipal demands. San Diego, California is a classic case, but the city negotiated a landmark deal with vegetable growers in the Imperial Valley. The farmers now conserve water and sell the surplus to the city (Purdum, 1997).

China is already practising what many water experts call the "zero-sum game" of water management. The zero sum game—when authorities increase water supply to one user by taking it away from another—involves both competing areas and competing types of use, as when cities compete with farmers or when human needs compete with those of ecosystems. China's freshwater supplies have been estimated to be capable of supporting 650 million people sustainably—only half of the country's current population of

1.2 billion (Qu Geping, personal communication, 1993). Across northern and central China some 300 major cities, including Beijing, face critical shortages. There is simply not enough water to meet the competing needs of the country's cities, industries, and agriculture. China has depleted underground aquifers and dammed, diverted, and drained surface waters. The water table under China's capital has dropped by roughly two meters a year for the last decade. One-third of the wells dried up because the pipes no longer reach the shrinking aquifer (Brown & Halweil, 1998). As the influx of China's rural farm workers seeking urban jobs grows ever larger, Beijing's water shortages are expected to worsen. The government is planning a huge aqueduct that will ferry water from the Danjiangkou Reservoir in Henan Province to Beijing, across 1,300 kilometers of heavily farmed agricultural land—land that also needs the water for food production.

China's Yellow River is a classic case of the zero-sum game in operation. The river is so over-subscribed that, for an average of 70 days a year for the past decade, its waters have dried up before reaching the Bohai Sea. In 1995, this dry period lasted for 122 days. In May 1996, one of the few years when farming villages near the river's mouth could take water to feed their crops, the government told them not to touch a drop. Instead, all of the water went to a state-owned oil field further downstream, bypassing hundreds of parched farms and factories along a 400- kilometer stretch of the river (Tyler, 1996).

India faces similar strains over water. In the last few years, India's states have become embroiled in disputes over water rights and dams that might provide more water for one state at the expense of another. According to Mohan Katarki, a lawyer who represented the Indian state of Karnataka in a dispute with its neighboring state Andhra Pradesh: "Water disputes, if not attended to, will become a major headache for the stability of Indian society" (Patel, 1997, p. 12). Karnataka and Andhra Pradesh are arguing in court over the height of a dam on the Krishna River. Andhra Pradesh, which lies downstream of the dam, claims that the dam's top five meters could rob it of water that it is entitled to under a 1976 water tribunal decision. Karnataka counters that the extra height will be used for generating power, not for irrigation (Patel, 1997).

Regional tensions. Regional tensions over limited water supplies are an emerging issue in nearly all water-short areas. For example, 54 of Africa's rivers are shared by two or more countries, and the region has one-third of the world's major international river basins. The Nile, Zambezi, Niger, and Volta River Basins all have the potential to ignite serious disputes.

The Aral Sea Basin is already beset by mounting international tensions over limited supplies of water. Turkmenistan, Uzbekistan, Kazakstan, Kyrgyzstan, and Tajikistan depend on the waters of the Amu Darya and Syr Darya Rivers for their very survival. But these countries find themselves increasingly at odds over the division of the rivers' waters. The water demands of all five nations are sparking disputes. Kyrgyz and Uzbeks disagree over water and land in the fertile Fergana Valley, while Kyrgyz and Tajiks argue over the allocation of irrigation water from the Syr Darya. In addition, Turkmens and Uzbeks cannot agree on the distribution of irrigation and drainage water from the Amu Darya (Postel, 1996b). Worse, in most years neither the Syr Darya nor the Amu Darya reaches the Aral Sea. The flow of both rivers, wholly diverted to feed water-intensive crops such as cotton and rice, now disappears in the desert about 100 kilometers from their former deltas.

Many other rivers are also becoming flash points for interstate disputes. The Colorado River, which flows through the southwestern United States and fed the explosive growth of Phoenix and other southwestern desert cities, is now so depleted from constantly escalating irrigation and urban demands that its waters no longer reach the Gulf of California. Instead, it trickles out somewhere in the desert south of the U.S.-Mexican border, and is now a constant source of bickering between the United States and its downstream neighbor (Postel, 1996b).

Ecosystems and Pollution

In 1996, the world's human population used an estimated 54 percent of all the fresh water contained in rivers, lakes, and aquifers (Postel et al., 1996). This percentage is conservatively projected (merely using population growth estimates) to climb to at least 70 percent by 2025. The figure will be more if per capita consumption continues to rise (Postel et al., 1996). By the year 2025, when the world is expected to have about eight billion people, more than 70 percent of all accessible fresh water could be used by humanity (Postel et al., 1996).

Endangered Ecosystems

Homo sapiens, of course, is not the only species that needs nature's supply of fresh water. A substantial portion of the total fresh water available in the hydrological cycle is needed to sustain natural aquatic ecosystems—marshes, rivers, coastal wetlands—and the millions of species they contain. Thus, as humankind uses a growing share of all water, less remains to maintain vital ecosystems. Of the world's 734 species of endangered fish in 1996, 84 percent are found in freshwater environments. Globally, over 20 percent of all freshwater fishes are endangered, vulnerable, or recently extinct (Brautigam, 1999).

Natural, healthy ecosystems are indispensable regulators of water quality and quantity. Flood-plain wetlands store water when rivers flood their banks, reducing downstream damage. The value of these services can be considerable. New York City, for example, recently invested several billion dollars to conserve and protect water catchment areas in upstate New York—the source of the city's drinking water. The alternative was to spend $7 billion on water treatment facilities (Revkin, 1997).

The world has few examples of successful ecosystem management. Instead, careless overuse of water resources is harming the environment in virtually all regions of the world:

- Diverting water from the Nile River, along with build-up of sediments trapped behind dams and barrages, has caused the fertile Nile Delta in Egypt to shrink. Some 30 out of 47 commercial species of the river's fish have either become extinct or virtually extinct. Delta fisheries that once supported over a million people have been wiped out (Abramovitz, 1996).
- Lake Chad, in Africa's Sahel region, has shrunk in area by 75 percent—from 25,000 square km to just 2,000 square km—in the last three decades, not only because of periodic droughts but also because of massive diversions of water for irrigated agriculture. The lake's once rich fisheries have collapsed entirely (Abramovitz, 1996).
- Despite cleanup efforts, the Rhine River, which runs through the industrial heartland of Western Europe, has lost 8 of its 44 species of fish. Another 25 are rare or endangered (Abramovitz, 1996).
- In Colombia, fish production in the Magdalena River has plunged from 72,000 metric tons in 1977 to 23,000 metric tons by 1992—a two-thirds drop in 15 years. The main causes have been pollution from agriculture and urban and industrial development, plus deforestation in the river's watershed (Abramovitz, 1996).
- Southeast Asia's Mekong River has had a two-thirds drop in fisheries production due to dams, deforestation, and conversion of 1,000 square kilometers of mangrove swamps into rice paddies and fish ponds (Abramovitz, 1996).
- In the United States, California has lost over 90 percent of its wetlands, and nearly two-thirds of the state's native fish are extinct, endangered, threatened, or in decline. Also, in most years the Colorado River completely dries up before reaching its once rich and thriving delta in the Gulf of California. The delta that once supported thousands of

wetland species of plants and animals is now desiccated and dead (Postel, 1997).

Water Pollution

Water pollution has become a major problem for both developed and developing countries. When coupled with the enormous quantities of water withdrawn for human use, water pollution has reduced the capacity of waterways to assimilate or flush pollutants from the hydrological system.

Water engineers like to say that "the solution to pollution is dilution." In today's world of mounting pollution, this saying has taken on new and frightening connotations. Roughly 450 cubic km of wastewater are discharged globally into rivers, streams, and lakes every year. Another 6,000 cubic km of clean water are needed to dilute and transport this dirty water before it can be used again (Shiklomanov, 1997). This amount equals about two-thirds of the world's total available runoff. Hydrologist M. I. L'Vovich has estimated that, if current trends continue, the world's entire stable river flow would soon be needed for pollutant transport and dilution (FAO, 1990).

Industrialized countries. Industrialized countries in Europe and North America face enormous water pollution problems. Over 90 percent of Europe's rivers have elevated nitrate concentrations, mostly from agrochemicals; and five percent have concentrations 200 times greater than background levels found in unpolluted rivers (WHO, 1992). Over half of Europe's lakes are eutrophied, the result of a glut of nutrients from agriculture and municipalities (WHO, 1992). Excess nutrients stimulate the growth of algae, which rob the water of oxygen when they die and decay. This process—known as eutrophication—has become one of the most serious problems affecting freshwater and near-shore marine environments.

Groundwater pollution in Europe is also worsening. Within 50 years, some 60,000 square km of groundwater aquifers in Western and Central Europe are likely to be contaminated with poisons from pesticides and fertilizers (Niemczynowicz, 1996). Of Hungary's 1,600 well-fields tapping groundwater, 600 of them are contaminated, mostly with agricultural chemicals (Havas-Szilagyi, 1998). In the Czech Republic, 70 percent of all surface waters are heavily polluted, mostly with municipal and industrial wastes (Nash, 1993). A full 30 percent of the country's rivers are so fouled with pollutants that they can no longer sustain fish. And in the United States, 40 percent of all surface waters are unfit for bathing or fishing, while 48 percent of all lakes are eutrophied (EPA, 1994; WHO, 1997).

Developing countries. Pollution is a vexing problem wherever populations are growing rapidly, development demands are great, and governments cannot afford to invest in proper sanitation and waste treatment facilities. In developing countries on average, 90 to 95 percent of all domestic sewage and 75 percent of all industrial waste on average is discharged into surface waters without any treatment whatsoever (Carty, 1991).

Consider the following examples:

- All of India's 14 major rivers are badly polluted. Together they transport 50 million cubic meters of untreated sewage into India's coastal waters every year. India's capital, New Delhi, dumps 200 million liters of raw sewage and 20 million liters of industrial wastes into the Yamuna River every day as it passes through the city on its way to the Ganges (Harrison, 1992).
- Thailand and Malaysia have such heavy water pollution that their rivers often contain 30 to 100 times more pathogens, heavy metals, and poisons from industry and agriculture than government standards permit (Niemczynowicz, 1996).
- Fully 80 percent of China's 50,000 km of major rivers are so filled with pollution and

sediment that they can no longer support fish life. In 1992, China's industries discharged 36 billion metric tons of untreated or partially treated effluents into rivers, streams, and coastal waters. In 1986, sections of the Liao River, which flows through a heavily industrialized part of northern China, died as a result of the over one billion tons of industrial wastes dumped into it. Nearly every aquatic organism within one hundred km died (Hinrichsen, 1998).

- The Tiete River, which passes through Greater Sao Paulo, Brazil, receives 300 metric tons of untreated effluents from 1,200 industries every day. The river contains high concentrations of heavy metals, such as lead and cadmium. The city also dumps some 1,000 metric tons of sewage a day into its waters. Only 12 percent of the sewage receives any treatment (WHO, 1992).
- The Tunjuelito River, a tributary of the Bogota River, is nearly biologically dead from all the industrial wastes from tanneries and petrochemical industries flushed into it as it passes through Bogota, Colombia.

Industrial and municipal pollutants. Recent decades have seen an enormous increase in pollution of many kinds from industry and municipalities. Industrial pollutants (such as wastes from chemical plants) are often dumped directly into waterways. Oils and salts are washed off city streets, while others (such as heavy metals and organochlorines) are leached from municipal and industrial dumpsites.

Secondary pollutants such as sulfur dioxide and oxides of nitrogen combine in the atmosphere to form acid rain, with pervasive effects on both freshwater and terrestrial ecosystems. Acid rain lowers the pH of rivers and streams. Unless buffered by calcium (i.e., limestone), acidified waters cause many acid-sensitive fish, like salmon and trout, to

In developing countries on average, 90-95 percent of all domestic sewage and 75 percent of all industrial waste is discharged into surface waters without any treatment whatsoever.

die off. Once in soil, acids can release heavy metals, such as lead, mercury, and cadmium, which can then percolate into watercourses.

Some of the worst pollutants are synthetic chemicals. More than 700 chemicals have been detected in drinking water in the United States alone; 129 of them are considered highly toxic. Some 70,000 different chemical substances are in regular use throughout the world. Every year around 1,000 new compounds are introduced into the market (World Resources Report, 1987).

A number of these pollutants, particularly halogenated hydrocarbons and organochlorines (such as DDT and PCBs), are long-lived and highly toxic in the environment. They do not break down under natural processes and thus tend to bio-accumulate up the food chain, where they pose risks to human health. For example, Beluga whales swimming in the highly polluted St. Lawrence Seaway (which connects the Atlantic Ocean to North America's Great Lakes) have such high levels of PCBs in their blubber that, under Canadian law, they qualify as "toxic waste dumps." Indigenous communities that once hunted these cetaceans had to stop because of the health risks (Pullen & Hurst, 1993).

Agricultural pollution. Agricultural activity is the world's largest polluter. In virtually every country where farmers use them, agricultural fertilizers and pesticides have contaminated groundwater aquifers and surface waters. What little water trickles back into rivers and streams after irrigation is often severely degraded by excess nutrients, higher salinity, more pathogens, more sediments, and less dissolved oxygen.

Water quality standards lacking. Pollution is pervasive throughout the world. Few developing or industrialized countries have paid adequate attention to safeguarding water quality and to controlling water pollution. Many countries do not have standards to control water pollution adequately, nor do they have the capacity to enforce existing pollution standards. Increasingly, international development agencies such as the World Bank are urging developing countries to devote more attention and funds to improving water quality. But the developed world must also spend more money on cleaning up its degraded waterways. Without clean water, future economic development will stall.

Policy Options

1. The Population Imperative

Over the next two decades, projected population increases alone will push most African countries and all of the Near East into water scarcity—that is, having less than 1,000 cubic meters of fresh water available per capita per year. To prevent this projection from becoming a reality, the world must stabilize population growth as soon as possible. At the same time, everyone—the international community as well as national and local governments—needs to manage water better and to take broad-scale conservation measures.

Nearly three-quarters of the world's people live in developing countries, and the developing world also accounts for over 90 percent of population growth. At current fertility rates, populations in sub-Saharan Africa, the Middle East, and parts of South Asia will double in 20 to 40 years. At projected growth rates, by the year 2050 the global population is expected to be 9.4 billion, of which 8 billion will live in developing countries (UN Population Division, 2001).

The world likely will be unable to stretch freshwater resources to accommodate another three billion people, which makes a water crisis nearly inevitable. Thus, a comprehensive water-management strategy must include efforts to slow population growth. Stretching limited supplies to serve more people is only part of the equation; bringing down birth rates will relieve pressure on the demand side of the water equation. As part of this strategy, family-planning and reproductive health services must be extended. In

the developing world, at least 100 million married women (and millions more unmarried women) who want to plan, limit, or space their births do not currently use contraception. This unmet need would account for about one-third of the projected population increase in developing countries over the next half century. Thus, providing family-planning services to these women should be an urgent concern.

Providing better reproductive health care will also help improve people's ability to manage limited supplies of water. Studies have found that a person's ability to manage natural resources, particularly water and land, depends in part on his or her level of education and overall health status (Robey et al., 1992).

In much of the developing world, where piped water is unavailable, women and female children usually have the job of fetching water. UNICEF estimates that they spend 40 billion hours a year fetching water, which often requires walking half a kilometer or more to the nearest source of fresh water (UNICEF, 1997). Giving women more choices about childbearing, improving education, and providing opportunities to participate in development conveys many benefits, including improved household hygiene. But no amount of education can compensate for lack of adequate clean water supplies.

2. The Need For New Policies

Without better policies for managing scarce water resources, the prospect of conflict becomes greater. As Swedish hydrologist Malin Falkenmark has admonished: "We have to stop living as if we had unlimited water supplies and start recognizing that we must deal with serious water constraints" (Falkenmark, 1991). In Falkenmark's view, the relevant question to ask about water is not how much water do we need and from where do we get it, but rather how much water there is and how can we best benefit from it.

Ismail Serageldin, vice president for environmentally sustainable development at the World Bank, cites four principal policy failures underscoring the world's general inability to manage water supplies sustainably (Serageldin, 1995):

- First, water management is "fragmented among sectors and institutions." Governments make few efforts to develop an integrated response to water management. Instead, too many ministries and agencies continue to hold their fingers on the tap, with no one coordinating sectoral water policies. Worse, issues of water quality and health often go unaddressed since they do not fall within the mandate of any one government entity.
- Second, there is a "heavy dependence on centralized administration to develop, operate and maintain water systems." In many countries, agencies charged with managing water supplies are often overextended and lack the technical competence needed for the tasks confronting them. At the same time, governments do not involve stakeholders in setting water policies and regulating use. Water projects often do not meet consumers' needs.
- Third, most countries "do not treat water as an economic good." It is not valued properly, and many heavy water-users (such as farmers) do not pay for the amount of water they use. Instead, they rely on government subsidies and often waste enormous quantities of water by growing water-intensive crops in areas better suited to dryland farming. Unfortunately, governments find it easier to develop new water supplies than compel users of large water quantities to pay for the water they actually use.
- Fourth, and perhaps most serious, current water-management policies neglect to link the quality of water to human health, the environment, and the quality of life. Water resources are degraded nearly everywhere. In Poland, for instance, three-quarters of the country's river water is too polluted even for industrial use. In India,

a country highly dependent on irrigated agriculture for food supplies, farmers have abandoned more than four million hectares of high quality land because of salinization and waterlogging.

The world's failure to manage water adequately has spilled over into land and coastal management, affecting many other economic sectors and disrupting natural ecosystem functions on a massive scale.

The world needs nothing less than a Blue Revolution—a more comprehensive approach to water management that takes account of the needs of various users and apportions water accordingly. But water needs to be managed sustainably for the benefit of all, not treated solely as a free commodity. Water must be regarded and managed as a vital resource basic for all development. In short, we need water managers to take the broad perspective. Managing supplies without regard for reducing demand will simply aggravate the trends described above and result in a deepening water crisis, ultimately affecting everyone and everything on this blue planet.

