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Water Development and the Environment

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ABSTRACT *Water use since the dawn of human history has increased steadily, and the current trend is no exception. For many reasons it would be a difficult task to alleviate the water crisis significantly in many parts of the world within a reasonable timeframe. Environmental and social aspects of water development have become important factors to consider in recent decades, but many serious methodological and operational constraints have to be overcome before environmentally-sound water management can become a reality. There are many fundamental problems with the environmental assessment procedures. This paper provides a comprehensive analysis of the present status of operationalizing the concept of sustainable water development in the real world.*

Introduction

Throughout history water has always been considered to be a critical natural resource on which mankind's very survival depends. Human history, from the earliest evolution of the human beings around the lake shores of northern Kenya to the development of the main civilizations on the banks of certain major rivers, can generally be considered to be water-centred. The early important civilizations developed and flourished on the banks of major rivers like the Nile, Euphrates, Tigris and Indus. In fact, the history of mankind can be written in terms of human interactions and interrelations with water (Biswas, 1970).

It is not difficult to realize why civilizations and habitats often developed along the banks of several strategically important rivers. Easy availability of water for drinking, farming and transportation were important requirements for survival. Human survival and welfare generally depended on regular availability and control of water. Floods and droughts inflicted major pains, often contributing to the deaths of human beings and livestock. Because water played a very important role, when Rishi Narada of India, probably the earliest leading authority on politics and who lived many centuries before the Christian era, met the great Pandava King, Yuddhistira, his greeting was water-centred because of its importance: "l hope your realm has reservoirs that are large and full of water, located in different parts of the land, so that agriculture does not depend on the caprice of the Rain God." Proper water control meant that the ravages due to droughts and subsequent famines could be significantly reduced.

Somewhat later, again in India, fiscal policies were often linked with water. Because of the critical importance of water availability to ensure a good agricultural harvest in a semi-arid country, the eminent Indian statesman Kautilya discussed the importance of rainfall for the economic and social

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well-being of the nation. In his epic *Arthasastra* (science of politics and administration), which was probably written towards the end of the 4th century BC, Kautilya discussed the organizations of a network of raingauges throughout the country. The network was considered important, indeed essential, for two very good reasons. First, land taxes were based on the amounts of rainfall received each year, since rainfalls were considered to be proxies for agricultural production, and hence the incomes of the farmers. Second, good information on rainfall was essential for farmers to plant crops, and thus maximize agricultural production on which national security and well-being depended.

Similarly, in Egypt, a country which the historian Herodotus considered to be a 'gift' of the River Nile, the flood levels of the river have been noted for some 5000 years. Agricultural production, and therefore the very survival of the ancient Egyptians, depended on the annual inundation of the Nile, and hence its flood levels were considered to be an important indicator of the next agricultural harvest and thus their future welfare.

The very fact that water control and management received such emphasis in countries as far away as India or Egypt some 3 to 5 millennia ago indicates clearly that the importance of this resource in the development process of the arid and semi-arid regions was recognized in different parts of the world from very ancient times. In spite of very significant technological development, this situation has not changed much over the past several millennia, especially for the arid and semi-arid countries of the world. On the contrary, the importance and relevance of water in such regions, if anything, has increased in recent decades, and it is likely to continue to do so in the foreseeable future.

Total Global Water Use

Total global water use has increased steadily throughout recorded history, and the trends observed in the 20th century have been no exception. However, a closer and detailed analysis of total global water use in recent decades indicates two significant differences compared with the trends observed in earlier times, which are worth noting. First, the rates of increase in total global water use have accelerated remarkably in the 20th century compared with earlier periods. The change is even more pronounced if the post-1940 period (Figure 1) is considered. Currently there are no visible indications that this increase in the rate of water use is likely to level off in the near future. Since water is a limited resource, clearly such high rates of growth cannot be sustained indefinitely in the future. At some stage, and most likely within the next one to four decades, total water uses in different parts of the world are likely to level off owing to physical, technical, economic and environmental constraints, first in certain individual countries and then globally.

The second factor worth noting is the extraordinarily high annual global water use at present. At nearly 5000 km^3 per annum, the current level of water use is vast compared with the past requirements, and total demand is still increasing rapidly.

Figure 1 also indicates that total global water use is likely to have increased some tenfold during the 20th century. It should, however, be noted that the estimates of global water use, as shown in Figure 1, should be taken as indicative rather than definitive because of the paucity of reliable data on total water uses at national levels even for advanced industrialized countries such as the United States or the Federal Republic of Germany. The situation is even worse for major

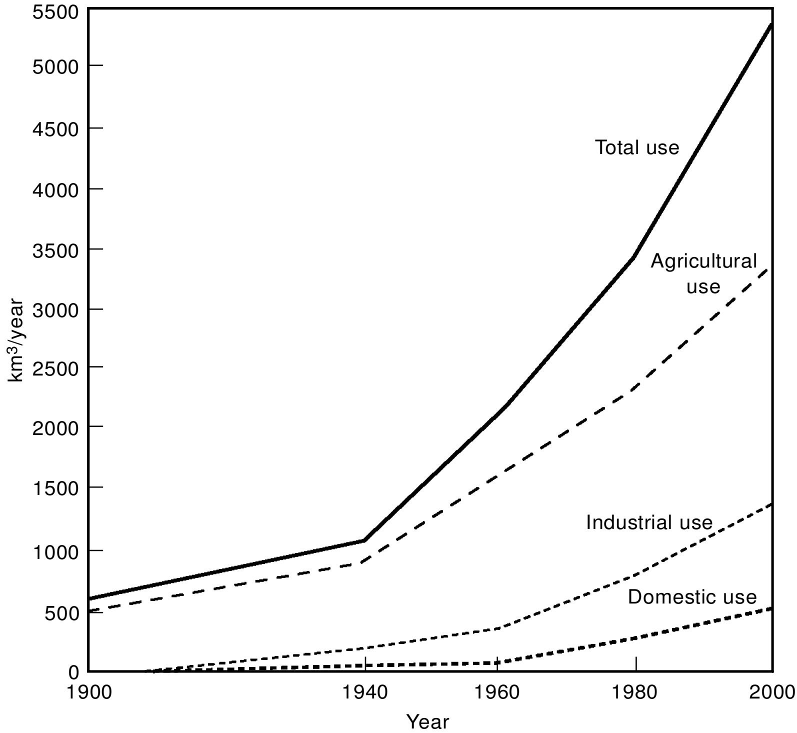

Figure 1. Expected increase in total water use during the 20th century.

water-consuming developing countries like China or India, where the quality of data on total national water uses leaves much to be desired. Thus, all data available at present on total global water use should be considered to be gross estimates, and therefore only indicative at best.

It is often generally assumed, somewhat erroneously, that the increase in global water use has paralleled population growth. While population growth is unquestionably an important factor in increasing total global water requirements, there are other contributory factors as well, some of which will be discussed later in the present paper. Suffice it to note at present the fact that the total growth rate in water use has been significantly higher than the population growth rate in the present century. In fact, if recent decades are considered, total global water use has grown almost three times faster than the population growth rate. If these trends continue well into the future, a doubling of the world's population would mean a six-fold increase in total global water requirements (Falkenmark & Biswas, 1995). This would most likely be an unsustainable situation on a long-term basis.

The very high rate of increase witnessed in the recent past does not axiomatically mean that total global water use will continue to rise at this rate indefinitely well into the distant future. It is likely that as water requirements escalate, and as the prices charged for water for all uses gradually increase so as to approach the real cost of obtaining and managing that resource, water use practices will become increasingly more efficient in all sectors in most parts of the world. This, in all probability, would decrease demand growth rates by encouraging water conservation practices. Accordingly, there is a high probability that during the earlier part of the 21st century there will be certain fundamental structural changes which would significantly alter the growth trends witnessed in the past. Similar structural changes were witnessed in the early 1970s in the energy sector, when higher energy prices significantly altered its demand and use patterns fundamentally on a long-term basis by making the sector increasingly efficient in terms of production and use. There is no reason to believe that the water sector would behave any differently compared with the energy sector, if water prices increased perceptibly in the future to reflect their true cost.

Equally, it is highly unlikely that the general pattern of various types of water uses would remain somewhat similar to what they are at present. Past experiences indicate that as the structure of economic activities changes with time in different countries, and as it becomes more expensive and difficult to develop new sources of water and thus continually increase the supply of water available, continuing trade-offs occur between the various uses. This pattern is most likely to continue in the future. For example, on a global basis, agriculture accounted for nearly 90% of all water used in 1900. By the year 2000, its share is expected to decline to around 62%, that is a 28% reduction in 100 years. An analysis of all the current trends indicates that the percentage share of agricultural water use is likely to continue to erode steadily well into the next century, even though more and more food has to be produced to feed an ever-expanding global population.

