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# FOCUS 9

OCTOBER 2001

# OVERCOMING WATER SCARCITY AND QUALITY CONSTRAINTS

## EDITED BY RUTH S. MEINZEN-DICK AND MARK W. ROSEGRANT



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# Overcoming Water Scarcity and Quality Constraints

## Overview

Ruth S. Meinzen-Dick and Mark W. Rosegrant

Focus 9 • Brief 1 of 14 • October 2001

Access to enough water of sufficient quality is fundamental for all human, animal, and plant life as well as for most economic activity. At the global level, plenty of water is available. But to meet the demand, water has to be supplied where and when it is needed. These spatial, temporal, and qualitative characteristics pose the greatest challenge to meeting the rising demand in all sectors. Water withdrawals are only part of the picture. Almost all uses put something back into the water that degrades it for other users. Water quality and competition between users are therefore critical issues for the future of water use. There is no single "magic bullet" to solve these complex and interrelated problems. Increases in water supplies, and especially storage, are needed, but so is demand management, including not only economic instruments but also education and other efforts to change behavior. Appropriate technologies and institutions must both play a role.

### TRENDS IN WATER USE

Throughout history, farmers and nations have depended on irrigation to produce sufficient, stable food supplies. Today, an estimated 40 percent of agricultural products and 60 percent of the world's grain are grown on irrigated land. Irrigation accounts for around 70 percent of water withdrawals worldwide and over 90 percent in low-income developing countries. But water constraints may make expanding irrigation to feed an additional 1.5 billion people by 2025 impossible.

Access to clean water for drinking, cooking, bathing, and other household needs is fundamental, but over 1 billion people still lack safe domestic water supplies, and 2.4 billion lack adequate sanitation. Compared to other uses, the volume of water required for basic domestic needs is not great; municipal and industrial demands are growing much faster. By 2025, urban populations are expected to grow by over 2 billion, posing additional challenges for municipal water supply. While water quantity is not a major constraint on domestic use, chemical and biological contamination threatens the quality of water for human consumption.

Water is the source of life and livelihoods. Water also sustains natural ecosystems. Excessive human water withdrawals and pollution have disrupted many vital habitats and species, leading to calls to reduce water withdrawals and reserve water for nature. Yet most economic activities require water. Factories need water for processing, cooling, and waste disposal. In the last 50 years, agricultural water consumption doubled, but industrial consumption increased six-fold worldwide, and even more rapid increases in industrial use are expected.

The competition for water among domestic use, agriculture, industry, and nature is leading to scarcity even in areas that seemed water-abundant. Two ways of dealing with scarcity are to increase supply and limit demand. We examine each of these in turn.

### OPTIONS TO INCREASE WATER SUPPLY

Many countries have sufficient water to meet demands for all uses. However, much of the rainfall and river flows are highly seasonal, so there is excess at some times and not enough at others. Domestic and industrial uses require water every day, and demands may be even higher in the dry season. Agriculture can accommodate seasonal flows of water, but irrigated production in the dry season is often the most productive and profitable type of farming.

Storage is the key constraint to providing water in dry periods, when demands are highest and supplies lowest. Dams, groundwater aquifers, and small-scale water harvesting provide water storage. Dams have received the greatest investment, especially in the last 50 years. However, dams have become increasingly expensive in financial, environmental, and political terms. As the best sites are used up, the environmental costs of submerging forests and wildlife and the loss of land and livelihoods for those who are flooded out have given rise to organized political opposition.

Groundwater is a major source of stored water for irrigation as well as for rural and urban domestic use. Heavy withdrawal has led to falling water tables in many areas, limiting the potential for expanding groundwater use without more recharge of aquifers. Furthermore, arsenic, fluoride, salinity, and other aquifer contaminants have become serious problems for those relying on groundwater.

As the limitations of larger-scale storage in reservoirs and aquifers have become apparent, there has been renewed interest in smaller-scale water harvesting. Although small, water-harvesting structures can collect considerable volumes of water for storage above ground or in soil profiles. However, water harvesting can be expensive per unit of water, and is unlikely to be able to meet rapidly growing water demands.

Other options to increase supply include interbasin transfers and nonconventional sources. Interbasin transfers bring water from areas of abundance to those of scarcity, but they share many of the financial and environmental problems of dams. Desalination is expensive and energy-intensive, and hence has limited application at present. Other types of recycled wastewater can be used for some purposes. Urban wastewater is used for peri-urban irrigation in many areas, but the financial costs of treating sewage and the health costs of using water with fecal contamination and heavy metals call for caution in relying too heavily on such recycling.

Overcoming water scarcity requires using all options to increase available water supply and storage capacity, but supply options face serious financial and environmental constraints. We need to look to managing demand as the other half of addressing scarcity problems.

## OPTIONS TO MANAGE WATER DEMAND

Economic measures such as pricing and water markets often receive the most attention in demand management. Water pricing is promoted as a means to recover the costs of building and operating water control structures. Water prices can also create incentives to conserve water, provided users can be charged based on how much they use. However, measuring and billing are often technically difficult and costly. There may also be public opposition to charging for water. Water markets can create economic incentives to conserve water, but the infrastructure and institutions to transfer water from one user to another must be in place.

Rationing is a prevalent demand-management measure and can be an equitable way of meeting basic needs because it does not depend on ability to pay, but it may be unpopular and difficult to administer. Rotational irrigation deliveries, limited hours of domestic water supply, or limits on water volumes for industry are examples of rationing.

Other forms of regulation can help reduce demand. Mandating water-saving toilets, flow regulators in plumbing, efficiency requirements for particular industries, and technological measures such as stopping leaks in municipal water supply systems or shifting to sprinkler or drip irrigation can also save water.

Education, social marketing, and public awareness campaigns to change behavior deserve much greater attention in water demand management. Awareness of water problems can motivate water conservation, while education can lead to effective changes in water-use practices. Such campaigns can also make pricing, rationing, or regulatory measures more acceptable to the public and more effective. Finally, measures to reduce water pollution such as regulations on industrial effluents, reductions in agrochemical use, or sewage treatment plants also alleviate water scarcity.

## TECHNOLOGY AND INSTITUTIONS

New technologies can increase supplies through low-cost desalination, wastewater treatment, water-lifting devices, or even long-distance transport. Technologies can also reduce water demand and increase productivity through water-saving industrial processes, household plumbing, irrigation devices, or new crops and varieties.

However, past experience has shown that science alone will not solve water problems. Much technology already exists but is not used because organizations and water users do not have the finances, knowledge, or incentives to use them. The right institutions are also required. Instead of separate government agencies for irrigation, water supply, sanitation, and environment, effective water management organizations will have to include new combinations of public sector, private sector, and civil society.

Basin management organizations can coordinate uses and allocate water among different sectors and regions. Effective basin management can result in more efficient and equitable water use and reduce conflict over water, especially in water basins that cross two or more countries.

Allocating water, whether through basin organizations or water markets, requires attention to many types of water rights. Rather than the government trying to establish rigid water rights, it should provide forums for negotiation between different users and claimants and work to strengthen the rights of the poor and disadvantaged groups.

Governments alone cannot and should not be expected to provide sufficient quantities of clean water for all uses. Users' participation in management is crucial for irrigation as well as domestic water supply systems and can contribute to more effective river basin organizations. Creating proper incentives and effective organizations for all users—women and men, poor and rich, from different sectors—to participate is complex and can be costly and time-consuming, but the returns in terms of improved water management, reduced conflict, and long-run sustainability of systems make this a vital investment.

## CONCLUSIONS

Rapid increases in water use and degradation of water quality are putting extreme pressures on this vital resource. There are a number of strategies for dealing with these challenges outlined in the following briefs, but there is no single solution to overcoming water scarcity and quality constraints. Concerted efforts are needed to increase supplies as well as balance the demands of agriculture, domestic use, industry, and the environment through economic measures, regulation, and campaigns to motivate and equip users to conserve. Technological and institutional approaches must combine to accomplish these goals. Achieving such a coordinated approach to water is challenging, but essential for feeding the world, reducing poverty, and protecting the earth. ■

**For further information see Cosgrove, W. J. and F. Rijsberman. *World Water Vision: Making Water Everybody's Business.* London: Earthscan Publications Ltd., 2000.**

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# Overcoming Water Scarcity and Quality Constraints

## Water for Food Production

Mark W. Rosegrant and Ximing Cai

Focus 9 • Brief 2 of 14 • October 2001

Water for agriculture is critical for food security. However, water for irrigation may be threatened by rapidly increasing nonagricultural uses in industry, households, and the environment. New investments in irrigation and water supply systems and improved water management can meet part of the demand. But in many arid or semiarid areas—and seasonally in wetter areas—water is no longer abundant. The high economic and environmental costs of developing new water resources limit supply expansion. Therefore, even new supplies may be insufficient. Whether water will be available for irrigation so that agricultural production can provide for national and global food security remains an urgent question for the world.

This brief examines the relationship between water and food production over the next 30 years using IFPRI's IMPACT-WATER model. This global model simulates the relationships among water availability and demand, food supply and demand, international food prices, and trade at the regional and global levels (Rosegrant and Cai 2000 describes the methodology and data sources). The baseline scenario incorporates our best estimates of the policy, investment, technological, and behavioral parameters driving the food and water sectors. We then look at how faster growth in municipal and industrial (M&I) demand and slower investments in irrigation and water supply infrastructure would affect food production.

### WATER INCREASINGLY SCARCE FOR IRRIGATION

Water withdrawal and consumption in 1995 and 2025 are shown in the table below. Withdrawal refers to water removed from a source, some of which may be returned to it and reused. Consumptive use is the water withdrawn from a source and actually consumed or lost to seepage, contamination, or a "sink" where it cannot economically be reused. Under the baseline scenario, total global water withdrawals for agricultural, domestic, and industrial use are projected to increase 23 percent from 1995 to 2025. Projected withdrawals increase 28 percent in developing countries.

Global consumptive use of water will increase by16 percent, the vast majority in developing countries, where consumptive use across all sectors will increase by 18 percent. Non-irrigation water demand will increase by 62 percent worldwide, 96 percent in developing countries, and 22 percent in developed countries. Consumptive use of water for irrigation worldwide will grow only 3.9 percent, which is significantly lower than the 12 percent increase in the rate of water use to meet full demand for irrigated crops. Of critical importance, the slow growth in irrigation water supply, especially in developing countries, will be due to water supply constraints and high non-irrigation demand, which will increase water scarcity for irrigation.

### FOOD PRODUCTION, DEMAND, AND TRADE

Under the baseline scenario, world food prices will decline, but more slowly than in the past two decades. Wheat prices are projected to decline by 8 percent between the base year and 2021–25, maize prices by 7 percent, and rice prices by 17 percent. This compares to a decline of 30–40 percent in these commodity prices between 1985 and 1995. The importance of developing countries in global food markets will increase substantially: 86 percent of the projected increase in global cereal consumption and nearly 90 percent of the increase in global meat demand between 1995 and 2021–25 will come from developing countries. Total cereal demand is projected to grow 43 percent by 760 million metric tons (mt).

**Water Withdrawal and Consumption ($km^3$) in 1995 and 2025**

| | Water Withdrawal | | Water Consumption | | Irrigation Consumption | | Non-Irrigation Consumption | |
|---|---|---|---|---|---|---|---|---|
| | 1995 | 2025 | 1995 | 2025 | 1995 | 2025 | 1995 | 2025 |
| Developed countries | 1,144 | 1,266 | 436 | 476 | 268 | 271 | 168 | 205 |
| Developing countries | 2,762 | 3,528 | 1,364 | 1,609 | 1,162 | 1,214 | 202 | 395 |
| World | 3,906 | 4,794 | 1,800 | 2,085 | 1,430 | 1,485 | 370 | 600 |

Substituting food imports for irrigated agricultural production paid for by urban and commercial growth (so-called imports of "virtual water") is a possible strategy for reducing agricultural water use. However, even under the baseline scenario, developing countries' reliance on food imports will increase dramatically. With the slowing of crop yield growth, import demand in developing countries is projected to increase from 108 million mt in 1995 to 238 million mt in 2021–25.

Irrigated and rainfed production will each account for about half of the increase in cereal production between 1995 and 2021–25. Irrigation plays a more dominant role in cereal production in developing countries, where nearly 60 percent of future cereal production will come from irrigated areas, accounting for four-fifths of the growth in global irrigated cereal production.

## WATER AND CROP YIELDS

With area harvested projected to grow slowly, crop yield growth is essential to future food production. However, cereal yield growth in most countries will slow. The global yield growth rate for all cereals is expected to decline from 1.5 percent per year during 1982–95 to 1.0 percent per year during 1995–2025; and in developing countries, average crop yield growth will decline from 1.9 percent per year to 1.2 percent.

Increasing water scarcity will be a primary cause of the slowdown in projected irrigated cereal yield growth in developing countries. The relative crop yield for cereals in irrigated areas in developing countries is projected to decline from 0.86 in 1995 to 0.74 in 2025. Relative crop yield is the ratio of the projected crop yield to the maximum economically attainable yields at specified crop and input prices under conditions of zero water stress. The fall in the relative crop yield index is a significant drag on future yield growth. For developing countries, the drop represents an annual cereal production loss of 139 million mt, which is higher than China's total rice production in 1995.

## ALTERNATIVE SCENARIOS

The baseline scenario, characterized by declining water supply reliability and relative crop yields, indicates the potential vulnerability of agricultural production to a worsening in water scarcity. What would happen if there were significant increases in non-irrigation water demand or declines in water investment and policy reform compared to the baseline? Under the high non-irrigation water (HNIRW) demand scenario that postulates faster growth in M&I demand, non-irrigation consumption will reach 681 $km^3$ in 2021–25, 33 percent of total water consumption (versus 25 percent under baseline). Under the second alternative scenario, which assumes low investment in infrastructure (LINV), the net increase of global reservoir storage for irrigation and water supply rises by only 396 $km^3$ between 1995 and 2025 compared to an increase of 690 $km^3$ under the baseline. Global average basin irrigation efficiency increases only to 0.57 versus 0.61 under the baseline, corresponding to a water consumption savings of 23 $km^3$ under the LINV scenario compared to 115 $km^3$ under the baseline. The net increase in withdrawal capacity between 1995 and 2025 is only 301 $km^3$ under the LINV scenario versus 844 $km^3$ under the baseline.

