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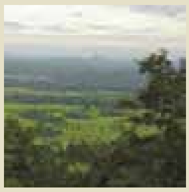
Asia and the Pacific

This region supports some 60% of the world's population with only 36% of the world's water resources. Growing population, rapid urbanization and economic development put heavy pressure on freshwater resources and further accentuate the disparities in their natural distribution.

The case studies presented in this section include striking examples from six Asian countries and the Pacific subregion, including the poorest country (Bangladesh), the richest (Republic of Korea), the smallest (in the Pacific islands) and the largest (China). The differing challenges, and the degree to which the countries are equipped to cope with them, show great variation, largely due to the wide range of economic development. However, water-related disasters are a common threat affecting all the countries, and the need to develop strategies for adaptation to climate change is a shared concern.

With major transboundary rivers characterizing much of Asia, regional cooperation among riparian countries surfaces as an important issue, and benefit-sharing is a paramount concern – one that is also highlighted in the third edition of the World Water Development Report, which this volume accompanies.



Bangladesh: the confluence of the Ganges, Brahmaputra and Meghna rivers

Recurring water-related hazards, declining freshwater availability and poisoning from naturally occurring arsenic in groundwater have undermined the health and livelihoods of millions in this densely populated country. Climate change might further aggravate this situation. Efforts to institutionalize integrated water resources management will play a significant role in reducing the burden of persistent poverty, especially among rural populations.

Setting the scene

Bangladesh is situated in the deltaic plain formed by three large rivers the Ganges, the Brahmaputra and the Meghna. The combined total catchment of about 1.7 million km^2 extends over Bhutan, China, India and Nepal.[1] Only about 7% of this huge catchment lies in Bangladesh. With its 140 million inhabitants (2004) and a surface area of 147,570 km^2, Bangladesh is one of the most densely populated countries in the world. It is almost completely surrounded by India, except for the Bay of Bengal in the south and a short border with Myanmar in the south-east. The only significant highlands are in the north-east and south-east. Most of Bangladesh is low-lying and relatively flat. A network of about 230 rivers, of which 57 are transboundary, forms a web of interconnecting channels throughout the country.[2]

Bangladesh has a subtropical monsoon climate, characterized by wide seasonal variations in rainfall, moderately warm temperatures and high humidity, with a hot, humid summer from March to June; a cool, rainy monsoon season from July to October; and a cool, dry winter from November to February. The annual rainfall varies from 1,200 mm in the north-west to more than 4,000 mm in the north-east.

About 90% of the annual rainfall occurs during the monsoon season. From November to May there is almost no dependable rainfall. Drought is widespread during this dry period, and irrigation becomes necessary for any crop production. Tropical cyclones, storms and tsunami-like tidal bores are quite common from March to May and during the monsoon season.

Climate change and variability: continuing vulnerability

Data indicate that minimum temperatures in the monsoon season have generally increased by 0.05°C and maximum temperatures by 0.03°C. Tidal data covering 22 years show that the sea level is rising about 4 to 7 mm per year.

Detailed climate modelling has not been carried out in Bangladesh. However, scenarios by the Intergovernmental Panel on Climate Change have consistently simulated potential warming throughout the country in all seasons, a moderate increase in monsoon rainfall and a moderate decrease in dry season rainfall. Accordingly, projections for the Ganges-Meghna-Brahmaputra river basin predict a temperature increase of up to 2.6°C by 2050 and a rise in annual rainfall of up to 5.5% by 2020. Bangladesh has long been vulnerable to water-related hazards due to its high population density, location in a low-lying delta subject to heavy rainfall, and inflows of large volumes of surface water that are confined to a relatively short monsoon season. Any change in climatic conditions is likely to aggravate the situation.

State of the resource: wide seasonal variation in surface water availability

A network of rivers, channels and other water bodies covers 8.23% of the surface area of Bangladesh. Overall,

Map 2.1 Bangladesh

[1] A simplified map showing the full extent of the Ganges, Brahmaputra and Meghna river basins can be found in the CD accompanying this volume of case studies.
[2] Except where otherwise noted, information in this case study is adapted from the executive summary of *Bangladesh Case Study Report*, prepared in 2008 by the Institute of Water Modelling and DHI.

the annual freshwater potential of the country is estimated to be 1,200 billion m³, of which more than 90% is inflow from upstream countries (Aquastat, 1999). Bangladesh has a treaty with India on sharing the water resources of the Ganges River.

The quantity of surface water varies greatly by season. During the dry season, which lasts from November to May, there is a serious shortage of water and demand exceeds availability (Table 2.1). In particular, the south-west and north-west are prone to drought. During the monsoon season, however, surface water is available in excess of water demand. Unfortunately, due to the flat topography of Bangladesh, storing this excess has not been possible. Storage would require a regional plan and the construction of facilities in the upstream countries of India and Nepal.

Table 2.1 Seasonal fluctuation in surface water availability and overall demand

	Critical dry period *(February–April)*	Wet season *(June–October)*
Average water availability	60 billion m^3	1,030 billion m^3
Demand	90 billion m^3	142 billion m^3

Bangladesh has a predominantly agrarian economy. Agriculture generates about 21% of total GDP and provides employment for about 52% of the national workforce. It also claims the biggest share of the country's land resources (55.8% of the overall surface area), followed by forests (14.2%) and urban areas (5.9%). Irrigation is common but not fully developed. Out of some 85,000 km² of arable land, about 52% is irrigated (FAO, 2003). Due to the shortage of surface water during the dry season and absence of diversion structures, groundwater resources are heavily used. For example, about 70% of irrigation water is abstracted from aquifers (Figure 2.1). Groundwater also accounts for nearly 95% of the household water supply. This has led to declining water levels, especially in urban areas. In Dhaka, the capital, the water table has declined at an alarming rate of 2 to 3 meters per year over the last decade. There is also evidence of wells drying up in rural areas.

Despite its agrarian base, Bangladesh is experiencing rapid urbanization. In 2006, only about 25% of the population was urban, but the share is expected to reach 40% by 2025. On average, 85% of urban dwellers and 78% of rural inhabitants have access to safe water supply. Although sanitation programmes have been implemented since the 1970s, on average only 36% of the population has access to improved sanitation (WHO/UNICEF, 2008). In the slums of major cities like Dhaka and Chittagong, access to sanitary latrines is estimated to be as low as 14%. Significant investment in infrastructure is required to improve water supply and sanitation coverage nationwide, especially in expanding urban areas.

About 57% of the rural population and 51% of city dwellers are poor. Poverty alleviation is central to the country's development agenda. Assuring equity in access to water and sanitation services has become critical for addressing poverty issues effectively. Bangladesh has made important gains in the fight against poverty: the proportion of people living below the poverty line has dropped significantly since the 1990s. In general, the depth and severity of poverty have been reduced more successfully in rural areas than in urban ones, although the former still lag far behind the latter in terms of development.

The country's industrial capacity has been growing since the 1970s. Industry's contribution to national income has reached almost 22%. However, industrial growth, especially in textile production and leather processing, has had dramatic consequences for water resources. Many companies withdraw water on their own property and tend to consider it a free commodity, resulting in inefficient water use. Moreover, companies do not monitor or keep a record of the wastewater they generate. Therefore, data on the pollution load of various industries are not readily available.

The potential for hydropower generation or conservation of surface water is limited by Bangladesh's flat terrain and high population density. Kaptai Dam is the only major hydropower facility in the country, and hydropower represents a minimal share of energy production. The upstream parts of the major river basins, however, have potential for water conservation and hydroelectricity generation, especially during the monsoon season.

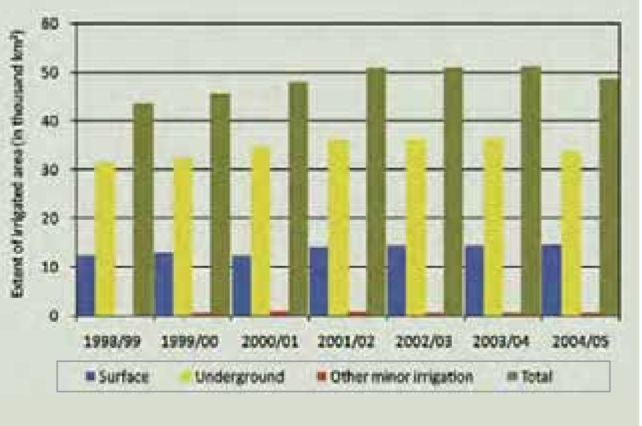
Thermal power stations and some industries use large quantities of water for cooling. When the water is released it is up to 10°C hotter, with adverse effects for both the environment and the operating efficiency of other power plants and industries downstream.

Policy framework and decision-making: action on reform is lagging

As many as 35 central government institutions, affiliated with 13 different ministries, have responsibilities and activities relevant to the water sector.

The National Water Policy (NWPo), published in 1999, aims for a holistic, multisector approach to water resources management and highlights the need to

Figure 2.1 Extent of irrigated surface area, by type of irrigation



Source Ministry of Agriculture, 2004

manage water as a commodity essential for human survival, socio-economic development and environmental preservation.

The NWPo identifies National Water Sector Apex Bodies (NWSABs), which include the National Water Resources Council (NWRC) and its Executive Committee (ECNWRC), the Water Resources Planning Organization (WARPO) and the Ministry of Water Resources (MoWR). The NWSABs are responsible for reforms in the water sector.

In this set-up, the NWRC is the highest national water management body. With 37 members and chaired by the Prime Minister, it is responsible for coordinating all water resources management activities in the country and formulating policy on various aspects of water resources management. The ECNWRC is essentially in charge of guiding national, regional and local water management institutions in formulating and implementing policies and plans for improved water management and investment. WARPO is the sole government institution for macro-level water resource planning and serves as the secretariat of the ECNWRC. The MoWR is the executive agency responsible to the government for all aspects of the water sector (ADB, 2004).

In 2001, the government introduced a National Water Management Plan, prepared by WARPO. The plan's aim is to implement NWPo directives and decentralize water sector management. It provides a framework within which line agencies and other organizations are expected to coordinate planning and implementation of their activities. It includes components for the short term (2000 2005), medium term (2006 2010) and long term (2011 2025). The original intention was to update it every five years, but the first update is pending.

A Water Act now being drafted will incorporate existing water laws related to ownership, development, appropriation, use, conservation and protection of water resources. It is also expected to establish a legal basis for ensuring that water rights are equitable, taking account of all uses and resolving inconsistencies and conflicts among various uses. The Act is expected to be finalized in 2009.

Integrated water resources management (IWRM) is a relatively new concept in Bangladesh. The institutional framework to deal with IWRM is not yet fully developed. Although Bangladesh has a capable private sector and a large network of non-government organizations dealing with water, it needs to create an enabling environment for IWRM. This will not be easy given the highly fragmented water sector and the differing views and priorities of the various agencies regarding the effective use of water resources. Nevertheless, the government is actively implementing a programme called Guidelines for Participatory Water Management.