In contrast, for the industrial water use sector, where value-added is much higher than in agriculture, and in which the process of industrialization started to accelerate significantly during the post-1940 period in many parts of the world, the percentage share of total industrial water use in the 20th century is expected to increase nearly fourfold, from 6% to about 24%. In all probability, this trend is likely to continue well into the 21st century.

The above figures are global averages. This means there are often significant differences in water use patterns between different countries, depending upon their respective levels of economic development, prevailing physical and climatic conditions, social norms, environmental requirements and other relevant factors. For example, in major agrarian developing countries like China or India, agriculture still accounts for more than 85% of all water used. Corresponding figures for industrialized countries show Japan at around 60%, the United States 42% and the United Kingdom 3%.

As water requirements have increased with time, countries have progressively increased supply by steadily increasing the extent of utilization of their available resources. Figure 2 shows the overall macro picture of the extent of water available that has been exploited in the various continents over time during the present century. Current estimates indicate that the ratio of water consumption to water availability in Asia, which has the highest volume of water requirements of all the continents at present, is likely to reach 22% by the year 2000. The growth rate in water requirements in Asia during recent decades has been phenomenal, since as recently as 1960 the corresponding ratio was only about 6%. Furthermore, at a ratio of 22%, the extent of available water utilization in Asia would be the highest among all the continents, and would be nearly twice the global average (Biswas, 1994).

Figure 2 also indicates that the extent of water utilization in Europe has closely shadowed that of Asia during the post-1940 period. However, the total volume of water used in Europe is significantly less than that of Asia, and thus the problem faced in Asia is unquestionably that of a higher order of magnitude.

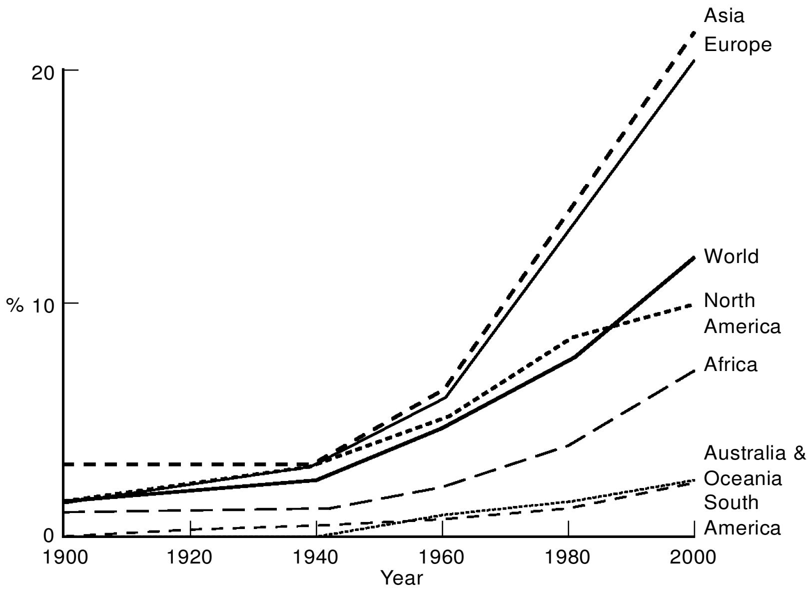

Figure 2. Dynamic of ratio of water consumption to water resources.

The fundamental question that cannot yet be answered is to what extent water available in a country could be developed economically with appropriate social and environmental safeguards. At present even appropriate methodologies to carry out such analyses with a reasonable degree of accuracy are still lacking. This is an area that will need increasing attention in the future.

As demands for all types of traditional water uses (domestic, industrial and agricultural) grow, the signs of conflicts between the various types of beneficiaries are becoming increasingly evident in most parts of the world. For example, in the western United States the conflict between urban-industrial users and the agricultural sector is becoming ever more fierce. In the Philippines, the domestic and hydropower generation demands for Metro Manila are creating water shortages for irrigation in central Luzon. In India, increasing water demands for the city of Hyderabad are having an adverse impact on irrigation of neighbouring areas. Similarly, in Indonesia, municipal water requirements for the Jakarta region and Surabaya are now in direct conflict with the existing irrigation arrangements for the surrounding areas. In South Africa, agricultural and domestic water requirements upstream are reducing flows of the rivers passing through the Kruger National Park, as a result of which many adverse environmental impacts can already be observed in this world-famous protected area.

While conflicts between various water uses are increasing, analysts so far have generally not considered the flow rates necessary to preserve the ecosystems of the areas around the rivers. At present, adequate knowledge is not available on how to estimate what percentage of flow is necessary for the ecosystem needs of any river. As the societal concern for environmental conservation continues to increase, it is highly likely that ecosystem needs will become a legitimate form of water use during the early part of the 21st century. If so, the conflicts between all the various water uses can only intensify further.

Water Crisis

As all the different water uses have continued to increase, many countries, especially those that are located in arid and semi-arid regions, have started to face crises, though the magnitude, intensity and the extent of the crisis may vary from one country to another, or even within the same country, and also over time. Not surprisingly, the responses of individual countries, or even states or provinces within a large country, to reduce the impacts of that crisis could vary as well.

There are many reasons, which are often interrelated, that could make a water crisis more pervasive in different parts of the world in the coming years. Only five major factors will be discussed.

First, it is an unfortunate fact that the amount of freshwater that is available to any country on a long-term basis is nearly constant for all practical purposes. Because of technical and economic considerations, only a certain percentage of the total water available can be used at any specific time. Even though technological advances have steadily increased the percentage of water available to any country that could be utilized economically, the fact still remains that a very high percentage of water will continue to remain undeveloped due to adverse economic conditions and environmental constraints. There is no question that extensive recycling and reuse can continue to increase the total volume of water that could be made usable in all countries over a period of time. However, total recycling or reuse is neither technically possible not economically feasible. Equally, only limited knowledge is currently available as to how many times water can be reused without serious deterioration of its quality and attendant ecosystems degradation.

It should also be noted that the total volume of freshwater that can be used in any country cannot generally be significantly increased by artificial transportation over long distances. Low unit price of water means that, unlike oil, it is generally not economic to transport water from one country to another. Furthermore, in contrast to the export of all other natural resources, even discussion of water export from a surplus to a deficient country generally generates strong public emotions. Even for two neighbouring countries like Canada and the United States that have had historically good diplomatic and economic relations with each other, the issue of export of water from Canada, a highly water surplus country, to the United States has always become so emotional and politically charged that successive Canadian governments have consistently considered even the technical analysis and discussions of possible water export unacceptable. The situation is no different in other parts of the world.

Water availability cannot be increased by desalination to any significant extent for economic reasons. Currently desalination can be a feasible option only under certain specific conditions and in very limited locations.

Second, water is an essential requirement for all human activities, ranging from drinking to agricultural production, and industrial development to all forms of large-scale energy generation. Accordingly, as the total global population increases, so do the aggregated human activities, which in turn increase water requirements. This contributes to two contradictory trends which make the water management process yet more complex. On the one hand a country's water requirements increase steadily owing to higher levels of human activities, and on the other hand per capita water available declines steadily since the total amount of freshwater available is limited. This is shown for a few select countries in Table 1.

Table 1. Population and per capita water availability for selected countries

	Population				Annual renewable freshwater available (km^3)	Per capita freshwater availability (1000 m^3)		
	Millions			Growth rate % per annum 1985–94				
	1994	2025	2050			1994	2025	2050
Argentina	34.2	46.1	53.1	1.4	994	29.06	21.56	18.71
Bangladesh	117.8	196.1	238.5	2.0	2357	20.00	12.02	9.88
Brazil	150.1	230.3	264.3	1.8	6950	46.30	30.18	26.30
Canada	29.1	38.3	39.9	1.3	2901	99.69	75.74	72.70
China	1190.9	1526.1	1606.0	1.4	2800	2.35	1.83	1.74
Egypt	57.6	97.3	117.4	2.0	59	1.02	0.60	0.50
India	913.6	1392.1	1639.1	2.0	2085	2.28	1.50	1.27
Indonesia	189.9	275.6	318.8	1.6	2530	13.32	9.17	7.94
Japan	124.8	121.6	110.0	0.4	547	4.38	4.50	4.97
Mexico	91.9	136.6	161.4	2.2	357	3.88	2.61	2.21
Nigeria	107.9	238.4	338.5	2.9	308	2.87	1.29	0.91
Turkey	60.8	90.9	106.3	2.1	203	3.34	2.23	1.91
UK	58.1	61.5	61.6	0.3	120	2.07	1.95	1.95
USA	260.6	331.2	349.0	1.0	2478	9.51	7.48	7.10

Note: 1994 population estimates and population growth rates are from the *World Bank Atlas* (1996); population projections (medium variant) for 2025 and 2050 are from the United Nations (1994).