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Table 1. Growing Water Shortages

Population Size and Growth and Renewable Freshwater Availability in Water-Short Countries, 1995 and 2025

Country	Population 1995 (millions)	Water Per Capita [a]	Population 2025 (millions)	Water Per Capita 2025 [a]	TFR 1998	% Pop. Growth Rate 1998
Water Scarcity in 1995 and/or 2025						
Algeria	28.1	**527**	47.3	**313**	4.4	2.4
Bahrain	0.6	**161**	0.9	**104**	3.2	2.0
Barbados	0.3	**192**	0.9	**169**	1.7	0.5
Burundi	6.1	**594**	12.3	**292**	6.6	2.5
Cape Verde	0.4	**777**	0.7	**442**	5.3	2.9
Comoros	0.6	*1,667*	1.3	**760**	5.1	2.7
Cyprus	0.7	*1,208*	1.0	**947**	2.1	0.7
Egypt	62.1	**936**	95.8	**607**	3.6	2.2
Ethiopia	56.4	1,905	136.3	**807**	7.0	2.5
Haiti	7.1	*1,544*	12.5	**879**	4.8	2.1
Iran	68.4	1,719	128.5	**916**	3.0	1.8
Israel	5.5	**389**	8.0	**270**	2.9	1.5
Jordan	5.4	**318**	11.9	**144**	4.4	2.5
Kenya	27.2	*1,112*	50.2	**602**	4.5	2.0
Kuwait	1.7	**95**	2.9	**55**	3.2	2.3
Libya	5.4	**111**	12.9	**47**	6.3	3.7
Malawi	9.7	1,933	20.4	**917**	5.9	1.7
Malta	0.4	**82**	0.4	**71**	2.1	0.6
Morocco	26.5	*1,131*	39.9	**751**	3.3	1.8
Oman	2.2	**874**	6.5	**295**	7.1	3.9
Qatar	0.5	**91**	0.8	**64**	4.1	1.7
Rwanda	5.2	*1,215*	13.0	**485**	6.0	2.1
Saudi Arabia	18.3	**249**	42.4	**107**	6.4	3.1
Singapore	3.3	**180**	4.2	**142**	1.7	1.1
Somalia	9.5	*1,422*	23.7	**570**	7.0	3.2
South Africa	41.5	*1,206*	71.6	**698**	3.3	1.6

Country	Population 1995 (millions)	Water Per Capita[a]	Population 2025 (millions)	Water Per Capita 2025[a]	TFR 1998	% Pop. Growth Rate 1998
Tunisia	9.0	**434**	13.5	**288**	3.2	1.9
United Arab Emirates	2.2	**902**	3.3	**604**	4.9	2.2
Yemen	15.0	**346**	39.6	**131**	7.3	3.3
Water Stress in 1995 and/or 2025						
Afghanistan	19.7	2,543	45.3	*1,105*	6.1	2.5
Belgium	10.1	*1,234*	10.3	*1,217*	1.6	0.1
Burkina Faso	10.5	2,672	23.5	*1,194*	6.9	2.9
Eritrea	3.2	2,775	6.5	*1,353*	6.1	3.0
Ghana	17.3	3,068	36.3	*1,464*	5.5	2.9
India	929.0	2,244	1,330.2	*1,567*	3.4	1.9
Lebanon	3.0	1,854	4.4	*1,261*	2.3	1.6
Lesotho	2.0	2,565	4.0	*1,290*	4.3	2.1
Mauritius	1.1	1,970	1.5	*1,485*	2.0	1.0
Niger	9.2	3,552	22.4	*1,452*	7.4	3.4
Nigeria	111.7	2,506	238.4	*1,175*	6.5	3.0
Peru	23.5	*1,700*	35.5	*1,126*	3.5	2.2
Poland	38.6	*1,458*	40.0	*1,406*	1.6	0.1
South Korea	44.9	*1,472*	52.5	*1,258*	1.7	1.0
Tanzania	30.7	2,964	62.4	*1,425*	5.7	2.5
Togo	4.1	2,938	8.8	*1,370*	6.8	3.6
Uganda	19.7	3,352	45.0	*1,467*	6.9	2.7
United Kingdom	58.1	*1,222*	59.5	*1,193*	1.7	0.2
Zimbabwe	11.2	1,787	19.3	*1,034*	4.4	1.5

Water-stressed countries are those with annual water resources of between 1,000 and 1,700 cubic meters per person, shown in italic. Countries suffering from water scarcity are those with annual supplies of less than 1,000 cubic meters per person, shown in ***dark type.***
TFR = Total Fertility Rate
[a]In cubic meters per year
Source: Gardner-Outlaw & Engelman, (1997). Gardner-Outlaw and Engelman base their calculations on UN Population Division population estimates. The growth rate and TFR data come from Population Reference Bureau (1998).

Table 2. Renewable Water Resources in Asia

Country	Population (1996)	Precipitation (mm)	Internal*	
			million m^3	m^3 per inhab (1996)
(Forumula)	(1)	(2)	(3)	(4)=3*10^8/(1)
Bangladesh	120,073,000	2,320	105,000	874
Bhutan	1,812,000	4,000	95,000	52,428
Brunei	300,000	2,654	8,500	28,333
Cambodia	10,273,000	1,463	120,570	11,737
China	1,238,270,000	648	2,812,000	2,271
India	944,580,000	1,170	1,260,540	1,334
Indonesia	200,453,000	2,700	2,838,00	14,158
Japan	125,351,000	1,728	430,000	3,430
Korea, DPR	22,466,00	1,054	67,000	2,982
Korea, Rep.	45,314,920	1,274	64,850	1,431
Lao, DPR	5,035,000	1,600	190,420	37,782
Malaysia	20,581,000	3,000	580,000	28,183
Maldives	263,000	1,883	30	114
Mongolia	2,515,000	251	34,800	13,837
Myanmar	45,922,000	2,341	880,600	19,176
Nepal	22,021,000	1,500	198,200	9,000
Papua New Guinea	4,400,000	3,500	801,000	182,045
Philippines	69,283,000	2,373	479,000	6,914
Sri Lanka	18,100,000	2,000	50,000	2,762
Thailand	58,703,000	1,485	210,000	3,577
Vietnam	75,181,000	1,960	366,500	4,875

* *Internal:* Originating within a country.
***External:* Originating outside a country.

Country				External Dependency Ratio (%)
	External**	Total		
	million m^3	million m^3	m^3 per inhab (1996)	
	(5)	(6)=(3)+(5)	(7)=(6)*10^8/1	(5)/(6)
Bangladesh	1,105,644	1,210,644	10,083	91.3
Bhutan	0	95,000	52,428	0.0
Brunei	0	8,500	28,333	0.0
Cambodia	355,540	476,110	46,346	74.7
China	17,169	2,829,569	2,285	0.6
India	647,220	1,907,760	2,020	33.9
Indonesia	0	2,838,000	14,158	0.0
Japan	0	430,000	3,430	0.0
Korea, DPR	10,135	77,135	3,433	13.1
Korea, Rep.	4,850	69,700	1,538	7.0
Lao, DPR	146,130	331,550	66,181	42.9
Malaysia	0	580,000	28,183	0.0
Maldives	0	30	114	0.0
Mongolia	0	34,800	13,837	0.0
Myanmar	165,001	1,045,601	22,769	15.8
Nepal	12,000	210,200	9,545	5.7
Papua New Guinea	0	801,000	182,045	0.0
Philippines	0	479,000	6,914	0.0
Sri Lanka	0	50,000	2,762	0.0
Thailand	199,944	409,944	6,983	48.8
Vietnam	524,710	891,210	11,854	58.9

Source: Facon (2000).

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Urbanization and Intersectoral Competition for Water

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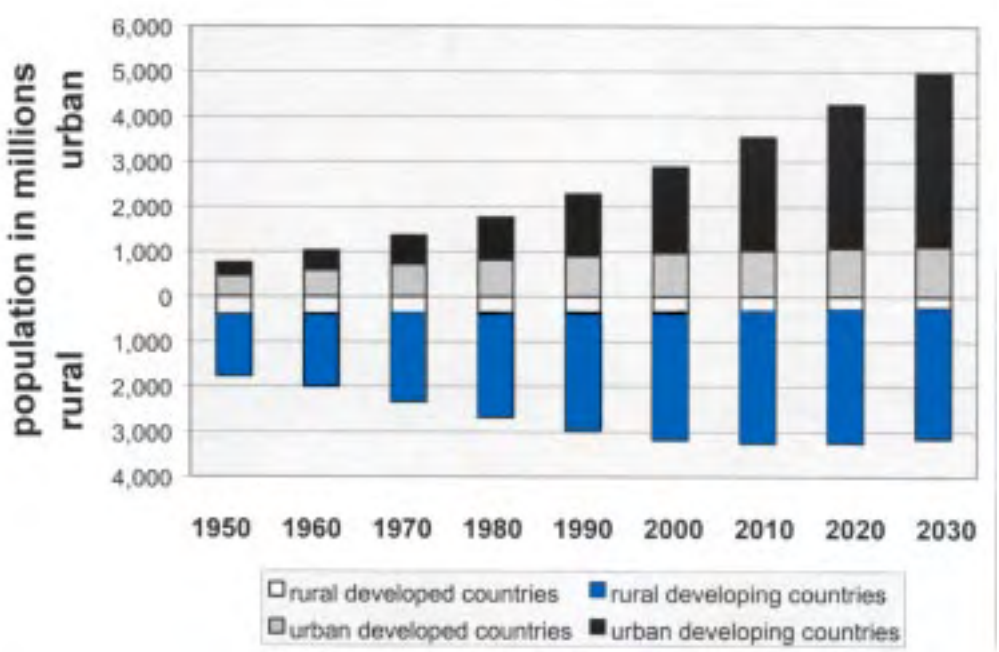
Introduction

One of the most dramatic demographic trends in the latter half of the 20th century was the urbanization of populations in both developing and industrialized countries—a trend likely to continue in the first half of the 21st century. Worldwide, cities added more than 2 billion people from 1950 to 2000, and they are expected to add more than 2 billion more from 2000 to 2025 (see Figure 1). As much as 95 percent of these increases is anticipated to come in developing countries, especially Asia and Africa. Whereas the populations of Europe, the Americas, and Oceania were by 1994 over 70 percent urbanized, Asia and Africa were only 34 percent urban. But these continents are projected to

Figure 1. Urban and Rural Populations in Millions, 1950-2030



Source: data from FAO STAT: http://apps.fao.org

be 54-55 percent urbanized by 2025 (United Nations Population Division, 1996). And while the rate of global urban growth is now actually declining (from 2.6 to 2.2 percent per year worldwide, and 3.8 to 2.9 percent in developing countries), the sheer number of people being added to cities will continue to grow rapidly. There are already 411 cities with more than a million people, and 19 megacities with over 10 million (Catley-Carlson, 2000).

Such concentrations of humanity pose enormous challenges to the social, political, and physical environment—challenges that apply not only to cities but rural areas as well. Countries that are urbanizing later are going through the process at a compressed pace, which makes it even more difficult to keep up. Perhaps the greatest two challenges imposed on natural resources by rapid urbanization lie in (1) the distribution of limited water supplies, and (2) the disposal of water-borne wastes. A closer look reveals that meeting urban water needs also has serious economic, social, and political dimensions.

Urban water demand comes both from: (a) the concentration in cities of people, who need water to survive; and (b) urban economic activity. Meeting the water demands of growing cities requires not only large quantities of high-quality water for domestic use, but also large volumes of water for industrial production. Although agriculture is still the largest user of water—accounting for an estimated 72 percent of water withdrawals worldwide and over 90 percent in low-income developing countries (Rosegrant & Ringler, 1998)—municipal and industrial demands are growing much faster (see Table 1). For example, urban water demand in China is projected to grow 60 percent over the next ten years, from 50 to 80 billion cubic meters (BCM); and Chinese *industrial* water demand will increase 62 percent, from 127 to 206 BCM (Nyberg & Rozelle, 1999, page 85). In India, the current domestic water use of about 25 BCM is expected to more than double by 2025 to 52 BCM,; while current water demand by Indian industry and energy generation of about 67 BCM is projected to increase to 228 BCM by 2025. Thus, Indian domestic and industrial water withdrawals will more than double over the next 25 years, accounting for 27 percent of total withdrawals for the country by 2025 (compared to 17 percent in the mid-1990s) (World Bank, 1998).

Table 1. Estimated Global Water Use in the 20th Century

Sector	***1900***	***1950***	***1995***
Agricultural use			
Withdrawal	513	1,124	2,504
Consumption	321	856	1,753
Industrial Use			
Withdrawal	22	182	752
Consumption	5	14	83
Municipal Use			
Withdrawal	44	53	344
Consumption	5	14	50
Reservoirs (evaporation)	0	11	188
Total			
Withdrawal	579	1,365	3,788
Consumption	331	894	2,074

Source: Shiklomanov (1999).

Currently, the world overall has sufficient water to meet municipal and industrial demands, which represent a small fraction of available water supplies (especially compared to agricultural water use) both globally and in most developing countries (Shiklomonov, 1999). But it is not enough to have sufficient quantities of water at a global or macro level. Water must be supplied *where* it is needed, *when* it is needed, and at a sufficient *quality*. It is these characteristics that both pose the greatest challenge to urban water supply and generate the greatest competition between water-use sectors.

This article examines the implications of urbanization for intersectoral competition over water, not only in technical or economic terms, but also in terms of political and social dynamics as well as the possibilities to meet the water needs of growing cities. It begins by looking at the water needs of each sector in urban and rural areas—the quantity, timing, and quality of water demand. It then treats (a) the intersectoral linkages in water quantity and quality, (b) the resulting competition and opportunities for cooperation posed by these linkages, and (c) the values of water in different uses. A closer look at the identity of the users provides insights on how competition for water is likely to play out in different settings. (However, this competition is not necessarily a zero-sum game.) The article identifies promising technical and institutional options for supply and demand management to provide adequate water services. It concludes by exploring the implications contemporary urban dynamics pose for future water policy.

Water Uses in Urban and Rural Areas

The major sectors of human water use are: (a) domestic consumption; (b) industrial production; (c) agricultural production (including livestock); and (d) recreational uses. Although domestic and industrial uses are usually associated with urban demand (and agriculture with rural demand), a closer look indicates that *all* of these uses cut across rural, peri-urban, and urban divisions.

Domestic Water Consumption

Most societies and national policies accord highest priority to water for direct human consumption, including drinking, cooking, bathing, and cleaning. Lack of access to sufficient water for drinking and bathing increases the spread of many water-borne and water-washed diseases, especially diarrheal and skin diseases. Furthermore, domestic water should be of good quality. Both bacterial and chemical contamination can also cause disease (Van der Hoek, 2001).

Defining basic human needs for water is difficult. Gleick (1999) estimates an average need of five liters/capita/day for drinking, plus 10 for food preparation, 15 for bathing, and 20 for basic hygiene and sanitation—making a total of 50 liters/capita/day. However, domestic water demand is not simply a multiple of the population size. Per capita demand increases with urbanization and rising incomes. Rural water supply systems in India, for example, use a norm of 40 liters/capita/day for domestic use without household piped connections, where it is assumed that other water sources can be used for bathing and washing clothes. Urban areas with piped water supply but no underground sewerage in India use 70 liters/capita/day, while India's urban areas with underground sewerage use 125 liters/capita/day, as in most major cities (MIDS, 1995). These norms refer to basic levels; water demand can rise even further with rising incomes. Residential use in Europe, for example, averages around 200 liters/capita/day, and in the United States, 400 liters/capita/day (Cosgrove & Rijsberman, 2000). By Indian standards, a population of one million people would require: 14.6 million cubic meters per year delivered to the end-users for domestic water supply in rural areas; 25.5 million cubic meters for piped urban supplies but no sewerage; and 45.6 million cubic meters for sewerage. The

same one million population in the United States would require 146 million cubic meters (plus transit losses).

Despite the recognized importance of domestic water supplies, an estimated 1.1 billion people worldwide do not have access to an adequate quantity or quality of domestic water. At least 2.2 million die annually of diarrheal diseases alone (WHO & UNICEF, 2000). This problem cuts across rural and urban divides. In rural areas, women and children often walk several kilometers to collect water. But urban dwellers are not necessarily better off. Both Lagos and Abidjan have average municipal water supplies of only 40-45 liters/capita/day for their entire populations. Nairobi has a mere 17.7 liters/capita/day, and Lome and Accra supply less than 10 liters (UNCHS, 1998). Even in cities with high average domestic water consumption, many people—especially those living in slums and peri-urban areas—do not receive an adequate share of the municipal supplies. A study in nine East African cities recorded a decrease from the late 1960s to the late 1990s in both (a) the proportion of households with piped water at their homes, and (b) the availability of water in the municipal systems. For those without household pipe connections, collection time for travel and queuing tripled from less than half an hour to more than an hour and a half per day, with private kiosks having the highest collection times (Thompson et al., 2000).

Industrial Water Use

Beyond domestic water needs, water is an input into the economic development process. Industrial production requires water, although the exact amount varies depending on the industry and the technology used. Because of the clustering of factories in cities, industrial demand forms a significant amount of urban water demand. However, a growing number of factories in rural areas also demand water. Industries not only require water for the manufacturing process itself but also for cooling or cleaning. This allows for the possibility of recycling water in factories.

Agricultural Water Use.

Agriculture is the largest water-consumption sector worldwide, especially in developing countries. Irrigation has been and will continue to be critical to achieving food security. Worldwide, irrigated agriculture contributes nearly 40 percent of total food production on 17 percent of the global cultivated area. Irrigated production supplies over 60 percent of the food in India and nearly 70 percent of the grain in China (Rosegrant & Ringler, 1998). Controlled water supplies were critical to the dramatic yield increases of the Green Revolution period of the 1960s-1980s, which allowed per capita food consumption to go up in developing countries (especially in Asia) despite increases in overall population. The increased food production needed to supply the growing urban and rural populations of the future will likely require even more irrigation: the International Water Management Institute (IWMI) estimates that 17 percent more water will be needed for irrigation by 2025 to meet food demand (IWMI, 2000).

Many irrigation systems appear to use water inefficiently, so that crop production itself consumes a relatively low fraction of the water diverted. For example, with surface water applications, only one- to two-thirds of the water applied at the field level goes directly for crop growth, with the rest seeping away or evaporating. Consequently, it appears that either increasing irrigation efficiency or reducing water losses (such as through new irrigation technology or management practices) would free up significant water for other uses, especially municipal and industrial uses. However, this process is not as simple as it seems: unused water from irrigating one field often becomes a source of water further downstream. Thus, overall basin-level efficiencies are generally much higher than they seem, leaving less “unused” water than is assumed (Seckler, 1996).

Within the agricultural sector, crop production receives the greatest attention, but fish and livestock also require water. Animals (including fish) consume a relatively small volume of water in comparison to crop consumption and can produce a very high value of output (Bakker et al., 1999). Moreover, as worldwide demand for animal products increases, the importance of supplying water for aquaculture and livestock is also likely to increase.

In terms of water quality, agricultural production does not require its water supplies to be as clean as those for domestic use. However, crop production is very sensitive to salinity levels and to some industrial pollutants. Treated sewage can actually provide nutrients to crops, but the danger from contamination depends on how and where the crops are used in the food chain (e.g., vegetables that are eaten fresh are most susceptible, followed by grain and tree crops; danger of contamination is least for fiber or fuel crops). Furthermore, continuous use of recycled sewage can lead to build-up of salts that make the soil unproductive. Meanwhile, agrochemicals in the runoff from irrigation systems can become a significant source of water pollution. Fertilizer runoff can cause eutrophication (excess algae growth) of water bodies, and pesticide residues can be toxic for fish and human consumption.

Although agriculture is a predominantly rural activity, urban agriculture is also significant. An estimated 800 million people worldwide take part in urban agriculture, with 150 million full-time farmers (UNDP, 1996). Gardens in cities and peri-urban areas contribute significantly to incomes, food security, and nutritional quality of diets, especially for the poor. Livestock production (including dairy) is also a significant source of income and micronutrients, while trees contribute to food, fuel, and air quality as they improve the overall urban environment (Smit & Nasr, 1992). All of this activity requires water drawn from municipal systems, local wells, water harvesting, or recycled wastewater.

Providing water for utilitarian purposes (production and domestic consumption) alone is not enough; people also demand water for recreational and aesthetic purposes. Ornamental gardens, lawns, swimming pools, and golf courses may not be considered "essential" water uses, but demand for such uses rises with income levels. They thus need to be included in long-term plans for water supplies or managing water demand.

In sum, stereotypical images of "thirsty cities" that equate (a) urban demand with "drinking water" or factories, and (b) rural water supply with irrigation do not adequately portray the water uses in each area. Rural areas also need domestic water supply; and with rural industrialization, factories are increasingly drawing water (and discharging wastes) in rural areas. Nor should the water uses of urban agriculture and landscaping be overlooked.

