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Chao Phraya River Basin, Thailand

By: The Working Group of the Office of Natural Water Resources Committee (ONWRC) of Thailand*

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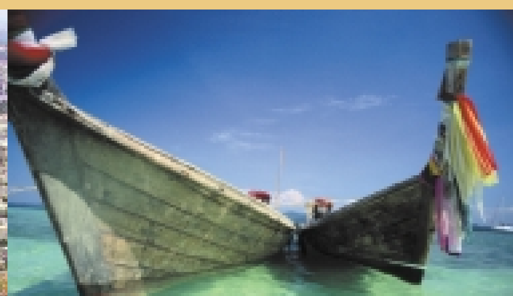
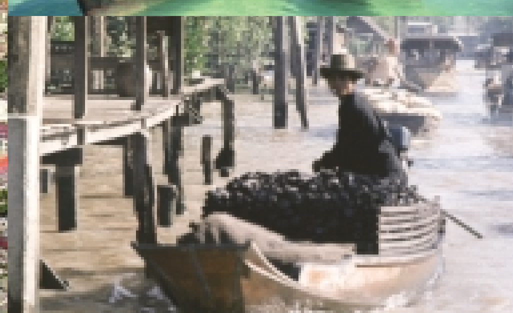
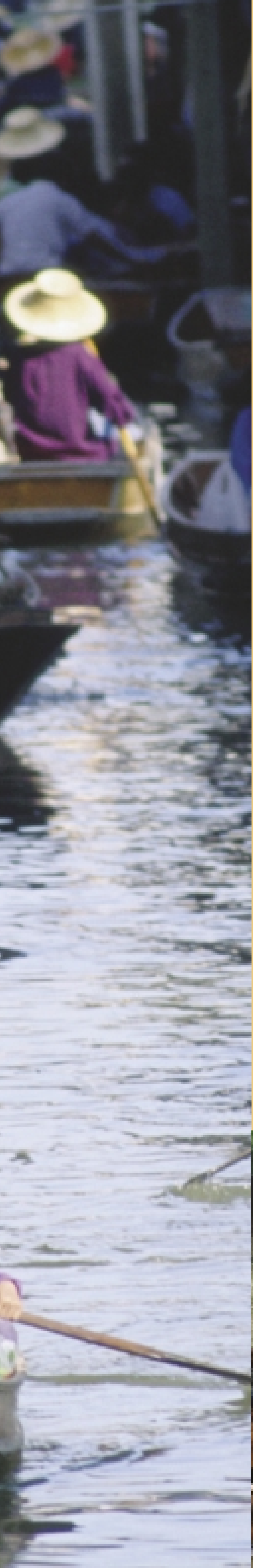
Chao Phraya River Basin



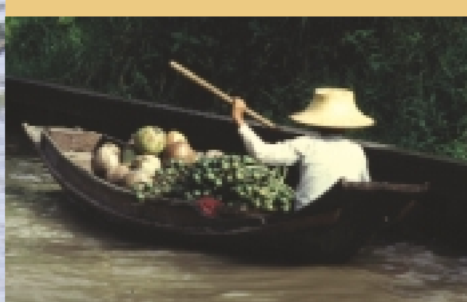




Scoop up the water, the moon is in your hands.

Zen saying by Kido Chigu (1185–1269)

THAILAND'S CHAO PHRAYA RIVER BASIN supplies a major metropolitan region. It covers 160,000 square kilometres (km^2), representing 30 percent of the country's total area, and is home to 23 million people. Of these, some 8 million live in the capital city of Bangkok. Unlike Japan and France, however, the country has been slow to adopt a comprehensive approach to reform and legislation. It also cannot afford high-tech solutions to such critical water problems as floods, droughts and pollution. When drought conditions lead to water shortages in Bangkok, the result is overpumping of groundwater and subsequent land subsidence and more flooding. Deforestation in the basin's rural areas leads to flash floods, erosion and landslides. There is hope that the newly created River Basin Committees will bring about a more equitable sharing of the resource and that participatory approaches will lead to wiser governance.



THE CHAO PHRAYA RIVER BASIN, traditionally the centre of rice production, is in transition from water richness to water scarcity due to the increasing demands on this limited resource. A more systematic and comprehensive approach to water management is needed to achieve three purposes: equitability (among the diverse stakeholders), sustainability (for the basin's rapidly deteriorating aquatic environment) and efficiency (for international competition). These cannot be accomplished, however, without first carrying out an accurate and up-to-date analysis of the basin's water situation. Assessment tools are therefore essential, and foremost among these are indicators measuring the various conditions in the basin. This chapter is a first attempt to describe the development of such indicators for the Chao Phraya River basin.

Map 16.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

Both initiatives, national and international, are overseen by Thailand's National Water Resources Committee (NWRC) through its secretariat, the Office of National Water Resources Committee (ONWRC). To coordinate these efforts, the NWRC set up a subcommittee. As Thailand's bureaucracy is being reformed[1] to increase popular participation and self-governance, as required by its constitution, a working group represented by involved government agencies was created under the subcommittee. This working group's responsibility is to develop, test and, eventually, transfer the indicators and their uses to River Basin Committees. The ONWRC is currently working to establish these committees, and, at the time of writing, all eight sub-basins of the Chao Phraya River basin have been equipped with River Basin Committees. The legislative framework of water management is also undergoing reform. The ONWRC is drafting a Water Resources Law, updating old laws and facilitating the country's systematic water management.

Location

The Chao Phraya River basin covers an area of approximately 160,000 km^2 and is located entirely within Thailand. The basin drains into the gulf of Thailand, part of the South China Sea and the Pacific Ocean. Bangkok, a city of more than 8 million people, is located near the mouth of the Chao Phraya River. Bangkok is not only Thailand's official capital city, but also the capital city for trade, government and South-East Asia air transportation, as well as being the gateway to Indochina and south China.

Major physical characteristics

The Chao Phraya basin is mountainous with agriculturally productive valleys found in the upper region. The lower region contains alluvial plains that are highly productive for agriculture. The Chao Phraya River drains from north to south. Monsoon weather dominates, with a rainy season lasting from May to October and supplementary rain from occasional westward storm depressions originating in the Pacific. Temperatures range from 15°C in December to 40°C in April except in high altitude locations. The whole basin can be classified as a tropical rainforest with high biodiversity. The lower part has extensive irrigation networks and hence intensive rice paddy cultivation. In recent years, however, encroachment of people into forest area in the upper part of the basin and its conversion to agricultural use has become problematic.

Table 16.1: Hydrological characteristics of the Chao Phraya basin

Surface area of the basin	159,283 km^2
Annual precipitation	1,179 mm/year
Annual discharge	196 m^3/s
Annual potential evapotranspiration	1,538 mm/year

1. As a result, ONWRC together with a few other agencies was combined to become the Department of Water Resources under the new Ministry of Natural Resources and Environment. This new Department became effective in October 2002 and acts as Thailand's Apex Body in water management planning and implementation.

Map 16.2: Basin map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Major socio-economic characteristics

Population characteristics

The Chao Phraya basin is the most important basin in Thailand. The basin covers 30 percent of Thailand's land area, is home to some 40 percent of the country's population, employs 78 percent of its work force and generates 66 percent of its Gross Domestic Product (GDP). In 1996, the total population of the Chao Phraya basin was 23 million inhabitants. The basin can be divided into eight sub-basins based on the natural distribution of its river system. About half the population (11.5 million) resides in the Lower Chao Phraya basin, in which the highly populated areas of Bangkok Metropolitan Area (BMA) and its environs of Samut Prakan, Nonthaburi and Pathum Thani are located. Similarly, there is a large concentration of population in the Upper Ping where Chiang Mai (the second largest city in Thailand) is located. Overall, about 68 percent of the total population of the basin is rural, but there is considerable variation with over 90 percent of the rural population in the Upper Chao Phraya basin compared to 45 percent in the Lower Chao Phraya basin. It is projected that in the next decade, the rural population will decrease by an annual rate of about 1.31 percent and that the population growth rate will remain low at about 1 percent per annum. These trends should ultimately induce aggregation of farming land with a consequential increase in household incomes. The average population density is 136 inhabitants/km^2, but varies greatly from 44 inhabitants/km^2 in the Nan sub-basin to 533 inhabitants/km^2 in the Chao Phraya sub-basin. Bangkok and its vicinity have the highest population density, with 1,497 inhabitants/km^2.

Economic activities

As Bangkok is located in the Chao Phraya sub-basin, this is economically the most important sub-basin, contributing 78.2 percent of the total GDP of the basin. The sub-basins can be divided into three groups based on their economic growth rate:

- Tha Chin, Chao Phraya and Upper Ping, which have higher growth rates than the national average;
- Pasak and Wang, at about the national average; and
- the Lower Ping, Upper Yom, Lower Yom, Upper Nan, Lower Nan and Sakae Krang sub-basins, all of which have lower growth rates.

The division of the basin into a prosperous north and south and a poor middle is reflected in the socio-economic conditions (see table 16.2). Formal employment and social services, such as health and education, are similarly concentrated in the Bangkok Metropolitan Region (BMR) and the Upper Ping, and generally have a higher per capita provision. Considerable variation exists in the Gross Provincial Product (GPP) and in the economic growth rates of provinces depending on the relative industrial and agricultural shares of sub-basin economies: high-growth sub-basins are industrial while low-growth ones are agricultural.

Agriculture accounts for 5 percent of the GDP in the basin, manufacturing for 33 percent, and wholesale and retail trade for 17 percent. The small overall share of the agricultural sector is due to the large influence of the GDP of the Lower Chao Phraya basin where urbanization and industrialization are intense.

Table 16.2: Population, per capita income and Gross Provincial Product (GDP) in the sub-basins in 1996

Sub-basin	Population	Per capita income in Baht (and US$)	Gross Provincial Product (GDP) in million Baht (and US$)
Upper Chao Phraya basin			
Ping	2,384,946	50,744 (US$1,223)	121,022 (US$2,916)
Wang	717,928	43,419 (US$1,046)	31,172 (US$751)
Yom	1,711,112	31,226 (US$752)	53,431 (US$1,287)
Nan	2,354,766	34,778 (US$838)	82,546 (US$1,989)
Pasak	1,340,559	52,923 (US$1,275)	70,946 (US$1,710)
Sakae Krang	461,542	38,578 (US$930)	17,806 (US$429)
Lower Chao Phraya basin			
Chao Phraya	11,477,193	193,388 (US$4,660)	2,105,979 (US$50,746)
Tha Chin	2,572,201	82,135 (US$1,979)	210,641 (US$5,076)
Total	23,020,247		2,693,543 (US$64,926)

Based on US$1 = approx. 41.5 baht. Considerable variation exists in the GPP and per capita income of the sub-basins: high-growth sub-basins are industrial and low-growth ones are agricultural.

The majority of people in Thailand are of Buddhist background. In the past, when population density was low, the area was rich in water, and the traditional way of life in the lower part of the basin often revolved around both water and agriculture. For example, the famous tourist attraction, the Songkran Festival (a traditional Thai New Year celebration in mid-April where water is splashed among spectators, passers-by and tourists), marks the beginning of the rice-planting season for Thai farmers. In the high-water month of November, another festival, Loi Kratong, involves people floating away their offering in small pontoons placed on the river.[2]

The political system is democratic with a long history of intermittent coups d'état until about ten years ago. The present Constitution, effective as of five years ago and obtained through an elaborate process of popular participation, paves the way for a promising future. With respect to water management in Thailand, the Constitution requires decentralization of water management (as a component of natural resources management) from government agencies to local governments.

2. For more details, see: http://sunsite.au.ac.th/thailand/special_event/songkran/, and http://mcucity.tripod.com/wat3.htm.

Water Resources: Hydrology and Human Impacts

Surface water

Riverine resources

The headwaters of the Chao Phraya River originate in the mountainous terrain of the northern part of the country and consist of four large tributaries: the Ping, Wang, Yom and Nan Rivers. The main river system passes through or close to many of the major population centres of the country including Bangkok, which is situated at its downstream end. The four upstream tributaries flow southward to meet at Nakhon Sawan and form the Chao Phraya River. The river flows southward through a large alluvial plain, called the delta area, splitting into four channels: the Tha Chin (also called the Suphan and Nakhon Chai Si further downstream), the Noi, the Lop Buri and the Chao Phraya Rivers (see table 16.3 for some river data).

Surface water storage

Since 1950, the government has constructed some 3,000 dams to store the monsoon flows for release in the dry season. This enables them to exploit the basin's vast agricultural potential and to meet the growing demands of industrial and urban users. The two largest dams constructed are the Bhumiphol and Sirikit dams, whose purpose is to supply stored water for electricity generation, irrigation, and domestic and industrial water use. Together these two dams control the runoff from 22 percent of the entire basin area. Bhumiphol dam on the Ping River has a live storage capacity of 9.7 billion cubic metres (bm^3), compared to the average annual inflow of 6.6 bm^3 from a drainage basin

Table 16.3: Annual average runoff in the sub-basins

Sub-basin	Catchment area (km^2)	Total volume (Mm^3)
Ping	35,535	9,073
Wang	11,084	1,624
Yom	19,516	3,684
Nan	32,854	11,936
Sakae Krang	5,020	1,096
Pasak	15,647	2,823
Tha Chin	18,105	2,449
Chao Phraya main stream	21,521	4,435
Total	159,283	37,120

Runoff is fairly constant all over the sub-basins; the Wang and Tha Chin sub-basins show a higher runoff.

of 26,400 km^2. The installed hydroelectricity generation capacity is 713 megawatts (MW). The dam was completed in 1963, and filled for the first time in 1970. Sirikit dam on the Nan River was completed in 1972 and has a live storage capacity of 6 bm^3 compared to the average annual inflow of 5.9 bm^3. The installed hydroelectricity generation capacity is 500 MW. Several other large dams (Kiew Lom, Mae Ngat, Mae Kuang, Mae Chang, Thap Salao and Kra Sieo) have also been built during the last twenty years to increase the total surface water storage in the basin, while another, the Pasak dam, was commissioned in 2000. Table 16.4 presents some information on selected dams in the basin.

Barrages

A number of barrages have been constructed in the Lower Chao Phraya basin to control and divert the water in the canal systems that provide irrigation water to some 1 million hectares in this area. The most important barrages in the delta area are the Rama VI barrage, completed in 1924, and the Chao Phraya (Chainat) diversion dam on the Chao Phraya River, built in 1957. Although the Rama IV barrage was constructed about seventy-five years ago, it still maintains its structure and remains operational. These barrages divert water to a complex system of interconnecting canals serving the Lower Chao Phraya basin irrigation system. Barrages have also been constructed above the Chao Phraya diversion dam. The Naresuan dam across Nan River at Phitsanulok was completed in 1985 and diverts water to the whole area of the Phitsanulok Phase I Project. The water released from the Sirikit dam meets the requirements of the Phitsanulok Irrigation Project as well as part of the demand for the Chao Phraya Delta area.

Groundwater

Aquifer distribution

Hydrogeologically, the Chao Phraya River basin is comprised of seven groundwater sub-basins: Chiangmai-Lampoon basin, Lampang basin, Payao basin, Prae basin, Nan basin, Upper Chao Phraya basin and Lower Chao Phraya basin. Within these groundwater sub-basins, water is held in either confined or unconfined aquifers. Eight separate confined aquifers are located in the Upper Tertiary to Quaternary strata of the Bangkok area. The natural groundwater within this succession of aquifers is highly confined, creating artesian conditions in each. Ease of exploitation, as well as the high chemical quality, are the main reasons for the original development of this source. Groundwater storage and renewable resources have been estimated for each groundwater sub-basin, as shown in table 16.5.

Recharge, flow and discharge

There are few existing estimates available of groundwater recharge on a regional basis. In an artesian aquifer, as that beneath Bangkok, storage depletion is seen through a decline in piezometric pressure and a reduction in the area in which

Table 16.4: Characteristics of major reservoirs

Reservoir name	Sub-basin	Maximum retention (Mm^3)	Normal retention (Mm^3)	Minimum retention (Mm^3)	Effective storage (Mm^3)
Bhumiphol	Ping	13,456	13,462	3,800	9,662
Sirikit	Nan	10,640	9,510	2,850	6,660
Kiew Lom	Wang	112	112	4	108
Mae Ngat	Ping	325	265	10	255
Mae Kuang	Ping	263	263	14	249
Mae Chang	Wang	108	NA	NA	NA
Thap Salao	Sakae Krang	198	160	8	152
Kra Sieo	Tha Chin	363	240	40	201
Pasak	Pasak	960	NA	NA	785

The two largest dams of the Chao Phraya River basin are Bumiphol and Sirikit; together, they control the runoff from 22 percent of the entire basin.

Table 16.5: Groundwater storage and renewable water resource of the sub-basins

Groundwater basin	Groundwater storage (million m^3)	Renewable water resources (million m^3)
Chiangmai-Lampoon	485	97
Lampang	295	59
Chiangrai-Payao	212	42
Prae	160	32
Nan	200	40
Upper Chao Phraya	6,400	1,280
Lower Chao Phraya	6,470	1,294
Total	14,222	2,844

The calculation is based on the assumption that the amount of groundwater stored depends on the change of water level, the area of the aquifer and the storage characteristics, which vary with the geology of each area – unconfined, confined or semi-confined. The Upper and Lower Chao Phraya groundwater basins are by far the largest ones: they store about 90 percent of the overall groundwater resources of the case study area. The table assumes that only 5 percent is renewable each year, a very small amount of the total in the basins.

artesian conditions exist. The continued decline in levels indicates that abstraction is not in balance with recharge. In unconfined aquifers, abstraction of resources in excess of natural recharge normally leads to a much lower rate of water level decline than that of confined aquifers.

Water quality

Surface water quality

A study in 1997 (Binnie & Partners, 1997) reviewed the water quality data for the Central River basin, which is routinely monitored by the National Environmental Board (NEB), the Pollution Control Department (PCD) and the Ministry of Public Health (MOPH). Results indicated that of the major rivers in the Lower basin there was evidence of heavy pollution in both the Chao Phraya and Tha Chin Rivers, while overall water quality was acceptable in the Pasak and Sakae Krang Rivers. The Chao Phraya River exhibited serious organic and bacterial pollution that was a threat to many species of aquatic life. Similarly, water quality in the Tha Chin River was heavily degraded, due to the combined discharges of industrial, domestic and rural inflow.

Groundwater quality

The main chemical constituents affecting groundwater quality are sodium and chloride. The average salinity of the groundwater in the unconfined aquifers shows a general increase in the downstream direction, with the exception of the Ping catchment whose lowest salinity level is comparatively high for its upper catchment location. The groundwater with the lowest salinity comes from the Wang catchment. Nitrate concentrations are almost invariably low in all catchments. The extent to which chemical quality is affected by contamination is not known, except in some specific areas.

Rainfall variation

The basin climate consists of long, distinct dry and rainy seasons. These give rise to typical water problems: water shortages, floods and water pollution. These problems can become the source of environmental and socio-economic problems: for example, water shortage in Bangkok leads to overpumping of groundwater and subsequent land subsidence and flooding. In the basin's rural areas, encroachment on forest land leads to excessive erosion, extreme floods and landslides. Water pollution is widespread in urbanized sections of the Chao Phraya River and its tributaries. Recently, due to encroachment on forested areas, flash floods and landslides have also become frequent.

Flooding

Floods are a natural phenomenon in the Chao Phraya River basin and while residents have adapted their lifestyle to deal with annual flood occurrences, they cause significant economic losses. The major causes have been the decline of flood retention areas and the confinement of flood plains due to increasing development, the rapid urbanization around Bangkok, the growth of provincial cities and the intensification of agriculture.

In recent years, the government has had some success in reducing flooding through the construction of multi-purpose reservoirs, dikes, and other flood control infrastructures. The containment has, however, resulted in a higher overall flood risk as elevation levels are reached more quickly.

Human impacts on water resources

In general, the basin is entering a critical period where small changes in the hydrologic conditions can create large socio-economic disturbances. Due to the increase in population, it is unavoidable that new settlements will arise in areas where water management is difficult. The human impact on water resources, and vice versa, is visible throughout the basin. Native plants acting as surface cover on native land are being destroyed at an alarming rate, causing flash floods, erosion and landslides. The construction of dams and diversions requires the resettlement of people, usually in unclaimed and infertile areas. Highly populated areas are producing solid waste and wastewater that pollute streams and water bodies, and as a result, many native species are disappearing. In the lower part of the basin where intensive irrigation networks exist, rice paddy is grown continuously throughout the year. Thirty years ago, the same area grew a single rice paddy a year. Since then, the number has doubled, then tripled, and today there is continuous cultivation. Clearly, the land is heavily used, with no time to be revitalized. The government now has mobile land doctor units helping farmers diagnose and remedy land degradation problems.

Data and information on water resources

The collection of data and information on water resources is complicated by the high number of agencies involved. This gives rise to such problems as repetition and inconsistency of data. In general, fundamental data on water resources are collected but are difficult to use due to data management problems.

Challenges to Life and Well-Being

Water for basic needs

Water for domestic purposes is provided by water service facilities in urban areas and by wells in rural areas. The majority of piped schemes for farm households are operated and managed by village communities. Eighty-five percent of the population has access to safe and adequate drinking water, 90 percent to latrines and 60 percent to rural pipe water systems.

Water for food

Surface water irrigation systems

Irrigation systems were developed in the Chao Phraya basin as early as the 1890s in the southern Chao Phraya plain. The area was subject to deep and prolonged flooding, and the approach then was to construct canals to provide access to large land areas for the cultivation of flood-dependent rice. The canals also helped spread the floods more evenly and promote drainage at the end of the flood season. Beginning in 1904, with the founding of the Royal Irrigation Department (RID) as the agency responsible for water resource development in Thailand, and through the 1930s, this mode of development was applied to more than 500,000 hectares. Today, irrigation area coverage totals 29 percent.

The irrigation systems in the northern part of the Chao Phraya basin consist of discrete irrigation systems served by their own reservoirs. Many small pump irrigation schemes have also been developed. However, several large dams were built to provide the Lower Chao Phraya basin with irrigation water. It is essential to appreciate that developing the irrigation systems in the Lower Chao Phraya basin was done progressively, often building and expanding on existing systems. The Lower Chao Phraya irrigation scheme, the largest in the country, was initially constructed to provide supplementary irrigation during the monsoon season, but was little by little required to provide ever-increasing amounts of irrigation water during the dry season.

The lower basin (delta) irrigation system is complex and consists of some twenty-six interconnected schemes below the Chao Phraya diversion dam. This barrage diverts the flow of the Chao Phraya River into a distribution network and at the same time releases the required water flow for river maintenance and downstream water needs. The water conveyance and regulation facilities of this system, whose operation is a major concern in efficient water management, are now quite old, and the canals are unlined earth constructions. The whole system is managed by the RID.

Groundwater irrigation systems

In agriculture, groundwater is mainly used to supplement surface water supplies. Groundwater consumption is more intense for land preparation during the dry season and in drought years, for crop needs in the early part of the wet season, and as a supplementary source of water for farms located at the tail end of distribution canals. Pumped irrigation schemes are being implemented by the Department of Energy and Energy Promotion to secure adequate irrigation water throughout the year in the middle-basin area. The potential exists to further develop the use of groundwater for irrigation purposes, but this should be undertaken after a thorough analysis of the sustainable yields of the relevant aquifer.

Water and ecosystems

Public recognition of water requirements for ecosystems is not widespread. It is known only within a limited circle of academics and technical agencies. Efforts are being made to prioritize water requirements for ecosystems in the forthcoming Water Resources Law, described further on. Environmental Law does exist, based on the polluter pays principle, but it is not effectively enforced. The Water Quality Index value for the basin is 59 percent. The index represents a mix of nine water quality items with higher value indicating better water quality.

Water and industry

Industrial growth across the region has been greatest in Bangkok, and pressure on existing infrastructure has led to the creation of new enterprises in the surrounding provinces where land, labour and other resources are more readily available and infrastructure is less congested. Future growth is expected to be greatest in these areas although there are also initiatives to encourage industrial expansion in a number of provincial centres. The amount of water used for industrial purposes in the whole basin is uncertain. Estimates for groundwater use are only available for the Chao Phraya sub-basin. Considerable inconsistencies are found in the data collected, and it is unknown whether figures also take account of inefficiencies in the system. A study (Binnie & Partneis, 1997) of industrial water use for the eight sub-basins estimated an industrial water demand of about 758 Mm^3 in 1996, of which 94 percent was attributed to use in the Chao Phraya/Tha Chin sub-basins. Surface water supplies are less important to industry with about 75 percent of water use derived from groundwater resources. Pipe water use, which is a more economical method of transporting water because of low evaporation and better water quality, represents 70 percent of water used. Indicators show that the polluter pays principle applies to 10 percent, while 50 percent of the water is reused.

Water and energy

Hydropower in the Chao Phraya basin is managed by the Electricity Generating Authority of Thailand (EGAT). Currently there are only two major hydropower installations, at Bhumiphol (713,000 kilowatts [kW]) and Sirikit (500,000 kW), with a smaller installation at Mae Ngat (9,000 kW) in the Upper Ping basin. At present, EGAT is not actively pursuing new hydropower projects in the basin. The construction of further large reservoirs with hydropower potential would involve large-scale resettlement, making such projects problematic. New reservoir construction in the upper basin has also encountered increasing opposition on environmental grounds. The economic value is not used in water allocation for hydroelectricity generation, but there is an Environmental Impact Assessment (EIA) for all hydroelectricity infrastructure.

Water for cities

Across Thailand, potable water supplies are generally provided by two agencies: the Metropolitan Waterworks Authority (MWA) and the Provincial Waterworks Authority (PWA). The MWA engages in production and distribution of potable water in the Bangkok metropolitan region while the PWA is responsible for all provinces in Thailand. The PWA is also responsible for water resource development, conveyance, pumping, treatment, storage and distribution facilities from all urban and rural communities in the provinces. Total domestic water requirements in 1993 were estimated at 3,194 Mm^3 per year. In contrast to industrial water supply, it was estimated that only 12 percent of domestic supply was being met from groundwater sources. There is no cross-subsidy from richer beneficiaries downstream to pay for the expense of protecting the upper watershed. Economic incentives are used in about 70 percent of the municipal areas, and the polluter pays principle is applied in an additional 10 percent of municipal areas.

Navigation

Since early times, the Chao Phraya River has been a major navigation route far into the central part of the basin. Ships and barges have provided a very important means of transport for commercial goods. However, the increasing diversion of river flow for irrigation has reduced minimum flow in critical reaches of the river, and navigation is now restricted during the dry season for vessels over a certain size. A study done for the Harbours Department in 1996 proposed construction of two barrages to restore navigation capacity in the main Chao Phraya River and into the lower reaches of the Nan River. Minimum river flow is also required for navigation in other waterways. Although generally restricted to a smaller and declining number of commercial craft, the Pasak (below Rama VI barrage) and the Tha Chin Rivers are still important waterways as are a number of the RID's supply canals in the lower part of the basin. Allocation of the basin's water supplies must take into account the need to maintain sufficient flow for river transport.

Management Challenges: Stewardship and Governance

Ownership and responsibility

The Chao Phraya basin has a long history of informal water allocation. In some northern areas, informal systems have been successfully implemented for over 200 years. The water allocation systems in the northern parts of the basin differ from those in the middle and lower areas. This is primarily due to topography. In the north, the river valleys are small and socially more defined. In the middle and lower sections, there was usually enough water for a rice crop in the wet season, which was sufficient to sustain a farm family and allow for home consumption throughout the year.

The water allocation system in the lower basin is as follows: EGAT controls the water release from both reservoirs. RID routinely checks the downstream water level at the Chainat diversion dam. If this level is lower than what it should be, considering the quantity released by EGAT, then too much water has been drawn off by users between the reservoirs and the Chainat diversion dam. This phenomenon has led the working group to design a rotation system to conserve water. Organizational and individual users in each province along the

Chao Phraya River basin are assigned a number of days on which water withdrawal is permitted. Provincial authorities are responsible for enforcing this, and are coordinated by the Ministry of the Interior. Compliance with the water allocation plan is good among the agencies represented on the working group but not among farmers, the central reason for this being that farmers can earn more income by planting a second rice crop in defiance of the plan. There is no enforcement because disobeying the water allocation plan is not illegal. Accordingly, efficiency and equity are low.

Institutions

Within the Prime Minister's Office there are six boards and committees responsible for policy planning and coordination of water resources at a national level. In addition, a plethora of government agencies are involved in managing water resource development, use and delivery in Thailand. The three dominant ministries, related to water management, include Agriculture and Cooperatives (MOAC), Science Technology and Environment (MOSTE), and Industry (MOI). The regional offices of government line agencies, provincial governments and local bodies are also involved in water resource development, use and management, while in some areas, farmers have formed strong water user associations to operate and manage water within local irrigation schemes.

National boards and committees

The principal boards and committees responsible for developing policies concerning water resource development, management and conservation are the National Economic and Social Development Board (NESDB), the NEB and the NWRC.

The presence of three bodies having similar functions leads to confusion and indecision in implementing water policies, particularly as their relative importance cannot easily be determined from their functions and powers. Based on the mandates of the three bodies, the NWRC's responsibility relates more directly to water resources than that of the other two boards, with NEB's tasks being more relevant to water resources than those of the NESDB. Since NESDB plans are usually quite broad, more detailed policies and plans are required for each individual sector. For example, when considering natural resources and the environment, the NEB elaborates detailed policies and plans within the framework determined by the NESDB plan. By the same token, since the NEB is not able to address all detailed policy issues regarding natural resources and environment – in particular, water resources – the NWRC should prepare more detailed water policies and plans. As a result, the NESDB plan should be considered as a framework for water policies formulated by NEB and NWEC, respectively. It is apparent that there is some confusion, duplication and lack of clarity and integration in the development and operation of national resource policies and strategies.

Regional offices, provincial government and local bodies

At the provincial level, the Provincial Administration and District Administration offices (and similar agencies at the local government level) have an operational role in supplying local domestic and industrial water, but in reality have little role in water resource planning and management insofar as basin-wide issues are concerned. RID regional offices perhaps contribute most to water management at the provincial and local levels. These offices work closely with water user groups and conduct training programmes in irrigation maintenance and other related issues.

The need for greater coordination of water management at the basin level has been recognized through the recent creation of basin subcommittees. Three such committees have been established in the Chao Phraya basin for the upper and lower Ping River tributary basins, and also for the Pasak tributary basin. These committees are in the formative stage, but have been given wide-ranging advisory roles covering most aspects of Integrated Water Resources Management (IWRM). The ultimate intention is to form such committees in all of the twenty-five designated river basins in Thailand, as they are an important initiative for creating a more appropriate institutional structure for river basin management in the Chao Phraya basin. It remains to be seen whether the committees can be empowered with the necessary knowledge and commitment to fulfil their potential. They must also be viewed as water resource managers and not water development committees if they are to effect good IWRM.

Water user organizations

Since the thirteenth century, the members of water user organizations have developed small-scale irrigation programmes in the Ping River basin without any assistance from the government. These irrigation systems (*Muang Fai*) had their own laws and regulations, agreed upon among the water users who had to pay a water fee either in cash or in kind as stipulated in the agreement. They also had to pay the maintenance fee, contributing to tools and equipment for weir repair and dredging the irrigation canals. The amount of labour and accompanying tools depended on the amount of individual cultivated land and water use in the system.

In general, there are very few successful water user organizations in Thailand. This stems from a number of issues.

The status of such organizations is ambiguous and the necessary legislation is lacking for them to obtain proper legal status. Furthermore, the idea of establishing water user organizations was not initiated by the water users themselves and historically there has been a lack of active farmer participation in all phases of project development as well as inadequate support from the concerned agencies. The successful creation and functioning of water user organizations depend on establishing obvious advantages for the water provider. The draft Water Bill encourages the creation of such organizations: in effect, Section D.3, item ii, states that Basin Committees would have to accommodate, advise and assist water users in forming organizations for the benefit of conserving, developing and utilizing water resources. The effectiveness of Basin Committees depends largely on the involvement of representatives of civil society and local water users in drawing up plans for water management and use.

Legislation

The 1997 Constitution

The enactment of the new Constitution in Thailand in 1997 enabled changes in the way the government, its agencies and local communities manage the country's natural resources. The Constitution is intended to impact on the government's natural resources and environmental policies, the implementation and operation of government projects, and the interpretation of relevant laws and regulations. In particular, the new Constitution provides:

- an increased requirement for the state to encourage citizens to participate in preserving, conserving and using natural resources and biodiversity in a sustainable manner;
- a greater decentralization of government responsibility for the subdistrict (*tambon*) level to manage resource use;
- a more direct participation by civil society in planning, managing and utilizing natural resources, and in developing and enacting laws; and
- a greater citizen access to information.

These provisions favour the concept of IWRM, which demands a high level of community/stakeholder awareness and participation, local-level planning and transparency.

The overall scope of the new Constitution establishes not only a climate of open management, but also an obligation for government administrations to implement this approach. This is particularly relevant to the function and operation of organizational units to be set up under the project to improve water sector management in the Chao Phraya basin. There can be no excuse for not including the basin community/stakeholders in future water resource management decisions: it is required by the new Constitution, and it should unleash a new level of commitment to achieving a balance of sustainable water resource management in Thailand.

Existing water laws

Thailand has at least thirty water-related laws, administered by over thirty departments overseeing water issues in eight ministries.[3] Like water policies, the mass of water laws, codes and instructions have all been framed for particular and usually singular purposes. There is no umbrella legislation linking these laws and codes, and consequently there is no legislative backing for an organization to undertake IWRM. In practice, this results in ad hoc and often erratic relationships among all agencies, as the agencies pursue their narrow objectives and mandates and seem more interested in enhancing water supply to meet the demands of politically powerful groups. Water permits are not issued and bulk water use for irrigation, hydropower, domestic, town water and industry is not properly controlled. New developments arise (though many of these are small and operate locally) and the adverse cumulative impacts of such implantations on the equitable distribution of water and on the health of the aquatic environment are significant. The absence of a modern, comprehensive water resource law is probably the most significant factor inhibiting IWRM in Thailand.

Draft water resources law

The inadequacies in the many water-related laws in Thailand have led to the drafting of a more comprehensive and integrative Water Bill. However, one fundamental flaw in the draft Water Bill is that it does not provide a mandate for any one agency to act as the national water resource manager. This should be at the core of any water resources law. Although it is specified in the draft document that the ONWRC is to be the water resource management agency, the functions specified do not allow the ONWRC to undertake comprehensive water resource management. The draft Water Bill covers water distribution and allocates this role to new River Basin Committees, who are to act as coordinating bodies concentrating largely on strategic natural resources or water resource planning, with a responsibility for

3. Ministry of Agriculture and Cooperatives, Ministry of Transport and Communication, Ministry of Industry, Ministry of the Interior, Ministry of Public Health, Ministry of Labour and Social Welfare, Ministry of Education, Ministry of Defence, and Ministry of Science, Technology and Environment.

broad or bulk allocation of water between water users within geographic zones. Under the new proposed law, they can be innovative and play an important part in achieving good river basin management, providing a critical link between communities and stakeholders at the tributary basin level and a higher regional or national authority.

In summary, the existing laws, policies and strategies relating to water resource management do not clarify roles and functions, and are too discrete to allow for IWRM. In its current form, the draft Water Bill would not provide a suitable basis for a comprehensive approach to river basin management. Clearly, considerable further work has to be undertaken to make the draft water law fulfil all the needs of IWRM throughout the country.

Groundwater

At present, the only direct law related to the regulation of groundwater is the Groundwater Act of 1977 (amended in 1992). The Groundwater Act was put in place with the intention of regulating groundwater use after the government realized the adverse effects of its uncontrolled use. The MOI regulates groundwater through the issue of permits for well drilling. The Groundwater Control Division under the MOI is responsible for reviewing well-drilling requests and for issuing well permits within the BMA and its surrounding provinces, namely Pathum Thani, Nonthaburi, Samut Prakan, Samut Sakhon and Nakhon Pathom. The Groundwater Control Division also takes responsibility for collecting the groundwater fee payment from private sector users, in accordance with the readings from well meters attached to the permitted wells.

Although some acts and regulations are outdated, legislation is in place to adequately control water use. The major problem in controlling excessive and illegal water use and implementing water charges is not the inadequacies of regulations, but lack of political will and the failure of responsible authorities to implement laws and regulations.

Finances

In the past, funding of the basin's water resources emphasized development rather than management. The government budget is allocated on a project-by-project basis, rather than applied to the water sector as a whole. Such a fragmented funding approach is a major cause of inefficiency. As of the next fiscal year, an improved system for allocating budgets will be applied. It is now too early to assess its impact.

Management approaches

Water-related risks such as drought and floods are presently managed on an ad hoc rather than systematic basis. Water valuation is less present in agriculture than in other sectors. Overall, economic tools are not yet fully applied. Water sharing at all levels (basin to basin, upstream to downstream, sector to sector) exists but without clear-cut policy or directions. IWRM and demand management have just been introduced and are not yet practiced. Stakeholder participation, required in the Constitution and the present National Development Plan, is practiced in establishing River Basin Committees. Public-Private Partnership (PPP) is already implemented in domestic and industrial pipe water supply, but not yet in agricultural water supply. Planning and development, done by government agencies in the past, are slowly changing. The newly established River Basin Committees are now expected to perform these duties, while agencies provide technical advice. A Unified Water Resources Information System will be created to ensure the knowledge base. The main features of the system will include public accessibility, and the sharing and linking of all existing agency information bases between themselves and to each individual River Basin Committee's information base.

Policy and policy implementation

Government development plans

Growth under successive five-year plans has been sustained and rapid, except during the economic crisis in Thailand, which started in mid-1997. It is, however, recognized that economic activity and prosperity have remained concentrated in Bangkok and the adjacent provinces. Recent five-year plans have attempted to restore the current imbalance between the more prosperous central region and the poorer rural areas, but with mixed success. One concern has been that the more developed areas are using a higher proportion of the country's natural resources, including water sometimes to the detriment of rural areas.

Water resource development

As previously stated, past government policies have been directed towards water resource development rather than management, with the specific aim of securing more supplies. Guiding principles for national water resource management are outlined in the National Economic and Social Development Plans, but they only indicate very broad objectives. For example, they encourage a holistic approach to basin development (Sixth National Plan) and sustainable development (Eighth National Plan.) A national water policy was announced by the Cabinet in October 2001, which is a starting point for budget allocation in the water sector under the present unified budgeting system.

Water quality

The National Policy regarding water quality is stipulated in both the National Economic and Social Development Plan and in the

National Policy and Plan for Natural Resources and Environment Management, which set long-term (twenty-year) goals, standards and strategies. In the Eighth Plan, the national goal is to maintain the quality of surface water at the 1996 level. Further planning is in process. An action plan for community pollution control will have to be completed for the twenty-five river basins in Thailand. In addition, an emergency plan to prevent and mitigate toxic water pollution has to be undertaken.

Conclusions

From the macro perspective, the critical problem in the basin is the inability to manage water so as to ensure optimum and equitable use and balance benefits (and burden) among the basin's stakeholders. In both its institutions and the dissemination of information, the water management system is disunified and ineffective, while water rights remain unspecified. Demand in all sectors keeps increasing as the economy expands, but water intake and economic output are unbalanced: while agriculture represents about 80 percent of water use, it only contributes to 30 percent of the GDP; industry uses 10 percent of the available water resources and contributes to 60 percent of the GDP. In a basin where one third of the population lives in Bangkok, urban inhabitants pay less for piped water than the production cost, even when the raw water cost, the cost of maintaining upper watershed areas and that of wastewater treatment are not taken into account.

However, these are now recognized problems and important reforms are in process. The bureaucracy is being reformed, and a coordinating water management body is emerging (Apex Body). The Constitution has recognized the need to involve local people in water management, as demonstrated by the establishment of River Basin Committees. The water resources law is being drafted, the water budget system is becoming more holistic, and, if not yet already practiced, IWRM is being introduced.

Box 16.1: Development of indicators

It is assumed in this report that assessment can be made only after indicators have been developed. For this case study, preliminary indicators have been developed but not included. Following is a summary of assessment results.

- Identification of indicators and their values is subject to ongoing improvement.
- Indicators and their values are area-specific. Some indicators are applicable to the whole basin, some are not.
- Each indicator has three components: a name, a target value and an actual value. The target value is the desired value, while the actual value is obtained from real-world situation. To properly assess the water situation at any level – global, regional, basin or other – the target values must be compared to the actual values.

An index for each challenge area may be developed by combining indicators under the same challenge area. Each indicator can be assigned a different value. From WWAP's eleven predetermined challenge areas, the Chao Phraya River basin's priorities relate to health, cities, water sharing, governance and risk management. It should be noted that these priorities are preliminary and apply to the basin as a whole. Priorities for each sub-basin may be different from these and from each other.

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17

Lake Peipsi/Chudskoe-Pskovskoe, Estonia and the Russian Federation

By: The Ministry of the Environment of Estonia and the Ministry of Natural Resources of the Russian Federation

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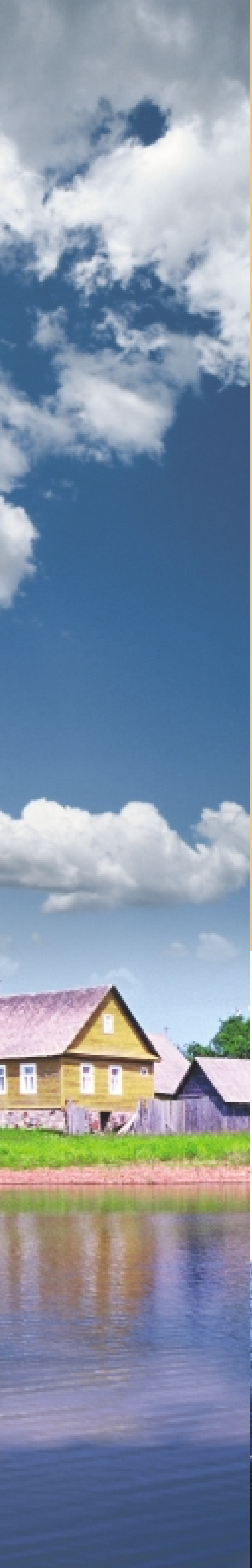
Lake Peipsi/Chudskoe-Pskovskoe



Every seed knows its time.

