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WATER: A PERSPECTIVE ON GLOBAL ISSUES AND POLITICS

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All the rivers run into the sea,
Yet the sea is not full;
Unto the place from whence the rivers come,
Thither they return again.

Ecclesiastes 1:7

INTRODUCTION

Water, said the Greek philosopher Pindar, as early as the fifth century B.C., is the best of all things. It may perhaps be an overstatement, but it certainly is not surprising, especially when it is considered that it has been one of the most precious commodities throughout man's recorded history. Water makes human, animal, and plant life possible, and without it, life and civilization cannot develop or survive. Wars have been fought in the past over the availability of water, and even now, relations between several countries are somewhat strained due to disputes over water.

The entire history of mankind could be written in terms of our need for water. From the very beginning, it was realized that water was an essential ingredient for survival, and therefore, early civilizations developed and flourished on lands made fertile by major rivers—Tigris and Euphrates in Mesopotamia, Nile in Egypt, Indus in India, and Huang-Ho in China. As early as 3000 B.C.,

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the Egyptians had already developed intricate water resources networks, especially irrigation systems. The historian Herodotus provides a vivid description of these early Egyptian water development works, and he was so impressed by the role of the river Nile in the country's survival that he called Egypt "the gift of the Nile."

Distribution of Water

Water is considered to be a renewable natural resource since it is continuously being renewed through nature's hydrologic cycle. However, it is an unique natural resource in the sense that the total amount of water available on a global basis is constant, and compared to other renewable resources, like wood or fish, its total stock can neither be increased or decreased by changing management practices. This, however, does not mean that local or regional sources of water cannot be exhausted by short-sighted use or rendered unusable due to large-scale contamination.

Approximately 71% of the earth's surface is covered with water, and nearly all of this water is saline. Current estimates indicate that the total volume of water on the earth is about 1.4×10^9 km^3, of which 97.3% is ocean water. The balance, 2.7%, is fresh water. At any given time, 77.2% of fresh water is frozen in the polar ice caps and in glaciers in various parts of the world, and thus, for all practical purposes, is unavailable for human consumption or for vegetation. Ninety percent of this ice is in Antartica, and the remainder, for the most part, is contained in the Greenland ice cap. Distribution of the world's water resources is shown in the following (15).

Location	Percentage
Ocean	97.3
Fresh	2.7
Distribution of fresh water:	
Ice cap and glaciers	77.2
Ground water and soil moisture	22.4
Lakes and swamps	0.35
Atmosphere	0.04
Stream channels	0.01

Ground water and soil moisture constitute 22.4% of global fresh water, but nearly two-thirds of this lies deeper than 750 from the ground level. Approximately 0.1% of this reserve (13,000 km^3) participates in the hydrologic cycle in an average year, mostly through contribution to stream flow. Nearly 30% of total stream flow is contributed by ground water. Lakes contain about 200,000 km^3 of fresh water, which is about four times the average annual run-off from all land areas. In contrast, man-made lakes store about 11% of the yearly run-off (about 5,000 km^3). Lakes, the atmosphere, and streams contain only 0.4% of fresh water, or 0.01% of the total volume of water. This tiny fraction is vitally important in sustaining life on this planet.

The tremendously dynamic nature of the hydrologic cycle can be demonstrated by two simple facts. Firstly, even though the mean annual precipitation of the earth is about 973 mm, the water content of the atmosphere at any given instant is only 0.001% of the total water of the earth, and if by some means all this vapor can be precipitated, it would cover the earth's surface by only about 25 mm. Secondly, notwithstanding large discharges of the major rivers, the amount of water contained in the world's rivers at any instant is relatively small. Thus, the important factor to consider in water resources planning and management is not the actual quantity of water in a channel at any time but rather its flow through the channel over time.

While it is not possible to give precise figures for the world water balance at the present stage of our knowledge, all recent estimates have been relatively consistent, even though different methods were used for the estimates. Table 1 shows such an estimate for the average annual water balances of the world (1). The major uncertainty in such analyses comes from the difficulty of estimating precipitation on and evaporation from the oceans due to lack of observed data.

Such a global picture, however, does not give a correct impression of the tremendous variability of water, both with regard to space and time. Water,

TABLE 1.—Average Annual Water Balance of World (1)

Regions (1)	Volume, in thousands of cubic kilometers		
	Precipitation (2)	Evaporation (3)	Run-off (4)
Africa	20.7	17.3	3.4
Asia	30.7	18.5	12.2
Australia	7.1	4.7	2.4
Europe	6.6	3.8	2.8
North America	15.6	9.7	5.9
Latin America	28.0	16.9	11.1
Antarctica	2.4	0.4	2.0
Total, land areas	111	71	40
Oceans	385	425	−40
Total, world	496	496	0

in any continent, is not evenly distributed. This can be easily shown by considering any continent. If the first continent of Table 1, Africa, is considered, nearly 50% of its total surface water resources are in one single river basin, that of the Congo. Nearly 75% of its total water resources are in eight major river basins—Congo, Niger, Ogooué (Gabon), Zambesi, Nile, Sanga (Cameroon), Chari-Logone (Lake Chad basin), and Volta. This relative abundance of water in the river basins of the equatorial zone of Africa is in sharp contrast to the total lack of water in the world's largest desert, the Sahara, to the north of the equator, and another major desert, the Kalahari, to the south, with varying degrees of water sufficiency or insufficiency in the intervening areas. The savannah area, between the humid equatorial belt and the deserts in the north and south, is most vulnerable to periodic and severe drought, permitting bare survival for man and livestock. Thus, the development of water resources of Africa is an essential prerequisite for the development of its agricultural and industrial potential, besides being a fundamental necessity to long-term survival of man.