The scenarios that project significant negative impacts on irrigation water consumption and irrigation investment result in declines in cereal production and large increases in cereal prices. By 2025, irrigated cereal production will be 58 million mt less under HNIRW, and 103 million mt less under LINV than under the baseline. Rice prices are projected to be 30 percent higher than the baseline in 2021–25 under LINV and 15 percent higher under HNIRW. Maize prices are 22 percent higher under LINV and 27 percent higher under HNIRW, and wheat prices 22 percent higher under LINV and 19 percent higher under HNIRW. High non-irrigation water use and low investment also results in increased variability in international prices, which can pose adjustment problems for farmers. Moreover, the fall in irrigated area and production creates additional pressure on the relatively fragile rainfed land base. Due to rising prices, rainfed cereal area will increase by an annual average of 7 million hectares under the LINV scenario in 2021–2025.

At the local and regional levels, price increases of this magnitude would cause a significant decline in the real income of poor consumers. Malnutrition would increase because many of the poorest people in low-income developing countries spend more than half their income on food.

## CONCLUSIONS

Investments and policy reforms in water and irrigation management will be significant determinants of future food production, demand, prices, and trade. Rapidly growing municipal and industrial water demand in developing countries will increase water scarcity for agriculture, and with a continued slowdown in water investments, could be a serious threat to future growth in food production. Food production, demand, trade, and prices will be affected. Three broad strategies can address the challenge of increasing water scarcity: (1) attack the problem from outside the water sector—for example, through crop breeding for more rapid yield growth; (2) increase the supply of water for food production through investments in irrigation, dams, or urban water supply; and (3) conserve water and improve the efficiency of water use through water management and policy reform. Appropriate water and food strategies must be country-specific and will combine elements of each of these approaches. A decline in water available for irrigation without compensating investments and improvements in water management and water use efficiency—in both irrigated and rainfed areas—will reduce production growth and sharply increase international cereal prices, causing negative impacts on low-income developing countries and consumers. ■

**For further information see Rosegrant, M. W. and X. Cai. "Modeling Water Availability and Food Security—A Global Perspective: The IMPACT-WATER Model." Working paper. IFPRI: Washington, D.C., 2000.; Hofwegen, P. van and M. Svendsen. *A Vision of Water for Food and Rural Development.* World Water Vision Report, 2000.**

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# OVERCOMING WATER SCARCITY AND QUALITY CONSTRAINTS

## DOMESTIC WATER SUPPLY, HYGIENE, AND SANITATION

HANS VAN DAMME

FOCUS 9 • BRIEF 3 OF 14 • OCTOBER 2001

The Earth was home to 6 billion people in 2000: 1.1 billion of them lacked safe water and 2.4 billion lacked adequate sanitation. As a consequence, water- and sanitation-related diseases are widespread. Nearly 250 million cases are reported every year, with more than 3 million deaths annually—about 10,000 a day. Diarrheal diseases impact children most severely, killing more than 2 million young children a year in the developing world. Many more are left underweight, stunted mentally and physically, vulnerable to other deadly diseases, and too debilitated to go to school.

This situation in today's world is humiliating, morally wrong, and oppressive. The global community has made advances in many fields but it has failed to ensure these most basic needs of deprived people. Worse still, if unprecedented global action is not taken, the lot of the poor is expected to worsen in the foreseeable future.

### CURRENT SITUATIONS

In spite of hard work and laudable progress, the number of people without access to both water supply and to sanitation in developing countries remained practically the same throughout the 1990s: the increase in population served was just enough to keep pace with population growth. According to the *Global Water Supply and Sanitation Assessment 2000 Report,* the majority of the world's population without access to improved water supply or sanitation services lives in Africa and Asia. Two-thirds of people without access to improved water supply and more than three-quarters of those without access to improved sanitation live in Asia.

No figures are available on hygiene. However, experience has shown that clean water alone leads to only minor health improvements. The essential factor is sound personal hygiene, with adequate public sanitation and clean water as supporting components. While each of the three components alone has some health benefit, their combined effect is far greater. Hygienic behavior is virtually impossible without a source of safe water and a safe means to dispose of human and other wastes.

Access to water and sanitation services is closely related to each nation's economy. The economic gap between rich and poor countries has widened over the last 20 years. Many of the least developed countries have been caught in a downward economic spiral. Their governments can find it hard to sustain basic social programs, including water and sanitation. Furthermore, aid programs often lack the flexibility essential in such cases. This crisis is most apparent in Sub-Saharan Africa. In Asia, the Middle East, North Africa, Latin America, and the Caribbean, the situation is generally better, although growing cities represent a critical challenge.

**WATER SUPPLY AND SANITATION IN 1980 AND 1994**

| | Millions Without Safe Water Supply | | Millions Without Adequate Sanitation | |
|---|---|---|---|---|
| Region | 1980 | 1994 | 1980 | 1994 |
| Africa | 243 | 381 | 315 | 464 |
| Latin America and the Caribbean | 109 | 97 | 150 | 176 |
| Asia and the Pacific | 1,461 | 627 | 1,250 | 2,206 |
| Western Asia | 12 | 10 | 20 | 26 |
| Total | 1,827 | 1,115 | 1,740 | 2,873 |

Sources: Data from WHO, "Water Supply and Sanitation Sector Monitoring Report: 1996 (Sector Status as of 1994)," in collaboration with the Water Supply and Sanitation Collaborative Council and UNICEF, New York, 1996.

The dissolution of the USSR has caused the quality of water services in large parts of Central Asia to slip backward. Throughout this region, institutional reform has become critically important to the goals of decentralization and encouragement of private initiative. In addition, collaborative mechanisms are badly needed to help promote common awareness and joint action across the diverse political, economic, and cultural philosophies and practices that these nations embrace.

### FUTURE NEEDS

The Population Council predicts that world population will grow to 7.8 billion over the next 25 years, with most of the increase in urban areas. The urban population will roughly double, to approximately 4.5 billion people. After 2020, all population growth—and most poverty—in the developing world will occur in urban areas, as the rural population declines. Universal water supply and sanitation coverage by 2025—a now widely acknowledged goal—will mean that in urban areas an additional 1.9 billion people will need water supply and 2.1 billion will need sanitation services. In rural areas, 1 billion people will need water supply and 2.1 billion will need sanitation.

Field experience and studies suggest that a minimum quantity of safe water is required for a person to drink, prepare food, ensure personal cleanliness, and use a sanitary latrine. Drinking and cooking take 10 to 15 liters per day. Water needs for hygiene and sanitation are less precise, and vary from one culture to another. But a person who practices personal hygiene and uses a latrine needs an absolute minimum of 20 liters per day. Further health benefits accrue when communities move from public tap to house connections. Those with house connections usually use 40 or more liters per head. The total volume of water required to meet basic needs for all is thus relatively small, even for a city of 1 million, compared to agricultural and industrial uses, and even to household use by the wealthy. Thus the problem in domestic use is not water quantity.

Sanitation is one of the most important interventions in improving the human condition. Yet many agencies neglect hygiene and sanitation because they are not included in agency mandates. What constitutes good hygienic practice varies from culture to culture although the common aim is to break the fecal-oral transmission route of disease. Disposing of human wastes in a manner that does not contaminate the environment and that further limits the likelihood of disease transmission from person to person is a fundamental requirement. Minimum sanitation standards should be established at the national level.

## THE WAY FORWARD

The constraints for improvement are neither financial nor technical—they are political, social, and managerial. Business as usual has proven unable to produce adequate water services. Democratic thinking and action, one of the most essential changes, is a prerequisite for development.

To find solutions for the imminent crisis in hygiene, sanitation, and water supply the Water Supply and Sanitation Collaborative Council (WSSCC) undertook a democratic consultation process that developed Vision 21 (see Box). If the goal of hygiene, sanitation, and water supply for all people is to be achieved, people's roles must change. The most important actors will be individuals and groups in households and communities with new responsibilities for their own hygiene, sanitation, and water services, as part of a collective strategy. Public authorities will need to provide enabling conditions, clearing large-scale obstacles, securing empowerment of people through self-reliance, supporting individuals and families in their efforts, and carrying out the work that households and communities cannot manage for themselves. Similarly, water-sector professionals must combine their technical skills with an ability to communicate with those they serve.

The fundamental premise is that people's initiative and management of their own quality of life must be at the center of planning and action. Visions and plans articulated at local levels are the building blocks for progress at the next levels of national, regional, and global action.

This approach demands collaborative action by empowered people in households and communities, and by authorities that support new roles for civil society. Fresh attitudes and commitments, reflected in new policies and activities, are needed at every level of society and governance. The foundation of the new approach is recognition that water and sanitation are basic human rights. Together, water and sanitation services can improve living conditions for all, and most particularly for children and women. They form a major component in poverty reduction. Such recognition can lead to systems that encourage genuine participation by men and women, resulting in the acceptance and practice of hygiene, coupled with safe water and sanitation at the household level.

### THE VISION 21 PROCESS

**The process began with meetings in towns and villages in 21 countries, where local men, women, and children joined local NGOs, citizens' groups, and other stakeholders. The groups looked a generation ahead and asked, "What water, sanitation, and hygiene environment would we like to see in our community in the year 2025 and what is needed to attain this?"**

**Following the local meetings, the national consultations reviewed the communities' answers, which started a dialogue (sometimes for the first time) among government, community representatives, and NGOs. Next, Vision 21 held five regional consultations. Contributors from the national meetings joined participants from countries that were not yet part of the national Vision 21 exercise. The final part of the process was a global consultation, where the final version of Vision 21 was endorsed by a gathering of stakeholders representing all the regions. All these people shared their aspirations and their strategies for practical action toward universal access to hygiene, sanitation, and water supply. Thus, Vision 21 opened the door to an approach that has the potential to reach everyone. What seemed idealistic has proved to be achievable.**

## INVESTMENT REQUIRED

Earlier estimates of annual expenditures on water and sanitation ranged from US$10 to US$25 billion, most on higher level services in urban centers whose cost is not recovered from the users. The Global Water Partnership's more recent estimate is that an annual investment of US$30 billion might be needed for water supply and sanitation.

The WSSCC suggests that if the principles elaborated in the Vision 21 document are seriously applied, the total cost for providing a basic level of service over the next 25 years (in addition to the costs borne by households or communities) totals US$225 billion, or approximately US$9 billion per year. This estimate is within the range of current expenditures. It reflects the potential for cost recovery possible through political determination, to which participation is the key. ■

**For further information see *Vision 21: A Shared Vision for Hygiene, Sanitation, and Water Supply and a Framework for Action.* Water Supply and Sanitation Collaborative Council: Geneva, March 2000.; *Global Water Supply and Sanitation Assessment 2000 Report.* World Health Organization, United Nations Children's Fund (UNICEF), and Water Supply and Sanitation Collaborative Council: 2000.**

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# Overcoming Water Scarcity and Quality Constraints

## Emerging Water Quality Problems in Developing Countries

Wim van der Hoek

Focus 9 • Brief 4 of 14 • October 2001

Safe water in sufficient quantities is fundamental to human health. The most important water-associated health problem is diarrhea, accounting for 3 to 5 million deaths per year, especially among children. Availability of safe drinking water, combined with sanitary facilities for disposal of feces and improved hygiene standards, could prevent diarrheal disease to a great extent in developing countries. Much emphasis has been placed on reducing biological contamination, but contamination from naturally occurring chemicals in groundwater and from industrial and agricultural waste is also becoming a serious problem in developing countries.

Conventional strategies that treat the drinking-water supply separately from water used for other purposes have limitations. Many emerging water-quality problems—and potential solutions—come from the interactions among uses, especially between domestic use and irrigation.

### *CONTAMINATION OF RURAL WATER SUPPLIES*

Policy documents on integrated management of water resources give highest priority to the drinking-water supply in water-allocation decisions. Rural drinking water may not seem to be a problem because water used for domestic purposes is only a small fraction of a country's total fresh water consumption. In Pakistan, water withdrawn for domestic purposes was estimated at 26 cubic meters per person in 1990, compared to 1,226 cubic meters of water per person for irrigation. The notion prevails that a small diversion from the irrigation sector could fulfill the demands of a growing population for domestic water. However, reallocation of water among sectors can be difficult, and a truly integrated water-management approach is constrained by traditional sectoral thinking and by priorities set by professionals in various disciplines.

Public health officials are mainly concerned with increasing deterioration of water quality due to industrial, agricultural, and urban waste and to insufficient investments in domestic water supply infrastructure. This global concern for water quality reflects the high standards imposed on drinking-water quality by institutions and professionals in the Western world, where the quality of drinking water ranks above all and where the direct use of surface water from irrigation systems for drinking seems unacceptable.

On the other hand, those who manage water for agricultural production believe their main responsibility is to provide water to meet crop-water requirements. Although few irrigation managers see supplying water for domestic use as their mandate, many rural residents draw their domestic water supply, directly or indirectly, from irrigation systems. Without acknowledging this reality, efforts to make irrigation systems more efficient might adversely affect the availability of irrigation water for nonagricultural uses. For example, lining canals with concrete to reduce seepage losses can cause shallow drinking-water wells to dry up.

The main strategy for improving rural drinking water has been to install low-cost hand pumps that draw groundwater uncontaminated by disease-causing microbes. In Bangladesh alone, more than 4 million tubewells have been installed over the past 20 years to provide safe drinking water to 95 percent of the population. This has reduced the incidence of diarrhea. Only recently have the high concentrations of arsenic in many of the tubewells become apparent. What seemed like a public-health success story became one of the biggest environmental health crises of the 20th century—chronic poisoning of more than 20 million people exposed to high arsenic concentrations in their drinking water. A similar crisis is developing in India, where an estimated 66 million people drink groundwater with too high a fluoride content. While arsenic is toxic and carcinogenic, fluoride is an essential element for development and protection of teeth and bones. In excess, however, fluoride leads to serious dental and skeletal deformities and other health problems. Installing filters or other devices at millions of tubewells to remove arsenic and fluoride is an almost impossible task. Therefore, alternative sources of drinking water must be found in affected areas.