Russian proverb

LAKE PEIPSI/CHUDSKOE-PSKOVSKOE, a transboundary lake that discharges into the Baltic Sea, is shared by Estonia and the Russian Federation, both of which are responsible for its management. There is abundant water to meet the needs of an ageing, essentially rural, local population. However, uncontrolled fishing, eutrophication and pollution from untreated wastewater and power plant emissions have put the environment under increasing pressure. A joint water commission was created in 1997, but so far the economic potential of the area is underexploited, and more could be done to engage local and regional authorities, stakeholders and private businesses in solving common problems. Many changes will have to occur in 2004/5, as Estonia must adopt new standards in order to gain entry to the European Union.

LAKE PEIPSI/CHUDSKOE-PSKOVSKOE, sometimes called Peipus, is the fourth largest and the biggest transboundary lake in Europe. Its three names originate from the three languages historically used in the region – Estonian, Russian and German. Lake Peipsi belongs to the watershed of the Narva River, a 77 kilometre (km)-long watercourse that connects Lake Peipsi to the Gulf of Finland in the Baltic Sea.

Map 17.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

The lake consists of three unequal parts: the biggest, northern Lake Peipsi *sensu stricto* (*s.s.*)/Chudskoe, the southern Lake Pskovskoe/Pskovskoe and the narrow, straits-like Lake Lämmijärv/Teploe, which connects Lake Peipsi *s.s.* and Lake Pskovskoe. Lake Peipsi is located on the border of the Republic of Estonia and the Russian Federation between Lake Peipsi lowland (eastern border of Estonia) and the East European Plain (the Russian Federation). The lake lies at 30 metres above sea level.

Major physical characteristics

The catchment area of Lake Peipsi is approximately 160 km in width and 370 km in length. It has a surface area of 47,800 square kilometres (km^2), of which 16,623 km^2 lie in Estonia, 27,917 km^2 in the Russian Federation and 3,650 km^2 in Latvia. The catchment area is a gently undulating glaciolacustrine or till-covered plain, belonging to the forest zone of the East Baltic Geobotanical Subprovince.

The formation of the lake basin is due mainly to Pleistocene glaciers. In the north, some topographical features originated more than 380 million years ago, and have been slightly modified by the glaciers. On the northern part of the lake, scarp, sandy beaches prevail. The flat shores, found mainly on the western part of the lake, are usually swampy, populated with reeds and bulrushes.

Table 17.2 provides some morphometric data on Lake Peipsi.

Table 17.1: Hydrological characteristics of the Lake Peipsi basin

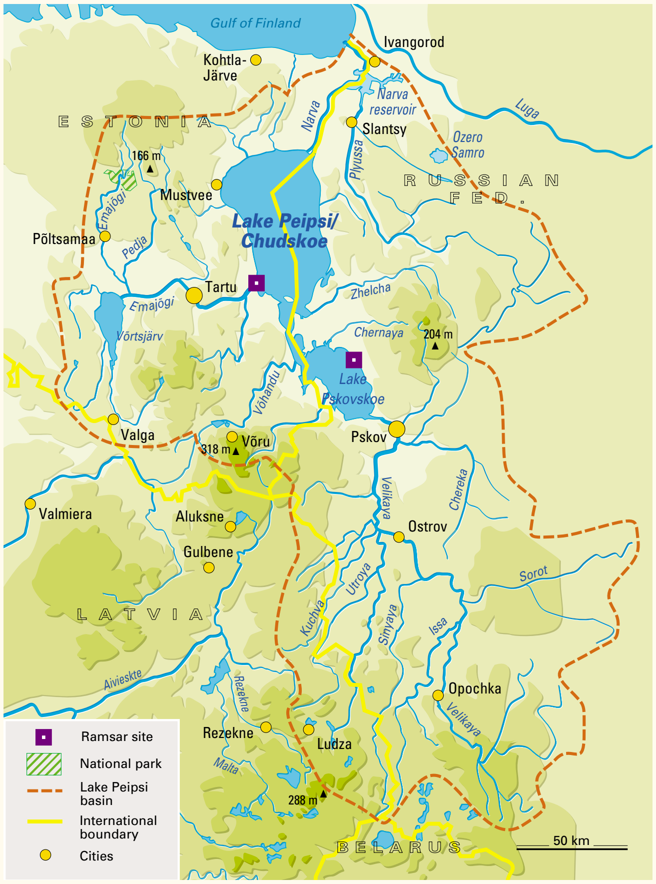
Surface area of the basin	47,800 km^2
Annual precipitation	575 mm/year
Annual discharge	329 m^3/s
Annual inflow to lake	324 m^3/s
Annual outflow from lake	329 m^3/s

Table 17.2: Morphometric data on Lake Peipsi

	Lake Peipsi s.s./ Chudskoe	Lake Lämmijärv/ Teploe	Lake Pskovskoe/ Pskovskoe	Lake Peipsi/ Chudskoe-Pskovskoe
Total basin area, km^2	2,611	236	708	3,555
Distribution of the waters between Estonia and the Russian Federation, km^2	1,387/1,224	118/118	25/683	1,564/1,991
Distribution of the waters between Estonia and the Russian Federation, %	55/44	50/50	1/99	44/56
Percentage of surface area	73	7	20	100
Volume, km^3	21.79	0.60	2.68	25.07
Percentage of total volume	87	2	11	100
Medium depth, m	8.3	2.5	3.8	7.1
Maximum depth, m	12.9	15.3	5.3	15.3
Length, km	81	30	41	152
Medium width, km	32	7.9	17	23
Maximum width, km	47	8.1	20	47
Length of shoreline, km	260	83	177	520
Percentage of total length, km	50	16	34	100

Source: Jaani, 2001.

Map 17.2: Basin map



Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Climate

Lake Peipsi has a moderate continental climate, rather wet, softened by the relative closeness of the Atlantic Ocean. Positioned between marine and continental climates, it is subject to unstable weather conditions all year. Summer is comparatively warm and wet, with a mild winter. The continental character increases to the east, where winters are longer and summers warmer. The watershed belongs to an area with high activity of low-pressure weather systems: an average of 130 depressions per year are registered, in other words, almost one every three days.

Between 1923 and 1998, the annual average temperature recorded at Tiirikoja, the meteorological station on the west coast of Lake Peipsi, was 4.6°C, with an average precipitation of 575 millimetres (mm) per year (Keevallik et al., 2001). The eastern coast generally has a more continental climate: at the station of Gdov for the same period, the average temperature in July was 17 to 18°C and, in February, -7°C to -8°C. The average annual precipitation near the Narva River is between 700 and 750 mm. The minimum temperature is -39°C on the lake's shores, but can reach -43°C inland.

Major socio-economic characteristics

Population and activities

The total population of the basin is approximately 1 million, but the population density differs in various parts: 24 inhabitants/km^2 in the Estonian and Pskov regions, compared to 11 inhabitants/km^2 on the sparsely populated eastern shore.

There are only two large towns in the basin: Pskov in the Russian Federation, with 204,000 inhabitants, and Tartu in Estonia, with 98,000 inhabitants. The majority of the basin population lives in small settlements. Only 27,000 people live in the local municipalities bordering the lake on the Estonian side. On the Russian side, the Leningrad region had 60,600 inhabitants in 2001, 87 percent of them urban dwellers. Of the 427,000 residents of the Pskov region, almost half live in Pskov itself.

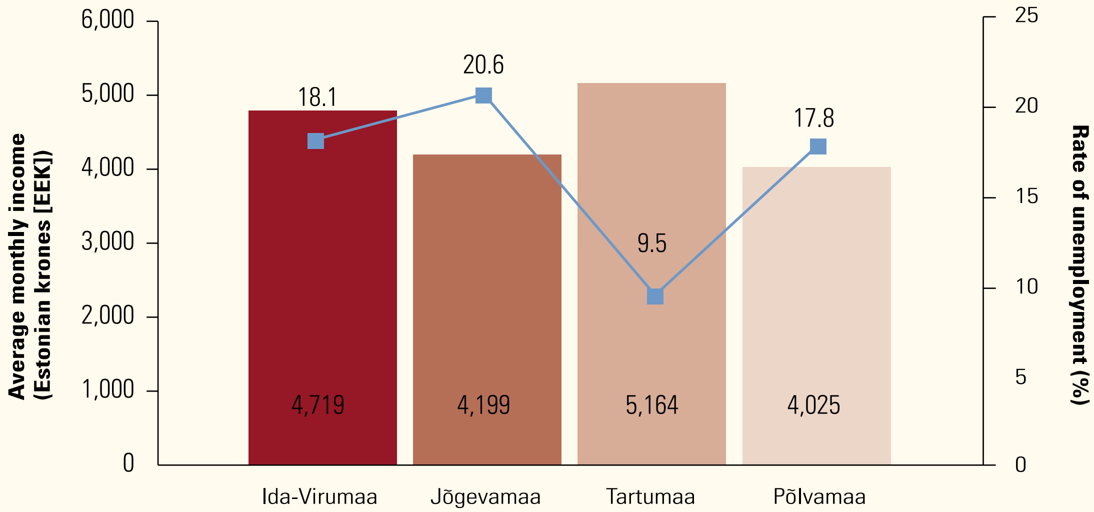
The greatest problems are the ageing population and the departure of the younger generation for bigger towns. An additional problem on the Russian side concerns the very low incomes in the Pskov and Leningrad regions (shown in figure 17.2). More than half the population have incomes that do not cover the cost of living. Comparisons between 1997, 1998 and 1999 indicate that the situation is worsening, in part due to the high rate of unemployment in these regions.

The Lake Peipsi basin can be divided into three regions (southern, central and northern) from the points of view of economic and social development, cultural composition of the population and the type of human impact on the lake.

The southern part of the basin is a rural, sparsely populated area with forestry and agriculture as the main livelihoods. Since agriculture is no longer profitable, many farmers live by cutting down forest from their own lands and selling it. This, and non-point source pollution from agriculture, comprise the main environmental problems of the area. Figures 17.1 and 17.2 show the unemployment rates in Estonian counties bordering Lake Peipsi and in the Pskov region.

Tartu and Pskov are located in the central part of the basin, and the area's economy is defined by the existence of these two population centres. In this region, rural settlements prevail, although on the Russian side the region is only sparsely populated. Pig farms and poultry factories dominate the agricultural sector. On the Estonian side, the culturally mixed rural communities are located along the lake's shores, among them Russian Old Believers, who are renowned for growing cucumbers and onions.

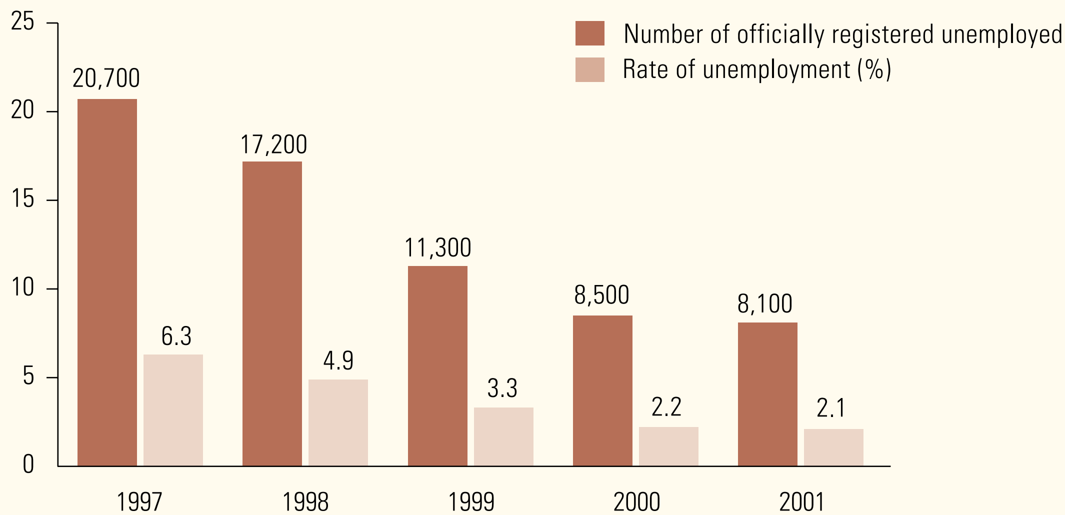
Figure 17.1: Unemployment and average income per month in Estonian counties bordering Lake Peipsi



17EEK = US$1. There is a very high rate of unemployment in Estonian counties surrounding the lake. There are, however, disparities: whereas in Tartumaa, unemployment is at 9.5 percent, in Jõgevamaa it reaches 20.6 percent. Meanwhile, the average monthly income is more steady, at around US$267.

Source: Taken from the web site of the Ministry of Labour of the Russian Federation, Department of Population Incomes and Standard of Life, 2002 (http://www.chelt.ru/income/3.html).

Figure 17.2: Unemployment in the Pskov region between 1997 and 2001



This figure shows both the number of registered unemployed people and the percentage that this represents compared to the total population. Unemployment in the Pskov region is steadily improving, with 2.1 percent unemployment in 2001 compared to 6.3 percent in 1997.

Source: Taken from the official site of the Administration of the Pskov region, 2001 (http://www.pskov.ru/region/invest/news/ 030401.html).

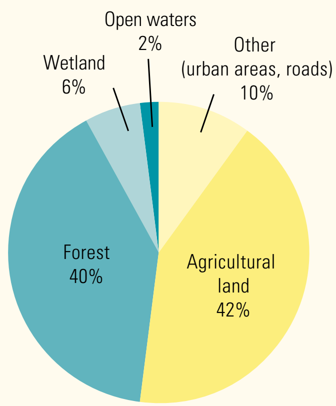
Commercial and small-scale fishing is currently an important source of income, particularly as many small enterprises have been shut down alongside access to the Russian produce market since the end of the Soviet era.

The northern part of the basin is the most industrial and is intrinsically linked to oil shale, the main natural resource of the area. In 2001, the Estonian Oil Shale Ltd. mines produced 11.4 million tons (Mt) of oil shale. The oil shale of the Baltic basin is one of the world's most unique for both its composition and high quality. Eighty percent of the oil shale mined is used to produce energy; the remaining 20 percent is used as raw material for chemical enterprises in the towns such as Kohtla-Järve (Estonia) and Slantsy (the Russian Federation).

Aside from oil shale, the small deposits of construction materials and the sands of the northern and western shores, the other basin resources (such as fish stock, forest, peat) are renewable. The main sources of air pollution are power plants and chemical enterprises. The Russian side of the basin produces construction materials and contains fuel and chemical industries associated with oil shale mining. Peat deposits are used for agricultural needs.

Figure 17.3 shows the distribution of land use in the Lake Peipsi basin.

Figure 17.3: Land use in the Lake Peipsi basin



Natural areas (forests, wetlands, lakes) cover almost 50 percent of the basin, but agricultural land use is quite important, at over 40 percent. Urbanized areas, however, cover only 10 percent of the basin.

Source: Taken from the Estonian Department of Statistics web site, 2002 (http://www.stat.ee).

History

Archaeological finds show that permanent agricultural settlements were founded in the first millennium AD. Permanent population centres of this kind existed in the vicinity of Alatskivi and Gdov on the coast of Lake Peipsi, and around Räpina on the coast of Lake Pskovskoe. At the end of the first millennium, Slavs reached Lake Pskovskoe and the eastern coast of Lake Peipsi. The first town-type settlements arose near the Pskov stronghold. In the fourteenth century, strongholds were also built at Gdov and Vasknarva. Beginning in the fifteenth and sixteenth centuries, fishing villages appeared on the coasts of the lake, and in time, the fisher population increased in the area west of Lake Peipsi as well. In the second half of the nineteenth century and the beginning of the twentieth century, the inhabitants of coastal villages grew vegetables and developed many handicrafts.

National minorities

Among the Russian populations dominating the western and northern shores on the Estonian side are the Old Believers. They first settled on the Estonian shore of Lake Peipsi in the eighteenth century to escape the reforms taking place in the Russian Orthodox Church. Since then, they have lived in a separate community by the lake and do not mix with Estonians. The world's largest concentration of them, however, is in the local municipality of Peipsääre, situated north of the mouth of the Emajõgi River. Of the 1,000 inhabitants, almost 900 are Old Believers.

Although the south-western shore of the lake is mainly peopled with Estonians, the eastern and southern coasts of the lake are home to a small Estonian minority group, the Setu. Unlike the majority of Estonians, Setu are orthodox. They have their own regional Ugric language, used by only 1,000 native speakers in south-eastern Estonia and on the Russian side of the border. They live in south-western Estonia and in the county of Pechory in the Pskov region. At present the border divides their living area. At the birth of the Estonian Republic in 1920, the Tartu Peace Treaty attributed the entire Setu area to the Estonian Republic. After the Second World War, this area was split between the Soviet Socialist Republics (SSR) and the Russian Soviet Federated Socialist Republic (RSFSR). The border problem arose during the restoration of the Republic of Estonia, and the Setu area is still halved, a situation that is endangering the Setu culture.

Water Resources

Hydrology

In addition to Lakes Peipsi and Pskovskoe, the region holds more than 4,000 lakes, the largest of which is Lake Vortsjärv (270 km^2). There are also a number of small lakes, with surface areas ranging from 0.1 to 10 km^2. These lakes, excluding Lake Peipsi, form 2 percent of the basin's area, with Lake Peipsi accounting for a further 5 percent.

There are about 240 inlets into Lake Peipsi. The largest rivers are the Velikaya (with a catchment area of 25,600 km^2), the Emajõgi (9,745 km^2), the Vohandu (1,423 km^2) and the Zhelcha (1,220 km^2). They account for about 80 percent of the whole catchment area of Lake Peipsi and of the total inflow into the lake. The only outlet is Narva River, which has a mean annual water discharge of 12.6 km^3 into the Gulf of Finland, about 50 percent of the average volume of Lake Peipsi.

There are considerable lake level fluctuations. Water level changes are characterized by a spring flood that lasts for one and a half months or longer, and is then followed by a low water level that lasts four to five months. A short-term rise occurs in the autumn. Extensive coastal areas are sometimes inundated, and long-term studies have revealed a distinct pattern in the water level fluctuations.

Double currents are commonplace in Lake Peipsi. In Lake Lämmijärv, the velocity of streams may exceed 0.5 metres per second. Owing to a considerable amount of solar radiation accumulated in summer, Lake Peipsi freezes over relatively late, the ice cover usually formed by the end of December. In severe winters, ice thickness may reach 70 to 80 centimetres (cm). In especially warm winters, it reaches about 18 to 20 cm, while in the middle of the lake, the ice cover may be unstable or even absent. Usually the lake thaws in April or at the beginning of May. The total inflow into the lake is 324 cubic metres per second (m^3/s), the total outflow 329 m^3/s, and the residence time is two years.

A comparison between the three parts of Lake Peipsi reveals very different concentrations of phosphorus, nitrogen and chlorophyll. In effect, Lake Peipsi is an eutrophic lake, whereas Lake Pskovskoe is close to being hypertrophic.

Human impacts on water resources

One of the main problems with water protection is the eutrophication of surface waters caused by the increased load of nutrients of anthropogenic origin. Lake Peipsi receives pollution mainly through river water and precipitation directly into the lake. The nutrient content in the basin's rivers was high at the end of the 1980s, causing eutrophication of water bodies. At the beginning of the 1990s, with the dissolution of all collective agricultural farms on the Estonian side and an economic depression on the Russian side where collective farms no longer received subsidies to use herbicides or to keep large cattle stocks, the nutrient load to the lake decreased considerably. Research results indicate that the nitrogen and phosphorus loads decreased by 53 percent and 44 percent respectively during that time.

In Lake Pskovskoe, pollution occurs predominately in the southern part of the lake. In 1999 water samples showed values of up to ten times Russian norms for copper, manganese, oil products, ferrous, nitrate and cadmium. Average biological oxygen demand (BOD) and chemical oxygen demand (COD) levels were also above the limits. The same pollutants also contaminated the eastern part of Lake Peipsi but to a lesser extent. In some samples here also, excessive BOD and COD levels were found. These figures are partially caused by the pollution brought by the rivers – for example, the Velikaya River carries all these pollutants in high concentrations.

The waters flowing into Lake Peipsi are classified as hydrocarbonated calcium-rich. The oxygen content in most of the rivers is quite high as there are no big industrial polluters affecting oxygen conditions in the basin. As the oxygen levels also depend on humic substances of natural origin, the lower oxygen saturation level is caused not only by human impact but also by bog waters carried into rivers. The pH value and alkalinity levels in the rivers of the Lake Peipsi basin are relatively high, indicating an excellent buffering capacity in all the catchment areas. The present BOD level in most rivers of the basin is quite low compared with that of the 1980s when the amounts of wastewater discharged were at their highest.

Figures 17.4 and 17.5 show the ratio of phosphorus and nitrogen pollution loads distributed by country and source.

The majority of phosphorus and nitrogen compounds are carried into the lake by the Estonian Emajõgi River and the Velikaya River in the Russian Federation. These two rivers account for 80 percent of the total nitrogen load and almost 85 percent of the phosphorus load in Lake Peipsi. The first carries biologically treated sewage from Pskov, the latter transports wastewater from Tartu – wastewater that went untreated until the treatment plant opened in 1998.

Studies done in the middle of the 1980s and 1990s show a great decrease in pollution loads, particularly those caused by agriculture. Annual inputs of nitrogen and phosphorus between 1989 and 1998 are described in figures 17.6 and 17.7.

North-east Estonia is one of the most industrially developed regions of the country, where oil-shale industry dominates the sector. The wastewaters and gaseous emissions, including toxic sulphur and nitrogen oxides from power stations and pulverized oil shale, impact on the chemical composition of water in Lake Peipsi.

Figure 17.4: Ratio of phosphorus pollution load by country and source

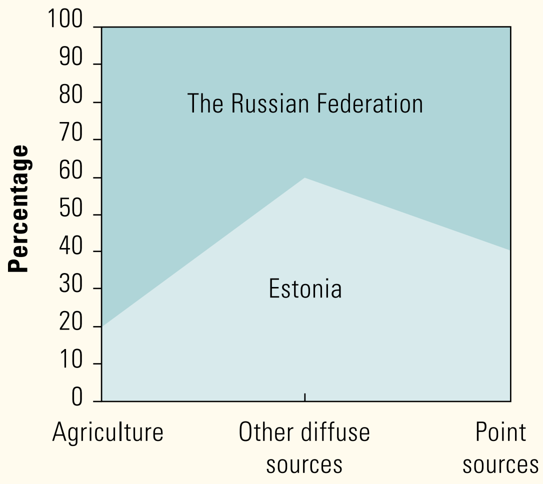
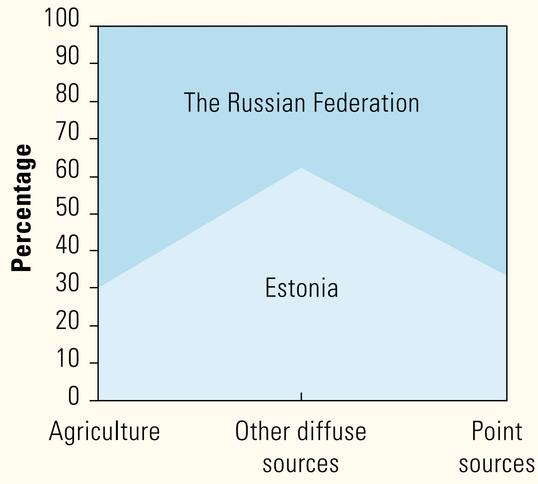


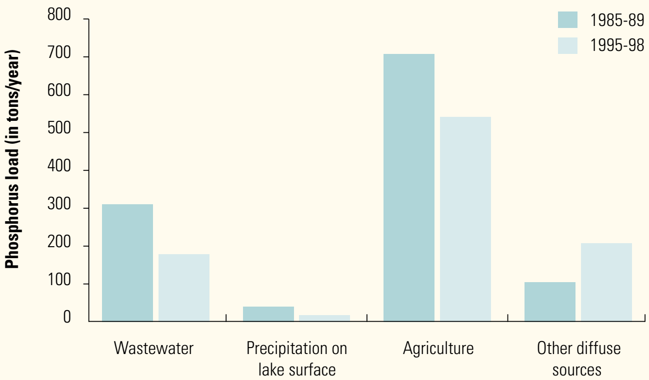
Figure 17.5: Ratio of nitrogen pollution load by country and source



The Russian Federation is the main source of agricultural phosphorus and nitrogen pollution, contributing 80 and 70 percent respectively. It is also the major emitter of other point-source pollution. Estonia, however, emits much more phosphorus and nitrogen from diffuse sources, with 60 percent of the total loads.

Source: Stålnacke et al., 2001.

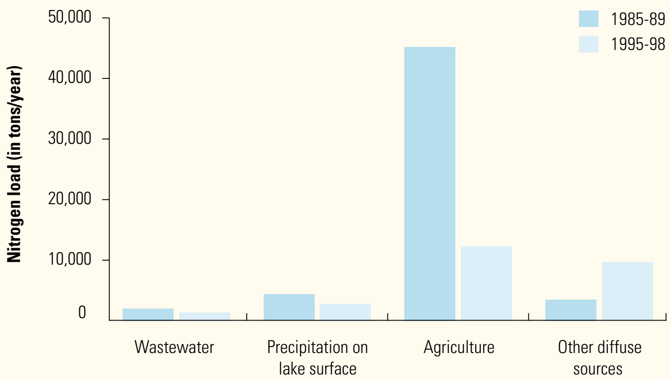
Figure 17.6: Comparison of annual phosphorus loads by source between 1989 and 1998



There has been a significant decrease in the amount of phosphorus pollution contributed by wastewater and agriculture between 1989 and 1998, but that contributed by other diffuse sources has almost doubled in the same period.

Source: Stålnacke et al., 2001.

Figure 17.7: Comparison of annual nitrogen loads by source between 1989 and 1998



The nitrogen load from agriculture has decreased dramatically. The load from other diffuse sources has, however, nearly tripled and is set to reach the same load as that of agricultural pollution.

Source: Stålnacke et al., 2001.

Pollution loads from big cities, Pskov (mainly to Lake Pskovskoe) and Tartu (to the southern part of Lake Peipsi and to Lake Lämmijärv/Teploe) decrease from south to north, while water transparency and alkalinity caused by the impact of the oil-shale mines and their sediment have the opposite trend.

Data and information on water resources

Each country collects and analyses environmental information on the lake basin in its own manner. Nevertheless, these data are to be exchanged during meetings of the Estonian-Russian joint commission and its working groups. Moreover, it has been agreed that existing programmes and sampling activities will be coordinated to enable joint monitoring activities. However, the joint assessment of the lake is complicated by the countries' different approaches to environmental assessment. Estonia and the Russian Federation have very different monitoring methods and equipment, as well as different norms and standards, so data comparability and credibility remain problematic.

Challenges to Life and Well-Being

Water for fish

The lake itself is not used for irrigation purposes, thus its main use for food production is fishery. According to present data, one species of lamprey and thirty-three fish species permanently inhabit Lake Peipsi or the lower reaches of its tributaries. In the catches, the main commercial fish are lake smelt, perch, pikeperch, ruffe, roach, bream, pike and, until the 1990s, also vendace. The second-rate commercial fish are burbot, whitefish and white bream. The annual catch usually totals 7,000–8,000 tons. Although fishery classifications have categorized the lake as a smelt-bream-type water body, since the second half of the 1980s it has acquired some qualities of a pikeperch lake.

In general, the management of fish resources is regulated by the bilateral intergovernmental Estonian-Russian agreement concluded on 4 May 1994 concerning cooperation in the use and protection of fish resources. In 1995 following this agreement, the Intergovernmental Estonian-Russian Commission on Fishery was formed. It aims, *inter alia*, to:

- adjust management requirements of fishery;
- coordinate scientific research and catches by either party in the other's territorial waters;
- legislate quota exchange; and
- establish catchment limits.

Water for ecosystems

The Lake Peipsi watershed is rich in wetland areas and contains two Ramsar sites: Emajõe Suursoo (Estonia) and Remdovsky (the Russian Federation). Bogs and marshes occupy about 15 percent of the lake basin, while wet areas in general are spread over 35 percent of the territory.

Emajõe Suursoo is located at the mouth of the Emajõgi River on the western shore of the lake. Its surface area is 255 km^2, 180 km^2 of which is covered by the protected area. The total surface area of the Ramsar site is 320 km^2 and also includes the island of Piirissaar. The site is a habitat for several globally endangered birds such as the corncrake, the lesser-spotted eagle and the white-tailed eagle.

The second Ramsar site, the Remdovsky reserve, located on the eastern shore of Lake Peipsi/Chudskoe and Lake Lämmijarv/Teploe, was founded in 1985 and covers approximately 65,000 hectares. In 1996 it was incorporated into the 'Lake Peipsi Lowlands', which is a Ramsar site. It aims to preserve the biodiversity of the region and has international importance due to the presence of endangered species (fifty-eight species of vegetation from the Russian Federation's Red Book, which lists endangered plant and animal species, seven from the Estonian Red Book, and eleven and fifteen species of birds, respectively).

Water for cities

Wastewater from the two main cities in the region – Pskov and Tartu – is partly responsible for lake eutrophication. Smaller towns also contribute to the problem but their populations are much smaller. The biological departments of the sewage treatment plant in Tartu, commenced in 1999, and the plant at Pskov are to be completed in the coming years in order to combat lake eutrophication. Water quality is important, as the inhabitants of Narva use water from the Narva River for drinking purposes. There is, however, sufficient clean groundwater and surface water in the Lake Peipsi watershed to meet the basic needs of the population.

Water for energy

Narva has two waterfalls, Omuti and Narva, stretching to about 7 metres in height and 125 metres in width. Unfortunately, the Narva waterfalls are presently dry, having been drained by the Narva hydropower station. Water that once flowed to the river is now stored in the Narva reservoir so as to guarantee a steady water flow to the hydropower station. The reservoir is also used by two thermal power plants (Baltic and Estonian) to refine oil shale. The biggest industrial user of the lake's water is the Baltic thermal power plant, which uses the water of the Narva River for cooling purposes, with an average annual demand of 470 million m^3. Cooling water accounts for almost 75 percent of Estonia's annual water withdrawals.

Two of the world's largest thermal power plants working on oil shale are located on the Estonian side, both of which are major energy producers. As previously noted, both the power plants and chemical enterprises are the main sources of air pollution.

Management Challenges: Stewardship and Governance

Political set-up and border issues

Both the Republic of Estonia and the Russian Federation are responsible for managing and monitoring Lake Peipsi. The total length of the Estonian-Russian border is 333.8 km, approximately two thirds of which run along Lake Peipsi and the Narva River.

The border treaty between the two countries has not been signed yet, so officially there is no border, but a control line. There are five international crossing points, but none of them are found on the lake, which means that the distance between the southern and northern crossing points is about 200 km.

Five east-Estonian administrative regions (Isa-Virumaa, Jõgevamaa, Tartumaa, Leningrad and Võrumaa) have a common border with the Russian Federation. On the Russian side, the Leningrad and Pskov regions border the Republic of Estonia. The lake is a natural border between people who settled around Lake Peipsi and has resulted in the watershed's large array of cultures.

Governance

There are three levels to Russian water management: federal, regional and territorial. The main state agency responsible for water is the Ministry of Natural Resources (MNR) of the Russian Federation, although other ministries and committees have supportive tasks. The Ministry itself works on the federal level and is represented by Water Basin Administrations on the regional (basin) level, and by Committees of Natural Resources at the territorial level.

In Estonia, water management is coordinated by the Ministry of the Environment and its fifteen country Environmental Departments. Lake Peipsi belongs to the Peipsi sub-basin, where the Tartu Environmental Department is responsible for implementing water policy at a regional/sub-basin level.

Policy issues

As Lake Peipsi is a relatively new transboundary water basin (the control line between Estonia and the Russian Federation was formed when Estonia separated from the Soviet Union in 1991), the procedures of international coordination of water management have still to be elaborated. As noted previously, this challenge will become particularly acute during Estonia's application to join the European Union (EU) in 2004 when it will have to adopt EU standards and norms, which are different from those used in the Russian Federation. Developing cooperative Integrated Water Resources Management (IWRM) is a long process, and especially complicated in the context of an international lake shared by transition countries.

The Water Framework Directive (WFD) of the EU is mandatory only for member countries, and is recommended for potential members. Nevertheless, it could provide a framework for decisions relating to water management in the Russian Federation as well.

Legislation

Each country has its own legislation for water management, but in order to use the water resources responsibly and in a sustainable fashion, several bilateral agreements were signed between the Estonian and Russian governments. These include the following.

- Treaty between the government of Estonia and the Russian Federation on the conservation and use of fish stocks in Lake Peipsi, Lake Lämmijärv and Lake Pskovskoe, concluded on 4 May 1994 in Moscow;
- Agreement between the two governments on cooperation in the field of the environment, concluded on 11 January 1996 in Pskov;
- Agreement between the two governments on cooperation in the field of protection and sustainable use of transboundary watercourses, concluded on 20 August 1997 in Moscow.

Institutions and infrastructure

The Estonian-Russian Transboundary Water Commission was established in 1997 after an intergovernmental agreement was signed aiming to protect and ensure sustainable use of transboundary water bodies between the two countries. The Commission is the main actor in managing Lake Peipsi.

- It organizes the exchange of monitoring data between the parties, in accordance with the agreed monitoring programme.
- It defines priority directions and programmes of scientific studies on protection and sustainable use of transboundary waters.
- It agrees on common indicators of quality for transboundary waters, methods of testing and conducting analyses.

- It facilitates cooperation between agencies of executive power, local governments, scientific and public interest organizations as well as other institutions in the field of sustainable development and protection of transboundary waters.

- It ensures publicity of questions related to the use and protection of the transboundary waters.

Over the last few years, the commission has received considerable support from the Swedish Environmental Protection Agency (EPA) for a project to raise its institutional capacity.

The other commission in existence, previously mentioned, is the Fishery Commission, which works on a constant basis and meets once a year (see section on water for fish).

Management approaches

Managing risks

Risk management is becoming more important in the basin. The Estonian-Russian Transboundary Water Commission established criteria for emergency situations in the whole Narva River basin. These criteria include: accidents on hydrotechnical constructions and transport vehicles, and negative impacts on water bodies (such as accidents at wastewater treatment facilities, extremely high or low water levels, radioactive pollution, heavy pollution and mass death of living organisms). In addition to these criteria, the process for sharing information in each situation was elaborated. Its main objectives are to ensure that each side informs the other in case of extraordinary situations, and to organize assistance and mutual aid. Each side should be informed of any event having transboundary impact (Estonian-Russian Transboundary Water Commission, 2001).

Valuing water

Water prices for home users and water taxes vary greatly in the basin. In Estonian counties, 1 m^3 of supplied drinking water costs between US$0.73 and US$1.37. Current water taxes for surface water amount to 150 krones (about US$9.5) per 1,000 m^3 and 440 krones (US$28.1) per 1,000 m^3 for groundwater.

In the Russian Federation, water prices range from 3 to 7 rubles (between US$0.1 and US$0.22) per cubic metre depending on the region and the type of drinking water (surface or groundwater). In the north-west region, 1,000 m^3 of surface water cost 148 to 172 rubles (US$5 to US$6), whereas the same quantity of groundwater costs 200 to 232 rubles (US$7 to US$8). The Federal Law 'On the payment for use of water bodies' established the base costs, and changes were last made in 2001.

Sharing the resource

As the whole Lake Peipsi and Narva River basin is shared between two countries, cooperation and collaboration in the field of water management is essential. In general, however, the basin has sufficient water so there is no serious competition between industries and local population.

Governing water wisely

One of the main characteristics of the Estonian and Russian water policy is the basin approach. By taking the basin as the main hydrological unit, it closely resembles European water management policy. Thus, the international basin of Lake Peipsi is governed in accordance with both Russian legislation and the EU WFD.

The Estonian-Russian Commission established a formal mechanism for developing cooperation with local authorities, non-governmental organizations (NGOs) and stakeholders, who can communicate their issues and interests directly to the intergovernmental commission. However, very few regional NGOs are involved in the work of the commission and most local NGOs and stakeholders cannot afford greater involvement. External financial support is necessary to develop their capacity and to enable their involvement in managing transboundary waters shared by countries in transition.

Regional NGOs, such as the Peipsi Center for Transboundary Cooperation (Peipsi CTC) and the Council for Cooperation of Border Regions, cooperate with local authorities and stakeholders on regional development projects as well as on educational, research and social projects in the region. Peipsi CTC is also actively involved in the work of the Estonian-Russian Transboundary Water Commission.

Local and regional authorities and businessmen in the Lake Peipsi region also promote their agenda for transboundary economic cooperation in the form of investments in the construction of roads, in water transportation and in tourism infrastructure, as well as international promotion of the region.

Ensuring the knowledge base

Estonian and Russian research cooperation was interrupted by the border re-establishment at the beginning of the 1990s. Estonian environmental experts, together with their Russian colleagues, published a comprehensive monograph on Lake Peipsi in 1999. The Swedish EPA, Danish Ministry of Foreign Affairs and Danish EPA, and the Norwegian Ministry of Foreign Affairs all supported regional studies and the development of strategies for reducing and preventing pollution, as well as regional development in the basin. Reports have also been published in English, Estonian and Russian and have been widely disseminated (see box 14.8 in chapter 14 for further details).

Conclusions

The Lake Peipsi basin faces various challenges, including serious eutrophication affecting both human and fish populations, pollution from power stations, large towns, oil shale industries and mining activities, and the difficulties inherent to transboundary water management. Although the anticipated economic growth in the region is likely to increase the pollution reaching the lake, measures are being taken such as the building of new wastewater treatment facilities to ensure that the pace of eutrophication is slowed.

The region also faces economic challenges. Although fishing has long been one of the major activities of the area, the lake's fish resources are now under severe pressure, further complicated by economic difficulties and high rates of unemployment. The depleted fish populations can no longer provide a living for so many and there is therefore an urgent need to diversify the economy in the basin.

Many bilateral agreements have been implemented concerning various aspects of joint management of the lake, but real coordination and cooperation remain problematic due to the absence of a comprehensive water programme, insufficient public participation and coordination in the lake basin, especially as regards environmental monitoring, and complicated border issues, which have so far impeded effective collaboration. There is, however, a developed legislative base and desire for greater efficiency on both sides upon which to build.

From an environmental point of view, the lake basin can be considered an extensive ecosystem in its own right. It is therefore essential to maintain it in as healthy a condition as possible, and to remember that the loss or change of any one component could have serious consequences on the entire system.

The most important planning and development issue in Lake Peipsi is preparation for the Lake Peipsi Management Plan. In cooperation with Estonian and Russian governments, regional and local authorities, private companies and the public, this is to be completed by 2007, and should provide a starting point for addressing the various challenges encountered in the basin in a more integrated manner.

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'A great challenge lies ahead in preserving the environment while building a better life for the Ruhuna basin's population, a good part of whom continues to suffer from malnutrition and poverty. Improving the access to relevant data, implementing more integrated management approaches and continuing the fight against poverty could go a long way to providing a more sustainable future for the basins.'

18

Ruhuna Basins, Sri Lanka

By: The Ministry of Irrigation and Water Management of Sri Lanka*

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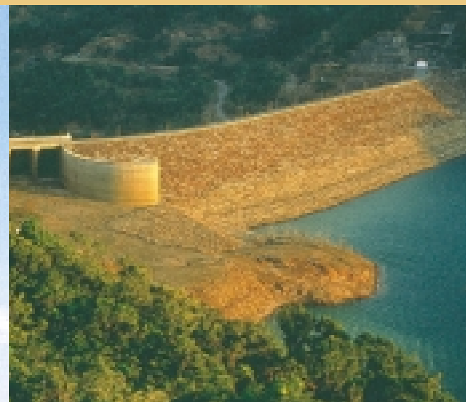
*A workshop was held on 7–8 April 2002 in the Koggala Beach Hotel in preparation for the case study report. The authors who presented papers to the workshop made the major input to this paper. Guidance provided by the Secretary of the Ministry of Irrigation and Water Management, the Secretary of the Ministry of Irrigation and the Secretary of the Ministry of Water Management, and the comments made by a large number of Ministries and stakeholder agencies are much appreciated. Special thanks are due to Mr. Ian W. Makin and Dr. Peter Droogers of the International Water Management Institute (IWMI) for their contribution to the study in general and assistance in editing the document, in particular.

Let not a simple drop of water that falls on the land go into the sea without serving the people.

Parakkama-Bahu I, King of Sri Lanka (1153-1186)

THIS CASE STUDY OFFERS THE PICTURE of a rural society that values water in traditional ways, but is changing rapidly. There is little coordination among the many agencies dealing with water. Water resources in Ruhuna are of good – though declining – quality and are highly regulated to support hydropower production and irrigation. However, the basin is currently experiencing water stress due to great seasonal variation in rainfall and a drought in the area. Paddies account for a whopping 95 percent of the total water consumption. Rural poverty is increasing and farmers are often perceived as mere beneficiaries rather than key partners in the management of irrigation and water resources. There is hope that the recent formation of Water Resources Councils can address the need for co-ordination, integrate the concerns of different users, and lead the way to a better life.



THE RUHUNA BASINS IN SOUTHERN SRI LANKA will face major changes over the next two decades. Ambitious development plans indicate that the dominant role now played by agriculture is geared to switch to much more industrial and service-oriented activities. Obviously, these changes will have an enormous impact on society as well as on natural resources and require the inclusion of issues of water management. Currently, almost all water resources that are diverted are used for irrigation with only a small percent used for industry and drinking water. Most recent development plans show that the use of water for urban areas and industry will increase from less than 10 million cubic metres (Mm^3) currently to 100–150 Mm^3 by the year 2025.

