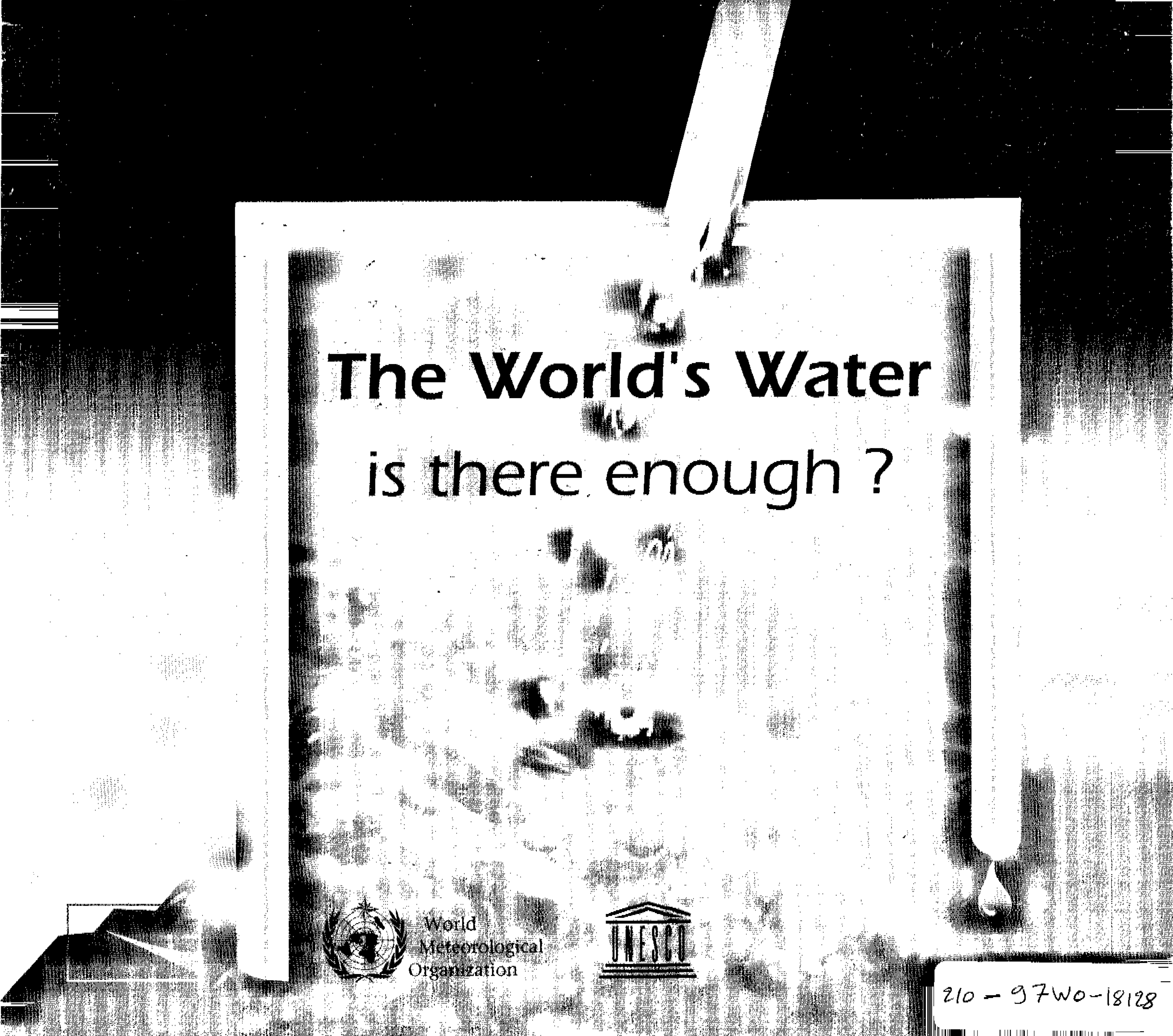

The World's Water

is there enough ?

World Meteorological Organization

UNESCO

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UNESCO

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NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Meteorological Organization concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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FOREWORD

The availability of fresh water is one of the great issues facing humankind today — in some ways the greatest, because problems associated with it affect the lives of many millions of people. During the next 50 years problems associated with a lack of water or the pollution of water bodies will affect virtually everyone on the planet.

The regions of the world that face shortages continue to grow in area and number. The concern is that, while the rising population demands more water, this finite resource must also satisfy the needs of every other form of life. The result could be a series of local and regional disasters and confrontations leading to a crisis of global proportions. Indeed, issues concerning the fresh waters of the world highlight the dilemma facing humankind. Can competition between the environment and development be transformed into a partnership between the two, so that the goal of sustainable development is attained?