Table 1 shows that for a country like Nigeria, whose population is expected to increase significantly from about 108 million in 1994 to some 339 million by the year 2050, per capita water availability is likely to decline from 2870 m^3/year to only 910 m^3/year by 2050. While this is likely to be the general global trend in the future, there would be some exceptions in a few countries like Japan, whose total population is likely to decline modestly during this period.

While water planners have generally considered higher water requirements in the future due to increasing population numbers, another associated issue has been mostly ignored. This is the established fact that, as the standard of living increases, lifestyles of people change and this increases per capita water requirements. For example, for England and Wales, if the present trends continue, total water requirements by the year 2020 are expected to increase by more than 20%, even though the increase in population is likely to be very modest. Lifestyle changes, primarily in terms of significant increases in dishwashers and washing machines, are primarily expected to account for this increase.

Similarly, per capita water use in Japan has exactly doubled in the 26-year period between 1965 and 1991, from 169 to 338 litres/capita/day (Figure 3). This increase in per capita water requirements is an important consideration in estimating future water needs for the planners of developing countries, whose water demands are accelerating at a very rapid and alarming rate. This aspect has thus far received very limited attention from both the countries concerned as well as the appropriate international organizations.

The steady increase in per capita water requirements, especially in developing countries, can no longer be ignored. As far as a country like India is concerned, around 10% of its current population can be considered to have a middle-class standard of living. Accordingly their water requirements are significantly higher than the rest of the country's population. While 10% of India's population may not seem much, as an absolute number it is more than 95 million, which is

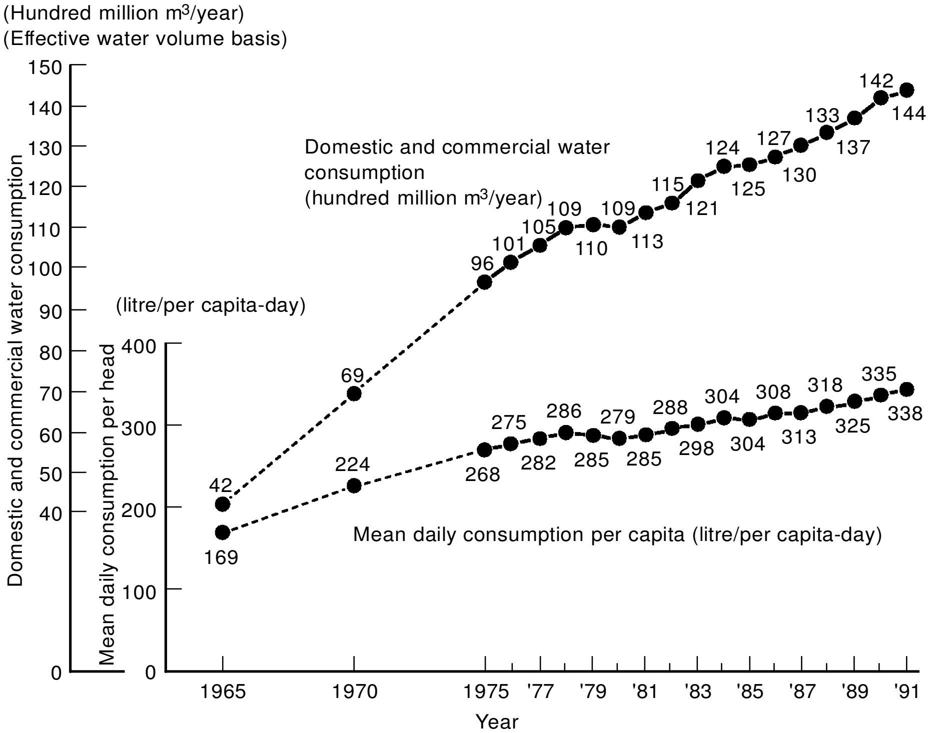

Figure 3. Annual domestic and commercial and daily per capita water consumption in Japan, 1965–91. *Source:* National Land Agency.

equivalent to more than 1.5 times the total population of the United Kingdom or around 75% of the population of Japan. Furthermore, because of high population growth and rapid economic development, the situation in India can only become even more serious and complex in terms of future water requirements. Since the total number of affluent people in India is expected to rise rapidly, this means that by the year 2025, the figure could be equivalent to 2.35 times the Japanese population, and their water requirements would increasingly become closer to the Japanese requirements. Hence, increase in per capita water demand in developing countries because of the improved lifestyles can no longer be ignored for future efficient water management.

Third, throughout the world, for the most part all easily exploitable sources of water have already been developed or are currently in the process of development. This means that the costs of developing new water sources in the future are likely to be significantly higher in real terms than has been observed in the past. For example, the average cost of providing storage for each m^3/sec of river flow in Japan has increased nearly fourfold during the past 10 years. Approximately 20% of this additional cost can be attributed to new social and environmental requirements which were not present earlier. The major part of the additional cost, around 80%, is due to the fact that the new projects are inherently more complex techno-economically, and thus significantly more expensive to construct. Similarly, World Bank (1992) analyses of domestic water supply projects from various developing countries indicate that the cost of development of each cubic metre of water for the next generation of projects is

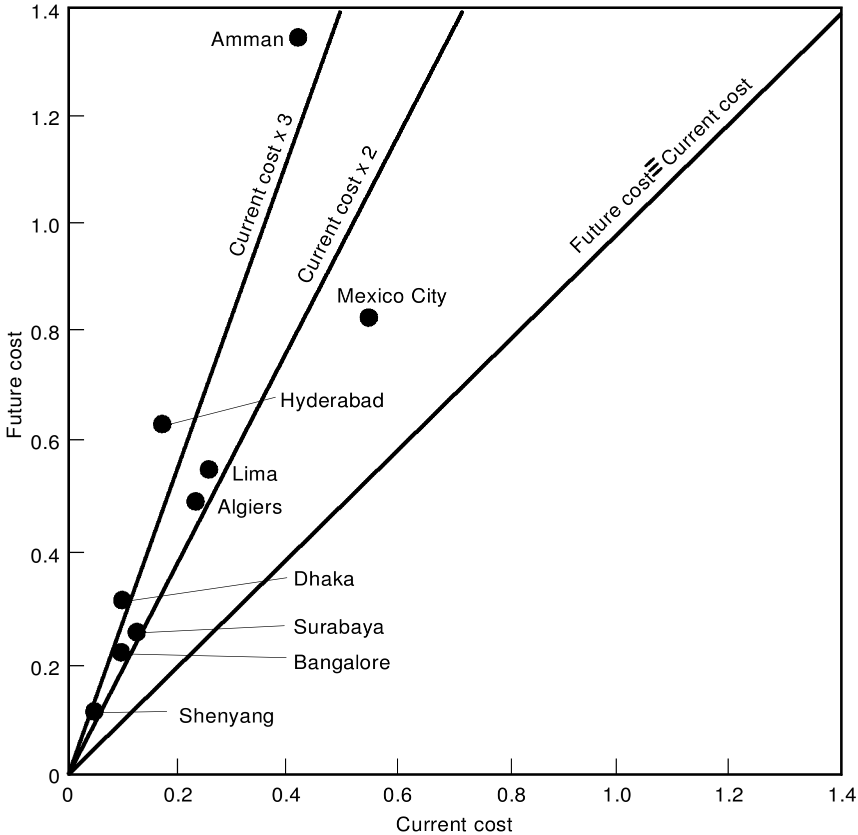

Figure 4. Current and projected future water costs per m^3 (US$1988).

often two to three times higher than that of the present generation. Figure 4 shows the current and projected costs in 1988 constant dollars for supplying each cubic metre of water to many major urban centres of the developing world.

The significant increase in the construction costs of future water development projects is a factor that has still not been realistically considered by planners in almost all parts of the world. This is likely to be an especially important factor for nearly all the developing countries, which are already facing high levels of external and internal debts. Accordingly, the amount of new investment funds that may be available to them in the future from different sources for the construction of new water projects is likely to be somewhat restricted. Furthermore, intersectoral as well as intrasectoral competition for the available funds will be more intense in the future. All these economic issues are likely to have an adverse impact on the implementation and management of the next and later generations of water projects. A realistic assessment has to be that most new water projects will experience major delays in implementation, certainly much greater than their planners generally anticipate at present. Since water demands will increase steadily in the future, but there are likely to be considerable delays in constructing new projects, the magnitude of the total water crisis is likely to be further exacerbated, at least in the near to medium term.

Fourth, as human activities have increased, so have effluent discharges to the environment, which have contaminated many currently used sources of surface and groundwater. The degree of contamination may vary from place to place, but the problem is serious in most parts of the world. Among the many contaminants are untreated or partially treated sewage, and all types of industrial effluents and agricultural chemicals. As comprehensive global water-quality monitoring programmes simply do not exist at present, a clear picture of global water contamination, and the extent to which water quality has been impaired for different purposes, simply is not available at present. However, on the basis of limited and anecdotal information available, it can be said that the problem is often serious near centres of dense population, especially for comparatively closed systems like groundwater and lakes, and for stretches of rivers near such centres.