Map 18.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

Already today, the Ruhuna basins are important in the broader Sri Lanka context: they are the location of a major hydropower plant, and irrigation schemes that make a significant contribution to food production and important nature reserves. However, even before the envisaged development plans are implemented, the basins are already experiencing major water resource problems, clearly demonstrated by the recent drought leading to reduced water for irrigated agriculture, insufficient supply of domestic water and nationwide power cuts for up to eight hours a day.

The Ruhuna basins area includes three main rivers and several smaller basins, and forms part of the hydrologic system of the ancient kingdom of Ruhuna.

Sri Lanka has a surface area of 65,500 square kilometres (km^2) and a population of 19 million inhabitants. It is renowned for its hydraulic civilization in which natural resources have been managed over thousands of years. The country has a mean annual rainfall of about 1,900 millimetres (mm) but this ranges from below 900 mm in the driest parts of the dry zone to over 5,000 mm in the central hills. There are 103 distinct river basins in the island, ranging in size from 9 km^2 to 10,450 km^2. The Ruhuna basins cover 8 percent of the Sri Lanka landmass.

Table 18.1: Hydrological characteristics of the Ruhuna basins

Surface area of the basin	5,578 km^2
Annual precipitation	1,574 mm/year
Annual runoff	78 m^3/s
Annual potential evapotranspiration	1,700 mm/year
Upper catchment	1,458 mm/year
Lower catchment	1,914 mm/year

Major physical characteristics

Geography

The Ruhuna basins are mountainous and relatively wet. Several catchment areas are poorly developed, but there are downstream flat areas with developed water resources. These lowlands consist of rolling plains dotted with a few isolated hills. The rivers originate from the southern slopes of the central highland massif at elevations of up to 2,000 metres. A large part of the basins is made up of many types of composed rock, such as granite, migmatite and quartzites (Panabokke et al., 2002).

Climate

The only source of water is rainfall. Monsoonal rains, which fall from November through March and May through September, contribute a major part of the annual rainfall, which is supplemented by inter-monsoonal rains. The mean annual rainfall for the basin is 1,574 mm, the depth of which decreases from the upper to lower reaches and from west to east. The recent rainfall records at selected stations show a trend of decreasing annual rainfall since 1970. The decrease is not uniform or highly significant in statistical terms. The ambient temperatures in the lowlands range from 25 to 28ºC, and in the upper elevations from 23 to 25ºC.

Major socio-economic characteristics

The Ruhunu basins include parts of the Ratnapura, Badulla, Moneragala and Hambantota districts with population densities of 307, 291, 71 and 217 inhabitants/km^2, respectively. The total population in the basins is approximately 1.1 million (Jayatillake, 2002b).

The average monthly income per household in the Badulla district is the lowest in the country. For the year 2000 the national average Gross Domestic Product (GDP) per capita was US$850, but for the Ruhuna basins, per capita GDP is estimated at about

Map 18.2: Basin map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

US$600. The percentage of households receiving food and economic support was measured at 60 percent compared to the national average of 39 percent (Department of Census and Statistics, 2000).

Tea and rubber are grown as commercial crops in the upper basin area, and rice is the major crop in the plains. The major land uses in the basins are: forests (29 percent), scrublands (26 percent), shifting cultivation or chena (23 percent), home gardens (12 percent) and paddy (10 percent). However, there are significant differences in land use among the main sub-basins (Panabokke et al., 2002): for example in the Menik Ganga basin, forests account for 57 percent of land use, compared to only 17 percent in the Walawe basin (see map 18.3).

Water Resources

Surface water

Based on the hydrologic characteristics of basins (see table 18.2) the annual supply of surface water per capita is estimated at 2,291 m^3. Kirindi Oya basin is the most water-stressed of the Ruhuna basins, as it has the lowest per capita surface runoff, relatively high flow requirements for environmental purposes, and farmers in the area are facing various water problems. The potential for further development of water resources within the Kirindi Oya basin is therefore negligible and several studies have been undertaken to explore the options for interbasin transfer.

Groundwater

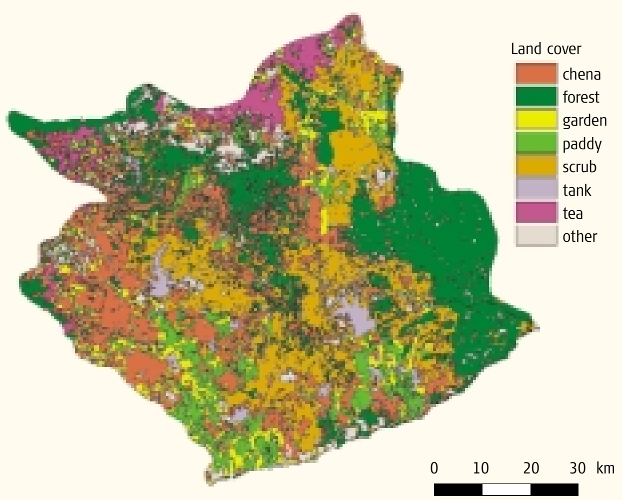
Many people in the basins depend on shallow groundwater for their domestic needs. Studies indicate that seepage losses from canals and reservoirs have been indispensable for maintaining water levels in shallow wells. Deep groundwater is concentrated in the fractured and weathered aquifers in hard rock areas and alluvial aquifers. Available information indicates that 7 to 10 percent of rainfall contributes to groundwater recharge in the hard rock terrain, and 40 percent in the sandy alluvial aquifers (Panabokke et al., 2002).

Groundwater accounts for 3 percent of total water withdrawals (Jayawardane, 2002 and Jayatillake, 2002b) and there is a high vulnerability to declining groundwater levels and saltwater intrusion in the lower reaches of the basins.

Water quality

To date, the upstream areas of the basins have not faced major water quality problems, as industrial activities are limited. However, studies have indicated that although surface waters are relatively free of fluoride, toxicity problems such as faecal coliform bacteria and organic waste contamination do exist. Data indicate that water

Map 18.3: Major land covers and uses in the Ruhuna basins



The Ruhuna basins are largely composed of forest, followed closely by scrublands and chena, or shifting, cultivation. Other cultivations include paddy, gardens and tea crops. There are also several large reservoirs (tanks) in the area.

Source: Drawn for the World Water Assessment Programme (WWAP) by the Survey Department of Sri Lanka, 2002.

Table 18.2: Comparison of basic hydrological parameters of sub-basins over a thirty-year time span

Basin	Catchment area (km^2)	Annual precipitation (Mm^3)	Annual surface runoff (Mm^3)	Annual discharge to the sea (Mm^3)
Walawe Ganga	2,471	4,596	1,524	525
Kirindi Oya	1,165	1,713	469	74
Menik Ganga	1,287	2,009	352	326
Malala Oya[1]	402	441	74	NA
Other[1]	253	252	42[2]	NA
Total	5,578	9,011	2,461	

[1]Ungauged rivers and streams [2]Assumed value

Source: Jayatillake, 2002b.

quality is poor in the coastal lagoons and river estuaries and the quality of water appears to deteriorate further especially during the dry season (Handawela, 2002).

There are two national agencies responsible for recommending water quality standards for drinking, bathing, irrigation and other uses: the Sri Lanka Standards Institute and the Central Environmental Agency (CEA).

Human impacts on water resources

Water resources in the basins are highly regulated to support hydropower generation and irrigation. There are twenty large reservoirs (three of which have a capacity exceeding 100 Mm^3) and about 280 smaller reservoirs, giving a total storage capacity of about 900 Mm^3. There are numerous river diversion systems, mainly for irrigation supplies, including eleven large and about 610 small cross-river structures. Storage volume in the three main basins ranges from 57 percent of annual (surface) water resources for the Kirindi Oya basin, to 40 percent in the Walawe basin and almost zero in the Menik Ganga basin.

Changes in land cover will affect water resources, of which about 2,720 km^2 (about 50 percent) is under forest and scrubland. In the Walawe and Kirindi Oya basins, substantial development works have been carried out and the forest and scrub cover have decreased by 30 percent and 23 percent respectively over the past forty years, which is a higher rate of land use change than the national average.

Data and information on water resources

The hydrometric network includes sixteen rainfall stations, seven agro-meteorological stations and six water level stations. The water level observation network is clearly inadequate to provide sound information on water resources in the basins.

The lack of sufficient regular flow observations have led to a large number of sporadic attempts by agencies involved with water resources to collect data, mostly in response to the internal requirements for development projects. The frequency of data collection intensifies during project studies but generally the frequency and quality of data observation diminish once the project is completed.

Integrated Water Resources Management (IWRM) in the basins clearly suffers from this lack of a consistent, continuous and accurate hydrometric network. Moreover, data access and data sharing between the different agencies remain limited, restricting the benefits obtained from even the existing data network.

Challenges to Life and Well-Being

Water for food

The major food crop in the basins is paddy, cultivated over approximately 52,000 hectares of which 90 percent is irrigated. Normally two crops can be grown during the year, during the two monsoon seasons. The water used by major irrigation systems, defined as irrigation duty at the reservoir outlet, is about 1,500 mm in rainy seasons and 1,800 mm in dry. However, a proportion of these releases is used indirectly by small irrigation systems and for domestic use, so actual irrigation applications are lower. Withdrawals for irrigation account for more than 95 percent of the total.

In general large irrigation schemes achieve cropping intensities in excess of 150 percent, while most minor schemes are close to 100 percent. Average paddy yields in major irrigation, minor irrigation and rainfed systems are 4,600, 3,600 and 2,900 kilograms (kg) per hectare, respectively.

In terms of water productivity, the amount of water used to produce 1 kg of crop has been shown in a study in the Kirindi Oya basin to be 0.29, 0.16 and 0.14 kg/m^3 of evapotranspiration, net irrigation and gross irrigation requirement, respectively.

The basins produce large amounts of marine and inland fish and cow and buffalo milk (Weerasinghe et al., 2002). Inland fisheries are becoming popular, are receiving support from the government and are an important source of protein for the rural population. No detailed information is available on the productivity of inland fishery at the basin level.

Water for basic needs

Sixty percent of the basin population has access to safe water and 71 percent to adequate sanitation (Ministry of Plan Implementation, 2001). These figures are slightly lower than the national average, which rests at 75 and 73 percent respectively (Shanmugarajah, 2002). National targets for water supply in Sri Lanka are ambitious: the target for access to safe drinking water is set at 85 percent of the population by 2010 and 100 percent by 2025. Similarly, the target for adequate sanitation is 100 percent by 2035 (Wickramage, 2002).

Some of the major towns in the basins obtain domestic water from irrigation reservoirs, while others abstract water from the river itself. Although the return flow from agricultural lands helps to maintain minimum flow requirements during the dry months in the Walawe sub-basin, it causes water pollution because of the presence of agrochemicals.

Water for ecosystems

'The paddy fields in Ruhuna basins are the most valuable wetlands I've ever seen', claimed a famous American ecologist. As well as these agricultural wetlands, the basins consist of several other ecologically important reserves, including the Ruhuna, Uda Walawe and Bundala National Parks, the lagoon systems adjacent to Bundala park and a large number of man-made reservoirs.

Sri Lanka's first Ramsar site, Bundala National Park, is spread over an area of 6,216 hectares. This area is designated as a sanctuary under the Flora and Fauna Protection Ordinance. Four shallow, brackish lagoons form the major part of the park. Bundala is the most important wintering area in southern Sri Lanka for migratory shorebirds, sometimes accommodating up to 20,000 birds. Elephants and leopards are also found in Bundala (CEA/Arcadis Euroconsult, 1999).

Ruhuna National Park is one of the largest in the country, covering about 126,000 hectares, some of which lie outside the basin. Most of the park's wetlands are well protected. The total land area protected under relevant legislation is about 1,200 km^2, which represents some 21 percent of the basin area. Water use for ecosystems is highest in the Menik River, which flows through the Ruhuna National Park. Concerns about the protection of downstream lagoons have been raised, as the minimum base-flows of the rivers are becoming inadequate to meet ecosystem requirements.

Water for industry

The basin does not currently house any major industrial activities. Some smaller factories – mainly for garment and paper – and hotels and rest-houses for the tourist industry do exist, but industrial water withdrawals are estimated at being less than 1 percent of total withdrawals.

Source protection measures are adopted by these industries only when they use their own water supply systems and when the source is located within their property. Where the industries are extracting water from public water supply systems, there is no specific contribution towards source protection, apart from tariff payment for the consumption of water (Senaratne, 2002).

However, major changes are expected when the proposed Ruhunupura City development plan, which will include an airport, industrial and commercial areas and a commercial harbour, is implemented. The water requirements of Ruhunupura are estimated at between 100 and 150 Mm^3 per year. Studies presently underway are exploring the reservoir options to retain floodwater from rivers in order to meet the greatly expanded water demand.

Water for energy

In 2001/2, Sri Lanka faced a major power crisis resulting in nationwide power cuts for up to eight hours a day for several months. The drought, in combination with hydropower's large share of total power generation (65 percent), was the main cause. The national targets relevant to power generation specify that a reliable electricity grid should be provided to at least 80 percent of the population at affordable prices and that the share of hydropower is to be reduced to about 32 percent by 2013.

The hydropower generation facilities in the Ruhuna basins are restricted to the Walawe sub-basin. Uda Walawe reservoir, constructed in the 1960s, has an installed hydropower capacity of 6 megawatts per hour (MWh). The installed capacity of the hydropower plant at Samanalawewa is 120 MWh, which is about 10 percent of the total installed capacity in Sri Lanka. Based on the records at Samanalawewa, about 1.3 Mm^3 of water was required to produce 1 gigawatt per hour (GWh) of energy (Somatilake, 2002). Water used to generate energy is recaptured downstream for irrigated agriculture, power generation and other uses.

Management Challenges: Stewardship and Governance

Cultural background and the value of water

The Ruhuna, along with being a subkingdom, served as a safe-haven for people fleeing foreign invasions. In ancient times, agriculture played a major role in the economy as well as in national security. Efforts to develop water resources in the area, as in other parts of the country, focused on irrigation. As rainfall is concentrated in the two monsoon seasons, and because of the large interannual variability of rainfall, a good number of reservoirs have been built. Water has been used for recreation, sanitation and hygiene for thousands of years, and as such has been given a very high value in the community.

This historical background has influenced the perception that water is a public good, and has maintained agriculture's role as both a tradition and a major component of the livelihood of the population. Traditions also emphasize that water is a valuable resource that is not to be wasted. A local management structure for water resources was developed that included provisions for cost recovery and regulation. These provisions enabled a self-sustaining rural agrarian society to exist in the villages.

Water-related cultural practices among the rural society emphasized the optimum use of water. However, this management structure was disturbed during the period of colonial occupations. An increase in rural poverty made people more dependent on state subsidies. To some extent this dependency continues under modern irrigated agriculture where, especially in major irrigation areas, there is a heavy emphasis on state control. Farmers are often perceived as mere beneficiaries rather than key partners in management of irrigation and water resources.

The broad recognition of centuries-old water traditions in Sri Lanka, and the considerable number of people still living below the poverty line, enhance the importance of water's social, environmental, cultural and economic values. For example, the numerous minor irrigation systems provide water for domestic use, livestock, wildlife, recharge of groundwater and also for enhancing the village environment. These multiple dimensions that make up the value of water must be considered equitably in planning, developing and managing water resources.

The economic value of water, however, has been the subject of intense discussion in the recent past. A draft policy document that made reference to water as an economic good was rejected following strong pressure from the public and media. Leading politicians have made statements implying that water is set to remain a free good for the foreseeable future.

In agriculture, still the main water use sector, farmers contribute to the maintenance costs of the irrigation network. But, in general, they pay no water supply or service fees. Operation and maintenance costs are minimal and farmers mostly pay through provision of labour for cleaning canals. This is similar to ancient practice. However, in some modern irrigation systems, a minimal service fee is levied.

Political set-up: institutions and legislation

Sri Lanka is a parliamentary democracy divided into eight provinces and twenty-four districts. Rivers flowing through more than one province, and irrigation systems that are served from these channels come under the purview of the central government. The Provincial Councils, which constitute the provincial government, manage smaller rivers, village and provincial irrigation, and environmental issues. The Ruhuna basins belong to the Southern, Uva and Sabaragamuwa provinces.

Water management responsibilities in the basins lie with institutions at the national and local levels: approximately forty agencies exist with responsibility or interest in water. These include the sector agencies dealing with domestic water supply, health and sanitation, agricultural and irrigation services, hydropower generation, groundwater development and ecosystem management. In addition, Provincial Councils established after the thirteenth amendment to the constitution in 1987 have devolved powers for water-related functions. The chief secretary of the province, district secretary and divisional secretary are key government officers that make decisions regarding the management of water resources at the respective levels. At the district and scheme levels, the District Coordinating Committee, District Agricultural Committee and Project Management Committee are also decision-makers.

Such a multitude of institutions requires effective coordination at different levels. At the national level, the Central Coordinating Committee on Irrigation Management provides a forum for policy issues in irrigation management. A similar forum is the Steering Committee on Water Supply and Sanitation. The recent formation of a Water Resources Council (WRC) addresses the need for coordination of water resource issues. Moreover, the proposed formation of river basin committees would rectify the existing inadequacy in dealing with issues of IWRM.

Non-governmental organizations (NGOs) make a significant contribution to water resource management. Several NGOs have invested in minor irrigation, and significant numbers play a vital role in protecting ecosystems and rainwater-harvesting activities. Better coordination of NGOs and government agency actions is essential and could be of great benefit.

Over fifty Acts of Parliament have been established to manage water resources (Ratnayake, 2002). A large number of agencies, each dealing with different aspects (such as irrigation, water supply, sanitation, industries and environment), are charged with implementing these acts. The proposed Water Resources Act, expected to be operational in 2003, should address gaps and implementation problems in the existing legislation.

Finances

Public investment in water resources focused on developing irrigation infrastructure from 1950 until the 1980s. The emphasis has since shifted towards investments in rehabilitation of existing infrastructure and improvement of water management. In the year 2000, national investments in agriculture and irrigation remained at about 8.5 percent of the total capital expenditure. The corresponding figure for the energy and water supply sectors was about 16.5 percent (Central Bank, 2001).

The main investors in urban water supply and sanitation have been the public sector, including the central government, the National Water Supply and Drainage Board (NWSDB), Provincial Councils and local authorities. Investments by community-based organizations and private individuals are significant in rural areas.

Additionally, a substantial portion of irrigation and water supply projects are foreign-funded. Two major irrigation rehabilitation projects and one comprehensive groundwater assessment project are ongoing in the basins and are funded by independent donors.

There have been several attempts to recover the cost of operation and maintenance of irrigation services, but these have so far proved unsuccessful. An ongoing programme consisting of turning irrigation systems over to the users has resulted in substantial contributions from farmers in system management, and in operations and maintenance costs.

Cost recovery mechanisms for urban water supply focus on recovery of operation and maintenance costs of the services. The level of recovery is lower in water supply schemes managed by local authorities. Private investment by individual families for the construction of protected wells and latrines is considerable (Wickramage, 2002).

Differing management approaches

Several management approaches exist in the Ruhuna basins.

- IWRM: although Sri Lanka has been implementing IWRM principles for several years, it is yet to be recognized as state policy. As an example of the attention given to IWRM principles, irrigation development projects in environmentally sensitive areas are submitted to an Environmental Impact Assessment (EIA) and must obtain its approval before they can begin. Also, the National Environmental Act was enacted in 1980 and a ministry was set up in 1991 to deal with specific environmental issues. A ministry dealing with water resource management and a Water Resources Secretariat, charged with formulating a National Water Resources Policy and relevant Water Resources Legislation, were established in 2000 and 1996 respectively.

- Demand management: demand management has been given special attention in recent government policies. In the domestic water supply sector, targets include minimizing unaccounted water and introducing demand management measures. In irrigated agriculture, there is a heavy focus on micro-irrigation methods and improved monitoring of agricultural operations. Optimal water use is a major focus for the ongoing irrigation rehabilitation projects in the basins. In the energy sector, there are campaigns to reduce power consumption.

- Public participation: in 1988, following a number of pilot experiments started in the late 1970s, Sri Lanka adopted participatory management in irrigated agriculture as state policy. A programme of irrigation management turnover (IMT) to farmer organizations is ongoing. Although no systems have been completely turned over, there has been a significant increase in the role of farmers in managing irrigation systems over the past two decades. Most major irrigation systems in the basin are partially turned over. Farmers have traditionally managed minor irrigation systems (command areas of less than 80 hectares). Attempts have been made to encourage community participation in environmental protection; however these efforts are still at an early stage. The Upper Watershed Management Project, implemented by the Ministry of Forestry and Natural Resources, is actively promoting participatory forestry in a focus area that includes the upper catchment of the Walawe basin.

- Public-private partnerships: the concept of farmer companies is being tested at two irrigation systems in the country. One site, the Chandrikawewa Farmer Company, is in the Walawe basin and promotes agricultural production and other rural business activities, while the public sector manages the irrigation system. As yet, a full evaluation of this pilot project has not been undertaken. The other pilot Farmer Company, outside the case study area, is involved in the operation and maintenance of irrigation systems in addition to agricultural input and output marketing. This other company may form a useful model for future public-private partnerships.

Managing risks

Most of the basin's area is located in so-called dry zones and receives less than 1,250 mm of rain annually. The major natural hazard, therefore, is drought. The area is also subject to occasional localized floods, but is at little risk from landslides, coastal erosion, cyclones and earthquakes.

Of the administrative districts of the basin, only Hambantota is classified as drought-prone: during the rainy season drought probability is 28 percent, the highest in Sri Lanka. During the dry season, it increases to 32 percent. Though not classified as drought-prone, some areas of the dry zone in the Moneragala district were seriously affected during the recent drought, as was much of the region. The government initiated a range of measures to mitigate the impacts of future occurrences of droughts. These include short-term emergency measures, such as development of groundwater for emergency domestic supplies, medium-term interventions such as introducing better water management practices; and longer-term studies on the possibility of interbasin water transfers.

Decisions on drought management in agriculture are taken in the seasonal cultivation meeting, attended by farmers and officers. Typical decisions include cultivating a reduced proportion of the command area and sharing the land. In general, domestic water needs are given the highest priority during droughts, a policy that will be formalized with the proposed National Water Resources Policy.

Another concern in some parts of the basins, especially the Moneragala district, is the incidence of malaria. This vector-borne disease can be a predisposing cause of anaemia and malnutrition (for details, see chapter 5 on water and health). Research by the International Water

Management Institute (IWMI) and others have shown that effective water management practices can contribute to eliminating the vector that causes malaria. Initiatives by the Ministry of Health, assisted by the World Health Organization (WHO) and the World Bank, in partnership with national agencies, have addressed the problem considerably.

Sharing the resource

Water delivered through irrigation facilities is a common source of domestic supply for major towns and villages in the basin. Thus, during periods of water shortages, allocating water among different uses becomes an issue.

In one instance, the challenge of sharing water between sectors has been further complicated by the prior water rights of Kaltota farmers, threatened by the Samanalawewa hydropower station. Constructed upstream of the irrigation scheme, the station extracts water from the river to generate energy. As a result, farmers at the Kaltota scheme have had to face occasional water shortages. After a period of intense negotiations and bargaining, a consensus is being built among the authorities dealing with irrigation and hydropower and the farmers.

Evaluating the knowledge base

There is a considerable range of data and knowledge about water and natural resources in the Ruhuna basins and indeed in Sri Lanka in general. However, the available data and information are scattered amongst the different agencies. The World Water Assessment Programme (WWAP) has instigated recognition of the need for greater access to the available information and sharing of knowledge resources between the involved agencies. To this end, a comprehensive database is in the initial stages of design and implementation. The database will be structured to enable monitoring of the WWAP challenge areas and, when complete, will allow improved sharing of data among the agencies.

Identifying Critical Problems and Opportunities

Challenges related to the nature of the resource

Analysis of the meteorological and hydrological data confirms the high temporal variability of rainfall and river flows. Of the three main rivers, a large proportion of the available Kirindi Oya water resource is already developed and there is little scope for further exploitation of the in-stream flows. In comparison, the water resources in the Menik Ganga basin are largely undeveloped, but concerns about the impacts of abstraction on nature and wildlife are currently restricting development plans.

Investigations show that groundwater quality is poor in the lower reaches of the basins, i.e. in the dry zone. In several places, fluoride, hardness, chlorides, sulphate and alkalinity contents are reported to be high, and shallow groundwater, in areas not recharged by irrigation, is falling in some locations due to increased use of agro-wells, that is, wells supplying water to agriculture.

Several water resource development projects are ongoing in the Walawe sub-basin, and other proposals are being studied. With scientific investigations and planning, there is a potential for further development of groundwater. Potential investors in the proposed Ruhunupura industrial complex have indicated their willingness to invest in desalination of seawater to the Ministry of Southern Development.

Challenges related to uses

The main water user in the basins is agriculture, principally for flood-irrigated paddy, the predominant staple-food crop. Paddy cultivation on highly permeable soils has contributed to high water use and thus water shortages and environmental problems. Studies carried out in selected irrigation schemes indicate that many farmers overapply pesticides, herbicides and nitrogen fertilizers (Renwick, 2001). The coastal lagoon system, which forms an important segment of the basin's ecosystem, receives a large volume of drainage flow during the irrigation seasons. This carries the residual wash-off of these agrochemicals. Reduction of dry-weather base flows by irrigation abstractions and increased groundwater use are reported to have aggravated the impacts of drought on the lagoon systems.

In addition to environmental problems from agrochemical use, minor industries in the basin are an occasional source of pollution, such as the paper mill and sugar factories in the Walawe sub-basin.

Several opportunities exist for improving the water use efficiency in agriculture. Increased reuse of irrigation return flows, diversification of crop patterns to include a higher proportion of more water-efficient crops, and the improvement of conveyance systems, better canal operations and field application methodologies are being introduced in the basins. Two donor-funded rehabilitation projects are also supporting initiatives to increase productivity and water use efficiency of the basins' irrigation systems.

It is argued that the village tanks, or dams, should not be considered merely as water sources and production systems but rather as a central part of the socio-economic and cultural system of the rural area. The widespread distribution of minor irrigation systems supports equitable access to water resources. However, transfer of technology innovations to minor irrigation and rainfed farming is less intensive than in the major irrigation schemes. Opportunities do exist to promote higher productivity in rice and other traditional cereal crops in these areas and contribute to sustainable water resource development. Ongoing work for new irrigation facilities has taken these aspects into consideration. Further advances in the use of small-scale groundwater resources (for example through agro-wells) and modern irrigation techniques, including drip, trickle and sprinklers, are supporting increased areas of market-oriented crops.

The reservoirs in the basin allow the impacts of river flow variations to be regulated. However, although farmers using irrigation have reported adverse impacts of other water resource developments, for example hydropower, good coordination and cooperation between sectors have provided more reliable water services to agriculture. Improving agricultural practices and coordination is likely to further ease pressures on basin ecosystems. The proposed river basin organizations will provide a stronger institutional framework to better integrate the concerns of different users in resources planning and management.

Challenges related to management

Several management problems have been identified in the basins. These include inadequate policies and poor coordination among agencies who deal with water, deficiencies in regulating mechanisms and lack of forums to discuss IWRM issues at the basin level. The major issues to be confronted in developing policy and implementing strategies to address the water-related problems include poverty, multisectoral use of water and the coordination of a large number of agencies. Major water resource development projects have focused on agriculture, and intersectoral reallocation is a sensitive issue. There are many legal enactments that deal with safety of infrastructure, water allocation and watershed management, but their implementation is split between several agencies.

Participation of women in decision-making by farmer organizations is low. Only an estimated 22 percent of participants in farmer organizations are female (Atukorala, 2002). As women are concerned with health, sanitation, domestic water and food supplies, their increased participation in water management could positively impact on the issues of sharing water.

Main policy issues related to water supply and sanitation include cost recovery and service coverage for the poor. Present cost recovery levels in urban water supply systems cover only the recurrent operation and maintenance costs and a small part of the capital cost. With government plans to reduce investments in these services, the service providers must, in future, recover the operation, maintenance and capital cost through water charges for urban water supply and sanitation. However, close to 40 percent of the urban population is considered to be poor and increased water charges would not only adversely affect their access to safe water and sanitation, but also hinder attainment of the national targets for service provision.

The government's plans for industrial development should increase employment opportunities and enhance the rural economy. High tariffs on industrial water supplies, the need for more efficient water use by industry, including reuse, recycling and pollution control are important policy issues.

Inadequate use of traditional knowledge about conservation practices has been cited as a cause for environmental degradation (Handawela, 2002). However, access to traditional technology has been found to be unavailable in most irrigation settlements as these are relatively recent developments (Jinapala and Somaratne, 2002). The state has concentrated on better management of irrigated agriculture with little attention directed towards rainfed farming. Even in the irrigated sector, there are administrative demarcations in the management of minor and major irrigation schemes, even though the systems are often linked and are therefore difficult to manage in isolation from one another.

Despite the problems identified, the basins do have great opportunities to establish sustainable water management systems. These opportunities are based on three key characteristics of the basins and the local populations:

- high literacy, which allows for effective communication;
- potential to expand the role of existing farmer institutions to contribute to integrated management of water and other resources; and
- minimal industrial reuse of water, allowing for development potential in that sector. Similarly, there is a possibility to improve reuse of return flows in agriculture.

Conclusions

The Ruhuna basins system is threatened on various fronts, including increasing competition for a scarce resource, agricultural pollution and plans for major industrial development in the future, which is set to raise the stakes even higher. One of the main challenges concerns the lack of IWRM. In effect, with a plethora of government agencies and an even larger number of legislative documents all dealing with water, there is an urgent need to bring these together in a more comprehensive manner. The establishment of river basin organizations has been proposed in order to counter this lack of coordination in both administration and monitoring facilities.

Many efforts have been made in the basins to ensure sustainable use of water resources, and the planned industrial developments are set to provide a great economic boost to the region, for example by creating employment opportunities.

A great challenge lies ahead in preserving the environment while building a better life for the basin's population, a good part of whom continues to suffer from malnutrition and poverty. Improving the access to relevant data, implementing more integrated management approaches and continuing the fight against poverty could go a long way to providing a more sustainable future for the basins.

Box 18.1: Development of indicators

Indicators are the cornerstones to effective management of water resources in the basins. A set of primary indicators has been identified as effective in describing the basins with only a few key numbers. The following indicators are the result of several stakeholder meetings, discussions amongst experts and analysis of available data.

Challenge areas	Sri Lanka indicators
SURFACE WATER INDICATORS	• Annual Water Resources (AWR) = 2,460 million m^3; annual rainfall = 9,010 million m^3 • Precipitation: 1,524 mm (basin average); evapotranspiration: 1,700 mm
WATER QUALITY	• Water quality measured at specific locations; measurements are not continuous • Poor quality experienced in estuaries and coastal lagoons
GROUNDWATER	• A comprehensive groundwater assessment is being carried out • Groundwater recharge = 7 to 10% in hard rock terrain • Groundwater reliance = annual groundwater withdrawals/total annual withdrawals = 3%
PROMOTING HEALTH	• Access to safe water = 60% (the available data do not indicate whether there is sufficient water) • Access to adequate sanitation = 71% • Hours of water supply/day as an indicator has been suggested, but data are not available yet
PROTECTING ECOSYSTEMS	• Total protected land area = 1,200 km^2 = 21% of basins • Forest cover = 1,418 km^2 = 25% • 1 Ramsar site
WATER AND CITIES	• No major cities at present; however, water for cities is a major issue for the future • With the planned industrial development, water needs for domestic and industry expected to increase to 100–150 million m^3
SECURING THE FOOD SUPPLY	• Average paddy yields: major irrigation (> 80 ha) = 4.6 T/ha • Minor irrigation (< 80 ha) = 3.6 T/ha • Rainfed = 2.9 T/ha • Water productivity (selected scheme) = 0.14 kg/m^3 (for paddy)
WATER AND INDUSTRY	• Annual water use (estimated)= 4 million m^3; water reuse is not very common; effluent discharge to open drains observed

Challenge areas	Sri Lanka indicators
WATER AND ENERGY	• Total installed capacity is about 126 MW • About 1.3 million m^3 is used for generating 1 GWh • Basin produces about 245 GWh annually
MANAGING RISK	• Dry season drought probability = 32% • Wet Season drought probability = 28.4% • Risk of malaria and other water-related diseases exist
SHARING WATER	• Agriculture is the major user; estimated use is about 95–97% • Industry use is about 1%. • Domestic water use is about 1–2% • In drought situations domestic water is the priority • Formal policy is being prepared
VALUING WATER	• Economic, social environmental and cultural values are considered in planning water resources • Pipe borne water supply is charged (more information is being collected) • Irrigation water is not directly charged, but part of the management cost is recovered through participatory management
ENSURING KNOWLEDGE	• Hydrometric network consists of 19 rainfall stations, 25 agro-meteorological stations and 6 water level stations • The existing coverage is considered inadequate for comprehensive water resources assessment • A considerable amount of data is collected, but not readily accessible
GOVERNING WATER	• Participatory management in irrigated agriculture became national policy in 1988 • A large number of agencies are involved in water management and related activities • Coordination effected at various levels • Participation by women considered inadequate • Farmer Companies concept is being promoted

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‘Improving water quality is still the major concern of the Seine-Normandy basin, despite real progress made over the last thirty-five years. Storm runoff during periods of heavy rainfall continues to create problems, causing wastewater to be discharged directly into rivers or overloading wastewater treatment plants, thereby decreasing their efficiency. Non-point source pollution from farming and urban areas is still a major problem as nitrate, pesticide and heavy metal concentrations continue to increase.’

19

Seine-Normandy Basin, France

By: The Seine-Normandy Water Agency (AESN, Agence de l'eau Seine-Normandie)

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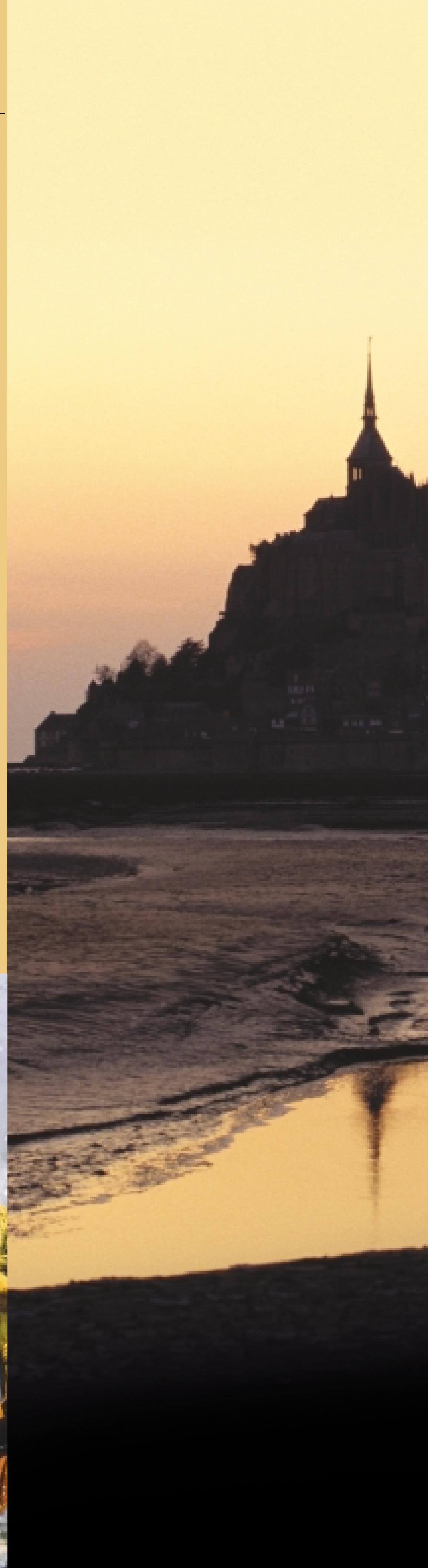
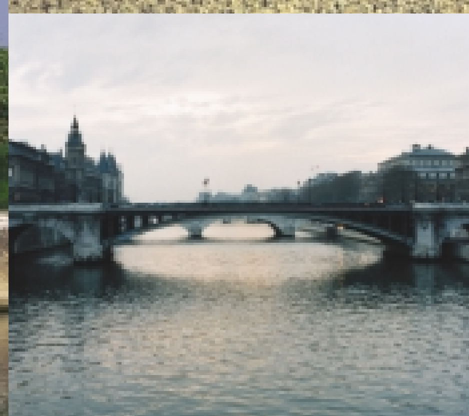
Seine-Normandy Basin, France



Under the Pont Mirabeau the Seine
Flows with our loves
Must I recall again?
Joy always used to follow after pain.

Guillaume Apollinaire

IT WAS ONLY FORTY YEARS AGO that the Seine River was declared 'dead'. Levels of pollution from industry and agriculture were dangerously high. Native fish had disappeared, plant life was dying, and the water was unsafe for swimming. Today, however, the river and its surroundings have been rehabilitated. The city of Paris even organizes fishing contests on summer afternoons. This dramatic change began with the recognition in 1964 of six river basins as the natural hydrographic units in France and the creation of six water agencies to manage them accordingly. Problems remain, especially nitrate pollution from fertilizers and the continuing disappearance of wetlands, but the case study presented here shows that the application of modern technology, a sound tax base and political will on several levels can go a long way towards reversing some of the neglect of the past.



THE SEINE-NORMANDY BASIN district in the north-west of France covers an area of about 97,000 square kilometres (km^2), nearly 18 percent of the country's total surface area. It is made up of the drainage basins of the Seine River and its tributaries, the Oise, Marne and Yonne, and those of Normandy's coastal rivers.

Map 19.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

The land is relatively flat with altitudes generally under 500 metres. The climate is oceanic and temperate with an average annual rainfall of 750 millimetres (mm) and an average annual potential evapotranspiration of 500 mm. Annual rainfall varies between 300 and 1,600 mm, depending on the area. In Paris, it varies from 400 to more than 800 mm from year to year. The average monthly temperature in Paris is between 2.5°C (in January) and 24.6°C (in August). Periods of freezing temperatures are short along the coast in the west, but lengthen as we move towards the eastern edge of the basin.

Geology

The Seine-Normandy basin includes a large portion of the sedimentary Paris basin. The geological structure of the Paris basin resembles a stack of 'saucers' with the most recent layers (Tertiary) outcropping in the centre and the oldest layers (Mesozoic) outcropping on the outer edges of the basin. These layers overlie the Hercynian bedrock (Palaeozoic) that outcrops in the western part of the basin. This type of geological structure contains numerous aquifers of extremely varying size and structure (alluvial, sedimentary and fractured aquifers). In the Paris basin, about ten of these aquifer formations are very important in terms of usage.

Leached brown soil covers the western part of the basin. There is a thinner layer of acid brown soil, eutrophic brown soil and calcareous soil on the eastern edge of the Paris basin and in Lower Normandy. The rendzina soil found in many places at the base of hills is used for vine growing in the Champagne region.

Population density

The Seine-Normandy basin has an estimated population of 17.5 million people, 80 percent of whom live in urban areas, most of which are located along the basin's rivers and in the Paris region (located approximately in the centre of the basin). Population density in the basin varies greatly. The Paris suburbs are now spreading into Upper Normandy. The Ile-de-France region around Paris is the most popular tourist destination in France and has, for example, 35 million foreign-tourist-nights per year. The populations of some of the departments along the Normandy coast are also subject to very high seasonal variations.

Table 19.1: Hydrological characteristics of the Seine-Normandy basin

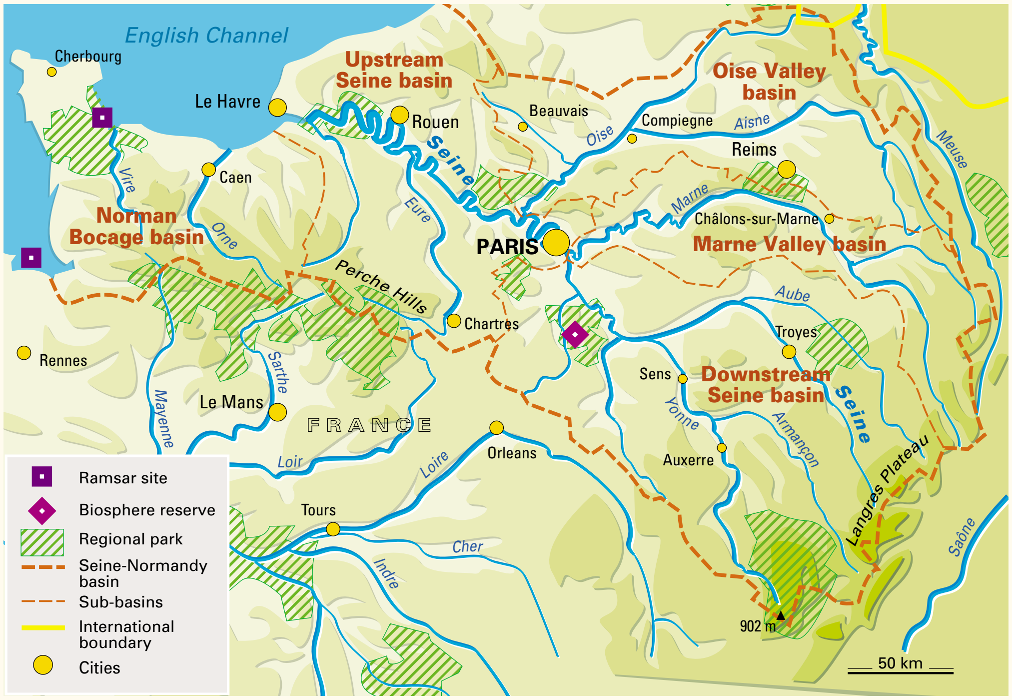
Surface area of the basin	97,000	km^2
Annual precipitation	750	mm/year
Annual potential evapotranspiration	500	mm/year
Average discharge in the coastal rivers of Normandy	125.8	m^3/s
Average discharge in the Seine River	460	m^3/s

Economics

Economic activity in the Seine-Normandy basin is dynamic. Industrial production in the basin alone accounts for 40 percent of domestic production, and includes 60 percent of France's automobile industry and 37 percent of its oil refining industry. There are agro-food industries located throughout the basin, whereas heavy industry (chemical, oil, paper, metallurgy) is concentrated in the Lower Seine Valley and the Oise Valley. There is a wide range of economic activity, in terms of both size and diversity, in the Paris region alone. The trades, service and commercial sectors, an integral part of the urban fabric, also flourish due to the high population density.