Despite continuing reductions in funding from development partners, external agencies continue to play an important role in the water sector. A network of local consultative subgroups and other formal and informal mechanisms promotes consultation, coordination and, in some cases, active cooperation among these partners.

The main challenges

Disasters and hazards: Bangladesh is prone to water-related hazards such as floods, cyclones, storm surges, flash floods, droughts, riverbank erosion and rain-induced landslides. In addition, salinity intrusion and waterlogging affect nearly one-third of the country in the south-west. The country suffered approximately 170 disasters between 1870 and 1998. Every year some 20% to 25% of the territory is inundated during the monsoon season (WMO/GWP, 2008). The frequency of major floods (Table 2.2), covering up to 70% of the country, is growing. During the 2007 flood and cyclonic storm, the death toll exceeded 300, with 8 million people displaced and serious consequences for the national economy and people's livelihoods. From 1970 to 2008, 12 major cyclones killed more than 620,000 people and affected 45 million others (MoFDM, 2008).

Because of the almost flat terrain, flood prevention through flow regulation is not an option for Bangladesh. A flood forecasting and warning system established in the 1970s covers all flood-prone areas and provides real-time flood information, with early warning for lead times of 24 and 48 hours. The country's flood management strategies have continuously evolved over the last 50 years, so that now more emphasis is put on other non-structural means of mitigating floods, including controlling development in flood plains and wetlands through legislation and involving communities in flood management (WMO/GWP, 2008).

Bangladesh is also vulnerable to recurrent droughts, such as those that occurred in 1973, 1978, 1979, 1981, 1982, 1989, 1992, 1994 and 1995. The droughts of 1994 and 1995 in north-western Bangladesh led to a 3.5 million tonne shortfall in rice production.

There is potential for regulating river flow in upstream countries to reduce flooding, especially during the monsoon season, and to augment water availability in the

Table 2.2 Socio-economic damage caused by floods in Bangladesh, 1954 2007

Year	Impact
1954	Affected 54% of the country.
1974	Moderately severe, over 2,000 deaths, affected 58% of the country, followed by famine with over 30,000 deaths.
1984	Inundated 53,520 $km^{2,}$ did damage estimated at US$378 million.
1987	Inundated over 50,000 km^2, did damage estimated at US$1.0 billion, caused 2,055 deaths.
1988	Inundated 61% of the country, caused damage estimated at US$1.2 billion, affected more than 45 million people, caused 2,000 to 6,500 deaths.
1998	Inundated nearly 100,000 km^2, affected 30 million people, damaged 500,000 homes, caused 1,100 deaths and heavy infrastructure loss. Damage estimated at US$2.8 billion.
2004	Inundated 38% of the country, caused damage estimated at US$6.6 billion, led to 700 deaths, affected nearly 3.8 million people.
2007	Caused more than 300 deaths. Over 8 million displaced.

dry season, as well as to maintain river levels to facilitate inland waterway navigation and sustain ecosystems. A better regulated flow could also reduce salinity intrusion caused by the decline in freshwater availability in the dry season. This, however, would require strengthened regional cooperation, which has not yet been realized.

River bank erosion takes a terrible toll on people, property and infrastructure. Major rivers, including the Jamuna, Ganges and Padma, consume several thousand hectares of flood plain per year and carry huge sediment loads. As a result, riverbank erosion and siltation occur frequently. An estimated 100 km^2 of land per year has been lost to erosion over the past 20 years. The mostly rural victims of river erosion sometimes lose all their personal belongings and property. Bangladesh also loses several kilometres of roads, railways and flood embankments annually to shifting waterways.

Response efforts for water-related natural disasters still focus primarily on emergency relief rather than on seeking ways to reduce vulnerability to natural hazards. There is a need to strengthen the awareness that risk reduction and disaster prevention make better economic sense than responding to consequences through emergency relief.

Health and water-related issues: The unreliable availability and fluctuating quality of surface water resources prompted the authorities to start developing a groundwater supply system in the 1970s, installing wells in an effort to provide safe drinking water. Bangladesh now has some 9 million wells, of which about half are public wells installed by government agencies (Jones, 2000).

Wells made it possible for about 97% of the rural population to have access to bacteriologically safe water by 2000 and helped lower the infant mortality rate from 156 per thousand in 1990 to 69 per thousand in 2006 (UNICEF, 2008). Unfortunately, particularly in shallow aquifers, the groundwater often contains arsenic at levels that can cause poisoning (arsenicosis). Only about 74% of the rural population has access to arsenic-free water. The naturally occurring arsenic is a major concern for drinking water supply and for animal husbandry and irrigation. It is also a major development constraint in coastal aquifers. In 61 of the country's 64 districts, groundwater arsenic levels are above the permissible limit. It is estimated that between 25 million and 35 million people depend on wells that expose them to the risk of arsenicosis.

The main cause of death in Bangladesh, however, remains poverty-related infectious diseases, which are exacerbated by malnutrition. A marked gender differential in health persists. About 70% of mothers suffer from nutritional deficiency anaemia and over 90% of children have some degree of malnutrition.

Pollution and environmental degradation: Water bodies in Bangladesh receive a large amount of pollution in the form of municipal, industrial and agricultural waste, including pesticides and fertilizers. There is also pollution originating in the upstream parts of the major river basins.

The National Water Policy and National Water Management Plan stress the importance of preserving the natural environment as a condition for the socio-economic development of the country. Both state that care must be taken to conserve goods and services provided by ecosystems, including fisheries and wildlife biodiversity. Yet the country's rivers, flood plains, mangroves and natural lakes continue to deteriorate. The situation is mainly due to poor enforcement of regulations and lack of integration with development activities in other sectors.

The degradation of water resources has a particularly detrimental effect on poor communities that are highly dependent on ecosystems for their livelihoods. In part to address these challenges, the Ministry of Environment and Forest supported the Environment Conservation Act of 1995 and the Bangladesh Environmental Regulation of 1997. These form the basis of modern pollution control in Bangladesh. The revised industrial policy of 2005 also recognizes the need to control pollution as stipulated under the Environment Conservation Act. However, pollution control legislation has only gradually been implemented.

Environmental impact assessments (EIAs) have been carried out in Bangladesh since the late 1990s to minimize the adverse effects of development projects. However, a lack of resources and capacity often hampers the process: most EIA consultants are poorly trained, developers lack the resources to conduct EIAs appropriately and there is inadequate awareness at decision-making level of the benefits of conducting EIAs.

Conclusions

Although significant progress has been made, poverty continues to plague the people of Bangladesh, particularly in rural areas. They depend mainly on land for subsistence and are severely affected by seasonal variation in surface water availability, frequent floods, droughts and cyclones, which cause substantial socio-economic damage. The effects of potential climate change are likely to worsen the situation, especially for the rural poor and the disadvantaged, who already bear the brunt of the consequences. To prosper in the 21st century, Bangladesh needs to improve the way it manages its water resources internally while continuing to work towards better regional cooperation that can offer benefits for all basin countries. A combination of these factors will also play a pivotal role in key economic sectors and in breaking the vicious circle of poverty.

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China: the Yellow River basin

Prolonged drought, floods and severe pollution combined with high demand from booming agricultural, industrial and urban sectors are challenging China to take remedial measures and implement a more integrated approach to managing its water resources.

Setting the scene

The Yellow River is the second longest river in China after the Yangtze River, and the sixth longest in the world. Originating on the Qinhai-Tibetan plateau in western China, it runs for some 5,500 km across the vast North China Plain, traversing nine provinces before draining into the Bo Hai Sea (Map 2.2). Its catchment area of 795,000 km² is home to 110 million people (2000) or about 8.7% of China's population. (The figures increase to 189 million and 14.9% if the flood plain surrounding the lower reach is included.) In 2000, about 26.4% of the basin was urbanized. As the cradle of the northern Chinese civilizations and the centre of China's current political, economic and social development, the river is known as 'the mother river of China'.[1]

Climate change and variability: declining tendency in rainfall

The basin lies in two different climatic zones: arid and semi-arid continental monsoon in the north-west and semi-humid in the south-east. More than 60% of the annual precipitation falls between June and September, during the crop growing season. Average rainfall recorded during 1956 2000 was 454 mm over the entire basin, the lowest level being in the upper reach (372 mm) and the highest in the lower reach (671 mm). There is a declining tendency observed in rainfall over the entire basin (Figure 2.2). During the 1990s, because of prevailing drought conditions, average precipitation was about 7.5% below the long term average (Box 2.1).

According to various models of the effects of climate change on temperature and annual precipitation in the Yellow River basin, annual average temperature could rise by up to 3.90°C and precipitation by 8.67% by 2080 (Xu et al., n.d.). Significant warming could reduce the availability of the water resources (Zhang et al., 2008). Consequently, better water management and adaptation of technology to improve water use efficiency will need to be considered to avoid a critical water shortage in the basin in the coming century.

State of the resource: declining quality and quantity

Average total renewable water resources for 1956 2000 were estimated at 66.1 billion m³, including 17.2 billion m³ of groundwater. However, in 2000, the total available water supply was around 48.4 billion m³.[2] Water demand in the basin sharply increased from 10 billion m³ in 1949 to 37.5 billion m³ in 2006. Groundwater has been extensively exploited in the basin since the introduction of the tube well in the late 1950s. In 2000, groundwater abstraction reached 10.7 billion m³ and there were some 380,000 tube wells in the basin. Consequently,

Map 2.2 The Yellow River basin

[1] Except where otherwise noted, information in this case study is adapted from the draft *Yellow River Basin Case Study Report*, prepared in 2008 by the Yellow River Conservancy Commission, Ministry of Water Resources.
[2] About 3 billion m³ of this comes from groundwater resources outside the basin's topographic boundaries.

Box 2.1 The drought decade

In 1987 the State Council of China established a Yellow River Water Allocation Scheme, to better balance available supply and actual demand by setting a cap on abstraction at 37 billion m^3 per year for average runoff of 58 billion m^3.

During the 1990s, however, drought prevailed throughout the North China Plain, including the Yellow River basin. Two main tributaries, the Wei He and Fen He, were reduced to a bare trickle. Runoff dropped by 24% compared to the long term annual average. Furthermore, flow in the lower part of the river dropped to 14% of its long term average. From 1995 to 1998, for some 120 days each year, there was no flow at all in the lowest 700 km of the river. This had serious repercussions, such as extreme water shortages in downstream provinces, the inability to flush sediment out to sea, and impaired sustainability in the delta ecosystem and coastal fisheries.

Since 1999 the scheme has managed to nominally end absolute flow cutoff, though the flow levels are sometimes so low as to be largely symbolic.

Managing water scarcity is now the number one priority in the Yellow River basin. Given the growing imbalance between supply and demand, it is difficult to meet any new water demand from one sector without lowering supply to the others. It is clear that hard choices will have to be made to address these diverging needs. Since agriculture is by far the largest consumer of water, one unavoidable conclusion is that water supply to agriculture must be reduced and new ways found to make agricultural water use more efficient.

overexploitation of groundwater resources has been a serious concern, particularly in the large and mid-size cities along the Yellow River. Springs in Jinan, once known as 'the city of springs', dried up in the late 1990s. Overall, groundwater levels have dropped significantly in 65 locations due to extensive withdrawals.