Intersectoral Linkages in Water Quantity and Quality

As long as there is unused water, meeting cities' growing water requirements poses primarily a technical and financial challenge. However, when water becomes scarce worldwide, meeting the demands of urban areas for drinking, industrial, and other uses will necessitate shifting regional water resources from rural to urban consumers. This need creates rural-urban and sectoral competition over the allocation of water resources.

Water use, however, is not simply a matter of withdrawal. Two other critical elements to consider when evaluating any form of water use are (a) the return flows it generates, and (b) the waste those return flows add to the hydrologic system. Although agricultural use also involves drainage back to rivers and aquifers, the proportion of the water returned as wastewater in urban areas is much higher. The sewage or industrial effluents discharged in urban situations have a high potential for polluting the surface or ground water—affecting the quality and therefore future potential uses for the water. Discharge of wastewater after municipal or industrial use can impose a negative externality (a social

cost) on the next user: the wastewater will have to be treated to minimize the pollution and maximize its utility.

This dynamic results in important intersectoral linkages in both water *quantity* and *quality*. Although the former has received greater attention in most water policies, water *quality* linkages are becoming increasingly critical. In both cases, the intersectoral linkages and possible conflicts that may emerge have to be managed by appropriate institutions, preferably at the basin level.

Water quantity linkages

The hydrological cycle provides periodic rainfall or snowfall to replenish the flow in the rivers and streams and augment the groundwater table. Water is therefore a renewable natural resource that can be utilized in a sustainable manner provided long term "use" does not exceed natural replenishment. The total available water resources in a given basin or region is fixed, however, and has to be shared among many users.

The International Water Management Institute (IWMI) distinguishes between *open* basins, which have enough water to accommodate new users, and *closed* basins, where all available supplies are allocated to existing uses (Seckler, 1996). More and more water basins, even in once water-abundant areas, are becoming "closed": increasing the water available for one use in a basin requires removing that water from other uses (including nature) or from other basins.

The timing of water demand causes further complications. Much agricultural water use is seasonal. By contrast, municipal and industrial water demands are year-round. In climates where rainfall or runoff are seasonal, supplying water in the dry season requires storage, generally in the form of groundwater reserves or surface reservoirs. Stored water is the most valuable (for agriculture as well as domestic and industrial uses), but also the scarcest.

Unlike irrigation, where crops consume large volumes of water through evapotranspiration (evaporation from the soil and transpiration by the growing plants), municipal and industrial uses return 70 percent or more as wastewater. In some cities and towns where individual homeowners or industries supplementally tap the local ground water, they may actually return a greater volume of wastewater than the amount of water they received from the public supply system. Storm water runoff from the streets also mixes with sewage in some urban settings. Much of this water can be recycled as it moves through the basin, provided it is treated to remove harmful wastes. However, over 40 percent of cities with a population over 500,000 are located on coasts (WRI, 1996), which reduces the scope for reuse. Unless these cities take special measures to recycle water (e.g., through industrial recycling or use of treated sewage for peri-urban agriculture), their wastewater is discharged into the sea and lost.

Water quality linkages

The quality of available water in rivers, lakes, and the sea diminishes with the return of wastewater, although the level of quality and potential future uses depend on the wastewater's origins. Municipal wastewater or sewage contains organic compounds, nitrogen, and solids that have to be removed through sewage treatment. Untreated sewage pollutes the water bodies into which it is discharged and could endanger public health and aquatic ecosystems. (The nutrients contained in sewage could be profitably utilized for urban agriculture such as tree crops or fodder.) Unfortunately, the sewage also contains various urban wastes from gasoline stations, photo shops, laboratories, and small industries. These can contribute heavy metals and other toxic compounds that are not suitable for agriculture.

Industry could use sufficiently-treated sewage. Since sewage is discharged continu-

ously throughout the year, wastewater is a reliable source of water for industry. For example, some of the large industries in Chennai (Madras) India that experienced severe water shortage problems in the 1980s (due to heavy reliance on ground water) collaborated with the local water agency to use partly treated sewage. The industries (a refinery and a fertilizer plant) set up treatment facilities to purchase and treat the sewage adequately so that it could be used not only for cooling but also for manufacturing pro-

Simply appropriating water from existing rural uses for transfer to cities and industries will cause rural resentment.

cesses. These industries have subsequently used sewage successfully for nearly a decade—a win-win solution that saves the water agency the cost of treatment and actually (a) brings revenue from selling the sewage, (b) reduces pollution, and (c) provides the industries with a reliable source of water.

Industrial effluents can also pollute water bodies or ground water, rendering the water unsuitable for other economic or ecological uses. The return flow from industries that consume large quantities of water for processing can restore a river's quantity of flow to its original level but also seriously impair its quality. Users downstream from such industries either cannot use the water or have to commit resources for treating the water to restore it to usable quality. The intersectoral impact is even greater where the effluent is discharged upstream of a dam. During the dry season when the dam is closed, the effluent accumulates in the reservoir, contaminating the surface water and even percolating to the groundwater table (Appasamy, 2000). In some cases, the effluents also flow directly on to agricultural land, affecting soil and ground water while also possibly contaminating drinking water wells. Additionally, the effluents may seriously harm the quality or usability of agricultural land and drinking water wells in the region, forcing farmers and

consumers to abandon them (Appasamy, 2000; Kurnia, Avianto, & Bruns, 2000).

Disposal of partly-treated or untreated effluents on land is often recommended in semi-arid regions of developing countries as a source of irrigation. Israel meets over 70 percent of irrigation with wastewater reuse, and it is estimated that over 500,000 hectares in Latin America are irrigated with untreated watewater, with half of that land in Mexico (see Scott, Zarazúa, & Levine, 2000). This technique is supposed to be a win-win solution that avoids creating pollution while providing farmers with water. Unfortunately, the technique promotes the buildup of salts and other toxins in ground water and soils, ultimately stunting crops. The negative impact may take time to manifest itself, by which time the water table is so contaminated that it may take years before the process can be reversed.

Fisheries and other aquatic ecosystems are particularly sensitive to water quality and can be seriously affected when industrial effluents are discharged into water bodies. The harm may travel up the food chain when other aquatic life or people eat the affected fish. Similarly, livestock require water for drinking and fodder, and milk is especially susceptible to poor quality water or contaminated fodder.

Economic Values of Water in Different Uses

When water scarcity arises, governments generally allocate water resources among sectors by assigning priorities and setting quantitative limits for each user. Economists have argued strongly for using market mechanisms (such as tradable water rights) or pricing instead as the instrument for allocation. The International Conference on Water and the Environment (ICWE, 1992) agreed upon the principle known as the Dublin Statement (which was subsequently affirmed at several other international forums, such as the 2000 Second World Water Forum) that water must be treated as an “economic good” on account of its relative scarcity. Though this has not been widely applied in practice, there is growing attention to economic aspects in water allocation (Dinar, 2000). There are several ways of estimating the economic value of water, either based on: (a) the value in production, actual water prices, or users’ willingness to pay; or (b) the cost of recycling or alternative water sources. However, it is important to recognize that there are two components to water costs: the cost of delivering the water, and the value of the resource itself. Water does not reach the end-user without infrastructure to collect it and deliver it to the user. The net benefit of water is the value (in use) less the cost of delivering the water.

Agriculture

Since water is an input into agricultural production, it is possible to compute the value of water to that production process. An irrigated plot yields much greater returns than does an unirrigated plot, with the difference in returns indicating the value of water to agriculture. But these conventional approaches to valuing irrigation water neglect the value of other overlapping water uses that are generally found in irrigation systems, especially in developing countries. The value of fish production, livestock, homestead gardens, domestic use and other enterprises that draw water from the irrigation system can be substantial. Because they are difficult to measure, however, they are often overlooked.

Industry

In the case of industrial water use, instead of estimating the value through the production route, researchers could determine how much industry would be willing to pay or

actually pays for the water. For industries that recycle water, the cost of recycling a unit of water could also be estimated (Bhatia, Cestti, & Winpenny, 1995). All these methods reflect the upper bound that industry sets on the value of water.

Households

In the case of households, researchers can carry out "willingness-to-pay" surveys to estimate the value of water. Where private markets for water exist, the scarcity value of water can also be observed in the marketplace. As in the case of irrigation, the cost of supplying the water must be deducted to estimate the net value of water for both industrial and domestic use.

Nature

Finally, the market (or "revealed preference") cannot reveal the value of water for ecological services, because such services are by nature public goods and valuable to future generations as well as our own. In this case, the measure of willingness to pay (e.g. for protecting a wetland or other aquatic ecosystems) also does not capture important non-economic factors, such as preservation of biodiversity or even aesthetics. Because of the difficulties in valuing ecological services and deciding who should pay for them, it may be preferable to allocate water for these purposes quantitatively, without debating their value vis-à-vis other sectors. Such a decision may have opportunity costs in the sense that the water set aside cannot be used for other purposes. On the other hand, it may be possible for certain uses to coexist. For example, aquaculture and capture fisheries can operate in the reservoirs and canals of irrigation systems in some cases, but in other cases excessive use of agricultural pesticides can compromise fisheries. Each case is location-specific and has to be examined independently.

In practice, the monetary value of water in the industrial or domestic sector is generally much higher than in the agricultural sector, as increases in food production over the past 20 years have led to a decline in real food prices (especially for wheat and rice, the major crops grown under irrigation in many developing countries). This dynamic does not mean that other sectors are more important than agriculture: growing populations will have to eat as well as drink. However, if the market alone allocated water, non-agricultural requirements would be met first. Societies, on the other hand, may wish to place equal or greater value on agriculture, since: (a) food is a basic need, (b) agriculture is vital to rural livelihoods, and (c) issues of future food security or equity may not be adequately captured by economic measures.

Arguments For Pricing

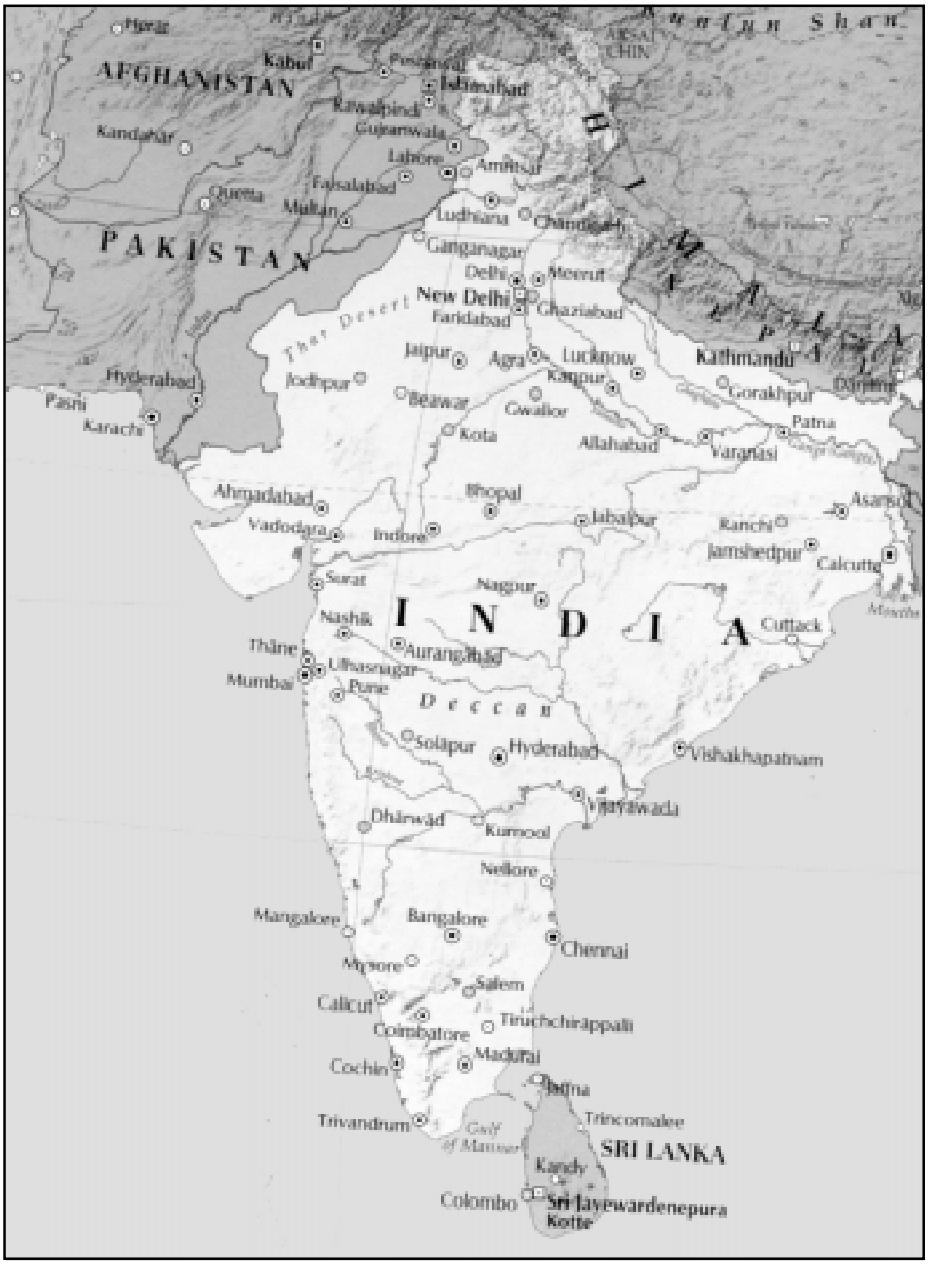
Within the agricultural sector, it is useful to compare the marginal value of water for different crops. In many cases in both developing and industrialized countries, irrigation water has been heavily subsidized for farmers as a government policy to increase food production and gain the political support of rural populations in countries from the United States to India. Even when farmers are charged for water, charges are rarely based on the amount of water used (largely because of technical difficulties and the cost of measuring and collecting volumetric charges). As a result, farmers have no incentive to economize their water use, and may choose to grow water-intensive crops like rice or sugarcane even in water-scarce areas. If the technical and managerial obstacles could be overcome, pricing irrigation water to reflect its real value would lead to more rational cropping-decisions by farmers.

The same principle applies to households, which tend to waste water. It is often suggested that pricing would force water conservation and reduce non-essential uses such as ornamental gardening or swimming pools. Yet water may not have high price elasticity. In

developing countries, those who use water for these purposes are rarely deterred by increased prices for publicly supplied water; in practice, they purchase water from private suppliers at far higher prices. Where price increases have reduced water use, the conservation effect decreases over time as people adjust to the new prices (UNCHS, 1996). If conservation is the purpose, quantitative restrictions may be more appropriate.

But there are other reasons for pricing domestic water at a higher price that is closer to

Map 1. India



Source: *The Times Atlas of the World* (1999)

the value the water holds for other uses. First, increasing cost recovery would provide funds for continued investment in and operation of water-supply systems (as well as for acquiring the water). Currently, many cities lose 40 to 60 percent in the form of unaccounted water (Wegelin-Schuringa, 1999). If water were priced realistically, cities would realize that their mismanagement is costing them a valuable resource (or, conversely, that they could double revenues by eliminating water loss).

Water valuation aids policymakers in making both allocation as well as pricing decisions. Pricing of water is important not only for making optimal use of the resource, but also to ensure the financial sustainability of the water agency—be it for irrigation, industry, or household use. There is a growing literature on the political economy of water pricing (e.g., Dinar, 2000), spurred by the resistance of interest groups (such as agriculture) to proposed reforms to current free or subsidized water supplies. Given the strain on public budgets, water agencies will face a difficult choice in the long run: either allow the infrastructure to deteriorate, or make the politically unpopular decision to price water efficiently for all sectors.

It is a myth that the poor will not pay for water. Many surveys indicate that poor people are willing to pay for water if they are guaranteed a reliable supply (Wegelin-Schuringa, 1999). And the poor currently pay for water when they purchase from vendors or if they have to spend time collecting the water from standposts and other sources.

But although water clearly has an economic value, pricing water is controversial because, unlike other commodities, water is essential for all forms of life—and therefore should not be denied because the user cannot afford to pay or because Mother Nature cannot express preference in the marketplace. It becomes necessary, therefore, to ensure a "lifeline" quantity not only for human beings, but also for livestock, fish, and all living ecosystems. In other words, the allocation mechanism must make provision for ecosystem uses, apart from purely anthropogenic uses. Beyond this baseline, water pricing can be useful to manage demand and make resources available to pay for adequate water services for all.

It is also important to value the waste-disposal services that rivers and lakes provide in assimilating effluents, thereby cleaning water flows. Analysts can value these services in terms of the cost of effluent treatment that would have been incurred in the absence of the water body. Of course, waste should not be exempted from treatment prior to its discharge into the water body. In practice, however, discharges are rarely treated. Analysts estimate that 90 percent of sewage in developing countries is discharged directly into water bodies without treatment; hence rivers, lakes, and coastal bodies in these regions have become severely polluted (WRI, 1996). In tropical countries (where rainfall is seasonal) there is the added problem that those rivers that only have seasonal flows have no capacity to receive even treated effluents in the dry seasons.

Water Users and Power Relations

Despite the Dublin Statement and a number of other international declarations that water should be treated as an economic good, the allocation and provision of water to different uses rarely follow strictly economic values and criteria. Rather, social and political factors exert a major influence on these decisions. Because water supply is so vital to life as well as to livelihoods, its provision is critical for social stability and political legitimacy of governments. Thus, intersectoral competition for water cannot be understood without looking more closely at (a) the users and other stakeholders, (b) their power relations, and (c) the strategies they employ to secure their water demands.

Box 1: Water Quantity, Quality, and Influence in Tiruppur, South India

The town of Tiruppur in South India exemplifies many of the dilemmas that developing countries face when a secondary city or town rapidly industrializes. Tiruppur's rapid expansion of population—from 235,000 in 1991 to 340,000 in 2001, with a predicted increase to 490,000 in 2011—has resulted in an increased need in the city for both water supply and underground sewage. Much of this population increase is drawn by the hosiery industry, which has grown rapidly due to the opening up of export markets. This industry employs over 200,000 people in the Tiruppur area and generates millions of dollars of exports. There are 702 bleaching and dyeing units in the area that require large quantities of water to operate.

Tiruppur has intersectoral competition over both quantity and quality of water. Water for the city's industries has been largely obtained by pumping local groundwater, which is being depleted. Some farmers have begun selling water to the city and industries—but while these farmers find selling water more profitable than using it on their own farms, surrounding wells are drying up because of the increased extraction.

The effects of increased industrial water demand on Tiruppur's water quality are even more serious. The effluents discharged by the local hosiery industry's bleaching and dying units have polluted the river and local ground water in the urban area. Residents have to rely on water brought from more distant sources. The effluents have also affected the city's irrigation tanks as well as a new reservoir downstream from Tiruppur. All of these are now unfit for both irrigation and fisheries, amounting to losses of $1 million for which the farmers and fishers were not compensated.

In collaboration with industry, a number of funding agencies are financing a 55 km pipeline to bring water from a local river to supply water for Tiruppur's municipality, industries, and wayside villages. Proponents of the project propose that its investment costs will be recovered through user charges. The implementation of the project will reduce the exploitation of ground water, but will still result in the discharge of effluents. The pipeline has been opposed by farmers' organizations and community groups.