In some regions, the availability of shallow groundwater for drinking is an increasing problem because of overexploitation for agricultural and industrial purposes. In some of the major breadbaskets of Asia, such as the Punjab in India and the North China Plain, water tables are falling 2 to 3 meters a year. Wealthier farmers can continue to drill deeper tubewells with larger, more expensive pumps. But poor farmers are not able to do so. All stakeholders see falling groundwater levels as a threat to food security. Groundwater depletion also causes the shallow drinking-water wells of poor communities to run dry, a problem that has received less attention. Deepening these wells is costly and beyond the resources of the poor. Too little is known about how pumping groundwater for irrigation might affect the levels of arsenic and fluoride in drinking water. However, it is clear that overpumping in coastal areas causes saltwater to invade freshwater aquifers, making the water unsuitable for drinking.

The often poor water quality in tubewells and the reduced availability of water in shallow dug wells make it necessary to look at other sources of drinking water. Harvesting rainwater is being explored, but it might not be feasible in very poor arid and semiarid countries. Is reverting to the use of surface water an option when this water is increasingly polluted by human fecal material?

## RECYCLING URBAN WASTEWATER

Poor surface-water quality is due mainly to disposal of untreated wastewater from urban areas in rivers, canals, and lakes. An alternative is to reuse wastewater for agriculture, an ancient practice being revisited because of growing water scarcity. Wastewater can be seen as a resource with high potential for reuse in agriculture, which presents an opportunity for increasing food security in rapidly growing urban areas. Definite environmental and economic benefits accrue from reuse that

- Avoids direct pollution of rivers, canals, and other surface water;
- Conserves water;
- Conserves nutrients, thereby reducing the need for chemical fertilizer;
- Disposes of municipal wastewater in a low-cost, sanitary way; and
- Provides a reliable water supply to farmers.

However, a number of disadvantages cannot be ignored:

- Health risks for the irrigators and communities in prolonged contact with wastewater;
- Health risks for the consumers of produce irrigated with wastewater;
- Contamination of groundwater with nitrates;
- Build-up of heavy metals and other chemical pollutants in the soil;
- Creation of habitats for mosquitoes and other disease vectors; and
- Possible limiting of marketing options (particularly for export) of agricultural produce.

To safeguard the health of irrigators and consumers, the World Health Organization (WHO) has formulated international guidelines on wastewater reuse in agriculture and aquaculture. The guidelines establish the number of fecal coliform bacteria and worm eggs allowed for unrestricted irrigation. Using wastewater for irrigation has the effect of localizing the health risk because the exposed group remains relatively small. Adequate health measures could be targeted at this exposed group. If untreated wastewater is dumped into surface-water sources, much larger populations of downstream water users could be exposed to less certain health risks. This is especially relevant for arid and semiarid countries such as Pakistan and Mexico, where irrigation canals are often the only open water bodies. These irrigation canals receive untreated wastewater from large cities, which is used for washing, bathing, and even drinking.

The solution appears simple: treat the wastewater before use and disposal. Excellent treatment methods exist. But they are prohibitively expensive for most developing countries, which have the most need for this source of irrigation water. The reality today is that two-thirds of the urban wastewater generated in the world receives no treatment at all. The cost of providing wastewater treatment facilities for all cities is astronomical. Even if the resources were available, improved water quality is not guaranteed. Many of the existing wastewater treatment plants are not functioning properly because local authorities often prefer high-technology solutions to more appropriate, lower-cost alternatives.

Most conventional treatment methods remove the nutrients in wastewater, reducing economic benefits to farmers. Restricting the type of crops being cultivated with untreated wastewater to tree or nonfood crops that pass less contamination into the food chain is another option, but difficult to enforce in many developing countries. Crop restriction also reduces economic benefits from the use of wastewater, since the vegetables most susceptible to contamination are also the most profitable.

In the foreseeable future, many towns in developing countries will continue or expand the irrigation of high-value vegetable crops with untreated wastewater. Governments may wish to regulate reuse but are unable to offer practical solutions to the users. It is urgent, therefore, to develop a framework for evaluating different options and trade-offs so that governments and communities can make better-informed decisions.

## CONCLUSIONS

Contamination of groundwater with arsenic and fluoride and increasing pollution of surface water with waste from urban areas are major water-quality problems. Since the same water serves multiple uses and users, solutions should be found within the framework of sustainable water management and in optimal recycling of water. This requires that policymakers, governments, donors, international organizations, and the research community appreciate the close links between water used for food production and water used for drinking. The growing worldwide scarcity of good-quality fresh water makes it essential to bridge the gap between the different sectors involved in water-resource management. ■

**For further information see Van der Hoek, W., F. Konradsen, and W.A. Jehangir. "Domestic Use of Irrigation Water: Health Hazard or Opportunity?" *International Journal of Water Resources Development,* 15 (1999): 107–119.; Blumenthal, U. J., D. D. Mara, A. Peasy, G. Ruiz-Palacios, and R. Stott. "Guidelines for the Microbiological Quality of Treated Wastewater Used in Agriculture: Recommendations for Revising WHO Guidelines." *Bulletin of the World Health Organization,* 78 (2000): 1104–1116.; Shuval, H. I., A. Adin, B. Fattal, E. Rawitz, and P. Yekutiel. "Wastewater Irrigation in Developing Countries: Health Effects and Technical Solutions." World Bank Technical Paper No. 51. Washington, D.C.: The World Bank, 1986.**

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A 2020 Vision for Food, Agriculture, and the Environment
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# OVERCOMING WATER SCARCITY AND QUALITY CONSTRAINTS

## WATER AND RURAL LIVELIHOODS

LINDEN VINCENT

FOCUS 9 • BRIEF 5 OF 14 • OCTOBER 2001

Livelihoods are the means people use to support themselves, to survive, and to prosper. Livelihoods are an outcome of how and why people organize to transform the environment to meet their needs through technology, labor, power, knowledge, and social relations. Livelihoods are also shaped by the broader economic and political systems within which they operate.

Water is the essential element in rural livelihoods because of the food security and income options it generates in rainfed and irrigated crop production, industry, domestic processing, aquaculture, livestock, recreation, navigation and transport, and electricity supply. Safe water and sanitation also shape health through potable water supply, safe food preparation, hygiene, better nutrition, and relaxation. Environmental security depends on peoples' actions to control salinity, drainage, and water pollution; manage droughts and floods; and manage land and water to guard those resources.

Unless there is new action to recognize both the roles water plays in rural livelihoods and people's capacity to manage their water sustainably and with social justice, water scarcity threatens to change people's options in production, employment, and exchange, and the relations among these activities, in ways that will exclude the small producer. For example, in Zimbabwe, new smallholder irrigation systems are being developed and old ones are receiving new support that can improve water supply and livelihoods for more people. However, irrigators must also now renegotiate water rights in the face of growing competition for water and new water legislation to promote more integrated water resources management. While there is still scope for improving livelihoods in irrigation and aquaculture, emerging competition for water will drive water users to defend and negotiate their water rights when their livelihoods are threatened. Water scarcity increases the need for pro-poor development support.

### IMPROVING LIVELIHOODS WITH PRO-POOR WATER PROGRAMS

Improved access to water is a powerful tool to diversify livelihoods and reduce vulnerability for small producers (see Box). Low prices, fluctuating markets, adverse tenancy, and insufficient labor can all explain why small farmers must engage in diverse livelihood strategies; they cannot survive from agricultural activities alone, even with better water husbandry. As water users, small farmers value their water access for its contribution to income, household needs, and the social networks and entrepreneurship it supports. Many argue that new opportunities still exist to help small farmers gain better livelihoods despite water scarcity and to build a more vibrant local economy around them. Indeed, it is essential to prioritize small farmers' water access in the interests of reducing poverty, vulnerability, and social injustice.

### HOW ACCESS TO WATER TRANSFORMS RURAL LIVELIHOODS

- **Production options in farmlands and home gardens for food, cash crops, and livestock extend across the year; yields and output improve for home consumption and sale.**
- **Employment for families, with and without land, increases; more local people are employed in operation of water systems and in agroprocessing; and livelihood options in fishing, tourism, and recreation emerge.**
- **Health improves through access to safe domestic water supply and sanitation.**
- **Opportunities to exchange gifts of food and seed and to build social networks increase.**
- **Participation in water committees widens social networks and empowers people.**
- **Farmers spend additional income locally, improving markets for goods and services.**
- **When women control outputs, they spend more on family welfare.**

Pro-poor programs work to build water assets, to widen different users' access to them, and to reduce the vulnerability of low-income cultivators and workers through water-related activities. These initiatives help, in particular, to reduce gender imbalances in access to and benefits from water use. They recognize the important roles women play in production and food security, and the competent roles they can play in water management. Pro-poor water and asset-based livelihood promotion has the following goals:

- ***Raise local value-per-drop of water.*** New technologies and production systems can promote the manufacture of high-value products locally. Programs can maximize employment through developing a range of productive enterprises and involving local people in construction and operation of systems. Planners can use water systems as "growth points" where services, markets, and employment are also stimulated. New methods are under development for assessing the value of water to small producers, including "water and well-being" indicators.
- ***Create and manage community-based water assets*** through small water points, water harvesting, or better soil and water management. Initiatives can also build disaster

preparedness, use short-term relief measures that build water assets, and work to break the link between ill health and poor water management.

- ***Allocate water in a way that creates roles for and empowers excluded groups,*** with a special focus on opportunities for women. Techniques to assess water use and value at the system and basin levels can aid decision-making about remaining water development options.
- ***Improve services*** through more accountability to water users in public and private water services, and through recognizing unregistered and excluded users, especially when they are poor.

These initiatives can work well in localized programs focused on specific water systems and watersheds. However, some water scarcity conditions and production transformations threaten to provoke struggle on a larger scale and require action of a different kind.

## NEGOTIATING AND DEFENDING LIVELIHOODS

When people build their livelihoods around water, they create relationships of cooperation and control in order to acquire and manage water systems, link with government and the private sector, broaden opportunities, and strengthen their negotiating power. How livelihoods survive under scarcity is related to how people understand water scarcity, organize social action to remedy it, and act to defend their rights.

"Livelihood thinking," which developed in the 1980s as an alternative to "production thinking," challenged beliefs about the neutrality of technology and the absolute ability of experts to promote optimal production systems. It also required a new professionalism to make resource management and technology serve small farmers. Livelihood thinking involves understanding water environments and technologies; understanding and working with the political processes through which local groups can question water assessment and allocation mechanisms, including "expert" solutions; and working directly with small farmers.

This shift in orientation can foster local water-control initiatives that support users in negotiating their rights to water and livelihoods—within both water-basin and local water systems. Livelihood thinking builds key design skills, communication and management capacities, and principles for collaboration on new actions that promote:

- ***Diversity in ecology, livelihood strategies, and water institutions.*** This includes participatory design and agro-ecological planning that builds on the knowledge and management capacities of users; strategic targeting of niche markets and production; and working with alternative production and construction systems to help maximize biomass productivity, equity, local employment, and use of local materials.
- ***Fair and sustainable water delivery.*** To resolve water scarcity issues, livelihood thinking seeks to understand the opportunities and needs created by different water technologies and institutions, and the interactions between them, given available water supply.
- ***Water-management reform negotiations.*** Empowering local groups and evolving user-sensitive water assessment tools can help build new multi-stakeholder platforms and institutions between local and catchment levels.

Creative thinking coupled with effective negotiation have already brought about new livelihoods for people in peri-urban settlements, in irrigation systems with temporal scarcities, in watersheds with new water harvesting options, and in systems and basins where water trading takes place. The combination has also yielded new rights for those previously excluded from formal recognition and has helped people explore local options before pursuing major changes in allocations between sectors or users.

## KEEPING RURAL LIVELIHOODS ALIVE

People are working in many ways at the local level to get access to water without giving up or giving in to the external water-crisis rhetoric. Thinking about livelihoods from the perspective of water can guide system redesign and allocations that retain local options, generate higher local value, and empower local management. However, understanding the processes that enable small water users to build and defend more secure livelihoods from water is also vital for new negotiation over water use. The water management principles that will help water users to negotiate their livelihoods under water scarcity are:

- Institutional viability that sustains water organizations, system operations, and water use practices;
- Equity that reflects access and social justice for water users;
- Political democracy that represents many different stakeholder groups;
- Economic viability that creates financially sound and economically viable livelihoods;
- Productivity, effectiveness, and efficiency based on locally valid criteria that ensure the integrity of hydraulic infrastructure and the value of land and water;
- Secure water access that includes the possibility of negotiating water-use rights and managing risks from system or production failure;
- Ecological equilibrium that builds sustainable water use and fights degradation.

Designers, planners, and managers can support rural livelihoods when dealing with water scarcity by appreciating the many roles of water in rural livelihoods and giving rural users scope to negotiate and defend their livelihoods. ■

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# Overcoming Water Scarcity and Quality Constraints

## Water and the Environment

Elroy Bos and Ger Bergkamp

Focus 9 • Brief 6 of 14 • October 2001

Water and ecosystems are inextricably linked. The ecosystems of our planet, and the plants and animals that live within them, need water for their survival. For instance, the Okavango Delta in Botswana, the largest Ramsar site (wetland) in the world at 35,000 square kilometers, directly provides a livelihood to 150,000 people and harbors a unique biodiversity with 2,500 plant species, 65 fish species, 20 large herbivores, and over 450 bird species.

Ecosystems, in turn, regulate the quantity and quality of water. Wetlands retain water in periods of high rainfall, slowly release it during dryer periods, and purify it of heavy metals and other contaminants. Forests recharge our groundwater, which can be used elsewhere for drinking or irrigation. The functions (goods and services) that natural and semi-natural ecosystems provide to humankind are often neglected in economic planning and decisionmaking. They include:

- ***Regulatory functions*** for essential ecological processes and life support systems, including air quality, climate, water supply, soils, waste treatment, and biological control of pests and pollination;
- ***Habitat functions*** for wild plants and animals (and native people) to maintain biological and genetic diversity, including refuges and nurseries for resident and migratory species;
- ***Production functions*** for food, fiber, shelter, fuel, fodder, fertilizer, medicines, genetic resources, and ornamental resources; and
- ***Information, aesthetic, and spiritual functions*** such as opportunities for reflection, relaxation, communion with nature, and cognitive development through aesthetically valued scenery, recreation and tourism, cultural and artistic inspiration, connection to history and heritage, and scientific education.