The basin also has a prosperous farming industry, with extensive farming on vast plains and the renowned wine-producing regions of Champagne and Burgundy. Sixty percent of the surface area of the basin is used for agriculture, and 80 percent of France's sugar, 75 percent of its oil and protein seed crops and 27 percent of its bread grain comes from this region. Since 1970, farming practices in the basin have followed the global trend towards large industrial crops with high added value (sugar beets, rapeseed, potatoes) with a concentration of cereal crops in the south-west and livestock production on the edges of the basin.

Map 19.2: Basin map



Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Water Resources

Increasing anthropogenic pressure on hydromorphology

The Seine-Normandy basin has 55,000 km of water courses. The Seine, fed by the Oise, Marne and Yonne Rivers, is the basin's central artery. The rivers have gentle slopes due to the flat terrain. During flood periods, river water overflows into floodplains that are, in places, more than 10 km wide.

Flooding is indeed a major concern in the basin. Runoff has increased as more of the basin has been rendered impermeable (1,600 km^2 of impermeable ground out of a total surface area of 100,000 km^2, though these areas are concentrated).[1] Flow is often disrupted by the overdeepening of riverbeds, dredging and gravel pits. Dams in the Seine-Normandy basin, partly meant for levelling off of peak flow, often have a minimal effect on floods due to their distance from the large urban areas and their limited capacity compared to the volumes of the exceptional floods.[2] However, these large dams do regulate low flow and without them the rivers upstream from Paris would be dry during the summer due to the large amount of water withdrawn by the Paris region.

Human development also harms the biology of the rivers: migratory fish cannot get past 60 percent of the hydroelectric power plants and less than 20 percent of the dams are equipped with fish-passes. Modifications to the basin's major rivers, particularly for navigation purposes (1,427 km of navigable waterways, 550 of which have large or medium clearance), are the principal cause of decline in the population of migratory fish species.

The quantitative effects of other anthropogenic pressures on the basin are not major issues. Out of about forty aquifer formations, only three have temporarily dropped below their water stress thresholds. In rivers, withdrawal mainly affects quality. The water in some rivers is now simply outflow from wastewater treatment plants.

Water quality: a mixed balance sheet

Despite greater human activity, which produces oxidizable waste, the dissolved oxygen concentration in the basin's rivers has increased over the last thirty years, after becoming seriously depleted in the 1960s.[3] The nitrate situation is, however, worsening. Since 1965, the nitrate concentration in the lower Seine has

1. Additional runoff due to the waterproofing of surfaces is estimated to be 760 million cubic metres per year, based on a runoff coefficient of 100 percent on impermeable surfaces and 20 percent on permeable surfaces, and an average annual rainfall of 600 mm.
2. While the large dams on the Seine, upstream from Paris, can hold 800 million m^3 of water, almost 4 billion m^3 flowed through Paris during the 1910 flood.
3. The average oxygen content at the Poses measuring station (lower Seine), has increased, on average, by 0.9 percent/year over the last twenty-five years, which therefore reflects the efforts made throughout the Seine basin.

increased significantly, even if the rate of progression has slowed since 1989. The same concentrations are also occurring in groundwater.[4] Today, some 25 percent of the basin's groundwater measurement points show more than 40 milligrams (mg) of nitrate per litre; 12 percent show more than 50 mg/litre. But these nitrate rates still are under the groundwater threshold for producing drinking water (which is 100 mg/litre, while it is 50 mg/litre for surface water). Nitrate is also the third biggest cause of coastal and seawater pollution. When combined with phosphate, it can cause eutrophication and the proliferation of toxic microalgae. Phosphate input from continental sources, which is the main cause of eutrophication in freshwater, has decreased considerably but is still too high.[5]

Metal concentrations are also decreasing.[6] While naturally present in small quantities in the aquatic environment, metals also come from insufficiently treated wastewater and from surface runoff in urban areas. While the accidental discharge of highly toxic contaminants that kill fish is now rare, high concentrations are still measured near contaminated sites.

On the other hand, polychlorinated biphenyl (PCB) concentrations are still alarming, even though they are decreasing.[7] Although PCBs have not been manufactured since 1987, they are still produced by the incineration of domestic waste and the manufacture of paints and lubricants. Along with metals and hydrocarbons, PCBs are the second biggest cause of coastal and seawater contamination (after microbiological pollution). Groundwater is, however, little affected by organic micropollutants other than pesticides.

Pesticides, used not only in agriculture but also along railways and roads and in gardens, are a serious problem in the Seine-Normandy basin. Triazines – highly soluble, mobile and persistent organo-nitrogenous compounds – are the most prominent. They are present in surface water (with peaks in spring), coastal waters and, above all, in groundwater.[8]

In general, organic micropollutants are a major water management problem because the concentrations that must be measured are extremely low and new synthetic molecules, which must also be detected, are constantly appearing. Map 19.3 shows the basin's physico-chemical fitness between 1997 and 1999.

4. In 2000, out of 407 wells, 37 percent had nitrate contents between 20 and 40 milligrams per litre and 14 percent had very poor quality water (>50 mg/litre).
5. The flux entering the Seine estuary decreased from 60 to 39 t/day between 1974 and 1999.
6. Since 1976, there has been a decrease at Poses (lower Seine) in the dissolved metal loads of cadmium (a tenfold decrease over the last thirty years), cobalt, chromium, mercury, nickel, lead and zinc. Those of other metals, such as copper, titanium, vanadium, iron and manganese are also decreasing, but less markedly.
7. Their concentration has been decreasing since 1978, but is still five to six times greater than the national average.
8. Half of the 371 wells in the monitoring network were contaminated in 1999. Forty percent had triazine concentrations of over 0.1 micrograms per litre.

Biodiversity on the upturn

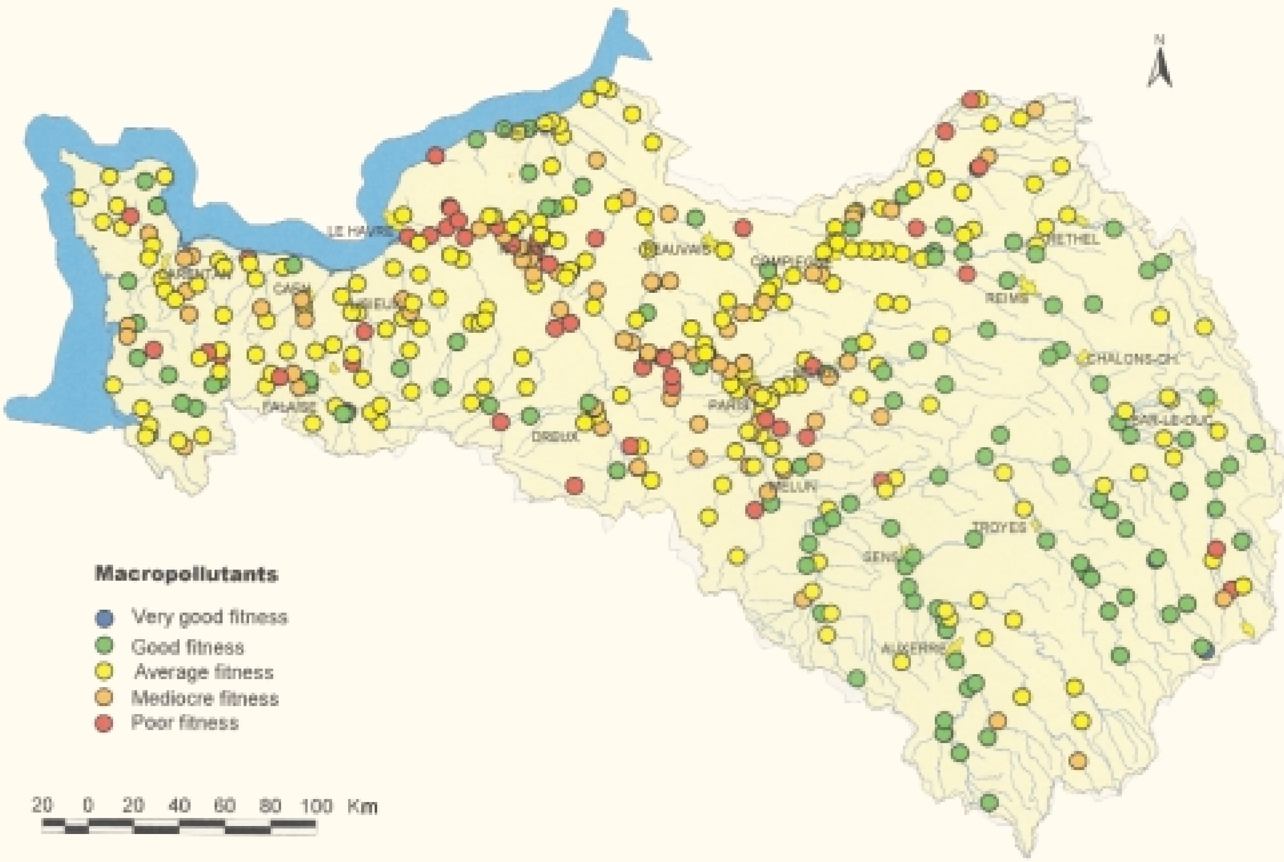
Out of a total of thirty-three fish species that have been identified as belonging to the local ecosystem, twenty-six are still commonly found today, a considerable improvement over the 1960s when the diversity and number of fish had declined due to heavy water pollution (Belliard, 2001). The Seine-Normandy basin's Hydrobiological and Piscicultural Network for monitoring fish populations now has 143 stations. Three or four times a year, electrical fishing techniques are used to study fish populations. The live fish are then returned to the river. While conditions near the edges of the basin are generally favourable to fish life, this is not the case in its centre (in the Seine River, in particular). In small rivers, non-point source pollution and the silting up of riverbeds are the main causes of the decrease in fish populations. In large rivers, the causes are mainly physical barriers and discharge from urban areas. Along with the negative impact of anthropogenic pressure (seven species are no longer present), about twenty new species have been introduced by humans,[9] who have also brought in invasive plant species, such as Japanese knotweed.[10]

Readily available water data

The Seine-Normandy Water Agency (AESN, Agence de l'Eau Seine-Normandie) and French government services, together with other public institutions, manage several measurement networks that gather quantitative and qualitative data on surface water and groundwater. For example, common surface water quality parameters were measured at 441 points in the basin in 2000. Of these, 171 were also analysed for metals and 120 for micropollutants. These points are sampled six to forty-eight times a year, for determination of more than 150 parameters (for a total of nearly 2 million data items/year), which vary in time and space with field conditions. The groundwater quality network uses 402 wells and piezometers to monitor the basin's ten major aquifers. Samples are taken twelve to forty-eight times a year for determination of more than 250 parameters (nearly 3 million data items/year). Networks have also been set up to monitor coastal waters. In 2000, water samples from 130 sites were analysed for swimming quality, twenty-two sites for shellfish and eleven sites for marine sediments. In estuaries, coastal rivers, swimming areas and at discharge points, the principal tests carried out are bacteriological analyses (*Escherichia coli*, Enterococci), backed up by chemical analyses

9. Examples of species that have been introduced are ruff and hotu (*Chondrostoma nasus*), and those that have disappeared include sturgeon, sea trout (or squeteague), salmon and sea lamprey.
10. The *phytophora fungus*, part of whose life cycle is in rivers, severely damages alders, which are of major ecological and silvicultural importance. The Dreissene is an invasive mollusc in rivers. *Cladophora* and *Vaucheria* are green algae that thrive in eutrophic environments and have been introduced by humans from aquariums. *Cyanophyta* are also disturbing in freshwater environments for health reasons.

Map 19.3: Water quality in the Seine-Normandy basin



Quantitative and qualitative data on surface water and groundwater are processed using a Quality Evaluation System (SEQ-Eau) based on indicator sets and use requirements.

Sources: AESN, 2001b. IGN-BD Cartho 94.

(suspended particulate matter, oxidizability, nitrate, chloride). Shellfish are analysed for bacteria (total coliform count, Streptococci, Salmonella), metals and radioactivity. Marine sediments are analysed for radioactivity.

The resulting data are processed using a Quality Evaluation System (SEQ-Eau) based on both the notion of indicators (groups of similar parameters, such as 'metal' or 'nitrate') and the requirements of the various uses (drinking water supply, irrigation, swimming). This system is very flexible and enables water quality to be evaluated according to the most relevant criteria for a given use.

Quantitative data are measured at 174 rain gauges, 214 piezometers and 418 hydrometric stations. These enable monitoring of flood risk and the possible effect of flooding on water quality. Water level records are stored in a database and are available to the public via web site.[11] Most of this data is also available to the public on the AESN web site,[12] which uses dedicated software to produce summaries by measuring point and parameter, upon request.

In France, the public is very aware of the seriousness of environmental problems, especially where human health may be affected. People living in the Seine-Normandy basin are much more concerned about water quality than they are about water shortages. They know that pesticides and chemical fertilizers are a major problem and understand that water has to be 'cleaned up' before it is discharged. They therefore consider it normal to pay for this service although they object when they think the price is too high for the service provided or that the costs are not being equitably shared among stakeholders. Interestingly, water consumption has dropped recently, but studies show that price is not directly responsible for this trend.

11. http://infoterre.brgm.fr/
12. www.eau-seine-normandie.fr

Challenges to Life and Well-Being

Stringent health control

The quality of drinking water is much better now than it was thirty-five years ago. Standards are higher and treatment techniques are much more efficient. Drinking water must satisfy criteria based on Maximum Permissible Doses (MPD). The European Water Framework Directive (WFD) requires that forty-eight parameters be taken into account, including microbiology, toxic substances and 'undesirables'. The drinking water of more than half of the basin's population is supplied by groundwater. With groundwater, biological standards can be met simply by protecting wells and slightly disinfecting the pumped water (except when the water is turbid, which can occur during periods of heavy rainfall in karst regions, thus depriving about 500,000 people of water for several days each year). In and around Paris, where drinking water comes mainly from rivers, the treatment required depends on the quality of the raw water. Surface water is ranked in three categories according to quality, each category requiring increasingly stringent treatment. The most polluted water may not be used as a drinking water resource. However, there are few instances of below-grade classification in the Seine-Normandy basin. On the other hand, the MPDs for atrazine (a chemical weed killer) pose a problem, especially since the limits set by the European Union (EU) are even more stringent than those of the World Health Organization (WHO) at 0.5 micrograms (µg) per litre for total organic micropollutants and 0.1 µg/litre for each individual substance. For nitrates, the EU recommends 25 mg/litre, but the current standard for both Europe and WHO is 50 mg/litre. Trends in the basin indicate that the MPDs for nitrate will also soon pose a problem. High lead content in drinking water is frequently a problem in old houses, due mainly to the state of privately owned pipes.

Bathing in rivers is still often restricted due to poor bacteriological quality. The basin's coastline is the site of flourishing tourist activity and a dynamic shellfish farming industry specialized in mussels and oysters, both of which require very high-quality seawater. Microbiological pollution from sewage systems, surface runoff and coastal rivers is the main threat, and has very harmful effects on economic activities. The situation has improved considerably since 1990, but isolated incidents still occur during periods of heavy rainfall. Areas used for shellfish culture are ranked in four quality categories, each of which requires increasingly stringent treatment in order to ensure that the commercialized products meet standards.

Drinking water supply and wastewater treatment

In 1999, 1,564 million cubic metres (Mm^3) of water were pumped in the Seine-Normandy basin for the drinking water supply. This corresponds to a distributed volume of about 1,240 Mm^3, given network losses (estimated to be about 20 percent), providing an average daily consumption of about 190 litres per inhabitant per day or 70 m^3/year.

Concerning wastewater treatment, reduced nitrogen discharge is considered to be the determining factor for river water quality. This depends on the capacity of the receiving environment and the efficiency of wastewater treatment plants.[13] Each city in the basin with a population of more than 10,000 inhabitants has a treatment plant. In 1999, 88 percent of the basin's population was hooked up to municipal wastewater collection networks (the rest of the population lives in isolated dwellings with private sewage disposal systems), and the basin's wastewater treatment plants had a total capacity equivalent to waste from 20.7 million inhabitants. They are usually very effective in removing suspended particulate matter (85 percent) and oxidizable matter (78 percent), but not as good for nitrogenous matter and compounds containing phosphorous (Seine-Normandy Basin Committee, 2000. While these results are adequate, they must be interpreted with caution because they do not include the 60 Mm^3 that flow directly into rivers each year during periods of heavy rainfall when storm runoff exceeds the capacity of the drainage network and/or the treatment plant. Figure 19.1 shows the improvement in water quality following the commissioning of the Saint Dizier treatment plant.

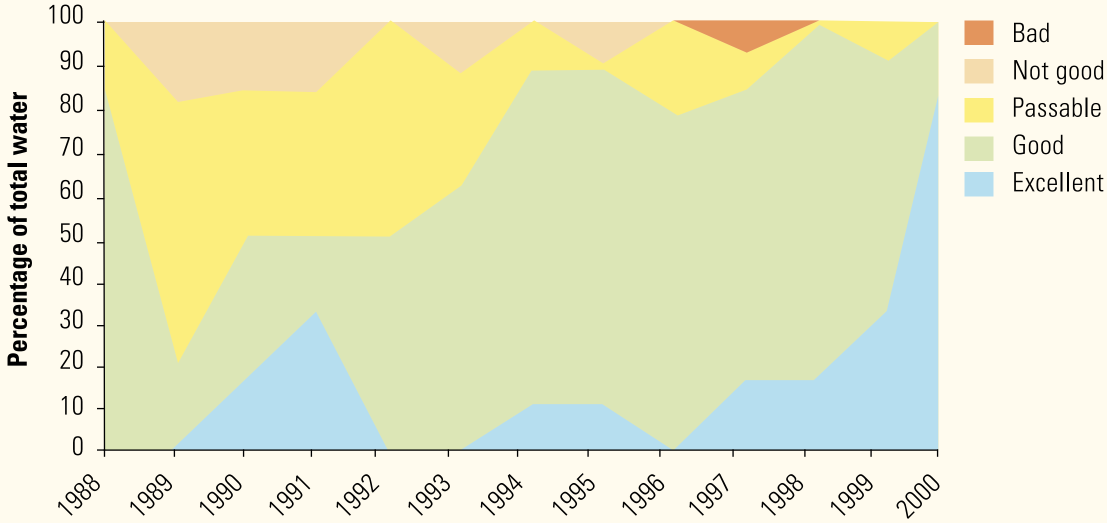
During storms, urban runoff is sometimes passed through wastewater treatment plants, depending on the storage capacity and treatment available, and on the storm's intensity. At present there is inadequate provision for treating contaminated and high-risk runoff. However, the city of Paris is planning to build new stormwater storage with a capacity of 1,6 Mm^3. Hazardous wastes, both solid and liquid, are deposited in seventy-seven private landfills within the basin. Five of these are used for dangerous materials; their impact on water is low and they are well monitored. The remaining seventy-two landfills are for normal waste. Taxes are paid on each ton of waste brought to the landfill.

Domestic users are also a source of non-point source pollution. Contaminants are carried off by surface runoff, which is rarely treated and flows directly into rivers. Waste from public areas and animal droppings in towns and cities are also major sources of contamination.

The disposal of treatment plant sludge (190,000 tons of dry matter/year) is also problematic. Most of it is recycled by farmers, which in turn poses the problem of heavy metals spreading on agricultural land.

13. The effects of an urban area on its drainage river can be expressed by an indicator calculated by relating the discharge capacity of the treatment plant, A, to the five-year minimum flow of the receiving river. Thus, the ratio A/Q_{mna5} enables us to calculate the maximum ammonium concentration in the river at the point of discharge.

Figure 19.1: Improvement of water quality of the Marne River



Thanks to the implementation of a wastewater treatment plant in Saint Dizier in 1995, the water quality of the Marne River has considerably improved: more than 80 percent of the water was considered of excellent quality in 2000, compared to 10 percent in 1995.

Source: AESN, 2002.

Agriculture

In the Seine-Normandy basin, irrigation is used to increase crop yield, to improve the quality of the produce, to regulate production and to grow crops that are very sensitive to water shortages (for example, potatoes for the industrial production of chips). At present, 394,000 hectares (7 percent of the usable farm area) can be irrigated: this has nearly doubled since 1988. The quality of the water withdrawn, 90 percent of which is groundwater, is generally very good. In spite of this sharp increase, irrigation still has little quantitative impact on the resource, except for occasional cases of overpumping that have been resolved by regulating demand.[14] Irrigation does, however, have an indirect impact on quality because it favours intensive farming techniques and spring crops, which leave the soil bare for long periods of the year and increase the chemical load in the rivers by leaching and draining.

Non-degradable substances from, or excessive use of, fertilizers, pesticides, liquid manure and other substances spread on crops or coming from livestock activities end up in rivers and groundwater. This has a harmful effect on both the environment and other water uses. Pollution is increasing as meadows are ploughed up (the total surface area of grassland decreased 22 percent between 1988 and 2000) and off-soil production becomes increasingly widespread, leading to problems of effluent management. Soil erosion, which causes water turbidity, is also closely linked to farming practices.

Industry

Industry in the Seine-Normandy basin consumed 1,612 Mm^3 of water in 1999, most of which was pumped directly from rivers, and most of which was used by power plants. The chemical and oil-refining industries also use large amounts of surface water. One third of the water withdrawn from the resource during low water periods comes from rivers. The volume of water withdrawn for industrial purposes, with the exception of power plants, has decreased by about 3 percent a year over the last ten years. The chemical and agro-food industries prefer to use groundwater, and often treat it before use.

Despite the high production of oxidizable matter (20 to 30 tons/day produced by the largest industrial units), treatment reduces average unit fluxes to 300 kilograms (kg) per day. Average purification rates are lower for nitrogenous matter, of which industry produces several hundred kg/day. Some industries are hooked up to municipal wastewater sewage systems, thus increasing the burden on wastewater treatment plants and the heavy metal load in the sludge, thereby limiting its use in agriculture.

Despite the large amounts of hazardous waste generated by industry (ten times more than domestic waste in terms of volume),[15]

14. For example, the water level in the Beauce aquifer dropped sharply in 1992 and 1997, causing water use conflicts.

15. The list of polluted industrial sites is available on the Internet at http://basol.environnement.gouv.fr.

industrial pressure on aquatic environments has been considerably reduced because the basin is very well equipped with waste treatment and disposal facilities.[16] Reducing pollution at the source by using clean processes and recycling polluted materials further reduces the industrial pressure on the resource. Remedial measures include improving the yield of wastewater treatment plants using denitrification processes. AESN is promoting this effort.

Another major issue concerns discharge from wine-producing activities and from the numerous small services and trades businesses that are an integral part of the urban fabric.

About thirty accidental pollution incidents from industrial sources occur each year. In more than half the cases reported, fish died and the contamination spread over more than 3 km.

Aquatic environments for biodiversity and tourism

In the Seine-Normandy basin, two major challenges must be met – protecting wetlands and combating eutrophication – if water is to act as a reservoir of biodiversity and an attractive and healthy environment for outdoor recreation.

The basin's wetlands (about 580,970 hectares) are capable of decreasing the levels of nitrogen and phosphorous in wastewater by 60 to 95 percent. They also help to reduce severe flooding by absorbing groundwater and providing room for rivers to expand. They are also of strategic interest for many water birds: 74 percent of the water birds that nest on a regular basis in France and 81 percent of the overwintering species find shelter in the basin. Six of the ten major migration routes that cross France pass over the basin. Unfortunately, twelve of the seventy-eight nesting species and fifteen of the ninety-four overwintering species are now in decline due to the deterioration of the environment. Indeed, half of the wetlands have disappeared over the last thirty years due to anthropogenic pressures, in particular, drainage for agriculture (1,400 hectares in 1999) and major navigation works, hydroelectricity schemes, and roads/railway lines.

Water is also a major tourist attraction and both rivers and beaches are threatened by eutrophication. In the summer, some beaches are invaded by 'green tides' that can result from a high phosphate and nitrate content in the water.

16. Twelve hazardous waste wastewater treatment plants that can generally destroy or trap more than 95 percent of the pollutants, five centres for burial of ultimate waste using efficient confinement techniques, and seventy-two centres for burial of common industrial waste.

Management Challenges: Stewardship and Governance

The 1964 and 1992 Water Laws and the European Union Water Framework Directive (WFD)

The first French Water Law laid the foundations for the French water management system. This law resulted from the growing need to coordinate the numerous local water uses and responsibilities when, in the early 1960s, the country was faced with both an increase in pollution as a result of urban and industrial growth and a sharp increase in the demand for water. The 1964 Water Law created the novel concept of Water Agencies,[17] each with its own 'water parliament', or Basin Committee. The decentralization of water management was reinforced by the second Water Law, which, in 1992, increased the role of the Water Agencies and created a Master Plan for Water Management (SDAGE, Schéma directeur d'aménagement et de gestion des eaux), guidelines for balanced water management on a river basin scale, to be drawn up by a Basin Committee.[18] The SDAGE reports on the state of the basin (see indicators in box 19.1 at the end of the chapter), with the approval of the various stakeholders, and determines long-term strategic objectives (ten to fifteen years). In 2000, the EU issued its WFD, which outlines the principles for Integrated Water Resources Management (IWRM) at the river basin level and requires that member states achieve 'good status' for all of its water bodies by 2015, using any methods they should choose. From an institutional point of view, the WFD follows the French system. The new French Water Law, which will come into force in 2003, transposes the WFD into French law.

Delineated water management roles

Distinctive aspects of the French water management system are the high degree of local responsibility, public-private sector partnerships, coordination on a river basin level and a taking into account of all water uses.

Municipalities (from small villages to big cities) have been responsible for all services associated with water since the nineteenth century. Today, they are not only responsible for initiating water works and operating facilities, but are also legally responsible for the quality of services and rates charged to users in their community. Towns, therefore, often set up intercommunity

17. The water agencies are public bodies administered jointly by the Ministries of the Environment and Finance. There are six in France, one for each of the country's major catchment basins: Seine-Normandy, Artois-Picardy, Loire-Britanny, Rhône-Mediterranean-Corsica, Adour-Garonne and Rhine-Meuse.
18. The Seine-Normandy SDAGE was approved in 1996; thematic data sheets concerning the SDAGE are available on the Internet at www.environnement.gouv.fr/ile-de-france.

associations to operate drinking water supply (an approach that concerns 67 percent of the basin's population) and wastewater treatment (16 percent of the basin's population) networks. They also create joint public-private partnerships by subcontracting water supply and treatment services to private companies under various types of contracts (85 percent of the basin's population for water supply, 36 percent for wastewater treatment). They are still, however, responsible for the system and the private service provider must return the network in proper working order at the end of the contract period.

In addition to water supply and treatment services, water management involves many responsibilities that are sometimes rather vague. An example of this is the management of privately owned rivers. Their maintenance is, theoretically, the responsibility of riparian owners but, in practice, is often undertaken by intercommunity volunteer groups.

All water users must comply with standards set by the water laws, and compliance is monitored by local representatives of state agencies. The state, therefore, remains the 'guardian' of the resource. It is also responsible for maintaining public rivers, a task largely delegated to the French Navigable Waterways Authority (Voies Navigables de France).

Faced with this complex allocation of responsibility, the role of the Water Agency at the river basin level is to promote measures undertaken to ensure a balance between water resources and needs. Its role is mainly financial. It allocates funds – in the form of loans or subsidies – for projects that correspond to the objectives of the Water Agency programme. Thus, by evaluating proposals and monitoring funded projects, it also plays an advisory and consultant role that is widely recognized by its partners. The money that it distributes comes from users in the form of taxes or fees based on the quantities of water consumed and the amount of pollution discharged. It collects all the water taxes from its river basin. The acknowledged neutrality of the Water Agency also enables it to act as a mediator.

Undeniable but limited public participation

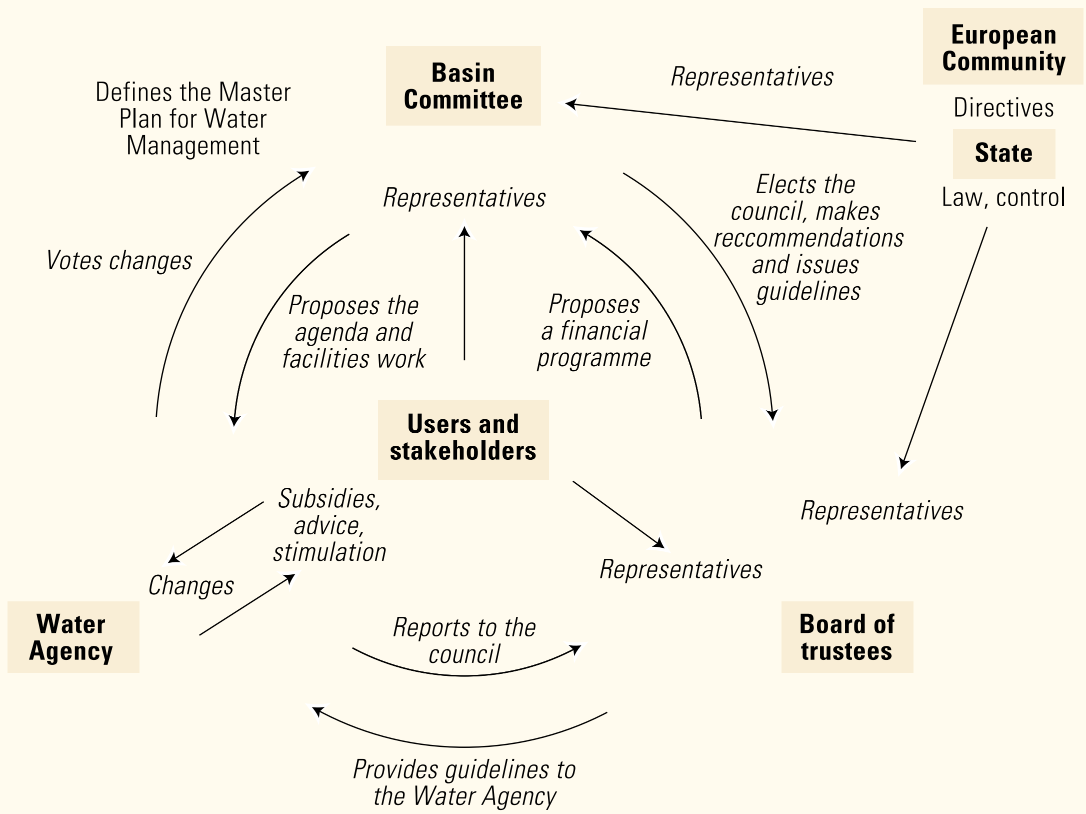
The Basin Committee is an advisory and decision-making body made up of three representative groups – elected officials, water users and people appointed by the state. After studying the situation within the basin, the Committee recommends water tax bases and rates, based on the five-year plans drawn up by the Water Agency and its Board of Trustees (which is made up in the same way as the Basin Committee). Water Agency programmes must follow the SDAGE guidelines, which, in accordance with Water Law requirements, are also the result of extensive collaboration. The state is, therefore, but one of many participants involved in the planning stages (see figure 19.2). It participates in discussions concerning policies that are made and financed by those directly involved. It has, however, administrative control over all of the actions carried out. At a local level (water course, groundwater), very decentralized mechanisms enable the allocation of local responsibilities. Cooperation is achieved through interdepartmental agreements, intercommunity associations and, in particular, local participatory initiatives such as local water management plans (SAGEs, Schémas d'aménagement de gestion des eaux), which are drawn up for sub-river basin catchment areas along the lines of the river basin level SDAGE, and 'rural contracts' created by the AESN.

The composition of the Basin Committee and the steering committees of the local participatory initiatives guarantee, in principle, that water management is, to a certain extent, open to the public. In practice, however, this attempt to be open is sometimes ineffective. User participation in debates is often minimal, local input often being limited to financial-level rather than project-level planning. Faced with this situation, which is closely related to the general timidity of civil society in France, it is clear that the Water Agency needs to encourage more public participation, in particular when the WFD goes into effect.

Payment of water services, financial aid and resource management

The water bill paid by domestic and industrial users hooked up to the municipal water supply network covers the cost of drinking water distribution and wastewater collection and treatment. The price of water varies according to its treatment, management, supply conditions, and wastewater discharge. The bill also includes a pollution tax and a resource withdrawal tax levied by the Water Agency. These taxes represent only a small proportion of the total water bill. Their revenues are redistributed by the Water Agency in the form of interest-free loans or subsidies, in accordance with a five-year programme drawn up jointly by representatives of water users within the framework of the basin's SDAGE. This financial aid is meant to incite users to reduce the impact they have on the resource through investments or improved techniques. The amount of financial aid allocated to the various categories of users is roughly equivalent to the taxes they pay. Funds are, however, shifted somewhat between the basin's various categories of users and geographic areas according to a principle of 'basin solidarity'. For example, domestic users in Paris pay, on average, more in pollution and withdrawal taxes than they get back in aid. This is understandable since their water is pumped upstream and they contribute significantly to pollution downstream. The WFD recommends that the actual cost of water be fully paid by users, that an 'actual cost' indicator be measured, and that appropriate rates be charged to improve quality. In the Seine-Normandy basin, and elsewhere in France, consumers are billed for the cost of

Figure 19.2: Water legislation in France



Many stakeholders are involved in the planning stages; the Basin Committee, the advisory and decision-making body, guarantees – to a certain extent – user participation.

distribution and treatment. But users do not pay for environmental damages due, for example, to non-point source pollution, in particular from agriculture. The basin must be more transparent about how it shifts funds between the various categories of users, the state and public institutions, and must take into account costs engendered by the environmental impact of uses.

The calculation of the Water Agency pollution tax is based on the actual quantity of polluted water. For instance, a water treatment allocation has been set up for industries, which is based on water treatment efficiency and the wastewater destination, so that they are taxed only for the actual amount of pollution that they release into the environment and into the local sewage systems. Water management in the Seine-Normandy basin is, therefore, in accordance with the polluter pays principle.

All Water Agency revenues are spent on supporting pollution reduction and clean-up actions. The nuisances caused by one specific water use over another (negative externalities) still have to be measured and accounted for in the rate setting. This WFD recommendation should be met by 2010.

In 1999, the average price of water in the Seine-Normandy basin was 2.74 €/m^3 (about US$2.8/m^3). The annual bill for domestic users was 126 €/inhabitant (about US$129/inhabitant), around 20 percent of which were taxes. The average amount spent on water per household was 1.03 percent of total income, and 4 percent of housing costs. In light of these figures, the socio-economic weight of the water sector, which employs 18,700 people in the basin (for water supply and treatment), can be estimated: it represents an annual investment of about 60 €/inhabitant/year (around US$61/inhabitant/year). Existing supply and treatment facilities were assessed, in 1999, at 9.360 €/household (around US$9.6/household). The annual expenditure per household in the water sector is therefore 0.5 per thousand of the Gross Domestic Product (GDP).

Achievements of this water management system

Decontamination projects

The Water Agency's first financial aid measures in the 1960s incited many municipalities that had been hesitant until then to launch costly water treatment programmes. During the Water Agency's first five-year programme, the number of wastewater treatment plants in the basin increased threefold. Between 1972 and 1976, financial incentives were created to increase the efficiency of wastewater treatment plants (which has since increased from 40 to 70 percent). Since 1971, SATESE units (technical support for wastewater treatment plants) employ people to monitor the proper operation of wastewater treatment plants. In 1976, inhabitants were made responsible for the pollution they generated and they now pay a unit price for pollution. As a result, wastewater collection and treatment networks have been renovated. At the same time, the Water Agency also began funding private sewage disposal systems. Between 1977 and 1981, Water Agency efforts focused on restoring river water quality by launching numerous joint actions at a local level that were to evolve into river development plans. Diagnostic studies of wastewater collection systems were funded, and the training of SATESE personnel was intensified. Between 1982 and 1986, priority was still given to improving wastewater collection systems. The Water Agency then created 'Reinforced Action Zones' where a higher pollution tax was levied (plus 70 percent) in exchange for an increase in financial aid. Between 1987 and 1991, the fifth Water Agency programme focused on 'black spots', highly polluted areas requiring remediation, and made wide use of pluri-annual contractual agreements to incite urban areas to undertake long-term waste treatment works. Today, the Seine-Normandy basin has 2,100 wastewater treatment plants, which collect wastewater from 3,200 municipalities or intercommunity associations. Current efforts focus on developing more efficient wastewater treatment methods, particularly in terms of nitrogen pollution that take into account surface runoff, and treatment methods that are better suited to rural areas (lagooning, spreading, sand filters, garden filters). The Water Agency is now encouraging small polluters to reduce the spread of pollution.

The Water Agency also participates in the construction of drinking water plants. At the present time, it is financing new filtration techniques.

Preventive measures

The pollution tax has incited industries to make decontamination practices both systematic and highly efficient. An increasing number of companies, supported by the Water Agency, are now using clean processes in order to reduce pollution at the source.

The recent implementation of rural contracts enables local actors to work together on local issues, particularly with respect to combating non-point source pollution. For the moment, these contracts play an important role in terms of raising awareness and inciting action. An encouraging sign in the Seine-Normandy basin is that policies are being developed jointly at the local and regional level to prevent pollution, particularly non-point source agricultural pollution.

In order to reduce this, the Water Agency is financing a pilot project to develop non-polluting farming techniques (soil cover in winter, better use of pesticides, more efficient matching of soils and crops) and to help stockbreeders bring their facilities into compliance with water protection regulations (by means of a new animal-farming tax). There are rules governing the storage of agricultural discharge and most stockbreeders pay an animal-raising tax that corresponds to the impact of discharges into the environment. Farmers using water for irrigation pay a fixed water tax based on their declared area of irrigation. If they own a meter, they pay lower taxes. The installations of meters is subsidized by the Water Agency. The Agency also provides financial assistance to stockbreeders in order to improve their farming practice. They are encouraged to bring manure pits into compliance with nitrate controls and to put down protective groundcover to avoid leaching. The Ministry of Agriculture prohibited the sale of atrazine after September 2002, and will forbid its use after June 2003.

Regulation of and changes in certain chemical products have also had beneficial effects. The increased use of phosphate-free washing powders, combined with particular efforts made by industry, have resulted in a significant decrease in phosphate levels. Cadmium concentrations in Seine estuary sediments have decreased during the last five years since by-products from the manufacture of phosphate fertilizers are no longer discharged into the environment.

Environmental protection and remediation

Other preventive measures specifically concern the environment. One of these is the protection of wetlands. While only 11 percent of the basin's wetlands are protected by regulatory measures, 55 percent are classified under international labels (Ramsar sites, United Nations Educational, Scientific and Cultural Organization [UNESCO] biosphere reserves). The Water Agency also buys wetlands outright (643 hectares were acquired in 2001, almost ten times more than in 1999, and 1,262 hectares have been acquired over the last five years). In addition, it participates in studies and the employment of local wardens and technical personnel. Moreover, for seven years now, the Water Agency has encouraged efforts to restore wetlands by awarding prizes at an annual competition. The Water Agency invested million US$1.53 (1.6 million €) in wetlands in 2000, more than twice the amount allocated in 1998.

The Water Agency has set up technical support units for river maintenance jointly with local authorities and fishermen's federations, and encourages the drawing up of river contracts. Some of these measures are already bearing fruit. Trout have been reintroduced in the Touques River in Normandy, for example, and its river banks have been improved for walkers and anglers. By 2002, some 200 dams were to be equipped with fish passes.

Risk management focused on water shortage, flood and health

The principal risks in the Seine-Normandy basin are those of flooding, severe low water levels and contamination of the drinking water resource. Twenty-two percent of the flood-prone communities have flood risk prevention plans. The local population is informed of the risk of flooding and has Internet access to relevant information.[19] A detailed flood risk map of the region is near completion. Permeable road surfaces are now being used to limit the adverse effects of impermeability on flooding. Since dams do little to control flooding, civil engineering works focus mainly on creating spreading basins. The Water Agency has been able to do little in this area up until now since it has never collected taxes for flood risk management. While the probability of losing life in a flood is extremely low in the basin, property damage is another matter. It is estimated that another flood like the one in 1910 would cost more than 4 billion € (US$4.1 billion).

The large dams on the Seine, the construction of which was subsidized by the Water Agency, ensure that the Marne, the Yonne and the Seine do not dry up in the summer as a result of withdrawals for the Paris region. Using hydrodynamic models, specialists can now study the principal aquifers, particularly as regards the risk of their drying up. Risk thresholds have been set, and specific measures stipulated in management plans are taken if these are exceeded (spreading basins that reduce the flow rate have been defined). Aquifer contracts between groundwater users ensure that, in the event of a crisis, the shortage is shared by all of the users according to a priority scheme (for example, irrigation quotas in the Beauce aquifer, see box 12.4 in chapter 12 for more details).

In order to decrease the risk of contamination of the Paris basin drinking water supply, a project to drill very deep wells to tap the Albien aquifer, 700 metres deep and extensive under the basin, is currently being studied.

Conclusions

Improving water quality is still the major concern of the basin, despite real progress made over the last thirty-five years. Storm runoff during periods of heavy rainfall continues to create problems, causing wastewater to be discharged directly into rivers or overloading wastewater treatment plants, thereby decreasing their efficiency. Non-point source pollution from farming and urban areas is still a major problem as nitrate, pesticide and heavy metal concentrations continue to increase. There are rules for farm waste, just as there are for industries, but only concerning stockbreeding.

Municipal and industrial wastewater treatment still needs to be improved by increasing the efficiency of wastewater treatment plants, particularly with respect to nitrate and phosphate. The wastewater collection system must be improved, and pollution discharged by small businesses and artisans must be controlled. Erosion is another source of non-point source pollution, especially in karst regions where domestic users are still occasionally deprived of drinking water due to turbidity. Combating floods and eutrophication, protecting wetlands, and the spread of treatment plant sludge are also major issues in the Seine-Normandy basin.