Demand for Water

During the late Stone Age, man started growing food by raising livestock and farming. Agricultural communities gradually developed on flat and fertile land adjacent to the river valleys. Since the population was small and water was plentiful, people simply migrated during prolonged droughts until better locations were found. Thus, from the very beginning, water has been treated as a "free" resource, a gift from God, that can be used as desired or squandered on whims. This freewheeling concept, until recent times, did not pose serious large-scale management problems.

The situation started changing with the advent of the Industrial Revolution. Centers of dense population started to develop as workers from agricultrual sectors were attracted to run the burgeoning industries. As the industrial cities developed, they attracted more migrants from the rural sectors, which, in turn, attracted more industries, and thus created a somewhat vicious circle. Unfortunately, many industries were often established in close proximity to large watercourses because of the ease with which the waste products could be discharged. In addition to the industrial effluents, cities often discharged their wastes into the rivers without much treatment and thus compounded the problem. The result of such developments was gross water pollution near and around centers of population. In medieval Paris, streets were often like open sewers, but the River Seine was clean and one could see fish swimming. Times have changed. Today, the streets of Paris are clean, but the Seine is murky and grey, and one would indeed be fortunate to see any fish.

The demand for water not only involves consideration of its quantity but also its quality. From a planning and management viewpoint, quantity, without any reference to quality, is a meaningless term. Thus, a certain quality of water that can be used for agricultural purposes, may not be used for industrial activities and vice versa. Quantity and quality, however, are closely related. For example, concentration of a pollutant in a stream is directly proportional to the flow. For a fixed amount of pollutant entering a river, the higher the flow, the better is its water quality and vice versa.

During the last decade, quality of water has become an increasingly important dimension in the eyes of the public. Increases in industrialization, agricultural development, urbanization, and per capita income have increased the total demand for water. In addition, especially in developed countries, shorter working hours, and pursuit of a better quality of life, have increased the demand for good quality water for recreation near centers of population. Such diverse developments have given rise to a major dichotomy in the water resources planning process. More and more water is being used for different purposes, which so far have tended to deteriorate the quality of water bodies, and simultaneously there is an increasing demand for good quality water near population centers. The situation is further compounded by discharges into the environment of new chemicals whose effects on humans are unknown, and increasing discharge of other pollutants whose discharge could be neglected earlier because of their low concentration. Examples of such pollutants are toxic substances like arsenic, cadmium, mercury, PCB, and different forms of pesticides, as well as other chemicals that may not be toxic but do produce obnoxious environmental effects, e.g., fertilizers that cause eutrophication.

Water is used for many purposes, chief among which are, domestic, irrigation, hydropower, industrial, navigation, recreation, wildlife habitat, and waste disposal. In addition, water resources management plans often consider flood control and low flow augmentation requirements. The quality and quantity of water required to satisfy each of these demands vary considerably, depending on types of demands, geographical locations, cultural traditions, standard of living, climatic characteristics, and other individual factors.

Policy Options for Sectoral Uses

Policy options for major sectoral uses on a global and regional scale will be briefly examined herein.

Rural and Urban Water Supply.—From a global perspective, the problem can be viewed within two extremes. At one extreme are the highly urbanized cites of advanced industrialized countries, where the vast majority of the population have in-house water connections and sewerage services, backed by adequate infrastructure and institutional arrangements, having access to adequate financing, high-level technology and necessary service personnel. At the other extreme is the rural sector of developing countries, having no service of any kind for either potable water or disposal of excretions. In between these two extremes are the majority of cases, where a certain percentage of the population has access to water supply or sewerage services, or both.

The World Health Organization (WHO) carried out a survey in 1976 on the extent of water supply and sewerage facilities available, at the end of 1975, to developing countries. Based on the survey questionnaire that was returned by 67 developing countries, the following scenario emerges (8). In urban communities, 57% of the population have house connections and another 18% have access to stand-pipes, making a total of 75% (390,000,000 people) that have access to potable water. The situation, of course, is far worse for the rural sector, where only 20% (248,000,000) have reasonable access to safe water. Considering both rural and urban populations together, only 35% (638,000,000) are adequately served.