The biggest direct impact of a booming economy coupled with rapid industrialization and population growth was on water quality. For example, the amount of untreated industrial sewage being dumped into the Yellow River has doubled since the 1980s to 4.2 billion m^3 per year. The river receives over 300 pollutants, and only about 60% of its course is now fit for drinking water supply. The reduction in quality has caused environmental problems and contributed to the reduction in quantity. Under the Water Pollution Protection Law, a legislative framework for better protection of water resources is being prepared. Necessary regulations and effluent standards have also been formulated. In parallel, the Water Resources Protection Law on the Yellow River Basin is being modified.

As a result of intensive water development between 1951 and 1987, many structures were built in the basin for flood control, hydropower and irrigation. In 2000, there were over 10,000 reservoirs in operation, with total storage capacity of 62 billion m^3; 23 involve large dams. Hydropower production in the basin amounts to 40 TWh per year.

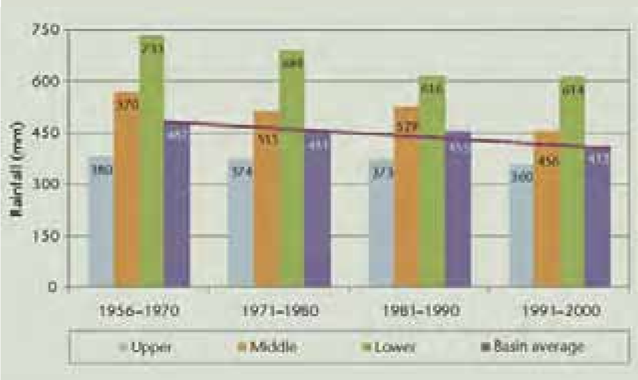
The expansion of irrigation in the basin has been rapid. The irrigated area rose from 8,000 km^2 in 1950 to 75,000 km^2 in 2000. Demand for irrigation water grew steadily, reaching 38.1 billion m^3 in 2000 (Li, 2005; YRCC, 2007). Although the trend stabilized in the early 1980s and agricultural water use has decreased since 2000 in accordance with the Yellow River Water Allocation Scheme, agriculture still accounts for 84% of total water consumption, followed by industry with 9% and households with 5%. The remaining 2% goes for environmental use (2006). When consumption exceeds water availability in the basin, the deficit is met by using groundwater resources outside the basin, as well as recycling.

Policy framework and decision-making

On a national scale, increasing water consumption due to the booming economy has led to water shortages. Consequently, the central government has increased its investment in the water sector and enacted legislation to alleviate water scarcity and assure continued economic growth. Many laws were passed in the 1990s, such as the Water Law, the Soil and Water Conservation Law, the Flood Control Law, the Environmental Protection Law, the Fishery Law, the Forestry Law and the Mineral Resources Law. Some related administrative rules and regulations for water management were also promulgated. In 2002, a new Water Law, emphasizing integrated water resources management, was passed. It has paved the way for a transition from engineering-dominated and demand-based development to a resource-oriented strategy that focuses on water availability.

At basin level, the Yellow River Conservancy Commission (YRCC), established in 1946, manages the water resources of the basin on behalf of the Ministry of Water Resources and the State Council. The YRCC prepares and implements the basin water development plan, decides the allocation of water resources at provincial level and is in charge of constructing and maintaining structures (except large dams) for water resource development and flood prevention.

Figure 2.2 Rainfall in various reaches of Yellow River basin, 1956 2000



Source YRCC, 2002

The water allocation is based on the integrated scheme approved by the State Council in 1987 (see Box 2.1). The provinces in the middle reach of the basin are allocated 22% of the available flow. The remainder is split equally between the provinces of the upper and lower reaches. The allocation is revised annually to reflect seasonal variations in availability.

Since 2000, in line with the most recent approach adopted by the Ministry of Water Resources, water management and related development activities in the Yellow River basin have aimed to integrate the interests of all regions and sectors. Consequently, to balance available water supply and the demand of various sectors, the YRCC developed a water use plan based on medium to long term supply and demand patterns. Annual water use plans are issued to users to assure adequate supply for priority areas, especially in the case of drought. Furthermore, the YRCC established regulations encouraging household users to install water-saving devices, farmers to adopt water-efficient practices and industry to promote techniques minimizing water use and waste discharge. It also established a market pricing system.

The main challenges

Managing sedimentation: The Yellow River gets its name from the colour of the heavy sediment concentration that it transports while flowing through an extensive loess plateau covering 640,000 km^2. The loose soil of the plateau is easily eroded, and it is carried into the Yellow River and its tributaries in massive quantities, particularly during the intense summer rainstorms. The average sediment load that the river carries is 1.6 billion tonnes per year. Of this, only about 25% is carried to the sea, while the rest is deposited on the riverbed. Due to this sedimentation, the riverbed has risen at an average rate of 5 to 10 cm per year and the dikes have been periodically raised in response. The impact of sedimentation on channel dynamics has made management of the river difficult, especially in its lower reaches.

Meeting environmental water requirements: Due to problems associated with the heavy sediment load of the river, the YRCC has made flushing out sediment its most critical environmental priority. Protecting biodiversity and sustaining the wetlands and fisheries at the mouth of the river are also important environmental concerns. The minimum flow required to flush out sediment is calculated as 14 billion m^3, and an additional 5 billion m^3 is necessary for other environmental requirements. With the surface water capacity almost fully used already, and with industrial, urban and agricultural demand growing as well as climatic variation putting further stress on the resource, assuring the required minimum environmental flow, which roughly equals one-third of total average annual flow, is a very difficult challenge to address.

Coping with floods and droughts: Millions of lives have been lost to floods and droughts during the long history of the Yellow River basin. From 206 BC to AD 1949, 1,092 major floods were recorded, along with 1,500 dike failures, 26 river rechannellings and 1,056 droughts. The flat North China Plain, which was formed by alluvial deposits from the Yellow River, was always prone to floods. However, following the establishment of the People's Republic of China in 1949, master planning for flood control and construction of numerous hydraulic structures significantly reduced the vulnerability and losses due to floods.

Embankments, reservoirs and flood retention areas have been established to increase flood control and enable drought management (see Box 2.1). The structural flood control system in China is designed basically for the discharge capacity of the maximum flood recorded since the 1950s for large rivers, and for five- to ten-year flood frequency for smaller rivers.

Non-structural flood control measures have been improved, mainly by developing and applying flood forecasting and warning systems, and by implementing laws, regulations, policies and economic approaches. These include managing river channels and controlling settlement in flood-prone areas. Potential flood risks are being reduced to a level which the society and economy can address, and flood management schemes have been established for extremely large floods.

The YRCC and the provinces of Shanxi, Shaanxi, Henan and Shandong have jointly set up a Yellow River flood control and drought relief headquarters, which provides crucial input to planning for such disasters and mitigating their impact.

Conclusions

Throughout history, the Yellow River basin has been associated with floods, droughts and a rising river bed. With large population increases, combined with rapid growth in all sectors, declining water quality and quantity have had a direct impact on the sustainable socio-economic development of the basin and the health of ecosystems. The water allocation scheme introduced in 1987 and various laws and regulations enacted in the 1990s aim to address these problems while taking a holistic approach that addresses the requirements of all stakeholders. However, the need to strike a balance between water demand for various sectors, sediment management and some serious pollution issues remains the major challenge facing the Yellow River Conservancy Commission and the ministries concerned.

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Pacific islands

The unique geography of the many small islands dotting the Pacific Ocean exposes them to water-related natural hazards compounded by the effects of climate change and variability, including sea level rise. Pacific island countries are struggling to build the capacity to address many challenges, such as developing coherent policy frameworks and integrated approaches to managing scarce freshwater resources.

Setting the scene

There are about 30,000 islands in the Pacific Ocean, only 2,000 of which are inhabited. Many of the populated islands are less than 10 km^2, while some, especially atolls, are less than 1 km^2. The 18 Pacific Island countries and territories considered in this study account for 550,000 km^2 of land and some 7 million inhabitants spread across 180 million km^2 of ocean about 36% of the earth's surface. If Papua New Guinea, a large island country, is excluded, the land mass drops to 88,000 km^2, occupied by 2.6 million people. Of this population, 1.6 million live in Melanesia, 600,000 in Polynesia and 450,000 in Micronesia.[1]

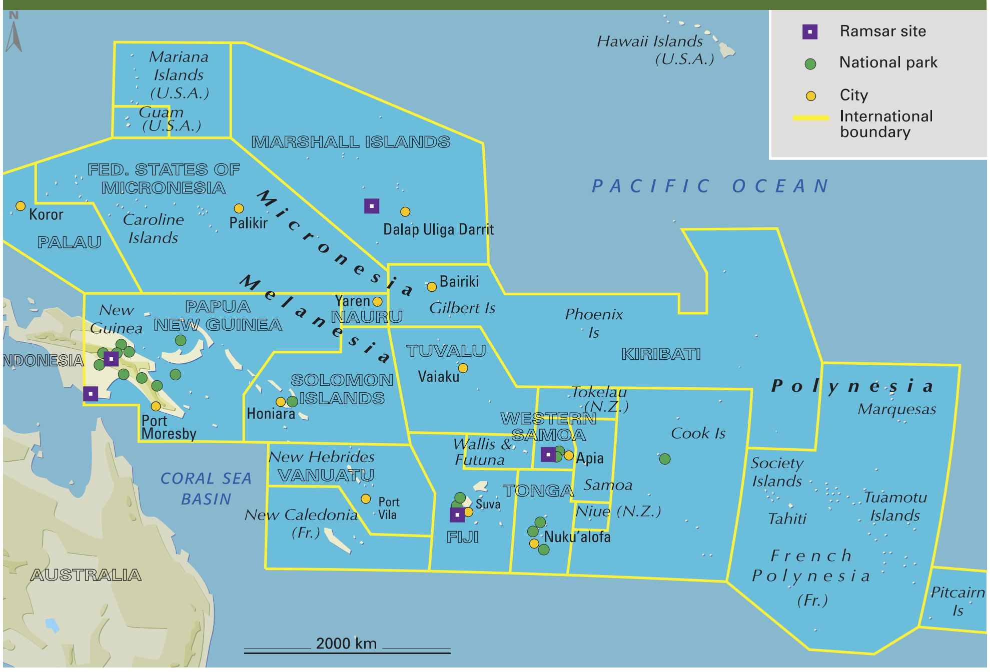
The climate of the small tropical Pacific islands depends on location and season, but is usually hot and humid, except in the cool highlands of some Melanesian islands. The year in many areas is equally divided between the dry and wet seasons. South of the equator in Melanesia and Polynesia, the dry season is from May to October. The wet season, which lasts the other six months, can include a period of cyclones in some locations. North of the equator in Micronesia, these seasons are reversed. Average annual rainfall varies considerably in the tropical Pacific, from over 4,000 mm to less than 500 mm. The higher altitudes of volcanic islands receive more rain, with about a 10% increase per 100 metre rise in elevation.

