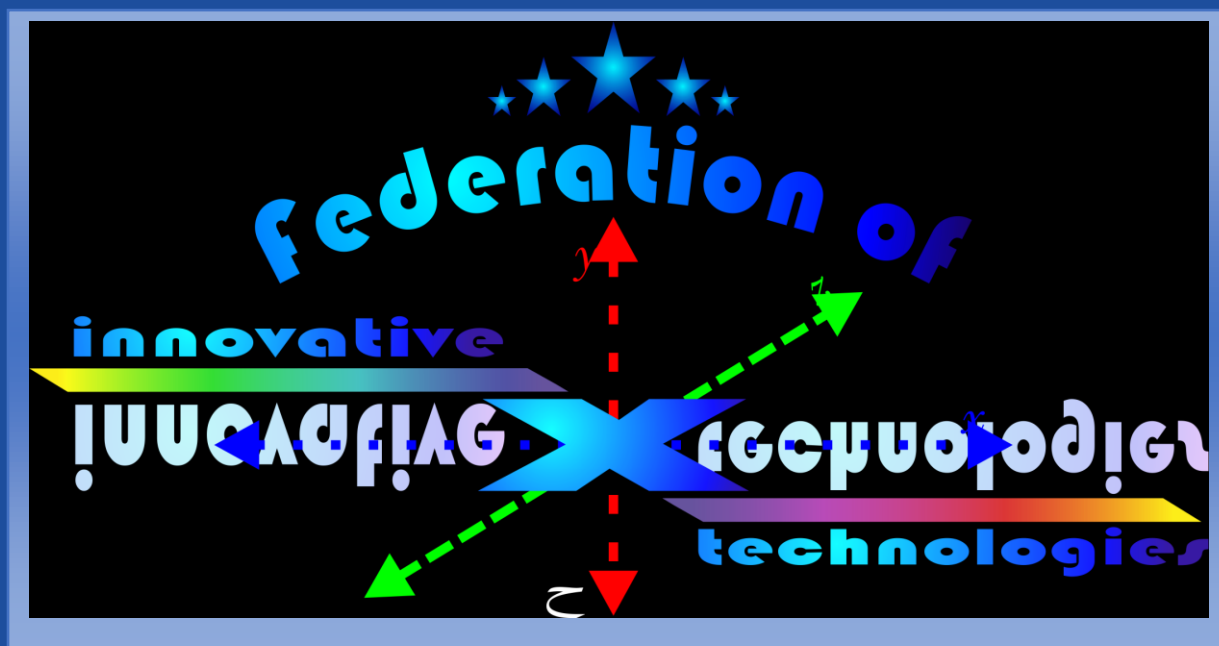


# 2.

The Use of  
Water Today



Today's water crisis is widespread, and continuing with current policies for managing water will only

widen and deepen that crisis



During the 20<sup>th</sup> century the world population tripled—while water use for human purposes multiplied sixfold! The most obvious uses of water for people are drinking, cooking, bathing, cleaning, and—for some—watering family food plots. This domestic water use, though crucial, is only a small part of the total. Worldwide, industry uses about twice as much water as households, mostly for cooling in the production of electricity. Far more water is needed to produce food and fibre (cereals, fruits, meat, cotton) and maintain the natural environment.

Providing six times more water now than a hundred years ago, an enormous task, has significant impacts on people and the environment. On the positive side:

- q A major investment drive, the International Drinking Water Supply and Sanitation Decade (1981–90) and its follow-up—led by national governments and supported through international organisations—ended with safe and affordable drinking water for 80% of the exploding world population and sanitation facilities for 50%.
- q Major investments in wastewater treatment over the past 30 years have halted the decline in—or actually improved—the quality of surface water in many developed countries.
- q Food production in developing countries has kept pace with population growth, with both more than doubling in the past 40 years. A successful international research program in agriculture—funded through the Consultative Group for International Agricultural Research—has produced higher-yielding varieties, and there has been a worldwide drive to intensify agriculture through fertiliser application and irrigation. A major factor in this success story—in agricultural productivity and farmer-controlled investment—has been the rapid growth of groundwater-irrigated agriculture in the past 20 years.
- q In perhaps the biggest achievement of the century, rising living standards, better education, and other social and economic improvements have finally slowed population growth.



- Today's water crisis is widespread
- Green water—and blue
- Passing the threshold of what's usable

But at the same time:

- q** An unacceptably large portion of the world population—one person in five—does not have access to safe and affordable drinking water, and half the world's people do not have access to sanitation. Each year at least 3–4 million people die of waterborne diseases, including more than 2 million children who die of diarrhoea, according to World Health Organization statistics (WHO 1996). Other sources provide even higher estimates.
- q** More than 800 million people, 15% of the world population, get fewer than 2,000 calories a day. Chronically undernourished, they live a life of permanent or intermittent hunger (Conway 1999b). Most are women and young children from extremely poor families. More than 180 million children under 5 are severely underweight—more than two standard deviations below the standard weight for their age. Seventeen million children under 5 die each year, with malnourishment contributing to at least a third of these deaths (Conway 1999a). Lack of proteins, vitamins, minerals, and other micronutrients in the diet is also widespread, particularly among children and women of childbearing age (UNICEF 1998).
- q** Much economic progress has come at the cost of severe impacts on natural ecosystems in most developed and transition economies. The world's wetlands were halved in the 20<sup>th</sup> century, causing a major loss of biodiversity. Rapidly declining surface and groundwater quality in almost all major urban centres in the developing world threatens human health and natural values. Because of the adverse social and environmental impacts, large dams have become controversial and have lost public support in many places.
- q** Water services—irrigation water, domestic and industrial water supply, wastewater treatment—are heavily subsidised by most governments. This is done for all the right reasons (providing water, food, jobs), but with perverse consequences. Users do not value water—and so waste it. To a large extent the subsidies do not end up with the poor but are captured by the rich. Water conservation technologies do not spread. There are too few investment funds and revenues to maintain water infrastructure and research and training systems. As a result the sector is conservative and stagnant, not dynamic with a stimulating flow of innovative thinking.

- q** Unregulated access to groundwater, affordable small electric and diesel pumps, and subsidised electricity and diesel oil have led to overpumping of groundwater for irrigation and to rapidly falling groundwater tables in key aquifers.
- q** In most countries water continues to be managed sector by sector by a highly fragmented set of institutions. This approach is not effective for allocating water across purposes. It does not allow for the effective participation of stakeholders. And it is a major obstacle to integrated water resource management.

The conclusion: while much has been achieved, today's water crisis is widespread. Continuing current policies for managing water will only widen and deepen that crisis.

## The world's water resources

A key characteristic of the world's freshwater resources is their uneven distribution in time and space. Until recently water resource management focused almost exclusively on redistributing water to when and where people want it for their use. This is a supply-side (engineering) approach. But there are many signs that water is running out—or at least getting a lot less plentiful in more places as populations and per capita water use grow—and damaging ecosystems from which it is withdrawn. So, we need to look at what water is used for and to manage these competing claims in an integrated framework.

Think of freshwater as green or blue. Green water—the rainfall that is stored in the soil and then evaporates or is incorporated in plants and organisms—is the main source of water for natural ecosystems and for rainfed agriculture, which produces 60% of the world's food. Blue water—renewable surface water runoff and groundwater recharge—is the main source for human withdrawals and the traditional focus of water resource management.