These, of course, are average figures, and hide the tremendous disparity that exists even within the developing countries. The range of this disparity can be easily seen by considering the community water supply situation in Africa. At the upper range are several countries where more than 90% of the urban population are served by potable water. These are Botswana, Lesotho, and Liberia (all 100%); Mauritius and Senegal (98%); Gambia, Guinea, Ivory Coast, Kenya, Togo, and Zambia (97%); Benin and Egypt (94%); and Morocco and Tunisia (91%). At the bottom end of the scale are the rural populations of many countries, where even 5% do not have access to safe water. These are Burundi, Gabon, Madagascar, and Sierra Leone (1% or less); Kenya (2%); Gambia (3%); and Togo and Zaire (5%). In addition, there are several other countries where data on rural sectors are not available, but they are virtually certain to be less than 5%. These are the Central African Republic, Ethiopia, Guinea, and Lesotho (14).

The goal of the Second Development Decade (DD2) of the United Nations is to extend water availability by 1980 to 100% of urban populations (60% through house connections and 40% through stand-pipes), and 25% of rural populations.

The investment required to reach this goal for Africa has been estimated at \$3.479 billion, \$2.576 billion for urban and \$903,000,000 for rural populations (17), which this writer estimates to be a conservative figure.

Unless a concerted effort is made to meet the DD2 targets, these will continue to remain targets. This is especially true in view of the latest unencouraging picture of Africa that has emerged from the Who survey (8):

> The percentage of the urban population served by house connections in Africa increased only marginally from 33 per cent to 36 per cent from 1970 to 1975. Therefore, a more realistic target of 45 per cent to be achieved by 1980 is now proposed for this region, instead of the global target of 60 per cent already adopted. The percentage of the urban population served by public standposts has actually decreased from 34 per cent to 29 per cent. The proposed new target is 35 per cent, giving a total 1980 urban target of 80 per cent, including both house connections and public standposts.
>
> In the rural sector, the percentage of the population having reasonable access to safe water increased from 13 per cent in 1970 to 21 per cent in 1975. In view of the progress made, a new target of 35 per cent is proposed for attainment by 1980.

If the DD2 targets are met for Africa by 1980, and this target is continued to the year 2000, the number of people without safe water will continue to increase with time. As shown in Table 2, during the period 1970 to 2000, populations served with safe water will increase from 92,000,000–433,500,000, but during the same period, the number of people not served will increase from 188,600,000–379,500,000. This means that unless the countries and the international community revise the DD2 targets upwards after 1980, all the population of Africa will not have access to safe water even by the year 2000 (14).

The quality of water available is of prime importance to human health. Use of potable water will undoubtedly reduce health hazards like cholera, typhoid, infectious hepatitis, and bacillary dysentery. It would further reduce human contacts with sectors of water-borne diseases like schistosomiasis, trypanosomiasis or guinea worm (*Dracunculus Medinensis*). Schistosomiasis will be considered later. With regard to trypanosomiasis, some have estimated that the Gambian sleeping sickness, *Trypanosoma gambiense*, can be reduced by 80% by good water supply schemes (7). While this figure may be somewhat optimistic, there is no doubt that the provision of potable water will reduce the incidence of the dreaded sleeping sickness disease by reducing the exposure of human beings to Tsetse flies during the water collection journey. Similarly, guinea worm infection, which currently affects some 48,000,000 people, chiefly in India and West Africa (12), can also be reduced. Maximum infection occurs during dry periods, when people rely on ponds and other shallow sources. Infection rates of over 50% have been observed in India and Nigeria, and incidences of around 20%–30% are commonly reported (10). The health and economic costs to the communities can be substantially reduced by rational water resources development and management. It would further reduce the water collection journey, mainly of women and children who currently spend up to 5 hr every day collecting the family water requirements (19). The time, thus freed, can be used for learning or productive work.

Water for Agriculture.—Water is essential for agriculture, and if the world food crisis is to be solved, there is no alternative but to increase the total

TABLE 2.—Water Supply Situation in Africa, 1970–2000

	1970			1980			2000		
Population (1)	Total (2)	Served (3)	Not served (4)	Total (5)	Served (6)	Not served (7)	Total (8)	Served (9)	Not served (10)
Urban	70.0	51.2	18.8	108.0	108.0	0	307	307	0
Rural	210.6	40.8	169.8	289.0	72.3	216.7	506.0	126.5	379.5
Total	280.6	92.0	188.6	397.0	180.3	216.7	813.0	433.5	379.5

Note: Population is in millions, and does not include Angola, Equatorial Guniea, Malawi, Mozambique, Namibia, Rwanda, South Africa, Rhodesia, Swaziland, and island countries and territories.

TABLE 3.—Yields of Paddy Rice with Different Degrees of Water Control (18)

Degrees of water control (1)	Material inputs (2)	Location (3)	Average yield for 1971–74, in tons per hectare (4)
No water control (rainfed, uncontrolled flooding)	nil	Laos	1.3
Successive introduction of water control			
Elimination of floods	nil	Kampuchea	1.5
Elimination of drought	low fertilizer application	Burma India Thailand	2.0
Improved water control (irrigation and drainage)	low to medium fertilizer application	Pakistan Vietnam Republic Sri Lanka Malaysia, West	3.0
Sophisticated management practices (mid season-drying)	high fertilizer use + improved seeds and pest control + diversification mechanization	Republic of Korea Japan	5.0 6.0
Experimental conditions			10.0

area under irrigation. The potential benefits to crop production under various degrees of water control, combined with additional material inputs and consistent with cultural practices, are shown in Table 3 (18) in which average output increases, with increases in the degree of overall control.