All of these problems are on the Water Agency's agenda. Taxes will be levied to more efficiently combat nitrate pollution (a nitrate tax, proportional to the agricultural wastewater discharge) and flooding (a water regime modification tax, based on the impermeable surface area, structures that impede river flow and barriers to flood expansion). An ecology tax has been levied on certain chemical products in order to reduce their use (pesticides, phosphate washing powders).

The European WFD not only confirms French water management principles (management at the scale of major hydrographic basins, direct involvement by those concerned), but also marks a major turning point by setting an ambitious goal to improve the quality of water resources and to achieve 'good status' over the coming fifteen years. Thus, specific prescriptive policies (such as determining discharge standards) will need to be broadened to cover all uses and assess overall environment impact. For those involved in water management, this will mean passing from an obligation of means (doing what is required by law, regardless of results) to an obligation of results (doing whatever is necessary to meet quality objectives required by law). WFD requirements will force the French water management system to increase its public participation and transparency, a task already undertaken by the creation of Basin Committees.

19. www.environnement.gouv.fr/ile-de-france

Box 19.1: Development of indicators

Since the Seine-Normandy SDAGE was implemented, an operating report has been published each year. Progress towards reaching the objectives set by the Basin Committee can thus be monitored. Monitoring is done with indicators that are well suited to the specific context of the basin and focus on Water Agency activities.

Theme	Indicators
MANAGEMENT OF AQUATIC ENVIRONMENTS	• Six indicators of river functionality (fish passes, financial aid for river maintenance) • Three indicators of wetlands preservation (surface areas drained, regulatory protective measures) • Two indicators of decreased dredging of gravel • One indicator of runoff and erosion control
WATER QUALITY MANAGEMENT	• Four indicators of general quality (polluted sites, Seine river water quality) • Five indicators of municipal and industrial discharge • Four indicators of decreased agricultural pollution (demarcation of vulnerable zones, controlling effluents from stockbreeding) • Two indicators of coastal pollution control • Two indicators of drinking water supply (water quality and well protection) • One indicator of pipes and major works
CRISIS MANAGEMENT	• Four indicators of extreme low water level management (expansion zones, warning zones, etc.) • Three indicators of flood control (risk prevention plans, improved forecasting)
INTEGRATED MANAGEMENT	• One indicator of SDAGE progress (local water development and management plans) • Two indicators of contracts
KNOW-HOW AND COMMUNICATION	• Three indicators of knowledge development (research programmes, inventories) • Three indicators of aquatic environment monitoring (measurement network, databases)
STATE OF THE ENVIRONMENT	• Six maps that indicate the state of the aquatic environment: groundwater levels, physico-chemical quality of surface water, pesticide content in surface water, quality of fish populations, quality of coastal waters, maximum nitrate and pesticide concentrations in groundwater

These indicators have been sufficient for monitoring changes in the environment and the management system under the current SDAGE. The EU WFD objectives for achieving 'good status' and covering actual costs will undoubtedly require additional monitoring indicators.

Within the framework of the World Water Assessment Programme (WWAP), the AESN recommends that the following indicators of the environment, governance and financial aspects also be taken into consideration.

Theme	Indicators
ENVIRONMENT: QUALITY (ADAPTABLE TO GROUNDWATER, WATER BODIES AND COASTAL WATERS)	• Maps made using a Quality Evaluation System, based, at least, on the following indicators: BOD5, NH4+, NO3-, P total, suspended particulate matter, pH, conductivity, colour, thermotolerant/ faecal coliform organisms, total chromium, mercury, lead, DDT op', DDT pp', lindane, endrine, dieldrine, aldrine
ENVIRONMENT: WETLANDS	• Surface area and evolution: protected wetlands and RAMSAR sites, basin wetlands, especially those in flood plains, drained areas. • Maps of urban areas and density of industrial fabric. • Changes in the pressures from intensive farming, industry and urban development in the basin.
ECONOMY	• Average price of drinking water/m^3, annual amount paid by inhabitants for drinking water, proportion of the price of water used to protect the resource, the value of distribution and treatment facility assets/household, funds earmarked for water/GDP, volume consumed annually/ inhabitant, annual water bill per household/ annual income. Cost recovery index. Pricing of services and financial autonomy of water works budgets.
GOVERNANCE	• Decentralization, involvement of public in water policy decisions, transparency, allocation of roles, openness to civil society, mobilization of know-how, sharing of knowledge, management system evaluation, public-private partnership (equity and efficiency).

Box 19.1: *continued*

If we attempt to assign global scores for sustainable resource management we run the risk of ending up with meaningless figures. The details on which the ratings are based must be preserved and accompanied by the individual scores for each indicator. The methods used to obtain and calculate indicators must also be described in detail. It might be difficult to assign a precise score to some indicators. The state of the environment, for example, is generally shown with a map. Weighting, which favours certain themes or indicators to the detriment of others, should also be carefully considered. For example, different weighting methods would result in different scores, each of which could be used to more accurately reflect a specific area of water management (shortages, governance, environment).

Data for some of the indicators proposed by WWAP are now being gathered at the Seine-Normandy basin level. Data gathering methods for others are still being developed, while for still others data cannot be gathered at present, or the indicators are too vague.

Challenge area	Seine-Normandy basin indicator
SURFACE WATER	• Withdrawals: 2,044 bm^3/year • Precipitation: 750 mm • Evapotranspiration: 500 mm
WATER QUALITY	• Yearly maps for monitoring the quality of water courses using indicators • SEQ tool (Quality Evaluation System) is used, which covers groups of similar parameters • French Environmental Institute (IFEN) quality indicators
GROUNDWATER	• 10 major water tables • Withdrawals: 1,213 bm^3/year • Volume of underground resources has not yet been accurately assessed • Piezometric monitoring of groundwater tables; three tables have overrun the hydric stress threshold over the last ten years, but have been filled up again due to recent heavy rainfall
PROTECTING HEALTH	• Incidence of water borne diseases is low • Virtually all households have access to good quality potable water (conformity level of potable water analyses > 99% for the sixty-two parameters) • 0.03% of the population is deprived of potable water several days per year due to turbidity in periods of heavy rainfall in certain zones • 88% of the population has access to collective sanitation and 10% use individual sanitation measures (in rural areas) • Right to water is legally recognized • Public drinking fountains, washing places or baths in each town or village • Temporary social aid for the poor in paying their water bills; water cuts very rare and theoretically forbidden for poor people

Challenge area	Seine-Normandy basin indicator
PROTECTING ECOSYSTEMS	• Present estimation of the surface area of wetlands: 580,969 hectares, 6% of the basin area), of which 2% is protected by national regulations and 9% by international regulations • In 2004, 31% of wetlands will be classified as sites of European importance. • Three Ramsar sites • 1.6% of the surface area in the basin has been rendered impermeable • Around 600,000 ha drained between 1974 and 1999 (in other words 6.2% of the basin area) • 33 fish species listed in the Seine
WATER AND CITIES	• Withdrawals of potable water: 1.6 bm^3 • 20% leaks and is used for cleaning the network; the inhabitants consume 70 m^3/year. • 100% have access to potable water • Access to sanitation in towns currently being evaluated • 100% of communities with more than 10,000 inhabitant equivalents have a wastewater treatment plant • The responsibility (penal) for water and sanitation services is incumbent on the local authority
SECURING THE FOOD	• Indicator that is not very relevant in the Seine-Normandy basin (no problems of securing food)
SUPPLY WATER AND INDUSTRY	• Annual use of water by industry: 95 m^3/inhabitant (of which 2/3 is used for cooling thermal power plants) for 188 m^3/inhabitant of the water withdrawn annually • Pollution from industries not connected to the sewage system: 147 t/day of oxidizable matter; 19 t/day of nitrogenous matter: 3.2 milliequivalents (Meq)/day of inhibiting matter; 2.9 t/day of toxic metals.

Box 19.1: *continued*

Challenge area	Seine-Normandy basin indicator
WATER AND ENERGY	• Annual use of water for cooling of thermal power plants 831 Mm^3/year
MANAGING RISKS	• 2,239 communities are at risk to flooding; 22% of them have a Risk Prevention Plan. Flooding map for the whole basin
SHARING WATER	• Welfare measures have been put into place to ensure that the poor have access to water (cutting off the water supply is prohibited) • 49% of withdrawals are for domestic water requirements, 27% for industry, 3% for farming, 23% for electricity and 5% for other uses (cleaning of roads, etc.) • If there is any conflict between sectors in the use of the resource, domestic supply water is treated as a priority • Water counters exist
VALUING WATER	• Price of potable water is on average 2.74€/m^3 (US$2.80/ m^3), which is 126€/inhabitant/year (US$120/inhabitant/year) • Tariff varies from 0.15 to 5.35€ (US$0.14 to 5.11), depending on the size of the community, the complexity of treatment required, and the specific management set-up • All consumers are billed for water and sanitation services • On average, households spend 1.03% of their income per year on water and sanitation • Pricing system is controlled by the state • On average, the fees represent 20% of the price of potable water • Annual water expenditure (potable water and sanitation) is 0.5% per thousand GDP
ENSURING KNOWLEDGE	• For surface water 150 parameters are measured 6 to 48 times per year, on 441 observation points, relating to 15,000 km of principal drains and 17 million inhabitants • For groundwater: 402 boreholes, measured 12 to 48 times per year, on 250 parameters; relating to 10 or so main aquifers, a total surface area of 97,000 km^2 and 17 million inhabitants

Challenge area	Seine-Normandy basin indicator
ENSURING KNOWLEDGE	• For quality of coastal waters: 130 'swimming' sites (ten or so parameters), 22 'shellfish' sites (around 5 parameters), 11 'sediment' sites (at least radioactivity, heavy metals) relating to 600 km of coast • In quantitative terms there are: 174 rain gauges, 214 piezometers and 418 hydrometric stations • In total around 5 million sets of data per year, a large proportion of which is available to the general public on the Internet • The quality data is analyzed using the SEQ (Quality Evaluation System), which allows maps to be produced by type of indicator (grouping together of similar parameters)
GOVERNING WATER	• Local authorities responsible for water and sanitation; programming, coordination on a catchment area level • Management interventions adapted to the scale of the problem (river contracts, management schemes on the small catchment area scale) • Effective delineation of roles and balanced public / private partnerships (delegation of water and sanitation services) • Insufficient participation by civil partnerships and vagueness for the responsibility for the upkeep of rivers • Transparency in the price of water and water budget autonomy, fees monitored and well discussed • Problems of imbalance in expertise and insufficient evaluation of management actions • Solidarity funds for rural zones to promote equity, basin solidarity between zones and end users • Delegating water and sanitation services to the private sector (46% of cases) • Close correlation between the public and water policy in small communities, representatives of associations in the Basin Committee, but these openings are not sufficient

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Senegal River Basin, Guinea, Mali, Mauritania, Senegal

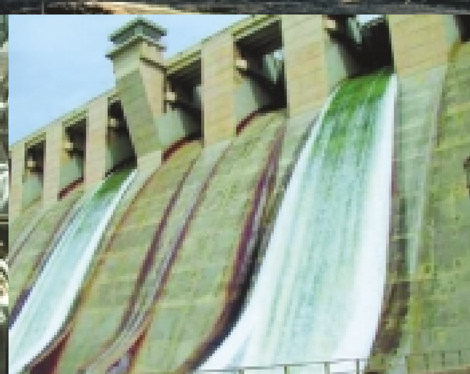
By: The Organization for the Development of the Senegal River (OMVS, Organisation pour la mise en valeur du fleuve Sénégal)

Table of contents

**The chameleon changes colour to match the earth,
the earth doesn't change to match the chameleon.**

African proverb

THE SENEGAL RIVER represents a 1,800-kilometre lifeline for a multi-ethnic, multicultural population where livestock outnumber people. It runs through sub-Saharan Africa in a mostly desert region characterized by water scarcity and subsistence economies. The Organization for the Development of the Senegal River (OMVS) was created in 1972 with a mandate to ensure food security and harmony among all riparian users. Thanks to the construction of two main dams providing energy, irrigated agriculture and year-round navigation – and to an original management approach based on a concept of 'optimal distribution among users' rather than volumetric water withdrawals – the area is gradually developing. Ironically, dam construction has brought problems as well as benefits, and the major concern is water-related diseases.



THE SENEGAL RIVER BASIN is located in West Africa, between latitudes 10°30 and 17°30 N and longitudes 7°30 and 16°30 W. It is drained by the 1,800 kilometre (km)-long Senegal River, the second longest river of West Africa, and its main tributaries, the Bafing, Bakoye and Faleme Rivers, which have their source in the Fouta Djallon Mountains (Guinea) or in Mali.

Map 20.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

Most of the Senegal River basin has a sub-Saharan desert climate, aggravated by more or less long periods of drought during the 1970s. Access to sufficient quantities of good-quality water is therefore a particularly sensitive issue and absolutely crucial for the health of the population and the economy.

Physical characteristics

The Senegal River basin covers a surface area of about 300,000 square kilometres (km^2). The high plateaux in northern Guinea represent 31,000 km^2 (11 percent of the basin), 155,000 km^2 are situated in western Mali (53 percent of the basin), 75,500 km^2 are in southern Mauritania (26 percent of the basin) and 27,500 km^2 are in northern Senegal (10 percent of the basin). The basin has three distinct parts: the upper basin, which is mountainous, the valley (itself divided into high, middle and lower) and the delta, which is a source of biological diversity and wetlands (see map 20.2). Topographical, hydrographic and climatic conditions are very different in these three regions and seasonal temperature variations are extensive.

Table 20.1: Hydrological characteristics of the Senegal River basin

Surface area of the basin	300,000 km^2
Annual precipitation	660 mm/year
Annual runoff (Bakel station)	
Before 1985	698 m^3/s
After 1985	412 m^3/s
Annual discharge (Bakel station)	
Before 1985	863 m^3/s
After 1985	416 m^3/s

Socio-economic characteristics

Population

The Senegal River basin has a total population of around 3,500,000 inhabitants, 85 percent of whom live near the river. This figure includes approximately 16 percent of the total populations of the three OMVS member states – Mali, Mauritania and Senegal – plus the population of the Guinean portion of the upper basin.

The population within the basin is increasing at a rate of about 3 percent per year, which is slightly higher than the individual averages for the three member states.

A large ethnic diversity also characterizes the basin's population, with, among others, Peuls, Toucouleurs, Soninkes, Malinkes, Bambaras, Wolofs and Moors. However, there is massive emigration among the young towards the major cities and to Europe.

Table 20.2: Summary of physical data

		Mali	Mauritania	Senegal	Guinea
Surface area (km^2)	National	1,248,574	1,030,700	197,000	245,857
	Basin	155,000	75,500	27,500	31,000
	(% of basin)	53	26	10	11
Rainfall	National	850	290	800	2,200
annual average (mm)	Basin	300 to 700	80 to 400	150 to 450	1,200 to 2,000
Temperature	National average	29	28	29	26
	Basin min. and max.	15 to 42	18 to 43	17 to 40	10 to 33

Half of the basin is located in Mali, but the main input in terms of water resources comes from the upper basin in Guinea with an average of 1,600 mm of precipitation.

Map 20.2: Basin map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Table 20.3: Summary of socio-economic data in the OMVS member states

	Senegal River basin	Mali	Mauritania	Senegal
Population (million inhabitants)	3.5	11	3	10
Annual growth rate (%)	3	2.97	2.9	2.8
Urbanization rate (%)	NA	41	53	51
Farmland (ha)	823,000	NA	NA	NA
Irrigated land (ha) – national total	NA	78,630	49,200	71,400
Part in basin		4,000	44,449	67,830
Cattle (x1,000 units)	2,700	6,427	1,394	2,927
Sheep and goats (x1,000 units)	4,500	15,986	10,850	8,330
Fish catch (t/year)	26,000 to 47,000	100,000	620,000	395,000

Population figures have been updated, based on growth rates in each country. Irrigation is the motor of development of the basin, especially in the valley and the delta, and livestock raising has always been a major activity. After agriculture, fishing is the second largest economic activity of the basin.

The financial support received from these people is very important to the livelihood of families remaining in the villages, especially during periods of difficulty, as with droughts or floods. Some of these emigrants return to their villages during the rainy period for seasonal work.

The enormous socio-economic potential of the Senegal River basin was identified long ago by colonialists and some resources were already being developed long before the countries gained their independence in the 1960s. Table 20.3 gives a summary of socio-economic data today in the OMVS member states.

Agriculture

The first major attempts to control the Senegal River discharge were made in the 1940s in order to grow rice in the delta (at Richard-Toll in Senegal). But it was not until 1973 that the State Company for Agricultural Development (SAED, Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal) decided to increase this activity by building dikes around 10,000 hectares of flood land and created, in 1975, an irrigated area of 650 hectares. Thereafter, small irrigated areas were rapidly created as a means to combat the drought cycles in the 1970s that made it almost impossible to grow rainfed and flood recession crops. On the left bank, the surface area of community-based irrigated fields grew from 20 hectares in 1974 to 7,335 hectares in 1983 and 12,978 hectares in 1986. Irrigated agriculture rapidly expanded after the new dams were filled (between 1986 and 1988). Today, irrigation is still the motor of development in the basin, notably in the valley and in the delta, due not only to improved technology, but also to the wider variety of produce grown (rice, onions, tomatoes, potatoes, sweet potatoes). About 100,000 hectares of land are now cultivated in the basin: 60,000 hectares during the rainy season (June-September) and 20,000 hectares during the dry season (March-June).

Livestock-raising has also always been a major economic activity in the basin. Due to the existence of rather high-potential pasture land, combined with the carrying capacity of the grasslands and the flood plains, the riparian populations, and even those living elsewhere, practice transhumance and extensive cattle-, sheep- and goat-raising. These activities are generally profitable.

Fishing, in terms of the income of the work force that it employs, is undoubtedly the largest economic activity in the basin after agriculture, notably for populations living near the river in the valley and the delta. Today, however, the future of this sector is in question because for several years now there has been a steady drop in the tonnage caught throughout the OMVS region. Some observers link this to the river development projects (dams, dikes) and to their impact on the environment (significant decrease in salinity, proliferation of floating water weeds and eutrophication). A recent OMVS study of fish resources indicates, however, that while it is true that some old species have disappeared, new fish species have appeared. It would even seem that the invasive aquatic plants are breeding grounds, which at the same time does not prevent them from seriously hindering the mobility of fishermen. The problem, therefore, needs to be studied in more depth to be able to objectively determine the actual impact of the dams on the fishing sector.

Mining sector

Before independence, mineral exploration carried out by the Geological Survey and Bureau of Mines (BRGM, Bureau de Recherches Géologiques et Minières) had already enabled the French to begin mining several economically profitable ores, notably gold in the Faleme River. The activity later became marginal and today only a few people still pan for gold in the Malian and Senegalese parts of the upper basin. Nevertheless, in light of the mining potential in the sector, with the energy provided by the Manantali dam, since September 2001, and the near completion of the river navigation project, mining will undoubtedly become one of the major development poles in the basin again .

Industry

The industrial sector is not sufficiently developed. The Senegalese Sugar Company (CSS, Compagnie Sucrière Sénégalaise) is the largest agro-industrial unit in operation in the basin. It has a production potential of more than 8,000 hectares of sugar cane in Richard-Toll, using water from both the Senegal River and Guiers Lake. Its two largest subsidiaries are the International Design Industry Services (IDIS), which manufactures polyvinyl chloride (PVC) pipes, and the Senal Cotton and Food Products Commerce and Industry Corp., which produces livestock feed. There are two other, smaller, companies in the Delta – the SOCAS canning plant near Ross Bethio and the SNTI, specialized in industrial tomato processing, in Dagana, Senegal. There are also industrial and private rice paddies managed by the SAED and a public rural development enterprise (SONADER, Société Nationale de Développement Rural) in Mauritania.

Energy

The hydroelectric power plant in Manantali has been in operation since September 2001. The initial objectives of this project were to produce 200 megawatts (MW), to furnish an average of 800 gigawatts per hour per year (GWh/year) to electricity companies in the three OMVS member states. The projected electricity production figures used to estimate profitability were, however, based on hydrological data from 1950 to 1974. New simulations done with data from between 1974 and 1994 when flow coefficients were low, which might correspond better to current conditions, predict an energy production of only 547 GWh. As a result of this decrease in the

Table 20.4: Water use by sector within the OMVS area (in millions m^3)

Sector	Mali	Mauritania	Senegal
Agriculture	1,319	1,499	1,251
Domestic use	27	101	68
Industry	14	29	41
Total	1,360	1,630	1,360
Per capita (m^3/year)	161	923	201

Reference year is 1987, except Mauritania (1985). Agriculture is by far the most important water user in the OMVS area.

Table 20.5: Seasonal changes in Senegal River discharge since 1951

Period	Rainy season (m^3/s)	Dry season (m^3/s)
1951–1999	1,538	138
1951–1971	2,247	172
1972–1999	1,007	112
1972–1990	993	71
1991–1999	1,036	201

This table clearly shows the benefit of the Manantali dam construction in the flow regulation (beginning 1991): the discharge never falls below 200 m^3/s.

energy capability of the Manantali power plant, the expected savings in OMVS member states expenditures for energy would unfortunately drop from 22 to 17 percent.

Navigation

Navigation on the Senegal River is today very limited. The OMVS is aware of the strategic importance of its development over the short term, and a navigation project is under study. Like the exploitation of mineral resources, the ability to transport heavy goods at a lower cost and, especially, access to the Atlantic Ocean for Mali could give a new impetus to the region's economy. Table 20.4 summarizes the water use distribution between the different sectors.

Water Resources

Hydrology

Rainfall

The river's flow regime depends, for the most part, on rain that falls in the upper basin in Guinea (about 2,000 mm/year). In the valley and the delta, rainfall is generally low and there is rarely more than 500 mm/year. During the 1970s (drought years), there was significantly less. This greatly accentuated the interannual irregularity of floods, which, before the dams were built, could vary six-fold between the wettest and driest years. The climatic regime in the basin can be divided into three seasons: a rainy season from June to September, a cold, dry off season from October to February, and a hot, dry off season from March to June. In the river, this creates a high-water period or flood stage between July and October, and a low-water period between November and May to June.

Surface water

The three main tributaries of the Senegal River produce together over 80 percent of its flow. The Bafing alone contributes about half of the river's flow at Bakel. The two largest tributaries on the right bank, above Bakel, the Gorgol and the Oued Gharfa, supply only 3 percent of the water in the Senegal River that flows into the Atlantic Ocean at Saint Louis. At Bakel, considered to be the reference station on the Senegal River due to its location below the confluence with the last major tributary (the Faleme), the average annual discharge is about 690 cubic metres per second (m^3/s), which corresponds to an annual input of around 22 billion cubic metres (bm^3). The annual discharge ranges between a minimum of 6.9 bm^3 and a maximum of 41.5 bm^3. Table 20.5 provides some discharge data.

The total capacity of the Manantali dam, built on the Bafing River, is 11.5 bm^3 of water for a useful volume of around 8 bm^3: it is the largest in the basin. Its purpose is to attenuate extreme floods, generate electric power and store water in the wet season to augment dry-season flow for the benefit of irrigation and navigation.

The Diama dam, located 23 km from Saint Louis near the mouth of the Senegal River in the delta, sits astride the territories of Mauritania and Senegal. Its threefold purpose is:

- to block seawater intrusion and thereby protect existing or future water and irrigation wells;
- to raise the level of the upstream water body, creating reserves to enable irrigation and double cropping of around 42,000 hectares at an altitude of 1.5 metres above sea level (m.a.s.l). and 100,000 hectares at an altitude of 2.5 m.a.s.l.; and
- to facilitate the filling of Guiers Lake in Senegal and Lake Rkiz and the Aftout-es-Saheli depression in Mauritania.

Groundwater

The deep aquifers are, for the most part, represented by the Maestrichian fossil formation and the Continental Terminal formation. The alluvial aquifer is the principal shallow aquifer. It is present in all of the flood plain at various depths, generally less than 2 metres, and has an average thickness of about 25 metres. This aquifer communicates in places with a discontinuous network of lenticular aquifers in the permeable strata interbedded in the alluvium (see map 4.3 on the world's groundwater resources in chapter 4, and map 12.4 on the aquifers in northern Africa in chapter 12).

These aquifers are recharged by the river and by all of the tributaries, distributaries, ponds and lakes in the flood plain. On the edge of the valley, the aquifers tend to deepen, usually with a steep slope, but this is highly variable from one place to another.

The water level in the alluvial aquifer varies with the seasons and river level, along with the general hydrological regime in the valley. Since the dams were filled, both the volume and duration of floods and the geographic distribution of the flooded areas have been disrupted, significantly modifying groundwater recharge and the piezometric surface. Reducing the volume of the floods and building dikes significantly reduces the area of natural recharge zones (infiltration ponds). On the other hand, flow regulation during low water periods (maintenance of a minimum flow) and irrigation of large surfaces, rice paddies in particular, increases groundwater recharge during part of the dry season in some areas.

Water quality

In the Senegal River basin there is, at present, no database for water quality similar to those that exist for quantity and discharge, both of which have been monitored since 1904. There are, however, time series and locally monitored data, generally collected by national water supply companies in Mali, Mauritania and Senegal and within the framework of research carried out by universities, training institutes, cooperative agencies, etc. These data indicate, in some places, a degradation of surface water quality. This deterioration would be caused primarily by eutrophication due to a reduction of the flow velocity and oxygenation of the water caused by the new dams and dikes, the proliferation of water weeds, and chemical and biological pollution related to the discharge of wastewater and pesticides into the river. Furthermore, even if there are, as yet, no figures to confirm it, small alluvial gold-washing activities in the upper basin are a threat to water quality because of the products used (such as mercury and flashlight batteries).

Groundwater in the Senegal River basin is generally salty in areas where there used to be seawater intrusion before the Diama dam was built. The alluvial aquifer has a relatively homogeneous salinity, whereas the lenticular, fluvio-deltaic aquifer formations have a slightly more heterogeneous salinity. As a result, there are large and sometimes abrupt variations, with concentrations rising from 1 or 2 grams (g) per litre to more than 150 g/litre. On average, salinity decreases as one moves away from the centre of the delta (more than 10 g/litre) towards the edge (10 to 0.15 g/litre). The aquifers have a higher load in high areas (with an average of 30 g/litre) than in depressions, which are regularly flooded (13 g/litre). However, the saltiest water is found in depressions such as the Aftout-es-Saheli sebkhas in Mauritania and the Gandiolais lagoons and Ndiael wetlands in Senegal. The pH values also vary (but not with salinity), with a high acidity in and depressions influenced by the acid sulphate deposits of the ancient mangroves. The Sodium Absorption Ratio (SAR)[1] of the aquifers is generally high, which means that there is a risk of alcalinization of soil horizons in contact with these aquifers.

Impact of development on the population and on natural resources

More than ten years after the dams were filled in 1986 and 1987 and the structures (dikes, irrigation systems) associated with the implementation of the OMVS development programme were built, several studies have been carried out, making it possible to conclude that these interventions are having both positive and negative effects on the basin's population and natural resources. Most important, the Senegal basin's flood plain ecology has changed from a salty and brackish aquatic environment with marked seasonal changes to a low-flow perennial freshwater ecology. There is, of course, a cause-effect relationship between the impact of human activities on the physical environment (water resources, soil, vegetation) and the impact of the restoration or degradation of this environment on people because the link between them is fundamental.

Principal negative effects

- Displacement of populations living in the areas where the dams were built;
- proliferation of water-borne diseases (bilharzia [schistosomiasis], malaria, diarrhoea) due to changes in ecological conditions as a result of the blocking of seawater intrusion, with the Diama dam;
- water pollution caused by the development of irrigated agriculture and the agro-industry (CSS, SAED in Senegal, SONADER in Mauritania);
- proliferation of water weeds in the valley and delta, clogging water courses and contributing substantially to making the ecosystem more uniform;
- degradation of the fish population available for independent fishermen (quantity and quality);
- reduction of pasture land;
- riverbank erosion, especially in the upper basin where the topography is much more rugged;

1. Water is generally ranked according to the risk of alcalinization: low hazard (2 to 10), medium hazard (7–18), high hazard (11–26), very high hazard above that (Fetter, 1994).

- degradation of cultivated land;
- modification of the hydrodynamic characteristics of the estuary with the reduction of the 'flushing' phenomenon; and
- disappearance of wetland areas.

The installation of the dams has been accomplished without taking due account of other important aspects of planning.

- Top-down planning has occurred without relationship to the local needs of the beneficiaries.
- The large schemes for groundnuts, cotton and irrigation have been less than successful due to application of inappropriate technologies, lack of markets or access to markets, and lack of local capacity.

Principal positive effects

- Year-round availability of freshwater in sufficient quantities (for agriculture, domestic uses, agro-industry, groundwater recharge), accompanied by reverse immigration of people who had left to find employment in the cities;
- development of irrigated agriculture in the valley (with double cropping);
- partial opening up and stimulation of exchanges between areas where dams have been built and the rest of the subregion due to road construction;
- access to healthcare for several villages near the dams with the construction of dispensaries and health clinics;
- access to drinking water installations for populations living near the dams;
- development of fishing activities for populations living near the Manantali dam;
- reappearance of local fauna and regeneration of vegetation
- flow regulation to decrease or eliminate flooding;
- cheaper electricity in the three member states thanks to the Manantali power plant.

Other positive effects expected over the short term concern:

- the electrification of villages near the dams (a study has been completed and funding obtained for the first phase); and
- navigation on the river between Saint Louis and Kayes (a study is underway).

Water resources database and information

OMVS has abundant quantitative data thanks to a discharge monitoring network set up in 1904, with updated records stored in a database of the OMVS High Commission.

The Technical Department of the High Commission also publishes a monthly hydrological bulletin for the technical services of the member states and other actors (producers, development partners, NGOs, industrial projects) carrying out activities in the basin.

Major studies carried out by the French Research Institute for Development (IRD, Institut de Recherche pour le Développement) and the OMVS have also made it possible to estimate withdrawal and losses during low flow stages. The results are the following: evaporation during low water stages is estimated to be at 65.4 m^3/s, withdrawal for human and industrial consumption at 2.6 m^3/s, and withdrawal for irrigated agriculture during the off-season at 19 m^3/s. The average total water needs downstream from Bakel (reference station) are, therefore, at 87 m^3/s during low water stages.

These studies have also made it possible to develop suitable resource management tools based on analysis of the hydrological behaviour of the river in relation to needs. Software (SIMULSEN) has been developed to evaluate the effects of the various Manantali dam management practices on the degree of satisfaction of demands such as hydroelectric production, flow regulation, flow at Bakel as a function of needs downstream. Specific studies have also been carried out on how flooding is related to the functioning of basins, providing important information concerning their filling and emptying, and the volumes of water potentially available during this period.

Data on water quality, health, livestock-raising, agriculture, fishing, climate and the environment do exist, but are dispersed in various government services, laboratories, universities and research institutes, or even in cooperation institutions, such as the IRD, the United States Agency for International Development (USAID), the United Nations Development Programme (UNDP), and the World Bank.

Data have been collected for many projects, but the resulting databases are incompatible or have simply been lost or abandoned upon completion of projects. The most acute need is in the upper basin, including Guinea, where the lack of data is a concern not only for the government of Guinea but for the whole basin.

Data gaps have long been a handicap for the OMVS. Thus, the High Commission set up an Observatory of the Environment in

November 2000 to create a network of all of the producers/possessors of thematic data and hook them up to a general database that would be managed by the Observatory's Coordination Bureau. Agreement protocols will soon be drawn up by these organizations and the OMVS to formally define the roles and responsibilities of each of the actors in the data collection, processing and storage procedures, on the one hand, and data development, dissemination and sharing, on the other.

Challenges to Life and Well-Being

A difficult context

Before the dams were filled in the mid-1980s, activities of the local inhabitants depended directly on rainfall (rain crops) or on floods (flood recession crops), in particular in the upper basin in Guinea (Fouta Djallon Mountains). But the dramatic and continuous drop in rainfall during the 1960s and 1970s led to the degradation of almost the entire base of natural resources (soil erosion, disappearance of vegetation, drying up of surface water, salinity 200 km upstream from the mouth of the river, drop in the groundwater level, degradation and disappearance of pasture land). Under these conditions, the local inhabitants could not produce enough to survive and the only alternative was emigration. Each year, a large percentage of the population, in particular young people, left the valley and the delta for capital cities in the subregion (Abidjan, Bamako, Dakar, Libreville, Nouakchott) or Europe (usually France or Italy).

The filling of dams

In response to these difficulties, a dam-building project was implemented, in order to partially or totally control river flow and, consequently, enable the development of large areas of land for agriculture to contribute to food security. In addition, the dams built to regulate flow could also be used for hydroelectric power plants, to solve the problem of the low supply and high cost of electricity, and to maintain a sufficient flow depth in the river for fluvio-maritime navigation to relieve Mali's isolation by giving it access to the Atlantic Ocean and lower the cost of transporting heavy goods (making it possible to exploit the basin's mineral resources). It is in this context that the OMVS programme was created.

After the dams were filled, sufficient quantities of water became available year-round, enabling local inhabitants to engage in various highly profitable activities. These new opportunities incited the young men who had left to try their luck elsewhere, without much success, to return home. People from the agrobusiness world also began coming into the area to invest in channels to market or to create small factories to transform the crops grown in the valley and delta.

Preliminary studies showed that the irrigation system would re-establish the basis of profitable production. Flow regularization would guarantee a minimum discharge of 300 m^3/s at Bakel (reference station), and the storage capacity of the Manantali and Diama dams and the Guiers and Rkiz Lakes could be used to irrigate a surface area of 375,000 hectares, three times the surface area cultivated before 1986.

Unfortunately, this initial enthusiasm diminished when, between the sixth and tenth year after the dams were filled, new problems arose. Two in particular, the degradation of ecosystems and the proliferation of water-borne diseases, very rapidly reached severe endemic proportions. These problems are described in detail further on in this chapter.

Management Challenges: Stewardship and Governance

The OMVS river basin organization was established about three decades ago by three out of the four riparian states. Mali's principal interests are the maintenance of river levels so as to obtain navigable access to the sea and energy produced by the Manantali dam. Mauritanian and Senegalese interests converge in power production and irrigation, while Senegal seeks improved livelihoods for local populations. These varied interests are typical of a transboundary water management situation. The Manantali dam, although located in Mali, belongs to all the members of the OMVS authority.

Legal and regulatory framework and governance

The first institutions to develop the Senegal River valley were created during the colonial period. On 25 July 1963, very soon after independence, Guinea, Mali, Mauritania and Senegal signed the Bamako Convention for the Development of the Senegal River Basin. This convention declared the Senegal River to be an 'International River' and created an 'Interstate Committee' to oversee its development. The Bamako Convention was supplemented by the Dakar Convention, signed on 7 February 1964, concerning the status of the Senegal River. The Interstate Committee laid the foundation for subregional cooperation in development of the Senegal River basin. On 26 May 1968, the Labé Convention created the Organization of Boundary States of the Senegal River (OERS, Organisation des Etats Riverains du Sénégal) to replace the Interstate Committee, broadening the field of subregional cooperation. Indeed, OERS objectives were not limited to the valorization of the basin but aimed at the economic and political integration of its four member states. After Guinea withdrew from the OERS, Mali, Mauritania and Senegal decided, in 1972, to set up the OMVS, which pursues the same objectives.

The OMVS has since created a flexible and functional legal framework enabling collaboration and a co-management of the basin. The principal legal texts governing OMVS are:

- the Convention concerning the status of the Senegal River (Convention relative au statut du fleuve Sénégal), 11 March 1972. By this convention, the Senegal River and its tributaries were declared an 'International Watercourse', guaranteeing freedom of navigation and the equal treatment of users;

- the Convention creating the OMVS (Convention portant création de l'Organisation pour la Mise en Valeur du Fleuve Sénégal), 11 March 1972;

- the Convention concerning the Legal Status of Jointly-owned Structures (Convention relative au statut juridique des ouvrages communs), 12 December 1978, supplemented by the Convention concerning the Financing of Jointly Owned Structures (Convention relative aux financements des ouvrages communs), 12 March 1982. These declare that:

  - all structures are the joint and indivisible property of the member states;

  - each co-owner state has an individual right to an indivisible share and a collective right to the use and administration of the joint property;

  - the investment costs and operating expenses are distributed between the co-owner states on the basis of benefits each co-owner state draws from the exploitation of structures. This distribution can be revised on a regular basis, depending on profits;

  - each co-owner state guarantees the repayment of loans extended to the OMVS for the construction of structures;

  - two entities manage the jointly-owned structures for the OMVS: one dedicated to the management and development of the Diama dam (SOGED, Société de gestion et d'exploitation du barrage de Diama), the other to the Manantali dam (SOGEM, Société de gestion de l'énergie de Manantali), both created in 1997.

- in 1992, signature of a framework cooperation agreement between Guinea and the OMVS (Protocole d'accord-cadre de coopération entre la République de Guinée et l'OMVS), creating a framework for cooperation in actions of mutual interest concerning the Senegal River and its basin, including a provision allowing Guinea to attend OMVS meetings as an observer;

- the Senegal River Water Charter, May 2002 (Charte des Eaux du Fleuve Sénégal) whose purpose is to:

  - set the principles and procedures for allocating water between the various use sectors;

  - define procedures for the examination and acceptance of new water use projects;

  - determine regulations for environmental preservation and protection; and

  - define the framework and procedures for water user participation in resource management decision-making processes.

The OMVS functions with the following management bodies:

- Permanent bodies;

- Conference of Heads of State and Government (CCEG, Conférence des Chefs d'Etat et du Gouvernement);

- Council of Ministers (CM, Conseil des Ministres);

- High Commission (HC, Haut Commissariat), executive body;

- Permanent Water Commission (CPE, Commission Permanente des Eaux) made up of representatives of the organization's member states, and which defines the principles of and procedures for the allotment of Senegal River water between member states and use sectors. The CPE advises the Council of Ministers;

- Non-permanent bodies;

- An OMVS national coordination committee in each member state;

- Local coordination committees;

- Regional Planning Committees (CRP, Comités Régionaux de Planification);

- Consultative Committee (CC, Comité Consultatif).

This organizational framework, statutorily strong but flexible on the operational level, enables all of the actors and stakeholders to participate effectively in the efficient management of both the basin's natural resources and its other economic potentials. For more than thirty years now, they have been able to find suitable solutions to all of the technical, social, political and other problems linked to the development of the Senegal River basin's water resources.

Finances

Two types of funding are used to finance the development of the Senegal River basin. The first one covers the operating costs of the various OMVS bodies, and comes from the three member states; each of them pays one third of the total in January of every year. To finance the jointly owned structures and other development activities, funds are sought in the form of loans extended either to the states or directly to the OMVS. In this case, the member states must guarantee the loans. Each member state ensures the reimbursement of its share of the loans.

The apportionment of costs and debts is done according to an accepted formula, subject to revision, as stipulated in the conventions. The underlying principle of cost recovery is that the users pay, but economic conditions are also taken into consideration. Taxes paid to the organization are used to cover operating expenses.

Managing multiple uses: an original approach

Due to potential conflicts between power generation and the other uses of the Senegal River, the three governments have embarked through OMVS on the implementation of an environmental impact alleviation and follow-up programme (PASIE, Plan d'Atténuation et de Suivi des Impacts sur l'Environnement). It is an environmental programme specifically designed to address, monitor and mitigate the environmental issues raised by (or related to) the development and distribution of power from the Manantali power plant.

The OMVS's fundamental conventions of 1972 and the Senegal River Water Charter signed in May 2002, which establish its legal and regulatory framework, clearly state that river water must be allocated to the various use sectors. The resource is not allocated to riparian states in terms of volumes of water to be withdrawn, but rather to uses as a function of possibilities. The various uses can be for agriculture, inland fishing, livestock raising, fish farming, tree farming, fauna and flora, hydroelectric energy production, urban and rural drinking water supply, health, industry, navigation and the environment.

The principles and procedures for the allocation of water were drawn up and a Permanent Water Commission (PWC) was set up to serve as an advisory body to the OMVS's Council of Ministers that makes decisions and asks the High Commission to oversee their application. The OMVS's process for managing needs has four steps.

- First, an inventory of needs is taken by the OMVS National Committees under the Ministries in charge of water in each country. The 'state of needs' is then sent to the OMVS High Commission.

- The High Commission centralizes all of the needs, writes a synthesis report and convenes a meeting of the Permanent Water Commission to vote on recommendations. It then draws up a record of the proceedings with precise recommendations for the Council of Ministers.

- The Council of Ministers makes decisions based on the information provided by the Permanent Water Commission, either in a formal meeting or by informal telephone consultation. The High Commission receives instructions from the Council of Ministers and transmits to member states and other actors the procedures for carrying out the measures adopted by consensus by the member states in the Council of Ministers.

- The work of the Permanent Water Commission and the criteria used by the ministers for decision-making are based on the following general principles:

  - reasonable and fair use of the river water;

  - obligation to preserve the basin's environment;

  - obligation to negotiate in cases of water use disagreement/conflict; and

  - obligation of each riparian state to inform the others before undertaking any action or project that could affect water availability.

The objective of the OMVS method of water allocation is to ensure that local populations benefit fully from the resource, while ensuring the safety of people and structures, respecting the fundamental human right to clean water and working towards the sustainable development of the Senegal River basin.

Approach/procedure

The construction of the basic first-generation infrastructures (the Diama anti-salt dam and the Manantali multipurpose hydroelectric dam) marks the partial conclusion of a major phase, based on a development approach.

Today, the OMVS is attempting to redefine medium- and long-term development strategy for the entire basin, associating development with inextricably integrated and sustainable management. In March 2002, the OMVS began drafting a Master Plan for Development and Management (SDAGE, Schéma Directeur d'Aménagement et de Gestion des Eaux) of the Senegal River basin. This procedure enables progress to be made in the following areas:

- education, by favouring collaboration between stakeholders;
- technology, by reassessing the situation (diagnosis of the entire basin) and defining the strategic orientations and measures required to establish sustainable resource management practices;
- legislation, by ensuring that regulatory actions carried out in all of the member states are coherent; and
- finances by focusing funding on future OMVS programmes.