The blue water available totals about 40,000 cubic kilometres a year (Shiklomanov 1999).<sup>1</sup> Of this, an estimated 3,800 cubic kilometres, roughly 10%, were withdrawn (diverted or pumped) for human uses in 1995. Of the water withdrawn, about 2,100 cubic kilometres were consumed.<sup>2</sup> The remainder was returned to streams and aquifers, usually with significant reductions in quality.

If we are withdrawing only 10% of renewable water resources, and consuming only 5%, what then is the prob-

Withdrawals for irrigation are nearly 70% of the total withdrawn for human uses, those for industry 20%,

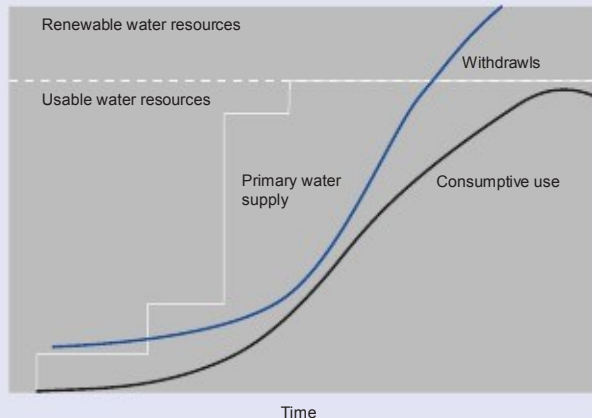
and those for municipal use about 10%

**Box 2.1 Renewable water resources**

Renewable water resources represent the water entering a country's river and groundwater systems. Not all this water can be used because some falls in a place or time that precludes tapping it even if all economically and technically feasible storage were built. Usable water resources represent the water that could be used if all economically and technically feasible storage and diversion structures were built. Usable water resources represent the upper limit to consumptive use even with future development.

The primary water supply is the amount of water that can be consumed given the current state of development of the water resource. At any point in time, the primary water supply sets an upper bound to the consumptive use of water. It represents the first-time diversions of water. Water diverted to a use that is not consumed either flows to a sink or re-enters the river or humanmade flow network and is recycled. Total deliveries, often reported as withdrawals, comprise primary water plus recycled water. Total water deliveries depend on how much water is recycled.

Passing the threshold of what's usable



Source: IWMI 2000.

lem? Not all renewable water resources are usable (box 2.1). The numbers may suggest that we are using only a small fraction of the available resources and that we should be able to increase this share fairly easily. Not so, for the following reasons:

- q Of global water resources, a large fraction is available where human demands are small, such as in the Amazon basin, Canada, and Alaska.
- q Rainfall and river runoffs occur in large amounts during very short periods, such as during the monsoon periods

in Asia, and are not available for human use unless stored in aquifers, reservoirs, or tanks (the traditional system in the Indian subcontinent).<sup>3</sup>

- q The withdrawal and consumption figures do not show the much larger share of water resources “used” through degradation in quality—that is, polluted and of lower value for downstream functions.
- q Water not used by humans generally does not flow to the sea unused. Instead, it is used in myriad ways by aquatic and terrestrial ecosystems—forests, lakes, wetlands, coastal lagoons—and is essential to their well being.

This leads to the following conclusions:

- q Even though people use only a small fraction of renewable water resources globally, this fraction is much higher—up to 80–90%—in many arid and semiarid river basins where water is scarce.
- q In many tropical river basins a large amount of water is available on average over the year, but its unequal temporal distribution means that it is not usable or that massive infrastructure is required to protect people from it and to store it for later use, with considerable social and environmental impacts.
- q In many temperate zone river basins, adequate water resources are relatively evenly distributed over the year, but they are used so intensively that surface and groundwater resources become polluted and good-quality water becomes scarce.

Main uses of water for human purposes

Withdrawals for irrigation are nearly 70% of the total withdrawn for human uses—2,500 of 3,800 cubic kilometres (table 2.1). Withdrawals for industry are about 20%, and those for municipal use are about 10%.

Water for food and rural development

A key ingredient in the green revolution, irrigation raises agricultural productivity—particularly in Asia, which contains about 70% of the world's irrigated area (figure 2.1).<sup>4</sup> Irrigation consumes a large share of the water it withdraws through evaporation from reservoirs, canals, and soil and through incorporation into and transpiration by crops.

- For agriculture and rural development
- For people and industry

Table 2.1 Global water use in the 20<sup>th</sup> century

Although we are withdrawing only 10% of renewable water resources, and consuming only about 5%, there are still problems for human use. Water is unevenly distributed in space and in time—and we are degrading the quality of much more water than we withdraw and consume.

Cubic kilometres	1950	1995
Use		
Agriculture		
Withdrawal	500	
Consumption	300	2,500
Industry		
Withdrawal	40	
Consumption	6	
Municipalities		
Withdrawal	20	80
Consumption	5	
Reservoirs (evaporation)	0	
Totals	90	350
Withdrawal	600	50
Consumption	300	200
	1,400	3,800
	750	2,100

Note: All numbers are rounded.  
Source: Shiklomanov 1999.

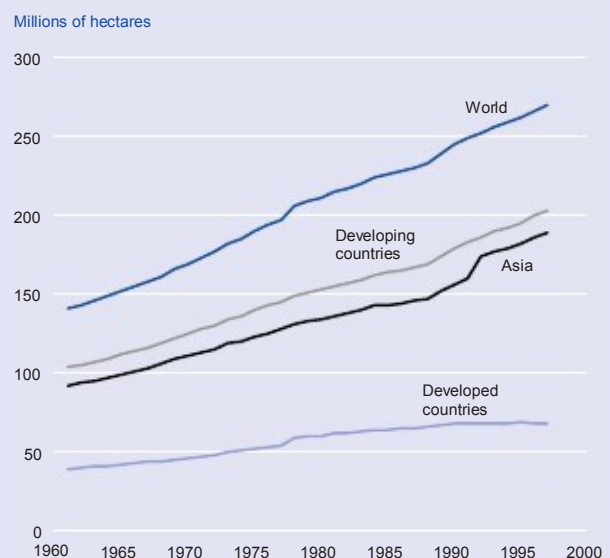
Depending on the technology, consumption can range from 30–40% for flood irrigation to 90% for drip irrigation. The rest recharges groundwater or contributes to drainage or return flows. This water can be—and often is—reused, but it has higher salt concentrations and is often contaminated with nutrients, sediments, and chemical contaminants (pesticides, herbicides) that can damage the ecosystem.

Unless carefully managed, irrigated areas risk becoming waterlogged and building up salt concentrations that could eventually make the soil infertile. This process probably caused the downfall of ancient irrigation-based societies and threatens the enormous areas brought under irrigation in recent decades. By the late 1980s an estimated 50 million hectares of the world’s irrigated areas, or more than 20%, had suffered a buildup of salts in the soil.

Perhaps the biggest revolution in water resource management has been the small, cheap diesel or electric pump that gives farmers the means to invest in self-managed groundwater irrigation. In irrigated areas of Pakistan private investment in groundwater development through tubewells (360,000 in 1993 alone) has been an engine of growth. In

Figure 2.1 Net irrigated area, 1961–97

Irrigated area nearly doubled in the last four decades of the 20<sup>th</sup> century, mostly in Asia (China, India, Pakistan) and the United States, with the pace of development slowing after 1980 in the developed world.



Source: WHO 1996; World Water Vision staff.