This dilemma occupies the attention of many institutions and has been addressed at a number of recent conferences, notably the International Conference on Water and the Environment (Dublin, 1992) and the United Nations Conference on Environment and Development (UNCED, Rio de Janeiro, 1992). The Dublin Principles and also Agenda 21, where these principles are embedded in the Freshwater Chapter, make it clear that water is a key to sustainable development. Following a call in 1994 from the second session of the United Nations Commission on Sustainable Development (CSD), a number of agencies of the United Nations System — including the World Meteorological Organization (WMO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) — in collaboration with the Stockholm Environment Institute, made a comprehensive assessment of the world's fresh waters. Based on that work, this brochure outlines the issues of:

- assessment of the world's fresh-water supply; and
- availability and use of that water's resources.

The purpose of this booklet is to draw the attention of all concerned to the urgent need to enhance the monitoring and assessment of water resources in rivers and in aquifers, particularly in basins shared regionally or internationally. It is vital in order to meet today's and tomorrow's increasing demand for water information and for the knowledge necessary for sustainable development.

We would also like to invite the national Hydrological Services, scientific and educational institutions and water agencies to take the necessary initiatives to develop concrete and visionary plans, and corresponding implementation strategies, as to how they might best contribute to national and regional water resources assessment activities in the coming years.

Action on water must be taken today so that human activities in the 21st Century will not be limited by a shortage of water.

(F. Mayor)
Director-General
UNESCO

(G. O. P. Obasi)
Secretary-General
WMO

William Shakespeare's vision of the hydrological cycle:

"Therefore the winds, piping to us in vain,
As in revenge have suck'd up from the sea
Contagious fogs; which, falling on the land,
Have every pelting river made so proud
That they have overbourne their continents."

A Midsummer Night's Dream, Act 2, Scene I

Wherever it appears and whatever its form, every drop of the world's water is locked into the hydrological cycle.

Water — A Matter of Life and Death

A world without water is difficult to imagine. But images from the moon and Mars show clearly what conditions might be like without it.

Water is vital for drinking, sanitation, agriculture, industry and countless other purposes. Life on Earth began in water; now fresh water brings life to thirsty cities and parched crops, and provides the habitat for a multitude of living things. However, water can also mean death and destruction. Floods are the worst of the natural disasters, killing more people and damaging more property than earthquakes, volcanic eruptions or similar hazards. Polluted water brings disease and death to those who drink it and kills the birds, fish and other forms of life that need it to survive.

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How Much Fresh Water?

Water is one of the most familiar features of our world:

- As a liquid it fills the lakes, rivers and reservoirs on the surface of the land, and occupies the surrounding seas and oceans;
- As a gas it occurs as water vapour in the atmosphere;
- As a solid it covers the polar regions and the higher mountains, and transforms the winter landscape;
- There is also a vast amount of water stored in the ground, both in the soil and beneath in the underlying porous formations known as aquifers; and
- Water is present in vegetation and in our bodies — humans are nearly 80 per cent water.

In the hydrological cycle, the sun constantly evaporates water into the atmosphere. Some of that water is returned as rain and snow. Part of this precipitation is rapidly evaporated back into the atmosphere. Some drains into lakes and rivers to commence a journey back to the sea. Some infiltrates into the soil to become soil moisture or groundwater. Under natural conditions, the groundwater gradually works its way back into surface waters and makes up the main source of dependable river flow. Plants incorporate some of the soil moisture and groundwater into their tissues, and release some into the atmosphere in the process of transpiration.

The hydrological cycle moves enormous quantities of water about the globe. Some of this movement is rapid; the average time a drop of water stays in a river is about 16 days and in the atmosphere about eight days. But this time can run into centuries for a glacier and tens of thousands of years for water moving sluggishly through a deep aquifer. Water drops are continuously recycled, carrying sedimentary material with them — thousands of tons per day in a river like the Ganges to barely measurable amounts in an aquifer.