Government pressure on the hosiery industry to recycle its effluents could have reduced both the water requirement and the downstream pollution problem. (Indeed, water scarcity has already reduced water-use per kg of cloth from 226.5 liters in 1980 to 144.8 liters in 2000.) However, there has not been effective coordination between Tiruppur's Public Works Department (which deals primarily with irrigation and water quantity) and the Pollution Control Board (which deals with industries and water quality). Farmers and local NGOs filed a petition with the Indian High Court, asking that local industries be required to treat their waste. As a result, most of the factories constructed individual or collective treatment units, and the remaining 164 industrial units were shut down for non-compliance. However, the treatment units still do not meet standards, and the factories are still able to exert considerable influence on local policymakers because of their importance to local employment and export revenues.

Source: Appasamy (2000).

Domestic Water Supply Users

At one level, domestic water supplies are the most cross-cutting type of water use. Rich and poor, urban and rural households alike need water for drinking, cooking, washing, and bathing. Women typically bear the greatest responsibility for domestic water use (and the greatest cost when it is not provided), but both men and women obviously need drinking and bathing water.

This universal human need for water is recognized in the primacy given to domestic water supplies in many government policies, religious statements on water, and local norms. The new South African water law is perhaps the clearest example of government law giving priority to basic domestic use (South Africa, 1997), but the importance of domestic use is also seen in Nepal's Water Resources Act of 1992 (Pradhan & Meinzen-Dick, 2001). Islamic law and hadiths stress the importance of providing water to guests, and extend the "right of thirst" for animals and plants as well (Farouqui, Biswas & Bino, 2001; Wescoat, 1995). In the Christian Bible, Matthew 25:40 relates that on judgment day, giving water to those who thirst will be one of the defining criteria for separating those who are to go to the kingdom of heaven from those who are to be cast out. In Hinduism, offering drinking water benefits the donor (Manu: IV:229). On the other hand, at least in one reported case in the hills of Nepal, it is believed that the persons who prevent others from gaining access to drinking water, even if the source is on private land, would go to hell (Upreti, 2000).

In principle, therefore, few begrudge allocating water for urban domestic use, especially since many rural families have members living in the cities. Rural opposition to transferring water for urban domestic use often comes from a perception that the cities will get a higher level of service, or that urban residents will use the water for non-essential purposes. For example, in the Lower Bhavani area of South India, when water from an irrigation reservoir was reallocated to Coimbatore city, many farmers did not oppose the transfer itself, because they recognized the importance of drinking water and because many had relatives living in the city. However, villages along the way protested that they did not have piped domestic water supply, so during the 1990s they were also given connections. As a result, the original allocation for domestic supply to the city had to be increased to supply the villages as well.

The universal human need for domestic water does not imply that everyone receives equal service. The differences lie not only between urban and rural situations but also between different types of cities and between classes within each area. The water problems of megacities often receive the greatest attention and resources from national governments and external donors; these cities are more likely to have exhausted locally-available water supplies and to have polluted their surroundings. However, only 15 percent of urban populations live in cities over 5 million; 60 percent live in cities and towns of less than a million (People and the Planet, 1996). Secondary cities and towns face problems in providing water similar to those of large cities, but they have fewer financial and political resources to address them.

At first glance, it may seem that rural and urban water interests are at odds with each other; but when we look closely at the household level, this characterization is revealed as not fully accurate. First, many rural households have family members in the cities, and thus can identify to some extent with urban water needs. Meanwhile, neither all rural nor all urban households have the same access to water. While a few rural households have their own tubewells close to the house or have access to piped water, other rural residents may (a) travel long distances to collect water, and (b) have problems with water quality. The differences in water access within cities are even more marked. Slum areas are often either not served by municipal supplies or have standpipes rather than household connections and no sewerage. Only 18 percent of low-income urban residents in develop-

ing countries have household pipe connections from the municipal water supply system, compared to 80 percent of high-income residents in these countries (WRI, 1996).

Industrial Users

Many governments give lip service to the priority of domestic water supply and may even list irrigation as the priority user in their water policy; but industrial uses generally prevail thanks to economic and political influence (see Box 1; for an example from Indonesia, see Kurnia, Avianto, & Bruns, 2000). This is seen not only in a society's water-allocation policy, but also in its degree of regulation over pollution. However, while large factories may have the greatest economic influence over policy decisions and their enforcement, they are easier to regulate than small factories: a large factory's supply and discharge occur at a single point, while many small and dispersed factories take water through a variety of legal, semi-legal, and illegal means and often discharge wastes with minimal treatment. And although many developing countries encourage rural industrialization in an attempt to prevent overcrowding of urban areas, the economies of agglomeration often make urban industrial production more efficient and easier to regulate. Indeed, discharge of effluent from rural factories has had very negative effects on agricultural production, e.g. in Indonesia and India (see Box 1).

Since factories employ so many people, it is not just industrialists who have an interest in securing water for factories. Even farm families often have family members employed in factories and therefore experience divided interests regarding industrial water use (Kurnia, Avianto, & Bruns, 2000). Also, the importance of generating exports and revenue for the government often leads to policies that favor industrial interests.

Farmers

Just as domestic and industrial users are not homogeneous and cut across rural and urban boundaries, farmers also differ greatly in wealth, influence, and ability to secure alternative water supplies and livelihoods. This makes it difficult to determine in advance how competition for water between agriculture and other sectors will play out. Those farmers who grow water-intensive or low-value crops may be able to switch to water-saving crops or technologies and still reap profits. Farmers who possess recognized senior water rights (those rights of longest-standing and with greatest legal backing) may be protected from water transfers or receive adequate compensation for such transfers. But many other farmers either lack the resources to change technologies or do not receive any compensation. Drought-related reallocations around Mendota, California from 1987-92 resulted in a 26 percent decrease in the number of farms. While larger farmers were better placed to cope with water losses, 70 percent of the Mendota area's small farms went out of business (Rosegrant & Ringler, 1998).

It is not only farmers' livelihoods that depend on water supplies: the entire rural economy of a region may be affected, including the tax base. Thus, "third-party effects" of intersectoral water transfers include not only the physical or hydrological consequences of water transfers, but also economic and livelihood effects. Moreover, even urban residents are stakeholders in ensuring stable agricultural production for food security.

Nature

Ecosystems (including wetlands, rivers, and discharges into the sea) require water just as critically as humans do. Demands to reserve water for nature generally increase with national income levels. Although local populations are most directly affected, national and even international environmental groups (e.g. the International Union for the Conservation of Nature (IUCN) and Green Cross International) advocate reserving water for nature (IUCN, 2000). Legislation such as South Africa's water law (South Africa, 1997),

court cases such as the application of the Public Trust Doctrine to limit water abstractions in the United States (Ingram & Oggins, 1992; Koehler, 1995), and international treaties such as the Ramsar Convention on Wetlands (UNESCO, 1994), all strengthen the bargaining power of nature advocacy groups to protect water supplies from further anthropogenic use. As ecosystem uses become recognized, there is less and less "unused" water available for growing urban demands, further increasing competition for existing water supplies.

Options for Meeting Urban Water Needs

There are three broad strategies for reconciling growing demands for urban water with the constraints on the quantity and quality available: (1) increasing supplies through new sources; (2) reallocation from other sectors; or (3) managing urban demand. Each of these calls for a combination of technical and institutional measures.

New Sources to Increase Water Supplies for Cities

The options for increasing water supplies through new sources include: (a) building new dams and water-control structures, (b) inter-basin transfers, (c) non-conventional sources such as desalination, and (d) water harvesting. As noted above, most urban uses require year-round access to water. In climates with seasonal rainfall (as in many developing countries), ensuring such supplies generally requires stored water. Ground water and reservoirs therefore play the largest role in supplying municipal water.

Ground water: Foster (1999) estimates that one billion urban dwellers in Asia and 150 million in Latin America rely on ground water for their domestic water supply. However, overextraction of ground water in and around cities has caused falling water tables. Cities such as Mexico City and Bangkok both face subsidence of the land itself as their aquifers are depleted and compacted, while almost all coastal cities face saltwater intrusion because of aquifer depletion (WRI, 1996). Moreover, contamination of aquifers through seepage from various wastes has reduced the quality of ground water, especially at shallow levels. Thus, groundwater storage has a limited capacity to meet even existing urban water demands.

Surface storage: Once a popular solution to rising water demands, new dams and reservoir building have become increasingly expensive in financial, environmental, and political terms. Almost all the best sites for such construction are already exploited; the environmental costs of submerging forests and wildlife are increasingly being recognized; and opposition to such environmental damage and the submergence of villages chronically provokes political opposition. Thus, cities often turn to water stored behind existing dams built for irrigation or hydropower.

Inter-basin transfers: Bringing in water from other areas represents another possibility to meet growing urban demands in water-short basins. Such projects often involve high-cost canals or pipes to transport the water, especially where the water must travel a long distance. Moreover, taking water from one basin may harm the environment, and the pipes or canals may have to cut through forests, agricultural land, or habitations—causing environmental or land acquisition problems. Increasingly, communities that lie in the path of such canals or pipes demand a share of the water, either for drinking or for irrigation.

Non-conventional sources: Desalination is expensive and energy-intensive under existing technology. Even after desalination, pumping water from the sea to its destination poses an additional cost. Thus, desalination is unlikely to be used on any large scale, except in very water-scarce and energy-rich countries (as in the Middle East).

Water harvesting: There are various forms of water harvesting that capture and store runoff during the rainy season, ranging in scale from a household rooftop to those

that cover a sub-watershed of several square kilometers—capturing water either in storage tanks, the soil profile, or recharging ground water (see Agarwal, Narain, & Khurana 2001; Kerr & Pangare 2001). These generally small-scale technologies are receiving attention from governments, NGOs, and donors because they are seen as environmentally friendly ways of increasing the availability of water

Water harvesting is especially important in monsoon climates with rapid runoff over a few months. The greatest emphasis has been placed on rural water harvesting, either for direct irrigation use or for recharging water tables. There is some debate whether this technique increases the water available for cities: critics claim that rural water harvesting reduces downstream flows, while proponents claim that effective harvesting can recharge water tables and bring seasonal rivers "back to life"—thus benefiting cities as well (Agarwal, 2000). Urban water harvesting certainly offers more direct possibilities to improve water availability in cities. As with rural water harvesting, rainwater and runoff can be either stored and used directly, or used to recharge the ground water. A growing number of cities, including Chennai and parts of Delhi, are requiring the inclusion of water-harvesting structures in all new buildings.

Reuse and recycling: As noted above, many forms of water use do not consume most of the water they withdraw. Much is eventually returned to the hydrologic system, though at a reduced water quality. Wastewater can be reused and recycled at various levels from the household to the city. "Grey water" from sinks or showers is often used for home gardens or can be diverted to soak pits to recharge the ground water. Treatment and recycling of wastewater for non-potable uses can be taken up in large buildings. Several cities have attempted to use treated sewage for urban agriculture or for industry, though there are concerns with the accumulation of salts and heavy metals that can harm the soil or human health (Flynn, 1999; Scott, Zarazúa, & Levine, 20001). Industries that recycle their wastewater simultaneously reduce their water requirement as well as the effluent discharged.

Reallocating Water from Agriculture to Cities

Although there is some capacity for tapping unexploited water sources to meet rising urban demands, these sources are becoming more difficult and expensive to access. Thus, supplying more water for cities will require taking water from another use. Increasingly, water is shifted from irrigation because: (a) it uses the most water worldwide, especially in developing countries; and (b) the estimated economic value of water in agricultural production is low relative to domestic and industrial use.

It is often argued that even a small percentage of water saved from agriculture could meet most urban demands (e.g., Rogers, Bouhia, & Kalbermatten, 2000). While this is true at an aggregate level, timing and location cause significant complications. Whereas much irrigation use is seasonal, non-agricultural requirements are year-round, necessitating storage. It is also usually not feasible for all farmers to save a small amount of water to transfer to cities; rather, those farmers near the cities usually become the major source of water transfers.

In many cases, water is simply expropriated from agriculture to meet other sectoral demands, as was done in the Bhavani basin in India or the Angat basin in the Philippines during a drought year. Such expropriations can cause political unrest as well as loss of income to others in rural communities and an erosion of the rural tax base. Further rural-to-urban migration might also be a consequence, as livelihoods and water dry up in rural areas. On the other hand, many farmers are often willing to share their water supply if they will be compensated. A myriad of cases—especially in the western United States, Chile, and Mexico—indicate considerable scope for negotiated transfers with mutual gain (for a review, see Rosegrant & Ringler, 1998). Under some of these arrangements, cities

can pay for investments in rural irrigation water conservation and then use the "saved" water; they can also pay farmers to not irrigate some of their land or buy outright rural water rights. Much of the success of these arrangements hinges on the extent to which the customary water rights of irrigators are recognized and alternative livelihoods are available. Even if the government has not conferred clear water rights to farmers, farmers who have been irrigating for a number of years generally feel ownership over the water; and such transfers do threaten their asset base and livelihoods (Bruns & Meinzen-Dick, 2000).

Tradable property rights for farmers (if recognized by the state) allow farmers to voluntarily transfer water to other users. This option offers the potential to protect farmers' interests while still providing an incentive for conservation and the transfer of water to higher-value (or higher-paying) uses (Rosegrant & Binswanger, 1994). However, such water markets will require (a) physical infrastructure for the transfers, (b) effective information systems, and (c) effective mechanisms for dealing with the consequences of such transfers for third parties. Reviewing the evidence on intersectoral water transfers, Rosegrant & Ringler (1998) concluded that outcomes are generally positive on rural communities under the following conditions:

Stereotypical images of "thirsty cities" that equate (a) urban demand with "drinking water" or factories, and (b) rural water supply with irrigation do not adequately portray the water uses in each area.

- farmers have secure water rights;
- farmers receive substantial compensation for transfers;
- farmers can sell only part of their water (and stay in farming);
- there are effective institutions to deal with third-party effects (including negative effects on the rural tax base and economy); and
- there are flexible tools (such as leases and options contracts) rather than just expropriation or outright sale of water to urban interests.

Managing Urban Water Demands

Increasing water supplies is not the only option for dealing with growing urban water use. There is also considerable scope for reducing water *demands* through physical and institutional mechanisms. In this regard, it is important to distinguish between (a) basic water *needs* for human and environmental uses, and (b) *wants* for water for additional goods and services (Lundqvist & Gleick, 1997). Reducing non-essential wants and wastage can reduce water demand substantially, reducing pressure on all water resources. While the following examples discuss urban water uses, the same principles can also apply to the rural sector as it attempts to conserve water in irrigation.

Given the high cost of transporting water from distant sources (as well as the opportunity cost of reallocating water from existing uses such as agriculture), urban water agencies are increasingly looking at ways to use the existing supplies more efficiently. Many cities in developing countries have "unaccounted-for water" (UFW) of 50 percent or more because of leakages, theft, or other problems in the distribution system. Reducing UFW and improving the physical efficiency of main supply and household plumbing will increase available water.

Leak detection: Leaks often occur at joints or at house-service connections due to corrosion or other structural problems. Mexico City alone loses an estimated 12 cubic meters per second because of leaks (Urban Age, 1999), amounting to 378 million cubic meters per year. Apart from the financial loss to water agencies, leakage affects the level of service to consumers. Moreover, contamination of protected water may occur if the leaking points are not repaired. Upon detection of leaks, water agencies may need to replace old pipes and take other remedial measures, but the water savings will make up for the cost of leak detection and preventive maintenance within one to two years (not counting the improvements in water quality that result).

Stopping water theft and illegal connections: Some UFW is not lost in leaks but is tapped and used illegally. Given the difficulty of tracking down unmetered connections, water agencies will need to work with communities in order to account for and recover some of the costs of illegal connections. If water is becoming scarce, the agency may have to consider an alternative institutional system such as a group tap, community tap, or vending kiosk (Wegelin-Schuringa, 1999). New pre-pay meters such as those being used in South Africa may provide a suitable technology for low-income areas, because the tokens can be bought in small increments (rather than larger monthly payments) and do not require regular meter reading and bill preparation.

In-house improvements: Water agencies may wish to provide water audit services (similar to energy audits) to increase the efficiency of water use at the household or institutional level. Because flush toilets use a large portion of domestic water use, introduction of nine- or six-liter flush toilets or dual flush toilets can save considerable amounts (e.g., 15 percent of total residential use in Israel) (UNCHS, 1996). By replacing 350,000 old toilets, Mexico City's water conservation program saved enough water to supply an additional 250,000 residents (Gleick, 2001). Water-saving washing machines and shower and faucet regulators can also save significant amounts. Incorporating such technologies into housing codes will generally increase adoption rates. Similarly, industries can do much to conserve water: recycling water from cooling, steam, and heating systems as well as seal water; pressure and flow regulators and valves; the use of lower quality water for some purposes; and air cooling.

Pricing urban water: The pricing structure for water is often blamed for inefficient water use. In most developing countries, farmers and households either do not pay a unit cost for water use or pay a low charge; both policies provide little incentive for water conservation. User charges, effluent charges, or tradable water rights can provide an impetus for conservation. However, pricing alone has a limited effect in inducing household conservation, because water charges form a small portion of family income, especially for the wealthier households that consume most water. Dramatic increases in water charges can reduce consumption, but as noted above the effect declines over time as people adjust to the new prices unless the price increases are accompanied by other measures, especially education campaigns (UNCHS, 1996). Nevertheless, all water-use sectors—agriculture, industry, and domestic—should pay prices that reflect at least the average cost of supply.

Education measures: Water conservation requires behavioral change as much as anything. Getting people to adopt such changes requires awareness and understanding on the part of the general public. Public information campaigns through the media and direct consultation with user groups can provide information on water scarcity as well as water conservation methods, habits, and measures to conserve water. School programs to educate young people about water conservation as well as sanitation can pay rich dividends in the long run. The public can become involved in water conservation through community organizations and other initiatives. In Chennai, the local water agency has formulated a Citizens' Charter as the first step in involving the users in water conservation efforts.

Decentralized systems: Many centralized city services do not provide uniform water and wastewater services to the poor communities they serve. For example, depending on the location and infrastructure available in formal and informal settlements, a city's water agency may provide special services through tanker trucks, stand posts, or kiosks, and will have to decide whether or not to charge for these services. Low-income communities may wish to have their own community-managed systems, either to improve services (by having them under their own control) or to reduce their costs. Urban authorities need to legally recognize and work with these community-managed systems to improve performance for all. For peri-urban and suburban communities, decentralized water and wastewater systems may be more appropriate; it is not clear that there are economies of scale in extending water services from a centralized system to these outlying areas. Again, local governments of these communities may prefer to manage their own systems.

Pollution control: Most countries have passed pollution-control laws that require polluting industries and municipalities to treat wastewater to prescribed effluent standards. However, implementation and enforcement of the laws is often more problematic.

Municipalities may not have the necessary resources to build sewage treatment plants without financial assistance from higher levels of government. If the municipal systems cannot handle heavy loads of effluents, industries will have to invest in either individual or common treatment plants or will have to pre-treat their wastes if they are not to overload the capacity of publicly-owned treatment plants. But in developing countries, industries have shown reluctance to undertake the capital cost of treatment without some subsidy and an even greater reluctance to operate the plants properly due to the costs of chemicals, power, and trained personnel.

Effluent charges based on the quality and the quantity of the effluent discharged into public systems or waterways can provide an incentive to industry to conserve water as well as to reduce pollution. Industries may treat their wastes up to a point and then pay for the balance as a tax. Some countries, such as China, Colombia, and the Philippines, have been experimenting with varying degrees of success with effluent charges. Marketable permits for pollution—similar to tradable water rights—have also been suggested but have not yet been employed in the case of water pollution in developing countries (Hoag & Hughes-Popp, 2000). In general, economic conservation and pollution-control instruments function best when coupled with stricter regulation and enforcement.

