Role of Geosciences in Water Resources Development

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Introduction

The role of water in the overall development process of countries became an increasingly important issue during the last decade due to several events, some natural and others man-made. First, severe drought in many parts of the world during the early Seventies contributed to a major food crisis. During the World Food Conference, which was convened in 1974 in Rome, Italy, to propose solutions to such a global crisis (Biswas & Biswas, 1975), it became quite evident during the deliberations that proper control and management of water is absolutely essential not only for further horizontal expansion of agriculture but also for increasing the overall yield from existing cultivated land. Second, steadily increasing prices of fossil fuels, especially oil, focused national attention on the development of hydro-electric power, a renewable source, as a viable source of additional electric power generation. This was a departure from the normal practices of the Fifties and Sixties, when many countries preferred to construct power plants with a fossil fuels base because of the economic advantages they offered and also the easy availability of fossil fuels. Third, the Lima declaration of the United Nations Industrial Development Organisation recommended that by the year 2000, 25 per cent of global industrial production should take place in developing countries. If this is to be achieved, more water will be required for further industrial development in such countries. Fourth, the United Nations Conferences on the Human Settlements (M. R. Biswas, 1978) and on Water (M. R. Biswas, 1977) emphasised the plight of people of developing countries, especially in rural areas, who do not have access to safe drinking water. At the recommendation of the Water Conference (Biswas, 1978), the decade of 1981–90 has now been officially declared to be the International Drinking Water Supply and Sanitation Decade by the General Assembly of the United Nations. Finally, pollution of inland and coastal water bodies and the oceans became an increasing focus of national and international concern, partly through the work of the United Nations Environment Programme, which itself was created in the early Seventies by the United Nations Conference on the Human Environment held in Stockholm in 1972. All these events, individually and cumulatively, clearly indicated the urgent necessity of sustainable water development which would ensure optimal utilisation of available water as well as the maintenance of its quality.

Priority Areas of Water Development

Any attempt to determine priority areas in water resources development has to be based on specific criteria. The first criterion invariably is the question of scale, i.e., the local, regional or global nature of the problem. For example, some problems which may be most important locally or regionally may not be a priority issue on a global basis. Thus, the problem of acid rain is now an important issue in countries like Canada or Norway, but is unlikely to be considered to be a priority issue in Argentina, China, Kenya or India. The first criterion for selection of priority areas in the present paper is their global interest and thus their impacts on a large number of people.

The second criterion used is the immediate nature of the problem, i.e., those problems that have already surfaced and which need to be solved. Accordingly, the priority areas selected do not contain potential future problems like the continuing increase in the concentration of carbon dioxide in the atmosphere which could affect the climate and thus the precipitation patterns in the 21st century.

The third criterion is availability of knowledge, that adequate information is available on the magnitude and extent of the problems, as well as the steps needed to be taken for their solution. In other words, while in certain cases some research may be necessary to solve a specific part of the problem, this would be short-term action-oriented research. Enough information is already available on the overall problem and thus it is not necessary to wait for results to be obtained from further research before action can be taken.

On the basis of the above criteria, the following four areas require priority attention:

i) Provision of safe drinking water;
ii) Efficient use of water;
iii) Water development on a sustainable basis; and
iv) Development of water bodies shared by more than one state.

It should be noted that the four priority areas are in some ways inter-related and for most developing countries actions have to be taken on all four areas simultaneously. The areas are not mutually exclusive.

i) *Provision of safe drinking water* While it is an accepted fact that a significant percentage of the world's population does not have access to clean water, reliable statistics on the precise magnitude of the problem are currently not available. The best information available at present is an aggregate of selected "raw" estimates of varying degrees of accuracy from many developing countries, provided by their governments and compiled by the World Health Organisation (WHO) of the United Nations. Its most complete recent survey, as of the end of 1975, rested on questionnaires returned by 71 developing countries, which unfortunately did not include the most populous country of the world – People's Republic of China.

According to this survey, 77 per cent of urban population had access to piped water supply through house connections or standpipes, and 75 per cent had reasonable sanitation facilities. The situation, as to be expected, was significantly worse for rural communities, where 78 per cent did not have access to safe water and 86 per cent did not have appropriate sanitation facilities (WHO, 1976).

The report further indicated that the number of people having access to public water schemes in developing countries increased from about 400 million to around 750 million during the period 1970 to 1975. Despite this dramatic increase, however, the number of persons *not* receiving clean water remained almost the same due to rapid population growth.