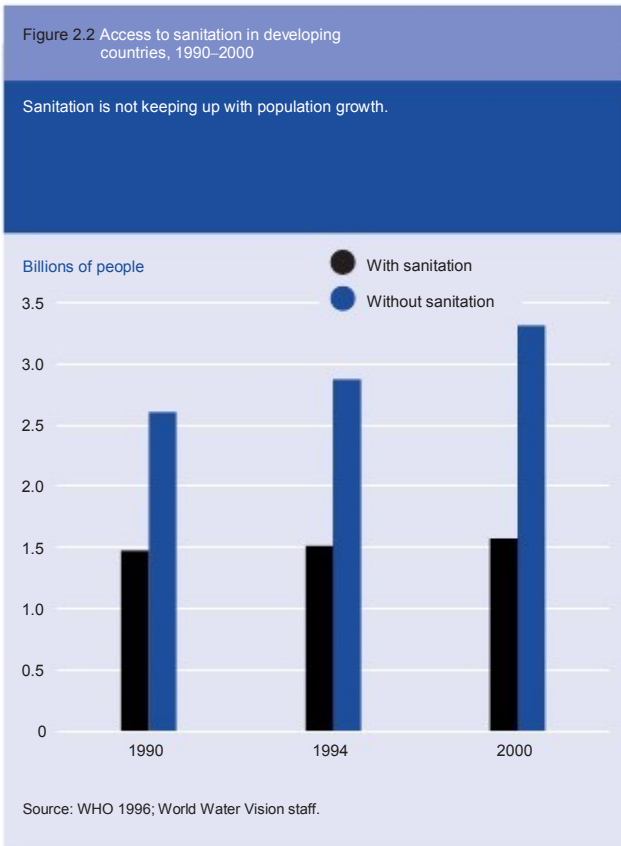
India almost half of all irrigated areas depend fully or partly on groundwater. In China more than 2 million pumps irrigate some 9 million hectares (Postel 1999). In the United States one of the world’s largest groundwater aquifers, the Ogallala, has been developed through privately financed wells feeding sprinkler systems. While groundwater irrigation has contributed substantially to the world’s food production and provided farmers with a dependable source of water, it has also led to massive overuse and falling groundwater tables. A lack of regulation of this common resource, combined with subsidised diesel fuel or electricity for the pumps, gives farmers an incentive to use groundwater as if there were no tomorrow.

#### Water for people and industry

A large share of the water withdrawn by households, services, and industry—up to 90% in areas where total use is high—is returned as wastewater, but often in such a degraded state that major cleanups are required before it can

Cheap pumping and a lack of regulation give farmers an incentive to use groundwater as

if there were no tomorrow



**Table 2.2 Water-related diseases and deaths**

Many children die of easily preventable diseases, and a huge number of older people get sick.

Disease	Annual illness and deaths
Fecal-oral infections (waterborne and water-washed) Diarrhoea	1.5 billion cases for children under 5, 3.3 million deaths (5 million deaths all ages) 500,000 cases, 20,000 deaths
Cholera	500,000 cases, 25,000 deaths
Typhoid fever	1.3 billion infected, 59 million clinical cases, 10,000 deaths
Ascariasis (roundworm)	
Water-washed infections (poor hygiene) Trachoma	146 million cases, 6 million people blind
Infections related to defective sanitation Hookworm	700 million infected

Source: Van der Hoek, Konradsen, and Jehangir 1999.

be reused. The amounts for personal use (drinking, cooking, bathing) are relatively small compared with other uses. And in developed countries the water fit to drink is mostly used to flush toilets, water lawns, and wash dishes, clothes, and cars.

The high per capita residential use rates in North America (around 400 litres per person a day) and Europe (about 200 litres) have declined somewhat in recent years, in response to higher prices and environmental awareness. But in many Sub-Saharan countries the average per capita use rates are undesirably low (10–20 litres per person a day) and need to be increased. In many larger cities of Asia and Latin America the total water produced by utilities is very high, from 200–600 litres per person a day, but up to 70% is lost to leaks. Service is often undependable, and water quality is often unreliable.

The real problem of drinking water and sanitation in developing countries is that too many people lack access to safe and affordable water supplies and sanitation (figure 2.2). The

World Health Organization's World Health Report 1999 estimates that water-related diseases caused 3.4 million deaths in 1998, more than half of them children. Other estimates are even higher, particularly for diarrhoea (table 2.2).

Behind those grim numbers is a mix of good news and bad. The good news is mainly about water. More people have gained access to safe drinking water since 1980 than ever before. Many countries doubled their provision during that time. And worldwide the provision of new water services is outpacing population growth.

The bad news is mainly about sanitation. Fewer people have adequate sanitation than safe water, and the global provision of sanitation is not keeping up with population growth. Between 1990 and 2000 the number of people without adequate sanitation rose from 2.6 billion to 3.3 billion. Sanitation statistics are less reliable than those for water, however, because some countries have changed their definitions of adequate sanitation.

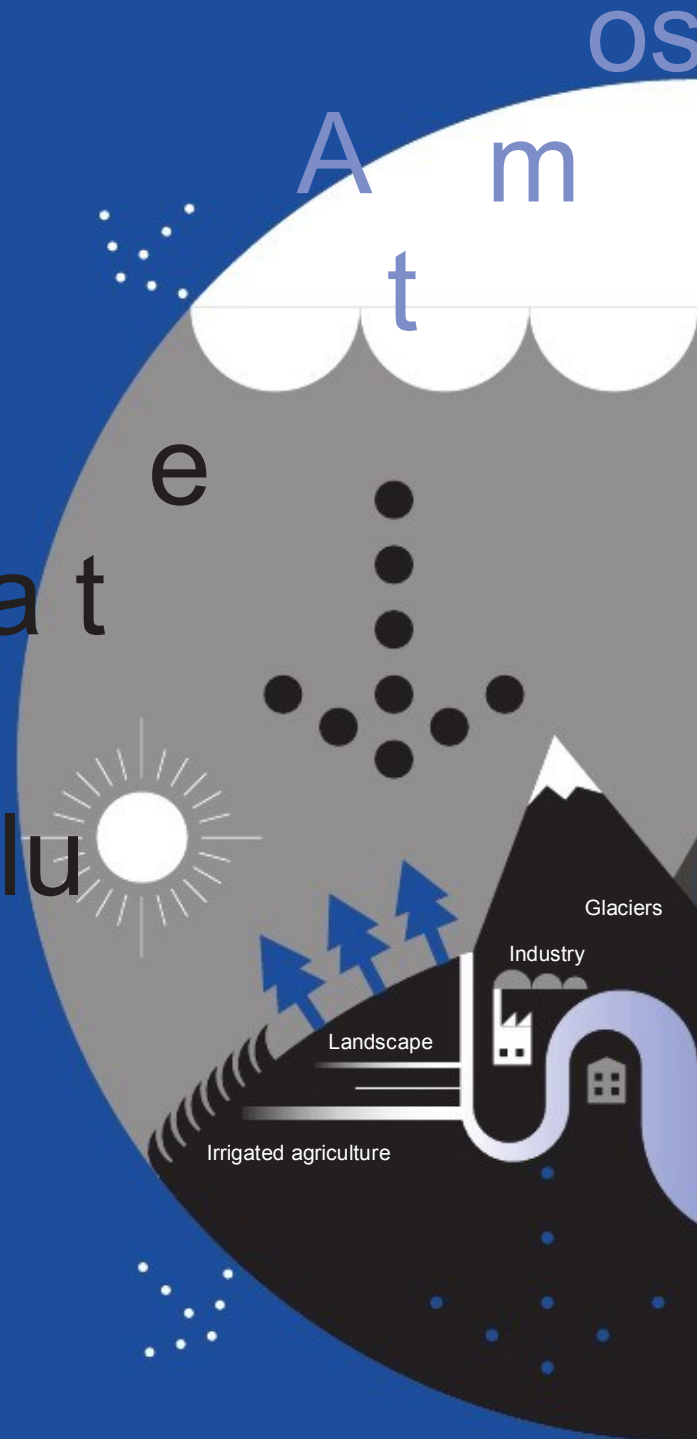
Inadequate collection, treatment, and disposal of household and industrial wastewater is not just a health hazard for