Climate change and variability: air-sea interactions and frequent storms

Two of the most important climatic influences on small Pacific islands are tropical storms and the El Niño and La Niña phenomena. The natural pattern of El Niño and La Niña episodes has a significant impact on many small islands, producing extensive wet and dry cycles. For example, an El Niño event combined with other climatic and oceanographic conditions brings abundant rainfall in the central Pacific but can cause catastrophic drought in Indonesia, Papua New Guinea and the other Melanesian islands. The reverse condition, known as La Niña, causes serious drought in the low equatorial islands of western Kiribati.

In addition to problems stemming from existing climatic variability, climate change and sea level rise could significantly exacerbate the situation. Climate change scenarios for the Pacific islands vary widely, depending on location and the model used. Most models predict an increase in frequency of El Niño episodes and intensity of cyclones (World Bank, 2000). There is less certainty about changes to rainfall, which could affect the availability of freshwater resources, although a general increase in sea temperature might favour an increase in rainfall for very small islands. Current scenarios indicate a rise in sea level of about 0.2 to 0.4 metres over the next few decades. Even the slightest rise is of great concern for small, low-lying island countries whose maximum elevations are only a few meters above sea level. Tarawa atoll in Kiribati has been the focus of impact studies under various scenarios for sea level rise and climate change. Results of groundwater modelling studies to assess the combined effect of pumping, climate change

Map 2.3 Pacific islands



[1] Except where otherwise noted, information in this case study is adapted from *Pacific Dialogue on Water and Climate: Synthesis Report*, (SOPAC, 2002), prepared by Tony Falkland, Marc Overmars and David Scott.

Box 2.2 Rainwater collection

On small islands with high rainfall (e.g. in Tuvalu), rainwater catchments, using the roofs of houses and some community buildings, are the primary source of freshwater (Taulima, 2002).

On other small islands, rainwater helps meet essential water needs (e.g. for drinking and cooking). During periods when rainfall is scarce or non-existent for months, household rainwater storage may be depleted unless very strict rationing is imposed. On Funafuti, the main island of Tuvalu, rainwater is collected in household and communal tanks. When households experience shortages during extended dry periods, small tankers deliver water from the communal tanks as a public service, for a fee. The Tuvalu Government recently resolved to combat drought by maximizing storage and spending disaster preparedness funds to buy rainwater harvesting tanks for households.

In addition to using roof catchments, islanders sometimes collect rain from specially prepared surfaces such as paved runways (e.g. in Majuro), which may be near storage tanks, and in artificially lined reservoirs (e.g. on some islands in the Torres Strait, between Australia and Papua New Guinea). Simple rainwater collection systems consisting of containers such as plastic barrels placed under the crown of a coconut palm, where rainfall is concentrated, are still used in some places (e.g. outer islands of Papua New Guinea).

and sea level rise indicate that the impact of initial sea level rise on aquifers is not detrimental (World Bank, 2000). This is particularly so when they are compared with the impact of current climate variability, pollution of groundwater from human settlements and overpumping (White et al., 2007).

Preliminary assessment of vulnerability and adaptation in some Pacific island countries in relation to climate change identified improved management and maintenance of existing water supply systems as a high priority, given the relatively low costs associated with reducing system losses and improving water quality.

State of the resource and water use

The limited freshwater supply in small Pacific islands is used for various purposes, including for towns, industrial activities, agriculture and forestry, tourism, environmental needs and mining. Non-consumptive uses include hydropower generation (e.g. in Fiji, Samoa and Vanuatu), navigation and recreation.

To meet growing demand, naturally occurring water resources are supplemented with non-conventional ones. The former are surface water, groundwater and rainwater collection (Box 2.2); the latter include desalination, imports, wastewater recycling and use of seawater or brackish water for selected purposes where potable water is not needed.

Some islands, including in Fiji and Tonga, have imported water as an emergency measure during severe drought. In some instances, people move from water-scarce islands to others nearby with more water. On many small islands, local or imported bottled water is an alternative for drinking water, although it costs more than water supplied by local water authorities.

The use of seawater and brackish waters can conserve valuable freshwater resources. For example, in densely populated parts of Tarawa and Majuro (Marshall Islands), dual pipe systems distribute freshwater and seawater. Seawater or brackish well water is used for baths, power plant cooling and firefighting, as well as in swimming pools.

Recycled wastewater is not a common source in small island countries but is sometimes used to irrigate gardens and recreational areas at tourist resorts and hotels, notably in Fiji and Maldives.

During severe droughts or after natural disasters, coconut water can substitute for fresh drinking water. People on some of the smaller outer islands of Fiji, Kiribati, the Marshall Islands and Papua New Guinea, for example, have survived on coconuts during extremely dry periods. The coconut palm is very salt-tolerant and can continue to produce fruit even when groundwater turns brackish.

Per capita freshwater use varies considerably between and within island states. It depends on availability, quality, type and age of water distribution system, cultural and socio-economic factors and administrative procedures. Although typical water use is of the order of 50 to 150 litres per person per day, leakage in poorly maintained systems can lead to unnecessarily high consumption. Water supply to resorts can also account for a high proportion of total water use on some small islands or parts thereof. Daily personal consumption in such resorts can be as high as 500 litres (UNESCO, 1991).

Many small islands, particularly coral atolls and small limestone islands, generally do not have sufficient water resources for irrigated agriculture, or suitable soil conditions. Irrigation on small islands thus tends to occur on a relatively minor scale except in cases like that of Fiji, where agriculture primarily water-intensive cultivation of sugar cane as a cash crop is the largest water user.

Policy framework and decision-making: highly complex and rooted in tradition

Water governance in small islands is highly complex because of socio-political and cultural structures related to tradition. Many inherited practices, rights and interests concerning the extended family, community, or tribal and inter-island relations (Box 2.3) may conflict with the demands of urbanized societies. Addressing related difficulties requires political will and institutional reform at all levels to create a framework for integrated water resources management (IWRM), as well as behavioural change through long term awareness

Box 2.3 Important considerations of culture and tradition in IWRM

Understanding the subtle fabric of a community's culture improves prospects for projects' sustainability and increases the ability to assure equity in participation. For example, in the traditional Fijian concept of the *vanua*, land, water, customs and human environments are not separate, but rather are indivisible. Water governance thus is not seen as separate from overall governance.

Similarly, projects relying on women's groups would need to be aware that in some communities, women who have married into a village are not seen as belonging to their husbands' village and so are not given the right to participate in decision-making at any level.

Examples from Papua New Guinea also reveal difficulties of working amid various ethnic communities. Social friction between families and villages, for instance, can hinder efforts at cooperation, especially when members of ethnic groups want to work only with their own leaders. In other cases, non-landowners may be indifferent to the sensitivities of landowners (SOPAC, 2007).

and advocacy campaigns, education, training and the like.

IWRM is a relatively new concept for Pacific island countries, and the formal development of this holistic approach within national governance structures is not widespread. Only a few countries have started drafting national IWRM plans. Yet the underlying approach, which involves taking socio-cultural, technical, economic and environmental factors into account in the development and management of water resources, has existed in traditional practices for centuries in Pacific island countries. In addition, since the 1990s it has been increasingly recognized that IWRM is necessary to adequately address competing water demands sustainably.

The major governance-related difficulties facing Pacific island countries are fragmented management structure, with multiple agencies dealing with water resources; lack of an overarching policy; outdated laws; poor administration capacity for integration, stemming from insufficient interministerial cooperation; and inadequate budgetary resources allocated to the water sector (PIFS/SOPAC, 2005). These combine to hamper progress towards preparation of water use efficiency plans and application of IWRM.

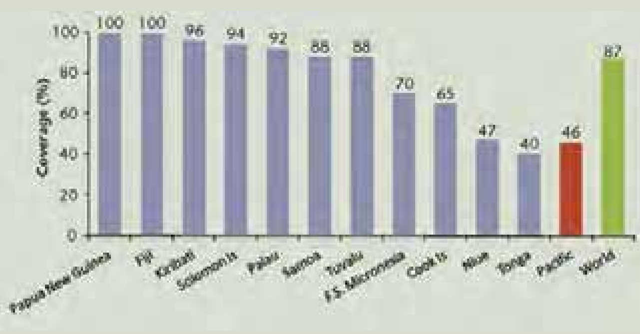
Some major challenges

Meeting the Millennium Development Goals: Pacific island countries have progressed at varying rates on the water and sanitation related Millennium Development Goals (MDG). For example, in 2006 only 46% of the population in the Pacific islands had access to improved drinking water. This corresponds to about half the 2006 global coverage rate. Although less populated countries such as the Cook Islands, the Federal States of Micronesia, Niue, Tonga and Tuvalu have high coverage, the low coverage of Papua New Guinea, which alone represents three-quarters of the region's population, pushes the regional average to levels comparable with those of the least developed regions (Figure 2.3). To make matters worse, rapid population growth, increasing urbanization, damage to water catchments resulting from deforestation, poor waste management practices leading to water pollution, and climate change are expected to exacerbate the challenge of providing access to safe water.

The proportion of households with access to improved sanitation varies greatly among the small Pacific island countries (Figure 2.4). Coverage is below 50% in nearly 40% of the islands. Sanitation systems in the Pacific islands rely principally on pit toilets and septic tanks.

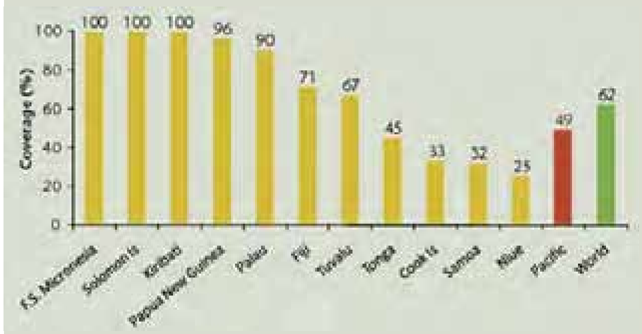
Contamination of water supplies caused by inadequate sanitation, along with other sources of pollution, low water availability and the use of poor quality groundwater as drinking water, leads to outbreaks of diarrhoea, cholera and other infectious diseases, such as hepatitis and typhoid. Installation of affordable sanitation systems and the introduction of social programmes focused on behavioural change are needed in small island communities to improve water quality and human health.

Figure 2.3 Access to improved drinking water supply, by country, 2006



Source WHO/SOPAC, 2008

Figure 2.4 Access to improved sanitation, by country, 2006



Source WHO/SOPAC, 2008

The figures on water supply and sanitation clearly demonstrate the need for regional improvement to meet the MDGs. However, the lack of priority on water and sanitation issues in national development strategies, along with the inadequacy of budgetary resources allocated to the water sector, jeopardize the progress made by Pacific island countries as regards the MDGs. Forecasts indicate that in most parts of the Pacific region, problems resulting from increasing demand for water and increasing pollution of water may be much more significant than the expected effects of climate change (Hay, 2000).