Not only do natural ecosystems help to prevent floods or provide shelter, millions of people also directly derive their food, water, and fuel from these areas. In the Hadejia Nguru Wetlands of Nigeria, the traditional use of the floodplain yields US$12 per cubic meter of water, compared to US$0.04 per cubic meter for a proposed irrigation scheme. Globally, natural ecosystems provide an estimated US$32 trillion to societies.

### THE DECLINE OF NATURE AND WATER

People are overusing water and natural resources. Half of the world's wetlands have already been lost due to overabstraction of water and conversion into agricultural land. With the loss of their ecosystems, more than 3,500 species are threatened worldwide, of which 25 percent are fish and amphibians. In 1999, 20 million hectares of forest were lost. Overuse and misuse of water harm the human population as well. When too much water is abstracted from rivers, one effect can be that seawater comes inland and makes arable land infertile. It can also damage coastal mangroves, which are vital spawning areas for shrimp and fish.

Human water management affects ecosystems, which in turn affect the livelihoods of the people that depend on them. Hydrological, ecological, and social processes are closely connected. People are an inalienable part of the ecosystem. Therefore, we must look at the big picture: the management of fresh water within an ecosystem.

### THE ECOSYSTEM APPROACH

An ecosystem approach looks beyond specific sectors, such as food production, hydropower, nature conservation, or sanitation, to find integrated solutions for the variety of demands we place on our freshwater resources. It establishes a management regime that mimics natural processes and productivity and considers all goods and services to be on equal footing with water delivery. It strives to maintain biodiversity and to conserve land and water resources and includes environmental monetary values in determining the cost-effectiveness of interventions and the sustainable allocation of resources.

Because users within a basin are interdependent, an integrated water management approach is essential. Upstream uses of water have an impact on downstream users, the management of the land affects the water resources, and vice versa. The ecosystem approach is holistic, taking all these aspects into account. Even though the ecosystem approach appears to emphasize hydrological and ecosystem processes, the real focus is on human processes. The different human uses and behaviors in a basin are interlinked; the actions of one can have an impact on another.

Large dams are a good example. In 1979, a dam was constructed in Waza-Logone (northern Cameroon) to supply water to a 70-square-kilometer irrigated rice scheme. But the resulting lack of water downstream of the dam changed the biodiversity of a 50,000 square kilometer area. Fish disappeared and grasses for livestock no longer grew. Downstream, people eventually moved out of the area because they could not feed their livestock. The benefits of the dam went to the owners of the irrigated lands. The communities downstream bore the costs.

For the proper management of a basin, all people that change the quality or quantity of water (the stakeholders) have to be involved and have a say in water management. Fighting over the resource will not work. It is better to establish the different needs of all parties involved and find the optimum solution for everyone. Local communities, governments, technical institutions, private companies, and nongovernmental organizations have to work together on problem definition, planning, and management of the natural resource base. Such cooperation also allows for setting objectives at the local and basin levels for conservation, sustainable management, and poverty alleviation.

**ECOSYSTEMS FOR WATER**

The protection of ecosystems should be a premise of water management deliberations, as ecosystems are the source of water and life. Some ecosystems, such as cloud forests, springs, and certain wetlands, provide clean water directly. Other ecosystems produce goods upon which communities rely. For ecosystems to continue producing their goods and services, a minimum amount of water must be left for the ecosystems to function. Using all the water there is destroys ecosystems and the communities that depend on them.

With regard to dams, there have been many debates on the negative impacts on downstream communities and biodiversity and the minimum flood releases required to mitigate or prevent such impacts. The recommendations of the World Commission on Dams need to be complemented by specific tools for optimizing dam design and management. More work needs to be done on the trade-offs between retaining water behind the dam for "reservoir-based livelihoods" (irrigation, hydropower) and releasing it downstream for "flood-based livelihoods." Based on this work, recommendations can be made for using multi-criteria analytical methods to make decisions on flood releases.

The consequence of the ecosystem approach would inevitably be to reduce the amount of water abstracted from ecosystems. The demand for water will have to decrease from irrigated agriculture, which is 70 percent of all the water used in the developing world, but also from industry and households (especially in the developed world). This requires both behavioral changes and technical improvements to increase water efficiency (drip agriculture, crops that require less water).

The same line of thought could lead to the restoration of ecosystems that have been degraded. As in the Hadejia Nguru Wetlands, traditional multipurpose use can be more beneficial than single-use, irrigated agriculture. Unfortunately, much of the economic value an ecosystem provides has been ignored in the past. At times, it can even be economically efficient to restore an ecosystem to deliver certain functions, especially if clean water becomes a scarce resource.

Increasingly, we see that certain parties in basins are paying for specific services. A water company may pay farmers for not using certain insecticides that pollute the water, or a city may pay mountain communities for protecting the forest that is vital for its water supply. Attention to the financial aspects of water management needs to increase and should start with a proper valuation of the services ecosystems provide. At the moment, much of their value is taken for granted or underestimated. Their proper assessment would certainly lead to other choices for management. Political systems also need to make the participation of stakeholders in basin negotiations possible, and effective laws are required to regulate the processes involved.

**THE PATH AHEAD**

Water is a scarce resource. If we continue to overuse and pollute our water and destroy our natural ecosystems, we may fulfill the prediction that 30 percent of the world's population will not have enough water by 2025.

The coming decade will be important for the management of water. The question is how we will use the available water to provide food, safe environments, health, and livelihoods to a growing world population, in harmony with nature. We need to grow more food with less water, meet the growing needs in cities and industry, and so on. It is a question of daunting complexity, but one that has to be answered in the coming years.

The ecosystem approach to water management may provide answers to the social, economic, and ecological problems we face. Water security is based on protection of the ecosystems on which resources depend. Recognizing the vital role of healthy ecosystems in the water cycle and protecting them should form the basis of any water management decision. ■

**For further information see IUCN. *Vision for Water and Nature: A World Strategy for Conservation and Sustainable Management of Water Resources in the 21st Century.* Gland, Switzerland and Cambridge, U.K: IUCN, 2000.; Pirot, J.-Y, P.-J. Meynell, and D. Elder. *Ecosystem Management: Lessons from Around the World.* Gland, Switzerland: IUCN, 2000.; World Commission on Dams, *Dams and Development, A New Framework for Decisionmaking,* London: Earthscan, 2000.**

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A 2020 Vision for Food, Agriculture, and the Environment
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# Overcoming Water Scarcity and Quality Constraints

## Dams and Water Storage

Jeremy Bird and Pamela Wallace

Focus 9 • Brief 7 of 14 • October 2001

Dams are at the center of many controversies related to the management of water resources and proposals to relieve water scarcity. Two strategic contributions to the Second World Water Forum held in The Hague in March 2000 provide insight. Van Hofwegen and Svendsen estimate that water supplies used in agriculture will have to be augmented by an additional 15 to 20 percent during the next 25 years—or a higher percentage if the assumptions regarding significant improvements in irrigation and agricultural productivity are not realized. In contrast, the IUCN (World Conservation Union) warns that over-abstraction will lead to depletion of groundwater, reduction in biodiversity, and loss of livelihoods that are dependent on a healthy ecosystem. It calls for a different approach to new infrastructure development that recognizes the value of ecosystems and re-examines the operation of existing projects. There has been a recent trend of declining dam construction. Financing for dam projects from multilateral and bilateral sources dropped from an estimated US$4.4 billion per year in the early 1980s to US$2.6 billion per year in the late 1990s.

### SEARCHING FOR A SOLUTION

Such contrasting positions, coupled with significant social consequences, underlie the intense debate on dams that ultimately led to the establishment of the World Commission on Dams (WCD) in May 1998. This was born out of a multi-stakeholder workshop organized by the World Bank and IUCN.

There are more than 45,000 large dams around the world, which, overall, have played a role in helping communities and economies manage water resources for food production, energy generation, flood alleviation, and domestic and industrial use. Current estimates suggest that some 30 to 40 percent of irrigated land worldwide now relies on dams and large dams are estimated to support 12 to 16 percent of global food production. Hydropower projects generate 19 percent of world electricity and account for over 50 percent of electricity generated in 63 countries. These are considerable contributions.

However, the projects in the Commission's knowledge base showed a high degree of variability in meeting predicted water and electricity services and related social benefits. A considerable portion fell short of projected physical and economic targets, while many continued to generate benefits beyond their projected economic life. Extensive impacts on ecosystems were evident including the loss of habitats, species, and aquatic biodiversity. In many cases, the measures explicitly designed to mitigate such impacts proved ineffective.

Those who bear the social and environmental costs and risks of large dams—especially the poor, the vulnerable, and future generations—are often those that receive neither the water and electricity services nor the social and economic benefits from them. An estimated 40 to 80 million people have been displaced by dam projects. Although some compensation was invariably provided, the Commission found that the full range of social impacts was frequently neither accounted for nor addressed. In particular, the impacts on the lives, livelihoods, and health of the affected communities upstream and downstream of the projects were not considered, and distribution of benefits was extremely inequitable. This gave rise to growing opposition to dams by affected communities worldwide. While dams have delivered many benefits, in too many cases the price paid to secure those benefits has been too high and could have been avoided. Applying a "balance-sheet" approach to assess the costs and benefits of large dams is seen as unacceptable, given existing commitments to human rights and sustainable development.

In proposing a way forward beyond the prevailing conflicts, the Commission provides a new framework for decisionmaking based on recognizing the rights of and assessing the risks to all stakeholders. Clarifying the rights context for a proposed project is an essential step in identifying those with legitimate claims and entitlements. The notion of risks is an important dimension to understanding how, and to what extent, a project may have an impact on such rights. The rights-and-risks approach introduces a departure from a balance-sheet approach, where the loss to those adversely affected has been traded off against the gain to the intended beneficiaries. It encompasses the concepts that those adversely affected should participate in the planning process and have a share in project benefits.

Seven strategic priorities and corresponding policy principles for water and energy resource development are proposed that build on the rights-and-risks approach. They can be summarized as follows:

1. ***Gaining public acceptance*** by recognizing rights, addressing risks, and safeguarding the entitlements of all affected people, particularly indigenous and tribal peoples, women, and other vulnerable groups. Decisionmaking processes should enable informed participation by all groups.
2. ***Undertaking comprehensive options assessment*** based on clearly defined needs for water, food, and energy, and giving social and environmental aspects the same significance as economic and financial factors.
3. ***Addressing existing dams to optimize benefits*** by changing water use priorities, physical and land use in the river basin, and by developing technological changes in environmental, safety, economic, and technical regulations. Outstanding social issues and environmental mitigation and restoration measures should be addressed.

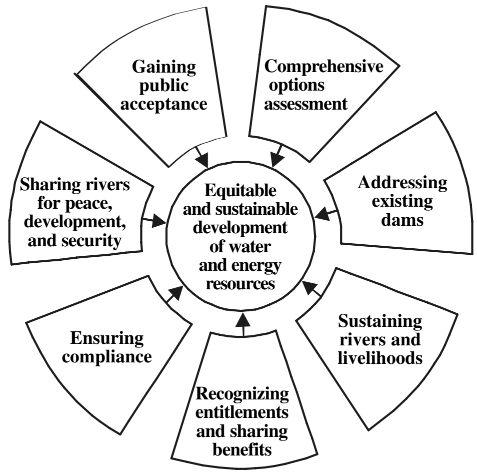
4. ***Sustaining rivers and livelihoods*** through understanding, protecting, and restoring ecosystems at river-basin level, avoiding negative impacts, prioritizing good site selection and project design, and releasing tailor-made environmental flows to help maintain downstream ecosystems and the communities that depend on them.
5. ***Recognizing entitlements and sharing benefits*** through joint negotiations with adversely affected people that result in mutually agreed-upon and legally enforceable resettlement, mitigation, and development provisions that improve livelihoods and quality of life.
6. ***Ensuring compliance*** with commitments made by governments, developers, regulators, and operators in the planning, implementation, and operation of dams. Regulatory and compliance frameworks use incentives and sanctions to ensure effectiveness where flexibility is needed to accommodate changing circumstances.
7. ***Sharing rivers for peace, development and security,*** especially with regard to transboundary rivers, so that the use and management of resources increasingly becomes the subject of agreement between states to promote mutual self-interest for regional cooperation and peaceful collaboration. The focus shifts to sharing benefits. External financing agencies support the principles of good faith negotiations between riparian states.

The Commission offers practical advice for implementing these priorities: a set of criteria for five key decision points in the planning and project cycles along with 26 advisory guidelines based on examples of good practice from around the world. Some examples of the advisory guidelines include: using multi-criteria analysis in options assessment to raise the significance of social and environmental concerns; conducting a distribution analysis to determine how costs and benefits of any option are shared; and developing mechanisms that provide incentives to promote greater compliance with commitments. In the long run, the Commission's report offers the opportunity to reduce conflict, delays, and overall costs to the dam operator, the government, and to society in general.

## WHERE DO WE GO FROM HERE?

When all 12 Commissioners from such varying backgrounds signed the WCD report, they sent a clear signal that it was possible for the international community to move beyond the conflict of the dams debate. With the launch of the report, the Commission completed its mandate and disbanded. The Commission recognized that its report was not the final word. Rather, it was the start of a process. Governments, financiers, affected-peoples' groups, NGOs, professional organizations, and the private sector reviewed the recommendations and have begun to take the process forward in a series of local multi-stakeholder initiatives. Given the contested nature of the debate, the wide range of reactions—from support to criticism—is not surprising. While a consensus has not been reached on all aspects of the WCD report, there is general agreement on the Commission's core values and strategic priorities. The challenge now lies in implementing them.

**The WCD's Seven Strategic Priorities**




**Source: World Commission on Dams, 2000.**

A Dams and Development Unit, hosted by the United Nations Environment Programme (UNEP), was established to continue the Commission's dissemination activities, promote dialogue, provide networking opportunities for those interested in learning from others' experiences and, where requested, to assist countries to work with the recommendations of the report.