## The water cycle

Blue water, or renewable water resources—the portion of rainfall that enters into streams and recharges groundwater, and the traditional focus of water resource management



water  
blue



Green water, or soil water—the portion of rainfall that is stored in the soil and then evaporates or is incorporated in plants and organisms

# spher e Gr ee n wa te r

Rainfed agriculture

People

- Green, or soil, water
- 60,000 km<sup>3</sup>
- Source for rainfed agriculture
- 60% of food production
- Primary source for
- terrestrial ecosystems

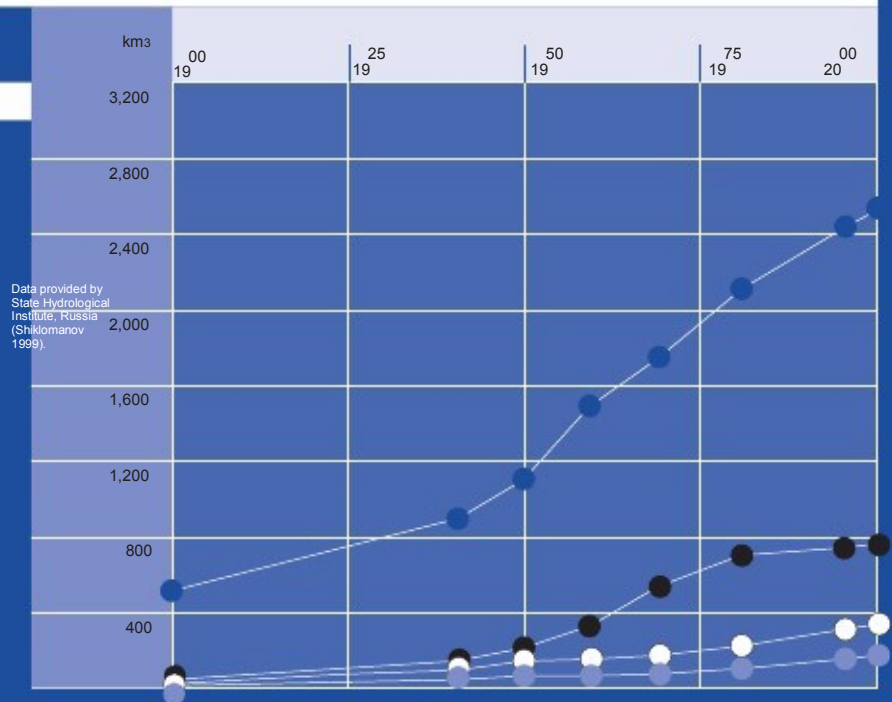


## Blue water, blue world

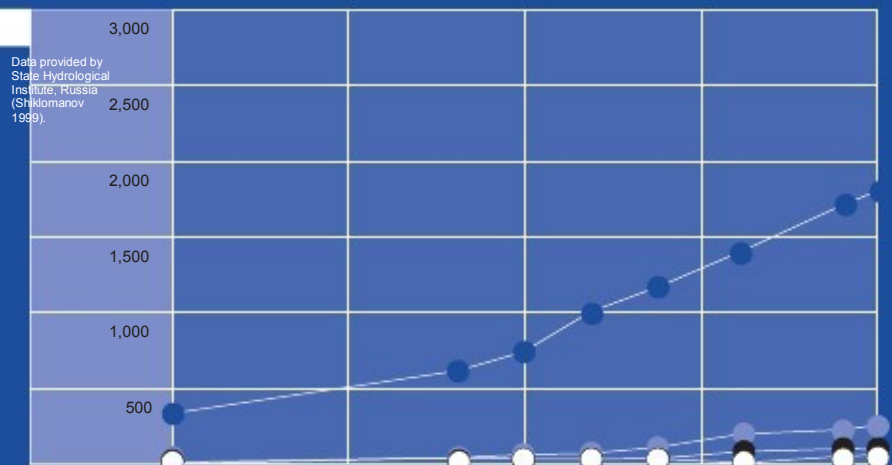
### 1 Dynamics of water withdrawal and water consumption

Irrigated agriculture is the main user of water, then industry, then municipalities.