It should be noted that once water is contaminated, its decontamination may not be an easy or economic process. For example, cost-effective technologies currently simply do not exist for removing many pollutants such as nitrates, or contaminated lake sediments.

Groundwater is extensively used as an important source of domestic water supply, ranging from 73% for the former Federal Republic of Germany, to 70% in The Netherlands and 30% in Great Britain. In the United States, groundwater is the primary source of drinking water for over 90% of the rural population and 50% of the total population. Increased contamination could mean that some of the groundwater sources may no longer be appropriate for all types of municipal uses. For example, in the US state of Nebraska alone, there are at present 38 towns where concentrations of nitrates in domestic water supply are so high that babies under the age of six months have to be given bottled water for health reasons (Biswas, 1993). Thus, increasing contamination would further accelerate the difficulty of ensuring that an adequate quantity and quality of water is available for municipal uses in the future.

Fifth, during the past two decades, the various environmental and social impacts of water development projects have gradually become increasingly important issues. While the importance of environmentally sound water development can no longer be questioned, and has to be considered to be an integral component of any long-term sustainable development strategy, the fact remains that the environmental analyses must be based on proven and scientific analyses and reliable data. However, it has not been uncommon to find in recent years that objective and scientific analyses have been replaced by unsubstantiated and untested hypotheses, short-term political expediency and emotional arguments. All these have not helped in the development of an objective and integrated framework within which assessment of the environmental and social impacts of the proposed water projects could be reliably carried out. This aspect will be discussed further later.

Of all types of major infrastructure development projects, opposition to large water development projects has been generally more intensive and more widespread globally compared with other types of projects. In certain western countries, where for the most part the major water development projects have already been constructed, and additional projects are not considered essential, opposition to the construction of new water projects in other parts of the world is often widespread. Major international funding organizations like the World Bank are currently under considerable political pressure from some of their major donors not to support large-scale water development projects in different parts of the world.

The very noticeable decline in the donors' interest in providing investment funds for major water development projects in developing countries and the high capital requirements for new projects mean that there are likely to be significant delays in the implementation timetable of the future projects. Unfortunately, these delays are yet to be recognized by the various national planning agencies, which means that additional new sources of water will not be available in the future as expected at present. This complacency, in all likelihood, will make future water crises even more serious than is expected at present.

The above five and other associated reasons mean that it will be an extremely difficult task to alleviate future water crisis in many parts of the world in any significant manner within any reasonable timeframe. The technological problems may prove to be comparatively easy to solve; the real complex issues are likely to be in the environmental, social, political and institutional arenas. Herein will probably lie the most difficult water-related challenge of the 21st century. The future welfare of millions of people all over the world will depend upon how the water profession meets this challenge of providing an adequate quantity of water of the right quality in an environmentally and socially acceptable way. This will not be an easy task.

Environment and Water Management

Interest in the environmental impacts of economic development started to become an increasingly important consideration in the late 1960s, first in the USA and later in the rest of the world. Public interest in the various environmental issues peaked around 1972–73, and then started to decline steadily for much of the next decade and a half. The overall interest in the various environmental issues was rekindled again in the late 1980s. It became a key political issue in the early 1990s, and probably reached its peak with the United Nations Conference on Environment and Development, which was convened in Rio de Janeiro, Brazil, in June 1992. The current anecdotal information available indicates that interest has declined somewhat since the 1992 peak. While it is likely that the public and thus political interest in the environment will ebb and flow with time, it is equally likely that a certain minimum threshold of interest will be maintained on a permanent basis.

Interest in the environmental aspects of water development has also fluctuated with time during the past three decades. Not surprisingly this has paralleled general overall interest in environmental issues. While forecasting future developments is always a hazardous task, one can say with almost total certainty that the days when water development projects could be planned, designed, constructed and managed without explicit consideration of the environmental and social factors are now history in nearly all parts of the world. In some countries, a certain amount of lip-service only is still being given to environmental protection. However, current indications are that it is highly likely that formal and real consideration of environmental factors in such countries will become a reality in the near future.

This, however, does not mean that the environmental impacts of water projects were completely neglected in the past. Closer analysis indicates that many specific environmental and social impacts have always been considered, among which are development of salinity and waterlogging due to inappropriate irrigation management practices, and resettlement of people because of inundation caused by newly constructed reservoirs. However, comprehensive and integrated environmental and social impact studies were not formerly carried out, nor were the study results properly implemented.

It should be noted that the environmental issues associated with water development projects were treated no differently in the past compared with all other types of infrastructural development activities. As societal interest in environmental issues accelerated, so too did concern with the environmental impacts of large development projects. It is a fact that no comprehensive environmental and social impact studies of any type of major projects were carried out anywhere in the world during the pre-1965 era. Water projects were thus not an exception. The current techniques for carrying out environmental impact assessment (EIA) were developed only after 1965, and the term EIA itself first gained widespread use in the 1970s.

Sustainable Development

Contrary to popular belief, the concept of sustainable development is not new. The general philosophy behind the concept has been expounded for centuries, if not millennia. The term itself started to become popular in the early 1980s, even though conceptually there is very little difference between this and other concepts like ecodevelopment, which were prevalent in the early 1970s.

Sustainability has unquestionably been a popular notion in recent years, but unfortunately it means different things to different people. The situation is somewhat similar to the popular support witnessed for the conservation movement in the USA during the earlier part of the present century, when President Theodore Roosevelt exasperatedly exclaimed: "Everyone is for conservation, no matter what it means!" The situation is somewhat analogous at present for sustainable development.

It should be noted that the term 'sustainability' has been used technically for several decades for harvesting reproducible natural resources, e.g., maximum sustainable yield of fisheries. This concept was broadened in the late 1970s by a small group of environmental scientists meeting under the aegis of the United Nations Environment Programme in Nairobi, Kenya, and was expected to be a 'new' idea for assessing and managing human impacts on the environment and natural resources.

The term became popular following the publication in 1987 of the Report of the World Commission on Environment and Development (popularly known as the Brundtland Commission) entitled *Our Common Future*. The Commission defined sustainable development in a somewhat amorphous and ambiguous way as "development that meets the need of the present without compromising the ability of the future generations to meet their own needs". Not surprisingly, with such a vague, simplistic and internally inconsistent and static definition, the Commission was totally unable to specify what was to be sustained. The report is replete with references to sustainability, but was incapable of recommending how the concept could be operationalized. Sustainability was expected to be achieved in an unspecified and undetermined way.

Once the concept became popular, dozens of new definitions were offered. Currently one can readily identify more than one hundred definitions of sustainable development without much difficulty. Even an organization like the

United Nations does not have a uniform consistent definition for use by all its component organs.

In spite of the present rhetoric, it has to be admitted that operationally it has not yet been possible to define a development process which could be planned and implemented in such a way from the very beginning that it would become inherently sustainable, however this may be defined. The best that can be achieved at present is to identify certain aspects of development which may contribute to unsustainability, and then take appropriate remedial steps to reduce, or even some instances eliminate, these undesirable side-effects. Unfortunately, it is simply not possible to devise a holistic process at present which could make a project intrinsically sustainable from its very beginning.

For example, if sustainable water development is considered, it has been known for more than a century that irrigation without appropriate drainage results in waterlogging and salinity, which in turn progressively reduces agricultural yields over a period of time. Since the main objective of introducing irrigation is to increase agricultural yields, clearly any system that does not fulfil this purpose over the long term cannot be considered to be sustainable. Similarly, if extensive use of fertilizers by the farmers increases the nitrate content of the groundwater so that its use for drinking purposes is impaired, then the practice cannot be considered sustainable. However, ensuring the system has proper drainage and that fertilizer use is efficient does not provide sufficient conditions to make an irrigation project automatically sustainable. There are numerous other factors which, singly or in combination, could contribute to its unsustainability. Some of these factors could be generic, and others may be project specific, and thus it may be difficult to identify all of them *a priori*. Accordingly, it is a very complex and generally an impossible task to ensure that every factor which could contribute to the unsustainability of a water development project can be identified during the planning and design phases, and then appropriate remedial measures be taken to eliminate all undesirable impacts.

While there are many issues that need to be considered simultaneously within the context of sustainable water development, the following three factors are worth looking at from a policy viewpoint:

(1) *Short- versus long-term considerations:* One of the fundamental assumptions behind the concept of sustainable development is that it would be viable over the long term. However, what constitutes 'long term' has neither been clarified nor featured much in current discussions. The time factor, either inadvertently or because of its complexity, has basically been left fuzzy: does sustainability cover 50 years, or 100, 500 or 1000 years or even more? Some have referred vaguely to several generations.

There are some fundamental dichotomies in the time framework for sustainability for practical application. For example, it is illogical to expect that the life period of a small check dam would be similar to that of a large multipurpose dam. Accordingly, however, if the timeframe for sustainability is defined, there should be considerable flexibility in terms of the type of projects being considered.