The Mauritius Strategy for the Further Implementation of the Barbados Programme of Action (BPoA+10) has emphasized that water and sanitation should be given high priority on global and national agendas during the 'Water for Life' Decade, especially within small island developing states. The Mauritius Declaration of 2005 highlighted water management and water access issues in Pacific island countries.

Vulnerability to water natural hazards: Pacific island countries are susceptible to floods, droughts and cyclones. Droughts are particularly dangerous as they affect the most vulnerable communities, such as those occupying marginal environments (ESCAP, 2000). Among the most widely used coping strategies are measures taken by individual households to conserve freshwater supplies and seek substitutes. Ideally, water management plans should address the inevitability of climate variability so that droughts do not necessarily require emergency response (SOPAC, 1999). This necessitates adequate hydrological data for analysis and design, as well as financial resources. But there is a significant lack of national capability for conducting water resource assessments in the South Pacific countries, and capacity-building is needed.

Floods are also a significant hazard, especially in high Pacific island countries of volcanic origin. The hazard is greatest when the islands are within the zone affected by cyclones and associated extreme precipitation. Yet in many island countries, flood forecasting systems are either non-existent or not functioning due to poor maintenance.

Tropical cyclones are more frequent in the western and central Pacific than in the eastern Pacific. The very high wind speeds of cyclones are often accompanied by extremely intense rainfall and storm surges, which can destroy buildings and coral reefs, damage crop trees, cause coastal flooding and erosion, and pollute water supplies. It is considered likely that climate change will result in increased cyclone wind speeds and even more damaging storm surges. Several island countries have taken initiatives to develop disaster management plans, often in response to particular disasters. However, resource constraints and the lack of coordinated national response plans continue to reduce the effectiveness of countries' preparedness, for example in Papua New Guinea.

Conclusions

Small island developing states in the Pacific face many constraints, including their small size and remoteness, the limited availability of freshwater, increasing population and insufficient human and financial resources. These, coupled with vulnerability to climatic conditions, sea level rise and the degradation of water quality due to inadequate sanitation and waste disposal, present tough challenges for water resource management. Failure to give adequate attention to water and sanitation issues in national development strategies hampers the region's ability to meet the MDGs and deal with climate variability and change.

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Pakistan: the Cholistan desert

The presence of a semi-nomadic population and 2 million head of livestock in the middle of a fragile desert ecosystem is encouraging the government to explore new ways to improve livelihoods by increasing availability of water resources through capture, storage and treatment.

Setting the scene

Cholistan is the largest of four major deserts of Pakistan. It is bordered on the south by the Thar desert in Sindh province and on the east by the Rajasthan desert in India (Map 2.4). The Cholistan desert covers about 26,000 km^2, which corresponds to 26% of the 110,000 km^2 of the country's total desert area and 3% of its overall surface area. Typical Cholistan vegetation consists of species adapted to a limited water supply. They provide fodder for the inhabitants' livestock and protect the soil against wind erosion. Over the years, continued overgrazing and cutting of shrubs and trees for firewood and temporary shelters have reduced the vegetative cover, so that only about 20% of it remains.[1]

State of the resource and use: rainwater harvesting and migration

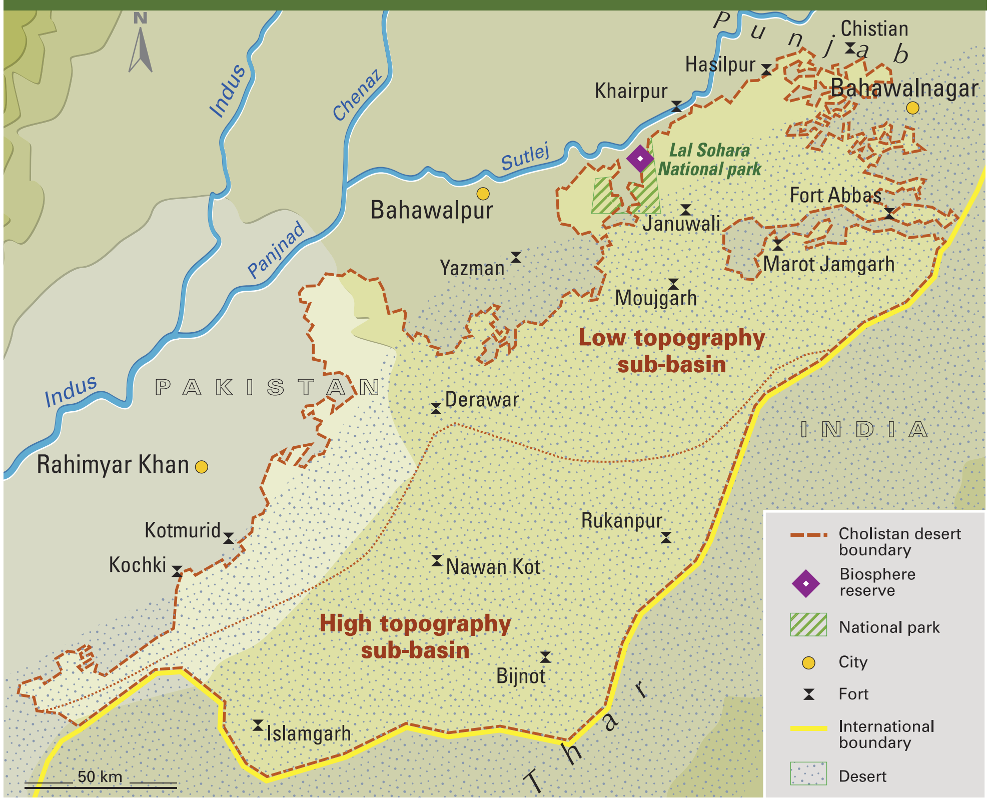
While most of the rainfall is received during the monsoon months of July through September, smaller quantities of rainfall sometimes occur in winter. The average annual rainfall in the desert ranges from 100 to 200 mm. Consequently, freshwater availability is very limited. There are no perennial or ephemeral streams, and most of the groundwater is saline with a medium to high range of dissolved solids that make it generally unfit for drinking (Akram and Chandio, 1998). High salt concentration also makes groundwater impossible to use even for saline agriculture without costly treatment. Because of the extreme aridity, the local people and their livestock are migratory (PCRWR, 2004). The only source of freshwater for about 110,000 inhabitants and their approximately 2 million head of subsistence livestock is the occasional rainfall. Fortunately, the average annual potential of 300 million m^3 for rainwater harvesting is more than sufficient to satisfy the combined water demand of the people and livestock (Table 2.3). To make the best use of this potential the herders have found ponds known locally as *tobas*. These store runoff water for use during the dry periods. Harvested rainwater is also stored for household use in large circular or rectangular tanks called *kunds*.

National legislation and responsibilities

In Pakistan, the provision of water for agriculture, industry and households has historically been the responsibility of provincial governments. However, provision of drinking water for the inhabitants of deserts and their livestock has not received much attention at this level. When runoff rainwater collected in *tobas* does not last through the dry season, the inhabitants migrate with their livestock to the edges of the desert, where perennial sources of water are available. These migrations impose severe physical hardships on families and create financial risks due to loss of livestock.

With Pakistan's population growing and the need to produce more food increasing, the national planning and development agencies are turning their attention to the vast expanses of the deserts. To provide more water

Map 2.4 The Cholistan desert



[1] Except where otherwise noted, information in this case study is adapted from the draft *Cholistan Desert (Pakistan) Case Study*, prepared in 2008 by the Pakistan Council of Research in Water Resources.

Box 2.3 Prospects for using renewable energy to desalinate water

Saline groundwater bearing dissolved minerals in amounts ranging from 400 to 20,000 parts per million is abundantly available at shallow depths throughout most of the Cholistan desert. Using reverse osmosis membrane technology, salt content can be lowered to levels that are acceptable for drinking and household use. The Pakistan Council of Research in Water Resources has built a desalination plant at the Dingarh Research Station that can treat up to 50 m^3 (50,000 litres) per day at a unit cost of about 1 Pakistani rupee (US$0.01). This is affordable for drinking water but quite high for livestock and other agricultural use. The long term increasing trend in the price of fossil fuel, combined with the availability of large amounts of solar energy and heat in the desert, argue strongly for research to find ways of using solar and thermal energy with reverse osmosis membranes to obtain drinkable water from saline groundwater in the desert.

and enhance water use efficiency, projects aimed at improving rainwater harvesting and reducing evaporation loss have been initiated. At the same time, to assure the economic development of the people living in the Cholistan desert, integrated approaches such as improved rainwater collection and rangeland management, as well as use of saline groundwater for fish production, are being studied and implemented to maximize benefits from water, land and livestock.

The main challenges

Health concerns: *Kunds* are concrete structures built to store rainwater for human consumption. There are about 200 *kunds* in the Cholistan desert. Generally, the stored water stays clean unless there are external contaminants. Analysis of water samples from several *kunds* showed that water was being polluted by human and livestock waste transported in runoff.

Drought and water availability: There is no reliable hydrometeorological data from which to draw conclusions about the frequency and duration of droughts. Estimates based on the recollections of longtime residents of the Cholistan desert indicate, however, that droughts are quite common and can last from a few months to a few years. Because of the limited availability of surface and groundwater resources, locals and government officials are working together to develop the potential of rainwater harvesting to meet current water needs and provide for future economic development. Various storage units, such as *tobas*, *kunds* and ponds, are in place. However, while *tobas* remain abundant, only 600 of the 1,600 existing ones are functional due to high sedimentation rates. *Kunds* are less susceptible to this kind of problem, but water quality issues limit their use. To increase storage capacity and reduce contamination, the government has built ponds equipped with slow sand filters, which have performed well. This has increased rainfall storage to 4 million m^3 per year. Given the 14 million m^3 in water supply capacity of wells, available water resources are sufficient to meet the annual water demand of inhabitants and their livestock. Nevertheless, the global scenario of climate change and climatic variation and their effect on water resource availability, coupled with the increasing price of fossil fuel (mainly used for pumping), has prompted the government to consider low cost solutions based on renewable energy sources (Box 2.3).