#### Water withdrawal



#### Water consumption

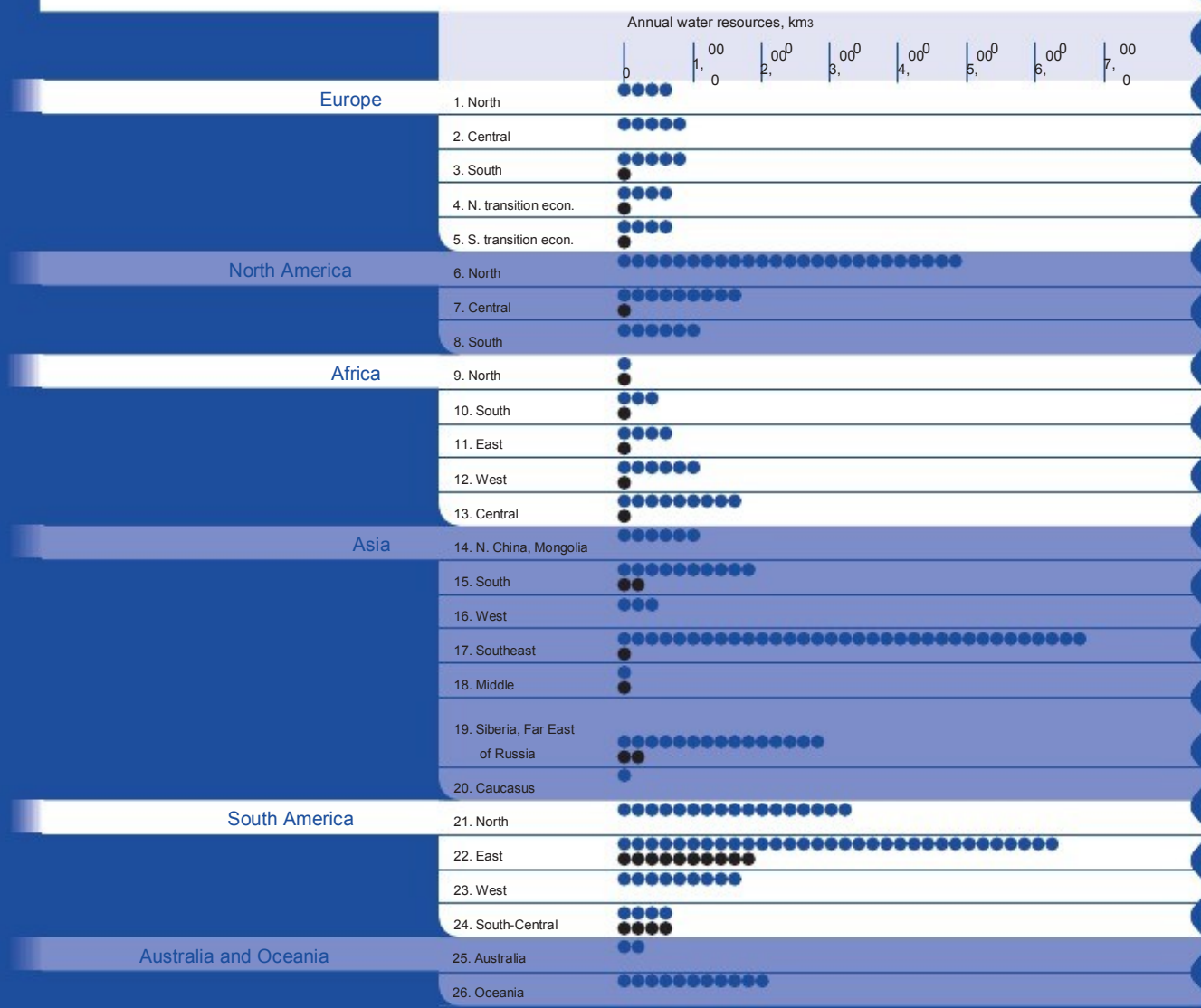


#### Use

- Agriculture
- Industry
- Municipalities
- Reservoirs

2 Annual renewable water resources by region

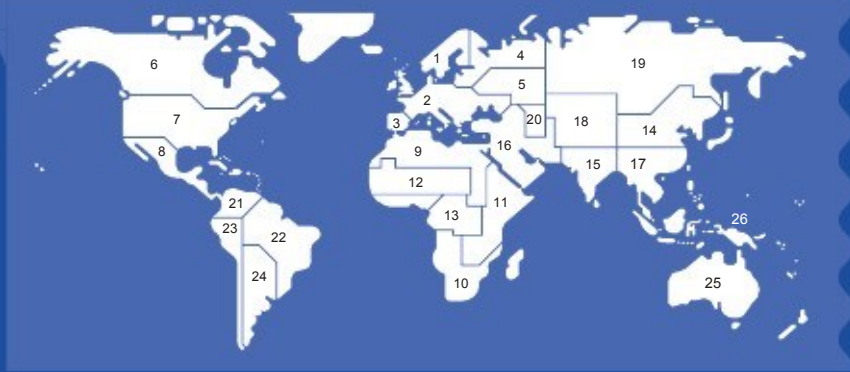
Much renewable water is concentrated in North America (especially Canada), Southeast Asia, and the eastern part of South America.



Locations

Source of water

- Local resources
- Inflows



- The news on sanitation
- Threats to nature and people
- To biodiversity
- To the quality of surface and groundwater

humans, it also pollutes aquatic ecosystems—sometimes with disastrous results. Why?

- q There is a lingering preference for costly waterborne solutions.
- q Supply-driven approaches with high subsidies still prevail in government programmes.
- q Promotion strategies are still driven by the suppliers' philosophy of sanitation for longer-term public health benefits, while consumers are interested in better sanitation for more immediate benefits such as status, convenience, higher property values, and privacy and safety.
- q The cost of removing 100% of pollutants is prohibitive, so some fraction accumulates in water and soil.

Yet there is good news on sanitation. Large numbers of women and men got better sanitation in the 1990s. New designs and low-cost technologies have significantly expanded the options available to periurban and rural communities.

Many piped water systems, however, do not meet water quality criteria, leading more people to rely on bottled water bought in markets for personal use (as in major cities in Colombia, India, Mexico, Thailand, Venezuela, and Yemen). Bottled water varies from luxury products such as carbonated mineral water in half-litre plastic bottles to filtered groundwater sold in 20-litre containers, and the industry is booming.

Consumption of bottled water in Mexico is estimated at more than 15 billion litres a year, almost doubling between 1992 and 1998, and growing by 35% in 1996 and 1997 alone. In the United States the bottled water market is worth about \$4 billion a year, and in the Pacific Northwest the dollar turnover of this “other” water sector rivals that of piped water. A large share of the unserved urban population in many developing country cities has to rely on water vendors who supply water by truck—water of unreliable quality that costs 10–20 times more than piped water (box 2.2). This market for high-priced water bought by low-income people demonstrates the failure—or at least the poor performance—of the subsidised, unaccountable, publicly owned water supply model.

Industry consumes just over 10% of the water it withdraws, heavily polluting the fraction that it returns. Industry is a major

### Box 2.2 It's expensive to be poor

In Port-au-Prince, Haiti, a comprehensive survey showed that households connected to the water system typically paid around \$1.00 per cubic meter, while unconnected customers forced to purchase water from mobile vendors paid from \$5.50 to a staggering \$16.50 per cubic meter.

Urban residents in the United States typically pay \$0.40–0.80 per cubic meter for municipal water of excellent quality. Residents of Jakarta, Indonesia, purchase water for \$0.09–0.50 per cubic meter from the municipal water company, \$1.80 from tanker trucks, and \$1.50–2.50 from private vendors—as much as 50 times more than residents connected to the city system.

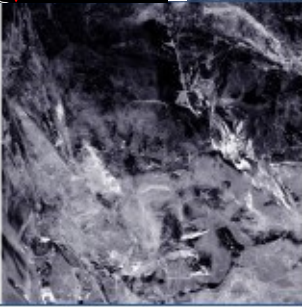
In Lima, Peru, poor families on the edge of the city pay vendors roughly \$3.00 per cubic meter, 20 times the price for families connected to the city system.

Source: WSSCC 1999.

user in OECD countries and even more so in transition economies, where water use per unit of output is often two to three times higher than in OECD countries and industry can rival agriculture in water withdrawals.

With total annual generation of 2.6 terawatt-hours, hydropower accounts for 20% of electricity production and 7% of energy production worldwide (IHA 1999). In the developed world roughly 70% of hydropower potential has already been developed—in the developing world, only about 10%. In some countries hydropower is the largest source of electricity production. While the construction of dams for hydropower has levelled off globally, several countries have new projects under way.

The power industry returns a large share of the water withdrawn after it has been used to turn turbines in hydroelectric plants or as cooling water in nuclear and other thermal power plants. Industrial water use responds strongly to the price or scarcity of water. As industrial process water gets more expensive, close to 100% of it can be recycled. In the food industry water is an essential production input, but the quantities are relatively small. Water used for cooling in the power industry can be recycled or replaced by other technological options (such as dry cooling towers). Good progress has been made on the treatment of industrial wastewater in OECD countries through enforcement of environmental standards and regulations. Left unregulated, however, and provided with free or almost free water resources, industry is likely to



Rapidly growing cities, burgeoning industries, and rapidly rising use of chemicals in agriculture have undermined the quality of many rivers, lakes, and aquifers

Box 2.3 Snapshots of the world's freshwaters and their biodiversity

- q Globally, 20% of freshwater fish are vulnerable, endangered, or extinct.
- q The rich endemic ichthyofauna of Lake Victoria in Africa have been reduced by predatory Nile perch, overfishing, and eutrophication.
- q The Thames River, polluted for centuries, is again habitable by fish.
- q Groundwaters as deep as 2.8 kilometres may have rich bacterial flora.
- q Agricultural embankment construction in Bangladeshi floodplains, one of the world's largest deltas, threatens the aquatic environment and fisheries critical to the survival of some of the world's poorest people.
- q Construction of dams planned for the Mekong River basin threatens fish adapted to seasonal flooding and unobstructed migratory movements.
- q Hydroelectric facilities in Brazil have disrupted migration patterns of economically important species, while the Hidrovia channel project in central South America may threaten wetlands and foster invasions of nonnative biota between drainage basins.
- q Zebra mussels are paving shallows of the Great Lakes, displacing native mussels and changing ecosystems.
- q The number of prairie ponds in North America has rebounded from less than 2 million in 1989 to about 4 million in 1996. And the duck population rose from less than 8 million to nearly 12 million, mostly due to the North American Waterfowl Management Plan (as well as water availability).
- q Of 30,000 rivers in Japan, only 2 are not dammed or modified.
- q The Ganges and Bramaputra Rivers carry more than 3 billion tonnes of soil to the Bay of Bengal each year, spreading it over 3 million square kilometres of seabed.