Similarly there are some significant practical difficulties which may have to be resolved if long time horizons are always to be taken into account in the real world. For example, if irrigated agriculture is to be considered, the normal planning horizon of farmers worldwide extends to the next cropping season, or at most to the next two to three seasons. The overriding concern is how to maximize income within the timeframe of the next harvest. Thus, farmers' mind-sets are inherently based on maximizing profits over a continual series of single seasons. Clearly these successive short-term approaches could have long-term individual and societal costs (e.g. in terms of soil erosion, salinity development, etc.), but short-term individual benefits have almost always won over the long-term societal costs.

Accordingly, if the societal goal is long-term sustainable irrigation development, a main consideration has to be how to reconcile the short-term expectations of the main users (farmers) with the long-term needs of society. Both conceptually and practically, it has not been easy to make these two diverging needs converge.

(2) *Externalities:* Externalities occur when private costs or benefits do not equal social costs or benefits. People operate primarily on the basis of their own private costs and benefits. If they perceive opportunities which could reduce their costs and/or increase potential benefits, they often take actions which could be beneficial to them but are unlikely to serve the common good. Examples include use of excessive irrigation water by farmers in the head-reaches of canals, which means that tailenders have an insufficient and/or unreliable water supply. This, in turn, could decrease agricultural yields and thus incomes of the tailenders substantially. Similarly, wastes from municipalities could be discharged into canals and rivers, which could impair existing water uses downstream.

Such costs could be internalized, at least conceptually, through taxes, subsidies and regulations. But in reality, even in developed countries, it has not been easy to internalize the externalities for four important reasons. First, methodologically, calculations of the precise value of externalities has been a very difficult task. Second, frequently there are politically powerful individuals and organizations who vociferously defend their own considerable private advantages against a large number of unorganized and disadvantaged individuals who may be experiencing additional costs somewhat indirectly. Third, externalities could develop steadily over time, and thus there could be a time gap before those affected realize the real costs they may have to pay, directly or indirectly. Finally, regulations to control such externalities in nearly all developing countries have proved to be somewhat ineffective and expensive.

(3) *Risks and Uncertainties:* A major issue confronting sustainable water resources development is risks and uncertainties that are inherently associated with such complex systems. For example, with the increasing population base of the Asian developing countries, there is no question that resources such as land and water have to be used intensively in order to maximize agricultural production. The fundamental question, for which there is no real clear-cut answer at the present state of knowledge, is: up to what level can an agricultural production system be intensified, without sacrificing sustainability? There are other difficult questions as well. For example, what early warnings could indicate the beginning of a transition process from sustainable to unsustainable? What are the parameters that should be monitored to indicate that such a transition is about to occur or, indeed, is occurring? Clearly, existing knowledge and databases are inadequate even to identify the parameters that could indicate the passage from one stage to the other.

Thus, currently it is not possible to accurately detect, much less predict, the transition of such a sustainable system to an unsustainable one, or vice versa. In addition, water resources systems are notoriously variable by nature. Their normal fluctuations could be so great that statistically significant data could be very expensive or even impossible to obtain in order to state categorically that such variations are due to natural causes or are signs of unsustainability. If, on already complex issues, additional factors such as potential climatic changes are superimposed, the degree of uncertainty in terms of detecting or predicting the transition process increases greatly (Abu-Zeid & Biswas, 1992). One is then confronted with the difficult issue of even identifying the direction of any change, let alone the magnitude of that change.

These types of fundamental issue need to be resolved successfully before the concept of sustainable water resources development can be holistically conceived and then implemented. Unfortunately, while much lip-service is given to sustainable water development at present, most of the published works on this subject are either somewhat general or a continuation of earlier 'business as usual' undertakings that have only been given the latest trendy label of 'sustainable development'. If sustainable water development is to become a reality, national and international organizations will have to address many real and complex questions, which they have not done so far in any measurable and meaningful fashion. If not, and unless the current rhetoric can be translated effectively into operational reality, sustainable development will remain a trendy catchphrase for another few years, and then gradually fade away like the earlier concept of ecodevelopment.

Environmental Assessment

Whatever terminology one uses, or whichever concept is 'popular' at any very specific period of time, the fact remains that water resources development projects must be planned, designed and operated in an environmentally sound manner. It is no longer adequate to consider only the technical feasibility and economic efficiency of a project: it is equally essential to consider its environmental desirability and social acceptability. Simultaneous consideration of all major technical, economic, environmental and social factors is a very difficult task, both conceptually and methodologically, but it is a task that needs to be accomplished. Current practices can be considered to be a useful initial step. However, these practices need to be reviewed objectively in terms of their application and then improved very substantially before water resources projects can be managed in an environmentally optimal way. It is now becoming increasingly apparent that while some progress has been made during the past two decades on how to plan, design, construct and operate water projects in an environmentally friendly way, much still remains to be done.

An essential ingredient for environmentally sound water management has to be proper environmental assessment. Experiences gained from different parts of the world during the past two decades indicate that reliable environmental assessment is at the heart of any environmental management process. Good and comprehensive assessments during project planning, construction and operation are pre-conditions for sound environmental management. Furthermore, assessments by themselves are not enough: assessments need to be properly integrated with the management and decision-making processes so that there is regular feedback between the results of the assessment and management decisions. An objective analysis of the present situation indicates that there are four fundamental problems which need to be resolved before proper environmental management of water projects, from the planning stage all the way to the operational phase, could be carried out successfully with any degree of confidence. These four interrelated problems are:

(1) limited framework for environmental assessment;
(2) absence of integrative approach;
(3) lack of scientific knowledge;
(4) absence of monitoring and evaluation during construction and operational phases.

Even though, for the most part, both the water and environmental professionals often believe that it is possible to manage water projects optimally, until and unless the above four problems are properly resolved, environmentally sound water management will remain sub-optimal at best. Unfortunately this fact has still not been properly recognized by either profession. Only when the real problems are recognized, and determined attempts are made to solve them by the professions concerned, will some progress in this area be noted. Progress, however, is likely to be painfully slow.

Limited Framework for Environmental Assessment

The assessment of environmental impacts became a formal requirement in the USA with the passage of the National Environmental Protection Act (NEPA) in 1970. Soon thereafter, environmental impact assessment (EIA) became necessary in Canada and certain European countries. Many Asian countries followed suit. In fact, EIA became mandatory in certain Asian countries like the Philippines and Thailand before some major West European countries like the Federal Republic of Germany, which adopted the process only in 1977. In general, the Asian countries have made more progress in instituting EIA than their Latin American and African counterparts.

A careful and objective global analysis of the existing practices for carrying out EIA indicates that the general techniques that are being used at present have undergone very minor changes, both conceptually and methodologically, compared with what was practised in the early 1970s when EIA was first introduced. The major notable change during the past 25 years is the fact that available computers have become progressively more and more powerful, as a result of which an increasing number of parameters and data can be analysed at present more cost-effectively than ever before. Equally, use of computers to carry out EIA has become far widespread all over the world.

In retrospect, the concepts used were acceptable and even laudable in the early 1970s since they constituted a significant improvement over the then prevailing practices. Unfortunately, the fact that these techniques have been used continuously for more than 25 years has meant that both the water and environmental professionals have now automatically assumed that the EIA analyses and processes as practised at present are reliable, usable, and contribute to significant environmental improvement. International organizations, ranging from the United Nations Environment Programme to the World Bank, now follow the same techniques and processes without having carried out any serious analyses as to what extent they actually preserve and/or improve the environmental issues on a long-term basis. Nor have there been serious attempts to identify the real shortcomings of the techniques in terms of application, and then take steps to improve them. Interestingly, more than one hundred EIA guidelines are available at present, but they vary only in very minor ways in terms of general approaches and concepts.

A careful and objective analysis would clearly indicate that significant changes and modifications are necessary for the techniques for environmental assessment, as used almost universally at present, to be considered appropriate for use during the latter half of 1990s. Yet, most unfortunately, these inappropriate techniques continue to be used without any serious questions being asked about their effectiveness in terms of total environmental benefits. It appears that without any extensive review or discussion of the overall validity and desirability of the techniques, these are currently being accepted, at least implicitly, to be the only available reliable alternatives. Since in general very limited, if any, reservations have been made as to the efficacy of current practices used for environmental assessment, there does not appear to be any long-term solution in sight.

There are at least three fundamental problems with the current environmental assessment techniques. First, at the policy level, the linkages between environmental assessment and the social and economic aspects of water development are not clear. The linkages are generally fuzzy, even at the conceptual level. Normally, limited attempts, if any, are made to link environmental impacts at the policy level with economic and social issues. Even in the few instances where such attempts have been made, the linkages were basically descriptive at best. Quantitative linkages are seldom made, and even theoretical methods to establish such interlinkages with any degree of reliability are conspicuous by their absence at present.