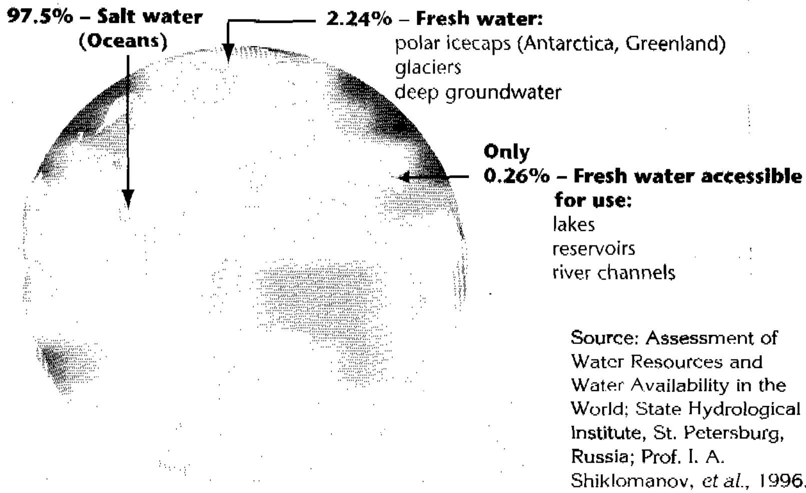
Much of the world's water has little potential for human use because 97.5 per cent of all water on earth is salt water, leaving only 2.5 per cent as fresh water, most of which lies deep and frozen in Antarctica and Greenland. Only the far smaller quantities of fresh water in the rivers and lakes, in the soil and in the shallow aquifers can be readily exploited.

These are the major components of the world's water resources, fed by precipitation and by melt water from glaciers in some areas, and supplemented by dew and fog drip in certain locations. Everywhere they are depleted by evaporation and transpiration. In many river basins, dams increase the volume of stored water, as do artificially recharged aquifers, while close to the sea desalinated sea water adds a tiny fraction of fresh water. Due to the variations in the hydrological cycle from place to place and from day to day, these water resources are far from constant. They are, however, the resources with potential for use and because of this they are precious to humankind.

Human actions modify the hydrological cycle and can seriously pollute available water. Removal of trees and vegetative cover, land use change, expansion of paved areas, building of dams and

Global fresh water availability

Water — "Blue" planet



Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.

Global Run-off per Capita

Year	*Average*
1970	12 900 m^3/person
1995	7 600 m^3/person

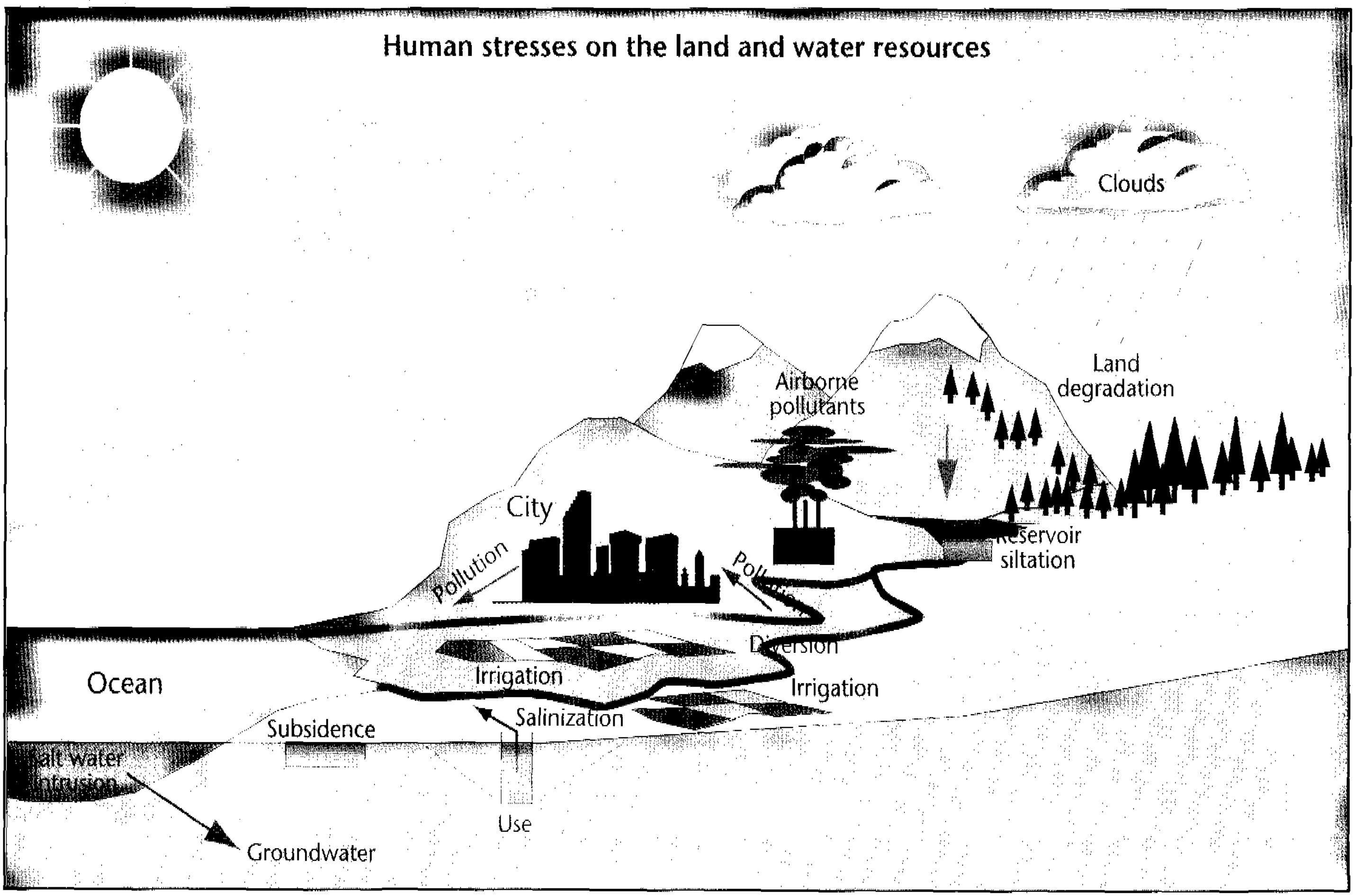
Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.