The upcoming World Summit on Sustainable Development (Rio +10) in Johannesburg, South Africa in 2002 will involve much discussion on sustainable water management, integrating land and water management, and promoting participatory approaches. The policies of many international organizations are being adapted to accommodate these concerns and to make them operational. There remains a significant gap between policy and practice. The dams debate embodies the tensions between providing water for increasing needs, alleviating poverty, and protecting the environment. The WCD report can help bridge the gap between policy and practice provided it is used in a responsible way. The challenge of constructive engagement, modeled on the Commission's own process, should be embraced by all involved. ■

**For further information see IUCN. *Vision for Water and Nature: A World Strategy for Conservation and Sustainable Management of Water Resources in the 21st Century.* Gland, Switzerland and Cambridge, U.K: IUCN, 2000.; Van Hofwegen, P. and M. Svendsen. *A Vision for Food and Rural Development.* Delft: Institute for Hydraulic Studies (IHE), 2000.; World Commission on Dams. *Dams and Development: A New Framework for Decision-Making.* London: Earthscan, 2000.**

*This brief is based on excerpts from the World Commission on* Dams report, Dams and Development: A New Framework for Decision-Making. *However, responsibility for the brief rests with the authors alone.*

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# Overcoming Water Scarcity and Quality Constraints

## Groundwater: Potential and Constraints

Marcus Moench

Focus 9 • Brief 8 of 14 • October 2001

Groundwater problems emerging in many parts of the world reduce drought-buffer supplies, threaten environmental values, and increase risks for many of the world's poorest people. Programs to improve public understanding and basic scientific information regarding the resource base and to encourage the evolution of groundwater management systems are essential. Furthermore, because many countries will need years to develop systems for managing groundwater, policies should encourage users to adapt to water scarcity conditions rather than attempt to solve water problems per se.

### NATURE AND SCOPE OF GROUNDWATER PROBLEMS

The Green Revolution, which led to dramatic increases in food production, especially in Asia, has also been called the "tube-well revolution" because part of what drove it was groundwater development on an unprecedented scale. The number of mechanized wells in India grew from a few thousand at the time of independence in 1947 to tens of millions today. As a buffer against drought and precipitation variability, groundwater plays a critical role in food and livelihood security. Increased access to groundwater has reduced risks substantially, enabling many farmers to move out of poverty. All such benefits, however, may have come at a high cost.

In recent summers, flows from the world's second-largest spring, the headwaters of the Al Khabour River in Syria, have declined from a long-term average of 50 cubic meters per second to only a few cubic meters per second. Similar stories are emerging in many regions. Groundwater-level declines of 1–3 meters per year are commonly reported for monitored wells in arid and semi-arid regions. In extreme situations, such as Sana'a in Yemen, shallow aquifers are almost depleted. Efforts to tap new groundwater supplies in Sana'a have been unsuccessful despite the drilling of wells that exceed two kilometers in depth. In the Middle East and North Africa, it is no longer uncommon to encounter wells drilled to depths that have historically only been seen in the oil industry. Even in humid regions such as Bangladesh, water-level fluctuations may be increasing, and water is scarce during the dry season. Furthermore, scarcity and quality concerns are linked. Groundwater pumping often mobilizes water that is saline or contains natural contaminants such as arsenic or fluoride. When combined with increasing pollutant loads from agriculture, industry, and municipal sewage, this pumping can irreversibly contaminate aquifers.

The threats to groundwater resources are clear, but their extent is far less so. Worldwide, most groundwater monitoring networks are relatively new and collect a limited array of data on water levels and basic water quality parameters. Detailed data on water quality and pollutants are rarely available except in relation to specific local concerns. Data are also often unavailable on critical components of the water balance—such as groundwater extraction, evapotranspiration from native vegetation, and deep inflows to aquifers. Furthermore, data on water-level changes can be misleading. Aquifers can take tens to hundreds of years to equilibrate when disturbed. As a result, short-term water-level declines do not necessarily indicate overdraft.

Nonetheless, water-level changes and fluctuations are the most important factors influencing access to groundwater for the environment and for human uses. For small farmers along the Ganges, the deep saturated basin beneath their fields is irrelevant. What they care about is whether or not water is available within the tens-of-meters range from which they can afford to pump. When levels decline below or fluctuate outside that range, farmers lose access to irrigation and households may lose access to drinking water. Fluctuations are equally important from an environmental perspective. Stream flows and wetlands often depend on high groundwater levels. Even modest seasonal declines can affect surface water bodies severely. Water quality is also affected when changing levels mobilize low-quality water or cause waterlogging and associated salinization problems. From the perspective of current usage, this dynamic—the interaction between groundwater levels, underground flow patterns, surface water bodies, and the economics of groundwater access—is far more important than the overall balance between extraction and recharge within an aquifer. Moreover, this dynamic is highly variable, heavily dependent on local conditions, and often missed in the data sets collected by groundwater departments.

### OPTIONS FOR MANAGING GROUNDWATER

The lack of information and understanding regarding groundwater dynamics presents a major challenge for those developing effective management systems. The challenge is as much social as technical. Without both data and a shared understanding of the problems, the social consensus needed to implement decisions is difficult to generate—and groundwater management decisions are often difficult.

Standard approaches to reducing groundwater overdraft, for example, often require metering of all wells, establishment of formal water rights, and regulatory and economic mechanisms to bring extraction down to sustainable levels. While progress toward this goal has been made in a few water-scarce countries such as Jordan and Israel, the situation is more complex in locations (such as India) with tens of millions of wells and conditions that vary greatly even at local levels. Even where management is most advanced, it is socially and politically difficult to reduce groundwater extraction to sustainable levels. Wells are generally private and highly dispersed. Inventorying them and monitoring extraction are problematic. Furthermore, reducing use to sustainable levels in arid regions often requires substantial reductions in extraction, which can have tremendous economic and social impact. As a result, governments are not inclined to force reductions.

Groundwater experts often propose community management of groundwater as an alternative to state regulation. Although global experience in this area is limited, experience with resources other than water indicates that several factors are critical to the success of community management—for example, clear boundaries on the resource and its user group, the ability to control free riders, and information on the use and condition of the resource. Such factors are difficult to establish in the case of groundwater.

Successful groundwater management has been achieved through intermediate-level institutions such as the quasi-governmental groundwater districts in the western United States and somewhat similar organizations in parts of France. Organizations of this type hold much promise. Their development, however, often takes decades, and to be effective they require data, technical capacity, and some degree of supporting social consensus.

Markets are also central to any framework for groundwater management. Water markets in the western United States are based on water rights systems that attempt to quantify the volume sustainably available in aquifers and allocate it among users. Transactions involve contracts and often the formal transfer of the water right as well as the water itself. In developing countries formal water rights are rarely involved. Instead, informal transactions occur between well owners and adjacent farmers for irrigation or tanker companies that deliver the water to urban customers. Prices for irrigation are low compared with tanker deliveries. In 1986 in Yemen, for example, the cost of extraction near Ta'iz was approximately US$0.005 per cubic meter. Rural irrigators paid US$0.02–0.05 per cubic meter; urban bulk users paid an average of US$2.60 per cubic meter for tanker supplies; and smaller customers paid as much as US$25.00 per cubic meter for purified groundwater. That pattern is typical: the urban poor generally pay the highest prices.

Two points merit attention. First, because formal rights are not involved, prices reflect short-term pumping capacity, not the longer-term sustainability of extraction rates. Second, even with rights systems, markets indicate the value individual users gain from extracting groundwater but not the economic, environmental, and sustainable use values that accrue when groundwater is left in place.

Aside from groundwater market prices, energy is the primary variable cost affecting groundwater extraction. In countries such as India, energy subsidies were used to encourage groundwater development during the Green Revolution. Now, despite water-level declines and huge effects on state budgets, those subsidies have proved politically difficult to eliminate. As a result, agriculture now officially consumes more than 50 percent of total power production in some Indian states. Appropriately structured energy prices can provide users with a major incentive to use groundwater more efficiently. Still, given the high yields associated with groundwater and the numerous factors affecting the economics of agriculture, energy prices alone cannot be expected to reduce groundwater extraction to sustainable levels.

## ACTION IN THE SHORT AND LONG TERM

How can emerging threats to the groundwater resource base be addressed? Most groundwater experts advocate the development of comprehensive integrated management systems. While important, such efforts require long-term data on aquifer conditions along with well-established institutional capacities that are unavailable in many regions. Therefore, integrated management initiatives rarely generate results over the short term. Alternative approaches—in particular those that encourage populations to adapt to conditions of water scarcity and to reduce pressure on the resource base—are essential. Existing coping strategies—such as the migration of populations out of agriculture and into urban areas along with the development of nonagricultural economic systems—represent a starting point for reducing pressure on areas where overdraft levels are high. Although they do not ensure sustainability of the resource base, such strategies can provide essential breathing space for the longer-term development of management institutions. ■

**For further information see Burke, J. and M. Moench. *Groundwater and Society: Resources, Tensions, and Opportunities.* New York: UN Department for Social and Economic Affairs and Institute for Social and Environmental Transition, 2000.; Foster, S., J. Chilton, M. Moench, F. Cardy, and M. Schifler. *Groundwater in Rural Development: Facing the Challenges of Supply and Resource Sustainability.* World Bank Technical Paper No. 463. Washington, D.C.: World Bank, 1999.; Foster, S., A. Lawrence, and B. Morris. *Groundwater in Urban Development: Assessing Management Needs and Formulating Policy Strategies.* World Bank Technical Paper No. 390. Washington, D.C.: World Bank, 1998.**

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A 2020 Vision for Food, Agriculture, and the Environment

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# Overcoming Water Scarcity and Quality Constraints

## Water Harvesting and Watershed Management

John Kerr and Ganesh Pangare

Focus 9 • Brief 9 of 14 • October 2001

The world's freshwater shortages result more from uneven distribution of water over time and space than from absolute scarcity. Even in some of the world's highest-rainfall areas, rain falls in concentrated periods followed by prolonged dry spells, so users must capture rainwater when it is abundant to use later when it is scarce. Similarly, even in some of the driest areas, occasional intense rainfall generates runoff that can be captured and stored for subsequent use. For example, harvesting only 100 millimeters of rainfall over a one-hectare plot would yield 1 million liters of water. Ancient water-harvesting systems throughout the world took advantage of this principle to smooth intertemporal variations in water availability, making human settlement possible in a wide variety of ecosystems.

Local water harvesting declined with the development of large systems in which water is transported hundreds of miles through canals and pipes or pumped from great depths below the ground. However, growing scarcity and intersectoral competition for water, along with groundwater depletion and the problems facing major surface-water control systems, have raised interest in revitalizing water-harvesting systems that capture rainwater wherever it falls.

### DEFINITION AND TYPES OF WATER-HARVESTING SYSTEMS

Water harvesting refers to the small-scale concentration, collection, storage, and use of rainwater runoff for both domestic and agricultural use. This definition implies that the catchment area from which the water is drawn is larger than the command area, where it is collected and used. The ratio of catchment to command is inversely related to the amount and intensity of rainfall, the impermeability of soil, and the slope of the land on which it falls. Rainfall intensity is particularly important, since intense storms generate the most runoff.

A watershed is an area that drains to a common point. It may be managed for various objectives, depending on local needs, including capturing runoff, minimizing erosion, and reducing nonpoint source pollution. In management of small watersheds, capturing runoff for local use is conceptually equivalent to harvesting water. This brief encompasses all small-scale, local systems for capturing runoff from rainfall.

Water-harvesting systems either concentrate water into a storage reservoir or apply water directly to the soil in the cropped area. Both types of systems can vary in scale from a few square meters benefiting a single household to a few square kilometers serving a larger group of people.

### RESERVOIR SYSTEMS

Systems that concentrate water into storage reservoirs can be used for a variety of purposes, including household, irrigation, or livestock consumption. Rooftop water-catchment systems provide domestic water in many places, especially dry areas with inadequate municipal supplies. A rooftop that is 50 square meters can supply an annual average of 50 liters per day with 500 millimeters annual rainfall. This supply can help reduce competition between agricultural and household demands and can free women from the chore of collecting water.

Harvesting water to collect it in village ponds is an ancient system in some places, including southern India. The principle behind this approach is to concentrate water spatially and temporally. In arid and semi-arid areas where rainfall is low and variable, harvesting rainwater allows users to conserve it until enough water is collected to reliably support a crop. The volume of water stored at the end of the rainy season determines how much area can be cultivated.

Traditional water-harvesting systems store water in ponds and reservoirs and deliver it by gravity. With the spread of motorized pumps in recent decades, water can now be captured in some places using the same techniques but allowing collected water to percolate into groundwater aquifers. The systems are small in scale, drawing from gullies and microcatchments to recharge groundwater that supplies a number of local wells.

### SOIL-MOISTURE STORAGE SYSTEMS

In many traditional water-harvesting systems, runoff water is channeled directly to the cropped area during rainfall and stored in the soil. Where rainfall is unevenly distributed and soils have high water-holding capacity, this system may store water until the end of the rainy season, when a crop is grown under gradually receding moisture. Where soils are sandier and do not retain moisture for a long time, moisture may be channeled spatially to the location where crops or trees can take advantage of it. Farmers in West Africa commonly use such systems, cultivating their dryland crops behind a variety of small earthen barriers designed to capture moisture. These systems can remain productive several months into the dry season when the surrounding land is barren.

Water-harvesting systems vary a great deal in the ratio of catchment to cultivated area. In dry areas with less available water, this ratio can easily reach 20:1. In such water-harvesting systems, cultivation systems must be extensive and located in sparsely populated areas so that command and catchment areas do not interfere with each other. Where rainfall is higher, the ratio declines—sometimes to the point that the entire catchment area lies within a single plot.

## ADOPTION AND REPLICABILITY

Constraints to developing improved water-harvesting systems and adapting existing ones for productive use relate to technical feasibility, financial viability, and social organization.

### *Technical Feasibility*

The key technical question for agricultural water-harvesting systems is whether capturing and storing enough water to raise crop yields is feasible. Much research has gone into measuring the water available to plants under different rainfall, soil, and slope conditions and into developing ways to increase runoff, reduce erosion, or improve storage. In field conditions, technical feasibility depends in large part on local agroclimatic conditions. For example, in India the Indo-German Watershed Development Project works only in villages where the terrain is conducive to water harvesting—that is, there is a sloped, uncultivated catchment area and a good opportunity to build storage ponds.

### *Financial Viability*

Even where water harvesting is technically feasible, it may not be cost-effective. A review of African water-harvesting systems found that many of them cost much more than US$1,000 per hectare to install, making adoption prohibitively expensive.