Second, while some progress has been made on the application of EIA at the project level, commensurate progress at policy and programme levels has simply been missing. At the present state of knowledge, it is simply not possible to carry out environmental assessments of water policies and programmes in any detailed and reliable fashion. Because of the generalized nature of the assessments, the results can at best be used operationally in a very limited way. In other words, usable environmental assessment techniques for water policies and programmes are still in their early stages. Much progress needs to be made before water policies and programmes can be analysed to make them environmentally sound prior to implementation. This area, unfortunately, has received very little research attention thus far.

Third, during the past 25 years many thousands of ElAs have been conducted all over the world for various types of infrastructural development projects, including numerous ones for the water area. Irrespective of where these ElAs have been carried out, from Albania to the USA, the overall processes and the underlying philosophies are somewhat similar; only the depth and rigorousness of the analyses may vary from one place to another.

A review of the ElAs carried out during the past 25 years would indicate that uniformly and universally, analysts have always concentrated on what is *not* environmentally sound water development rather than what is. The emphasis exclusively has been on certain aspects of development which may not be sustained. By trying to analyse and define sustainable water development by *only* those factors that could contribute to unsustainability, clearly the entire focus of the analyses has been on just one part of the equation. The other part, which could possibly be as important as the non-sustainable negative factors, has been completely ignored. The whole focus of sustainable water development, as it is construed at present, concentrates on what it is not, and then tries to ameliorate the negative impacts. A holistic approach to the issue would be to consider first what contributes to sustainable water development. This approach is simply missing at present. Instead, the overriding emphasis has been on how to identify and ameliorate the negative impacts. Clearly this approach to environmental assessment is highly skewed, and is unlikely to yield optimal environmental, economic and social benefits.

Furthermore, it is worth noting than even though all major water development projects would have many impacts, some of which would be positive and others negative, the word 'impact' in the context of EIA has developed almost exclusively negative connotations. While any large project, irrespective of its nature, will unquestionably have both positive (otherwise why should a decision be taken to construct them?) and negative impacts, all current analyses of the environmental and social impacts invariably consider only the negative ones and their potential amelioration. Maximization of positive environmental impacts should be an equally important consideration, but it is completely ignored at present.

To a significant extent this overwhelming and almost total emphasis on the negative aspects of development projects can be explained by reviewing the historical conditions within which the EIA techniques were first developed and used. During the pre-1970 period, all project planning and analyses primarily consisted of technical and economic considerations; environmental and social analyses were mostly neglected. To the extent these were considered, they were limited to a very few select issues only, e.g. waterlogging and salinity developments and resettlement of people from the reservoir areas. Even these issues, though invariably analysed, were often not properly considered, especially in terms of implementation. Because of this general neglect of environmental and social factors, and numerous visible and adverse impacts of certain development projects on the environment and society as a whole, a movement gradually developed for environmental protection in a few western countries in the 1960s. Within a very short period, environmental protection became an increasingly important item on the political agendas of a few countries such as the USA and Canada. Numerous environmental pressure groups and other non-governmental organizations focused on the negative environmental impacts of various development projects to show, in many cases justifiably, that these projects were contributing to serious unwanted environmental and social side-effects. Water projects were not an exception to this general overall trend.

Not surprisingly this general attitude to and perception of environmental issues was reflected during the discussions of the United Nations Conference on the Human Environment held in Stockholm, Sweden, in 1972. This was the first of the several mega-conferences that were convened by this world body during the 1970s at a very high governmental decision-making level. A retrospective analysis of the Stockholm Action Plan, as approved by all members of the UN, clearly indicates an overall negative approach to environmental management: stop all pollution resulting from any development activity; stop exhausting non-renewable resources, and stop using renewable resources faster than their regeneration. The plan focused on what should not be done rather than what should be done and how this could be achieved. The result was not surprising since the Stockholm Action Plan reflected the prevalent attitude of that time, that is, that development activities primarily have adverse environmental impacts. Positive environmental impacts were basically ignored.

Accordingly, EIA techniques which were developed during that period reflected the concerns of that time, which were exclusively related to the identification and amelioration of negative impacts. The implicit assumption was that large development projects can only have negative environmental impacts, and the positive impacts, if any, were so minor that they could safely be ignored. Because of this incorrect and somewhat unfortunate beginning, the term 'impact' in the context of EIA very quickly assumed negative connotations only. This emphasis only on negative impacts has remained generally unquestioned and unchallenged during the past 25 years.

One undesirable side-effect of this one-sided concern has been that while much is known about the adverse environmental impacts of large water development projects, very limited progress has been made on identifying and quantifying positive impacts. The few examples that are currently available are case-specific, and accordingly may not be adequate to draw generic conclusions on the prevalence and extent of the occurrence of such positive impacts, which are likely to be extensive and substantial.

In addition, and specifically for the area of water resources development, another factor may have had a perceptible and continuing impact on general thinking on the environmental impacts of large dams. This was the publication of a series of articles in the popular media in the USA by the well-known journalist Claire Sterling on the adverse environmental impacts of the Aswan High Dam in Egypt. Her well-written articles at the beginning of the environmental movement, when the philosophies and techniques for environmental assessment processes were being formulated, caught the imagination of the general public, including most scientists. Her articles were a good interpretation of the then prevailing views of western environmentalists as well as some prominent Egyptian scientists, that the Aswan High Dam has contributed to numerous environmental problems only, and that these overwhelmed the positive benefits. These opinions were of course hypotheses since virtually no serious monitoring and evaluation of the environmental parameters were carried out for the dam on a comprehensive basis until the late 1980s. Sterling's articles reinforced the general bias that had started to develop in that era that large infrastructure development projects generally contributed to only major adverse environmental impacts.

The articles suited the times of a 'small is beautiful' era very well for at least four important reasons:

- The Aswan High Dam was a large infrastructure which had the misfortune of being completed in 1968, exactly when the new and emerging environmental movement had started to flex its muscles.
- The USA, which had initially indicated that it would finance the construction of the dam, declined to do so primarily because President Nasser of Egypt became one of the four major personalities of the time who launched the new Non-Aligned Movement. Egypt was thus no longer allied to the Western group. With the withdrawal of the USA offer, the Soviet Union promptly

stepped in to finance the project and to provide the necessary technical assistance. Since it was the first ever major structure that was built in any African country by the Soviet Union, the dam generated considerable publicity in the West.

- Prime Minister Khrushchev requested and received an official invitation from Egypt to participate in the opening ceremony of the dam when he boasted that the Soviet Union would drown capitalism in Africa, and their assistance in the construction of the dam was the beginning of this process. These political factors made the reputation of the dam a casualty of the cold war, and further contributed to its adverse public image in the West.
- It was much easier to severely criticize a new major structure built with Soviet help in a far-off country than one in the West. Since technically the dam was properly constructed, and its economic benefits were never in any doubt, it was only possible to criticize it on environmental grounds, even though no scientific evidence was available for such criticisms.

Sterling's high-profile articles on only the negative environmental impacts of the dam found a very receptive audience in the West, who were mostly convinced that such large development projects could only be environmental disasters. Very few people, if any, realized that the articles were based on conjecture and not on facts. Sterling's writings simply reinforced the then prevailing biases and helped to make the Aswan High Dam a *cause célèbre* among environmentalists as a shining example of a bad, large development project. These generic criticisms were soon extended to many other major new water projects that were being constructed, nearly all of which were in developing countries. Sadly attitudes do not appear to have changed much in the past two decades.

Thus, the Aswan High Dam very quickly became a symbol of everything that could be wrong with a major water development project. Unfortunately this view remains widely held, and most international publications available on this subject still do not provide an objective discussion of all the real benefits and costs of the dam. Extensive data collected over the past two decades, primarily with the support of the Canadian International Development Agency, indicate that many myths now surround the dam that are generally accepted as facts. This is especially true outside Egypt, since the Egyptians had no doubt concerning the overall true benefits and costs of the dam.

In reality, the Aswan has been a remarkably successful dam without which Egypt would have been in dire economic and political straits. It has unquestionably contributed to some adverse environmental impacts. However, the real issue can no longer be whether the dam should have been built, since without it Egypt would have been facing a continuing catastrophe, but rather what steps should have been taken to maximize the positive environmental impacts and reduce the negative ones (Biswas, 1992, 1996).

In retrospect, however, these developments had one major beneficial impact. The engineering profession, which dominates the water development field all over the world, has recognized explicitly that there are other important issues in addition to the regular techno-economic analyses which need to be seriously considered to maximize human welfare. Accordingly environmental and social assessments, which were mostly neglected during the pre-1970 period, increasingly became accepted as an established procedure.

Absence of Integrative Approach

Environmental assessment methodologies have continued to consider only certain selective aspects of water development projects: an integrative approach has basically been missing. Many instances of this narrow and restrictive approach can be cited, but only one example will be discussed here: the health impacts of irrigation projects.