Cropping intensity is a key element in determining the value of irrigation and benefits to be accrued from such developments. These indices are especially important where arable land is scarce, and thus limits to agricultural production will be determined by crop yield and intensity of cropping. Table 4 shows irrigated areas and cropping intensities for developing market economy countries for 1965 and 1975, and projected values for 1990 (18). The cropping intensity for 1975 ranged from 89 in Latin America to 129 for Asia, and the 1975 values for all four regions are higher than the corresponding figures for 1965.

Agriculture is the largest user of water, and accounts for some 80% of global consumption (comparable figure for the United States is slightly over 40%). In 1975, the total area irrigated in the world amounted to 223,000,000 ha, of which 92,000,000 ha were in developing countries. By 1990 it is estimated that these figures will have risen to 273,000,000 ha, and 119,000,000 ha, respectively (18).

It is however not enough to increase irrigated areas. Effectiveness and efficiency of the supply and distribution system must be maintained. Current estimates indicate that some 86,000,000 ha throughout the world are now in need of improvement. Similar improvement will be necessary on 45,000,000 ha of the developing market economy countries mentioned in Table 5, out of a total of 92,000,000 ha, by 1990. The estimated cost for such improvement, at 1975 prices, will be more than $22.5 billion. In addition, adequate drainage improvement work has to be carried out on 52,400,000 ha (much of it within the 45,000,000 ha of irrigation improvement) at an additional cost of $12.4 billion for the proper control of water and salt balance in the soil. Thus, the total cost of irrigation improvement schemes for the developing market economy countries, up to the year 1990, is expected to be $34.9 billion.

TABLE 4.—Irrigated Land (IL in thousands of hectares) and Cropping Intensities (CI in percentage utilization of Cultivated Area) for Developing Countries, 1965–90 (18)

Region	1965		1975		1990	
	IL (2)	CI (3)	IL (4)	CI (5)	IL (6)	CI (7)
(1)						
Africa	1,882	104	2,610	107	3,570	121
Latin America	9,623	77	11,749	89	14,850	95
Near East	13,329	80	17,105	95	21,400	106
Asia	45,691	119	60,552	129	74,370	142

As more difficult and expensive land and water resources have to be developed in the future than in the past, the cost for new irrigated land (22,200,000 ha) for the same countries mentioned earlier is expected to be over $61 billion, at 1975 prices, giving an approximate average price of $2,800/ha. Provision of adequate drainage is included in the estimate, ranging from $200/ha–$1,000/ha. The recent experience of escalating costs by the World Bank, however, does not bode well for the world. Costs of the magnitude of $5,000/ha–$6,000/ha, for exclusively gravity irrigation systems, are now not exactly uncommon. Thus, if anything, the latest estimates may be somewhat on the conservative side.

The enormity of the task of expanding and maintaining irrigated areas in the developing market economy countries up to the year 1990 is, in itself, staggering, the magnitude of which can be seen from the following summary: (1) 22,200,000 ha of new irrigation; (2) 45,000,000 ha of irrigation improvement; (3) 78,200,000 ha of drainage improvement, including 52,400,000 ha on irrigated land; (4) 440 billion m^3 of additional water; and (5) $97.8 billion of investment at 1975 prices.

These investment costs, it must be realized, do not include costs of new irrigation or improvement of existing irrigation systems outside developing market economy countries. It is estimated that, by 1990, for the rest of the world, new irrigation will have been provided for 23,100,000 ha, 41,300,000 ha of existing irrigation will have been improved, and all these developments will require an additional 528.4×10^9 m^3 of water. The investment cost for this additional part is not available at present.

Water for Industry.—Industry requires a large amount of water. In the United States industrial demand accounts for nearly 40% of the total water requirement, and five major industrial groups—food and kindred products, pulp and paper, chemicals, petroleum, coal products and primary metals—account for slightly more than 85% of total withdrawals. Nearly 60%–80% of water required for industrial processing is for cooling, and need not be of high quality. However, such an enormous discharge of heated water has intensified the problem of thermal pollution, and some studies indicate that the quantity of heat to be dissipated to the aquatic environment will increase ten-fold in the United States during the last three decades of this century (3). The possibility of using thermal discharges for beneficial purposes is not very significant at the present time (5).

There are basically two sets of policy issues with regard to industrial use of water: (1) Use of river systems to dispose of industrial wastes; and (2) the striking difference between the gross amount of water needed for various industrial processes to manufacture the same product. Besides discharging heated water, industry is responsible for the disposal of a whole variety of waste products, depending on the stringency of local pollution control measures. Thus, discharges of mercury to the aquatic environment have created serious problems in Japan and Canada, with the resulting development of the Minimata disease. Similar problems have been observed with cadmium, arsenic, and PCB, as a result of which new rules and regulations are being drafted and updated in different parts of the world.