Moreover, the May 2002 effective date of the Senegal River Water Charter and the start-up of environmental monitoring by the Observatory represent golden opportunities for increasing the involvement of representatives of the various stakeholders in the resource management decision making process. This participatory approach will be reinforced by the launching of the Master Plan next year.

Identifying Main Problems

Degradation of ecosystems

The flood plain ecosystems have been most affected by dam construction. In less than ten years, the degradation of these environments and the consequences on the health of the local population have been spectacular.

Upstream of Diama, the functioning of regularly flooded wetlands, lakes and ponds, such as the Djoudj, Guiers Lake and Lake Diawling, has been seriously disrupted. After 1986, Diama dam blocked seawater intrusion. The water above the dam is now fresh year-round, creating ecological conditions favouring the proliferation of freshwater plants (*Typhas*, *Pistia startioles*, *Salvinia molesta* and various alga species). These are very invasive and eutrophication has begun at some places in the valley and the delta. Downstream of the Diama dam, perturbations in the functioning of ecosystems takes the form of an increase in salinity and/or a drying-up during part of the year (Ndiael wetlands) due to the reduction of flooding or the destruction of water inflow channels during construction of the development works (dikes, irrigated areas). Anthropogenic pollution is caused by the discharge of industrial and agricultural chemicals into these environments.

Other problems arise from increased competition for agricultural land and firewood. As marginal land on slopes and river banks is cleared, there is increased erosion. In addition, large areas of the basin have been denuded due to overgrazing. As was shown in table 20.3, a big percentage of the population is pastoral and therefore must compete for land, increasing competition between agriculture and pastoralism.

Public health

The degradation of the basin's ecosystems has affected the riparian population to various degrees. For example, there has been a drop in productivity in some economic areas (agriculture, fishing, livestock-raising) compared to productivity during the first years after the dams were filled, which has led to a decrease in income and, therefore, a decrease in the standard of living.

The most serious problem that the basin has had to face since 1993/4, however, is the impact of the dams on public health. There has been not only a rapid increase in the prevalence of water-borne diseases that were already present in the area (malaria, urinary schistosomiasis, diarrhoea, intestinal parasitic diseases), but also the appearance of intestinal schistosomiasis, a much more dangerous form of the disease.

Malaria

Malaria is a major public health problem in the basin. Indeed, it is the primary reason for consultations in health clinics and the primary cause of death. It causes 90 percent of the cases of fever. It is caused by *Plasmodium falciparum*, the most deadly species of *Plasmodium*, carried by the anopheles mosquito *Anopheles gambiae*.

Diarrhoea

Surveys done recently by the OMVS in the three member states indicate a diarrhoea prevalence of 15 to 30 percent around Podor (Senegal). This rate is estimated to be about 25 percent in Mauritania and 15 percent in Mali. Many factors favour the appearance of diarrhoea, but in the Senegal River basin, aside from general hygiene, the primary cause is the abusive use of agricultural fertilizers and pesticides, which, at the end of the hydrological cycle, end up in the human food chain.

Schistosomiasis (bilharzia): urinary and intestinal

In the OMVS area of the basin, there are two types of human schistosomiasis: urinary and intestinal. Intestinal schistosomiasis was unknown in the region before the dams were built, but today is rampant in the valley and delta. The blocking of saltwater intrusion upstream has allowed the snails that host the parasite (*Schistosoma mansoni*) to proliferate in the desalinated river and irrigation canals. Humans are contaminated when the parasite penetrates the victim's skin.

Surveys conducted in 2000 by OMVS health services in the member states indicated a prevalence of urinary schistosomiasis disease in about 50 percent of the region around Saint Louis. In Mauritania, in the Trarza, the average infestation is estimated to be at 25 percent, with places where the increase in prevalence is quite spectacular. For example, in Lexeiba, the infestation rate increased from 8 to 50 percent in only a few years. In Mali, urinary schistosomiasis is highly present, with a rate of 64 percent.

The development of intestinal schistosomiasis demonstrates even more clearly the impact of development on the health of the region. Unknown in Mauritania before the dams were filled, the first cases were reported in 1993. One year later, a survey showed that the population of school children in Rosso had an overall prevalence of 32.2 percent. In Senegal the situation is even worse, with a 44 percent rate of infestation in the Walo flood plain, 72 percent in the area around Guiers Lake where more than 90 percent of the villages are affected. In Mali, this form of schistosomiasis is still present in specific areas, with an infestation rate of 3.34 percent in 1997, but the situation calls for close monitoring.

Conclusions

The OMVS has demonstrated its effectiveness. It has been tested for more than thirty years now, and was recently improved by the adoption in May 2002 of the Senegal River Water Charter. This framework enables a collaborative management approach, with effective involvement of local actors/stakeholders, recognized and accepted by all of the riparian states including Guinea, who has signed cooperation agreements with the OMVS prior to being reintegrated into the organization.

It also establishes the principles and terms of water sharing between the different usage sectors, based on the original concept of 'water distribution' among the users and riparian states in which sharing the water resource is not a matter of withdrawals, but rather one of optimal satisfaction of usage requirements. The OMVS looks for an equitable managing and distribution of water resources among multicultural ethnic groups who are gathered around the river basin and its water resources. The new dams and institutional framework have brought greater prosperity and economic revenue and replaced a situation of water scarcity and conflict among users as that which prevailed before the 1980s.

However, these undeniable achievements cannot hide new difficulties emerging with the dams' implementation: displacement of populations, water-borne diseases, proliferation of invasive aquatic vegetation, degradation of cultivated land and water pollution are the major issues the basin will have to cope with in the near future.

Box 20.1: Development of indicators

At the OMVS, the insufficiency or even total lack of temporal and spatial data for several sectors has made it almost impossible to correlate the increased availability of the water due to developments and the environmental and health problems that this has caused and their direct and indirect impact on the living conditions of local populations. Therefore, to eliminate this information control constraint, and to better understand the evolution of development in the basin, the OMVS is being reorganized so that it can collect, process and store all the data needed to monitor development project performance indicators from the upper basin to the mouth of the river. The Environmental Observatory was created by the High Commission in November 2000 for this purpose. Between November 2000 and December 2001, indicators were defined and strategies set up to gather, process and store data that will enable OMVS to correlate water availability, public health, the state of the environment and socio-economic development. These indicators concern:

- the productivity of activity sectors (agriculture, livestock raising, fishing, mining);
- the market rate of crops grown in the basin;
- the percentage of participation of women in economic activities;
- the impact of the involvement of women by activity sector;
- the quality and the quantity of domestic water use;
- the rate of access to drinking water of the populations living along the river;
- the prevalence of water-borne diseases (human and animal);
- the state of the environment (degradation of soil, forests, water bodies);
- the quantitative estimation of the degradation of ecosystems by sector of activity;
- the quantitative estimation of the health situation in each sector of activity;
- the rate of immigration and emigration in the zone; and
- the quantitative estimation of the corrective measures taken to eliminate the negative impact of developments.

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'There is an urgent need to intensify the fight against poverty and to drastically improve the health system in the [Lake Titicaca] region. Great benefits could be achieved through the provision of better services for waste disposal and treatment, the promotion of environmental education and the continuation of the water regulation works already in progress. Most importantly, however, there needs to be far greater investment in public health services in order to ensure a better quality of life for the population.'

21

Lake Titicaca Basin, Bolivia and Peru

By: The Binational Autonomous Authority of Lake Titicaca (ALT, Autoridad Binacional del Lago Titicaca Bolivia-Perú)

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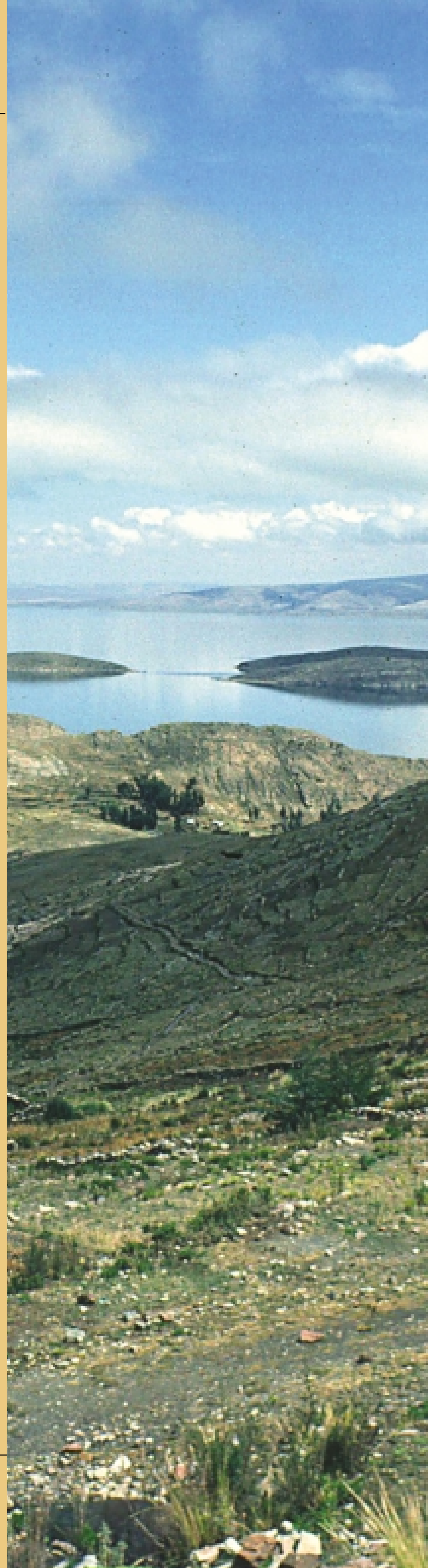
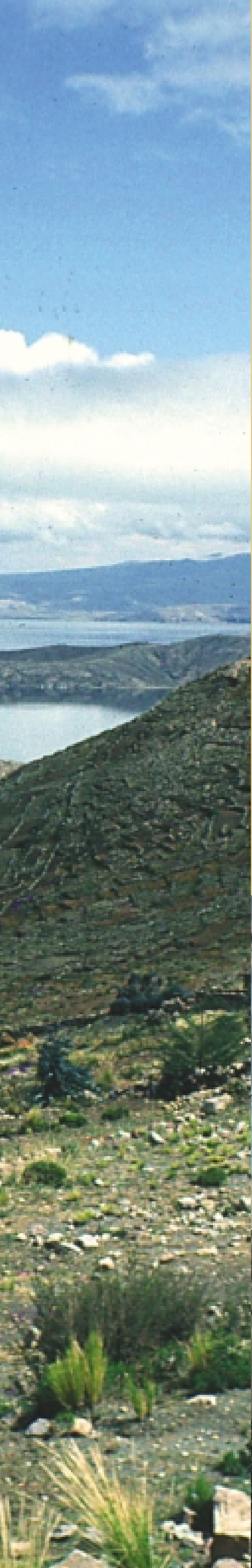




The frog does not drink up the pond in which it lives.

Inca proverb

SITUATED AT AN ALTITUDE OF 3,600 to 4,500 metres in the highest plateaux of the Andes, Lake Titicaca straddles the border of Bolivia and Peru and comprises a basin network of four distinct lakes. The surrounding environment is fragile, subject to flooding and, increasingly, pollution. A unique feature of this pilot case study is the presence of indigenous, pre-Hispanic peoples who continue to follow their ancient cultural traditions and resist assimilation into Western-style societies. These people are extremely poor, and only about 20 percent have access to water and sanitation. The major challenges for the Binational Autonomous Authority of Lake Titicaca, therefore, are to find ways to promote land tenure reform, adopt appropriate farming and irrigation techniques, and develop legislation that will provide an enabling environment in which culturally sensitive development and resource-sharing may occur.

LAKE TITICACA IS A REGION OF MYSTERY AND LEGEND. Originally inhabited by the Urus, a race today extinct, it was dominated successively by Aymara warlords, Quechuas of the Inca empire and Spanish conquerors. Along its banks flourished the Tihuanacu culture (1500 AC) that left behind immense megalithic constructions and complex agricultural systems redolent of an advanced civilization. Before it mysteriously disappeared, its art, culture and religion had spread throughout the entire Andean region.

General Context

Location

At 14 degrees south, the Andean ridge is divided in two branches: the eastern and western ridges. Between them is a closed hydrological system of approximately 140,000 square kilometres (km^2) located between 3,600 and 4,500 metres above sea level (m.a.s.l.). Within that system lie four major basins (see table 21.2): Lake Titicaca (T), Desaguadero River (D), Lake Poopó (P) and Coipasa Salt Lake (S). Desaguadero River is Titicaca's only outlet and flows into Lake Poopó, the overflow from which in turn gives rise to Coipasa Salt Lake. These four basins form the TDPS system of which the main element, Lake Titicaca, is the largest in South America, the highest navigable lake in the world, and, according to Inca cosmology, the origin of human life.

Major physical characteristics

Topography

Three geographical units can be distinguished in the system:

- the mountain ridge, with altitudes greater than 4,200 m.a.s.l.;
- slopes and intermediate areas, ranging in altitude between 4,000 and 4,200 m.a.s.l. with moderate to steep slopes and a dense hydrographic network; and
- the high plateau, from 3,657 to 4,000 m.a.s.l., in which Lake Titicaca is located. The surrounding area, the most densely populated of the system, varies in height from 3,812 to 3,900 m.a.s.l. Between Titicaca and Poopó, there is a ridge rising to 1,000 metres above the level of the plateau, which is split from west to east by the Desaguadero River. Along the far western edge is a narrow strip

Table 21.1: Hydrological characteristics of the Lake Titicaca basin

Surface area of the basin	57,293 km^2
Annual precipitation	702 mm/year
Annual discharge	281 m^3/s
Annual potential evapotranspiration	652 mm/year

Map 21.1: Locator map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Map 21.2: Basin map

Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Table 21.2: TDPS system size

Basin	Area (km^2)
Lake Titicaca	56,300
Desaguadero River	29,800
Lake Poopó	24,800
Coipasa Salt Lake	33,000
TDPS System	143,900
Lake Titicaca	
Average area	8,400 km^2
Average altitude	3,810 m.a.s.l.
Average volume	930 km^3
Maximum length	176 km
Maximum width	70 km
Maximum depth	283 m
Desaguadero River	
Length	398 km
Average flow	70 m^3/s
Average gradient	45 cm/km
Lake Poopó	
Average area	3,191 km^2
Average altitude	3,686 m.a.s.l.
Coipasa Salt Lake	
Average area	2,225 km^2
Average altitude	3,657 m.a.s.l.

of desert that runs along the Pacific coast, and to the east are the Amazon plains that extend to the Atlantic Ocean. The system is located in the southern part of Peru and the north-west of Bolivia. The source that feeds the lake, situated to the north, belongs mostly to Peru. Of the five major rivers flowing into the lake, four run through Peruvian territory. The southern part of the system, which belongs to Bolivia, is drier and ends in the Coipasa Salt Lake, which is formed by the evaporation of overflow from Lake Poopó.

Climate

The climate within the TDPS system is that of a high mountain region with a tropical hydrological regime of great interannual irregularity. In the surrounding area, Lake Titicaca exercises a moderating influence on temperatures and rainfall.

Precipitation varies between 200 and 1,400 millimetres (mm), with maximum value of 800 to 1,400 mm at the centre of the lake. The system shows zones of diminishing humidity from north to south, going from humid around Lake Titicaca, to semi-arid in Lake Poopó, to arid in the Coipasa Salt Lake. There are great seasonal variations, as the area usually has wet summers and dry winters, with a rainy period from December through March and a dry period from May through August. The air temperature varies within the system depending on latitude, longitude, altitude and proximity to the lake, with minimums of -10 to -7°C and maximums of 19 to 23°C. Humidity is low throughout the system, with an average of 54 percent and variations depending on latitude and season. The area also receives strong solar radiation with an annual yield of 533 calories per square centimetre (cm^2) per day: this high radiation explains the intense evaporation that occurs in Lake Titicaca.

Land types

There are four types of land in the Lake Titicaca basin, classified as follows.

- Arable land: Due to climatic conditions and the altitude of the high plateau, special agricultural practices are required. Most of the soils have organic matter and nitrogen deficiencies. Only 33.9 percent of the TDPS land area is arable land. It covers 44,692 km^2.
- Non-arable land: Such land requires special practices to maintain permanent plant cover. Non-arable surface covers 28,063 km^2 or 21.3 percent of the total.
- Marginal lands: These are characterized by moderate to strong erosion processes, but with potential use for extensive grazing of llamas and alpacas. The total area is 40,844 km^2 or 31 percent of the whole basin.
- Badlands: Although unsuitable for agriculture or grazing, such areas can be used for wetlands, recreation and mining. Badlands cover 18,178 km^2, representing 13.8 percent of the system.

Major socio-economic characteristics

Population

The pre-Hispanic ethnic groups on both sides of the lake maintain ancestral cultural patterns which are unlike those of Western culture. The annual economic growth rate for the system is very low, with a declining tendency in the rural areas. This is due mainly to extensive poverty, which results in high infant mortality and rural-to-urban migration. A diminishing soil fertility rate can also be observed. Tables 21.3 and 21.4 give an overview of the system's populations.

Poverty is the most critical social problem in the TDPS system, affecting both rural and urban populations. Families have to devote all their energies to meeting basic needs, and locally available resources are too limited to offer much hope of improved living conditions. Extreme poverty and a lack of opportunity compel the rural population, especially young people, to migrate to the cities,

Table 21.3: TDPS population data

	Peru	Bolivia
Population	1,079,849	1,158,937
% of total	48.2	51.8
Average population density (inh/km^2)	17.6	15.56
Maximum density (inh/km^2)	215	245
Minimum density (inh/km^2)	2.0	2.3
Rural population (%)	60.8	47.9
Urban population (%)	39.2	52.1
Growth rate (%)	1.6	from -1.6 to 9.2
Population trends	generally decreasing	rural decreasing
Population in poverty situation (%)	73.5	69.8

Peru and Bolivia show comparable population situations in terms of numbers, density and the high percentage of people living in poverty. There are, however, more rural populations in Peru than in Bolivia.

Table 21.4: Population in main cities

Main cities	Population	% of country population
Puno (Peru)	91,877	4.10
Juliaca (Peru)	142,576	6.37
El Alto (Bolivia)	405,492	18.11
Oruro (Bolivia)	183,422	8.19

where they crowd into degraded districts. In 1993 Bolivia's urban population grew by 4.3 percent while the rural rate was negative at -0.4 percent. In the same year, the Peruvian side of the TDPS registered 3.4 percent annual growth in population, while the rural population grew at only 0.7 percent.

Education

The conditions of structural poverty in the zone are such that the struggle to survive takes precedence over anything else. Education is therefore not a priority. The illiteracy rate is 22 percent and is differentiated by area and gender. It is higher in rural areas than in cities, and within rural areas, it is higher for females. Among the problems affecting the quality of education are dispersion of the rural population and the existence of non-Spanish mother tongues. The Bolivian Educational Reform Programme has been trying to address both situations for eight years.

Health

Health problems in the TDPS system are clearly related to endemic poverty and, by extension, to such attendant problems as poor nutrition, lack of clean water and sanitation, a fragile environment and the absence of leverage to help people improve their lives or livelihoods. In several cases, the problems are compounded by the existence of strong and persisting ancient cultural traditions; child vaccination, for example, has only recently been adopted by local populations because of legal enforcement. The main health indicators in the region include:

- high rates of morbidity and mortality, mainly in children;
- low life expectancy at birth (lower than the national average);
- high incidence of infectious, respiratory and gastrointestinal diseases;
- high incidence of diseases linked to conditions such as water quality (gastrointestinal diseases) and climate (respiratory diseases);
- deficient nutritional levels in general, both in quantity and quality; and
- health services that are generally poor and mostly concentrated in urban areas.

Economic activities

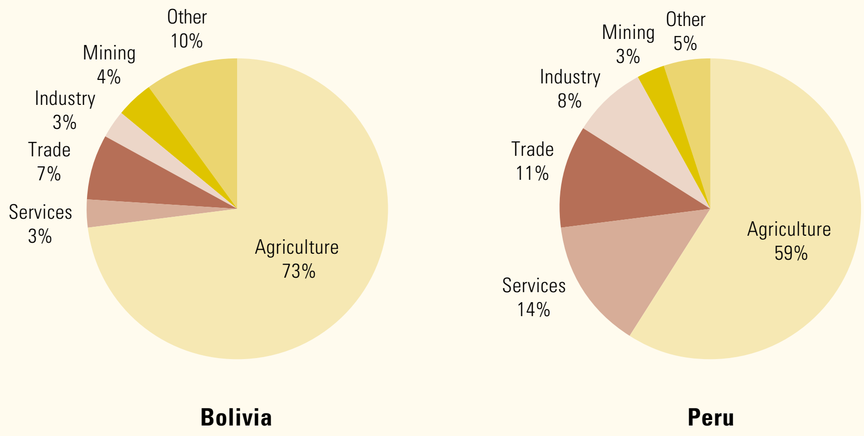
Bolivia, with a human development index of 0.648, and Peru, with 0.743, are both in the middle human development range. The Gross National Product (GNP) is US$116.6 x 10^3 million Purchasing Power Parity (PPP) in Peru and 19.2 x 10^3 million PPP in Bolivia. GNP per capita is US$4,622 and US$2,355 PPP respectively. However, in 1993 it was estimated that GNP per capita in the Bolivian sector of the TDPS amounted to 35 percent of the national value.

Table 21.5: Health data

	Peru	Bolivia
Life expectancy (years)	60.6	58
Available hospital beds/1000 inhabitants	1.1	1.3
Number of physicians in the area	212	1,128
Infant mortality rate/1000 children < 1 year	81	121
Children suffering chronic malnutrition (%)	71	84
Morbidity (children < 1 year)		
respiratory diseases (%)	39.6	27
nutritional deficiencies (%)	18.5	18
diarrhoea and gastrointestinal diseases (%)	18.7	13
other (%)	23.2	24
Morbidity		
respiratory diseases (%)	20	22
nutritional deficiencies (%)	14	15
diarrhoea and gastrointestinal diseases (%)	7.6	6
other (%)	66	57

The health challenges facing the basin are significant in both countries.

Figure 21.1: Distribution of the active working population of Bolivia and Peru



Although Bolivia has a more active agricultural sector than Peru, with a 73 percent working population, both countries are dominated by this activity. Industry is a far less important sector, accounting for only 3 percent of the active working population in Bolivia and 8 percent in Peru.

Agriculture and cattle-raising activities, both focused on food production, are the main economic activities. The staple crops are: quinoa, potato and other tubers, fodder and some leguminous species and vegetables. In general, yields are low because of the limited use of sown seeds, fertilizers and machinery. Drought, floods and frost events are also significant factors (see figures 21.3 and 21.4 further on).

By the middle of the twentieth century, both Bolivia and Peru had independently begun reform processes directed at modifying land ownership. In both countries, land was formerly concentrated among a few owners of large land holdings. But the reform effort resulted in a decrease of agricultural production and an excessive fragmentation of the rural property, particularly in Bolivia. Land holdings on the Peruvian side vary from 0.5 to 20 hectares. Average rural holdings on the Bolivian side of TDPS are small, in extreme cases perhaps no more than a few square metres. In such conditions only small-scale subsistence agriculture is possible. In Bolivia the Political Constitution of the state declares rural property (specifically in the TDPS area) inalienable, meaning that it cannot be sold or used as collateral for a loan, and in fact no market for rural property exists.

Other industries are also present within the system. Agro-industry is underdeveloped and small scale. Forestry is poor although there is potential for increasing production. Trading of farm products is inefficient. Credit is limited and selected, particularly because of the difficulties the native population encounters in trying to understand the banking process. There is a growing trend towards cooperative credit. Although of potential importance, fishery is not dynamic: the fish biomass of Lake Titicaca has been estimated at some 91,000 tons, while extraction fluctuates between 4,000 and 7,000 tons. Figure 21.1 shows the distribution of the active working population in the two countries.

Cultural background

Lake Titicaca is known by the name of Lago Sagrado (Sacred lake) among the Aymaras and constitutes the central element of Inca mythology. The high-plateau population practices its own cultural traditions, which prevail in spite of four centuries of Spanish colonization. The cultural pattern is agrocentric whereby all human activities take agriculture as a central reference point and the value of work becomes the unifying social force as well as the only source of wealth. From this assigned value there are related values pertaining to reciprocity, redistribution and communal democracy.

These patterns and the ways of customary law co-exist with Western patterns and in many cases result in underdevelopment and social exclusion. Because cultural tradition plays such an important role in the lives of local people, it is necessary to understand and take account of the prevailing value system before attempting to introduce changes. Among the many elements to consider, the most important are the following.

- Indigenous wealth: Indigenous peoples in the Titicaca area seek to minimize risk rather than maximize production.
- Property: There exists a complex system in which communal property is superimposed over individual holdings and territory.
- Water resources: The traditional property pattern that exists among the upstream communities sets certain conditions for determining how the resource is shared.

Water Resources

Hydrology

Surface water

As described earlier, four main hydrographic basins form the TDPS system: Lake Titicaca is the main element. Its principal tributaries are located in Peruvian territory: Ramis and Huancané to the north, Coata and Illpa to the west, and Ilave and Zapatilla to the south-west. In Bolivia, the most important affluents are: Huayco, Suchez and Keka to the north and east, and Catari and Tiwuanacu to the south. The Ramis River is the most important as it represents 26 percent of the tributary basin. Its flow is about 76 cubic metres per second (m^3/s). Annual flow in ten stations of the system is shown in table 21.6.

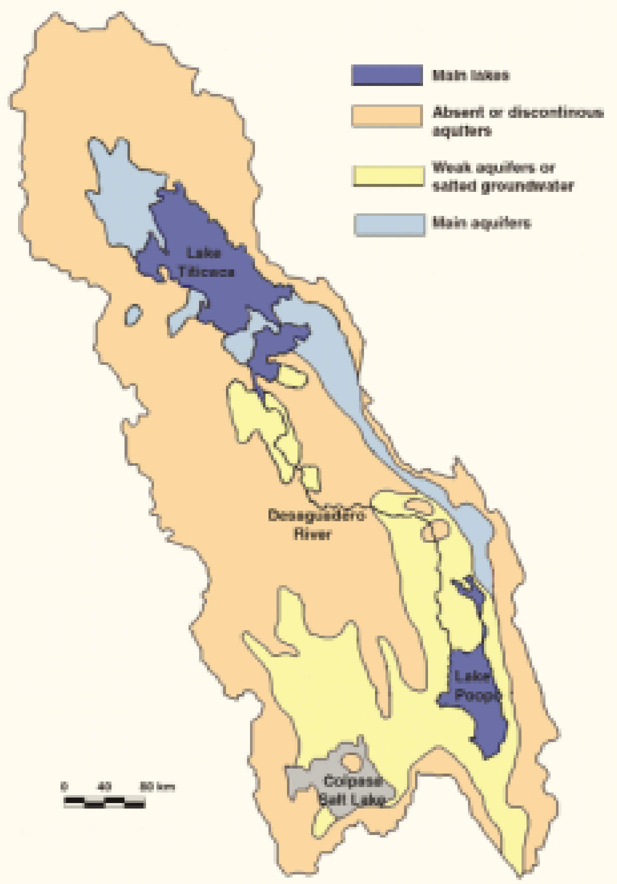
Overflow from Lake Titicaca, observed at the source of the Desaguadero River, amounts to 35 m^3/s. This flow represents only 19 percent of the inflow of the five main tributaries, demonstrating the great volume lost through evaporation.

Between 1914 and 1992, historic levels of variation took place during different cycles: a major cycle lasted twenty-seven to twenty-nine years while an intermediate one lasted twelve to sixteen years. Lake-level oscillation in this period had an amplitude of 6.37 metres compared to the average annual oscillation of about 1 metre.

Groundwater

As can be seen in map 21.3, the main aquifers are located in the middle and lower basins of the Ramis and Coata Rivers, in the lower basin of Ilave River and in a strip that extends from Lake Titicaca to

Map 21.3: Distribution of groundwater in the TDPS system



The main aquifers are located in the middle and lower basins of the Ramis and Coata Rivers, in the lower basin of Ilave River and in a strip that extends from Lake Titicaca to Oruro, bordering the eastern ridge.

Table 21.6: Annual flow in ten control stations of Lake Titicaca and Desaguadero River

River	Station	Average (m^3/s)	Maximum (m^3/s)	Minimum (m^3/s)
Ramis	Ramis	75.6	130.4	24.4
Huancané	Huancané	20.0	38.8	6.9
Suchez	Escoma	10.6	18.9	4.0
Coata	Maravilla	41.5	75.5	2.4
Ilave	Ilave	38.5	96.6	5.0
Desaguadero	International	35.5	186.5	–3.5
Desaguadero	Calacoto	51.9	231.6	6.2
Mauri	Abaroa	4.9	9.8	2.3
Caquena	Abaroa	2.8	5.6	0.9
Mauri	Calacoto	18.6	31.8	5.7
Desaguadero	Ulloma	77.1	282.7	19.7
Desaguadero	Chuquiña	89.0	319.3	20.0

The main tributary of the Lake Titicaca basin is the Desaguadero River, with an average annual discharge of 89 m^3/s and a maximum of 319 m^3/s.

Oruro, bordering the eastern ridge. The approximate total volume of groundwater that goes into the system is 4 m^3/s. Most of this groundwater comes from tube wells used to supply water to cities. Such is the case of El Alto, Oruro and several other small towns.

Water table morphology shows that groundwater flows follow the direction of water reservoirs, the location of recharge areas and their base levels. The water tables of Huancané, Ramis, Coata and Parco River basins on the Peruvian side, and Tiwanacu and Catari River basins on the Bolivian side, drain into Lake Titicaca with average hydraulic gradients of 1 to 0.1 percent.

The optimum yield of aquifers and capacity in the Peruvian sector range from 1 to greater than 100 litres per second, and from 0.3 to 5 litres per second respectively. In the Bolivian sector, optimum yield ranges from 2 to 75 litres per second and specific capacity from 0.3 to 4 litres per second.

Water quality

There are higher levels of salinity found in the south of the TDPS system, a result of greater rainfall in the northern part of the system that reduces the concentrations of dissolved salt. On the other hand, evaporation, which is greater in the southern part of the system, increases the concentration levels of dissolved salt. Thus, there is a progressive increase of electric conductivity from north to south. Likewise, it is not uncommon to find tertiary and quaternary formations, which are mainly present on the TDPS system, with parental material formed by rocks containing gypsum and salt.

In general, Lake Titicaca and its tributaries have normal values of water salinity (less than 1,000 milligrams [mg] per litre). Desaguadero River has values between 1 and 2 mg/litre, but downstream values are greater than 2 mg/litre. Lake Poopó has salinity values above 2,000 mg/litre due to natural conditions and mining activity in the surrounding area. Maximum salinity values were found in Coipasa Salt Lake where evaporation is high and rainfall is only 200 mm per year.

Mining activity is the principal cause of heavy metal contamination, and is mostly found in the southern part of the TDPS system. High concentrations of arsenic are found at La Joya, in the western arm of the Desaguadero River. Lake Poopó as well as Coipasa Salt Lake present high levels of lead, cadmium, nickel, cobalt, manganese and chromium.

High values of faecal-coliform (1,000 parts per million [ppm]) and organic matter throughout the Puno Bay are a good indicator that pathogens are present in the water. Those high values are mainly the result of wastewater from the Puno City sewer system. This contamination has generated a process of eutrophication and the growth of aquatic lentils in the bay.

Both water and fish from Lake Titicaca reveal high parasite levels, probably due to inappropriate disposal of wastewater in the cities of Puno and Juliaca in Peru, and Copacabana in Bolivia, as well as animal-raising and agricultural activities in areas surrounding the lake. The parasites infect humans as well, hence the high incidence of gastrointestinal diseases.

Extreme events

Most extreme events in the TDPS system are related to flood risk conditions around Lake Titicaca, drought in the central and southern parts of the system and the incidence of hail and frost throughout (see maps 21.4 and 21.5).

Human impacts on water resources

Surface cover

Until approximately the year 1000, the high plateau was covered with a native tree forest (*Polylepis sp*). Around the year 1100, a severe eighty-year drought changed the surface cover and the forest disappeared. After 1500, inappropriate agricultural practices and imported livestock permanently modified the conditions of the surface cover. Over the last century, human activities have not had a significant impact on the surface cover of the system in large part because of the arid environment and lack of vegetation.

Dams and diversions

The 6.37 metre variation between maximum and minimum registered lake levels produced historical flood events in the lake and surrounding areas. The Master Plan of the TDPS system (see further on for details) has required regulation works to be built that maintain the lake level at the minimum of 3,808 m.a.s.l. with a maximum of 3,811 m.a.s.l. during a normal hydrological cycle.

Pollutants

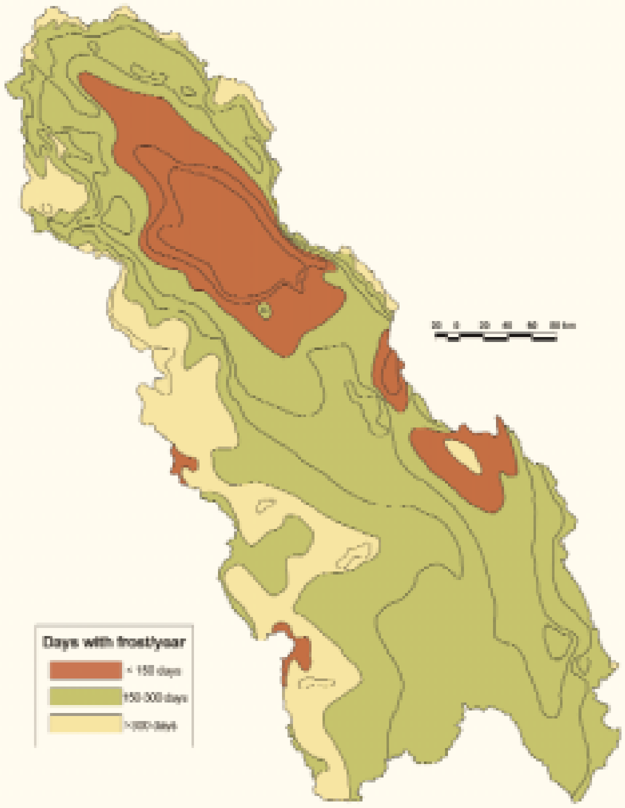
Organic and bacteriological contamination is caused by human activity, in particular urban wastes and mining. Poor waste disposal is the central cause of organic contamination in all the important urban centres in the basin. The most polluted areas affected by sewage discharge are Puno's interior bay (undergoing a moderate eutrophic process), the lower course of the Coata River, because of the discharge from the city of Juliaca, and Lake Uru Uru, due to discharge from the city of Oruro.

Heavy metal contamination is the result of mining activities in the zone. Although there is not enough available information on this subject, mercury and arsenic concentrations of 0.4 ppm have been found in mackerel captured in Puno Bay.

Non-native species

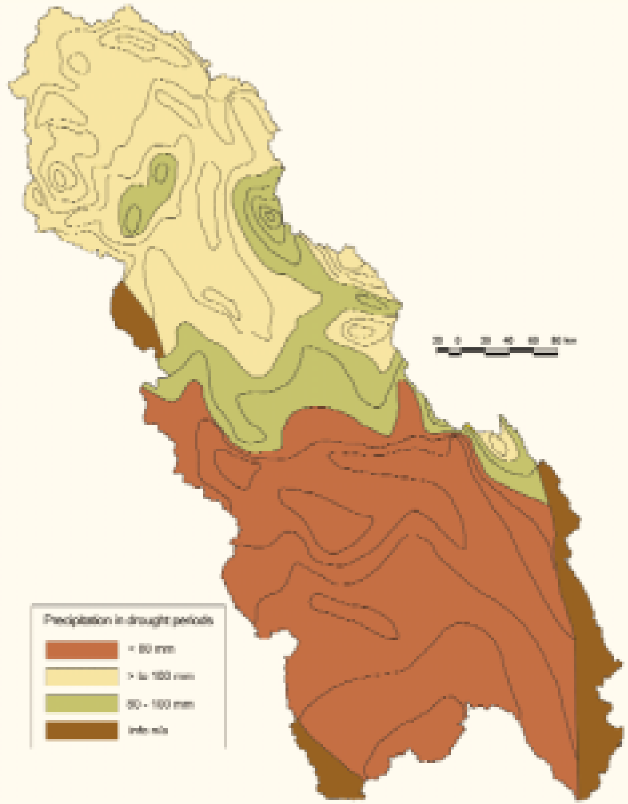
Non-native fish species with high economic value such as trout and mackerel were introduced into Lake Titicaca around 1930. Since then some native species such as karachi (*Orestia sp*) and boga (*Trichomicterus sp*) have decreased, and their populations are considered vulnerable and endangered.

Map 21.4: Incidence of extreme events – frost



Frost occurs less frequently in the centre of the lake system, where it occurs less than 150 days per year. Most of the system suffers from frost 150 to 300 days per year, while the outer rims of the basin can have frost on more than 300 days.

Map 21.5: Incidence of extreme events – precipitation during periods of drought



The northern part of the lake system receives more precipitation (more than 100 mm) during drought periods than the southern part (less than 80 mm).

Overharvesting

Land areas suitable for crops and pasture are comparatively lower than the occupied land, with the percentage of areas exploited above their capacity reaching 35.2 percent. This overexploitation is one of the serious environmental problems affecting the high plateau, especially considering the area's very low productivity and the rudimentary technology used to exploit it.

Data and information on water resources

Since the creation of the Binational Autonomous Authority of Lake Titicaca (ALT) in 1993, several efforts have been made to consolidate the available information on water resources in the TDPS system. Most of the information was scattered among different institutions in Bolivia and Peru. Early in the 1990s, international consulting firms prepared a Master Plan that compiled most of the available information about the TDPS system.

The creation of ALT and the elaboration of the Master Plan allowed data and information from different sources to be systematized and it is now possible for Bolivia and Peru to share this information through ALT. However, it is still necessary to improve data collection and dissemination and to standardize the information generated by different institutions.

Table 21.7: Water use in the TDPS system

Use and sector	Surface water (litres/second)	Groundwater (litres/second)	Total use (litres/second)	Net consumption (litres/second)
Domestic	**1,210**	**912**	**2,122**	**424**
Bolivia	361	761	1,122	224
El Alto	51	382	433	86
Oruro	34	379	413	82
Other urban	133		133	27
Rural	143		143	29
Peru	849	151	1,000	200
Puno	25	151	176	35
Juliaca	300		300	60
Other urban	334		334	67
Rural	190		190	38
Irrigation	**7,294**	**85**	**7,379**	**5,534**
Bolivia	4,494		4,494	3,370
Peru	2,800	85	2,885	2,164
Other	1,000		1,000	200
Bolivia	590		590	118
Peru	410		410	82
Total	**9,504**	**997**	**10,501**	**6,158**
Bolivia	5,445	761	6,206	3,712
Peru	4,059	236	4,295	2,446

Irrigation is by far the greatest water user in the TDPS system: it accounts for 75 percent of total withdrawals.

Challenges to Life and Well-Being

Water needs, uses and demands in the TDPS system are mainly directed at covering basic needs and irrigated agricultural production. However, it should be noted that increased water alone cannot improve the local living conditions, which are limited by extreme poverty. Table 21.7 illustrates present water use in the TDPS system.

Water for basic needs

Drinking water and sewage systems are largely deficient throughout the TDPS area. On the Peruvian side, drinking water coverage is between 12 and 30 percent with an average of 19 percent. Sewage system coverage is between 13 and 39 percent with an average of 20 percent. Conditions on the Bolivian side are similar. There is an average drinking water and sewage system coverage of 24 percent and 13 percent respectively.

Bolivian and Peruvian consumption is about 30 and 50 litres per person per day, respectively. However, only 20 percent is taken as a loss to the system because about 80 percent returns to the system as sewage.

Water for food

About 48 percent of the TDPS system area is being used for agriculture; 4.4 percent for crop production, 21.7 percent for grazing, 14.9 percent for grazing-forestry and 7 percent for other uses.

Most of the crop production area is located in the areas surrounding Lake Titicaca. However, only 17 percent of the total area is truly suitable for crop production. Therefore, soil erosion and degradation are a major concern. Excessive property fragmentation is another common problem throughout the system. This fragmentation causes low crop productivity because farmers are not able to use technology to increase their crop yield.

Forestry takes up only 3 percent of the basin. Native brushes cover 2.3 percent of this area and 0.7 percent is formed by modified forest comprising native trees called Kiwiña (*Polylepis sp*).

Irrigated land represents about 19,444 hectares, of which 10,960 lie on the Bolivian side and 8,484 lie in Peru. Taking into consideration the combined needs of water for irrigation projects, crops and potential irrigation areas, the water available for irrigation purposes has been estimated at 7,379 litres per second, mainly taken from surface resources.

In contrast with water for basic needs, water for irrigation represents a significant loss for the system. Most of the water used for irrigation goes to the atmosphere through evaporation and transpiration processes, and only 25 percent returns to the system.

Water for ecosystems

The TDPS has a broad variety of flora and fauna. Biodiversity in the basin area is in a precarious position due to the overexploitation of some species. Both the Bolivian and Peruvian governments have responded by establishing protected areas to help preserve these living resources.

Aquatic flora

Green algae and diatoms are the main components of Lake Titicaca plankton, but there are also cyanobacteria with the capacity to fix nitrogen, as well as large populations of chlorophyll and clorococales. Algae populations are found down to depths of 80 and 100 metres, while nitrogen from agricultural runoff seems to be the main constraint on algal development.

Macroscopic plants – macrophytes – are represented in the system by about fifteen species and are located in shallow zones. Some macrophytes such as Totora and Llachu are important elements for animal feed, especially for cattle. They also help absorb heavy metals such as arsenic, zinc and lead. In the same way, Totora is of central importance for many human activities such as building boats and thatching roofs.

A new algae called Carophiceas (Charas) has been observed in deeper sectors and is important for biomass in the lake systems, as it appears to have a good resistance to high levels of salinity.