An objective and comprehensive analysis of the current practices and existing literature in this field will clearly indicate that almost exclusive emphasis has been only on *one* issue: vector-borne diseases like malaria and schistosomiasis. Irrespective of the accuracy of the oft-quoted evidence for increases in waterborne diseases due to the construction of irrigation projects, an issue that will be discussed later, it is becoming increasingly evident that the present generally accepted conceptual approach is not only simplistic but also somewhat incorrect for the following reasons.

Viewed in any fashion, irrigation has to be considered an important component of the rural development process. With expansion of the irrigated area due to a new project, agricultural activities and production increase as well. With higher per capita food availability and diversification of crop production in the area, significant improvement occurs in the food and nutritional status of the local people. New employment opportunities are generated because of intensification of agricultural and associated economic activities, which in turn improves the financial conditions of the population, including landless labourers. Evidence from different parts of the world indicates that the nutritional status of rural people is often further improved through increased livestock holdings and the development of inland fisheries in the newly created reservoirs.

Furthermore, if irrigation is properly planned to be an integral part of rural development, the health of the rural population is enhanced significantly because of improvements in education, health care and transportation facilities and the lifestyles of women. These overall interrelationships are shown diagrammatically in Figure 5. All current environmental assessments of the health impacts of irrigation projects totally ignore these positive impacts, thus resulting in an incomplete and overall skewed assessment. Nor are these impacts monitored later.

At the present state of knowledge, methodologically it is possible to carry out post-project reliable and integrative environmental monitoring and assessment. For instance, the evaluation carried out for a major international development agency for the Bhima Command Area Development Project in India is a good example of how such integrated analyses can be carried out (Biswas, 1987). Such analyses, however, are exceptions rather than the rule.

Only two impacts of the Bhima Project will be discussed here as examples of how the absence of this integrated approach clearly could contribute to suboptimal results and incorrect conclusions. The first is women's education. Before irrigation was introduced in this economically disadvantaged region, landless labourers had to move constantly from one place to another searching for employment opportunities. Their daughters invariably moved with them during this nomadic lifestyle, and thus could never attend schools. With the introduction of irrigation, employment opportunities in the rural areas have increased significantly. Consequently, such labourers can stay in one village and find

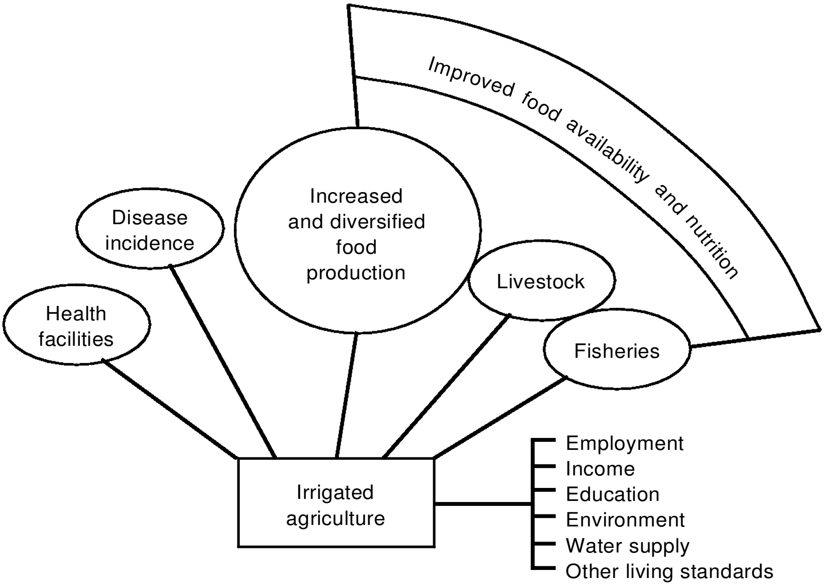

Figure 5. Interrelationships between irrigated agriculture and health.

employment within daily commuting distance. Because of this stability and the increased economic opportunities due to irrigation development, they have started sending their daughters to schools without any formal encouragement and support from the government. Environmental assessments have not even cursorily considered women's education as a possible important benefit of the introduction of irrigation.

The second environmental impact noted was the changing patterns of biomass fuel utilization in the project area as a direct result of irrigation. The percentage of people purchasing fuelwood for cooking, or the total amount of fuelwood purchased per family, or both, in irrigated areas soon became significantly lower than in non-irrigated areas for three reasons:

- Higher cropping intensities as well as yields significantly increased the availability of agricultural residues, which were then used for cooking.
- Increased livestock holdings in the irrigated areas produced more dung than ever before. Dry dung cakes became an important fuel for cooking.
- Increased employment opportunities and incomes encouraged people to move away from biomass fuels to more convenient commercial forms of energy.

The reasons for the reduction in the use of biomass fuels are shown diagrammatically in Figure 6. These developments contributed directly to the following three major environmental and social benefits:

- reduction in pressure on the forests in and around the region since fuelwood demands were noticeably reduced;
- decline in time spent by women and children in collecting fuelwood; and
- money saved by many families in not buying as much fuelwood as used before could be used for other productive purposes.

There are just two examples of how an integrated approach could contribute to

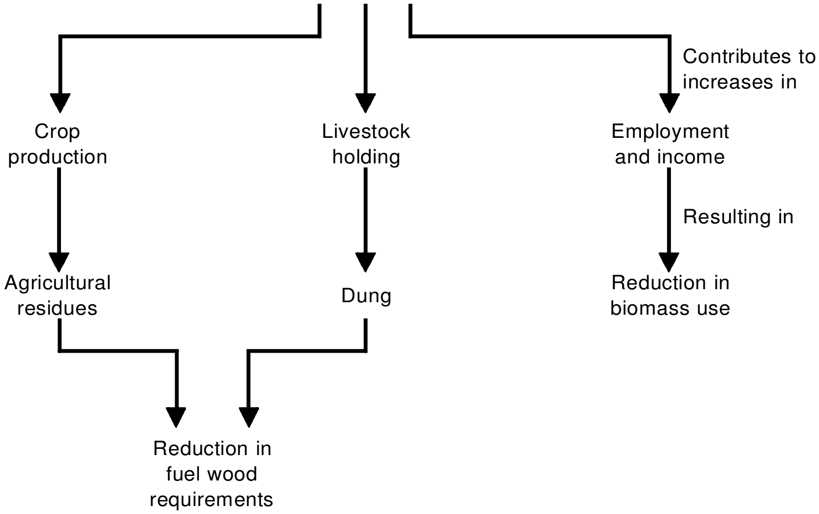

Figure 6. Impact of irrigated area on biomass use.

an objective and more accurate environmental assessment. Unfortunately such an approach is for the most part lacking at present.

Lack of Adequate Knowledge

There are many areas of environmental assessment where adequate scientific knowledge simply does not exist. Equally there are many areas where the current knowledge can at best be misleading and at worst totally erroneous. Regrettably, often the right questions are not even being asked. For example, the two most widespread and important vector-borne diseases are probably malaria and schistosomiasis, but it is not possible at present to predict to what extent a water development project *per se* may increase or decrease their incidence. Neither is any attempt being made to answer such questions. The problem is further complicated by the site-specificity of the answers, and numerous interlinked associated factors.

An exhaustive study by the Indian Malaria Research Centre has indicated that the resurgence of malaria in that country occurred independently of irrigation expansion during the Green Revolution (Sharma, 1987). There is, however, no doubt that irrigation and agricultural practices, rice cultivation and migration of agricultural workers have important bearings on the mosquito vector fauna and malaria transmission processes. The linkages are not clear, and there is no scientific evidence that a one-to-one relationship exists between irrigation development and malaria incidence.