The second set of policy issues is on the actual use of water by industry. The amount of water required depends on the type of industry, processes being used, availability of water, and legal requirements. The cost of water is rarely a major issue, since it represents 0.005%–2.58% of total manufacturing costs for the five most intensive water using industries mentioned earlier. Seldom does this cost exceed 1%. Within these limits, water requirements vary tremendously for the same industrial group, as shown in Table 5 (15). It is quite common to find some industrial plants requiring five to 40 times more water than other plants manufacturing the same product. The example of soap, given in Table 6, indicates the higher range to be 38 times that of the lower. Such drastic differences in net amounts of water required are due to the use of extensive in-plant recirculation and treatment technologies, as compared to simple once-through flow processes. While water requirement for industrial purposes is high, a small fraction of the water used is actually "consumed," i.e., incorporated into the product, or lost through evaporation or seepage.

According to DD2 targets, industry in developing countries is expected to grow at an annual average of 8%. The Lima Declaration and Plan of Action envisages that their total share of manufacturing output will increase to 25%

TABLE 5.—Water Requirements and Waste Loads for Selected Industries (15)

Industry (1)	Unit (2)	Range of water requirements per unit of product (3)	Pounds of 5-day BOD per 1,000 gal of process water discharge (United States) (4)
Steel	Ton	8,000–61,000	—
Soap	Ton	960–37,000	16.70
Gasoline	Kiloliter	7,000–34,000	2.50
Paperboard	Ton	62,000–376,000	2.21
Sugar beets	Ton	1,800–20,000	9.16

TABLE 6.—Potential and Current Hydropower Developments of Different Continents (15)

Continent (1)	Potential available 95% of time, in thousands of kilowatts (2)	Potential output 95% of time, in millions of kilowatt-hours per year (3)	Present installed capacity, in thousands of kilowatts (4)	Current annual production, in millions of kilowatt-hours per year (5)	4/(2) × 100 (6)
Africa	145,218	1,161,741	8,154	30,168	2.6
Asia	139,288	1,114,305	47,118	198,433	17.8
Europe (including USSR)	102,961	827,676	135,498	505,317	61.0
North America	72,135	577,086	90,210	453,334	78.5
Latin America	81,221	649,763	18,773	91,415	14.1
Oceania	553,810	4,434,468	307,362	1,307,564	29.5

by the year 2000. If these targets are to be met, industrial water requirements for developing countries will increase substantially. Effects of such manifold increases of industrial activities on water will depend on availability of supply and, more importantly, on the standards set by the various administrative bodies on the quality of receiving waters.

Hydroelectric Power.—Hydroelectric power is an important product of water development, and currently accounts for 70%–90% of all electricity generated in Brazil, Canada, Morocco and Norway. With the current energy situation, hydroelectric power makes a great deal of sense in many countries, especially in terms of achieving self-reliance and reducing balance of payments problems due to the importing of energy-producing materials. While capital costs for hydropower developments are quite high, the running costs are minimal. In addition, such developments, if properly planned, could be highly labor-intensive and thus reduce unemployment problems in developing countries.

The potential for hydropower has been exploited to a great extent in North America and Europe, including the USSR, as shown in Table 6 (15). However, there is a vast potential that can be exploited in Africa, Asia, and Latin America. Africa is the most underdeveloped, the current annual production being only 2.6% of the potential output. In sharp contrast to North America, where the share of hydropower in total electricity generated has been steadily declining, and is expected to continue to decline in the future, the situation in Africa—even with the current very low level of development—has been quite the opposite. Thus, the share of hydropower has increased from 22.9% in 1962 to 28.4% in 1974. This trend towards increased emphasis on hydropower generation, in preference to other forms of energy development, is expected to continue in the foreseeable future.

There is a major misconception with regard to hydropower. Many people tend to think that because of economics of scale, all recent developments must be large-scale, like the Aswan in Egupt, Volta in Ghana, or James Bay in Canada. The global situation is somewhat opposite. It is the small and medium-sized potentials that offer the greatest promise in the future.

Social and Environmental Impacts of Water Development

All water resources development projects have social and environmental implications. Whether such implications are acceptable depend very much on individuals concerned, there personal interests, views, and biases. It is quite common to find that a new development project is unacceptable to a certain segment of society, while another segment lobbies hard for its implementation.

The social and environmental implications of water development are many, and the resulting effects often extend much further than the river basin unit itself. The interactions of diverse forces are often so complex that ecologists and environmentalists are hard-pressed to predict overall effects with any degree of certainty. At the present stage of the art, ecologists often find it impossible to convince engineers, economists, and politicians that certain developments are unwise, or of the necessity to spend scarce resources on appropriate remedial measures because of the lack of hard facts or solid scientific evidence. In addition, water resources development has been traditionally within the domain of engineers and, consequently, social and environmental considerations have often been neglected during the planning process. A typical example is the near disaster in the Peace-Athabasca Delta in Canada, due to the construction of the Bennett Dam. Consistent reduction of the level of the lake played havoc with the local flora and fauna, which seriously affected the life-style of the local Treaty Indians and Metis. The social dislocation was quite serious, and the situation was finally rectified at significant economic cost.