This regulatory process can be aided by involving the local community. Public disclosure of information on pollution could motivate polluters to reduce their effluents. "Green" ratings of industries can pressure polluters to comply with environmental regulations: consumers may boycott these industries' products, while their investors may worry about regulatory penalties or liability settlements. Stock prices may also reflect the green performance of polluting industries, which in turn affects their credit rating and ultimately the cost of borrowing. Indonesia's Program for Pollution Control, Evaluation and Rating (PROPER) was effective because public disclosure of emissions combined external pressure with improvements in plant managers' own awareness of pollution levels and opportunities to improve their performance (Afsah, Blackman, & Ratunanda, 2000). Again, economic or normative sanctions work best when combined with education about what can be done and how to do it.

Whether or not industries can be pressured into treating their effluents, municipalities may need financial assistance to meet water quality standards. In India, the Ganga Action Plan and the National River Action Plan provide substantial resources to towns and cities to control pollution entering the major rivers of the country. Under these plans, sewage and storm water outfalls are diverted to a chain of sewage-treatment plants to treat the wastes before discharge into the waterways. Thus, both the carrot and the stick may be needed for a comprehensive program to improve water quality in both urban and rural

areas.

Water boards and basin organizations: Traditionally, water quantity and water quality have been managed by different institutions at the regional and local levels. There is growing recognition that this separation is an artificial disciplinary boundary and does not reflect the fact that water is a unitary resource. Quantity and quality are irrevocably linked in both nature and in the minds of average users. If there is sufficient quantity, contaminants can be diluted to make the quality acceptable; and if the quality is too bad, it can make water quantities unusable. Future institutions must be able to simultaneously examine and manage water resources from both the quantity and quality perspectives. Basin organizations were initiated with the Ruhr basin in Germany, and have been adopted in a number of European countries, especially France. The Murray-Darling Basin Organization in Australia was one of the first river basin organizations to devise appropriate water-quality management measures, which have been used as indicators of the improvements in water quality. Other countries (e.g. Indonesia, Brazil, Mexico, Venezuela, Bulgaria, Poland, Ukraine, and India) are working to establish similar bodies for integrated development and management of each river basin (UNDDSMS, 1996). If these river boards are to be effective, they must have sufficient representation of all users in order to make decisions on the intersectoral linkages of water quantity and quality.

Financing: All these efforts require the provision of not just water but infrastructure. The scale of necessary investments is massive. The Global Water Partnership estimated in 2000 that developing countries would require US$13 billion of investment per year for drinking water, $17 billion for sanitation, $70 billion for municipal waste water treatment, and $30 billion for industrial effluent treatment—a total of $130 billion per year, compared to current investment levels of $35 billion (Global Water Partnership, 2000). Financing agencies such as the World Bank are setting up urban infrastructure funds in some countries to facilitate this process. Cost recovery is becoming increasingly important to donors as a means to improve both financial sustainability and demand management. However, even with these efficiencies, the public sector will not be able to invest enough. To meet the gap between what is needed and what public sector and international financial institutions are prepared to provide, private-sector participation is increasingly sought either directly from national and multinational corporations or through the domestic and international capital markets (World Water Commission, 2000; International Conference on Freshwater, 2001). Mobilizing resources from the capital markets may be done by issuing bonds backed by government agencies; but in other cases, private-sector firms are directly involved through water concessions or a range of contracts for building, operating, or maintaining water supply systems. For example, Ondeo, a subsidiary of the French multinational corporation SUEZ, is involved in water supply in major cities in Argentina, Morocco, Indonesia, Philippines, Chile, and South Africa (ONDEO, 2001). But involvement of private firms requires appropriate pricing and regulation to balance out the interests of the company in cost recovery with the interests of consumers and political stability.

Conclusions

The process of urbanization that shaped the latter half of the 20th century will continue in the 21st—not only in megacities, but also in towns and secondary cities. Of all the challenges posed by the dramatic growth of cities, none will continue to have greater impact on the quality of human life or the environment than (a) the provision of water, and (b) the treatment of waterborne wastes.

Water is essential for life and livelihoods in both rural and urban areas. Considerable amounts of water are necessary to produce food for both rural and urban populations, and

globally the water needed for irrigation is likely to increase in the next 25 years. Secure rural livelihoods are also critical to prevent excessive urbanization, and much of the stability of rural production and employment depends on safe and secure water supplies. At the same time, urbanization is an engine of economic growth in developing countries, with great potential to reduce poverty. To realize this potential, cities also need water for industries and to ensure a decent quality of life for all their citizens.

The traditional result has been intersectoral competition over quantity and quality of water. But there are also possibilities for mutual gain. A closer look at types of water uses shows that domestic, agricultural, and industrial demands for water are all found in both rural and urban areas (although in different concentrations). Simply appropriating water from existing rural uses for transfer to cities and industries will cause rural resentment. Negotiated approaches that allow farmers to voluntarily reduce water use and profit from water transfer to cities are likely to cause less resistance and less loss of livelihoods in rural areas.

Both economic progress and government stability depend on meeting the water needs of rural, urban, and peri-urban areas. Meeting these needs will require substantial investments in urban infrastructure for water supply, treatment, and disposal. At the same time, very few muncipalities will be able to meet unchecked urban water demands. Therefore, demand management will also be necessary. Water pricing, which has received considerable attention as a means of demand management, may not be very effective without complementary regulations, education campaigns, leak detection, retrofitting, recycling, and other technical improvements.

Providing water in an efficient, equitable and sustainable manner to both urban and rural areas in the 21st century poses as much of an institutional as a technical challenge. The ad hoc and sectoral approaches of the past do not adequately address the interrelated nature of urban water use. To meet urban water needs, water institutions must expand their vision in at least two directions: (1) to extend services to low income communities and peri-urban areas, and (2) to protect the quality of surface and ground water. But this expansion will require a move from centralized decision-making to the consistent involvement of many different types of stakeholders. If water transfers from agricultural use are to be accomplished with minimal negative impact on rural livelihoods, decision-makers and administrative officials must develop negotiation processes and capacity.

Although vital and challenging, water quantity issues are also only part of the story. Much more attention must be given to water quality. This includes: (a) technical innovation in water-quality monitoring and wastewater treatment, (b) financing of municipal and industrial-water treatment plants, and (c) institutions to monitor and enforce water quality standards. As in the case of water conservation, public education can play a major role.

Finally, dealing with the water needs of the poor (who constitute almost one-third of the global urban population) will require far greater efforts. Such efforts must go beyond conventional engineering approaches to include a wider range of options for water supply and sanitation. Addressing these needs also requires rethinking institutional approaches to incorporate community organizations in decision-making as well as implementation.

Acknowledgements

The authors are grateful for the help of Monica Di Gregorio, Michael Paisner, and Mark Rosegrant of International Food Policy Research Institute (IFPRI) in preparing this paper. Responsibility for any errors rests with the authors.

Note

[1] Abderrahman (2000) reports a cost of $0.70-$.90 per cubic meter for desalination plants in Saudi Arabia, with a further cost of $.20 per cubic meter to pump water over 460km and 620 meters of elevation to Riyadh.

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Exploring the Population / Water Resources Nexus in the Developing World

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Introduction

Any discussion on the population/water resources nexus in the developing world tends to be clouded by preconceived notions. The very concept of "population growth" is invariably constructed so as to be linked with value-laden notions like the "population time-bomb" and "population explosion," which are, in turn, closely associated with Malthusian catastrophe and social decay. This article explores the population/water resources nexus by using empirical examples from Africa in order to isolate some of the strategically important issues that policymakers should recognize. Two distinct areas of Africa have been selected: first, "Southern Africa," which for purposes of this article will mean countries belonging to the Southern African Development Community (SADC); and second, "East Africa," which for purposes of this article will mean countries geographically located within the Nile River Basin.[1]

The article begins by listing some fundamental points of departure, laying out our approach to the concepts of scarcity, resources, and legitimacy. These concepts provide a logical conceptual foundation for the article's subsequent analysis. This foundation is followed by an analytical separation between what will be identified as "first-order" and "second-order" levels of analysis. It is in this separation that the article offers an alternative perspective on the issues at hand. Special attention will be paid to the use and usefulness of technologies like Geographic Information Systems (GIS) in the context of this first-order/second-order framework. The article concludes by answering four key questions, which are deemed to be important to an understanding of the strategic significance of water resource management in Africa.

Points of Departure: Some Key Concepts

What immediately follows are fundamental ideas that form the article's logical foundation. Three concepts of this foundation are of paramount importance: scarcity, resources, and legitimacy.

1. "Water scarcity" seems at first so tantalizingly straightforward as to seduce the non-specialist reader into a rather superficial understanding of its definition and implications. Isn't water scarcity simply a shortage of water in time and space? While this definition adequately defines the concept in many cases, the spatial/temporal dimension of water scarcity involves subtle but important nuances. Rather, water scarcity should be defined as a condition in which demographically-induced demand for water exceeds the prevailing level of local supply (Turton & Ohlsson, 1999). Pressures resulting from absolute population growth and increasing density from urbanization of course raise the number of people per unit area. But a focus on "demand" forces us to take into account how the notion of scarcity is also economically and culturally constituted. Beyond the three liters per person per day required for basic human survival, "demand" and even "need" are not absolute values; they depend on social and consumptive habits that are culture-

bound, differing between countries and within regions.

The availability of water also quite naturally changes with the season. For large parts of Africa, a drought condition is a totally normal set of circumstances if viewed in terms of oscillations within the global hydrological cycle. This climatic variability acts as a fundamental driver to many of the African ecosystems in the semi-arid regions, and humans and other living organisms have adapted to it. The timing and intensity of a flood can make the same sum total of floodwater a boon or a curse for the cropping season.

Thus, the technical ability with which societies are able to handle their water-resource base is paramount. A perceived condition of water scarcity may in fact exist in the face of apparent abundance. Current work in Zambia (Turton et al., 2000a), one of the most well-endowed countries in Southern Africa in terms of water availability, shows how acute water scarcity can exist even in that country simply because its government lacks the capacity to harness its water in dams and then process and distribute it via an adequate reticulation system. Heavy water pollution also results in a form of scarcity, sometimes called "hydrocide" (Lundqvist, 1998). Water quality has a major impact on the functionality of water: the better its quality, the more social, cultural, economic, and environmental functions it can perform. So water scarcity is more than just a simple non-availability of water.

When discussing scarcity, we should also give due cognizance to use and ownership. Sexton (1992) has differentiated between *absolute* (i.e. technology-limited) scarcity and *economic* scarcity, the latter referring to economic choices that have created winners and losers. Warner (1992) has noted that the key limit to water availability is redistribution and hence is political rather than technical in nature; and this distinction suggests yet another distinct form of scarcity—*induced*. This supports Homer-Dixon's (1994) resource capture thesis, which we shall address below.

2. Just as the concept of water "scarcity" is subtler than first meets the eye, we will also have to come to grips with the nebulous concept of a "resource." An important point of departure in this article is that an epistemological and conceptual distinction can be made between what we will define as a "first-order" and a "second-order" resource. To our knowledge, Leif Ohlsson (1998; 1999) was the first to systematically analyze resources in this way. In his analysis, a *first-order* resource is any natural resource (such as water, land, or minerals) with which a country can be either well- or poorly-endowed. In other words, a first-order resource like water can be either scarce or abundant; and the *degree* of scarcity and/or abundance is relative spatially, temporally, and in terms of quality. What is stressful in one environment is not a problem in another.

A *second-order* resource, on the other hand, is a social rather than a natural resource. A *social* resource refers to a need (acutely perceived by societies, administrative organizations, and managers responsible for dealing with natural resource scarcities) to find the appropriate societal tools for dealing with the social consequences of first-order natural resource scarcities (Ohlsson, 1999, page 161). This conceptual distinction makes it clear that what is critically important is not so much the availability of the natural resource itself but rather how society adapts to changes in that supply—either by way of (a) long-term increases in water scarcity as a result of population growth and/or climate change, or (b) short-term water abundance in the form of floods.

Recent articles using this distinction depict water management as a series of oscillations between first and second-order resources over time, much like the turning of a screw (Ohlsson & Turton, 1999; Ohlsson & Lundqvist, 2000). Priorities change from supply-sided management (mobilizing more water) through demand-sided management (doing better things with available water), ultimately to adaptive management (adapting to absolute scarcity). Couched differently, Ohlsson's (1998; 1999) second-order resource is

another way of looking at Thomas Homer-Dixon's (1995; 1996) concept of "ingenuity." But the importance of this conceptual difference is that it allows the analyst and policymaker to effectively develop coping strategies to deal with the bottlenecks inherent in water management globally. This has particular relevance for an understanding of the problems confronting developing countries.

This conceptual distinction makes it possible to develop a whole range of unique

Figure 1. Resource Matrix

Quantitative Aspect of the Resource	Type of Resource: Second-Order (Social Resources)	Type of Resource: First Order (Water Resources)
Relative Abundance	Position 1	Position 2
Relative Scarcity	Position 3	Position 4

concepts by means of a matrix showing different levels of first- and second-order resources within any given social entity. This is illustrated in Figure 1.

Four combinations of first- and second-order resource are possible. For purposes of this article, only the last three of these combinations (those entailing at least one relative scarcity) are relevant:

- *Structurally-Induced Relative Water Scarcity* (SIRWS) is a combination that consists of a relatively high level of first-order resource availability (Position 1) in conjunction with a relatively low level of second-order resource availability (Position 4). Water scarcity in these situations is probable as a result of the inability to mobilize sufficient social resources to effectively manage the problem. SIRWS countries are relatively well-endowed with water, but lack institutional capacity and have other problems that render them unable to mobilize that water (via dams and related hydraulic infrastructure) and reticulate it to the end-user. A logical outcome of this condition would be low economic activity, poor public health, and a general low level of infrastructural development. This condition is clearly unfavorable, and could result in a Malthusian catastrophe if combined with high population growth. But creative

and responsible decision-making can still save the day provided that the alarm bells are heeded in time. It is these societies that offer examples of the debilitating effects of Homer-Dixon's (1995; 1996; 2000) "ingenuity gap." Examples include Angola, Congo (DRC), Mozambique, and Zambia.

- *Structurally-Induced Relative Water Abundance* (SIRWA) refers to a combination that consists of a relatively low level of first-order resource availability (Position 3) with a relatively high level of second-order resource availability (Position 2). In other words, water abundance is made possible in a relative sense as a result of the ability to mobilize sufficient social resources to effectively manage the problem. SIRWA countries are relatively poorly endowed with water resources, but use their relative abundance of social resources to develop a set of management solutions that are effective and legitimate in the eyes of the population and therefore sustainable over time. A logical outcome of this condition would be sustained economic growth, good public health, and a high level of infrastructural development even in the face of endemic water scarcity. This condition resembles the Cornucopian argument that is often presented as an alternative to Malthusian collapse. Indeed there are rich examples of the positive impact of Homer-Dixon's (1996; 2000) concept of ingenuity to be found in an analysis of the water sector in many countries. Arguably the best example is Israel, but South Africa occupies a close second in this category.
- *Water Poverty* (WP) refers to a combination that consists of a relatively low level of first-order resource availability (Position 3) with a relatively low level of second-order resource availability (Position 4). WP countries cannot manage the debilitating effects of water scarcity because of their lack of social resources, unleashing a spiral of underdevelopment that results in a gradual decline in almost all developmental indicators. A logical outcome of this condition would be long-term economic stagnation, deteriorating public health, a low level of infrastructural development, and a high probability of social instability and political decay as the black hole caused by a combination of expanding population and a declining resource-base takes hold. In short, this is an example of the classic Malthusian collapse. Clearly this condition is one to be avoided.

3. Finally, "legitimacy" (which can loosely be defined as the popular support by the broad population for any given decision by government) is an important concept for effective water management. For Water Demand Management (WDM) policies to be effectively implemented, a high level of legitimacy is required of the functional agency responsible for water-resource management (Turton, 2000a, page 144); yet that government's craving for legitimacy easily leads to policies that have the opposite effect. In many political systems, intersectoral allocation of water (Turton & Ohlsson, 1999; Turton, 1999; Allan, 2000, page 184) is typically considered only as a last resort because it is so politically and socially risky that politicians generally favor softer (but also less effective) options instead.

When river basins reach closure and all available first-order resources have been allocated, one of the most important forms of management strategy—after all other supply-sided options such as Inter-Basin Transfers (IBTs) and desalination of water have been exhausted—is the allocation of water away from high-consumption but low-yield activities (as typically found in the agricultural sector) to lower-consumption but higher-yield activities (typically found in the industrial and domestic sectors) (Falkenmark & Lundqvist, 1995). There are a number of unintended consequences of this, such as those arising from new economic dependencies and the restructuring of society away from an agricultural base to an industrial base. Whether this will actually happen depends in part on the second-order capacities and structures for change that exist in society. But as the public

sector tends to be lead actor and regulator as well as often the formal owner of water resources, a successful adaptation to first-order stress also depends on the relationship between the state and society. A power relationship is legitimate when the relationship can be *justified* in terms of people's beliefs—when there is congruence between power and beliefs, values and expectations (Weber, 1947).

If people already believe in the need for an adaptive response to water stress, and if the government's legitimacy base is strong, a society will be more responsive to regulatory measures aimed at bringing about this adaptation. If these values are not strongly developed, a government perceived as legitimate may well still have the political capital to guide society to a new mindset. However, if a ruling government perceives that it lacks legitimacy, it may not be willing to take the political risk of implementing unpopular policies, even when the society faces an uncontrolled and ultimately unsustainable spiral of water consumption. The state may be tempted to pursue wasteful but popular water projects instead.

The world is filled with examples of ill-considered water projects that have been used to buy political support, otherwise known as patronage. Specific examples range from to pork-barrel projects in the United States, the Pongola-Poort Dam in South Africa, and many instances in India where unsustainable water projects cannot be changed because they are supporting too many jobs and therefore potential voters. This situation is found in several postcolonial states, which started large, unsustainable projects to kick-start economic development. When these aspirations come to nothing, the government starts losing the political capital needed to make social adjustments to water policy that address an eroded and unsustainable resources base. As Ohlsson (1999, page 10) notes, the first victim of people's frustrated developmental expectations is state legitimacy. Incidentally, this is not limited to the developing world. The so-called "pork-barrel projects" in the United States that Reisner (1993) so eloquently describes illustrate patronage in a sophisticated democratic setting.

Finally, a situation is conceivable in which society may have a latent willingness and ability to adapt, but *systemic* legitimacy (of the political system itself) is sorely lacking. In apartheid-era South Africa, for example, all reform was hampered by the systemic illegitimacy of the system itself, resulting ultimately in a collapse and radical restructuring of the overall political process. A decision-making entity perceived as illegitimate will not receive the necessary popular support, and the population at large will undermine such government policies as a form of civil disobedience. Notably, in the developing world, we find examples of governments and implementing agencies with a low level of accountability and consequently a low level of systemic legitimacy. Instead of initiating reflexive change, these governments and agencies tend either to ignore the water crisis or to deflect it by further squeezing their natural resource bases, often in the form of intensified production (otherwise known as "water mining").

Under such stress, the process that has been called "resource capture" (Homer-Dixon, 1994; Homer-Dixon & Percival, 1996) is especially prone to manifest itself. This occurs when powerful groups in society systematically shift (first-order) resource allocation in their favor over time, usually to the long-term detriment of the group from which the resource base is being captured. Since these powerful groups must gain control over the resource allocation mechanisms in order to gain such unequal access, *structural scarcity* (a highly specific form of water scarcity) ultimately results. A good example of structural scarcity is apartheid-era South Africa, whose "hydraulic mission" effectively mobilized water in order to distribute patronage to the white minority, thereby retaining the support of the white farmers who owned most of the land at that time (Abrams, 1996; Turton, 2000a, page 142).