Source: McAllister, Hamilton, and Harvey 1997.

be a major water user, causing significant health and environmental impacts through wastewater discharge.

In addition to the three big water users—agriculture, industry, and municipalities—water resources provide a range of other services, such as navigation or recreation and tourism. Water transport is experiencing substantial growth on a global scale, even as its importance has diminished in Europe and North America. Population growth and the opening of economies to the world market are leading to increasing inland navigation in Brazil (Tietê-Paraná Master Plan), China (Yangtze), and Venezuela (with 48,000-tonne push-tows on

the Orinoco). Russia (with 50,000 kilometres of high-capacity waterways) will probably be a leader in this expansion.

Threats to nature—and to people

Freshwater ecosystems have been declining—in some parts of the world, for hundreds of years—threatening the economic, social, and environmental security of human society and terrestrial ecosystems.

Ecosystems and biodiversity

Freshwater and terrestrial ecosystems are integral parts of the water cycle. Their protection requires careful management of the entire ecosystem. For freshwater ecosystems, this implies integrated planning and management of all land and water use activities in the basin, from headwater forests to coastal deltas.

Freshwater biodiversity is high relative to the limited portion of the earth's surface covered by freshwater (box 2.3). Freshwater fish, for example, make up 40% of all fish, and freshwater molluscs make up 25% of all molluscs. Freshwater biodiversity tends to be greatest in tropical regions—with a large number of species in northern South America, central Africa, and Southeast Asia. Worldwide the number of freshwater species is estimated to be between 9,000 and 25,000.

The loss of freshwater biodiversity is poorly monitored except for some larger, commercial species (box 2.4). Available data suggest that 20–35% of freshwater fish are vulnerable or endangered, mostly because of habitat alteration. Other factors include pollution, invasive species, and overharvesting.

Surface and groundwater quality

Rapidly growing cities, burgeoning industries, and rapidly rising use of chemicals in agriculture have undermined the quality of many rivers, lakes, and aquifers. The industrial revolution turned the Thames into a stinking, black health hazard as it ran through London in the late 19th century. Major investments in wastewater treatment and cleaner production have gradually restored its recreational and environmental value.

Most large cities in newly industrialising and developing countries have rivers in the same condition as the Thames in the 19th century. They are a health hazard. They threaten downstream irrigation areas. And they destroy ecosystems. Because of inadequate management, water quality is deteriorating at

- Polluting groundwater
- Rivers drying up
- Floods and droughts

**Box 2.4 Disappearing species**

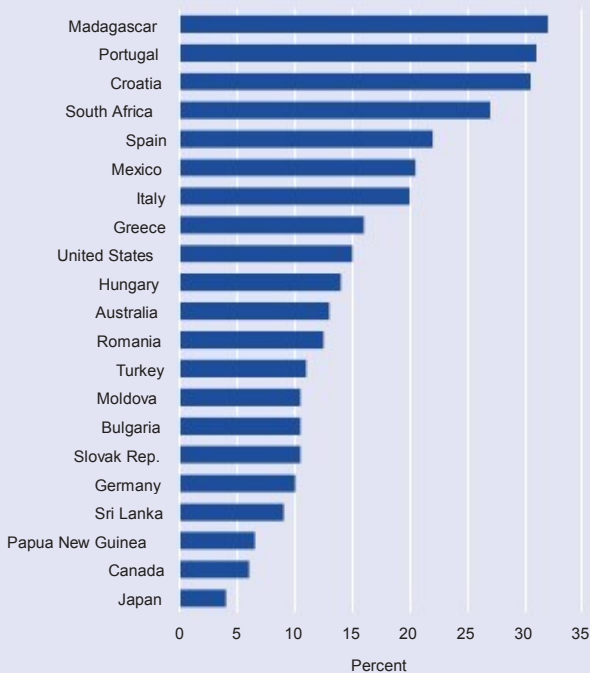
Biodiversity losses have been only partly detected and measured. Just a few larger organisms are monitored or considered. But more than 100 freshwater-associated vertebrates (birds, amphibians, fish) became extinct after 1600, 55% of the extinctions for these three classes.

Worldwide, 20% of freshwater fish are vulnerable, endangered, or extinct; 20% of threatened insects have aquatic larval stages; 57% of freshwater dolphins are vulnerable or endangered; and 70% of freshwater otters are vulnerable or endangered. About 75% of freshwater molluscs in the United States are rare or imperilled. With the possible exception of North America and parts of Europe, nearly all inland fisheries show signs of overexploitation. Cichlid fisheries in Lake Victoria have been replaced by Nile perch catches, but many of the endemic cichlids are extinct. Many stocks of salmonids in western North America have been lost.

About half the world's wetlands have been lost. Ecosystem integrity has declined in about 25 million kilometres of rivers following the construction of dams. Water quality in lakes in populated areas has declined, and many lakes and rivers contain exotic species.

The few rivers whose ecosystems have been restored, like the Thames and the Chesapeake Bay basin, show that restoration of freshwater ecosystems is possible.

Freshwater fish species threatened, selected countries



Source: McAllister, Hamilton, and Harvey 1997; Groombridge and Jenkins 1998.

an increasing rate throughout a large part of the world. Much is unknown about the impacts of water resource development on ecosystems, and even basic data on water quality are not available on a global scale. But we can still draw some conclusions:

Q There is a critical need to integrate water and environmental management, as provided for under the concept of integrated water resource management.

Q Investments are lagging behind urban needs for the collection, treatment, and disposal of municipal and industrial wastewater—and behind rural needs for more efficient irrigation, drainage of surplus irrigation water, and control of agricultural runoff.

Q Water quality may be the biggest emerging water problem in the industrial world, with the traces of chemicals and pharmaceuticals not removed by conventional drinking water treatment processes now being recognised as carcinogens and endocrine disrupters.

Q Leaks of nuclear waste into aquifers and surface water have not been brought under control, especially in the transition economies of Central and Eastern Europe. A long-term solution for the safe disposal of nuclear waste, to prevent contamination of water resources, has not been implemented anywhere.

Q Half the rivers and lakes in Europe and North America are seriously polluted, though their condition has improved in the past 30 years. The situation is worse in developing countries that lack sewerage and industrial waste treatment.

The impacts of agriculture on water quality are less visible but over time as least as dangerous, because many of the fertilisers, pesticides, and herbicides used to boost agricultural productivity slowly accumulate in groundwater aquifers and natural ecosystems. Their impact on health may become clear only decades after their use, but their more immediate impact, through eutrophication, is on ecosystems. These problems accumulate in fresh and saltwater bodies, such as the Baltic and Black Seas.