Source: Comprehensive Assessment of the Freshwater Resources of the World, Report to the Commission on Sustainable Development, 1997.

channels, inter-basin transfers, irrigation and drainage, and many other activities change the hydrological balance. Assessing the effects of such modifications and of human uses of water in factories, cities and farms requires detailed data on amounts and quality of water at a location or in a region. In addition, adequate reliable hydrological data are a prerequisite for understanding the global climate system.

Assessing Water Resources

Water Resources Assessment (WRA) provides the basis for a vast range of activities, such as domestic and industrial water supply, maintenance of human health, hydropower production, irrigation and drainage, mitigation of flood losses and droughts, food security measures, navigation, tourism and the preservation of the



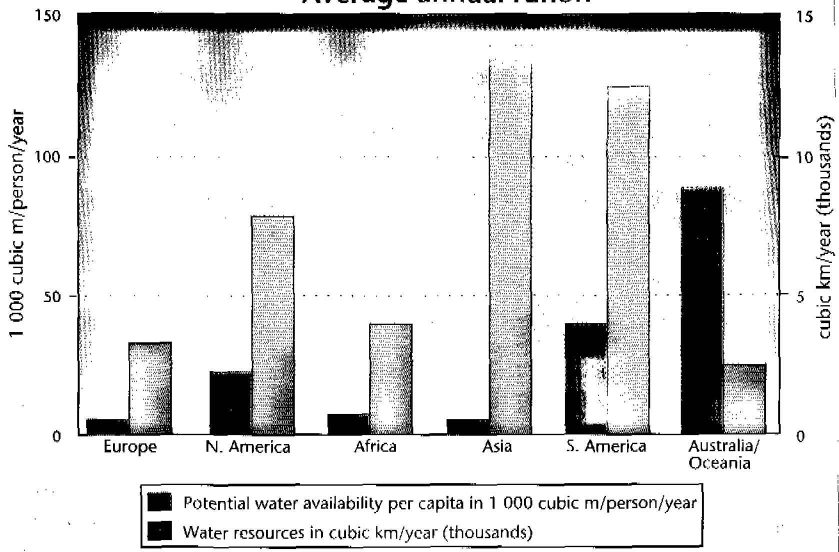
aquatic ecosystem. In addition, the data produced contain signals of the sustainability of the different activities that are carried out within the river basins being sampled. WRA is a tool and part of the decision-making process.

The existing and future uses of water must be determined giving due consideration to quality and to the needs of the aquatic environment as a legitimate user of the resources. Alternatives for balancing supply and demand need to be evaluated, assessing those that reduce demand as well as those that increase the available supply. As scarcity increases and conflicts develop, alternative uses must be considered and trade-offs made between large-scale uses such as for agriculture and high-value uses such as for tourism and industry. WRA will often identify the need for:

- new coordinating and integrating mechanisms;
- new legislation and regulations; and
- strategies and policies that deal with priority of uses and resolution of conflicts.

The need for critical skills and database requirements will be identified as well. In short, WRA is a prerequisite for sustainable development and management of a country's water resources.

A WRA can be conducted at a number of levels. Increasingly, the river basin is being recognized as the appropriate planning level. Rather than wait for a national or regional assessment to be completed, it may be prudent to assess separately such potential "hot spots" as river basins containing heavy industry or major urban centres, so that remedial action plans can be developed and future problems averted.



Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.

Is There Enough Water?

Employing the existing data, hydrologists have made a number of estimates of the average annual flow of all the world's rivers. These are seen as guides to the sum of the globe's water resources, both surface and groundwater — the finite limit of the world's water resources. These average flows range from 35 000 to 50 000 cubic kilometres a year, probably less than 1 per cent of the total volume of fresh water, and there are considerable variations in these figures from year to year and from region to region. Up to 80 per cent of the total annual discharge of a particular river may take place during the floods caused by snow melt or heavy rain, while six months later its flow may be just a trickle. The Amazon, with a basin of 5 870 000 km^2, drains 4 per cent of the earth's total land area. It contributes almost 16 per cent of the total

The Global Hydrological Network

	No. of Stations
• Precipitation (Recording + non-recording)	194 000
• Evaporation (Pans + indirect methods)	14 000
• Discharge (Recording + non-recording)	64 000
• Sediment discharge (Suspended + bed load)	16 000
• Water quality	44 000
• Groundwater (Observation wells level)	146 000

Source: WMO/OMM INFOHYDRO Manual, 1994.

National Agencies Collecting Data

	No. of Agencies
Total agencies	*480*
Surface water quantity	416
Groundwater	189
Climatology	280
Sediment discharge	158
Water quality	220

Source: WMO/OMM INFOHYDRO Manual, 1994.

runoff, while the world's arid and semi-arid zones produce only 2 per cent of the runoff, despite occupying more than 40 per cent of the land area.

Another problem is that many of the largest rivers and most important aquifers are far from the major conurbations. Because of the high cost of transporting water these sources cannot be employed to satisfy demand. In addition, many of these conurbations discharge partially treated and untreated sewage to the surface and groundwaters in their surroundings. Discharges from industrial processes and drainage from mines and industrial waste, together with leaching of the residues of fertilisers and pesticides used in agriculture, increase the pollution load. The result is that only about a third of the potential resource, probably about 12 500 cubic kilometres a year, can be harnessed to human needs — and this is a proportion that is declining as the extent of pollution increases. This is the globe's available fresh water.

"Measurement of components of the [illegible] quantity and quality, and of oth[illegible] characteristics [illegible] water management."
The Knowledge [illegible]

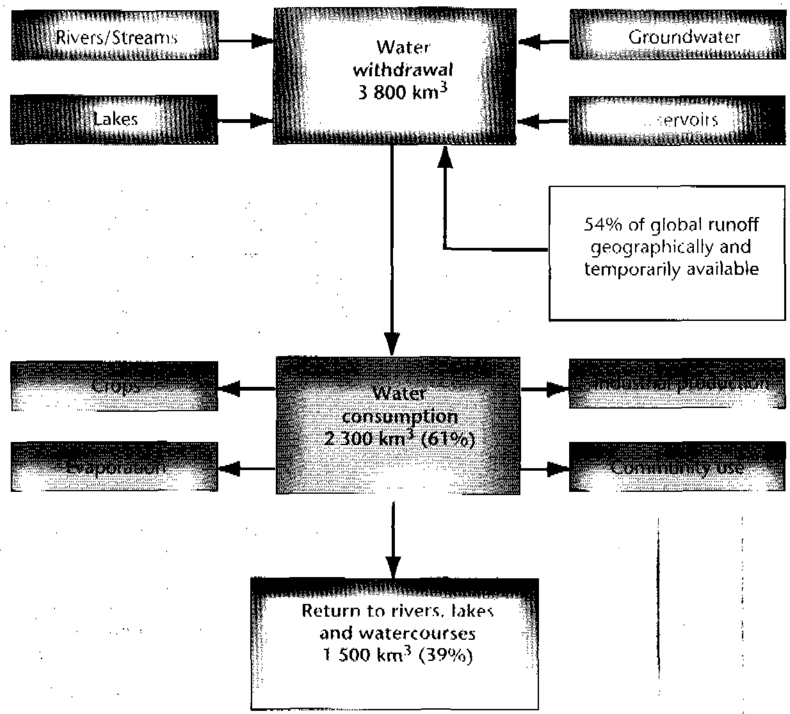
Basis for Assessing

Measuring on a regular basis the hydrological elements which control water resources is necessary to determine how much water is available for use. These elements include precipitation, evaporation and river flow, as well as the water stored in soil, aquifers, reservoirs and glaciers. The water's quantity, quality and biological characteristics should all be measured regularly. The table on page 11 gives an indication of the total number of instruments in the global hydrological network dedicated to measuring these different elements. Analysis of the records from this network — which is the sum total of networks of nearly 200 countries and territories — provides our only source of knowledge of world water resources, from the smallest river basin to the global scale, and from hours and days to the long-term average.