Aquatic fauna

Zooplankton, benthic fauna, fish and frogs make up the principal aquatic organisms living in the TDPS system. Among the main groups that form the zooplankton, copepods are broadly dominant over the clodoceros population, and their reproduction occurs throughout the year. Globally, more than 95 percent of the benthic population in Lake Titicaca is found within the first 15 metres of the Minor Lake and in the first 25 metres of the Major Lake.

The TDPS system is rich in fish species, distributed in different hydrological units of the system. Lakes Titicaca and Poopó have the major concentration of commercial fish species.

The frog population is grouped into four genera, among them the *Telmatobius* genus, which includes one of the biggest aquatic species in the world.

Terrestrial plants and animals

Plants and animals living in the TDPS system have adapted to the ecological conditions of the region. The system can be divided into two main regions: Puna (lower than 4,400 m.a.s.l.) and the Altoandina (higher than 4,400 m.a.s.l.). There are different species of bushes and trees in each, including grasslands and native trees. In addition, Lake Titicaca itself was declared a Ramsar site in 1998. It is the only Ramsar site in the TDPS System (see box 6.5 in chapter 6 for further details).

Water and cities

Access to sanitation is low, at only 17.2 percent throughout the basin. One city, El Alto, has a drinking water system administered by a private company (Aguas del Illimani). The others cities are managed by the municipalities. Average coverage in major cities reaches about 60 percent. Average tariffs for drinking water consumption vary from US$0.13 per litre in Puno and Juliaca to US$0.22 per litre in El Alto. The smaller urban centres have small drinking water systems that are managed by the community.

El Alto is the only city that has a wastewater treatment system. The other main cities in the TDPS (Oruro, Puno and Juliaca) do not have appropriate systems and their sewage disposals are a cause of water contamination.

Water and industry

Water demand for mining and industrial activities is not a major problem inside the TDPS system because there are few industries and their water consumption is very low. Water use for mining has not been measured, but is considered insignificant. Conversely, mining is an important source of water contamination.

Industrial pollution of waterways results from inappropriate discharge of wastewater and drainage from mines and mineral processing systems. Water from mines is very acidic and highly contaminated with heavy metals, particularly in Oruro where materials have appreciable amounts of pyrite that produces sulphuric acid when it comes in contact with water. This acid leaches metals such as arsenic, cadmium, cobalt and nickel, producing contaminated water that eventually flows into the basin.

Water and energy

Energy production is not a major activity in the TDPS system. Although there is a lack of information with regards to energy, it has been observed that energy consumption in the area is low and the principal source of energy is biomass (about 70 percent). Only 21 percent of homes on the Peruvian side and 29.8 percent in Bolivia, mainly in urban areas, have electricity. This electricity is generated outside the system and water is not used for hydraulic energy production. There is a small-scale use of liquefied petroleum gas, limited to urban areas due to the difficulties inherent in its transportation.

Other uses

Although recreation and transportation are not considered activities that can affect the water balance or water quality, they are significant activities when viewed as potential new alternatives for developing the TDPS area.

Transportation is of fundamental importance in Lake Titicaca. The lake includes twelve islands where the local population rely on boats and ships for travel. Likewise, Copacabana City, located in the

Manco Kapac Province, is one of Bolivia's most important tourist sites, and getting there necessitates crossing the lake through the Tiquina Strait. Recreation activities are being extended in response to increased demand from international as well as national tourism.

Management Challenges: Stewardship and Governance

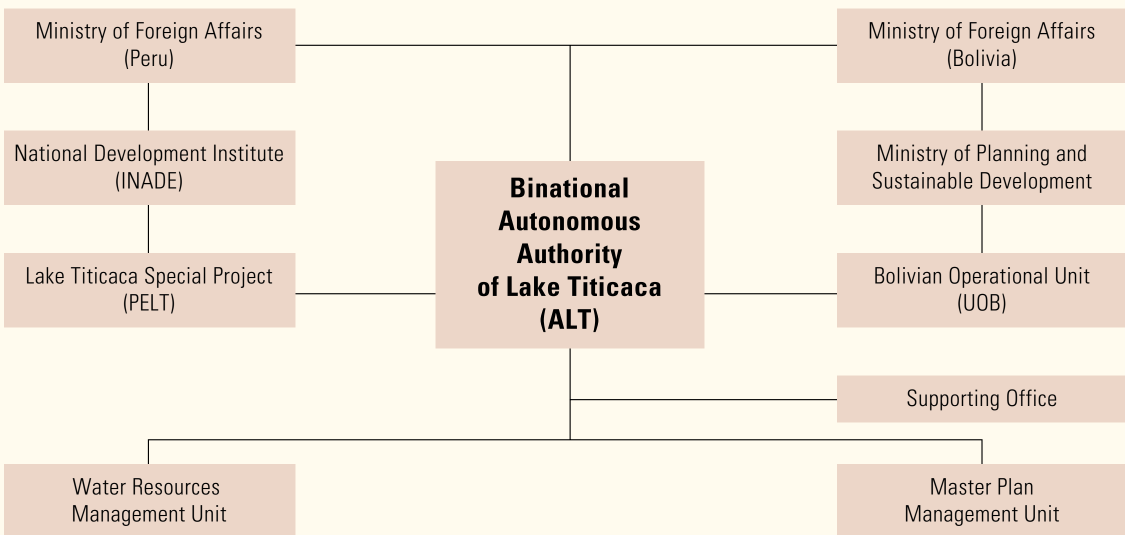
The surface of Lake Titicaca is evenly distributed between Bolivia and Peru, countries that exercise an 'exclusive and indivisible joint ownership' over its waters. In fact the joint ownership model not only applies to the water of Lake Titicaca, but also to the watershed, as a way of ensuring integrated management of the water system.

Institutions

Three institutions operate in the TDPS system area with clearly defined roles.

- The Ministry of Sustainable Development and Planning, in Bolivia. By law, this ministry is the supreme national water authority in the country, in charge of designing, planning and enforcing policy, strategies and development initiatives.
- The Peruvian Development Institute (Peru). This institute has the equivalent functions of the Bolivian Ministry of Sustainable Development.
- The Binational Autonomous Authority of Lake Titicaca (ALT). This entity of public international law was created in May 1996. It has two national operative units and its general function is to promote and conduct programmes and projects, and to decide, implement and enforce the regulations on management, control and protection of the system's water resources within the framework of the adopted Master Plan. ALT's political functioning is associated with the Peruvian and Bolivian Ministries of Foreign Affairs. ALT has units for administration, planning and coordination within each government. Two national projects were established for Bolivia and Peru and both technically depend on ALT. The Bolivian project is the Unidad Operativa Boliviana (Bolivian Operative Unit, UOB), located in La Paz, and the Peruvian project is called the Proyecto Especial del Lago Titicaca (Lake Titicaca Special Project, PELT), located in Puno. The units are responsible for coordinating actions with national governments and for centralizing information. The Hydrological Resources Unit and Master Plan Management Unit are in charge of monitoring the water resources and tracking development of the Master Plan, respectively. Figure 21.2 illustrates the structure of the ALT.

Figure 21.2: ALT structure



Legislation

Current legislation is incomplete and outdated, both in Bolivia and in Peru. The main legal bodies are:

- 1906 Water Law (Bolivia);
- Bolivian Civil Code;
- Decree No. 03464 on Land Reform and the 1953 Water Regime (Bolivia);
- 1969 General Water Law (Peru);
- 1990 Sanitation Code (Peru);
- 1990 Environment and Natural Resources Code (Peru);
- 1992 Environment Law (Bolivia);
- 1999 Basic Sanitation and Drinking Water Law (Bolivia).

Finances

Investment in the TDPS system comes from the Bolivian and Peruvian governments, international agencies and non-governmental organizations (NGOs). ALT is an autonomous organization with an annual budget of US$250,000 based on equal contributions by the Bolivian and Peruvian governments. In addition, ALT acts to facilitate external donations. In this framework the ALT has developed and is carrying out a number of projects, notably the regulatory works of Lake Titicaca (US$7,000,000), the dredging of the Desaguadero River bed (US$800,000) with ten-year projections (US$25,000,000), a biodiversity conservation project (US$920,000) and other projects oriented to research and validation of Inca and pre-Inca agricultural technologies.

Management approaches

Risk management

TDPS system regulation works allow, under normal hydrological conditions, the maintenance of Lake Titicaca's waters within an average level of 3,809.5 m.a.s.l. with a variation of 1.5 metres. This regulation scheme, based on technical and statistical data, has diminished the flood risk.

Valuing water

The value assigned to water varies according to the rural or urban nature of the water supply systems and the number of served inhabitants. Tariffs for the most populated cities fluctuate between US$0.135/$m^3$ (Puno and Juliaca) in Peru and US$0.22/$m^3$ (El Alto and Oruro) in Bolivia. Single tariffs and the concept of non-quantified water are applied in water supply systems for small towns.

The economic value of water is not fully recognized, particularly in rural areas. There is no water use rate and use of water for irrigation is defined by customary practice.

Sharing the resource

The two main uses of water in the system, human consumption and irrigation, are not in conflict at the present time. There is, however, a potential conflict between upstream and downstream users, notably with respect to water for irrigation. The model provided by customary use and the way in which communities have traditionally related to each other play an important role in determining distribution patterns and claims. Upstream communities consider that they have priority over downstream communities through a complex system of retributions and favours.

Governing water wisely

Water management between Bolivia and Peru has been established in terms of the joint ownership of the Lake Titicaca and the entire catchment area. In this way, the ALT has become the proper administrative entity for resolving any such conflicts that may arise.

ALT administration is based on Integrated Water Resources Management (IWRM). The general model promotes coordinated management and development of water, land and related resources, although certain border conditions do not yet permit a complete implementation of the model. Nevertheless, two aspects are coming along slowly: valuing water as an economic good and an improved level of community participation in water management issues.

The Master Plan, developed with the cooperation of the European Community, was drawn up between 1991 and 1993 under the title *Master Plan for Flood Prevention and the Usage of Water Resources of the TDPS System*. This plan constitutes the basic reference and twenty-year framework for the future development of the system. To date, the general scheme proposed by the Master Plan has been implemented.

Ensuring the knowledge base

Implementation of the Master Plan implies the development of a broad knowledge base. In addition to the hydrological knowledge needed for management of the resource, projects for restoration and rescue of ancestral agricultural techniques have been carried out and show a high degree of productivity.

Policy implementation

The following elements are identified as implicit in the Master Plan:

- focusing actions in a framework of sustainable use of natural resources, with these resources as the central element;
- recovering the system's ecological integrity in terms of protecting endangered species, replenishing fish populations and mitigating human impact on the system; and
- promoting human development within the basins.

Lake management shows a good degree of adjustment to the first two points. However, promotion of human development within the system has had a low level of success due to the difficulty of overcoming basic poverty in the area.

Identifying Critical Problems

Challenges related to uncertainty and variability of the resource

Agriculture is the principal economic activity in the TDPS system. As such, and given the general poverty in the area, it is particularly vulnerable to such extreme events as drought and flood. The farmers' survival strategy is thus to diversify their crops in the hope of minimizing risks derived from resource variability.

Although water regulation works in Lake Titicaca have brought a degree of protection against floods, they are effective only during a relatively normal hydrological cycle. Floods have a significant impact on the economy of the area. Although there is no risk of human losses, due to the slow rise of flood waters, the economic damage over a ten-year period has been estimated at US$890,000 for agriculture, animal raising and infrastructure. In addition, flood losses over a twenty-five-year period are estimated at US$1,506,000. These are huge amounts given the region's extreme poverty.

Vulnerability to drought is high and in addition to the economic losses associated with an extremely dry year, drought also causes loss of genetic diversity in native varieties, and thus farmers are forced to buy imported seeds for the following years. There is no available information about losses due to drought events.

Hail and frost cause significant agricultural losses. In the case of frost, Lake Titicaca acts as thermal insulation. Away from the lake, however, and at higher latitudes, frost increases can cover over 300 days a year.

Water salinity increases to the south. It severely limits the soil's agricultural capacity. At the extreme south of the system, the highly saline soils have formed the Coipasa Salt Lake.

Challenges associated with needs, uses and demands

As previously mentioned, sewage discharge from the urban centres in the basin has resulted in organic contamination of the area. The tropical situation of Lake Titicaca, the high levels of solar radiation and the high rate of evaporation make the system very vulnerable, particularly to pollution problems. In contrast, the size of the water body helps to maintain pollution at acceptable levels, although there are some eutrophication problems close to the coastal villages. In addition, there are also problems relating to heavy metal contamination, resulting from mining activities in the zone.

Management-related problems

Although the ALT provides a regulatory framework to both countries, each nation has specific approaches to water management, with no provision for the disparities between them. This lack discourages private investment in the sector, while encouraging poor valuation of the water resource. The nature of the resource as an economic, social or mixed asset has not as yet been defined at the regional or national levels. Because of this, it becomes impossible to allocate installation, maintenance or treatment costs for water systems of any kind. In May 2002, the Interinstitutional Water Council (CONIAG) was created in Bolivia with the mission of reforming the legal, institutional and technical framework of the water sector.

There is, however, work ahead to attain a better integration of community organizations into the management model with the aim of ensuring that the ALT will have higher levels of representation. At present, due to the social and economic instability in both countries, there is no appropriate political climate in which to reach community consensus.

Problems affecting ecosystems

Mining activity, overharvesting and pollution from urban centres all put pressure on the natural resources of the TDPS system.

During the 1980s a regional economic depression diminished mining activity in the area and the level of poverty increased. It was exacerbated by drought and floods, and resulted in increased rural to urban migration. The subsequent depopulation of rural areas, together with a stagnating mining sector have all greatly relieved the pressures on natural resources. However, pollution in urban centres has visibly increased. It is difficult to predict the future with regard to environmental stress and ecosystem health, as so much depends on the general levels of poverty in both countries.

Other problems

Differences between indigenous and Western cultural patterns make it difficult to adopt new agricultural technology, improve production and establish efficient market systems. Associated with these difficulties is the prevailing land ownership model. At present, rural property is fragmented into numerous small plots that are then divided through inheritance into still smaller plots. This model prevents farmers from making the transition to a more efficient and agricultural production and, combined with current land legislation, makes the existence of a real estate market virtually impossible, all of which adds to the structural poverty.

Achievements

Water resources assessment in the TDPS system

In the mid-1950s many initiatives were taken at different levels to make use of the waters of Lake Titicaca, one example being the proposal for bringing irrigation water to the arid zone of Chile. These initiatives involved the extraction of given flows from the lake, but without any evaluation study of the real hydrological potential. Out of concern for possible negative impacts, the Bolivian and Peruvian governments took the first steps to establish the foundation of a binational management system, signing an agreement to study the issue.

Binational Master Plan

The subsequent result of this investigation was the formulation of a Binational Master Plan to provide the guidelines and framework for the future development of the system. One of the conclusions of this study estimates that as little as 20 m^3/s of water could be extracted from the basin for economically productive uses, a much lower volume than proposed in the original. In this way, a possible ecological disaster similar to that of the Aral Sea in the former Soviet Union was averted, and the groundwork was laid for a harmonious and technically effective binational model of administration.

Within the framework of the Master Plan, the following documents were developed:

- a development strategy for irrigation and drainage;
- a strategy for hydraulic regulation of the system;
- an environmental survey and analysis; and
- a conservation plan.

Hydraulic regulation works

Taking into account the fragility of the system with regard to flood protection and prevention, a series of flow regulation works have been defined at basin level and in the system in general, for an amount of US$38 million. In 2001 the first dam was finished, close to the international bridge over the Desaguadero River. The main objective of the dam is to prevent, or at least protect, the surrounding area from floods, according to a rational and planned handling of the lake level when it rises above 3,810 m.a.s.l. Other benefits of this dam include protection of the vast fish populations and aquatic vegetation, provision of 50,000 hectares of secure irrigation to Peru and 15,000 hectares yearly to Bolivia up to a maximum potential of 35,000 hectares, and flood protection for 6,000 to 10,000 hectares on both sides of the lake.

The ALT model

One of the most successful aspects of ALT is its very smooth operation. As indicated earlier, the process of creating the Binational Authority has gone through four stages: conducting an evaluation of resources, designing a legal framework, building a management model and implementing a master plan. These stages represent a scale model that can be replicated nationally as a guide in the process of regulating hydrological resources.

Conclusions

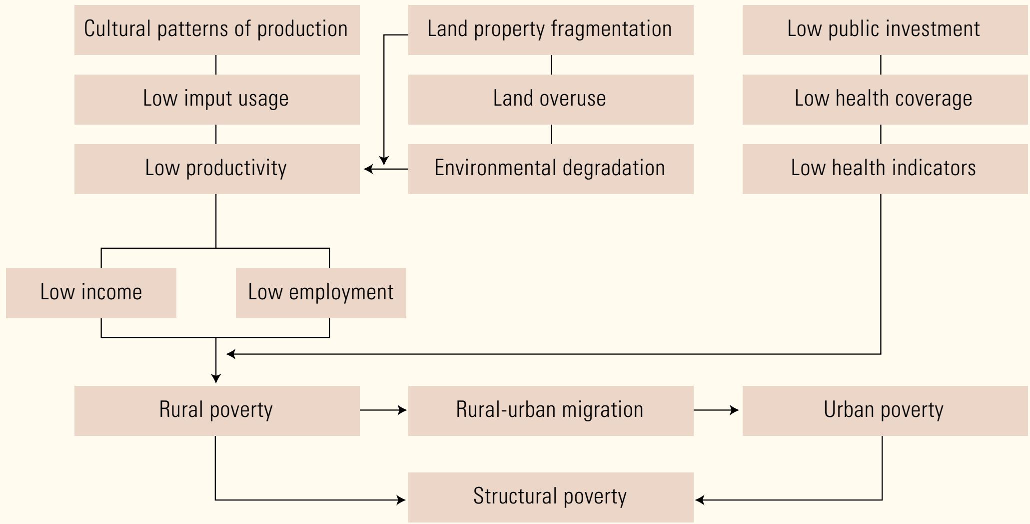
Problems in the TDPS system are mainly of a structural nature. Local poverty undermines every effort to prioritize solutions to problems, thus causing a negative feedback loop. Figure 21.3 represents the cause-effect relationships of the main problems.

There is an urgent need to intensify the fight against poverty and to drastically improve the health system in the region. Great benefits could be achieved through the provision of better services for waste disposal and treatment, the promotion of environmental education and the continuation of the water regulation works already in progress. Most importantly, however, there needs to be far greater investment in public health services in order to ensure a better quality of life for the population.

Other possible means of development include increasing the irrigated surface area of the basin. Much of the agriculture is currently not irrigated. This is due in part to the land fragmentation caused by traditional property rights. The result is a decrease in productivity, which helps to perpetuate the region's poverty. Developing the irrigation potential would require a more detailed evaluation of water reserves and development of the country's extensive natural gas reserves for cheap energy to power the scheme. One possible way to implement more efficient agricultural technologies is through the establishment of legislation that would promote associations of producers managing land surfaces of a more adequate size.

Although there is a legislative body in place and many efforts have been made to develop the area, more can be done to ensure the birth of a more equitable way of life for the inhabitants of the Lake Titicaca basin.

Figure 21.3: Chain of causality



This figure shows the various causes of structural poverty in the TDPS system. Among these causes are fragmented land holdings and inefficient health services, both of which contribute to low unemployment and high poverty in the area.

Source: Prepared for the World Water Assessment Programme (WWAP) by A. Crespo Milliet, 2002.

Box 21.1: Development of indicators

Challenge areas	Lake Titicaca indicators
SURFACE WATER	• Water use (U) = 416.3 m^3 10^6/year • U/A = 0.60 • Rainfall varies between 200 mm and 1,400 mm (normal year)
WATER QUALITY	• Coliforms load 46 unt/100 ml • Puno water system abduction • 1,000 unt/100 ml (Puno Bay) • Turbidity = 1.27 parts per million
GROUNDWATER	• Net recharge = 4 m^3/s; 0.89% of total (see groundwater map for more details)
PROMOTING HEALTH	• Child mortality 14% • 77,663 households with sanitation = 17.2%: Peru = 19%; Bolivia = 24% • Health investment: Peru = 278 Purchasing Power Parity (PPP)/year; Bolivia = 150 PPA/year
PROTECTING ECOSYSTEMS	• Six protected areas 922 km^2 = 0.62% • One Ramsar site: Lake Titicaca 8,400 km^2 = 5.6% of total area
WATER AND CITIES	• 60% of population in major urban centres • 750 tons/day solid waste; 140,000 m^3 wastewater • Only one major city (El Alto) where water system is administrated by a private company
SECURING THE FOOD SUPPLY	• Irrigated land = 19,444 hectares = 0.43% of total productive land
WATER AND INDUSTRY	• No water recycling in the system
WATER AND ENERGY	• Electricity is not generated in the lake area • No water recycling in the system
MANAGING RISK	• Flood area = 90,000 hectares controlled, out of 120,000 hectares in Puno and 10,000 hectares in Desaguadero
SHARING WATER	• Agriculture = 90%; Drinking water = 7%; Other = 3%
VALUING WATER	• Varies between US$0.135 per m^2 (Puno and Juliaca) in Peru and US$ 0.220 per m^3 in Bolivia (El Alto and Oruro) • No demand-responsive water development policies • No demand-responsive water development institutions
ENSURING KNOWLEDGE	• Effective hydrometeorological data collection system exists in both Peru and Bolivia • Data can be collected by requesting institutions • Between Bolivia and Peru there is one main authority (ALT) and eight water scientists
GOVERNING WISELY	• Decentralization process in course; roles are 60% defined • The basin authority has the central and very autonomous responsibility to plan and manage the lake

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22

Greater Tokyo, Japan

Coordinated by: The National Institute for Land and Infrastructure Management – Ministry of Land, Infrastructure and Transport of Japan (NILIM-MLIT)

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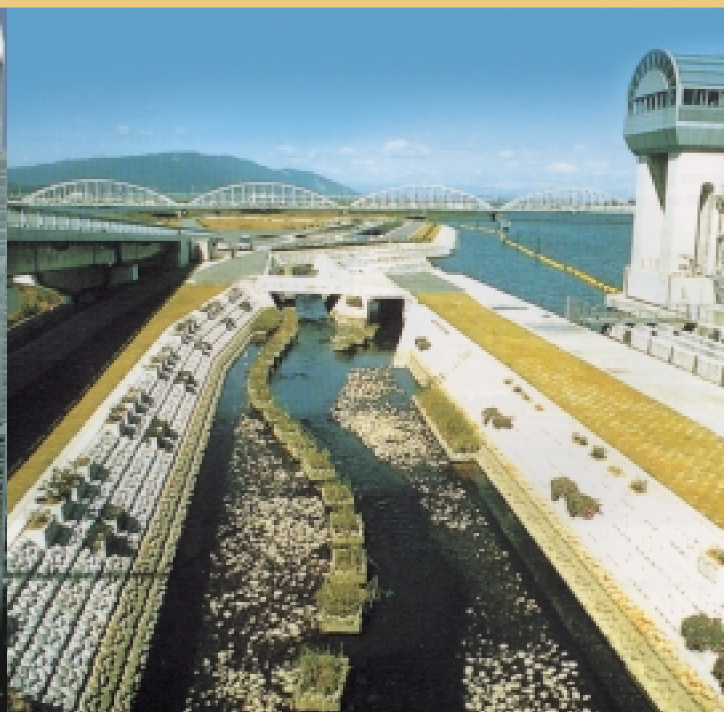
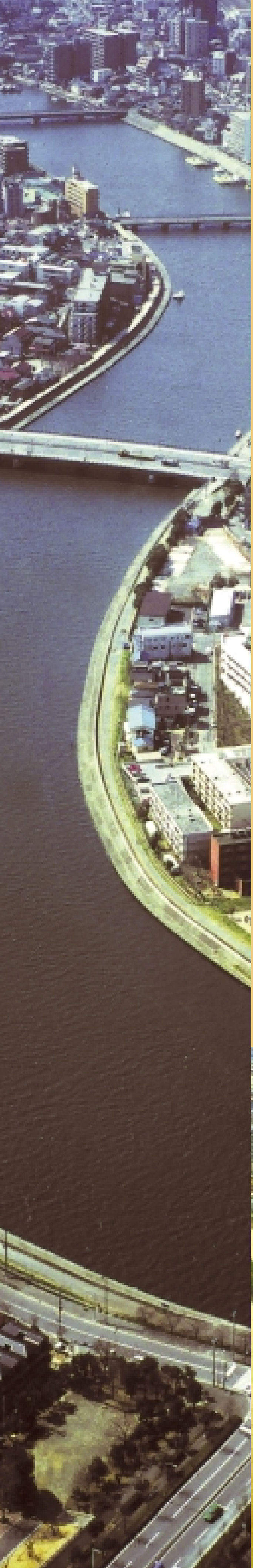
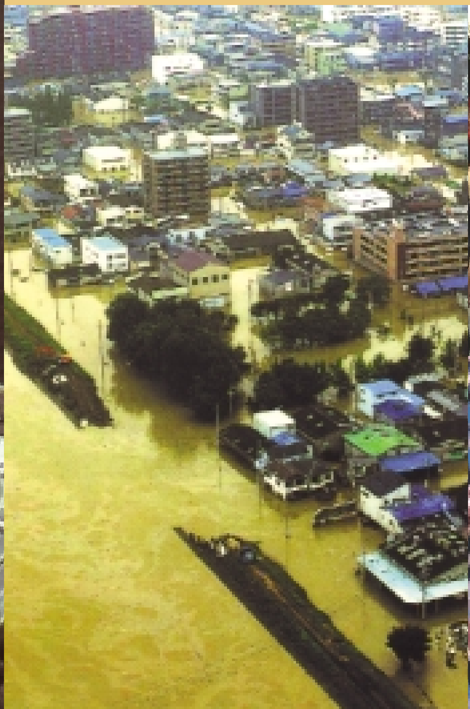




Ah, what a pleasure
to cross a stream in summer
– sandals in hand.

Buson (1716-1783)

THIS CASE STUDY PRESENTS the example of river basins that serve one of the world's most populous areas, a region of 27 million people. In addition to its extremely high density, Tokyo metropolitan is subject to seasonal floods and other hazards such as droughts and earthquakes. However, because it is a rich and industrialized country, Japan has the means – and the skills – to manage these risks using infrastructure such as dams, levees and underground floodways. There is also great emphasis placed on public awareness and disaster preparedness. The authorities have developed early warning systems that rely on the Internet, Geographic Information Systems (GIS) and hazard mapping, and there are shelters where people can take refuge. Such continuous efforts have ensured that one of the world's largest economic developments has been able to safeguard its population in the high-risks region. Other concerns include a degraded natural environment and pollution of groundwater, and many efforts, such as river restoration works, are being implemented with wide public participation.



THE GREATER TOKYO REGION (hereafter Greater Tokyo), with its densely populated megacities, includes five river basins covering an area of about 22,600 square kilometres (km^2), with a total population of 27 million and property value assets totalling about US$2.9 trillion. Due to human and industrial activities, various water-related problems have developed, and the need is increasing for better water quality, diversification, protection and improvement of the environment.

Map 22.1: Locator map

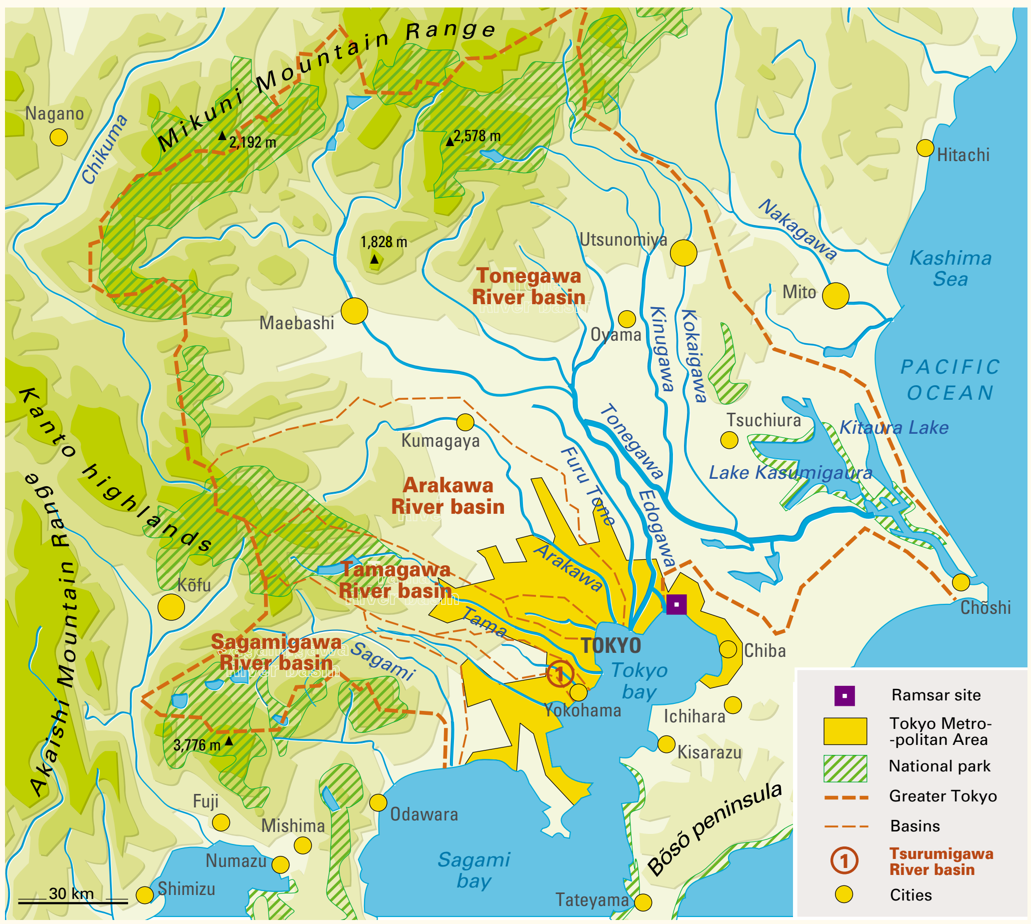
Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

General Context

The enormous water resources needed to supply the cities and maintain the safety degree against drought are difficult to manage. In addition, groundwater withdrawal is still causing land subsidence.

About 13.25 million people and 170 trillion yen (approximately US$1.36 trillion) worth of assets in property value are concentrated in 4,800 km^2 of the region's alluvial plains, often the site of substantial flood damage, accentuated by the fact that Greater Tokyo suffers the severe weather conditions of the Asia monsoon period. Changes in land use and increase in rainfall have also enhanced the danger of flood in recent years.

Map 22.2: Basin map



Source: Prepared for the World Water Assessment Programme (WWAP) by AFDEC, 2002.

Table 22.1: Hydrological characteristics of the five river basins in Greater Tokyo

	Tonegawa (1)	Arakawa (2)	Tamagawa (3)	Sagamigawa (4)	Tsurumigawa (5)
Location	Central Honshu, Japan N 35° 32′–37° 5′ E 138° 24′–140° 51′	Central Honshu, Japan N 35° 39′–36° 10′ E 138° 43′–139° 52′	Central Honshu, Japan N 35° 32′–37° 51′ E 138° 494′–139° 46′	Central Honshu, Japan N 35° 32′–37° 5′ E 138° 24′	Central Honshu, Japan N 35° 28′–35° 35′ E 139° 24′–139
Area	16,840 km^2	2941.5 km^2	1,241 km^2	1,668 km^2	239 km
Origin	Mt. Ohminakami	Mt. Kobushi-gatake (2,475 m)	Mt. Kasatori	Mt. Fuji	Tanaka Yato (valley) (Machida, Tokyo)
Outlet	Pacific Ocean	Tokyo bay, Pacific Ocean	Tokyo bay, Pacific Ocean	Sagami bay, Pacific Ocean	Tokyo bay, Pacific Ocean
Length of main stream	322 km	169 km	138 km	108 km	42.5 km
Highest point	1,834 m (trunk of Tonegawa)	Mt. Kobushi-gatake (2,475 m)	1,953 m (trunk of Tamagawa)	3,776 m (trunk of Sagamigawa)	164 m (trunk of Tsurumigawa)
Lowest point	River mouth (0 m)	River mouth (0 m)	River mouth (0 m)	River mouth (0 m)	River mouth (0 m)
Main geological features	Mountain area: sandstone, slate, limestone from the Paleozoic and Mesozoic eras, and volcanic rocks. Plain area: Pleistocene and alluvium.	(Upper basin) Paleozoic, Tertiary; (Lower basin) Quaternary (alluvialand diluvial)	Upper reaches: the Chichibu Paleozoic and Mesozoic strata. The hilly and flat area: the loamy layer of the Kanto District. The low-lying parts: sediments from the delta and coastal sedimentation.	Mountain area: lava bed, conglomerate and volcanic ash. Plain area: igneous rock, mudstone. The low-lying parts: sediments (consisting of lithified clay, sand, silt and conglomerate).	The hilly and flat area: the loamy layer of the Kanto District. The low-lying parts: sediments from the delta and coastal sedimentation.
Main tributaries	Katashinagawa (676.1 km^2) Agatsumagawa (1,355.2 km^2), Kanna-gawa (417.6 km^2), Kaburagawa (632.4 km^2), Karasugawa (759.1 km^2), Watarasegawa (2,621.4 km^2), Kokaigawa (1,043.1 km^2), Kinugawa (1,760.6 km^2)	Akabiragawa (250.0 km^2), Irumagawa (737.3 km^2), Shingashigawa (392.3 km^2), Sumidagawa (243.9 km^2)	Asakawa (154 km^2), Hirasegawa (13 km^2), Nogawa (68 km^2), Hiraigawa (38 km^2), Akigawa (170 km^2)	Doshigawa (152 km^2), Nakatsugawa (140 km^2), Sasagogawa (93 km^2), Kuzunogawa (115 km^2), Mekujirigawa (34 km^2)	Yagamigawa (28 km^2), Hayabuchigawa (20 km^2), Toriyamagawa (11 km^2), Ondagawa (31 km^2)
Main lakes	Kasumigaura, Kitaura, Chuzenji, Imba, Tegan, Ushiku	None	None	Kawaguchi, Yamanaka	None
Main reservoirs	Yagisawa (115.5x10^6 m^3, 1967), Naramata (85.0x10^6 m^3, 1991), Hujiwara (31.0x10^6 m^3, 1958), Aimata (20.0x10^6 m^3, 1959), Sonohara (13.2x10^6 m^3, 1966), Shimokubo (120.0x10^6 m^3, 1969), Ikari (32.0x10^6 m^3, 1956), Kawamata (73.1x10^6 m^3, 1965), Kawaji (76.0x10^6 m^3, 1983)	Futase (26.9x10^6 m^3, 1984), Arima (7.6x10^6 m^3, 1984)	Ogouchi (water supply and power only 185.4x10^6 m^3, 1957)	Sagami (no flood control dam 48.2x10^{6}m^3, 1947), Shiroyama (54.7x10^6 m^3, 1964), Miyagase (183x10^6 m^3, 2000)	Tsurumigawa multi-purpose retarding basin (39x10^6 m^3, 2002)
Mean annual precipitation	1,162.6 mm at Maebashi, 1,580.1 mm at Choshi (1971–2000)	1,367 mm (1951–1980), at Chichibu	1,385 mm at Ogouchi (1985–2001)	1,658 mm at Saito bridge (1985–2001)	1,616.5 mm at Tsurukawa, 1,628.5 mm at Tsunashima (1990–2000)

Table 22.1: *continued*

	Tonegawa (1)	Arakawa (2)	Tamagawa (3)	Sagamigawa (4)	Tsurumigawa (5)
Mean annual runoff	165.2 m^3/sec at Yattajima, 220.6 m^3/sec at Kurihashi (1960–2000)	26.4 m^3/s at Yorii (927km^2) (1952–1985)	30.2 m^3/sec at Ishikawa (1991–2000)	50.0 m^3/sec at Sagamiohashi (1991–2000)	8.69 m^3/sec at Kamenoko bridge (1990–1999), 83.4 m^3/sec at Sueyoshi bridge (1983)
Population	About 12,000,000	9,046,643 (1985)	About 3,571,000 (1995)	About 1,284,000	About 1,840,000
Land use	Forest (45.5%), paddy field (18.2%), cropland (11/2%), orchard (3.3%), urban (3.7%), residential area (6.4%), water surface (5.1%), other (6.6%)	Forest (48.2%), paddy field (5.1%), agriculture (6.5%), water surface (4.0%), urban (26.5%) (1985)	Forest (59.6%), paddy field (0.7%), cropland (1.8%), orchard (0.1%), urban (31.3%), other (incl. water surface) (6.5%) (1997)	Forest (78.2%), paddy field (2.5%), cropland, etc. (2.7%), urban (9.0%), other (incl. water surface) (7.6%) (1997)	Paddy field and cropland (10%), forest (5%), urban (85%)
Main cities	Maebashi, Takasaki, Saitama, Tsukuba, Utsunomiya	Tokyo, Omiya, Urawa, Kawagoe, Chichibu	Kawasaki, Chofu, Tachikawa, Tokyo (Ota-ku, Setagayaku)	Hiratsuka, Chigasaki, Zama, Atsugi, Sagamihara	Yokohama, Kawasaki, Machida

Sources: (1) UNESCO-IHP; (2) UNESCO-IHP; (3) Kanto Regional Development Bureau, MLIT; (4) Kanto Regional Development Bureau, MLIT; (5) Kanto Regional Development Bureau, MLIT.

Furthermore, due to intense urbanization, the quality of water in Greater Tokyo has deteriorated. Action was taken to reduce the discharge load, such as drainage regulation and sewage maintenance, and the quality of water started to improve in major rivers. However, the concentration level is still high in some tributaries, lakes and marshes, and new Environmental Endocrine Disruptors have been problematic. In addition, the increase of imported non-native species of fish and plants is becoming a serious ecological problem.

Water Resources

Hydrology

The average precipitation in Greater Tokyo has been 1,551 millimetres (mm) per year for the past thirty years. During periods of drought, the average is 1,213 mm/year, which is 20 percent less than in normal years. Over the last one hundred years, overall precipitation has been decreasing. However, recently, there have been more and more rainfalls of over 100 mm/day (Water Resources Department, MLIT, 2002). Water resources in seven prefectures, including Greater Tokyo, average 374 billion cubic metres (bm^3) per year. During droughts, which occur once every ten years, the average is 247 bm^3, which is 30 percent less than normal (Water Resources Department, MLIT, 2002).

As for the water quality in Greater Tokyo, following are some biological oxygen demand (BOD) measurements taken in 1998: more than 8 milligrams (mg) per litre in Tsurumigawa River, about 4 mg/litre in Arakawa River, less than 2 mg/litre in Tamagawa River and Sagamigawa River. The BOD levels in the Tsurumigawa and Arakawa Rivers tend to increase while those in the other rivers remain stable. In the last ten years, the worst levels were found in Tsurumigawa and Arakawa Rivers. In 1999, the chemical oxygen demand (COD) concentration level was about 7.5 mg/litre (MLIT, 2001a). Generally, the water quality in rivers and lakes has improved; however, the presence of Environmental Endocrine Disruptors, chemical substances thought to affect the endocrine system, was recently discovered in some rivers. It is not yet known if these disrupters have an influence on health or the ecosystem (Ministry of the Environment, 2002). Figure 22.1 shows the variation in BOD levels over a number of years.

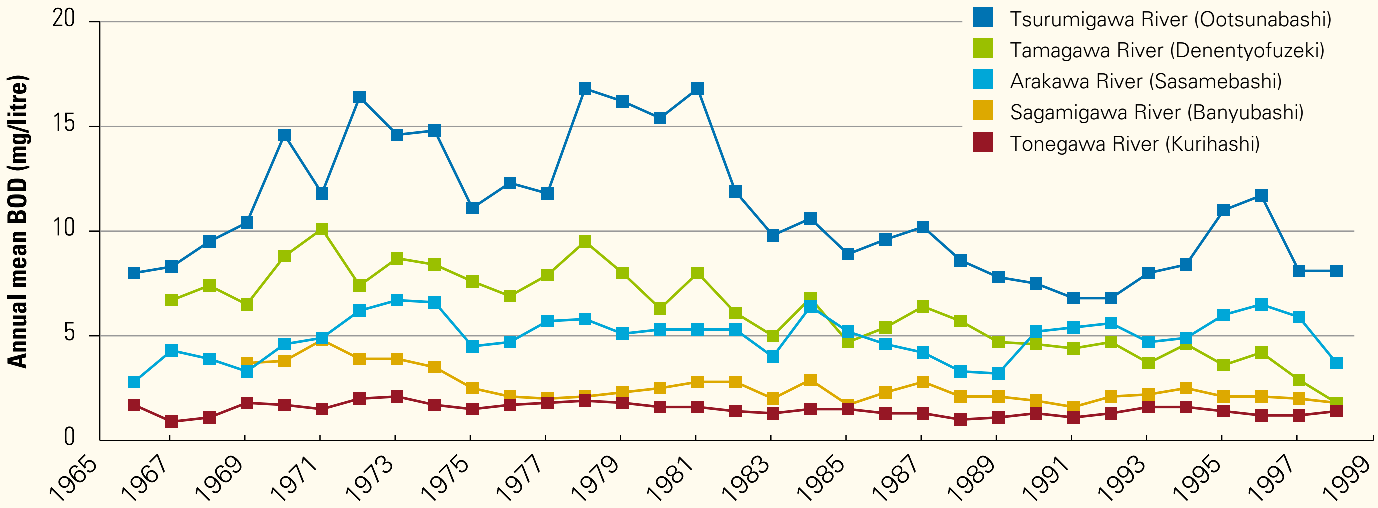
Human impacts on water resources

In seven prefectures, including Greater Tokyo, the proportion of lands used for building has increased from 13 percent in 1974 to 20.2 percent in 2000, while that of agricultural lands has diminished, going from 46.3 percent to 39.1 percent. In order to preserve the proportion of lands used for forests and woods, which has been kept stable (although only private forests have so far been counted), only agricultural lands are used for building.[1]

In April 2001, Greater Tokyo counted 183 dams with a total water storage capacity of about 2.5 bm^3. The dams are built for flood control, water supply and electricity generation purposes (Japan Dam Foundation, 2002).