A typical problem in storing water is the need to line catchment or storage areas so that water can be stored until dry periods when it is actually needed. However, using a plastic or concrete lining can raise costs beyond the financial returns. An example of where lining is most likely to be cost-effective is in mountain regions where water enables farmers to grow counterseasonal crops that can be sold in the plains at high prices.

The main constraints to rooftop collection systems are the need for a tile or sheet metal roof that can capture runoff and a storage tank, both of which can be prohibitively expensive in very poor areas. In that case, village-level systems housed on public buildings may be more viable, along with smaller-scale household systems. The key issue with storage tanks is how to make them large enough to store plenty of water while also keeping costs down.

Given growing water scarcity and the high financial, social, and environmental costs of alternatives, governments may find subsidizing water-harvesting systems attractive, especially those for domestic supply. Some countries already subsidize rooftop collection systems.

### *Social Organization*

Water harvesting requires collective action in densely populated areas where more than one person uses catchment and command areas for multiple purposes. The key question in such cases is whether the benefits of water harvesting exceed the costs of coordination among users. Often this can be the most daunting constraint of all, especially where some resource uses are mutually incompatible and any intervention will impair at least one potential use, as in India. Successful water harvesting requires protecting upper reaches of small catchments against erosion that would re-duce water-storage capacity in the lower reaches. Typically, upper catchments are denuded, so protecting them requires limiting their use for grazing and fuel collection. This restriction imposes the greatest costs on landless people who depend the most on these areas and who do not stand to gain directly from water harvesting. Long-term success requires devising institutional approaches to ensure that landless people gain from the water-harvesting intervention.

## CONCLUSION

Water harvesting is certain to grow in importance in coming years as policymakers and planners seek cost-effective solutions to water supplies. Many simple systems can easily be put in place to overcome water scarcity, particularly rooftop collection for domestic use. As water becomes increasingly scarce, treatment of storage ponds to reduce leakage may become more financially viable. On the other hand, systems that require cooperative management and strict limits on land use will probably not become any simpler as local economies and land-use systems become increasingly complex.

Water harvesting does not make large dams and groundwater extraction obsolete. Rather, each system has its own advantages and disadvantages, and all systems can complement each other. The major advantage of water harvesting is that it begins to address problems locally, relieving the pressure on large-scale, centralized systems. Integrating water harvesting with other systems, as well as improving the management of demand, will lead to reliable, cost-effective water systems. ■

**For further information see Agarwal, Anil, Sunita Narain, and Indira Khurana, *Making Water Everybody's Business: Practice and Policy of Water Harvesting.* New Delhi: Centre for Science and Environment, 2001, <http://www.cseindia.org>; World Com-mission on Dams, *Dams and Development: A New Framework for Decision-Making,* <http://www.dams.org/report/>, especially Chapter 5, Thematic Review 4.3, and background papers on rain-water harvesting.**

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A 2020 Vision for Food, Agriculture, and the Environment
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# Overcoming Water Scarcity and Quality Constraints

## Water Pricing: Potential and Problems

R. Maria Saleth

Focus 9 • Brief 10 of 14 • October 2001

Water pricing policy has the potential to mitigate water scarcity. Because of its key role in managing water demand and augmenting water supply, water pricing is an important policy instrument for creating incentives to conserve and allocate water efficiently. By providing financial justification for developing additional supplies from conventional and unconventional sources, pricing policy can make more water available to users. Unfortunately, the water pricing policies being pursued in most countries fail to perform these vital roles due to faulty approaches and inappropriate institutions, both of which have their roots in political economy.

The state provides many irrigation and domestic water supply systems at subsidized rates because doing so delivers public goods in the form of secure food supplies, public health, or legitimacy for the government. But low water charges and poor cost recovery lead to declining funds available for investment in water infrastructure, poor maintenance of existing systems, inefficient water allocation, and growing conflicts between those with and without access to water. Economic and political pressures stemming from these problems have promoted a renewed debate on water pricing policy.

### ROLE OF WATER PRICING POLICY

Financially, water pricing is the main mechanism for cost recovery. Economically, it signals the scarcity value and opportunity cost of water and guides allocation decisions within and across water subsectors. The financial function requires water rates to cover the cost of supplying water to users. The supply cost is usually calculated by adding the operation and maintenance costs and the capital costs of constructing the system. But full cost recovery also requires water rates to reflect the long-term marginal cost (the cost of supplying an additional unit of water including the social cost of externalities).

The economic and allocative role of water pricing requires water rates to capture the scarcity value (or the marginal productivity/utility) and to equalize the opportunity costs (the value of water in its next best use) of the resource across uses. As water moves from least productive to most productive uses, places, and time points for efficient allocation, there will be a convergence of the scarcity value, opportunity cost, and long-term marginal cost of the resource. Unfortunately, such a convergence is rarely seen in practice. Unrealized opportunities still exist and water rates can be designed to capture at least a part of these opportunity costs. For this to occur, technology to store, transport, and deliver water is required, as are institutions to govern the development, allocation, and utilization of the resource.

### COST RECOVERY AND ECONOMIC INCENTIVES

The effectiveness of the financial and economic roles of water pricing policy depends on pricing methods, sectors, and countries. Water pricing may be either volumetric (based on the quantity of water used) or flat rate (based on area irrigated or households benefited). Volumetric pricing is conducive to creating incentives for efficient allocation and use, but the cost of establishing volumetric water delivery structures is often prohibitive, especially in large and spatially spread surface irrigation systems serving many smallholders. As a result, area-based fixed rates are dominant in most irrigation systems. However, volumetric water rates are widely used in many urban water supply systems.

Water rates are generally higher in countries with severe water scarcity (such as Algeria, Sudan, and Israel) and institutionally developed water economies (such as Australia and Israel). The industrial and power sectors within a country usually pay the highest water rates and receive a higher, more costly level of service throughout the year, as do domestic users. Agriculture pays the least, but also receives the lowest level of service. Within each sector and country, there can also be a wide variation in costs as domestic users buying water from private vendors pay much more than those connected to municipal systems and farmers receiving irrigation from public canals pay far less than those receiving irrigation from private wells.

Full cost recovery is legitimate both in economic and equity terms only if the users gain all the benefits from investment. On this count, some argue that since food prices fall when irrigation increases food production, consumers benefit, and that higher water rates for full cost recovery could adversely affect farmers' incomes. But this need not be the case because farmers benefit from irrigation partly from higher output and partly from increased land prices. In any case, the kind of full cost recovery being contemplated in many contexts does not cover even 10 percent of the additional income from irrigation, let alone the land value appreciation.

Water rates are still subsidized even in countries with a relatively mature water economy such as Australia, Israel, and the United States. This is rooted in the political economy of water, as powerful state and user interests often oppose charging the full cost of water. As a result, the gap is vast between the observed water rates and the ideal economic prices of water, as reflected by its scarcity value and opportunity cost. This illustrates the real magnitude of the task of designing pricing policies effective enough to play, simultaneously, the financial and economic roles.

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## THE INSTITUTIONAL DIMENSION

The policy debate has increasingly focused on the broader economic and allocative roles of water pricing. There is growing recognition that a realistic water pricing policy that ensures full cost recovery can be politically feasible only when it is designed to perform well in its economic and allocative roles. Also notable is the growing realization that institutional reforms to enhance the effectiveness of water pricing policy are indispensable. Pricing reform does not end with raising water rates. It also involves concurrent changes in pricing methods and approaches and the creation and strengthening of supportive institutions.

Volumetric pricing, though necessary, is not sufficient to ensure an effective economic role for water pricing. As long as the rates are below both supply cost and water productivity and there is no upper limit on individual water withdrawals, volumetric pricing per se can neither achieve full cost recovery nor solve the key incentive problem. For this purpose, volumetric pricing needs to be accompanied by price levels that are consistent with prevailing economic and resource realities. A system of transferable water quotas (rights) specifying upper limits for individual water withdrawals needs to be established for water markets to emerge that can, in turn, provide a basis for determining economically consistent water rates.

Pricing reform can be effective and practical only with the necessary institutional and technical conditions that enable cost recovery and allocative roles for water pricing policy. These institutions include an independent water pricing agency and regulatory body, financially autonomous agencies to supply water, clearly defined water rights, and transfers of management to user organizations or the private sector. Technical conditions include volumetric delivery, measurement structures, and infrastructure to move water over space, type of use, and time. These institutional and technical conditions can encourage the emergence of direct allocation mechanisms such as water markets and implement water pricing reforms.

It is true that the institutional and technical changes involve huge costs. But the present bureaucratic system of water administration is equally costly. International experience shows clearly that the promotion of intra- and intersectoral water allocation through markets in tradable water rights can have financial, efficiency, and equity gains far higher than the costs of transacting the reforms.

## CONCLUSION

Although water continues to be subsidized in most sectors and countries, there is growing recognition of water pricing as a key policy instrument for cost recovery and demand management. Given the seriousness of the informational, technical, and political constraints, the technical and institutional conditions needed for full cost recovery or for efficient allocation cannot be created overnight. A realistic strategy for water pricing reform involves, therefore, an incremental approach that sequences reform components appropriately, focuses first on cost recovery, and gradually broadens to address the economic and allocative role of water pricing. Enhancing and sustaining the economic and welfare contributions of water resources depends ultimately on the ability to face the twin challenges of supply augmentation with the lowest ecological and social costs, and the development of institutional frameworks for an efficient use of existing and future supplies. The future of the market-based water economy in most countries rests on how quickly the institutional reforms are undertaken.

**For further information see Asad, M., L.G. Azevedo, K.E. Kemper, and L.D. Simpson. *Management of Water Resources: Bulk Water Pricing in Brazil,* World Bank Technical Paper No. 432. Washington, D.C.: The World Bank, 1999.; Briscoe, John, "Managing Water as an Economic Good: Rules for Reformers," *Water Supply*, 15(4) (1996): 153–172.; Dinar, Ariel, ed. *The Political Economy of Water Pricing Reforms.* New York: Oxford University Press, 2000.**

### LEVELS AND METHODS WATER RATES: VARIATIONS ACROSS SECTORS AND COUNTRIES

| | Fixed Rate/ Hectare/Year or Season | Variable Rate/M$^3$ | Fixed Rate/ Household/Year or Month | Variable Rate/M$^3$ | Fixed Rate/ Plant/Year or Season | Variable Rate/M$^3$ |
|---|---|---|---|---|---|---|
| Algeria | 3.79-7.59 | 0.02-0.02 | – | 0.06-0.27 | – | 4.640 |
| Australia | 0.75-2.27 | 0.02 | 9.00-162.00 | 0.23-0.54 | – | 7.82 |
| Brazil | 3.50 | 0.004-0.032 | – | 0.40 | – | – |
| Canada | 6.62-36.65 | 0.002-0.002 | – | 0.34-1.36 | – | 0.17-1.52 |
| Egypt | – | – | – | 0.07-0.09 | – | 0.12-0.59 |
| France | – | 0.11-0.39 | – | 0.36-2.58 | – | 0.36-2.16 |
| India | 0.16-27.47 | – | 0.82 | 0.01-0.08 | – | – |
| Israel | – | 0.16-0.26 | – | 0.36 | – | 0.26 |
| Japan | 246.00 | – | – | 1.56 | – | – |
| Jordan | – | 0.01-0.04 | – | 0.27-1.03 | – | 0.12-0.35 |
| Mexico | 33.00-60.00 | – | – | – | – | 0.08-0.35 |
| Pakistan | 1.49-5.80 | – | 0.25-1.63 | 0.06-0.10 | – | 0.38-0.97 |
| Sudan | 4.72-11.22 | – | 1.67-3.33 | 0.08-0.10 | 1.67-3.33 | 0.08-0.10 |
| Yemen | – | 0.02-1.45 | – | 0.10-13.79 | – | 0.10-13.70 |

Source: Dinar (2000).

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A 2020 Vision for Food, Agriculture, and the Environment

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# Overcoming Water Scarcity and Quality Constraints

## Markets for Tradable Water Rights

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Focus 9 • Brief 11 of 14 • October 2001

Water markets have been advocated as a means of improving water resources management by increasing the efficiency of water use and allocation within and among sectors. Water markets are more flexible than command-and-control instruments in moving water to higher-valued uses in a manner agreeable to all parties, thus promoting economic growth and diminishing social tension from competition for scarce water resources. Sometimes water markets are also expected to mitigate environmentally detrimental effects from overexploitation of water resources. However, they can also have drawbacks, and decisions about the introduction of a water market in a specific setting need to be informed by a thorough institutional analysis of the local socioeconomic, cultural, and hydrological context.

### WHAT IS A WATER MARKET?

In its most basic definition, a water market is an arrangement in which holders of water rights trade them with each other or to outside parties. However, there are differences between water markets, and design will depend on the prevailing hydrological regime, including whether trades involve surface water, groundwater, or both; the previous existence of informal water rights and trading; the types and numbers of water users and right holders, including whether all are irrigation farmers or from different water-use sectors; and the physical arrangements for moving water between users. However, appropriate institutional arrangements must be in place to ensure positive outcomes from water markets.

### INSTITUTIONAL ARRANGEMENTS FOR EFFECTIVE FUNCTIONING OF WATER MARKETS

The implementation of water markets requires both government involvement and active water-user participation. Institutional ingredients needed for other approaches to improving water-resources management—such as an administrative system that registers and enforces timely water deliveries, a transparent and accepted water measurement system, and a well-maintained delivery system—are all required for a functioning market. Therefore, the difference between the implementation of administrative systems and a market system may not be as large as expected. The principal difference is the need for the following:

- ***Definable and transferable water rights.*** Reallocation by trading means getting compensated. That is different from administrative reallocation, where right holders may not receive any compensation when water is reallocated to a different use. Under water markets, right holders will not only consider what the water can produce for themselves, but also the opportunity cost of the water (such as the value added by using the water in car manufacturing). Thus, the highest value of water use is taken into account, providing an incentive for more efficient use and reallocation of water to a higher-valued use.
- ***Internal institutional market arrangements.*** Buyers and sellers need to find each other and have confidence in the characteristics of the goods they want to exchange. In a well-functioning water market, this implies measuring the water available for trading, developing a simple mechanism to find prospective buyers and sellers, and carrying out the transfer. If the official transfer is difficult, then informal trading will likely occur anyway. The disadvantage of informal trading is that water use is hard to track. This is the case in Mexico and India, where groundwater levels keep sinking despite water trading.
- ***A physical delivery system.*** Traded water is likely to move from one user to another. Depending on the hydrological conditions or previously constructed infrastructure, the cost of adequate infrastructure may be too high and outweigh the benefits from transfers, rendering the water price so high that no buyers can be found. The government may absorb the cost, but thorough analyses are needed to establish whether the introduction of a tradable system will produce sufficient societal benefits to warrant large investments.