Despite the large total number of stations, the coverage of the network is seriously inadequate, particularly in the developing world where, paradoxically, the need for water data is greatest. Indeed, national networks in much of the developing world are declining to the extent that many nations are less able to determine their water resources in 1997 than they were in 1967. It is a problem to assemble these data regionally and globally. The establishment of the Global Runoff Data Centre in Koblenz, Germany and the WMO's GEMS Collaborating Centre for Surface Water and Ground Water Quality in Burlington, Canada has improved this situation. Nevertheless, a number of nations have not supplied data to these centres. With the currently available records, it is extremely difficult to establish the state of the world's water resources, and in particular those of a particular region or river basin, and for a given year, month or day. Yet such information is vital for investment purposes, as well as for advancing scientific understanding.

It is a paradox that governments and agencies are willing to invest many millions in projects which have such fragile hydrological data foundations, and which may not be sustainable, but they are unwilling to spend the much smaller sums needed to ensure that data are collected and processed to meet current and future needs and to demonstrate the sustainability of projects. The argument usually is that there is no time for data collection. The response is that now is precisely the time to start collecting data for the future, using rapid assessment techniques in the meantime.

Global water withdrawal and consumption (1995)

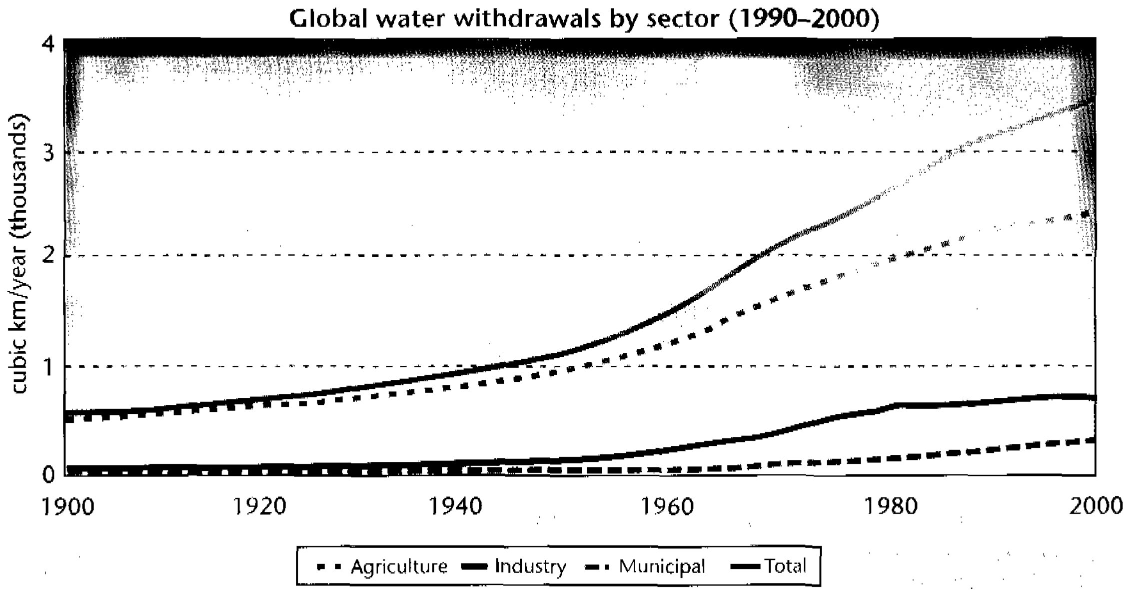


Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.

Who Assesses?

It is tempting to draw an analogy between the role of the Hydrological Services in terms of water projects and the role played by financial institutions. Banks make available the financial resources which enable enterprises to grow and function. Hydrological Services make available knowledge of water resources to allow activities and projects to take place and operate.

Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.