1. *Kotei-shisan no Kakaku-tou no Gaiyou Chousa* (Outline of Protocols, such as Price of Fixed Assets). Taken from the web site of the Ministry of Home Affairs at http://www.soumu.go.jp/czaisei/shiryo.html.

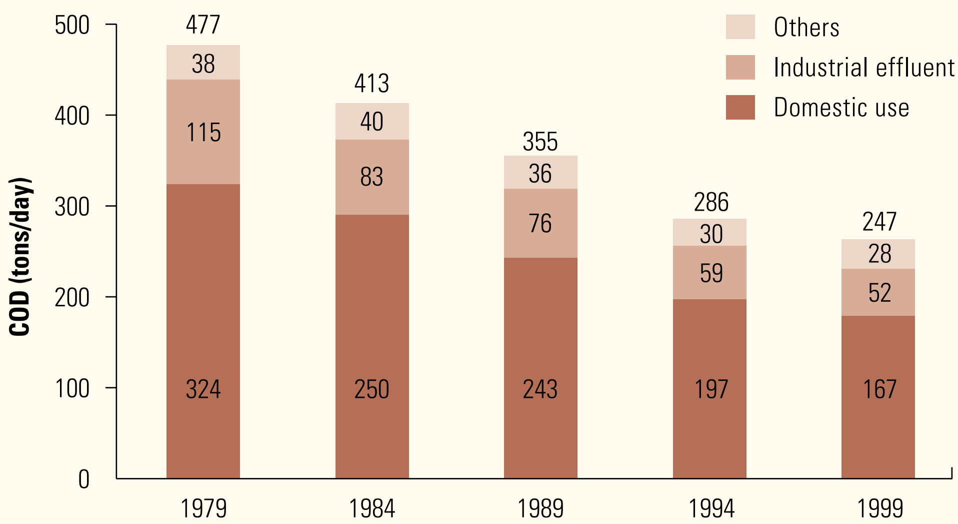
Figure 22.1: Variation in river water quality – biological oxygen demand (BOD) levels



The BOD levels have decreased since the 1970s in all five rivers of Greater Tokyo. However, the level remains high in the Tsurumigawa and Arakawa Rivers.

Source: River Bureau, MLIT, 2001a.

Figure 22.2: Variation in the chemical oxygen demand (COD) discharge load by sector in Tokyo bay



The majority of discharge load in Greater Tokyo is from domestic use, accounting for close to 70 percent of the total amount. The discharge load has drastically decreased, to about half of what it was twenty years ago.

Source: Ministry of the Environment, 2001.

Most of the effluent load of four prefectures (Tokyo, Chiba, Saitama and Kanagawa) is emptied into Tokyo bay, where the COD level in 1999 reached 247 tons per day. Seventy percent of this load is from domestic use (see figure 22.2). Due to drainage regulations, the discharge load has drastically decreased, to about half of what it was twenty years ago (Ministry of the Environment, 2002).

Groundwater resources are widely used in the region. One tenth of the water used to supply Tokyo metropolis is from groundwater resources. Analyses of the water quality in 1998 show results lower than the standard values, except for tetrachloroethylene (a product known to carry severe health risks), which exceeded environmental standards in three out of eighty-seven measurement points (Environmental Bureau of the Tokyo Metropolitan Government, 2000).

A survey in 1999 of non-native species in Japan's rivers yielded the following results: fish represented 6.1 percent, benthos 2.2 percent, plants 11.0 percent, birds 2.4 percent, amphibians 5.3 percent, reptiles 7.7 percent, mammals 18.4 percent and insects 0.7 percent (Foundation for Riverfront Improvement and Restoration, 1999). Black bass and blue gill, which are non-native fish, were found in 40 percent and 30 percent of dams, respectively (Water Resources Environment Technology Center, 2001).

Challenges to Life and Well-Being

To meet the needs and demands of the large human and industrial activities, vast water resources and policy implementation are necessary. The following is a summary of water uses in the region. The water volumes given below represent the total seven prefectures, not the five river basins.

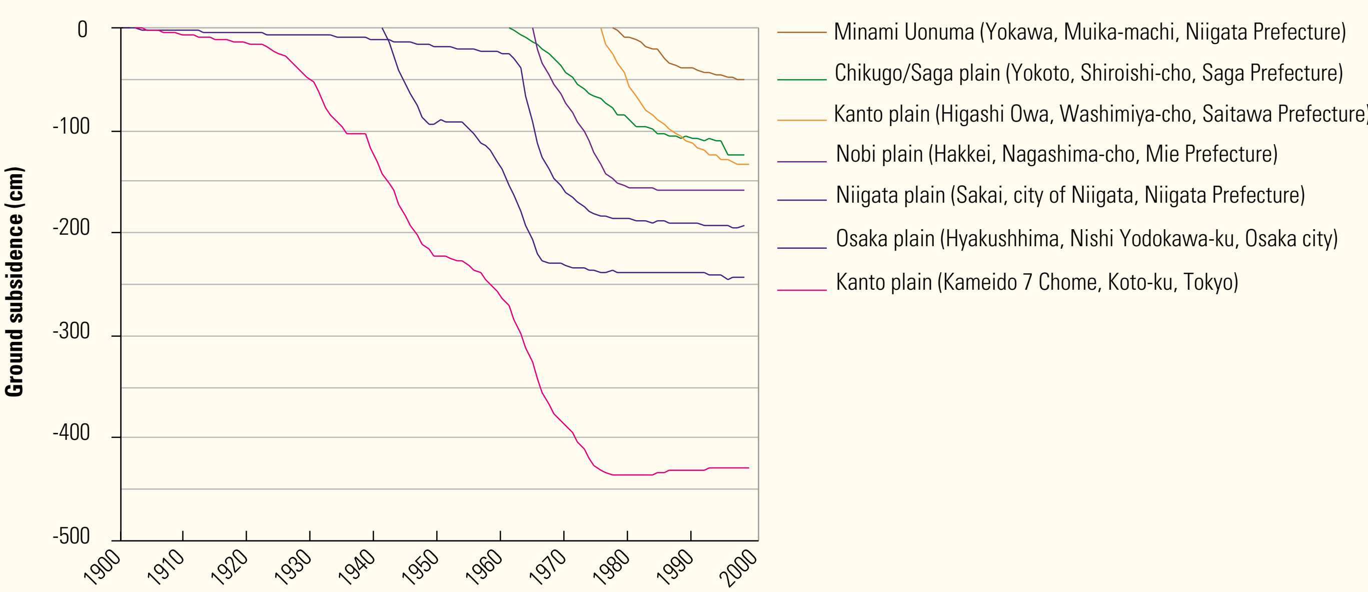
Water use in industry and cities

In 1998, the total volume of water used in Greater Tokyo was 163.5 bm^3. Thirty-four percent of this water is used for households, 14 percent for industrial activities and 52 percent for agricultural activities. The volume of water used in agriculture in Tokyo region is relatively low compared to the 66 percent used country-wide. The volume of water for households has slightly increased in recent years, while that of water used for agriculture has not changed. As for the volume of water used in industry, there is only a very slight increase, the result of massive water recycling (Water Resources Department, MLIT, 2001).

In Greater Tokyo, 44 percent of total water resources are used during normal years, and 66 percent during drought years. This percentage is twice that of the whole country (Water Resources Department, MLIT, 2001).

Groundwater resources make up 22.8 percent of total water use inland, and 13.1 percent in seaside areas. Some 45 percent of households and industries, considerably more than agricultures, rely on groundwater. So as to prevent land subsidence, groundwater withdrawals have been regulated. Limits on withdrawals of groundwater come in the form of two laws: the Industrial Water Law, which targets groundwater used for industrial purposes, and the Law Concerning the Regulation of Pumping-up of Groundwater for Use in Buildings, which targets groundwater used for cooling and other building-related purposes. Groundwater withdrawal in the northern part of the Kanto plain has decreased from 13.1 bm^3 in 1985 to 9.6 bm^3 in 1999 (Water Resources Department, MLIT, 2001). As a result, the rate of land subsidence has stabilized (see figure 22.3).

Figure 22.3: Rate of ground subsidence in cm/year



There has been a dramatic increase in ground subsidence in the Greater Tokyo region in the past century. Since the 1980s, this subsidence has stabilized. The Kanto plain has suffered particularly significant ground subsidence, and is now over 4 metres lower than it was in 1900.

Source: Water Resources Department, MLIT, 2001.

Securing the food supply

In 1998, agricultural water use in Greater Tokyo represented about 85.7 bm^3, of which 52 percent was spent on food production. Consumption of rice has decreased, while livestock products and consumption of oils and fats have increased. After 1998, though it had been steadily declining, the food production rate in Japan became stable. In addition, Japan's cereal production has been rising: this is mainly due to an increase in domestic wheat production and feed crops combined with a decreasing demand for livestock (Ministry of the Environment, 2002 and Ministry of Agriculture, Forestry and Fisheries).[2]

Protecting ecosystems

According to a 1998 survey, people's expectations for natural environment and beautiful landscapes are higher than what they were in 1990. About one hundred years ago, wetlands represented about 0.3 percent of the area of seven prefectures, including Greater Tokyo. In 1999, they represented only 0.11 percent, which is a drop of about 60 percent (Geographical Survey Institute, MLIT).[3]

Management Challenges: Stewardship and Governance

The population and property in Greater Tokyo are concentrated in alluvial plains, mostly below flood level, making flood damage potentially serious. Many years of flood control efforts have reduced the total inundated area and made the alluvial plains available for residential, industrial and agricultural use. Since the 1960s, increased land use has required enormous development of water resources especially for households and industry. There was a significant increase in river water use for generating hydroelectric power and for industrial and household water supply. To meet the new demands, a systematic framework for flood control and water use was established. In 1964, the institutional framework was improved by introducing an integrated river management system. A long-term plan for the development of water resources all over the country was also established. However, the increase in population and assets led to environmental problems such as the aggravation of the river water quality and changes in the ecosystem, making environmental conservation an important issue. In addition, with changes in economic and social conditions, the water management system was expected to not only fulfil flood control and water resource purposes, but also provide for recreational use and habitat diversity. As people's concerns about water and the environment grow, public involvement and consensus-building with proper information have become indispensable. In light of these changes, the River Law, on which the river administration is based in Japan, was revised. The revision established a comprehensive river administration system for flood control, water use and environmental conservation.

Water governance

There are several agencies in charge of governing water resources in Japan. Table 22.2 lays out the various water organizations.

Some examples of water management include some of the following elements.

- Water supply: in principle, municipal governments are responsible for water supply, but private sectors can participate upon authorizations from local municipal governments. Since April 2002, outside organizations, including the private sector, have been qualified to conduct technical works on the maintenance of water supply systems.
- Water for agriculture: 'Land Improvement Districts' are responsible for agricultural water use under the Land Improvement Act. The Land Improvement Districts are farmers' associations, and in principle each farmer pays maintenance fees.
- River administration: under the River Law, official river administrators own all rivers for comprehensive river management. The national government (Ministry of Land, Infrastructure and Transport) manages major parts of the 109 river systems. Local governments manage the rest. The river administrators are responsible for flood control, proper use of rivers and conservation of the fluvial environment.

Water rights

The water of Japan's rivers has historically been dominated by a large number of river users with vested water rights, conferring the right to use water, both public and private. With the development of human society and disputes arising over water rights, the need arose for a legal system to regulate water use. The Japanese water rights system was then altered, and the River Law, established in 1896 and which prescribes river management, was revised in 1964. Until then, it had focused only on flood control, and the revision provided a systematic framework for both flood control and general water use. Under this law, an official river administrator manages a basin under a unified and consistent system, and with it water becomes a public resource. In order to better cope with the expanded River Law, it has been necessary to seek conciliation with the prior vested interests: the 1964 revision attempts to modify the system while at the same time taking into account and maintaining

2. See web site at http://www.maff.go.jp/.
3. See web site at http://www1.gsi.go.jp/ch2www/marsh/part/list_4.html.

Table 22.2: Water governance in Japan

Affair	Organization	Sub-section	Main laws
Water supply	Ministry of Health, Labour and Welfare	Water Supply Division, Health Service Bureau	Waterworks Law Law on Execution of Preservation Project of Water for Water Supply
Water use for agriculture	Ministry of Agriculture, Forestry and Fisheries	Rural Development Bureau	Land Improvement Act
Water conservation forest		Forestry Agency	Forest Law
Industrial water supply	Ministry of Economy, Trade and Industry	Industrial Facilities Division, Economic and Industrial Policy Bureau	Industrial Water Law Industrial Water Supply Business Law
Hydropower		Agency of Natural Resources and Energy	Electric Power Development Promotion Law
Sewerage	Ministry of Land, Infrastructure and Transport	Sewerage and Wastewater Management Department, City and Regional Development Bureau	Sewerage Law
Rivers, water resource facilities		River Bureau	River Law Specified Multipurpose Dams Law
Comprehensive and basic policies for water supply and demand, reservoir area		Water Resources Department, Land and Water Bureau	Water Resources Development Promotion Law Water Resources Development Public Corporation Law Law Concerning Special Measures for Reservoir Areas
Water quality, environmental conservation	Ministry of the Environment	Water Environment Department, Environmental Management Bureau	The Basic Environment Law Water Pollution Control Law

the permission systems of the past (Water Use Coordination Sub-Division, Water Administration Division, River Bureau, MLIT, 1995).

Developing water resources

Water resource policies should be carefully promoted from a long-term and comprehensive viewpoint. The new 'National Comprehensive Water Resources Plan' ('Water Plan 21') clarifying the basic direction for the development, conservation and utilization of water resources was settled on in June 1999. This plan provides guidelines for examining various measures concerning water resources for the target years of 2010 through 2015, forecasting water supply and demand for that period. It cites measures against disasters such as the 1995 Hyogoken-Nambu earthquake, as well as the development of policies for conservation of and improvement in the water environment, and for the restoration and nurturing of water-related culture (National Land Agency, 1999). Under the national plan, basic plans for water resources development are established in major river basins, their aim being to reach a water volume of about 258 cubic metres per second (m^3/s) in the Tonegawa and Arakawa Rivers. In 2001, 64 percent of this target had been achieved (Water Resources Department, MLIT, 2001), but more is still needed to meet prospective water demand.

Dams are one of the major tools for water resource development: meeting the demand through river and groundwater intake alone became impossible. As previously mentioned, dams are built for several purposes including household water supply, industrial and agricultural water use, electricity generation and flood control. In April 2001, after improving the water resources development facilities, the total water storage capacity reached about 2.5 bm^3 (Japan Dam Foundation, 2002).

Compensation measures for upstream inhabitants

Before proceeding with the construction of water resource development facilities such as dams, it is important to reach an arrangement with inhabitants in reservoir areas that may suffer significant effects as a result of dam construction. Various measures were designed to mitigate negative effects suffered in reservoir areas and invigorate local communities, and a Law Concerning Special Measures for Reservoir Areas has been created for this purpose (Water Resources Department, MLIT, 2001).

Drought measures

Drought conciliation councils have been established in the Tonegawa, Arakawa, Tamagawa and Sagamigawa Rivers. The conciliation takes place among the water users themselves, while the river administrator offers necessary information at the initial stage of the process, presents drought conciliation proposals and facilitates the process. For example, the drought conciliation in Tonegawa River is characterized by integrated reservoir operation. The efficient operation of several dams as one and the same water system requires consistent management of all dams (River Bureau, MOC, 1997). The Tonegawa Drought Conciliation Council was established in 1970, and comprises the Ministry of Land, Infrastructure and Transport (MLIT), six prefectures and the Water Resource Development Public Corporation (Kanto Regional Development Bureau, MLIT).[4]

Using water effectively

Effective use of water resources does not generally require new large-scale facilities to relieve demand-supply gaps, and is also important in attenuating the effects of drought. One of the examples established in Greater Tokyo is the use of water such as treated sewage, recycled industrial wastewater, rainwater and other types of non-standard water resources. These are lower in quality, but provide for such purposes as toilet-flushing, refrigeration and cooling, and sprinkling (Water Resources Department, MLIT, 2001). Actions such as the construction of water-saving residences are promoted (MOC, 2000).

River improvement measures

Levee maintenance

Between 1991 and 2000, losses resulting from flood damage in Greater Tokyo amounted to about 900 billion yen (US$7.22 billion). The years 1991 and 1998 registered the highest losses, with more than 200 billion yen and a little under 200 billion yen, respectively (equivalent to US$1.6 billion). So far, levee maintenance and dam construction have been adopted as river improvement countermeasures. The levee improvement ratio went from 34.8 percent in 1985 to 45.9 percent in 1999 and, due to such improvements, flood adjustment capacity also increased, from 325 million m^3 (Mm^3) in 1985 to 685 Mm^3 in 2001 (Japan Dam Foundation, 2002; River Bureau, MLIT, 2001b; Japan River Association, 1986-2000).

Non-structural measures

Although the embankment works improved the degree of flood control safety, large flood damage was still a threat, as most of the population and assets are concentrated in the basins. Other measures were therefore necessary to reduce potential flood damage. Non-structural measures include flood warnings, announcement of flood protection measures and the preparation of inhabitant refuges (Arakawa Lower River Work Office, MLIT).[5] Moreover, flood hazard maps are made public to help inhabitants rapidly and efficiently find refuge. The hazard map shows each city's danger zone and the location of the refuge area, specifying access routes (MOC, 2000). With the changes in the rainfall pattern increasing flood risk, the Flood Protection Law was revised in June 2001. Measures such as flood forecasting and the securing of accessible refuges in danger zones were legally supported (MLIT, 2001b).

Managing the environment

With the urbanization of Greater Tokyo, environmental problems arose, such as deterioration of the river water quality, changes in the ecosystem and variations in the landscape. Investigations into water quality and the ecosystem were carried out so as to monitor the actual condition of the river environment.

Monitoring the ecosystem

Local governments (prefectures and designated cities under the Water Pollution Control Law) carry out regular quality surveys of public waters. The waters covered by this survey include those to which Environmental Quality Standards (EQS) are applied. EQS for water pollutants are target levels for water quality to be achieved and maintained in public waters under the Basic Environmental Law (Ministry of the Environment, 2001). The 'National Census of Rivers and Watersides' is another one of the tools for monitoring the condition of the ecosystem. This census examines living conditions for fish and shellfish, benthic organisms, plants, etc., and human activities in rivers and waterside. The census started in 1990 in one hundred and nine class-A rivers (those rivers managed by the national government) and eighty dam reservoirs, and major class-B rivers (those managed by the local government) were added in 1993. The status of non-native species in rivers and dam reservoirs was also investigated (MOC, 2000). As mentioned previously, the River Law was revised in 1997. As well as the usual flood control and water use purposes, the concept 'maintenance and preservation of river environment' was included (see figure 22.4), (MLIT, 2002).[6]

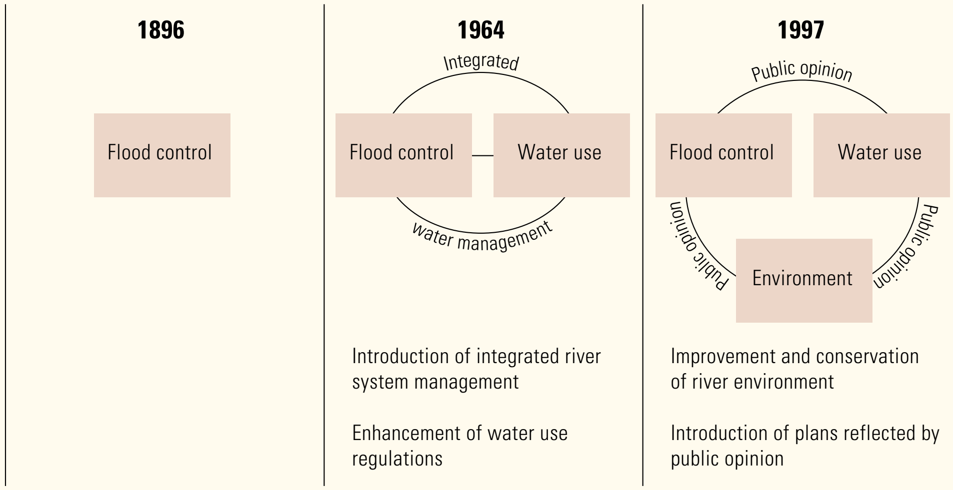
Evaluating the environmental impact

In 1999, the Environmental Impact Assessment Law was implemented, and screening and scoping procedures[7] were

4. See web site at http://www.ktr.mlit.go.jp/kyoku/.

5. See web site at http://www.ara.or.jp/arage/.
6. See web site at http://www.mlit.go.jp/river/.
7. Scoping is the process by which a research plan is developed under the Environmental Impact Assessment Law. Screening is the process which determines the necessity of an Environmental Impact Assessment.

Figure 22.4: Revision of the River Law



Source: River Bureau, MLIT, 2001c.

introduced. The law also called for 'proper consideration of environmental preservation', including ecosystem and communication activities. Under this law, suitable environment preservation countermeasures are taken for the development of water resources and flood control facilities (Water Resources Environment Technology Center, 2001).

Improving the water quality

The Water Pollution Control Law establishes national effluent standards and authorizes more stringent prefectural standards to regulate wastewater discharged from factories and business establishments into public water bodies. The reinforced factory regulations have been effective in improving water quality, but problems with domestic effluent remain, especially in enclosed or semi-enclosed water bodies such as Tokyo bay (Ministry of the Environment, 2001). Sewage systems are one of the essential components for ensuring the quality of public waters. In 1999, 77 percent of people had access to sewage systems, and 97 percent received clean water through water service systems (Japan Sewage Works Association, 1973–2000 and Ministry of Health and Welfare, 1966–2000).

Public involvement in the river improvement plan

In addition to the preservation measures taken for the river environment, the river-planning system was radically reconsidered in the 1997 River Law revision because of rising concerns about environmental and regional needs for river improvement. By providing comprehensible information to the population and respecting their opinions, the planning process was effectively opened to public participation (MLIT, 2002).[8] In March 2001, the river improvement plan was applied first in the Tamagawa River basin, through various discussions with the inhabitants to gather their opinions, which were also collected through the Internet (Keihin Work Office, MLIT, 2002).[9] Such activities are actively conducted in other basins. For more details on the Tamagawa River Improvement Plan, see box 15.2 in chapter 15 on water governance.

Sharing information

Some database systems exist in Japan, notably the yearly report on water quality in public waters by the National Institute for Environmental Studies[10] and the water information system by the Ministry of Land, Infrastructure and Transport.[11] There are also several paper-based databases, such as *Water Resources of Japan* (Water Resources Department, MLIT, 2002), *Water Service Statistics* (Ministry of Health, Labour and Welfare, 1966–2000) and the *Report on Industrial Statistics (Industrial Land and Water),* (Ministry of Economy, Trade and Industry, 2002).

Greater Tokyo's catch-phrase, 'the water-aware country', refers to land in which any water-related information is collected, shared with the public and used in a practical way, with consideration given to different geographical settings. It contributes to water resource management, flood control and management of the environment.

8. See web site at http://www.mlit.go.jp/river/.
9. See web site at http://www.keihin.ktr.mlit.go.jp/.
10. See web site at http://www.nies.go.jp/index-j.html.
11. See web site at http://www1.river.go.jp/.

For watershed management, water information such as drainage and basin groundwater needs to be kept updated. People need higher quality services for river administration: downsizing administrative services, making river administrative services more efficient with proper information updating, privatizing some parts of services and simplifying contract procedures. In addition, river information, such as water quality and ecosystem data, has become more useful in education systems.

In 'the water-aware country', information technology is used to manage and share information efficiently. For example, when an area's flood safety degree can be calculated more precisely by information technology, human losses will be reduced through the combination of people reaching suitable refuge under proper guidance, and the river administrator's efficient operational facilities. River GIS also attempt to deal rapidly with water-related disasters, through such measures as structure maps, waterway figures, maps showing the placement of dangerous objects and a water database. To these ends, super-high-speed, big-capacity optical fibre networks are connected to the related organs in order to make the latest data in emergency situations available (Sato, 2002).

Fitting the Pieces Together

In densely populated Greater Tokyo, the water management policy can be considered a success in providing the population and industries with water, and many years of flood control efforts have reduced the total inundated area. Water resource development has focused on stabilizing river flow and meeting new water demands. However, the high concentration of people and industry makes this success fragile and risky. Flood damage has only slightly decreased, due to a higher concentration of population and property: access to a stable water supply has accelerated the rate of concentration and created a new demand for water. The need for water resource management has become more diversified. People are more concerned with the environment and nature. In addition to the water resources policy, it is necessary to establish more integrated river management suitable for sharing risk information and coping with this risk. The concept of risk management is consistent with the revised 1997 River Law, which calls for public participation and environmental consideration. The various policies relating to efficient water use will be evaluated, easily comprehensible water quality indicators developed, and a commitment will be made and enforced to restore the natural environment and to make information public. These are highly related to the participation of citizens and non-governmental organizations (NGOs) in water policy.

Managing risks

As a countermeasure to the high flood damage in Greater Tokyo, an easily comprehensible indicator showing the degree of risk of flood damage was developed and made public (Yasuda and Murase, 2002). The safety degree against flood damage can be expressed through a combination of the flood frequency and the inundation level. This two-dimensional aspect of floods renders it difficult to develop a single-dimensional indicator by which the risk can be expressed.

Figure 22.5 shows that the frequency of floods and the inundation level can be expressed by a colour and a height, respectively. The green represents low flood frequency while the red represents high flood frequency. Comparing the flood levels with the height of people and houses directly indicates a degree of safety against flood damage. Inter-temporal changes in the safety degree can also be expressed, as shown in figure 22.6.

Based on this, flood risk expression has been developed in Tokyo region. The index in the legend is the Flood Risk Indicator (FRICAT) employed in Japan for policy evaluation. The FRICAT represents how often the expected annual damage by flood is higher than that of fire. The average expected annual fire damage in Japan between 1998 and 2001 was 1,165 yen (approximately US$9.3) per person.

Improving water resource management

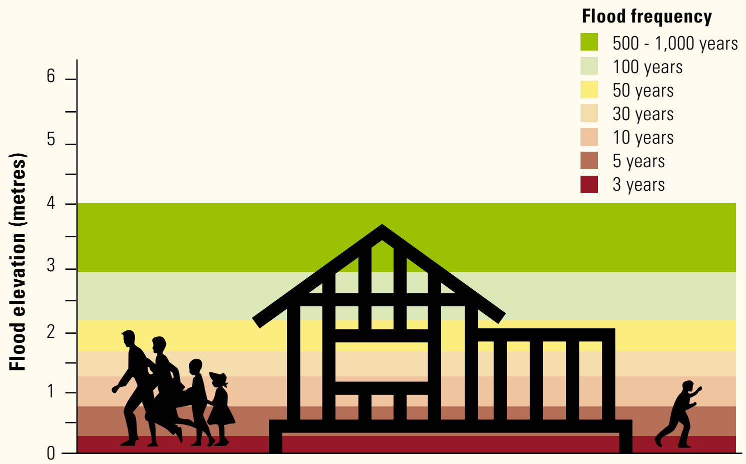
The tight water resources in Greater Tokyo must be carefully managed, as they have to meet the competing demands of a large population. It has become difficult to develop new water resources facilities such as dams. To further improve the water resource management system, an evaluation of the various policies for efficient use of the limited water resources is being carried out.

Integrated Water Resources Management (IWRM)

The combination of an increased concentration of population and industries, the expansion of urban areas, changes in industrial and social structures and changes in the climate, have all given rise to a variety of water-related problems in Japan. These include water shortages in rivers and groundwater and deterioration of the quality of water, as well as an increase in urban flood damage. The problems originate from changes to the hydrological cycle, such as a lack of infiltration or continuity between surface water and groundwater. Water authorities in Japan are divided among several institutions. In 1998, they reached an agreement on fundamental policy for restoring a healthy hydrological cycle. The policy advocates adopting an integrated water basin approach and sharing knowledge about the hydrological cycle, and encourages efforts to improve the situation in each basin. In addition, case studies were conducted in some rivers around Tokyo and Osaka to monitor and analyse problems.

Greater Tokyo, Japan

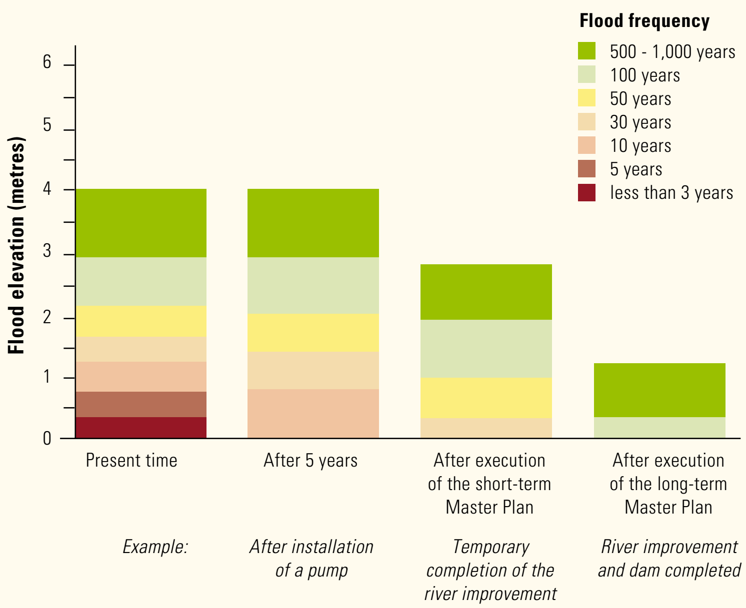
Figure 22.5: Expression of the safety degree



The frequency of floods and the inundation level can be expressed by a colour and a height, respectively. The green represents low flood frequency while the red represents high flood frequency. Comparing the flood levels with the height of people and houses directly indicates a degree of safety against flood damage.

Source: Yasuda and Murase, 2002.

Figure 22.6: Expression of the safety degree with a time variable



This figure shows how wise management can improve the safety degree against floods.

Source: Yasuda and Murase, 2002.

Use of existing facilities

As the construction of new water resource development facilities is becoming difficult due to the lack of suitable grounds, it is essential to use the already existent facilities as efficiently as possible (MOC, 1995). The Reorganization of Dam Groups is designed to redistribute the storage capacities of the existing dams by taking into consideration the particular features of each type of dam. This redistribution seeks to improve flood control and water use functions, that is, seeks to mitigate flood risk by enhancing the flood-regulating effect, and to improve the riparian environment by restoring the river's flow. The first project for this trial will start in the upper Tonegawa River (Improvement and Management Division, Bureau River, MLIT, 2001).

Upstream/downstream cooperation

Many Japanese cities have developed in downstream areas whereas water facilities were built upstream. People living in upstream areas worry about changes in their lives and jobs, and gain no benefit from the construction of dams, unlike downstream inhabitants. To deal with this problem, measures for the reservoir area development were taken, based on the Act on Special Measures for Reservoir Area Development implemented in 1974. In September 1999 however, a meeting about measures taken for this development highlighted the need for good management of water resources, and for the cooperation between authorities in upstream and downstream areas. In this meeting, the importance of basin management was also raised (MOC, 1999).

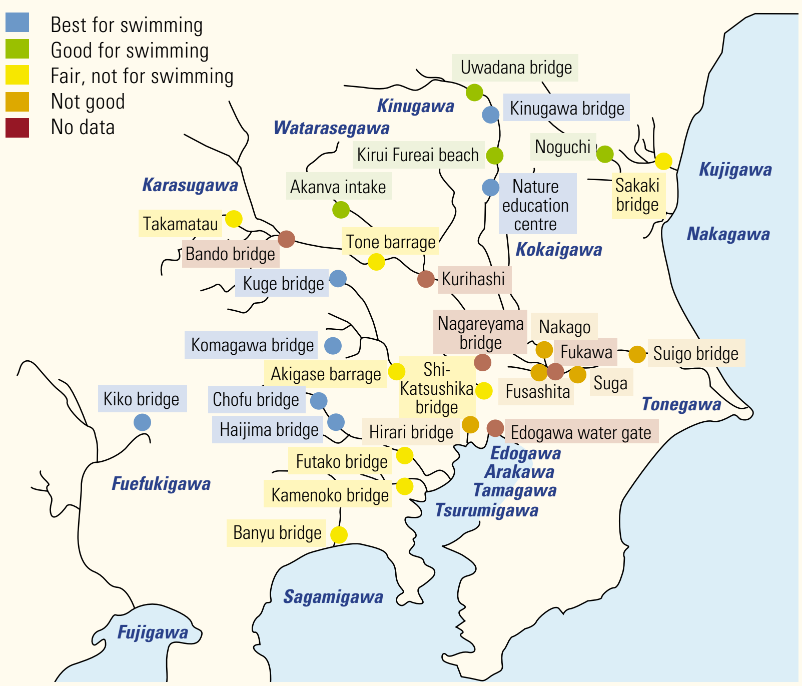
Coping with diverse needs

Protecting the natural environment and quality of water has become more important in water management. With people more involved in the water management process, it is necessary to make the process of improving the natural environment and water quality as transparent as possible, with full disclosure of all information. Also, with urbanization, many people have begun to search more actively for places to enjoy nature. More effort must be made to create communities where the places in which people work and live are integrated with a natural river environment.

Developing a water quality indicator

Existing indicators such as BOD levels cannot fully describe the present water condition. In 1998, a study was conducted in the five rivers of Greater Tokyo for the development of easily comprehensible indicators to monitor the water quality conditions, and new indicators are being developed (Kanto Regional Development Bureau, MLIT, 2002). The river administrator proposed indicators through the Internet and collected opinions from the public (see map 22.3). Comprehensibility of indicators is considered important, and the study emphasized and proposed indicators based on three aspects: people's relationship with water, rich biodiversity and drinking water.

Map 22.3: Proposed new water quality indicator for recreational use



This proposed water quality indicator clearly and efficiently shows the public which areas in Greater Tokyo are suitable for recreational use.

Source: Kanto Regional Development Bureau, MLIT, 2002.

Greater Tokyo, Japan

Project for nature restoration

To cater to the population's diverse needs, especially with regards to the natural environment, projects for nature restoration have been implemented. These include the restoration of river meandering, improvement of riverside woods and the restoration of wetlands by frequent flooding, for better habitats along rivers. Such projects are being applied all over the country (Prime Minister of Japan and His Cabinet, 2001). The restoration project of dried wetlands started in the Watarase retarding basin of Tonegawa River (River Bureau, MLIT, 2001c).

Non-structural measures of risk mitigation

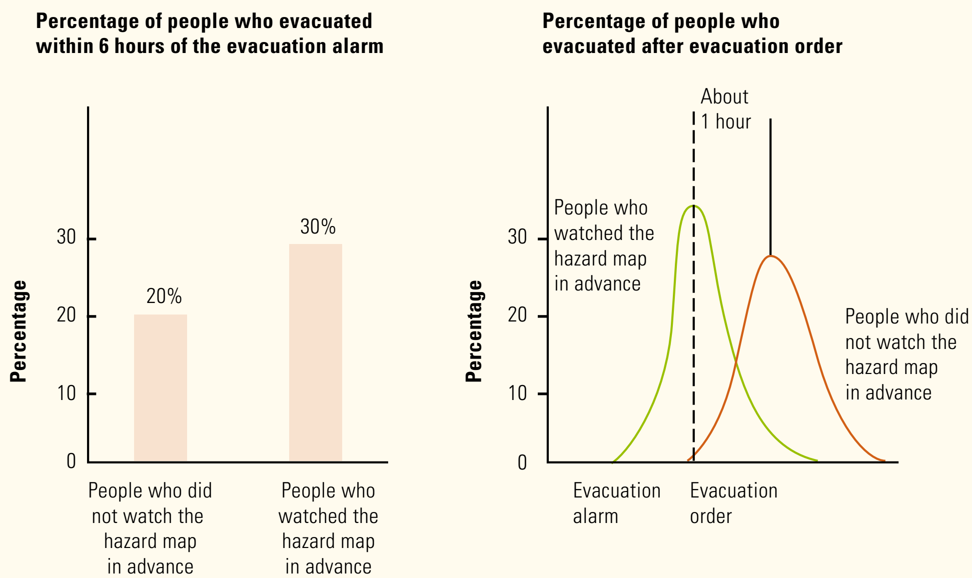
Water resource management includes 'hard' and 'soft' management. A hazard map is one of the tools for soft management; it enables people to prepare for disasters and evacuate promptly. Figure 22.7 shows the effect of hazard maps. There is a clear difference between people who watched the map in advance and those who did not. Efficient and comprehensive soft management measures, such as hazard maps, are ensured by the information systems. In Japan, the river administrator processes and provides information to governmental agencies and local residents so that appropriate river management and flood defence measures can be taken.

Conclusions

Greater Tokyo houses one of the world's largest populations and industrial spreads, much of which is set on flood plains and other high-risk areas. In order to mitigate flood damage and to ensure a better quality and security of life in the metropolis, the government of Japan has invested large amounts of money in new technologies, structural measures and greater public information services. Development of comprehensible indicators has also been one of the main priorities in the region. Water is of varying quality in the five rivers that make up Greater Tokyo, with BOD levels sometimes significantly above recommended standards. However, as both this and other environmental matters become increasingly important in the public eye, more and more efforts are being made to control any potential problems.

Greater Tokyo is an area where the public has found a voice in matters of the environment, as the population is frequently consulted and involved through discussions, meetings and media such as the Internet. Although the region faces many challenges, including floods and droughts in a great many urban areas with millions of yen worth of assets, the development of such initiatives as have already been implemented feasibly meets and overcomes many of the challenges that lie ahead.

Figure 22.7: Effect of hazard maps on public safety



Public awareness of the hazard maps significantly increases safety during floods: 50 percent more people made it to the refuge areas after having watched the map.

Source: Katada Laboratory, 2001.

Box 22.1: Development of indicators

Establishing indicators based on clear criteria is essential for future assessment. The Greater Tokyo case study team proposed the following six criteria: relevance, cost, comprehensibility, clarity, continuity and social benefit (Yasuda and Murase, 2002). The indicators proposed by the World Water Assessment Programme (WWAP) are discussed in the following table. Some indicators are too vague to be calculated.

Challenge areas	Greater Tokyo indicators
SURFACE WATER	• Average water use/water resources normal years: 44%; drought years: 66% • Precipitation inland parts: 1,549 mm/year Precipitation seaside parts: 1,535 mm/year
WATER QUALITY	• Pollutant load in Tokyo bay (not whole basin) was 286 tons/day in 1994. • Biological oxygen demand (BOD): Tonegawa: 1.8 mg /litre Arakawa: 4.4 mg/litre Tamagawa: 2.6 mg/litre Tsurumigawa: 10.4 mg/litre Sagamigawa: 2.1 mg/litre
GROUNDWATER	• Dependence on groundwater inland parts: 22.8% seaside parts: 13.1% • Groundwater withdrawal: northern part of Kanto plain: 960 million m^3 • Degree of dependence of households on underground water: 18.7%
PROMOTING HEALTH	• Number of houses with sewage: 12,052,059 • Percentage of houses with water supply: 97.3% • Investment in water supply: 778,098 million yen • Investment in sanitation: 2,732,671 million yen
PROTECTING ECOSYSTEMS	• Urbanization rate: 13.0% (1974), 20.2% (2000) • Percentage of wetlands: 0.11% • 1 Ramsar site (Japan has 11 sites)
WATER AND CITIES	• Water supply: 97.3%; sanitation (sewage): 76.9% • The basic total pollutant load control system is being applied to Tokyo bay, not the whole Tokyo region. • Pollutant load from household wastewater in Tokyo bay was 167 tons/day in 1999.
WATER AND CITIES	• Comprehensive flood control measures are implemented through the establishment of the Council for comprehensive flood control measures for individual river basins and through the formulation of basin development plans that include improvement of the environment.
SECURING THE FOOD SUPPLY	• Self-sufficiency ratio in food (all Japan data for 1999) • Self-sufficiency ratio in calorie supply: 39 • Self-sufficiency ratio in staple food cereals: 58 • Self-sufficiency ratio in cereals: 26 • No data at regional level. • Volume of virtual water import: 43.86 bm^3/year.
WATER AND INDUSTRY	• Industrial use of water by total developed water in Tonegawa and Arakawa basins: 25.4% (2000) • Amount of manufactured goods shipped (yen)/amount of water used (m^3): 6,092 yen/m^3 • Ratio of recycled water use: 85.4% • Basic total pollutant load control system is being applied to Tokyo bay, not the whole Tokyo region. • Pollutant loads from industrial wastewater in Tokyo bay was 52 tons/day for 1999.
WATER AND ENERGY	• Amount of annual output/capacity of dam plant for generation of electricity: 9.0 kWh/year/m^3 • The amount of water use for cooling/ amount of water used for industry: 78.9%
MANAGING RISK	• Number of people living within 100-year flood area in Arakawa basin: 2,148,360 people
SHARING WATER	• Industry: 15.4% • Agriculture: 66.1% • Households: 18.5% • Formal policy exists. In addition, drought conciliation are held to conduct a constant water supply during drought.

Box 22.1: *continued*

Challenge areas	Greater Tokyo indicators
VALUING WATER	• Water rate per household: 2,316 yen/month (1999, all Japan) • Water rate per capita: 861 yen/month (all Japan) • No available data on water use by amount of income. • Percentage of water charge/average income: 0.4% • Percentage of water charge/average consumption expenditure: 0.7% • Effective storage capacity of dam/population: 60.3 m^3/capita • Effective storage capacity of dam –flood control storage/population: 49.2 m^3/capita
ENSURING KNOWLEDGE	• Effective computerized system of hydrometeorological data collection exists. • Most data are maintained on local government bases, not on basin-wide. • For transparency, a disclosure law was enacted in 1999, and effective database systems have been developed.
GOVERNING WISELY	• Amount of water resources investment/ population: 3,334 yen/year (2000, all Japan) • Various comprehensive policies such as basin management exist. • River Law exists, revised in 1997. • Institutional cooperation for healthy hydrological cycle started in 1998 (e.g. the River Improvement Plan)

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