In international river basins, countries may also try to shift the burden of resource

closure (that condition when all of the resource-base has been allocated) to other riparians. Upstream riparians may capture the resource before it reaches the downstream countries, while downstream countries may strengthen their claim to a river's water by leveraging non-water power threats (Warner, 1993). The importance of water is blown out of proportion under these circumstances, and hydrological information may even be classified because of it. This process propels water management into a national security issue in which the resource becomes non-negotiable, forestalling an equitable agreement on its sharing. This "securitization" of water, often an unsatisfactory state of affairs, leads to zero-sum hydropolitical dynamics.

One possible way of accomplishing a desirable de-securitization of the water issue is (a) to develop uncontested data with which to build confidence between riparian states or water users, and (b) to institutionalize the conflict potential that arises under conditions of scarcity. According to Haas (1993), "epistemic communities" may converge around a body of accepted scientific procedure and thus facilitate the creation of a legitimate base for negotiation. The creation of water regimes can therefore be seen as a manifestation of second-order resources within any given regional security complex. Processes of the securitization of data (Warner, 2000) can still obstruct the dissemination and exchange of reliable hydrological information within the emerging regime, however, and act as a mitigating factor. In Israel, for example, hydrological data are classified as secret and is thus not available to the public or other interested parties. This article will later address the issue of whether GIS can enhance openness and data exchange, thereby facilitating confidence building in water-sharing arrangements.

The Population/Water Resource Nexus in Africa

First-Order Type of Analysis

If water resources are relatively finite within any given country, then a doubling of that country's population will cut in half the volume of water available per capita. This calculation is seductively simple, so let us don the eyeglasses of first-order analysis and look at some African countries. Table 1 shows the population data for Southern African and East African countries in Columns 2-6. The population growth over that time period (39 years) is shown as a percentage in Column 7 as calculated by the FAO (2000) database. In general terms, this table gives an indication of how the baseline population, which was arbitrarily taken as being 1961, had grown by 2000. Column 8 shows the water availability expressed in cubic meters per capita in 1998. The World Bank Atlas (2000, page 30) defines water availability per capita as the total renewable water resources of a given country (including river flows) divided by the population and expressed in cubic meters.

Two assumptions (both of which are strictly of a first-order nature) can be made for purposes of analyzing this data. The first assumption is that a three percent growth in population over a 39-year period is high. All of the countries that have a population growth in excess of this have been listed in Table 1 in bold, and their corresponding figures in Column 7 have been highlighted. The second assumption is that, in terms of availability of fresh water, anything above 10,000 cubic meters of water per person per annum is high. Here, too, the countries concerned have been listed in bold, and their corresponding figures in Column 8 have been highlighted. Clearly, these assumptions are rather arbitrary and can be challenged. But it should also be emphasized that (a) these assumptions are relative and not absolute, and (b) they establish a clear split in the data in order that basic trends can be detected (see the following discussion on GIS). As such, they act as filters enabling raw data to be analyzed in some meaningful ways (see Box 1 for a full explanation of the methodology used in this circle).

Table 1. Population Growth (Millions) and Water Availability Data

Southern Africa (SADC Member States)

Country	1961	1970	1980	1990	2000	Growth 1961-2000 (%)	Available m^3/cap 1998
Angola	4.8	5.5	7.0	9.2	13.1	2.68%	15,783
Botswana	.49	.63	.90	1.2	1.5	3.18%	9,413
Congo (DR)	15.7	20.2	27.0	37.3	50.9	3.11%	21,134
Lesotho	.88	1.06	1.3	1.7	2.0	2.13%	2,527
Malawi	3.6	4.5	6.1	9.3	11.3	3.20%	1,775
Mauritius	.67	.82	.96	1.0	1.1	1.31%	1,897
Mozambique	7.6	9.3	12.0	14.1	18.3	2.25%	12,746
Namibia	.63	.79	1.0	1.3	1.7	2.73%	27,373
Seychelles	.43	.53	.63	.70	.80	1.49%	n/a
South Africa	17.8	22.0	27.5	34.0	43.3	2.35%	1,208
Swaziland	.33	.41	.56	.75	.92	2.79%	4,552
Tanzania	10.4	13.6	18.5	25.4	35.1	3.22%	2,770
Zambia	3.2	4.1	5.7	7.2	10.4	3.16%	12,001
Zimbabwe	3.9	5.2	7.1	9.8	12.6	3.26%	1,711

East Africa (Nile Basin States)

Country	1961	1970	1980	1990	2000	Growth since 1961	Available m^3/cap 1998
Burundi	2.9	3.5	4.1	5.4	6.3	2.16%	561
Egypt	28.5	35.2	43.7	56.3	67.8	2.29%	949
Eritrea	n/a	n/a	n/a	n/a	3.65	2.19% **	2,269
Ethiopia	24.7	30.6	38.7	50.9	62.9	2.43%	1,795
Kenya	8.5	11.4	16.6	23.5	30.6	**3.51%**	1,031
Rwanda	2.8	3.7	5.1	6.9	7.6	2.21%	798
Somalia	2.8	3.6	5.8	7.7	8.7	3.05%	1,730
Sudan	11.3	13.8	18.6	24.0	31.1	2.65%	5,433
Tanzania	10.4	13.6	18.5	25.4	35.1	**3.22%**	2,770
Uganda	6.8	9.8	13.1	16.4	23.3	**3.11%**	3,158

Sources of Data:
Population growth data (Columns 2 - 6) - FAO (2000).
Population growth since 1961 (Column 7) - FAO (2000).
Water availability per capita m^3 in 1998 (Column 8) - World Bank Atlas (2000, page 34-35).
** Eritrea Data calculated from 1993 - FAO (2000).

From this rather crude assessment, an interesting picture starts to emerge. All of the countries that have a relatively low population-growth (i.e. less than a three percent increase in 39 years) in conjunction with a relatively high availability of freshwater are found in Southern Africa and include Angola, Mozambique, and Namibia. Conversely, countries that have a relatively high population-growth rate in conjunction with relatively low water-availability include Botswana, Malawi, Tanzania, Zimbabwe, Kenya, Somalia, and Uganda. Two countries—the Democratic Republic of the Congo (DRC) and Zambia—stand out alone in terms of this assessment, displaying a relatively high population growth rate in conjunction with a relatively high water-availability.

The analysis also suggests that the countries in the first group (low population growth and high water-availability—Angola, Mozambique, and Namibia—have population and water-resource fundamentals that ought to predispose them to a degree of prosperity. But this is not the case. While Angola is richly blessed with a wide range of first-order resources, it remains embroiled in a debilitating civil war; if anything, its resources (particularly oil and diamonds) only fuel the conflict. Mozambique has a seemingly high volume of water resources, yet it too has suffered from a quarter-century of civil war and is in fact a downstream riparian on almost all of the river basins passing through it, making it vulnerable to the whims of upstream states. Namibia is relatively prosperous and politically stable, yet it has a small population and therefore a small tax base—a debilitating factor. Namibia's physical size is massive and its population far removed from water resources, meaning that any infrastructural projects actually have a low number of taxpayers per kilometer of pipeline.

The second group of countries (high population growth and low water-availability) suggests future Malthusian catastrophes in each country except for Botswana. Botswana is actually one of the most politically stable countries in Africa; it has a functioning multiparty democracy, and its high population growth rate is off a low original population base, so there are not in this case the normal problems related to a rapidly growing population. Significantly, Botswana is also adopting progressive water policy options that include the preference for food security rather than national self-sufficiency. Malawi, Tanzania, Zimbabwe, Kenya, Somalia, and Uganda have all had histories of political instability and economic stagnation, although this is changing for Tanzania and Uganda. First-order types of analysis in these cases are clearly superficial and can be downright dangerous: it is from this type of analysis that the so-called "water wars" literature derives its empirical basis.[2]

Kaplan's (1994) presentation of sub-Saharan Africa as an anarchic, conflict-ridden basket-case has raised suspicion (Ó Tuathail et al, 1998) that such accounts fit certain North American national security agendas. Whatever the agenda, the image of an imploding and chaotic Africa undermines investor confidence in the continent and marginalizes it in policy debates as a lost cause. The Kaplan thesis assumes that water resources are finite, which they are not. Those such as Gleick (1993) who proclaim a "water crisis" only focus on that fraction of precipitation that ends up in rivers, lakes, and aquifers (what has come to be known as Falkenmark's "blue water"). Even in this case, baseline data often unreliable. The remainder either evaporates to the atmosphere, is taken up by vegetation, or percolates into the soil, where it remains as soil moisture and lies unaccounted for in the "water crisis" vernacular. This latter amount (which has become known as Falkenmark's "green water") is so abundantly available in the temperate zones that these areas can export huge quantities of "encapsulated water" in the form of grain to semi-arid zones that are structurally deficient in soil moisture. On the basis of this principle, Allan (1996; 2000) has shown that trade in *virtual water*—the water embedded in cereals—is a viable alternative provided that sufficient foreign currency can be generated to pay for such exports (see Box 2). Allan notes that as much water flows into the Middle

East North Africa (MENA) region as subsidized grain in the form of virtual water as flows down the Nile annually. It is this trade in virtual water that has helped prevent the confidently-predicted water wars (Starr, 1991) from erupting (Turton, 2000b; Allan, 2000).

In addition to ignoring these international economic processes, the water-in-crisis thesis misunderstands the nature of "resources" that are often interpreted in environmentally deterministic ways long since abandoned in geography (Bradnock & Saunders, 2000). Such an analysis simply ignores the capacity of states to develop coherent and

Box 1. Methodology

The methodology that has been used in this article is based on four assumptions, each of which has been arbitrarily defined. The purpose of these assumptions is to act as a type of filter through which raw data can be processed in order to arrive at a conclusion that can assist with the development of a set of core hypotheses. These hypotheses can then be used in other case studies, in order to test their validity, but also in order to refine the underlying concepts and thereby develop new knowledge. This is necessary because the notion of a second-order resource is relatively new and consequently in need of conceptual refinement. These four assumptions are as follows:

- The first assumption is that a 3 percent growth in population over a 39-year period is High, with a growth below this level being considered as Low. This is an arbitrary selection in order to give us a starting point in our analysis. Because of the contested nature of population figures in developing countries, the data from the FAO (2000) is being taken as the legitimate source.
- The second assumption is that in terms of the availability of fresh water within a given country, anything above 10,000 m^3/cap/yr^{-1} is High, with anything less than this value being considered as Low. The data used are derived from the World Bank (2000:34-35) because such data are highly contested in the developing world, and the criterion for the High/Low split is arbitrarily defined in order to give us a starting point for the analysis.
- The third assumption is that a GNP/cap when adjusted to Purchasing Power Parity (PPP) for any given country as defined by the World Bank (2000:42-43) is considered to be High if above a value of US$5,300. Conversely a value below US$5,299 is considered to be Low.
- The fourth assumption is that with respect to the percentage of a national population that has access to relatively safe drinking water as defined by the World Bank (1999), a value greater than 65 percent is considered to be High, with a value below 64 percent being Low.

It must be noted that these assumptions are not ironclad. In reality data is highly contested in the developing world, and these will be no exception, which means that the debate normally degenerates into one about the unreliability of the figures being used. This is a sterile debate; so in order to make some headway in our quest for the development of new knowledge, these four assumptions have been made. They should not be seen as being concrete in any way, but when used in combination form a valid methodology on which the rationale of this article has been based. This methodology enables us to steer a reasonably safe course through the minefield of unreliable data that are a characteristic of the developing world, and it enables us to compare countries in a meaningful way.

Table 2. Comparison of First and Second-Order Resources

Southern Africa (SADC Member States)

Country	First-Order Indicators		Second-Order Indicators	
	Population Growth (since 1961) a (b)	**Water Availability** $m^3/cap/yr^{-1}$ 1998 a (b)	**GNP/cap** US$ Purchasing Power Parity 1998 a (b)	**Access of Population** to Safe Water % a (b)
Angola	2.68% (low)	15,783 (high)	999 (low)	32% (low)
Botswana	3.18% (high)	9,413 (low)	5,769 (high)	70% (high)
Congo (DR)	3.11% (high)	21,134 (high)	733 (low)	27% (low)
Lesotho	2.13% (low)	2,527 (low)	2,194 (low)	52% (low)
Malawi	3.20% (high)	1,775 (low)	551 (low)	45% (low)
Mauritius	1.31% (low)	1,897 (low)	8.236 (high)	98% (high)
Mozambique	2.25% (low)	12,746 (high)	740 (low)	32% (low)
Namibia	2.73% (low)	27,373 (high)	5,280 (low)	57% (low)
Seychelles	1.49% (low)	n/a	10,185 (high)	97% (high)
South Africa	2.35% (low)	1,208 (low)	8,296 (high)	70% (high)
Swaziland	2.79% (low)	4,552 (low)	4,195 (low)	43% (low)
Tanzania	3.22% (high)	2,770 (low)	483 (low)	49% (low)
Zambia	3.16% (high)	12,001 (high)	678 (low)	43% (low)
Zimbabwe	3.26% (high)	1,711 (low)	2,489 (low)	77% (high)

East Africa (Nile Basin Riparian States)

Country	First-Order Indicators		Second-Order Indicators	
	Population Growth (since 1961) a (b)	**Water Availability** $m^3/cap/yr^{-1}$ 1998 a (b)	**GNP/cap** US$ Purchasing Power Parity 1998 a (b)	**Access of Population** to Safe Water % a (b)
Burundi	2.16% (low)	561 (low)	561 (low)	52%
Egypt	2.29% (low)	949 (low)	3,146 (low)	64%
Eritrea	n/a	2,269 (low)	948 (low)	7%
Ethiopia	2.43% (low)	1,795 (low)	566 (low)	27%
Kenya	3.51% (high)	1,031 (low)	964 (low)	53%
Rwanda	2.21% (low)	798 (low)	n/a	n/a
Somalia	3.05% (high)	1,730 (low)	n/a	37%
Sudan	2.65% (low)	5,433 (low)	1,240 (low)	50%
Tanzania	3.22% (high)	2,770 (low)	483 (low)	49%
Uganda	3.11% (high)	3,158 (low)	1,072 (low)	34%

Sources of data for Table 2:
Population growth since 1961 (Column 2) - Column 7 of Table 1.
High/Low Population growth split (Column 2) - Arbitrarily defined as >3.0% is high, <2.9% is low.

Water availability $m^3/cap/yr^{-1}$ 1998 (Column 3) - World Bank Atlas (2000, pages 34-35) and Column 8 of Table 1.
High/Low water availability (Column 3) - Arbitrarily defined as >10,000 $m^3/cap/yr^{-1}$ 1998 is high, <9,999 $m^3/cap/yr^{-1}$ 1998 is low.

GNP/cap 1998 (Column 4) - World Bank (2000, pages 42-43)
High/Low GDP/cap split (Column 4) - Arbitrarily defined as >$5,300 is high, <$5,299 is low.

Access of Population to Safe Water (Column 5) - World Bank (1999).
High/Low Access of Population split (Column 5) - Arbitrarily defined as >65% high, <64% is low

sustainable policy choices with which to manage the problem of water scarcity. It is this type of capability that fits into the category of "second-order resources," which can loosely be defined as the social resources needed to manage changes in the level of first-order natural resource availability—otherwise known as social adaptive capacity—over time.

Second-Order Type of Analysis

When it comes to second-order analyses, we are confronted with a basic problem. How do we identify and measure social adaptive capacity? How do we know when it exists and when it is absent? These questions are currently the subject of a research project at the African Water Issues Research Unit (AWIRU) (Turton et al., 2000a; Turton, 2002; Turton & Kgathi, 2002). Their answers require a set of indicators of second-order resource presence (or absence). Again, one needs to make certain assumptions in order to gain insight. For the purposes of this article, two key indicators will be used:

- Let us assume that the existence of second-order resources will result in a higher degree of economic prosperity than the absence of those resources, in line with Homer-Dixon's (1995; 1996; 2000) ingenuity thesis. If this is true, then the adjusted GNP per capita at Purchasing Power Parity (PPP) as presented by the World Bank (2000, pages 42-43) can be used as an indicator.
- The percentage of a given national population that has access to reasonably safe drinking water is an indicator of a government's capacity to provide basic services. World Bank (1999) data on these percentages will be used as an indicator.

Table 2 presents these indicators in the following sequence. Column 1 of the table names the country concerned. First-order indicators are presented in Columns 2 and 3. Column 2a shows the population growth rate for that country as shown in Column 7 of Table 1. This provides an indicator of the country's population dynamics over the last 39 years, which is shown as a High/Low split in Column 2b. (See the first assumption in the previous section for a discussion of the criterion for this split.) Column 3a presents the availability of first-order water resources per capita expressed as cubic meters per annum as shown in Column 8 of Table 1. Column 3b shows this data as a High/Low split (using the second assumption that is based on the criterion discussed in the previous section). This provides a crude but useful indicator of first-order water resource availability *assuming that the country can develop those resources*.

Table 3. Classification of Various African States in terms of Proposed Typology

	First-Order Problems	Second-Order Problems	More Complex Problems
	SIRWA	**SIRWS**	**WP**
Southern Africa	Botswana Mauritius South Africa	Angola Congo (DRC) Mozambique Namibia Zambia	Lesotho Malawi Swaziland Tanzania
East Africa			Burundi Egypt Eritrea Ethiopia Kenya Sudan Tanzania Uganda

Second-order indicators are presented in Columns 4 and 5 of the table. Column 4a shows the GNP per capita as US dollars adjusted in terms of Purchasing Power Parity (PPP). Column 4b presents this data as a High/Low split, with the criterion arbitrarily defined as >$5,300 being High and <$5,299 being Low (our third assumption). While this is an unsophisticated way of processing the data, it serves as a filter that shows an ultimately useful relative tendency. Column 5a shows the percentage of a given national population that has access to relatively safe water. Column 5b presents this data as a High/Low split, with the criterion arbitrarily defined as >65% being high and <64% being Low (our fourth assumption). This is also crude, but serves the same purpose of filtering out a general tendency. The combination of these indicators (when subjected to the High/Low filtering process) can then form the foundation of a hypothesis that can later be empirically tested. (Again, see Box 1 for a full explanation of this article's methodology.)

By concentrating exclusively on Columns 3-5, an assessment can be made using the following logic. Suppose one (mistakenly) assumed that first-order resource abundance (an independent variable) naturally predisposes a country to economic prosperity (a dependent variable). One would then anticipate finding a rough correlation in terms of High/Low splits between Columns 3 and 4. A cursory glance at Table 2 will show that this is not the case; so one can conclude that first-order resource abundance on its own is an insufficient condition to guarantee economic prosperity—suggesting that some form of interceding variable is at work. If this interceding variable is expressed in terms of a second-order resource, then a comparison of Columns 4 and 5 reveals that in all cases except one (Zimbabwe) the existence of such resources as reflected by a higher GNP per capita determines the capacity of the government to deliver basic services like the provision of clean water.