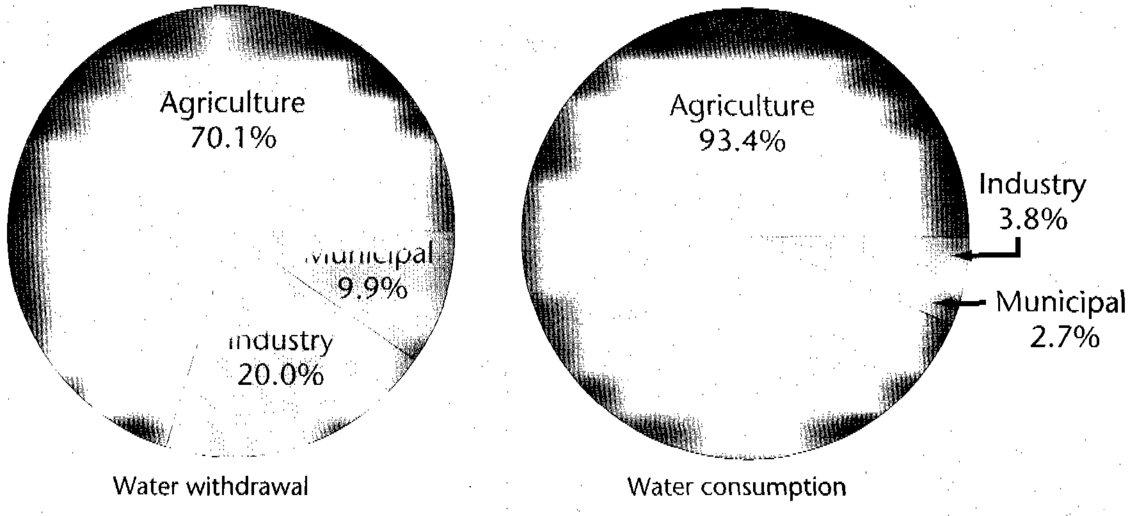
Because of these impediments WMO, in collaboration with the World Bank, European Union and other agencies, has embarked on the establishment of the World Hydrological Cycle Observing System (WHYCOS). This system is expected to provide quantity and quality data in near real time from a network of about 1 000 stations on the world's largest rivers, including those shared by several nations. Work on establishing the network has begun in the countries surrounding the Mediterranean Sea and in Southern Africa.

Using Water

In contrast to the diminishing resource, global demand for water is rising. Demand is estimated to have risen six to seven times from 1900 to 1995, more than double the rate of population growth. It is a rise which seems likely to accelerate into the future, because the world population is expected to reach 8.3 billion by the year 2025 and 10 to 12 billion by 2050. Of today's estimated global demand for water, some 4 000 cubic kilometres a year, agriculture probably takes more than 80 per cent, mostly for irrigation. But significant amounts of water are employed by industry, for energy production and for many other purposes, as well as for domestic usage. Data on water use are even scarcer and are sometimes less reliable than water resources data, principally because of the lack of measurements in many countries.

To meet the demand for water, humankind has been modifying the hydrological cycle since the dawn of history by constructing wells and

Present water withdrawal and consumption by sector



Source: Assessment of Water Resources and Water Availability in the World; State Hydrological Institute, St. Petersburg, Russia; Prof. I. A. Shiklomanov, *et al.*, 1996.

boreholes, reservoirs, aqueducts, water supply systems, drainage systems, irrigation schemes and similar facilities. Governments and public bodies spend large sums of money to develop and maintain these facilities. One way they do this is through initiatives such as the International Drinking Water Supply and Sanitation Decade, which was aimed at improving the water services of the developing world. Despite such initiatives, in 1995 some 20 per cent of the globe's population of 5.7 billion people still lacked a safe and reliable water supply, while more than 50 per cent were without adequate sanitation. Lack of these services is one reason that more than a billion people live in poverty.

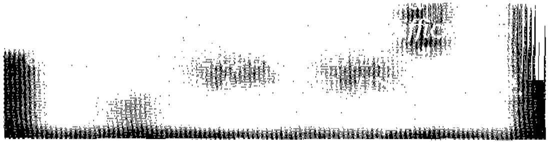
Increasing demands for water are causing water resource problems in many parts of the world. Because so much water is abstracted from some rivers, their flow decreases downstream and lakes are shrinking. During dry periods much of the flow in many rivers is made up of waste water. Groundwater levels in some aquifers have declined by tens of metres because of over-pumping, making it more difficult and expensive to abstract more water. This has resulted in land subsidence. Declining groundwater levels have reduced the dry weather flow of many rivers fed by groundwater and have caused some to disappear completely. More water is being pumped out of a number of aquifers than is being replaced by the natural recharge due to percolation of precipitation and melt waters. This is serious for small islands as it leads to the intrusion of sea water. It is equally serious in arid areas where the aquifers contain "fossil" water and there is no possibility of recharge under current climatic conditions.

resources, including their uses.