Groundwater, the preferred source of drinking water for most people in the world, is also being polluted, particularly through industrial activities in urban areas and agricultural chemicals and



### Water quality may be the biggest emerging water problem in the industrial world, with traces of chemicals and pharmaceuticals not

removed by conventional drinking water treatment processes now recognised as carcinogens and endocrine disrupters

**Box 2.5 Water supply shortfalls in Jakarta, Indonesia**

Jakarta's water supply and disposal systems were designed for 500,000 people, but in 1985 the city had a population of nearly 8 million—and today, more than 15 million.

The city suffers continuous water shortages, and less than 25% of the population has direct access to water supply systems. The water level in what was previously an artesian aquifer is now generally below sea level—in some places 30 metres below. Saltwater intrusion and pollution have largely ruined this as a source of drinking water.

Source: Sundblad 1999.

fertilisers in rural areas. In Western Europe so many nutrients are spread over croplands that excess nitrate finds its way into groundwater, ruining drinking water sources in Denmark, France, and the Netherlands. The difficulty and cost of cleaning up groundwater resources, once polluted, make the accumulation of pollutants in aquifers particularly hazardous (box 2.5).

#### Drying up

Some of the world's largest rivers do not reach the sea. In the wake of economic development of the communities along rivers comes an increase in water consumption that depletes the rivers of their reserves. At the extreme end of the spectrum, the Amu Darya and Syr Darya—two major rivers in Central Asia that feed the Aral Sea—have been deprived of close to their entire water reserves for cotton irrigation. The Huang He (Yellow) River in China did not reach the sea on some days in 1972—or for seven months in 1997. The Colorado River in the southwestern United States and the Indus River, between India and Pakistan, are two of the many other rivers in a similar predicament.

In some countries more water is being consumed by humans than is being renewed by nature (box 2.6). And as populations grow, more countries and regions will be in this unsustainable situation.

#### Extremes of flood and drought

While the preceding discussion focused on average flows and quality, a key characteristic of water is its extreme events: floods and droughts. Floods sometimes provide benefits in a natural system, and some ecosystems depend on them. Moreover, some people rely on floods for irrigation and fertilisation. But floods are better known for their devastation of human lives and infrastructure (table 2.3).

**Box 2.6 People depleting the world's water**

Four billion years ago the atmosphere around the earth thickened, water vapor condensed, and the oceans formed. The quantity of water on the earth's surface today is the same as it was at that moment in the history of our planet. Through the process of evaporation as part of the solar-powered water cycle, only a small amount of water falls as rain. Most of this rainfall is soaked up by the soil, then used by plants or evaporated. This water never gets counted in the world's renewable water resources, but it is the engine that drives all ecosystems as well as rainfed agriculture. A small part of all rainfall runs off over the surface into creeks and rivers, and another part soaks through the soil to recharge groundwater reservoirs. Only this amount, into rivers and groundwater, is counted as the economically usable water supply. But rainfall is not evenly distributed in time or space, and about three-quarters of the river flows are flood waters.

In the 20<sup>th</sup> century the world population tripled—while water use multiplied sixfold!

Source: World Water Vision staff.

In the 1990s severe flooding devastated the Mississippi River basin, and thousands of lives were lost to flooding in Bangladesh, China, Guatemala, Honduras, Somalia, South Africa, and most recently Venezuela (White 1999). Internationally, floods pose one of the most widely distributed natural risks to life; other natural hazards such as avalanches, landslides, and earthquakes are more regional (Clarke 1996). Damage, disruption, and deaths from floods are common. Between 1973 and 1997 an average of 66 million people a year suffer flood damage (IFRC 1999). This makes flooding the most damaging of all natural disasters (including earthquakes and drought). The average annual number of flood victims jumped from 19 million to 131 million in 1993–97. In 1998 the death toll from floods hit almost 30,000.

- Inequalities in use, access, participation
- Subsidies

The economic losses from the great floods of the 1990s are 10 times those of the 1960s in real terms. In addition, the number of disasters has increased by a factor of five. There has been a 37-fold increase in insured losses since the 1960s. Given the trend towards multiple risk insurance cover, which normally includes flood losses, insurance losses will go up even more. Yet the majority without flood insurance will continue to suffer more.

How do floods compare with other natural hazards? They:

- q Account for about one-third of natural catastrophes.
- q Cause more than half the fatalities.
- q Are responsible for one-third of the economic losses.
- q Have less than a 10% share in insured losses (figure 2.3).

There are a number of reasons for the increase in the number of catastrophes and in the amount of damage they cause:

- q Population trends globally and in exposed regions.
- q Increase in exposed values.
- q Increase in the vulnerability of structures, goods, and infrastructure.
- q Construction in flood-prone areas.
- q Failure of flood protection systems.
- q Changes in environmental conditions—for example, clearance of trees and other vegetation and infilling of wetlands that reduces flood retention capacities.

**Key water management issues**

The fragmentation of institutions in the water sector is a serious obstacle to the integrated management of water resources advocated as the desired approach for several decades. The people, organisations, and laws and regulations for water supply and sanitation for residential use often have very little to do with those applicable to the water used for, say, irrigation, flood protection, or hydropower. And surface and groundwater are often managed separately. On top of the fragmented approach within the water sector come the

Table 2.3 Major floods and storms

Floods devastate—people and structures.

Year	Location	Deaths
1421	Holland	100,000
1530	Holland	400,000
1642	China	300,000
1887	Yellow River, China	900,000
1900	Galveston, Texas, U.S.	5,000
1911	Yangtze River, China	100,000
1931	Yangtze River, China	145,000
1935	Yangtze River, China	142,000
1938	Yellow River, China	870,000
1949	Yangtze River, China	5,700
1953	Holland	2,000
1954	Yangtze River, China	30,000
1959	Japan	5,098
1960	Bangladesh	10,000
1963	Vaiont, Italy	1,800
1979	Morvi, India	15,000
1991	Bangladesh	139,000
1991	Philippines	6,000
1991	Huai River, China	2,900
1998	Central America	18,000
1998	Yangtze River, China	3,000
1998	India and Bangladesh	2,425

Source: White 1999.

insufficient links to planning and management of other, closely related, sectors. First and foremost is the link to land use planning. As Falkenmark (1999) notes, a land use decision is also a water decision. Planning and management of land and water resources should be closely linked, or better, completed integrated.

**Inequalities in use, access, and participation**

The supply-oriented approach to water management that has been the main focus throughout the sector until recently—and still is in many places—assumes that making water available to “society” or “the population” will provide adequate access to everybody. It doesn’t.

From the experience that supply-oriented projects and programmes do not automatically reach a major group of intended users has come the call for more participatory approaches. About 10 years of experience with participatory approaches to water management have led to a reconsider-

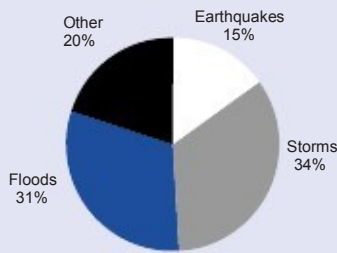


## Water provided free of charge does not get used wisely, or conserved and recycled

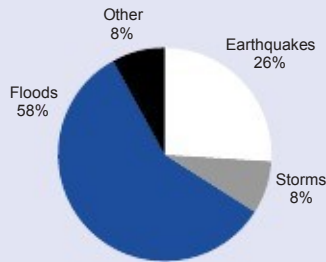
Figure 2.3 Natural catastrophes worldwide, 1988–97

Nearly a third of natural catastrophes are floods—but only a small share of the losses is insured.