Here the logic of Homer-Dixon's (1995; 1996; 2000) ingenuity thesis is relevant. The presence of a higher level of second-order resource translates into a higher level of economic activity, which in turn impacts on the ability of the state to deliver basic services. Botswana offers a revealing insight in this sense. A country with a relatively small population size but a high population growth rate, it faces severe constraints in terms of

low water-availability, yet still maintains a high level of service delivery. A similar trend is evident in Mauritius and South Africa, where high levels of service delivery are possible despite severe first-order water constraints. Namibia is also revealing. A small population in absolute terms usually impacts on the availability of water by showing a high potential for development. In Namibia, however, a low level of economic activity (coupled with a small tax base) acts as a severe constraint that is reflected in the country's low level of service delivery. Namibia and Botswana also both lack permanently flowing rivers within their borders, leaving their hinterlands dry and consequently difficult to develop. Both countries also have a relatively small population and consequently a small tax base. (The fact that the GNP/capita indicator is split differently for these two countries is probably irrelevant, given the crudeness of the criterion used and the arbitrary selection of the threshold at $5,300—see Table 2.)

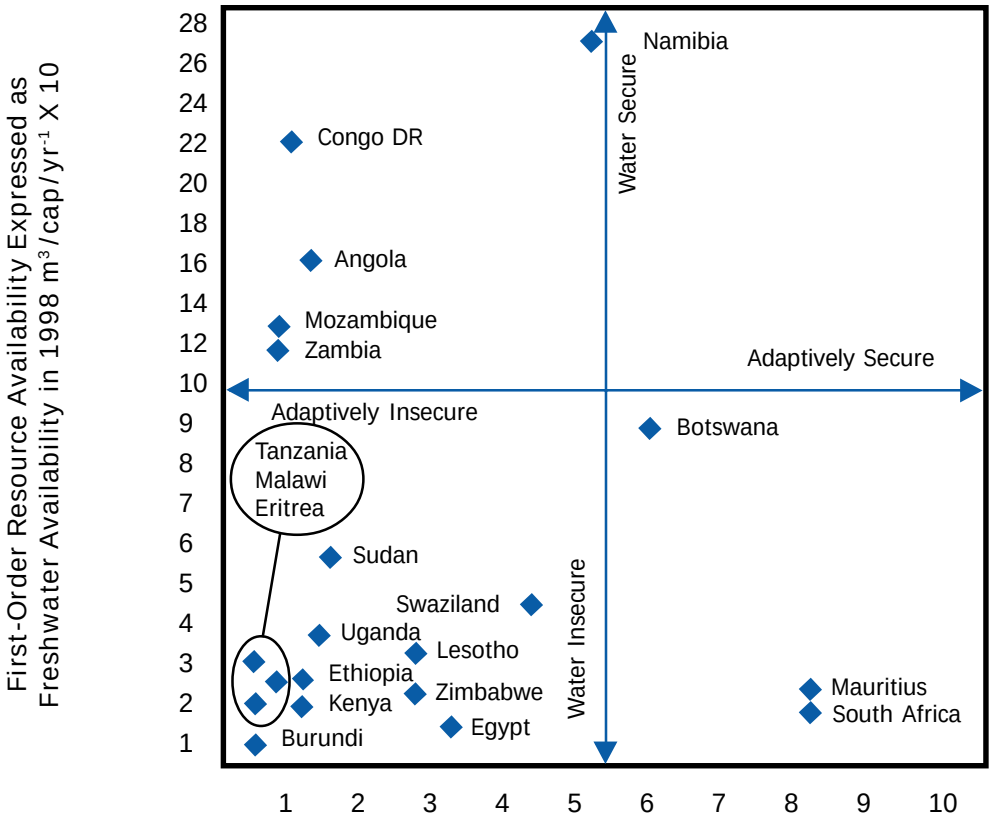
Applying this methodology to Table 2 yields a neat differentiation of cases consistent with the key concepts presented at the start of this article. Particular emphasis is placed on the three conditions: SIRWA, SIRWS, and WP. This typology is presented in Table 3.

Table 3 shows that the typology manifest in the concepts of SIRWA, SIRWS, and WP can be applied to all cases for which data are available—with only one exception. Zimbabwe presents an anomalous situation that does not fit neatly into this framework: it has a combination of low levels of both first- and second-order resources, but a high level of service delivery. While Zimbabwe's current political leadership has had a negative impact on the economy, creating an acute shortage of second-order resources, the country's high levels of service delivery are manifestations of early Mugabe-era achievements. Zimbabwe still has a high potential for development, provided that the negative ramifications of its poor political leadership can be resolved.

The matrix's analysis of Southern Africa yields results that correspond well with each country's first- and second-order resource rating. The three SIRWA cases in Southern Africa are known to be the most prosperous countries in the region. (Should data have been available for Seychelles, then this country would probably also fall into this category.) For these countries, water-related problems are primarily of a first-order nature—namely, the continued search for and mobilization of alternative sources of water supply. The relative economic prosperity of these countries affords them a wide range of options, covering supply-sided solutions (i.e., development of ever-more-distant water resources via IBTs and desalination where appropriate), management of demand, and the importation of virtual water in an attempt to balance national water budgets. Indeed, these countries are enacting all three strategies (Turton et al., 2000b).

The five SIRWS cases are all countries that ostensibly have an abundance of water but that lack the institutional, financial, or intellectual capital to translate this into economic growth and development. As such, the type of problems facing these countries are primarily of a second-order nature. Angola and the Democratic Republic of the Congo (DRC) are politically unstable because of seemingly endless civil wars. Mozambique has turned its back on civil war and is seemingly on the road to economic recovery; its institutional capacity, however, is extremely weak, and its high debt burden continues to hamper this recovery. The major floods that took place in Mozambique in early 2000 set the country back significantly economically (Christie & Hanlon, 2001) and also illustrated the government's inability to respond to crisis. Namibia is politically stable, but it has become embroiled in the wars in Angola and the DRC and is starting to hemorrhage precious financial resources that could be used on institutional development instead. Namibia also presents an interesting case in the sense that its first-order type of indicators shows the country to be relatively well-endowed with water. However, this water can only be found on the northern and southern borders of the country and is also difficult to mobilize. Namibia's low population levels also create a false impression by presenting a

Box 2. Turton/Ohlsson Grid



Data Source: *World Bank Atlas* (2000).

The linkage between water availability and development was drawn directly from the pioneering work by Malin Falkenmark, who sought to develop a scale with which to measure what she called "water stress." Her work makes a direct linear relationship between water availability and the capacity for economic development within a given political economy.

Stated simplistically, Falkenmark (1986) hypothesized that water scarcity presents a rigid barrier to economic and social development. She sought to measure this by doing an analysis of various countries in which she found the following: Iraq uses 4,400 $m^3/cap/yr^{-1}$; Pakistan uses 2,200 $m^3/cap/yr^{-1}$; Syria uses 1,300$m^3/cap/yr^{-1}$; Egypt uses 1,200 $m^3/cap/yr^{-1}$; India uses 800 $m^3/cap/yr^{-1}$ and Israel uses 500 $m^3/cap/yr^{-1}$ (Falkenmark, 1986, page 197). By taking Israel as a baseline case, Falkenmark concluded that a realistic level for a developing state is $m^3/cap/yr^{-1}$, as this would allow 100 $m^3/cap/yr^{-1}$ for domestic and industrial use, leaving the remaining $m^3/cap/yr^{-1}$ (80 percent of the total) for irrigation. In the quest to develop a scale based on standard units of measurement, Falkenmark then converted this baseline volume (500m^3) to 2,000 people per "flow unit" of water (one million m^3 of water per year). This lead her to conclude that *more* than 2,000 people per "flow unit" would preclude a region or country from having sustainable economic or social development. While not directly stated by Falkenmark, this notion implied that water scarcity "beyond the barrier" would result in social decay and possibly political instability. The notion also contributed to the "water-

(Continued on page 66)

wars" literature, in which this linear relationship was assumed to mean that countries will go to war over water scarcity at some time in the future.

The analysis seemed intuitively useful at the time, but subsequent research has shown that countries with a large volume of water available to them do not necessarily develop economically. Conversely, countries with a limited water supply (such as Israel, Botswana, and South Africa) are capable of economic development close to or even beyond the hypothetical barrier. In contrast, the concept of the second order resource has proven pivotal in translating water availability into economic development. When second-order issues are considered, how a social entity deals with a scarcity rather than the scarcity itself becomes the critical issue. Thus, emphasis shifts away from the analysis of water availability (as a first order resource) to social adaptive capacity (Ohlsson, 1999; Ohlsson & Turton, 1999) or "ingenuity" (Homer-Dixon, 1995; 2000). Water scarcity itself is seen as a relative thing, with a variety of forms in existence (Turton, 2002).

But what actually is a second order resource? Turton & Ohlsson (1999) developed a grid showing different combinations of first- and second-order resources, and from this they generated some new conceptual definitions. This was refined by Allan (2000, page 324) and used to explain the Middle East North Africa (MENA) water situation. There is a strong need to refine the notion of second order resources further. Five key indicators of second order resources are currently being developed by Turton (2002):

- *GNP/Capita adjusted to Purchasing Power Parity*. This is a crude indicator of potential for institutional development in a given country and allows a rough comparison to be made between countries (as shown in the attached grid).
- The ability to generate data is a direct indicator of *technical ingenuity*. Data are needed to support decision-making, and contested data are often at the root of hydropolitical tension between riparian states in shared river basins.
- The ability of a given country to generate *coping strategies* with which to manage water scarcity is an indicator of both social and technical ingenuity. In this regard, certain *issues* (such as a policy change from national self-sufficiency in foodstuffs to food security) are a key indicator. Food security requires foreign currency with which to purchase "virtual water" embedded in cereals and thereby balance out the national water budget in a "politically silent" way. In other words, water scarcity is actually a local issue rather than a global one if one re-defines the problem. Underlying this is what has been called the "Paradox of Perception" which defines the way that the problem is initially formulated, and therefore also influences the development of a solution from a possible range of options (Turton & Kgathi, 2002). Importing food that has been grown elsewhere can ameliorate localized water scarcities. Since it takes 1,000 tons of water to produce one ton of wheat, importing a ton of wheat effectively imports 1,000 tons of water in an abstract sense. This redefinition can be done without having to admit that water scarcity is a strategically important factor (hence the importance of being politically silent). But in order to do this, one needs to redefine political priorities away from national self-sufficiency in food to *food security* instead. This move, however, is fraught with political risk, as it opens up a new set of political and economic dependencies on the developed countries of the North (see Allan, 2000).
- The *willingness* and *ability* of all role-players to *negotiate* in order to generate coping strategies or develop institutions is an indicator of social ingenuity. It is the ability to gain consensus on hydrological data that builds confidence in otherwise-contested river basins. This also allows the core problem of water-resource management to be re-defined in such a way that the trade in virtual water can become an effective strategy. The Paradox of Perception is relevant in this regard (Turton & Kgathi, 2002).
- Finally, the ability of a given social entity *to sustain institutions once created* is an indicator of both social and technical ingenuity. This article suggests that countries with a higher GNP per capita are more likely to sustain institutions than those with a lower GNP level for a variety of reasons—including the technical ability to generate data on which incremental decision-making can be based.

relatively high per capita water availability, showing the flaws in merely first-order analyses. Zambia is politically stable but has a low level of economic activity. It is also negatively affected by the civil wars in both Angola and the DRC. Should Angola, the DRC, Mozambique, and Zambia manage to solve these problems, they could conceivably become the regional breadbaskets, using their natural resource endowment to balance the regional water scarcity by becoming virtual water exporters within the Southern African Development Community (SADC) (Turton et al., 2000b).

The four southern African WP cases present a complex set of problems indeed. Since there is a relative scarcity of both first- and second-order resources in these cases, their dependence on external aid is likely to grow over time. Lesotho is an interesting case as it is first-order resource poor, yet it is also the source of water for South Africa via the Lesotho Highlands Water Project (LHWP). Water represents one of the few natural resources that Lesotho can exploit (the other being labor and, to a lesser extent, diamonds). So it sells water to South Africa, using the royalties to finance other development projects. Significantly, all of the East African countries fall into the WP category. This suggests that East Africa faces relatively more complex development problems than Southern Africa does.

Some Hypotheses for Testing

The results presented in Table 3 suggest a series of hypotheses that can be tested more exhaustively elsewhere. To review, four such hypotheses are evident:

- In all cases presented, the relative abundance (or scarcity) of the second-order resource determines the outcome.
- For countries with a relative abundance of first-order resources and with a relative scarcity of second-order resources, developmental potential is likely to remain low. This condition can be labeled *Structurally-Induced Relative Water Scarcity* (SIRWS), an unhealthy condition that policy development should seek to counter vigorously.
- For countries with a relative scarcity of first-order resources and with a relative abundance of second-order resources, developmental potential is likely to be high. This condition can be labeled *Structurally-Induced Relative Water Abundance* (SIRWA), a healthy condition to be actively sought as a policy outcome.
- For countries with a relative scarcity of both first- and second-order resources, developmental potential is likely to remain low. This condition can be labeled *Water Poverty* (WP), a debilitating condition that is likely to result in a spiral of social and economic decay over time, with no apparent end in sight short of external intervention in some form. Under these conditions, policy intervention is likely to be exogenous in nature—dependent on third-party involvement.

It would be most illuminating to test these hypotheses by means of a more robust methodology and by using a wider range of indicators. Turton (2002) is developing such a methodology, along with indicators that are applicable to the management of international river basins. These indicators include aspects such as the ability to generate data independently of foreign assistance, and the ability to legitimize that data by means of building consensus among all riparian states. (See Box 2 for more details.) The outcomes of such a venture would be valuable for policymakers and water-resource professionals in the developing world.

GIS as a Management Tool—Just a Matter of Representation?

The previous detailing of population and water scarcity nuances in the developing world has laid the groundwork for an assessment of the role of technology in general—

and Geographical Information Systems (GIS) in particular—in managing such problems. Is GIS a helpful tool for gauging population growth and water stress, or is it a manipulative device for representing the world in the image of the powerful? This is an issue of increasing relevance, meriting far greater attention outside the world of geography and water resource management. It is particularly relevant to the developing world.

Since its inception in the developed world in the 1960s, remote sensing has been a growth industry, becoming a highly popular representational tool to locate three-dimensional data. Yet critics such as Pickles (1991) charge that GIS tends to be used unreflectively—those who use it are not alert enough either (a) to the assumptions underlying their technology of choice, or (b) the implications of its use. This criticism is necessarily bound up with value issues and ethics. Like any map, a GIS representation of the world imposes a set of values on its users. The answer to a research question is dependent on the assumptions underlying that question. Thus, if the question is whether GIS can shed light on water and population stress, this not only implies the assumption that there is a question of stress but also that this stress could lead to problems.

For example, knowledge constructs like "water wars" (most famously coined by Joyce Starr) and the "population time-bomb" express the pessimistic Malthusian perspective. These constructs have not gone unchallenged, and as a result the doomsayers seem to be beating a retreat—see, for example, ICRC (1998), in which Tony Allan argues that it is the "optimists" who are right (although he deems them dangerous, as they promote complacency about real challenges to be met). This debate highlights the need to take solution-capacity into account as much as problem-potential.

If stress is the ratio of challenge to coping capacity (Lazarus, 1966), then coping with stress may involve reducing the challenge (needs) or increasing the coping capability (adaptive capacity). Fortunately, revised projections on population growth and a greater understanding of virtual water—one example of the adaptive capacity introduced above—provide a more optimistic view. One such view is Allan's dictum that the pessimists are wrong but useful, while the optimists are right but dangerous (Allan, 2000). Researchers should therefore be careful both to point out what they believe and what information they rely on to back up those beliefs.

It is important to realize that GIS is an information management tool rather than a data-gathering tool. What emerges from a GIS exercise in itself does not say anything about the policy issue that gave rise to the exercise in the first place. As a consequence, the "garbage-in, garbage-out" principle applies with a vengeance to GIS. For example, a researcher might attempt to gauge the world's level of urbanization by the amount of light its cities emit. The larger the dots on the world map, the bigger the urban population. Yet this analysis would make sense only if the level of energy use is equal across the globe, which it obviously is not. There are striking differences between per capita energy use in Sana'a, Yemen and Cape Town, South Africa; as a consequence, Yemen fails to appear on some urbanization maps (Allan, personal communication, 2000).

The phrasing of the research question, the data input, and the criteria for assessment all matter, because each impacts on the overall construction of the knowledge that we seek to build. A good example is early warning in famine policy. In many emergency situations, food may well be available, but the mechanisms of exchange (entitlements) by which people have traditionally gained access to food have ceased to function (Sen, 1981). In these cases, famine is caused not by a failure of supply but by a failure of meeting effective demand (Hutchinson, 1998).

The concept of the "water barrier"[3] is a relevant application of these observations on the nature of questions to be asked to the water sector. The renowned Swedish hydrologist Malin Falkenmark (1990) introduced the concept as a practical rule of thumb, but eventually she almost came to regret coining it (Falkenmark, personal communication,

1995) as the water sector began to interpret it as an unassailable rule. While the water barrier is a handy device to show how many countries may be mining their way into future misery, its subsequent uses ignored other factors such as second-order resources. The concept of the "water barrier" in itself provides a useful, confrontational view that underscores an alarmist agenda about the state of the water resource, intended to awaken governments to the unpleasant realities of current trends in the available water stock.

Falkenmark intended the "water barrier" to provide a guide to the minimum water requirement for an average human being, which she calculated at 1,700 $m^3/cap/yr^{-1}$ (Falkenmark, 1989). The concept was soon enshrined in policy documents as a hard and fast rule, unfortunately reinforcing existing platitudes that assume water is recovered, handled, and distributed everywhere in a uniform way, thereby ignoring institutional, cultural, and economic differences. This problem is common for analyses in which first-order resources are the sole focus of attention. A meat-eating, industrial-consumer society such as the United States has a rather different water-demand pattern than a vegetarian, self-sufficient nomadic tribe living on a bottle of water a day. Local water scarcity is also only a problem for an area when non-native people either want to, or have to, live there. One consequently needs to take into account first-order natural resources, second-order social resources, and the settlement pattern of people if the problem of water resource availability is to be adequately understood. Taking data as absolutes can easily lead to non-adaptive conclusions (Geldof, 1994), which are clearly unsatisfactory.

GIS and Social Context

The issue of social context is also critical in appraising the validity of a particular technological application. Social context suggests (as did the first section of this article) that there are different types of scarcity. Sexton's (1992) concept of "economically-induced scarcity" and Warner's (1992) "politically-induced" scarcity both hint at an underlying mismatch between the water wealth offered by nature and the actual amount of water available to specific groups and individuals in society. Ohlsson's (1998, 1999) differentiation between first-order and second-order resource scarcity is also a dynamic concept; it addresses response to stressors (such as drought, floods, and famine) rather than viewing scarcity as frozen in absolute terms in a particular moment in time. Countries that are poorly endowed with water resources are not necessarily in trouble if they have adaptive capacities and mechanisms that are either in place or capable of mobilization before the debilitating effects of absolute scarcity become a limiting factor. A country that has found ways to use ingenuity—what we would call its "water IQ"— will not always result in economic stagnation and political instability.

Conversely, a country that is seemingly on the safe side of the "water barrier" does not necessarily have reasons for complacency. On the basis of this insight, Ohlsson (1998; 1999) has endeavored to rank countries according to proxy indicators of social scarcity, guided by the UNDP's Human Development Index. As a result, we now have proxy indicators for second-order scarcity that can be developed further if found to be useful—see, for example, Sullivan et al. (2000). Yet one must bear in mind the "proxy-ness" of the indicators that are being used in this work. Even if one managed to refine the method to a high level of mathematical sophistication, there is still the question of reliability of inputs from official statistics.