### HANDLING EXTERNALITIES

Imagine a river where a right holder uses only 70 percent of her water so that the remaining 30 percent is available for her neighbors. If she decides to sell her full right to a buyer who will use all of this water, then the downstream neighbors will be deprived of the extra water, which they count on. They may go to court to prevent the sale, thereby causing high transaction costs, or courts may not be available and they will have to accept the loss. A mechanism is therefore needed to either negate third-party interests or to mitigate the impacts of water trading on the different stakeholders, including an effective conflict resolution system. Such a system could be linked to water courts or taken care of by the riverbasin management agencies where the market is located.

The most challenging institutional feature of a water market may thus be the definition and registration of water rights, together with the implementation of adequate information and transaction mechanisms that provide equal possibilities for all water users to participate in the market. These mechanisms would have to include access to price information and the registration, enforcement, and monitoring of rights.

## INTRODUCING WATER MARKETS IN DEVELOPING COUNTRIES

Developing countries characteristically suffer from weak institutional frameworks, such as slow judicial systems, unclearly defined land rights, strong concentration of land ownership, and unenforced laws and environmental regulations. Before the introduction of water markets, the necessary legal and institutional requirements in each site should be compared with what already exists. An evaluation should be made to determine whether the laws and institutions could be changed with low political and social transaction costs to permit the introduction of a well-functioning water market.

Socioeconomic asymmetries need to be considered because of the different types of water users, who will vary in their educational background, culture, and economic power. When water rights were allocated and made tradable in Chile, electricity companies bought up a large number of them to be held for future use, to the detriment of smaller users who at the outset did not understand the implications of their selling the rights. Given that water is the basis for agricultural production, the sale of a water right may severely undermine smallholders' livelihoods. In response, the Chilean government has been discussing the prohibition of holding water rights for more than five years without beneficial use.

As in the case of land rights, poor farmers may use newly allocated water rights to pay off their debts, ending up without their entitlement in the long run. A phased approach to water trading may be the most appropriate, starting with the introduction of water rights, monitoring, and enforcement, and followed at a later stage by tradability. This would give water users—especially the more vulnerable segments of society—the time to realize the value of their new rights. Instituting a seasonal or annual leasing system could also permit right holders to experience market transactions without permanently endangering their livelihoods.

Another important issue is the impact of water reallocation on higher-valued uses and their impact on regional economies and the environment. International experience is inconclusive. In Mexico, small farmers with severe groundwater overdraft do not have the capital to invest in deeper wells, so they sell their water rights to large agribusinesses that do invest in wells. The small farmers win because, without the water market, they could neither invest and nor receive any compensation. Furthermore, the company creates local and regional jobs. On the other hand, by obtaining more water rights, the company also strongly contributes to the declining groundwater level, thus hurting more small farmers and the environment.

The need for integrating a functioning system of water-resources management with the water market approach is clear. Such a system would include water measurement, enforcement, sanctioning of infractions, and user participation in decisionmaking about regional water-resources management goals. The Chilean and Mexican examples also show that water markets—like other approaches—have social and environmental implications that cannot be disregarded if they are to enhance sustainable development and economic growth.

## CONCLUSION

Water markets can help improve water allocation and use. To function, they need a set of institutional arrangements, which are partly the same as so-called "administrative water-management tools," namely riverbasin management, water measurement, enforcement, sanctioning, water availability information, and water-user participation. In addition, some parts of the institutional arrangements needed are incremental, such as tradable water use rights, and appropriate infrastructure and transaction mechanisms.

A gradual approach to introducing water markets may be the most appropriate, putting into place water measurement systems, defined (though not tradable) water rights , and water user participation. In many settings worldwide, these steps would be the basis for much-improved water-resources management and would permit the stakeholders to get adjusted to a new set of rules. Eventually, rights to water use could be made tradable, but should take into account and make appropriate provisions for vulnerable user groups and uses, including the environment.

While the benefits of water markets can be substantial, potential negative socioeconomic or environmental impacts need to be included in the analysis prior to taking any steps toward implementation. The gradual approach proposed here would not only permit a long-term evaluation of institutional change, but would also help include the different stakeholder groups in shaping the institutional arrangements for water resources management. ■

**For further information see Graff, J. T. and D. Yards, "Reforming Western Water Policy: Markets & Regulation."** ***Natural Resources & Environmental Law,*** **Vol. 165 (1998).; Hearne, R. R. and K.W. Easter,** ***Water Allocation and Water Markets: An Analysis of Gains-From-Trade in Chile.*** **World Bank Technical Paper No. 315. Washington, D.C.: World Bank, 1995.; Mariño, M. and K. Kemper, eds.** ***Institutional Frameworks in Successful Water Markets: Brazil, Spain and Colorado, U.S.A..*** **World Bank Technical Paper No. 427. Washington, D.C.: World Bank, 1999.**

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# Overcoming Water Scarcity and Quality Constraints

## Recognizing Water Rights

Franz and Keebet von Benda-Beckmann

Focus 9 • Brief 12 of 14 • October 2001

The time when water could be freely used without being subject to legal rights and obligations is past. Because of population growth, industrial and agricultural development, and new water technologies, water has become increasingly scarce. As competition has become more acute, the tendency to appropriate water and exclude others from using it has increased. This has created pressures on the regulation and appropriation of water resources and rights for different purposes, such as drinking, agriculture, industry, and hydropower. It has also made the need for new regulation more urgent. Moreover, technical measures—such as building an irrigation system, dam, or river lining—may affect existing rights to water and create new rights without explicit legislation. In the near future, competition over water will only increase and the need for regulation will be more acute than ever.

Control over and use of water has been regulated in diverse ways that involve bundles of rights. These bundles assign legitimate authority and the obligations to control water and determine the priority of water use. They lay down who has the right to appropriate water, whether or not water can be transferred, and the relation between water rights and land rights. Such bundles of rights range from the most exclusive forms of individual ownership, to communal rights at the local-community level, to public regulation at the national or state level, to agreements at the international level, or a combination of these. Usually, any set of regulations regarding a particular water resource involves both private and public rights and obligations. The specific character of water resources requires forms of organization that often transcend or cut across the ordinary administrative boundaries of local community, district, and state. A command area of an irrigation system may lie in more than one village; a river basin may run through several countries.

### STATE AND CUSTOMARY LAW

In many countries, the state claims sovereignty and ownership over all its water resources. However, especially in developing countries, state law is not the only source of regulation. Local regulations (or "customary" law) and religious regulations often assign rights and obligations that differ from and sometimes contradict state law. By definition, customary legal orders are based on different notions of who may control, regulate, and have access to water. The state does not always recognize non-state legal orders and their ideas about water rights as valid. Nevertheless, they continue to exist and exert their influence on water-resource management practices.

Recognition of customary and religious law has been a political issue since colonial times and recently has acquired new impetus with debates about efficient and equitable use of water. The debates lead to such questions as:

- Are some types of rights more conducive to efficient or sustainable use of water than others?
- What are the criteria for equitable distribution?
- Are state regulations more efficient and equitable than customary legal forms?

These issues have been subject to misunderstandings that result from untenable assumptions concerning the character and function of the various kinds of water rights. In dealing with these questions, policy must not only devise new sets of water rights and obligations based on realistic assumptions but also accommodate complex existing legal constellations in the field of water resources management.

In assessing the nature and function of customary legal rights, policymakers often make three mistakes. First, many assume that all norms and regulations that do not emanate from state institutions are customary and long established. In fact, many rules and regulations emerge locally as new responses to outside intervention by the state or other institutions. Second, policymakers assume that everybody acts according to these rules because they are deeply ingrained in local society. However, human behavior never fully corresponds to norms and regulations. Every property regime allows for variations in behavior, and each local community adapts its legal system and the structure of rights to changing social and economic conditions. Third, policymakers assume that all customary property is communal property. In fact, no property regime is fully communal; it is always a combination of communal and individual elements, and of public and private elements.

The focus of interest shifted from economic development to sustainable development in the late 1960s in the debate about appropriate management of "the commons." Communal property rights were blamed at that time for unsustainable resource use. More recently, the argument has been reversing. Communities, community-based rights, and communities' customary law are now being promoted as inherently conducive to sustainable resource use. The arguments are particularly powerful in relation to natural resources, such as water, forests, fisheries, and natural reserves. However, here again experience has shown that overexploitation and resource degradation can occur under state, individual, or communal ownership. The extent to which resources are managed sustainably depends on the ways in which wealth is distributed and on whether the users have alternative economic possibilities.

Customary law is also often considered to be more equitable than other legal regimes. However, there is little consensus on how equity is defined. Customary legal systems may show considerable inequalities based on class, gender, age, and caste. One important reason is the unequal distribution of land. Rights to water are usually closely connected to land rights. Springs are often owned by whoever owns the land on which the spring originates. People living along a river are entitled to draw water from the river. In cases of irrigation, the rights to irrigation water are usually distributed among those having land in the command area; or they belong to those who participate in building the system, again usually people that own the land to be irrigated. Where land is unequally distributed, water is also usually unequally distributed. Poor people tend to have land at a disadvantaged position within irrigation systems or even outside the command area of irrigation systems.

Water is also distributed unequally by gender. For their water rights, women often depend on men: fathers or brothers while unmarried, husbands after marriage. Thus, women are excluded from the right to make decisions in public arenas. Interests that tend to be more specific to women, such as accessibility to household and drinking water, are often disregarded. This is not so much a result of a conscious exclusion from water rights as such, but of more general gender differences that do not allow women to participate in the public domain, or that do not allow women to inherit or acquire property independently.

State water regulations may also show inequalities. Present state policies to create water markets, meant to increase efficiency, will certainly increase inequality unless very serious measures are taken to ensure that the poor have access to this market.

## POLICY IMPLICATIONS

This brief should not be read as a plea for following customary law blindly in all respects. There may be very good reasons for wanting to change customary water rights, for example, to bring about more efficiency, sustainability, and gender equality, or to alleviate poverty. In addition, major changes in the scope of water redistribution cannot be achieved at the relatively small political and geographical scale on which customary legal systems operate. Change should build upon a realistic and careful assessment of existing rights to water and other natural resources in all their complexity. Because rights to water are intimately linked to a wider set of social relationships, successful change requires a full analysis of existing inequalities within a society.

Any policy that simply ignores existing rights—whether defined in state law, in local legal systems, or in religious law—is bound to fail and to create more, rather than less, insecure rights. This is potentially harmful for the people that policymakers intend to protect. Policies based on false assumptions about the social working of law inevitably lead to disappointment. Replacing customary water rights with a new property regime designed from scratch is bound to meet with strong opposition from those threatened with loss of their existing rights. Changing water rights alone may only marginally redress inequity in access to water. Making changes in inheritance regulations or land redistribution may also be required.

Devising a new set of categories of rights to water will not suffice unless attention is also given to the actual distribution of water through these rights. This involves deciding on the distribution of available water resources among different uses and setting priorities. It also involves distribution decisions between different segments of the population within sectoral uses, and the legally valid means through which such redistribution is to be effected.

The legal complexity of this issue and its potential for social and political tension also demand a policy style that is open to hearing and negotiating with those holding rights to water under multiple legal orders. Perfect legal regulation is likely to be an illusion, and compromises will have to be made.

Finally, local and customary rights vary considerably in content and function from region to region. Policymakers are well advised not to cover them under uniform legislation that does not take these variations into account. New legislation should lay down a general framework and leave room for the elaboration of local variations in specific cultural, legal, and hydrological conditions. ■

**For further information see Boelens, R. and G. Davis, eds. *Searching for Equity: Conceptions of Justice and Equity in Peasant Irrigation.* Assen: Van Gorcum, 1998.; Bruns, B. R. and R. S. Meinzen-Dick, eds. *Negotiating Water Rights.* New Delhi: Vistaar Publications, 2000.; Pradhan, R., F. von Benda-Beckmann, K. von Benda-Beckmann, H. J. L. Spiertz, S. S. Kadka, K. A. Haq, eds. *Water Rights, Conflict, and Policy.* Colombo: IIMI, 1997.**

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# Overcoming Water Scarcity and Quality Constraints

## Integrated Management of Water in River Basins

Mark Svendsen

Focus 9 • Brief 13 of 14 • October 2001

Until the beginning of the 19th century, human water use was limited. Natural features and forces largely dictated river flow regimes, and natural biota were the primary water users. By the 20th century, a great remaking of river systems occurred as humans manipulated the natural hydrology to meet the domestic supply, sanitation, food, fiber, and industrial needs of growing populations and rising standards of living. Water resources in many river basins are fully committed to a variety of in-stream and remote purposes, degrading water quality, threatening river-dependent ecosystems, and intensifying competition and strife.

### WHAT IS INTEGRATED RIVER BASIN MANAGEMENT?

Integrated river basin management (RBM) systems bring fragmented water uses and users together (see Box). RBM creates a framework that deals with an entire basin or sub-basin, such as the Colombia, the Indus, or the Limpopo, not just a single water use or administrative jurisdiction. A river basin can be defined by the watershed limits of a system of waters, both ground and surface, flowing to a common terminus. RBM integrates this system of waters within its broader natural environment and its social, economic, and political contexts. Basin units cut across administrative divisions used to manage water. This is their strength and their challenge.

Water in a river basin is both renewable and reusable. The hydrologic cycle renews the resource annually; water within a basin can be reused many times on its way from headwaters to the sea. Some are in-stream uses, such as hydropower generation, navigation, recreation, or ecological sustenance. Other uses, such as municipal water supply, industrial cooling, or irrigation, extract water but return much of it downstream. As a result, a blend of water that has been used and reused comprises the lower reaches of most major river systems. This multiplier effect allows withdrawals to exceed by many times the natural flow in a river and provides a number of management options for optimizing the utility of water in a basin, but creates significant measurement and quality management problems.