The social and environmental impacts of water development can best be considered by dividing the effects on three categories of subsystems: physical, biological, and human.

Physical Subsystem.—Development projects invariably change river and ecosystem regimes, and thus the real question is not whether a dam will affect the environment, but how much change is acceptable to society as a whole, and what countermeasures should be taken to keep the adverse changes to a minimum and within that acceptable range. The Aswan dam in Egypt, one of the major dams of the world, has received its share of criticism for contributing to environmental disruptions. The scheme, built primarily for generating hydropower, has reduced the fish population of the Mediterranean by abruptly breaking the aquatic food chain in the Eastern Mediterranean. Planktons and organic carbons have been reduced by about two-thirds because of the lack of the Nile sediments, which are now trapped in the reservoir created by the dam. It has, in turn, substantially reduced the sardine, scombroid, and crustacean population of the area. Erosion has become a major problem, and the fertility of the Nile valley has been lowered by the lack of sediments. Already a proportion of Egypt's 2,400,000 ha of cultivated land need artificial fertilizer, and it is anticipated that the rest will need it in the near future (2). Salinity in Middle and Upper Egypt is increasing rapidly, and some agronomists have predicted that it will be a very expensive process to rectify the situation. This, however, does not mean that the Aswan dam should never have been built since it is absolutely essential for Egypt's economic development but rather secondary and tertiary effects should have been foreseen to the extent possible, and appropriate measures should have been taken during the planning phase to reduce them to an absolute minimum.

Water development projects to increase irrigated agriculture have also contributed to problems that eventually reduced total food production. Among such problems are deterioration of soil fertility and eventual loss of good agricultural land, due to progressive development of salinity or alkalinity. At one time Pakistan alone was losing 24,280 ha of fertile cropland every year, and currently, nearly 10% of the total Peruvian agriculture is affected by land degradation due to salinization (6). Among other major areas affected by salinization are Helmud Valley in Afghanistan, the Punjab and Indus Valleys in the Indian subcontinent, Mexcali Valley in Northern Mexico, Imperial Valley in California, and the Euphrates and Tigris basins in Syria and Iraq. A study of major modern irrigations schemes in the Punjab shows that seepage from unlined canals has, in the first 10 yr of operation, raised the water table 7 m–9 m above the long-term levels recorded since 1835 (13).

On a global scale approx 20,000,000 km^2 of soil has been destroyed or degraded, which is nearly 35% more than the 14,000,000 km^2–15,000,000 km^2 of arable land currently being used for agriculture (16). Currently 46% of the earth's surface affected by degradation hazards can be directly related to water. These hazards can be roughly estimated as follows: (1) Water erosion, 22%; (2) waterlogging and flood damage, 8%; (3) salinity and alkalinity, 5%; and (4) frost, 11%.

The possibility of inducing earthquakes by construction of large dams is another environmental problem that has not received adequate attention so far. The 1967 Koyna dam disaster in the Indian peninsula, which resulted in a heavy loss of lives and considerable property damage, was due to an earthquake whose epicentre coincided with the dam itself. In general, the seismic disturbances can be traced to the existence of inactive faults and it seems likely that the effect of the added forces contributed by the dam and reservoir liberate orogenic tensions of much greater strength.

Biological Subsystem.—One of the most serious impacts of irrigation developments in the tropical and semitropical regions is the secondary effect of spreading water-borne diseases, and the consequent suffering of millions of human beings and animals. Irrigation schemes have often enhanced and created favorable ecological environments for parasitic and water-borne diseases such as schistosomiasis, liver fluke infections, filariasis, and malaria to flourish. These diseases are not new; e.g., schistosomiasis was known during the Pharaonic times. But unprecedented expansion of perennial irrigation systems has introduced such diseases into previously uncontaminated areas.

Such developments have been conclusively demonstrated in several countries of the world. In Egypt, the replacement of simply primitive irrigation with perennial irrigation has caused a high incidence of both *S. mansoni* and *S. haematobium*; where basin irrigation is still practiced, the incidence is much less. Infection rates in four selected areas, within 3 yr of introduction of perennial irrigation, rose from 10%–44%, 7%–50%, 11%–64% and 2%–75%. The life expectancy of males and females in heavily infected areas is estimated to be 27 yr and 25 yr, respectively. In Sudan, with the introduction of perennial irrigation to 900,000 acres under the Gezira Scheme, the incidence of blood fluke rose greatly. It also increased the incidence of flukes in cattle and sheep. In Kenya, Lake Victoria is hyperendemic for schistosomiasis. *S. mansoni* infection in school children is up to 100% in areas associated with irrigation schemes. In Transvaal, South Africa, the *S. mansoni* infection rate in European farms was 68.5% compared with only 33.5% in the reserves, because the former had irrigation. Similarly, in some countries in the Far East, irrigation has not only increased schistosomiasis, but also liver fluke infections, eosinophilic meningitis, and bancroft filariasis.