Figure 7 shows a district-by-district average annual parasite rate (API) between 1982 and 1984 on a rice area map of India. Rice cannot be grown without extensive rainfed or perennial irrigation. The API registers the number of malaria cases per thousand population in one year. The map indicates that for large parts of the country, with high areas of rice cultivation, malaria incidence rates are negligible (API <0.5), or extremely low (API <2). Equally there are some rice-growing areas where the incidence of malaria is moderate (API 2 to <10) or high (API >10). This analysis indicates there is no specific direct

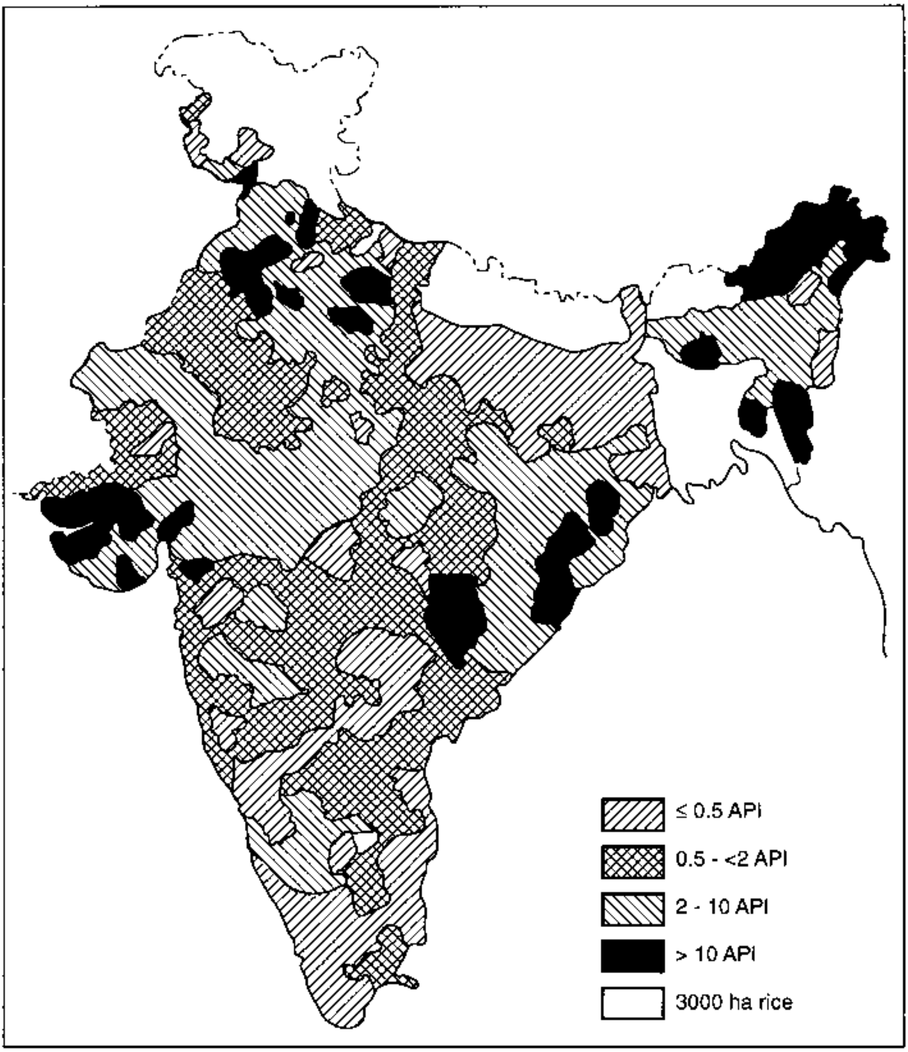

Figure 7. Relationship between area under rice cultivation and average annual parasite rate in India, 1982–84. *Source:* Sharma (1987).

interrelationship between irrigated areas and malaria transmission rates. There appear to be many other important factors which govern disease transmission.

There are other issues which further complicate the linkages between irrigation and malaria. A study of two villages in the Kano plains of Kenya, one a newly established village within the Ahero irrigation scheme and the other an older village nearby in a non-irrigated area with traditional mixed agriculture, showed remarkable differences in terms of mosquito species present. In the new village, 65% of mosquito bites were from *Anopheles gambiae* (the principal vector of malaria in tropical Africa), 28% were of *Mansonia* species (vectors of lymphatic filariasis and Rift Valley fever) and 5% were of the *Culex quinquefasciatus* variety (another vector of lymphatic filariasis). In contrast, 99% of the mosquitoes in the older village belonged to the *Mansonia* species and less than 1% were *Anopheles* *gambiae*. Thus, irrigation may change the transmission patterns of mosquito-borne diseases by changing species composition through habitat modification.

There are other stratification issues as well. The evaluation of the Bhima project indicated that malaria appears to be attacking women more than men. How widespread this type of stratification is, in India or elsewhere, is simply unknown at present. These types of specific questions have not been considered thus far, and hence no definitive answers are available.

As regards schistosomiasis, there is no doubt that the construction of an irrigation system in a tropical or semi-tropical country, with extended reservoir shorelines and canal and drainage systems, creates a favourable habitat for snails which are the vector of this disease. However, extensive studies in Egypt and several Asian countries indicate that much of the infection occurs not during the irrigation process but during domestic interactions with canal waters due to the absence of water supply and sanitation facilities. Improving the availability of domestic water supply, and the provision of sanitation facilities, health education and care have reduced total schistosomasis incidence in Egypt very significantly. Currently it is estimated that within a decade the disease will no longer be considered endemic, for the first time since the Pharonic era.

A major difficulty in terms of how best to consider the interrelationships between irrigation and vector-borne diseases arises from a plethora of misleading and unreliable data, and the absence of an adequate number of scientifically rigorous studies. The area is thus replete with poor and conflicting information, extensive repetition of data that have seldom been critically examined and the elaboration of personal biases. To some extent, major international organizations have contributed, albeit not deliberately, to this sad situation. Scientists have automatically assumed that data and information published by such organizations are accurate. Unfortunately, many times they are not. For example, the current estimate of the World Health Organization (WHO) is that globally 200 million are infected with schistosomiasis. Incredibly, this number has remained constant at least for the last 27 years! The United Nations Environment Programme (UNEP) has incorrectly stated that schistosomiasis has been (completely eradicated in China. The Food and Agricultural Organization (FAO) has stated that water development significantly increases onchocerciasis, whereas all available data indicate otherwise. Unquestionably, a major problem in this area has been caused by the uncritical acceptance and repetition of published information that is unreliable. As these dubious data are quoted and requoted by different scientists and institutions without any qualifications, they become ‘facts’. Accordingly, the existing knowledge base needs to be substantially improved.

Monitoring and Evaluation

While EIA has become a necessary pre-project activity to obtain the necessary governmental approval for implementation of water development projects, there is very little regular monitoring and evaluation of the important environmental parameters during construction or after projects become operational. This is the normal situation all over the world. There are no institutional arrangements as to who should monitor and evaluate such projects, the process by which these should be monitored, to whom such information should be provided, how the information should be used, and who should pay for the entire process. Regrettably, the entire emphasis at present is on the preparation of ElAs and their clearance as a discrete activity; monitoring and evaluation of environmental parameters during the operational phase only receives lip-service at best, both from national and international organizations.

This practice has contributed to major problems in term of efficient environmental management of large water projects. This is because in many ways EIA is still an art and not a science. There are many interacting physical, technical, economic, environmental and social factors, and it is impossible to predict in advance the net results of all the complex interactions. In addition, many impacts are site specific, and thus may not be easy to predict in advance. Equally most impacts depend, at least to a certain extent, on post-project management practices. For example, if the management of drainage systems is poor, salinity and waterlogging will become problems. However, when such problems could surface depends on the management practices: it may take 5, 15, 25, 50 or even more years. Accordingly regular monitoring and evaluation at appropriate intervals is essential to identify when problems are developing so that the necessary remedial actions can be taken to rectify them.

In addition, because of the complexities involved, it is currently simply impossible to predict *all* the environmental impacts of a major development project, the time when individual problems may surface, the magnitude of each impact and the spatial distribution of the impacts over the project area. Accordingly, unless the project managers receive regular timely information on the problems during their early phases, appropriate remedial actions cannot be taken. By the time some of these problems become clearly visible, many of the possible damages may have already occurred. Normally it is significantly more expensive to rectify problems when they have become serious compared with taking remedial action in the earlier phases.

However, one of the most fundamental problems that has been created by this near total absence of monitoring and evaluation of water development projects is the validity of the hypotheses that are being used to make forecasts during the EIA process. Irrespective of the current rhetoric, the number of large dams anywhere in the world whose environmental and social impacts have been scientifically and objectively evaluated can be counted on the fingers of one's hands, with a few fingers left over. In the absence of monitored results, the hypotheses on which EIA forecasts are being made cannot be validated, and thus the biases and errors are being continually perpetuated worldwide. The impact evaluation of the Aswan High Dam is a good example, which clearly indicated that the perceived wisdom at present on issues such as increases in schistosomiasis or rates of bed and bank erosion are clearly erroneous and require extensive revision. Without extensive monitoring of actual environmental and social impacts of large dams in different parts of the world, generic conclusions, which could be used to substantially improve the existing techniques for forecasting environmental impacts, cannot be drawn.

Thus, monitoring and evaluation of the environmental impacts of large water projects is not only necessary to improve management practices and thus enhance their overall contribution to the socioeconomic conditions of the region, but is also essential to improve the existing EIA forecasting techniques significantly.

Clearly proper environmental assessment of water projects is an important requirement to ensure achievement of the planned and expected economic and social benefits. However, the current almost exclusive emphasis on carrying out environmental assessment only during the pre-construction phase is an important requirement but is not a sufficient condition to ensure that the environmental benefits of the project are maximized and the costs minimized. Regular monitoring and evaluation at the requisite intervals during the operational phase of a project, and feedback of these results to the decision-making levels are absolutely essential to ensure long-term environmentally sound management of water projects.

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