Conclusions

In an arid environment where there can be as few as three rains a year, freshwater resources become critical not only for socio-economic development but also simply for survival. While Pakistan's government has been making efforts to find good-quality groundwater and create rainwater storage units in parts of the Cholistan desert, water scarcity persists because of the size of the desert, the poor quality of the groundwater, high evaporation rates, contamination, the low storage efficiency of *tobas* and the reduction in their capacity due to siltation. Severe water scarcity forces the people of the Cholistan to migrate with their herds in pursuit of water and grazing land, which entails social and economic hardships. Although authorities have carried out projects intended to diversify the economy, animal husbandry remains the main source of livelihood. The

Table 2.3 Rainwater availability and estimated water demand in the Cholistan desert

	Population[1] (million)	Human water demand[2] (million m^3)	Livestock[3] (million)	Livestock water demand[4] (million m^3)	Available potential for water storage (million m^3)	Surplus water available for other uses[5] (million m^3)
1990	0.08	0.50	1.52	11	215	204
2000	0.10	0.670	2.04	15	273	258
2005	0.12	0.76	2.30	17	220	203
2006	0.12	0.78	2.36	17	369	352
2007	0.12	0.80	2.40	18	227	208

1 Population is based on actual figures
2 Human water demand is estimated at 18 litres per person per day
3 The number of livestock is estimated at 20 head per capita
4 Livestock water demand is estimated at 20 litres per animal per day, on average, for small and large ruminants; actual demand may be less than the calculated value
5 The number indicates remaining freshwater potential that can be tapped if the rainwater harvesting capacity is improved

success of integrated approaches designed to boost the inhabitants' health and the economic opportunities available to them, while also improving the quality and availability of water, will require determination and continuous support on the part of the government.

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Republic of Korea: the Han River basin

Efforts to respond to new pressures and expectations stemming from the economic success of this developed country include water sector reforms, while measures to address shifts in demand and competition between upstream and downstream interests would benefit from the presence of a central coordinating mechanism.

Setting the scene

The Republic of Korea is located at the eastern tip of the Asian continent, where it is bounded on the north by the Democratic People's Republic of Korea. In the east it is characterized by high mountain ranges, whereas the west is composed of flat coastal plains. The annual average precipitation is about 1,200 mm, 70% of which falls during the flood season from June to September. The Han River basin, located in the centre of the Korean Peninsula (Map 2.5), accounts for 23% of the territory of the Republic of Korea and is the country's largest river basin, covering some 23,000 km². The Han River region is divided into the main Han River basin and the Imjin River basin; this case study focuses only on the Han River basin.[1]

The capital, Seoul, one of the world's largest cities, is located in the Han River basin. The population of the basin, now 41% of the national total, almost tripled between 1966 and 2005, from about 7 million to almost 20 million. Nevertheless, urban areas account for just 1% of the basin. Forests make up 78%, cultivated areas 16%, and grasslands and water bodies 5%. The Han River basin is considered the heart of South Korea.

Climate change and variability: fewer rainy days but heavier storms

Statistical analysis of rainfall data in the Han River basin reveals two noticeable changes since the early 1970s: a rapid increase in heavy storm frequency and an increase in storm intensity. The number of heavy storms associated with intense rainfall of 100 mm per day or above went from 222 in 1971 1980 to 325 in 1992 2001. In addition, the number of rainy days has decreased while precipitation has increased, which means greater likelihood of floods.

State of the resource

Annual renewable water resources in the Han River basin are estimated at 16 billion m³. As of 2003, 8.5 billion m³ of this amount was actually in use. Owing to the high rate of urbanization, the household sector which accounts for 2.8 billion m³ (33% of overall consumption) is the number one source of consumption, followed by agriculture (1.6 billion m³ or 19%) and industry (0.8 billion m³ or 9%). The remaining 3.3 billion m³ is allocated for environmental purposes. The quality of surface water varies by location, with downstream Seoul being the worst. However, implementation of the Environmental Water Management Master Plan should make a big difference throughout the basin: it aims to

Map 2.5 The Han River basin

[1] Except where otherwise noted, information in this case study is adapted from the draft *Han River Basin Case Study Report*, prepared in 2008 by the Ministry of Land, Transport and Maritime Affairs (formerly Ministry of Construction and Transportation).

Box 2.4 Equity tools: water use charges and basin management funds

The quality and quantity of water resources, as well as land development decisions, have always been sources of contention between upstream and downstream users. What usually happens is that tighter restrictions are imposed on upstream users, who may suffer financial losses due to land regulation practices meant to preserve water quality for downstream uses. Meanwhile, downstream users usually have more flexibility in their use of water and land resources. This situation violates the principle of equity.

In the Republic of Korea, the 'polluter pays' principle is reinforced by the 'user pays' principle, which requires downstream residents to pay additional water use charges. Collected charges have been used to create basin management funds, beginning in the Han River basin in 1999, (Table 2.4), and in three other basins in 2002. The funds have been used since 2003 to actively support water quality improvement projects, community awareness programmes and the installation and operation of environmental facilities. By the end of 2004, some US$350 million (515.6 billion won)* had been spent on community support projects and US$545 million (804.6 billion won) on the installation, operation and maintenance of environmental facilities.

* US$1 equalled about 1,475 won as of December 2008

Table 2.4 Han River water use charges, 1999 2006, in million US$ (won)

1999	2000	2001	2002	2003	2004	2005	2006	Total
18.8	118.9	156.4	167.3	182.1	192.4	206.3	229.1	1,271.2
(27,675)	(175,358)	(230,688)	(246,741)	(268,644)	(283,732)	(304,326)	(337,908)	(1,875,072)

bring drinking water source quality to 'good' or 'better' (based on biochemical oxygen demand) by 2015 by increasing the number and capacity of wastewater treatment facilities. To promote more efficient use of water resources in the city of Seoul, wastewater recycling and rainwater collection are required by law.

Agricultural water use in the Han River basin accounts for about 10% of water use for agriculture in the Republic of Korea. Rice fields alone consume 70% of the total. As the Han River basin receives some 74% of its annual runoff in just four months, storing water is crucial for meeting year-round needs. Consequently, there are 724 reservoirs, primarily serving the agricultural water requirements in the basin. Of these, 127 meet the international standards for large dams. The increase in agricultural water withdrawal is expected to be stabilized or even reversed as a result of the long term master plan for water resources, which forecasts a reduction in cultivated area. In parallel, to minimize water loss in agriculture, a plan for irrigation channel improvement and agricultural water management automation is being implemented. As of 2003, almost 40% of the irrigation channels had been rehabilitated, and the share is expected to reach 55% by 2011.

The Republic of Korea has a much larger water footprint than figures suggest: statistics indicate it is the world's thirteenth largest importer of virtual water, and number five in terms of net imports of virtual water, taking both imports and exports into account (Hoekstra and Hung, 2002). Some 74% of its virtual water imports are in the form of grain.

Access to water and sanitation facilities improved rapidly as what is now the Republic of Korea became industrialized. By the end of 2007, 92.1% of the population had access to safe drinking water, compared with 18% in 1945. Access to sanitation facilities increased from 6% in 1979 to 85.5% at the end of 2007. Subsidized water rates and extended grace periods before service cutoff, available to the poor and disadvantaged, help assure a minimum standard of living for everyone.

Three multipurpose dams and eight hydroelectric dams are located in the Han River basin. The Government of the Republic of Korea has identified energy efficiency as a key priority and has started promoting an increase in the share of renewable energy in overall energy production, setting a goal of 5% by 2011. Hydropower, one of the most conventional forms of renewable energy, is getting a boost through measures aiming to increase the capacity and performance of existing facilities. In 2006, the share of hydropower in overall energy production was 1.4%, down from 5.3% in 1980.

While the rapid increase in agricultural, industrial and municipal water consumption in the Han River basin has been slowing, the environmental value of water is getting more political attention and the share of water for environmental purposes is increasing. Since the beginning of the 2000s, this positive trend has been reflected in policies and in various large river environment restoration projects. Implementation of water use charges and creation of watershed management funds also helped increase water use efficiency, especially in industry, and protection of water resources was improved as well (Box 2.4).

Although the Han River basin is well endowed with water resources and no shortage is expected in the near future, the overall picture is different in the rest of the country. In the past, increased demand could be met by developing new water resources, but conditions no longer allow this. Although agricultural and industrial water use is expected to fall, there is no national or regional coordinating institution capable of redistributing and reassigning traditional water rights to different sectors. This lack seems to be a major obstacle to optimum use of the resources.

Figure 2.5 Variations in the flood damage index, 1982-2003

Note The flood damage index for a basin is calculated by taking into account the number of human casualties, property damage and the extent of inundated area The index has no unit and its value ranges from 0 to 3
Source Ministry of Land, Transport and Maritime Affairs

Policy framework and decision-making: Poor coordination

In the Republic of Korea, water management has not been adequately decentralized. Local authorities merely execute policies set by the central government. The lack of an integrated approach means each ministry works more or less in a vacuum, developing and executing work plans without much interaction. Local governments face complications in executing the national water management plan because functions and responsibilities are distributed among a number of agencies. The main problem lies in the absence of a body or a mechanism to coordinate the tasks of the organizations in charge of water resource management. To address these challenges, since 2000 the water management system has been undergoing restructuring towards a more holistic approach promoting involvement by local governments, public organizations, the private sector and other stakeholders, including local communities. Notable outcomes of this reform include formation of local and basin networks and increased voluntary river restoration efforts.

A recently proposed Water Management Act, taking the basin as the principal watershed management unit, would have provided for the preparation of a national integrated water resources management plan and established basin commissions and a national water management commission. However, the Act did not win approval in the National Assembly in 2008. A national commission such as that proposed in the Act could play an important role in bringing together the agencies responsible for water management, and thus serve as a platform for settling conflicts among different land and water users.

The main challenges

Sharing water resources: Two tributaries of the Han River the Imjin River and the northern part of the Bukhan River are shared between the Republic of Korea and the Democratic People's Republic of Korea. Although negotiations are ongoing, South and North Korea have not yet reached agreement on joint development of common water resources. Meanwhile, upstream water development efforts are having a negative effect on water availability in the south. The hydrological properties of certain parts of the basin have not been studied adequately, mainly because of the demilitarized zone between the countries. Although the potential for waterways exists in the Han River basin, none have been developed due to political and environmental problems.

Coping with water-related disasters: In the Republic of Korea, although the extent of floods has decreased thanks to continuous improvement in flood management, the economic damage has increased significantly (Figure 2.5). This is basically due to dense urbanization and encroaching development on the river's natural flood plains. Non-structural measures such as early warning systems have helped reduce the number of casualties, but the number of people vulnerable to floods is increasing, not only due to growth in the urban population but also because the society is aging, which means more individuals at greater risk from the impact of frequent flash floods.

Conclusions

The Han River basin is considered the heart of the highly developed Republic of Korea. Given the availability of sufficient water resources, the water demand from various sectors does not pose a critical problem in terms of quantity, at least for the time being. Rather, the outstanding issues are at the national level, where a national commission is needed to coordinate the agencies responsible for water resource management and the sharing of transboundary waters. Although current water sector reforms and a possible future Water Management Act will address the coordination challenge, dealing with transboundary issues will require more effort.

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Sri Lanka: the Walawe River basin

In an area hard hit by the 2004 tsunami, integrated approaches and community management of resources are examples of the tools being applied to reduce poverty and environmental degradation.

Setting the scene

Sri Lanka is an island country in the Indian Ocean with a total land area of 65,600 km². About 78% of its 20 million inhabitants live in rural areas. The terrain is mostly coastal plains, with mountains rising in the south-central part. Rainfall varies greatly, from about 900 mm in parts of the dry zone to about 6,000 mm in the central hills. The dry zone, defined as the area that receives less than 2,000 mm of annual rainfall, covers 80% of the land.[1]

There are 103 distinct river basins. The Walawe River basin, located in the south-east, has an area of 2,500 km². Covering 4% of the total land mass of the country, it is one of Sri Lanka's biggest basins (Map 2.6).