In the above examples of the use of GIS in policy-relevant science, it was the *interpretations* of geographic information that were at issue rather than the input. Unfortunately, interpretations are in many instances where the trouble begins. In a country where an aggressive hydraulic mission is bent on mobilizing more water as a foundation for socioeconomic development, experts tend to rely on a positivist approach to knowledge —"objective" and precise science, dominated by experts and high technology and

excluding lay knowledge and "fuzziness." An example is the science of hydrology. While hydrology claims to be based on hard data and uses mathematical logic, poor data quality in the form of short time-sequences (coupled with the problems of extrapolation) ultimately yield gross distortions of reality. Another example is flood forecasting, in which cost-benefit assessments on flood protection are made despite lacking adequate time series to justify their extrapolations (Green & Warner, 1999). Politically rational processes are less orderly and predictable than hard science—emotions, values, hard-nosed opportunism get in the way. The measurement of such processes does not lend itself to the use of concrete numbers, so such processes tend to play havoc with this purported objectivity, with potentially deleterious effects on knowledge-building.

It should be noted that the GIS experts with whom we have interacted are often well aware that GIS is not a miracle toolbox but an instrument that necessarily reflects the biases of its filters and the project's aims. While the GIS community should perhaps display even greater receptivity to acknowledging the shortcomings of GIS, it is fair to say that policymakers are equally responsible when they receive information that reflects their biases.

The technical ability with which societies are able to handle their water-resource base is paramount.

Securitization of Water

Water resources are often securitized in semi-arid countries, especially when those countries have a strong hydraulic mission and face closure in shared international river basins (Turton, 2001). Securitization is the elevation of an issue above normal politics in light of the perceived national security interest, legitimizing extraordinary management measures (Buzan et al., 1998). As a result, in political settings such as Israel, Portugal, and Turkey, domestic scholars have found it frustratingly difficult to get access to essential water data because the government considers such data too sensitive to release. Like water, information can become scarce if perceptions of threat to the national interest prevail. During the Oslo negotiations, Palestinians had to rely on Israeli water maps that

were open to varied interpretation, thereby undermining confidence in the process. Drawing on Buzan et al's (1998) work on security strategy, this phenomenon may be called the securitization of information (Warner, 1998). The securitization of information often makes official statistics rather dubious, particularly in the Middle East.

When water has been elevated to a national security concern, projects promoting water development become undebatable. The persistence of this phenomenon has given rise to a concept known as the "sanctioned discourse," whereby a select elite determines what may be said about water-related development projects and by whom. Both in Turkey (the multi-dam Southeast Anatolia Project or GAP, on the rivers Euphrates and Tigris) and in Egypt (the Tushka project, which seeks to irrigate Egypian desert land by means of a spillway), criticism of pet projects has been taken as criticism of the state (Warner, 2000).

Abd al-Aziz Ahmad, a senior Egyptian official in the State Hydropower Commission, generated a series of now-famous reports that raised questions about the long-term sustainability of the Aswan High Dam (Waterbury, 1979, page 120); he subsequently met with ostracism in Egypt. Bureaucratic politics (Allison, 1999 [1971]) provide yet another and especially distorting element in this respect. Large organizations such as governments tend to form what Eric Wolf has labelled the *tributary social organization* (Wolf, 1990). Government bureaucracies, for example, form a tributary system that collects resources to finance public works: just as water flows from a tributary stream into a lake, wealth (through taxes and interest payments) flows towards those bureaucracies or departments that create new projects. Control of water then becomes the institutional ability to develop new projects (Johnston & Donahue, 1997). Concomitantly, the way to seek rapid promotion within the dominant organization becomes the completion of a successful project; and often the grander such projects are, the better they are perceived by gate-keeping elites. This dynamic favors the alignment and suppression of negative information; under such circumstances, any statistics generated by powerful water boards are not necessarily reliable, and consultants are under pressure to conform to the wishes of the bureaucracy (Brichieri-Colombi, personal communication, 2000).

Thus, as the output of GIS depends both on the input and the questions underlying it, GIS represents the world in a way that reflects those interests. Depending on what gate-keeping elites want to show, they can manipulate their computer images to highlight and represent their image of reality. The selection of such filters is a key passage point that is easily overlooked in evaluating GIS. Commercial applications of GIS can all be used to accumulate a plethora of personal information building up to detailed demographic profiles, and the intelligence community has always used data from civilian satellite systems in carrying out its security mission (Morain, 1998). Technologically advanced countries can spy on less well-endowed countries to see where strategic resources (such as water, oil, or natural gas) are without them necessarily being able to return the favor.

When we admire GIS data, therefore, we need to consider *whose* reality the shiny GIS material represents.

GIS as a Reductionist Tool

Apart from the influence of interests, there is a fundamental issue at stake regarding the way the world is analysed. At the philosophical, epistemological, and ontological level, GIS represents a Western tradition of decomposing the world into minutiae rather than integrating it holistically. Conventions such as the Convention on Climate Change require countries to collect data according to a certain model that (a) brackets in countables prioritized by the developed world, and (b) brackets out non-countables such as cultural and religious values as well as common-law institutions. The unified approach on measuring vulnerability to climate change proved much more compatible with countries like

the Netherlands than islands in the South Pacific, which not only find it harder to come by physical and economic data to fit into the system, but also have raised the issue of different norms such as communal ownership of resources. Forcing them to adopt a framework reflecting Western-oriented values may well mean the non-appearance of local values in the comparative data, which will make it harder for them to bargain for specific compensatory and rehabilitating measures.

Also, just as school atlases of yore listed each colony's raw materials, GIS can be used to pinpoint the last exploitable energy and water reserves and, in so doing, promote their capture. A transferred technology may not conform to indigenous values held by beneficiaries. This disconnect becomes ever more salient as GIS technologies develop into a must-have for the developing South. To keep up, the developing countries seek access to the same reality-transforming technology that they see in the developed world. The use of GIS is now universal in the West, but close allies such as Egypt also benefit from the latest American technology. Yet poorer countries, or those less sympathetic to Western-style capitalism, may be left out: for example, peoples without officially-recognized states (such as the Palestinians) cannot legally buy remote-sensing images, which puts them at a distinct disadvantage. The same issue of availability and access is consequently not just relevant for water, but also for information tools like GIS.

There is also the issue of whether a country that is the subject of GIS analysis can actually do anything with the results that the technology yields in the first place. When floods hit Mozambique in February 2000, flood-warning technology was well in place in the region, but Mozambique did not seem to benefit from it for lack of a working knowledge infrastructure. Thus, no matter how promising epistemic communities are (such as those that involved in global warming and regional-knowledge building), strictures such as those of communication, representation, and logistics may prevent the development of an effective regional water security regime for Southern Africa.

GIS as a Management Tool

Thus far, this article has mainly pointed out serious questions about much of the current use of GIS. But we should not overlook the possibilities GIS opens up if it is used mindfully. The aim should be to make GIS a more *varied* toolbox for understanding the world. The technology lends itself to control *and* resistance strategies—both between countries and between state and society. Like the Internet, the increasing affordability of GIS could, with time, democratize the technology into a tool for use by those with only a reasonably powerful computer. From controversial dams in India to river-deepening and widening projects in the Netherlands, from illegal industrial pollution to covert military operations, researchers who pool resources should be able to parse potentially distorted official statistics and get the "real" numbers. And, in this regard, GIS could promote the democratization of science for policy in general. Fortunately, the ever-falling cost of GIS also allows previously-silenced critics to turn the tables and break the monopoly of information use by elites.

What Turton & Ohlsson (1999) have called the "second transformation" starts with new voices on the scene, such as civil-society groups consisting of NGOs and community-based organizations. While underestimated at first as being irrelevant and repressed, these voices have increasingly started to be integrated into government, particularly where institutional government capacity is weak. In this role, such voices provide a chance to mobilize the second-order resources that some countries may lack by mobilizing untapped knowledge and governance capacities and bridging the ingenuity gaps. The social and environmental consciousness that these advocates express has started to challenge the approach of those still enthralled by a "hydraulic mission" (Reissner, 1996).

In the light of these developments, hailing GIS as the return of positivism would be to

paint too simplistic a picture of a changing reality. It would make more sense to try and convince those who work with GIS that theirs is one knowledge among many—such as the traditional knowledge systems of many local water users in the developing world. Interestingly, noted natural scientists for some time now have been advocating the involvement of non-experts in policy debates to help decide on contested value-laden policy problems as well as those surrounded by a great measure of uncertainty (e.g., Funtowicz & Ravetz, 1983). Bringing in "lay" (non-expert) voices and rationalities, perceptions, and emotions as considerations for policymaking (Geldof, 1994) will be perceived by some as a striking blow to the positivist outlook. However, this article advocates: (a) promoting the adaptation of GIS systems such that they allow for a diversity of questions to be raised; and (b) making GIS a tool that can also be operated by those of limited means or those seeking to promote an alternative, counter-hegemonic agenda. The difference between availability and actual access is also a crucial one. GIS can be especially helpful in showing not just the location and distribution of people, but by showing the physical infrastructure or "pipelines of power" (Turton, 2000a), thus showing how hydraulic structures can be developed to ensure differential access to water.

When second-order resources are mobilized in sufficient quantities and in sufficient time, the pitfalls of rapid population growth can be averted.

But the mainstream GIS community is confused by these criticisms, and dialogue towards progress on these issues has so far been painful and generally non-productive. As Schuurman (2000) notes, GIS experts have problems coming to terms with the *language* of GIS critics. Social science can also do its bit by phrasing its arguments in language that is intelligible to those who have been trained in the natural sciences. Fortunately, a new generation of engineers and physical geographers seem to be more sensitized to these questions than their predecessors were. One example is Initiative No. 19 of the University of California-Santa Barbara's National Center for Geographic Information Analysis' (NCGIA) Initiative, in which critics of GIS work together with their GIS-savvy peers (Schuurman, 2000). But we will need to do much more—ultimately redesigning engineering, geography, and social science curricula in a cross-disciplinary way so that the next generation will learn to speak multidisciplinary languages understandable to a wider audience.

Key Questions

Despite the debate over the values and shortcomings of GIS, it remains an important tool in the water availability/scarcity debate. With that debate in mind, it is now possible to focus attention on answering four critical questions.

Question 1. *Will there be enough water to support regional populations in the future?*

The African cases presented (even those characterized here as "low") almost all show an alarmingly high rate of population growth when compared to trends in the developing world. The doubling and even tripling of populations over the 39-year period for which data have been selected is cause for alarm. In terms of first-order analysis alone, this phenomena represents a significant reduction in the availability of water per

capita over time—ranging from half to a third over the period. When second-order resources are mobilized in sufficient quantities and in sufficient time, however, the pitfalls of rapid population growth can be averted. Second-order resource management therefore becomes the key management issue, relevant to water resource managers, aid agencies, and foreign policy practitioners alike.

SIRWA countries have a wider range of options available to them and are likely to manage water scarcity more effectively than SIRWS countries. SIRWA countries have the problem of mobilizing more water, so the issue of "running out of water" (another flawed concept that is often used in first-order analysis) is more relevant to them; but given their capacity to adapt, they are likely to implement coping strategies in time to avert a disaster. Virtual water trade is likely to become more important for these countries, raising the issue of increased vulnerability to global grain price fluctuations, increased dependence on erstwhile colonial powers, and other strategic considerations. SIRWS countries, in contrast, do have the problem of developing the water resources that they naturally have. WP countries are likely to face catastrophe after catastrophe with crisis management being the norm, so they are less likely to maintain social, economic, and political stability. Water scarcity is therefore likely to become a critical developmental constraint, with its debilitating effects unevenly distributed within WP countries and potentially exported regionally in a domino-effect of instability.

Question 2. *Can Geographical Information Systems (GIS) technology be used to map water resources and future population growth?*

Clearly GIS is a powerful management tool with enormous potential. There are a number of pitfalls, however, as discussed above. First, as noted in the introduction, political legitimacy and accountability are generally low in the developing world. Under such conditions, resource capture by the economic elite is increasingly likely. A powerful tool like GIS can therefore become an instrument of manipulation and political control rather than a water-management support platform. The impact of this should not be underestimated.

Second, while GIS represents an information management tool, it is not a science (Wright et al., 1998). As such, its effectiveness is hampered by the type and quality of data that originally available for input. In SIRWA countries, the likelihood of adequate primary data (coupled with the existence of sufficient intellectual capital and institutional capacity with which to collect, store, process, interpret, and share that data) is such as to generate optimism about GIS's applicability. For those countries, GIS is thus likely to become a powerful management tool in the future, and in many cases this trend is already evident. For SIRWS countries, the lack of substantial second-order resources is likely to mean that institutional development will be low and intellectual capital will be scarce; as such, the prognosis for the success of GIS in these cases is dubious. The same holds true for WP countries.

Third, the issue of North/South dependency becomes relevant. In the case of GIS, the technology is developed in the industrialized North and selectively exported to the developing South, possibly exacerbating the existing maldistribution of global power and creating new forms of marginalization and dependency.

Question 3. *Has the question now become one of managing demand for water rather than supply?*

There is no simple answer to this question because it is dependent on a series of other issues—such as (a) the capacity of a state to negotiate with riparian states in shared river basins, along with (b) the ability to develop the institutional capacity neces-

sary for developing effective coping strategies. In this regard, the Turton-Ohlsson typology presented in this article provides a useful framework for unpacking these issues. There are at least three necessary conditions for demand management to succeed:

- There must be sufficient institutional, intellectual, and administrative capacity in order to generate viable water-demand-management (WDM) solutions in the first place. Similarly, there must be the capacity to meter water consumption, bill users accordingly, collect payment, and sanction those who do not pay. All of these aspects are second-order-resource in orientation.
- There must be a high level of political legitimacy if WDM policies are to be supported by the general public.
- There must be a culture of payment for water services received. This also implies that there must be general acceptance of water as an economic resource.

For SIRWA countries, the prime management issue is about doing more with less. Under these conditions, WDM is likely to become an important component of a management strategy; however, as Gilham & Haynes (1999) have demonstrated, it is unlikely to be the sole solution. Where WDM is implemented, political legitimacy is likely to be severely tested. In Zambia and in Botswana, for example, attempts by the government to introduce charges for water (which was culturally seen to be a gift from God) are placing strains on the political system. The challenge under these conditions is therefore to develop the right mix of culturally-appropriate and politically-acceptable supply- and demand-sided solutions. Supply management will always remain important, with a shift of emphasis away from large water-transfer schemes to more sophisticated desalinization and water recycling systems. It is therefore simplistic to assume that a hard transition will occur from supply-sided to demand-sided management. In reality, both elements are needed in an effective water-resource policy, but with a shift in emphasis between the two over time toward the management of demand.

The second-order scarcities in SIRWS countries are likely to inhibit the development and implementation of viable WDM strategies. Popular support for WDM is unlikely in these cases, and civil disobedience can be expected to actively undermine such policies. The lack of institutional capacity in SIRWS cases is also likely to mean that water meters are not installed, billing capacity is likely to be non-existent, and legal sanction for non-compliance lacking. Clearly under such conditions the prognosis for success is low. The same holds true for WP countries.

Question 4. *How will WDM be achieved?*

Since the key management issue revolves around second-order resources, three elements are likely to be crucial:

- On the structural side, institutional development is important. Such institutions should: (a) be adequately staffed; (b) have sufficient data processing and sharing capabilities with which to develop and monitor solutions; and (c) be adequately funded in order to ensure sustainability. It is critical for demand-management institutions to meter water consumption, generate bills and collect monies due, and prosecute those who adopt a non-compliant posture.
- On the social side, there needs to be a culture of payment and a high level of support for the decision-making bodies. A cultural acceptance of water as an economic resource that has value and should be paid for is critical.
- On the political side, there needs to be unconditional support by politicians. Without this support, the overall credibility of the management process will be under-

mined. If politicians continue to promise free water to potential voters, then WDM strategies will be compromised.

Current research underway at the African Water Issues Research Unit suggests that three components are necessary to manage water demand, at least in an African context. The first of these is *accessibility to water*. Where water is inaccessible, its use is low and the time taken to fetch it is high. These dynamics change when water becomes more readily available and convenient to use. This means that the second component of any given demand management strategy is *pricing*. As water becomes more readily available, people are willing to pay for the resource. Demand can be managed through an innovative tariff structure such as that currently used in Durban, South Africa—but this is only effective if adequate access to water has already been established and if people's attitudes to the use of water have changed. The third component is, consequently, *education.* Education must target a wide spectrum of audiences—from water users up through the water supply chain to the political level. If politicians continue to offer free water as a means of securing votes, demand management is doomed to fail! An important end-goal of the education process is to change the attitude that water is a free good, in keeping with the Dublin Principles (ICWE, 1992) and World Water Vision (Cosgrove & Rijsberman, 2000).

Conclusion

The development and sustainability of second-order resources determine how well a society can manage a resource such as water. Typically, this type of resource is in short supply in the developing world. Hydropolitically-related foreign policy initiatives are likely to fail if this subtle but important nuance is not taken into consideration. Many cases of aid dependence result directly from an attempt to stimulate development in the absence of any recognition of the importance of second-order resources. Similarly, applications of modern technology such as GIS is likely to fail if second-order resources are not taken into account. Where correctly applied, however, GIS is likely to become a powerful and equalizing management tool of the future. The strategic significance of some of these nuances is important, given the impact of the 2001 terror attacks on New York's World Trade Center and the Indian Parliament. The foundation of this strategic significance derives from the fact that there is a correlation between (a) countries that have the potential to export terror, and (b) the existence of WP as defined in this article.

Acknowledgements

The authors wish to acknowledge the valuable support by the Woodrow Wilson International Center for Scholars for sponsoring this project and enabling it to be presented to a wider audience. In particular, this support enabled Richard Meissner, a research associate at the African Water Issues Research Unit (AWIRU) based at the Centre for International Political Studies (CIPS) at Pretoria University, to spend some time in London collecting data and consulting with Jeroen Warner. The Water Research Fund for Southern Africa (WARFSA) is also acknowledged for its support to the current WDM study that is being conducted at AWIRU. However, the authors alone accept the responsibility for the conclusions of the project.

Notes

[1] This distinction is not a clinical one, however, because many other criteria could be used. Even in this case, there are still overlaps. Tanzania, for example, falls into both classifications.

[2] The "water wars" argument suggests that, as a country's uncontrolled population growth erodes its available water resources, conflict potential in that country will increase to the point where war over water is inevitable (Turton, 2000b, page 39). By relying on so-called "hard" primary data (population and water availability), this linkage results ultimately in a teleological argument. In reality, this so-called "hard" data are not hard at all; it involves a high level of generalization combined with specific assumptions. For example, U.S. Census (2000) lists Angola's population in 2000 at 10,145,000, while the UN (2000) World Population Data reports a figure of 13,134,000. At best, such data are broad generalizations only and should not be regarded as being the final word on the issue.

[3] The "water barrier" was defined by Falkenmark (1990:181) as a conceptual "barrier" that was set at 2,000 people per standard "flow unit," consisting of one million cubic meters of water per year. Falkenmark considered any figure above the water barrier to make any form of economic development virtually impossible given current technologies.

Subsequent analyses have shown difficulties in universal application of the water barrier. Israel, for example, seems to be capable of surviving at a figure well beyond that set by Falkenmark. South Africa is approaching the barrier and also seems set to survive the transition. These anomalies have given rise to new explanations, leading to the concept of second-order resources. In the cases where states can survive beyond the water barrier, they all have high levels of second-order resources.

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