Human Subsystem.—Naturally all the effects mentioned earlier have direct impacts on human beings, but the distinction could be made that such developments at first contribute to environmental and ecological changes, which, in turn, affect the human subsystem. Under the present subheading only the direct impacts will be considered.

Many of the large dams have contributed to the displacement of local inhabitants, which in certain cases has resulted in serious problems. Thus, the Kariba dam on the Zambesi displaced approx 57,000 Tonga tribesmen, who had to pay a great price for this progress. What the planners, often from outside Africa, did not realize was the enormously complex relationship between the African tribes and their land. The resettlement program for the Tonga tribesmen left much to be desired; not only did they suffer great cultural shocks when thrust into communities as different from their own as theirs are from Great Britain, but also it took 2 yr to clear sufficient land to meet their subsistence needs. The government had to step in to avert famine and very serious hardships and, ironically, this good-intentioned step was probably the most destructive. The food distribution centers also became transmission sites for the dreaded sleeping sickness disease.

This, however, has not been a unique occurrence. Approximately 100,000 people had to be relocated for the Aswan High dam without adequate planning, and the World Food Program had to rush in famine relief for the Nubians. Similarly 80,000 people had to be relocated because of the Volta dam in Ghana, and the World Food Program had to step in again to avoid a major catastrophe (4).

Politics of Water

Politics and water are closely interconnected. Invariably the final decision to develop a water resources scheme is very much a part of the political process. The planners and experts do not make the final decision, nor do they pass legislative actions that directly or indirectly affect the planning process. They do, however, where possible, point out the cost-effectiveness of the various alternative courses of action, and this information helps the decision-makers arrive at responsible decisions. Thus, the real decision-making lies with the politicians. In fact, water resources planning, project authorization, and level of funding are all essentially political processes. Thus, *the planners decide the feasibility of the project, and politics decides the implementation of the plan.* It can be argued that, irrespective of the technical feasibility, economic profitability, and social desirability of a project, it can happen only if effective political leaders can champion its cause in the right way at the right time.

There are other important political dimensions of water management. In countries like the United States, Canada, the Federal Republic of Germany, or India, there is a continuing scope for conflict between the two levels of government—federal and provincial. For example, in Canada, water is under the provincial jurisdiction (except for international waters), but the Federal Government maintains a strong interest in the area. Parts of the Canada Water Act have never been implemented because of the thorny question of jurisdiction over water. Many of the Canadian pollution control regulations are based on the fact that fish is under Federal jurisdiction, and accordingly harmful discharges that affect fish can be controlled or prohibited by Federal regulations.

Conflicts between neighboring states over water resources development projects occur quite frequently in India. The most common unit for water development plans has been the river basins, many of which fall in two or more adjacent states. Ideally, it would be desirable to develop an optimal water utilization plan for a specific river basin, and then let the states share the profits and costs, on some equitable basis. This has seldom worked. Distrust and suspicion between states, determination by one or two to get more than their fair share of the benefits for less than their fair share of the costs, and long-standing hostilities over other issues, seriously complicate the negotiation process to develop mutually advantageous plans. The question of language further complicates the issue, since very few neighboring states in India have the same common language. In addition, because of the mutual distrust, very seldom is available and complete technical, economic, and social information willingly shared. Thus, it is quite common to find that both states are collecting the same information separately, and carrying out individual assessments. Neither is it uncommon to find long and protracted negotiations between states, often hostile, and the parties concerned cannot come to an agreement at the end. This often necessitates setting up a tribunal, at great expense, and all these events, not only delay the development process up to anywhere in the region of 10 yr, but also ensure the evolution of suboptimal plans.

While the problem of resolution of interstate conflicts within a country is not satisfactory, the situation is far worse for international river basins. At least there are some infrastructural arrangements and precedents to solve interstate conflicts in a country, but these are virtually nonexistent for international problems. One recent report concludes (11):

> International river issues often entail conflict between public international morality, as expressed by international law, and Basin State self-interest. There are few sanctions to apply against those countries which disregard internationally accepted rules of behaviour and accepted principles of sharing, except the disapproval of the international community.

Because of such a sad state of affairs it is not surprising to find that major conflicts have developed between several countries in recent years, which have severely strained their mutual relationships. Many such conflicts are yet to be solved. Typical examples of such current conflicts over shared water resources are between India and Bangladesh, Iraq and Syria, and Brazil and Argentina. As more and more water is required by all countries for further development of urban, rural, agricultural, industrial, and other sectors, such conflicts between countries over shared water resources will continue to increase, at least for the next decade.

This poses a major question: will enough water be available for future developments in the world? Some poeple have already suggested that water, rather than land, could be the major constraint for increasing world food production during the final years of this century, but this is difficult to justify at present.