Recent water resources development has linked some adjacent small river basins to the Walawe basin. Thus, the total area covered in this study is 3,300 km² and includes the Malala Oya, Kachchigal Oya and Karagan Oya.

The study area has a population of about 650,000. To address poverty, the Sri Lankan Government has begun paying more attention to industrial and commercial development of the region.

Climate change and variability: much less rainfall for agriculture

Nationwide, statistical analysis indicates that air temperature increased by 0.016°C per year between 1961 and 1990. A similar rise was observed in the Walawe basin, which lies in the dry zone. A decline in rainfall is mostly noticeable during the north-east monsoon and the second inter-monsoon period, which bring the bulk of the rainfall to the dry zone. Measurements covering the last 50 years show that rainfall has decreased by at least 18% at some stations and by as much as 42% at others. Nevertheless, there is still a debate revolving around climate change and other external factors affecting water availability. As about 45% of the employed population is in agriculture, the changes to rainfall and runoff patterns are having a pronounced impact not only on water availability but also on farm livelihoods. The impact is most pronounced on small-scale water diversions in the upper Walawe basin and on small tank cascade systems, which usually depend on rainwater for their supply and do not have much carryover storage.

Map 2.6 The Walawe River basin

State of the resource and water use

The annual flow of the Walawe River is 1.5 billion m³, or 3% of the country's total renewable water resources.

Agriculture is the biggest water user in Sri Lanka. In the Walawe basin, more than 95% of the total volume of water diverted is for irrigation. To address the high level of water consumption, programmes are being put in place to improve efficiency through better scheduling, participation of stakeholders in water management, augmentation of water supply to small reservoirs, improvement of groundwater recharge and rehabilitation, and modernization of irrigation systems. High yielding rice varieties with a shorter growth period have been developed locally to reduce water use. Although limited, some improvements in efficiency have been observed as a result of these efforts. In the mid-1980s attempts to introduce a fee for irrigation water ended in failure. As the issue is socially and politically sensitive, the government is not keen to repeat the experiment. But some farmer organizations collect fees from their members, which are used to improve irrigation systems.

Irrigation and other developments have brought environmental problems, such as contamination and unsustainable use of groundwater, loss of cropland within coastal wetlands due to salinity, and degradation of coastal ecosystems. Excessive drainage has prompted residents to open lagoons to the sea. The drainage and artificial sea

[1] Except where otherwise noted, information in this case study is adapted from the draft *Walawe River basin (Sri Lanka)*, prepared in 2008 by the Ministry of Agriculture, Irrigation and Mahaweli Development.

Box 2.5 Community participation in water project management

Because rural facilities tend to be relatively small and widely dispersed, it is difficult for centralized agencies to manage them. A more appropriate approach is to actively involve the beneficiary communities in the management of their own water resources. To this end, Sri Lanka recently established independent, voluntary community-based organizations (CBOs) to manage rural water projects serving a population of 6,000 or fewer. The CBOs are formed during the early planning stages, and capacity-building is carried out to enable them to take over responsibility for operations and maintenance once the system is operational. Among projects promoting community management of rural water supply in the Walawe basin are the Community Water Supply and Sanitation Project and the Third Water Supply and Sanitation Project. CBOs fund operations and maintenance of these projects through tariff structures specially formulated for each individual system. In rural and small-town piped water systems, the tariffs aim for full cost recovery, and in some cases may be higher than the national water tariff. Some CBOs have already managed to recover about 20% of the capital cost. The achievements thus far of CBOs are promising, and their contribution lessens the government burden in achieving the relevant MDG targets.

outlets have caused fluctuations in salinity. In addition, the drainage has resulted in siltation and decreased the lagoon area. Chemicals contained in agricultural runoff have also contributed to the deterioration of water quality. All these factors combine to adversely affect fish populations and thereby the livelihoods of those who depend on fisheries and tourism. These negative observations have been confirmed in several coastal wetlands, including Bundala National Park, the first Sri Lankan wetland listed as a protected area under the Ramsar Convention.

The recently concluded Uda Walawe Left Bank Development Project introduced innovative water management measures that should address some of these problems. The measures include night storage reservoirs to minimize drainage losses from the irrigation system. Other successful technological innovations in the Walawe basin that have the potential to be replicated elsewhere in the country include the Mau Ara and Weli Oya development projects, where the storage capacity of small village reservoirs was used in lieu of larger storage structures.

Hydropower generation was the main source of energy production in Sri Lanka until a few decades ago. However, frequent droughts since the late 1990s have made hydropower a less reliable source, and electricity generation has shifted towards petroleum-intensive operations. Nevertheless, proposals have been prepared to make maximum use of the hydropower potential of the water infrastructure. There are four hydroelectric power plants in the Walawe basin, with total installed capacity of about 130 MW, representing about 10% of the country's overall installed hydropower capacity. In 2006, 78% of the households in Sri Lanka had access to electricity.

District values indicate that access to safe drinking water in the Walawe basin ranges from 73% to 83%, which compares well with the national average of 85%. However, as piped water is not available around the clock in several locations and there are quality problems during dry periods, those percentages represent an optimistic upper limit. In 2006, about 92% of Sri Lanka's population had access to improved sanitation, and estimates for the study area ranged from 85% to 95%. Rural settlements have less drinking water and sanitation coverage than urban settlements, but community involvement programmes are being developed to improve the situation (Box 2.5). Overall the country is on track to achieve the Millennium Development Goal concerning access to safe drinking water and improved sanitation.

Current water consumption in industry is not significant in the Walawe and adjacent basins, though there are plans for major industrial development that could increase industrial water demand in the future.

Policy framework and decision-making

Policy-making in Sri Lanka's water sector has been only moderately successful. Studies in the early 1990s identified policy gaps and institutional problems in the sector, including much overlap among a multiplicity of institutions and laws. Since 1996 several attempts to prepare a national water resources policy have been made, but progress stalled around 2005 before a comprehensive policy was produced. Despite substantial policy development in such allied sectors as environment, agriculture, and the management of watersheds, rainwater and disasters, the policy gaps make it difficult to adequately address the important issues of deteriorating water quality, the need to regulate water extraction and the lack of full stakeholder participation in water resources management.

Consequently, Sri Lanka does not yet have a national plan formulated on the basis of integrated water resources management planning and development. The new Dam Safety and Water Resources Planning Project, launched in August 2008, is expected to address some of these concerns by formulating a master plan for national water use.

In the Sri Lankan agricultural sector, farmer participation in decision-making at project level has improved over the years, resulting in better accountability and greater transparency in use of funds. In the case of the Walawe basin, the Mahaweli Water Panel manages water resources to achieve optimum benefit from irrigation as well as from hydropower. It decides water allocation for irrigation from the reservoirs of hydropower facilities. Though farmers and households are not directly represented in real-time decision-making, their interests are usually covered by the service delivery agencies.

Coordination among stakeholders is critical in the Walawe basin because of the area's substantial contribution to agriculture, hydropower generation, water-related risk management and expected industrial development. Case studies from Sri Lanka in the first and second editions of the *World Water Development Report* also highlighted this issue (UN-WWAP, 2003; UNESCO-WWAP, 2006*a*, 2006*b*).

The main challenges

Healing the wounds: The worst disaster of recent times, the Asian tsunami of 2004, devastated the coastal regions of the Walawe basin. Prior to the tsunami, Hambantota district, which forms the downstream portion of the Walawe basin, accounted for 5.5% of the fishing fleet and 12.9% of total marine fish production in Sri Lanka. In addition, about 93% of the people working in the fisheries lived in coastal areas, which greatly increased the tsunami's impact on the sector.

Official statistics indicate that the tsunami affected 16,994 families, caused more than 3,067 deaths and left 963 people missing in Hambantota district. Total damage to the district was estimated at US$220 million. More than 90% of the fishing fleet and 3.9 million m^2 of farmland were affected. Today, most of the fishing fleet and housing have been restored, together with public infrastructure.

In addition to the rebuilding, several developments in policy and institutional development can be observed. A disaster management law was enacted in 2005, and institutions have been strengthened. Also, community participation in disaster management is now actively promoted in the Walawe basin. Through such activities, flood-prone areas and vulnerable families in the coastal plains have been identified. Emergency action plans have been developed with the participation of the communities involved.

Poverty reduction, showing signs of improvement: Poverty is a general problem in Sri Lanka. Although the share of the population living on less than US$1 per day was only 5.6% in 2001 2004, 41.6% of the population lives below US$2 per day. In the poorer areas of the country, such as the east and south, where the Walawe basin lies, the poverty rates are higher than the national average. The percentage of population below the poverty line ranges from 13% to 33% in the Walawe basin, while the national average is 15.2%.

In the last 50 years, thanks to major investments in rice production, provision of health facilities, safe drinking water and improved sanitation, the infant mortality rate has been reduced and life expectancy has increased. Studies in the Walawe basin indicate that water resource development has helped reduce poverty levels. However, despite a declining percentage of poor households over the last decade, current statistics indicate that Sri Lanka is not on track to achieve the MDG target on poverty by 2015; poverty remains a major challenge.

Safeguarding public health: Some areas of the Walawe basin were almost unpopulated for centuries due to malaria. Government-sponsored campaigns to address the problem have made noteworthy gains. For example, the number of cases was 591 in 2006, down from 210,000 in 2000. Furthermore, while malaria claimed 76 lives in 2000, no deaths were reported in 2006. On the other hand, the incidence of water-related diseases such as Japanese encephalitis, leptospirosis (rat fever) and dengue have increased significantly in recent years. Reports show that leptospirosis resulted in 150 deaths from January to September 2008, including patients from the Walawe basin. Furthermore, Ratnapura and Hambantota districts in the Walawe basin are identified as being high risk areas for dengue, where the incidence of disease has increased by 35% over the corresponding period in 2007. In 2008 there were 18 dengue-related deaths. Continuous and persistent national and international input is needed to combat these water-related health problems.

Capacity-building: The Sri Lanka National Water Development Report (UNESCO-WWAP, 2006*a*), prepared for the second *World Water Development Report*, concluded that a substantial amount of international investment had been made in infrastructure development. However, funding in several water-related subsectors, such as irrigation management, water quality monitoring, pollution control and water related research, is not adequate. Serious investment in research and capacity-building is considered the most urgent priority, as it will make the earlier investments sustainable.

The knowledge gap in the water sector is a constraint for water resource management. Although noteworthy changes in climate and weather patterns are being observed, scientific conclusions about trends and future scenarios are not being drawn. Recent studies have exposed the inadequacies of the existing databases in this regard. Similar gaps exist concerning water-related issues. Although water quality problems are believed to be responsible for some ailments peculiar to agricultural areas in the dry zone, it is not clear what type of pollution is causing them, and hence effective action to control the pollution is not being taken. The gaps in databases and research outputs constitute a constraint on mobilization of the community, policy-makers and decision-makers to meet water challenges. These issues, as well as deficiencies in access to data and its dissemination, are highlighted in the earlier *World Water Development Report* case studies cited above.