Wasting Water

Unfortunately, much of the water abstracted from surface and groundwater sources for human activities is wasted or used very inefficiently. In irrigation, for example, about 60 per cent of the water seeps from the channels of the distribution systems and is lost by evaporation from the channels and from the bare soil between the crops. To make matters worse, seepage causes waterlogging and salinization in about 20 per cent of the world's irrigated lands, resulting in significant reductions in crop yield. Another consequence of poor land and water management is the erosion of rain-fed croplands. Erosion causes losses in production, and degrades the water resource by introducing large volumes of sediment into streams and rivers, thereby reducing reservoir capacity. Many industrial processes use water inefficiently and fail to make savings through techniques such as recycling.

Losses also occur in the public water supply distribution systems, particularly where the water mains are old and have not been well maintained. Leakage of 50 per cent of the water is not uncommon in some developing countries and there are losses revolutions occurred in industry and agriculture. Today water pollution comes from many different sources, often in large volumes. Some of the forms this pollution takes include untreated sewage, industrial discharges, leakage from oil storage tanks, mine drainage and leaching from mine waste, and drainage from the residues of agricultural fertilisers and pesticides. Water pollution varies in severity from one region to the next depending on the density of urban development, agricultural and industrial practices and the presence or absence of systems for collecting and treating the waste waters.



In most developing countries untreated sewage finds its way into the nearest watercourse, something that used to

mercury, silver and chromium — which are highly toxic to aquatic life — is one of these inherited problems. Some heavy metals are stored by fish and then consumed by humans.

The history of pollution in the developed world provides a model for the likely scenario in other areas. For example, the eutrophication, caused by abundance of phosphorus and nitrogen in discharges, which first affected lakes in Europe and North America in the 1950s, has extended to all continents. The elevated levels of nitrate in surface and groundwater, associated with intensive farming practices and high rates of fertiliser application, have also become widespread.

initial tactic in this strategy is the alteration of attitudes towards water. Water must be generally acknowledged to be a precious resource, one we cannot do without. Consequently, water must be the environmental issue at the top of the agenda of governments, institutions and individuals alike. Without this commitment it is illusory to maintain that the other measures proposed here will deflect the course of events from the coming crisis.

Because knowledge of water, through the availability of water data, is the key to development — management, investment, capacity building and policy formulation — access to reliable water data needs to be given high priority by governments.

All nations need to assess their water more carefully and regularly, and measure the use of water in the same fashion, in order to provide the scientific knowledge of the hydrological cycle essential to integrated water resources development and management. Networks of experts and institutions need to be fostered to counteract the fragmentation which is rife in the water sector, both nationally and internationally. Global freshwater assessments have to become more formalized within the United Nations system for governments to reach a global water consensus.

These assessments can show, for example, whether the desired efficiency improvements in irrigation are being attained. The savings made by lining channels, installing drip irrigation systems and using waste water more extensively could accommodate much of the anticipated extra demand up to the year 2025.

Conclusion

Water resources assessment, identification of available supplies, projections of future use and the presentation of development options and their potential impacts, are the basis for the sustainable management of the world's water resources into the future. However, the building blocks of water resources assessment — the hydrological data collection networks of the world — are in poor shape. Evaluations by WMO and UNESCO reveal that the capability and the databases necessary for water resources assessment are sadly lacking in many developing regions of the world, particularly Africa and parts of Latin America and Asia. Several steps outlined in the box on page 22 can help countries rectify mistakes of the past.

> *"If sustainable development is to mean anything, such development must be based on an appropriate understanding of the environment — an environment where knowledge of water resources is basic to virtually all of man's endeavours."*
>
> Report on water resources assessment, WMO/UNESCO, 1991

The world's natural resources must be managed, protected and conserved to meet the needs of present and future generations. Water resources assessment is one of the key tools in ensuring that this will happen. WMO and UNESCO will continue to play their roles in this regard at the international level within the UN system.

A — Change the Approach

Water scarcity and pollution are symptoms of an ecosystem under stress. To put sustainable development of the precious water resources on the global agenda, changes in approach and attitude are necessary, as are innovative thinking and political commitment, together with concerted efforts at the local, national, regional and global levels.

B — Assess the Resource

Collection, storage and analysis of data identifying the sources and use of freshwater must be accorded priority in national planning.

C — Promote Self-dependence

International action is required to overcome the limitations mentioned above, and assist those countries most in need to reach self-sufficiency in terms of gathering reliable information and carrying out water resources assessments and sustainable management of the water and related resources.

D — Improve Economies and Incomes

Underpinning these different actions is improvement in economies and income generation programmes. This will provide the motor for building human and institutional capacity to cope with and solve water problems. Included in capacity building are education and the creation of legal frameworks, institutions and informed opinion — especially among women, teenagers and members of voluntary bodies — so that they are able to make soundly based decisions for creating a sustainable water future.