Several studies are now available that assess the world water situation on regional and global bases up to the year 2000, and one to the year 2060 (9). While specific figures vary somewhat, general conclusions are remarkably similar, and can be summarized as follows:

	1973	2000
Estimated population $\times 10^6$	3,860	6,500
Potentially available water per person per year, in cubic meters	10,400	6,200
Prospective demand per person per year, in cubic meters	1,000	1,000
Ratio of 2:3	10	6

This indicates that even without extensive conservation and recycling processes, only one-sixth of the potentially available water will be used by the year 2000. It should be pointed out that minimum water requirements, according to the WHO estimate, are 150 l/person/day for sanitary reasons, which works out to be 54 m^3/person/year. The figure of 1,000 m^3 of water use per person per year includes a much higher water use than recommended by WHO, and water required for other sectoral uses.

What then is the problem of water availability in the future? It is basically a problem of rational management. Water resources of different regions, on which adequate data are not available, have to be assessed and, based on such assessments, long-term development and management plans have to be established. Water and land should not appear as constraints in the overall planning process of a country; rather, realistic development and production targets should be matched as to their availability.

If the current trends continue, water problems will appear in certain regions of the world. This, however, need not be the case, since such shortages can be significantly alleviated by more efficient use of water. More emphasis has to be placed on demand management rather than on supply management, as has generally been the case so far. The concept of supply management, which considers an increase in supply as virtually the only management choice, will gradually disappear—except perhaps for a few areas exceptionally well-endowed with water resources or experiencing relatively low levels of demands.

There is considerable scope for improving the efficiency of water use in virtually every country and in every sector. The agricultural sector, which accounts for nearly 80% of the global water consumption, is probably the most inefficient sector, thus, where most improvements could be made. Existing efficiencies of irrigation systems are often so low that they do not by any means reflect the real water requirements for crop production. In fact, in many instances present water consumption patterns are not only wasteful but are also definitely harmful. From some of our recent studies of several developing countries, it is quite common to find that 80%–85% of water delivered to the head gate of the main canal never reaches the crop. Thus, projection of future global water requirements based on present day "demands," is highly misleading and the time has come to ask whether such analyses have any technical value. Water consumption per unit area has been decreasing slowly during the recent past, but it must be admitted that it is still far from the real value.

Despite this sad situation, there is a considerable reluctance in many countries to allocate resources to improve the situation drastically. The emphasis is much more on construction of new dams and projects than to improve the efficiency of the present irrigation systems. Naturally, such policies do not make sense for several reasons. Firstly, the efficiency of new schemes deteriorate very fast without appropriate maintenance measures. Secondly, it is cheaper to rehabilitate existing schemes than to construct new ones. As a rule more water is available per unit cost from the improvement of existing systems than from building new projects. Finally, the time required to plan and build new schemes is significantly longer.

Despite these advantages, one may legitimately ask why has the rehabilitation of existing schemes not received the priority it deserves? The answer is complex but, at the risk of simplification, the following explanation is offered. An analysis of past priorities and the actions taken in many countries indicate that agriculture (and thus irrigation) has not received the importance it deserves. Many large new dams have been built with the main objective of providing cheap power for rapid industrialization of the country; irrigation development, and especially improvement, took a back seat. Also, several developing countries, at least in the past, opted for prestigious projects such as large dams, football stadiums, nuclear power plants, or airports, rather than putting through critically necessary land reforms or irrigation improvement. The reason for such a course of action is not difficult to discern. A brand new prestigious structure has "sex appeal"; politicians can make political hay out of it. Such projects have also served the donor countries well, both in terms of propaganda value and opportunist motives; they seem to be often more interested in financing large and visible structural projects, irrespective of their immediate relevance to the recipient country's national needs. Such attitudes seem to be changing, but progress is slow.

Efficiency of water use can also be significantly improved in industrial and domestic sectors. In some countries, like Canada, where industry claims nearly 84% of total withdrawal (comparative figure for India is 1%), extensive recycling and process changes, especially for new industry, will bring water requirements towards the lower range of the values shown in Table 5. Use of existing knowledge, supported by more rational water pricing structures, can reduce these values even further.

There is considerable scope for water conservation in the domestic water supply sector as well. In developed countries, the original principle objectives of potable water supply, drinking and washing, have long been relegated to secondary roles in terms of the quantity of water used. The major uses are now for lawn watering (it may account for 50% of water used in middle and upper income nieghborhoods), washing machines, dish washers, and car washing. Extremely high levels of loss in the distribution systems, especially in the developing countries, is a major problem. In certain urban areas such leakage losses could account for one-half of the total water pumped. For a city like Calcutta, that has an acute water shortage problem, no one really knows how much potable water is lost due to such leakages. Further problems are created due to lack of service personnel and proper maintenance practices. Thus, 70% of hand pumps installed are out of order in many parts of the world, and constantly running standpipes are now quite common sights in many rural and urban centers of the developing world.

To sum up, the major problem in the area of water resources is not one of the Malthusian specter of impending scarcity, but one of instituting more rational and better management practices. What is urgently needed is the formulation of long-term policies that reflect changing water demand patterns consistent with efficient use, and better appreciation of the social and environmental effects, with a view to minimize the adverse impacts. In fact, one can argue that the time has come when the emphasis should shift to comprehensive land and water planning, treating land and water as an integrated and interacting unit, rather than water planning *per se*.

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