Conclusions

The major challenge in the Walawe basin is to address environmental problems while assuring the sustainable socio-economic development essential for alleviating poverty. Successful but isolated water sector innovations in the basin give hope for the future; however, nationwide problems, such as gaps in capacity and the knowledge base as well as the absence of any comprehensive water policy, seriously handicap the country in its ability to address current challenges and make the adaptation needed to cope with future pressures from climate change and climatic variation.

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Uzbekistan: the Aral Sea basin

Regional cooperation and moves towards efficient water use are the keys to recovering from loss of livelihoods, mass migration, rampant pollution and ecosystem damage resulting from unsustainable irrigation practices and other legacies of the past.

Setting the scene

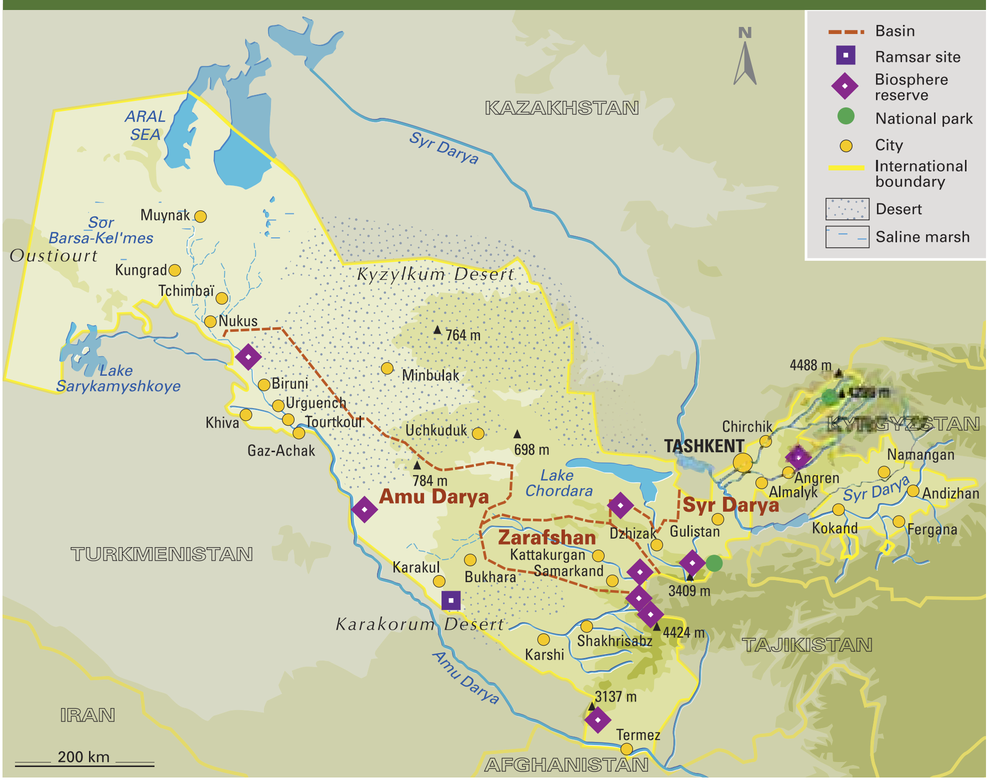
Uzbekistan is located in Central Asia, bordered by Afghanistan and Turkmenistan to the south, Kyrgyzstan and Tajikistan to the east and Kazakhstan to the west and north (Map 2.7). The South Aral Sea, which formed in the late 1980s as the main Aral Sea (a saltwater lake) shrank, lies largely in northern Uzbekistan. The population of around 27 million (2007) occupies a land area of 447,400 km². Uzbekistan is a dry country with a continental climate.[1]

Climate change and variability: higher temperatures, more rainfall, increased flood risk

The Aral Sea basin contains over 14,752 glaciers with a total area of some 1,043 km². The ones located in Uzbekistan account for 1.1% of the total glaciated area in Central Asia. Recent assessments indicate that the country's glaciers and ice reserves are receding. Since 1957 the glaciers have shrunk by almost 20%, losing 104 billion m³ of water. A fluctuation in water resources ranging from -7% to +3% is forecast for the near future, which falls within the range of normal variability. An expected rise in ambient temperatures is likely to be accompanied by higher rainfall, potentially causing a 30% to 35% increase in floods by 2030.

Another negative impact of increasing temperatures will be higher evaporation rates and a likely rise in agricultural water consumption of up to 10%.

Map 2.7 Uzbekistan



State of the resource and water use: unsustainable agriculture is predominant

The bulk of freshwater resources in Uzbekistan comes from the Syr Darya, a river originating in Tajikistan; the Amu Darya, which flows in from Kyrgyzstan; and, to a lesser extent, the Kashka Darya and Zarafshan rivers. Available freshwater resources in Uzbekistan are estimated at 67 billion m³ per year. Of this amount, 55.1 billion m³ comes from surface waters and

[1] Except where otherwise noted, information in this case study is adapted from the draft *Uzbekistan Case Study Report* (unpublished), prepared in 2008 by the Institute of Water Problems at the Academy of Sciences.

7.8 billion m^3 from groundwater. The rest is reclaimed in the form of return water from leaking irrigation channels and infiltration from irrigated fields, which collects in localized depressions.

Agriculture plays an important role in the economy, employing over 60% of the population. Although only 10% of the 444,000 km^2 of arable land is irrigated, the irrigation efficiency is low, so this water demand amounts to 92.5% of overall annual water consumption in Uzbekistan (Table 2.5).

Table 2.5 Water use, by sector, 2001

Water use	Annual demand (billion m^3)	Share in overall consumption (%)
Agriculture	52.10	92.5
Households	2.90	5.2
Energy production	0.12	0.2
Industry	0.77	1.4
Fisheries	0.40	0.7
Total	56.29	100.0

With demand for water growing in all sectors, it will be impossible to meet the combined needs in the medium term. Projections based on existing consumption trends indicate there could be a water deficit of up to 14 billion m^3 by 2015. Although the growth in household and industrial water demand could be met through increased efficiency, the need to reduce agriculture's overall share is clear. Despite a decision of the Cabinet of Ministries not to revise water allocation to the various sectors for 15 years, a regulation adopted in May 2007 is aimed at developing a programme of water conservation and efficient use of water resources.

Policy framework and legislation

The main legislation governing water management is the 1993 Law on Water and Water Use. Uzbekistan is in the process of adopting a series of measures intended to improve water supply so as to promote employment and better living standards. In 2002, Uzbekistan developed the Concept of Sustainable Water Supply of the Regions of the Republic of Uzbekistan, which sets forth Principal Directions of Water Management and Amelioration Measures for 2008 2011. These directives envisage major improvement in land use through better drainage, an increase in agricultural water supply through modernization of irrigation, and the introduction of integrated water resources management.

The main challenges

Mass migration: Mass population movement in the Aral Sea basin began as early as 1966 when a major earthquake destroyed much of Uzbekistan's capital, Tashkent. From then until the collapse of the Soviet Union in 1991, mass migration was mainly due to compulsory movement of labour from overpopulated regions to new development areas. Since 1991, ethnic and environmental factors have played increasingly important roles in shaping migration. Deteriorating environmental conditions, combined with recurring drought, have resulted in agricultural and fisheries production declining by as much as 50%, spelling economic disaster for almost 3 million people (including those in areas of Turkmenistan and Kazakhstan near the Aral Sea) whose main source of income was agriculture. Aggregate losses in Uzbekistan associated with mass migration from provinces near the Aral Sea between 1970 and 2001 are estimated to be above US$20 million. Many people still living in the high-migration areas suffer protein and vitamin deficiencies resulting from malnutrition and extreme poverty. In addition, since the migrants have generally been young, the birth rate has decreased significantly.

Environmental degradation: Uzbekistan faces pressing problems due to water pollution and environmental degradation. Unsustainable irrigation projects, introduced during the Soviet period, have irreversibly damaged the Aral Sea and its basin. Continuing use of similar practices since the collapse of the Soviet regime poses a still greater danger for local people's livelihoods. Pollution and other environmental contamination are causing major public health problems, and diseases stemming directly from exposure to untreated water and toxic waste are on the rise. Direct discharges of wastewater containing high concentrations of pesticide, fertilizer, and industrial and household waste have rendered much of the surface water unfit to drink. In addition, nearly 38% of groundwater reserves are now unusable.

Inefficient use of water in irrigation, combined with ineffective drainage systems, has flooded large areas of land with a mixture of fresh and polluted return water. Aerial photos taken in 2005 reveal pools of semi-contaminated water, covering as much as 800 km^2 in all. On the other hand, these areas have become diverse and flourishing ecosystems, which contribute to the region's socio-economic development through recreational uses as well as fishing, hunting and reed collection. Yet because there is no legislation regulating their management, these ecosystems have no economic or environmental status and are at risk from invasive species, gradual salinization and eutrophication (nutrient pollution).

Allocation of transboundary water resources: the need to set common priorities

Following the Second World War, as part of the regional socio-economic development plan under the Soviet regime, the water resources of the major transboundary rivers, the Amu Darya and Syr Darya, were mainly allocated for irrigating vast tracts in the Aral Sea basin. Water resources development projects were prioritized to meet irrigation needs. In the 1990s, the potential of the Syr Darya-Narin basin was almost fully developed to assure a constant flow of 32 billion to 33 billion m^3, or 94% of the river's natural regime. The Amu Darya was also modified to maintain a flow of 60 billion to 64 billion m^3. The regional development plan also relied on hydropower generation to meet electricity needs in Central Asia, although this was considered only a side benefit because agriculture contributed more to the region's GDP.

After the Central Asian countries became independent in 1991, water management problems began to surface. They largely stem from differences in the needs and priorities of the five Aral Sea basin countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Most notably, a shift in upstream countries towards using water for hydropower generation has upset the balance for areas needing irrigation water. The water administration agencies of the five countries urgently need to come up with a sustainable water management framework that favours socio-economic development and a stable water supply without ignoring the ecological needs and priorities required to offset the environmental catastrophe caused by previous practices.

Conclusions

Unsustainable use of water resources in Uzbekistan since the mid-20th century, carried out as a part of a larger Aral Sea basin development plan, has caused irreversible damage in terms of water quality and ecosystem degradation. The damage has rendered many soil and water resources unusable, seriously threatening the livelihoods of Uzbeks and leading to major population movements. Although environmental protection and sustainable socio-economic development remain priorities in the national agenda, the sheer scale of the problems, combined with economic difficulties, leaves the government short of solutions. Transboundary water resources, long the lifeline of extensive irrigation in Uzbekistan, now pose quantity and quality challenges due to rampant pollution and changing priorities in upstream countries. Development of national plans and establishment of regional cooperation, along with international assistance, are necessary to assure sustainable development while reversing environmental damage, to the extent possible.

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