Because of the large variability in river flows across seasons and years, flood protection works and artificial storage are important elements of river basin systems. The degree of control afforded by reservoirs varies enormously. The reservoirs on the Colorado River in the U.S. can store four times the annual flow of the river, whereas the Mekong River in Southeast Asia is largely unregulated. There are many more management options and the value of water in the Colorado River basin is higher, since regulated flows generally have much greater utility for human uses than unregulated ones.

#### Integrated Basin Management

**Although the term "integrated" most commonly refers to integration across use sectors, such as agriculture and urban water supply, it can also encompass a number of other divisions, including the following:**

- **Administrative jurisdictions;**
- **Ground and surface water;**
- **Upstream and downstream reaches;**
- **Environmental and human uses;**
- **Supply and demand management;**
- **Water quantity and quality;**
- **Land and water use; and**
- **Transboundary uses.**

This value comes at a cost to natural ecosystems, which have evolved from and adapted to natural cycles of flood and recession. Manipulating reservoir releases to mimic key portions of these natural cycles has increased, but much remains to be learned in this area.

As river basins approach full utilization, systems of specifying, quantifying, and assigning rights to the water become more formalized. Those affected try to protect, defend, and perhaps augment their rights; interact with other right holders, claimants, and aspirants; and sometimes conflict with them. RBM must therefore establish the rules of the game and mechanisms to govern these interactions, so that they take place in a productive and efficient way. All interests and stakeholders in the water affairs of the basin must have suitable protection and adequate representation, including the natural environment and less powerful water users. The most important decisions in RBM are made on the basis of contemporary social values, not on technical grounds. Effective RBM requires both good process and good science.

### TYPES OF MANAGEMENT STRUCTURES

There are two archetypal organizational models for implementing RBM. The first is the authority model, in which a single unified organization is empowered to make decisions. The second is the coordinative model, in which existing administrative units work together to cover an entire river basin or sub-basin. While new structures may be created, the bulk of routine work is done by existing organizations.

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A strength of the authority model is that its operational span of control coincides with the boundaries of the basin. This internalizes upstream/downstream and other conflicts, making them easier to deal with. And it concentrates the decisionmaking authority needed to resolve disagreements. But there are disadvantages too. Since the authority will very likely deal only with water, water will be isolated from relevant policy sectors such as agriculture, the environment, and the economy. Authority is centralized rather than devolving to the lowest practicable level. And for international rivers, the authority model requires establishing a supranational authority, which is extremely difficult to do. Finally, governance of an RBM authority may not include broad-based stakeholder representation and accountability.

The coordinative model addresses some of these weaknesses. Because coordination involves voluntary agreement among participating jurisdictions, it provides a strong political base for action. Linkages between water and other types of policy remain, since states, nations, or other jurisdictions are jointly responsible for a range of policy sectors. Such a set-up also provides a natural base for decentralization of responsibilities. On the other hand, decisionmaking can be cumbersome, costs of coordination may be high, and political changes in participating jurisdictions can upset agreements.

These two models represent polar extremes. Specific cases often blend the two. In Australia's Murray-Darling Basin, a cooperative Ministerial Council comprising representatives of the four involved states and the federal government, sets policy while an authority-like commission supports and executes the council's decisions. In France, a river commission made up of local and national government representatives and users sets water policy, which an associated water agency implements. Publicly held companies manage the distribution infrastructure and make bulk water deliveries to user associations. In the United States, there is generally no formal apex council in a river basin, and policymaking authority is distributed among federal and state agencies and departments. Committees and working groups link stakeholders to discussion and decisionmaking fora. Legislation and legally binding negotiated agreements are important instruments for establishing policy and practices, and the court system resolves disagreements and disputes. In the state of California, a water plan that is updated every five years provides a rolling framework for managing the state's water resources.

The most prominent examples of authorities are those whose primary mandate is to develop a river basin, such as the Tennessee Valley Authority (TVA) in the U.S., the Rio São Francisco Development Agency in Brazil, and the Mahaweli Development Authority in Sri Lanka. When their primary development tasks are finished, authorities often transition to a broader resource management role, with varying degrees of success.

## THE CONTEXTUAL FIT

Most of these examples are from higher-income countries. But can RBM models from wealthy countries like Australia and the United States work in other contexts? River basins across the world are reaching full allocation and experiencing many of the problems outlined earlier. The TVA model has successfully developed water resources in places like Sri Lanka, but its record as an RBM model is checkered. Sri Lanka is struggling to transform the Mahaweli Authority into a basin management agency. Applying the TVA model to the Damodar Valley Authority in India in the 1950s was a resounding failure. Current attempts to use the Murray-Darling model in Vietnam and China are encountering fundamental problems.

Experience with RBM in developing countries and in developed countries may differ because in developing countries:

- Dense populations live in upper watershed catchments and require access to water along with downstream urban populations;
- Water use is widely dispersed rather than concentrated and easily controlled;
- Administrative capacity to monitor and enforce regulations and standards is limited;
- Governance mechanisms to assign rights and regulate and enforce agreements and contracts are nonexistent or weak;
- Technical capacity to measure and monitor basin hydrology is limited;
- Civil society does not possess the internal structure of groups and associations needed to represent various stakeholder interests;
- Pressures for transparency in public decisionmaking and regulation, including independent, investigative media, are not strong.

These differences preclude the wholesale importation of developed-country models. RBM strategies must be adapted to the particular context. Building institutional capacity in critical areas may have to proceed simultaneously with the development of RBM organizations. In such cases, it may be necessary to defer assigning particular functions to these organizations until sufficient capacity has been developed.

Achieving effective basin management requires a strong knowledge base, suitable governance mechanisms, administrative capacity, adequate stakeholder representation, transparency, and political will. This challenging set of requirements is matched by equally rewarding potential outcomes, such as more efficient use of each drop of water, enhanced reuse of water, mitigation of past environmental damage, and redirection of water to uses that society values most highly. The overarching imperative is to accomplish these ends in a way that treats all stakeholders, particularly weaker and poorer stakeholders, fairly and equitably. ■

**For further information see Abernethy, C. L., ed. *Intersectoral Management of River Basins.* Proceedings of an International Workshop on "Integrated Water Management in Water-Stressed River Basins in Developing Countries: Strategies for Poverty Alleviation and Agricultural Growth," Loskop Dam, South Africa, 16–21 October 2000. Colombo, Sri Lanka: IWMI and German Foundation for International Development (DSE), 2001.; Mostert, E., ed. *River Basin Management.* Proceedings of the International Workshop, The Hague, 27–29 October. UNESCO, 1999.**

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# OVERCOMING WATER SCARCITY AND QUALITY CONSTRAINTS

## WATER, CONFLICT, AND COOPERATION

AARON T. WOLF

FOCUS 9 • BRIEF 14 OF 14 • OCTOBER 2001

River basins and groundwater aquifers that cross international boundaries present increased challenges to effective water management because hydrologic needs are often overwhelmed by political considerations. While the potential for paralyzing disputes is especially high in these transnational basins, the record of violence is actually greater within a nation's boundaries. Moreover, history is rich with examples of how water has become a catalyst to dialogue and cooperation, even among especially contentious riparians.

### WATER AND INTRANATIONAL CONFLICT

The scarcity of water for human and ecosystem uses leads to intense political pressures, often referred to as "water stress." As a consequence, competition for water resources has contributed to tensions around the globe between competing uses—urban vs. agricultural, environmental protection vs. industry—and users, from neighboring irrigators to neighboring nations. While water quantity has been the major issue of the 20th century, water quality has been neglected to the point of catastrophe. Water demands are increasing, groundwater levels are dropping, surface-water supplies are increasingly contaminated, and delivery and treatment infrastructure is aging.

These tensions have spilled into violence on occasion, mostly at the intranational level, and generally among ethnic, religious, or tribal groups; water-use sectors; or states/provinces. Examples of internal water conflicts range from interstate violence and death along the Cauvery River in India, to California farmers blowing up a pipeline meant for Los Angeles, to much of the violent history in the Americas between indigenous peoples and European settlers.

While these disputes can and do occur at the sub-national level, the human security issue is subtler and more pervasive than violent conflict. As water quality degrades—or as quantity diminishes—over time, tensions can spill across boundaries. The overall effect on the stability of a region can be unsettling.

### BACKGROUND ON INTERNATIONAL WATERS

There are 261 watersheds and countless aquifers that cross the political boundaries of two or more countries. International basins cover 45.3 percent of the land surface of the Earth, affect about 40 percent of the world's population, and account for approximately 60 percent of global river flow.

These basins have certain characteristics that make their management especially difficult, most notably the tendency for regional politics to exacerbate the already difficult task of understanding and managing complex natural systems.

Disparities between riparian nations—whether in economic development, infrastructural capacity, or political orientation—further complicate international water resources management. As a consequence, development projects, treaties, and institutions are regularly seen as inefficient at best and, occasionally, as a source of new tension themselves.

### DEVELOPMENT, CRISIS, AND CONFLICT RESOLUTION

A general pattern has emerged for international basins over time. Riparians of an international basin first implement water development projects unilaterally on water within their territory in an attempt to avoid the political intricacies of the shared resource. At some point, one of the riparians, generally the regional power (either upstream riparian or country with the most military, political, or economic strength), will implement a project that impacts at least one of its neighbors. The project might aim to continue meeting existing demand in the face of decreasing relative water availability, such as Egypt's plans for a high dam on the Nile or Indian diversions of the Ganges to protect the port of Calcutta; or to meet new needs reflecting new agricultural policy, such as Turkey's GAP project on the Euphrates. A project that impacts one's neighbors can, in the absence of relations or institutions conducive to conflict resolution, become a flashpoint, heightening tensions and regional instability, and requiring years or, more commonly, decades, to resolve.

It feels both counterintuitive and precarious that the global community can let water conflicts drag on to the extent they often do—the Indus treaty took 10 years of negotiations, the Ganges 30, and the Jordan 40—while water quality and quantity degrade to the point that the health of dependent populations and ecosystems is damaged or destroyed. A re-read of the history of international waters suggests that in the absence of agreement, neither human suffering and death nor the health of aquatic ecosystems is sufficient incentive to cooperate. This problem gets worse as the dispute gains in intensity. Some ecosystems, such as the lower Nile, the lower Jordan, and the tributaries of the Aral Sea, have been allowed to deteriorate because posturing states did not cooperate to protect them. They have effectively been written off to the vagaries of human intractability.

## PREVENTIVE DIPLOMACY AND INSTITUTIONAL CAPACITY BUILDING

There is some room for optimism, though, in the global community's record of resolving water-related disputes along international waterways. The record of cooperation has consistently prevailed over acute conflict related to international water resources. In fact, the last (and only) war fought specifically over water took place 4,500 years ago, between the city-states of Lagash and Umma along the Tigris River. Over the last 50 years, there have been only 37 acute disputes (those involving violence). During the same period, 157 treaties were negotiated and signed; only 507 events were conflict-related; 1,228 were resolved cooperatively. Moreover, almost two-thirds of all events are only verbal and, of those, more than two-thirds are reported as having no official sanction at all. The most vehement enemies around the world either have negotiated water-sharing agreements, or are in the process of doing so as of this writing. Violence over water seems neither strategically rational, nor hydrographically effective, nor economically viable. Shared interests along a waterway seem to consistently outweigh water's conflict-inducing characteristics.

Furthermore, once cooperative water regimes are established through treaty, they turn out to be impressively resilient over time, even between otherwise hostile riparians, and even while conflict is waged over other issues. For example, the Mekong Committee has functioned since 1957, exchanging data throughout the Vietnam War. Secret "picnic table" talks have been held between Israel and Jordan ever since the unsuccessful Johnston negotiations of 1953–55, even while these riparian nations were in a legal state of war. And the Indus River Commission not only survived two wars between India and Pakistan, but treaty-related payments also continued unabated throughout the hostilities.

These patterns suggest one valuable lesson: international waters are a resource whose characteristics tend to induce cooperation rather than incite violence, which is the exception. The greatest threat of the global water crisis, then, comes from the fact that people and ecosystems around the globe lack access to sufficient quantities of water at sufficient quality for their well-being.

## LESSONS FOR THE INTERNATIONAL COMMUNITY

Despite the complexity of water disputes, the historical record shows that they do get resolved, and that the resulting water institutions can be tremendously resilient. The challenge for the international community is to get ahead of the "crisis curve," to help develop institutional capacity and a culture of cooperation in advance of costly, time-consuming crises that in turn threaten lives, regional stability, and ecosystem health.

One productive approach to the development of transboundary waters has been to examine the benefits in a basin from a multi-resource perspective. This has required riparians to get past looking at water as a commodity to be divided and to develop instead an approach that equitably allocates not the water, but the benefits derived therefrom.

The most critical lessons learned from the global experience in international water resource issues are that:

1. Water crossing international boundaries can cause tensions between nations that share the basin. While the tension is not likely to lead to warfare, early coordination between riparian states can help ameliorate the issue.
2. Once international institutions are in place, they are tremendously resilient over time, even between otherwise hostile riparian nations, and even while conflict is waged over other issues.
3. A gradual decrease in water quantity or quality, or both, is more likely than violent conflict. Over time, such water decreases can affect the internal stability of a nation or region, and act as an irritant among ethnic groups, water sectors, or states/provinces. The resulting instability may have effects in the international arena.
4. The greatest threat of the global water crisis to human security comes from the fact that millions of people lack access to sufficient quantities of water of sufficient quality for their well-being. ■

**For more information see Postel, Sandra. *Pillar of Sand: Can the Irrigation Miracle Last?* New York: W.W. Norton, 1999.; Gleick, Peter. *The World's Water: The Biennial Report on Freshwater Resources.* Washington, DC: Island Press, 1998 and 2000.; Biswas, Asit, ed., *International Waters of the Middle East: From Euphrates-Tigris to Nile.* Oxford: Oxford University Press, 1994.; Amery, Hussein and Aaron Wolf, eds., *Water in the Middle East: A Geography of Peace.* Austin: University of Texas Press, 2000.; Wolf, Aaron, ed. *Conflict Prevention and Resolution in Water Systems.* Cheltenham, U.K.: Edward Elgar, 2001.; Wolf, Aaron, Shira Yoffe, and Mark Giordano. "International Waters: Basins at Risk." *Water Policy,* forthcoming.**

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