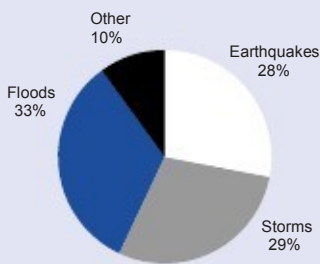
Catastrophes  
5,750



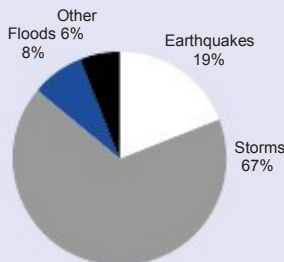
Deaths  
390,000



Economic losses  
\$700 billion



Insured losses  
\$130 billion



Source: White 1999.

ation of technologies and to taking into account the experience, knowledge, needs, and expectations of local water users. Recognition by water agencies of the need to involve and negotiate with different stakeholders—and establish joint management systems—has increased the efficiency and effectiveness of water projects and made water agencies more accountable to users.

At the same time, the experience with participatory approaches shows that identifying who uses water and for what purpose is essential. Communities contain competing interest groups—individuals and groups who command different levels of power, wealth, influence, and ability to express their needs, concerns, and rights. Where water is scarce and vulnerable, those at the lower end of the power spectrum will lose out. Efforts need to be made to ensure that community participation is based on democratic principles that increase social stability and create conditions for all stakeholders to be ensured fair rights, access to information, and an adequate share in decisionmaking.<sup>7</sup>

Most of the 1.3 billion people living in poverty are women and children, the largest groups systematically underrepresented in water resource management (UNDP 1995). The ways water resources are managed in and between different water sectors are highly gender-specific. And a gender-specific division of tasks, means, and responsibilities implies that the different needs, interests, and experiences of women and men need to be taken into account explicitly in water resource management (Van Wijk, de Lange, and Saunders 1998).

### Subsidies that mask the high value of water

Governments—or, more accurately, taxpayers—are heavily subsidising irrigation, making both canal water and groundwater available to farmers at no or minimal charge. The direct subsidy to (surface water) irrigation in India, for example, is estimated at \$800 million a year, while the indirect subsidy (through subsidised electricity used to pump groundwater) is estimated at \$4 billion a year (Bhatia, Rogers, and de Silva 1999).

The fact that water for different uses is often provided for much less than the cost of providing it—or for free—leads users to give it a low value. Water provided free of charge does not get used wisely, or conserved and recycled. It does not give users incentives to conserve water. Nor does it provide sufficient revenues to operate and maintain water systems, to invest in new infrastructure, or to research new technologies. A centralised system that provides low-cost



- Masking the value of water
- Dams and reservoirs

water but is not accountable or responsive to users can lead to a vicious cycle in which systems deteriorate and require more than normal rehabilitation.

Low water prices have hampered the introduction of water-saving technology and contributed to overuse. It is estimated that 150–200 cubic kilometres more groundwater is pumped each year than is recharged in overexploited aquifers (Postel 1999). As a result groundwater tables are falling by up to several metres a year—with the risk of collapse of agricultural systems based on groundwater irrigation in the north China plain, the U.S. high plains, and some major aquifers in India and Mexico.

### Obstacles and options for dams and reservoirs

Of the more than 39,000 large dams (a height exceeding 15 metres) in the 1998 New Dam Register of the International Commission on Large Dams, almost 90% were built since 1950 (Lecornu 1998). They are a large factor in the “irrigation miracle.” With a combined capacity of 6,000 cubic kilometres they offer development benefits through hydropower, drinking water supplies, flood control, and recreation opportunities. Dams increase the share of renewable water resources available for human use. But they have also had considerable environmental impacts, and a few very large projects have displaced large numbers of people. In addition to the 39,000 large dams are countless small dams that perform an economic function but block the migratory patterns of fish and reduce naturally nourishing deposits downstream.

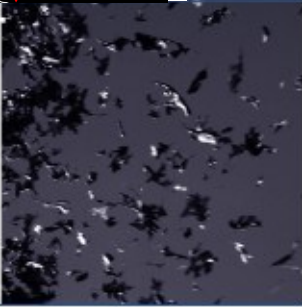
Reservoirs are silting up at about 1% a year on average, through soil erosion upstream. Part of this, foreseen in the design stage, has been accounted for in so-called dead storage. In other places developments upstream or incomplete information at the time of design have led to considerable underestimation of the siltation rate, with reduced life expectancies for dams and reservoirs. In any case, some investment is required simply to maintain and gradually replace the infrastructure as it ages. During the 1990s dam construction for large surface water reservoirs slowed to being barely sufficient to maintain current global capacity, let alone expand it at the rates of the 1950s to 1970s.<sup>8</sup>

Dam professionals—such as those in the International Commission on Large Dams and the International Hydropower Association—have undertaken considerable work on possible measures to mitigate dams’ impacts. But the general perspective in the environmental community is that

mitigation does not work or has not been carried out as foreseen in the feasibility or design phases. Opposition to new large dams has become heated. Because of lack of agreement between dam proponents and opponents on the development effectiveness of dams, respected representatives of both sides agreed to the establishment of the World Commission on Dams, a joint initiative by the World Conservation Union and the World Bank, with private sector sponsorship and significant participation from developing countries. The commission is expected to deliver a balanced analysis of the benefits and costs of dams and the conditions under which their continued development is desirable.

### Notes

1. The World Water Vision is based on 1995 data for water availability and use at the national level for residential, industrial, and agricultural purposes; these data are drawn from Shiklomanov (1999). This is essentially the same database, but updated, as used for the United Nations Comprehensive Freshwater Assessment (Shiklomanov 1997) and the International Hydrological Programme’s report on world water resources (Shiklomanov 1998).
2. Consumptive use is the part of water delivered to a use that evaporates, or is incorporated into products or organisms such that it becomes unavailable to other users. The upper limit to consumptive use within a basin is the primary water supply.
3. In most of India, for example, annual precipitation occurs in just 100 hours. The other 8,660 hours of the year are dry (Agarwal 1999).
4. More than 275 million hectares of land are currently irrigated. An additional 150 million hectares have a drainage system only (Malano and van Hofwegen 1999, based on FAO data).
5. Here sanitation refers to the disposal of household wastewater and excreta. However, this waste issue should not be addressed without taking into consideration related community design issues of household solid waste disposal, industrial waste disposal, and drainage.
6. Here flooding is broadly defined as including both excess water caused by rainstorms that subsequently leads rivers to flood (spill over their banks) as well as severe coastal storms or cyclones that can lead to excess water through largely tidal surges.



A centralised system that provides low-cost water but is not accountable or responsive to users can lead to a vicious cycle in which systems deteriorate and require more than normal rehabilitation

7. User participation and sustainable solutions may—in the short term, at least—point in opposite directions. The most effective way of preventing groundwater overdraught, for example, is to recognise existing groundwater (property) rights and give the rights holders incentives to limit access and reduce overpumping. Because the existing rights are often not equitably distributed, this leads—at least in the short

term—to a conflict between equity and sustainable resource management. We are grateful to John Briscoe for pointing this out.

8. The International Hydropower Association and International Commission on Large Dams estimate that in the 1990s about 300 dams over 15 metres were constructed each year.