A later WHO estimate for 1980, which is more unreliable than the earlier, indicated that the percentages of urban and rural populations having access to clean water increased to 75 per cent and 29 per cent respectively (WHO, 1981). Since rural populations predominate in developing countries, the percentage of total population having such access increased from 38 per cent to 43 per cent during the five-year period.

Two important issues emerge from a review of the limited information available. First, the problem is at present overwhelmingly a rural rather than an urban one. This situation has developed over the years not only because of distinct urban bias on the part of the planners but also due to the prevalent political and institutional pressures. The elites who hold power are urban-based, and the policies, in spite of the rhetoric, clearly favour the urban areas, where their power centres normally lie. The fact that rural people tend to be poor, illiterate and malnourished and thus have very little political power, does not help matters. There is no doubt that often the direct beneficiaries of national policies are educated urban elites who are in power. Furthermore, inadequate planning, insufficient budget, incomplete execution of plans, limited appreciation of the problems of rural people and lack of understanding and emphasis by donor countries and agencies have not helped the cause of water supply in rural areas.

Second; from the existing scattered data available, it has to be concluded that while major advances have been made during the past 20 years in increasing the percentage of people having access to clean water in most countries, there have been declines in some regions as well. WHO carried out three surveys in 1962, 1970 and 1975. The data obtained are not strictly comparable, since the number of countries surveyed was different in each survey: 75 countries in 1962, 91 in 1970 and 71 in 1975. Furthermore, an examination of 1970 and 1975 data indicates that even individual national estimates of many countries differ significantly from one period to another due to major differences in enumeration, presumably because of different people involved and/or different techniques used.

In spite of these constraints, when changes in percentages of urban population served during the 1962 to 1970 period are considered, the situation in the Southeast Asia and East Asia regions improved remarkably, both improving by more than 20 per cent. In contrast, the situation was much different in the Latin American and the Caribbean region which registered a ten per cent decline. Similarly, in the 1970 to 1975 period, Southeast Asia and East Asia and Western Pacific showed most improvement, 15 per cent or more, but unfortunately in Africa, south of the Sahara, the situation deteriorated and showed a two per cent decline.

As this deplorable situation of water availability became better recognised, a series of goals and objectives were approved at inter-governmental levels during the last decade (Biswas, 1981). Among these is the United Nations Conference on Human Settlements, commonly known as Habitat, held in Vancouver, Canada, in 1976, which approved a sweeping goal of safe water for all by 1990, if possible. The following year, United Nations Water Conference approved that "all peoples have the right to have access to drinking water in quantities and of a quality equal to their basic needs". It recommended "priority attention" should be given to "the segments of the population in greatest need". It re-endorsed the Habitat target of clean water for all by 1980 and urged the countries to develop, by 1980, suitable national plans and programmes to meet the targets. It further recommended that the decade 1980–1990 should be designated as the International Drinking Water Supply and Sanitation Decade (Biswas, 1978).

A realistic estimate the chances of success in achieving the goals of the Decade has to be that they are not very great for a variety of reasons which have been discussed elsewhere (Biswas, 1981). Goals and targets are easy to design and resolutions are easy to pass, but resounding and pious declarations are not enough. The Decade objective of clean water for all by 1990 should probably be best considered to be targets to be aimed at and preferably achieved in as many countries as possible. They should be considered as the beginning of more intensified programmes and activities, with the first stage of providing even intermittent water supply in urban areas and standpipes in rural areas. The final phase would be the provision of running water in all homes.

Clean water and sanitation for all by 1990 may appear like the "impossible dream" sought by Don Quixote, the Man from La Mancha, but for many citizens of the world this dream could become a reality with intensified efforts and that alone is worthwhile.

ii) *Efficient use of water* While availability of safe drinking water is very important, on a quantitative basis agricultural and industrial sectors are the major users of water, significantly more than community water supply. On a global basis agriculture is the largest user of water, accounting for approximately 80 per cent of global consumption (Biswas, 1978, 1979). Industrial water use is a major consideration in certain countries like the United States, where it accounts for nearly 40 per cent of total water requirements.

While agriculture is the largest user of water, much of it — as currently practised — is used inefficiently. On a global basis, 1.3 million million m^3 of water is used for irrigating crops for which 3 million million m^3 of water is withdrawn (FAO, 1978). In other words 57 per cent of total water withdrawn is lost in the process.

One of the most inefficient aspects of existing irrigation systems is often the section where water is transferred from canal outlets to farms. It has almost become a no-man's land due to undefined responsibility, which in turn contributes initially to improper design and later to unsatisfactory operation and maintenance. While much research has been carried out on losses from canals, very little work has been done on losses from such sections. Studies carried out on 40 such sections in the Indus Basin during 1975 and 1976 indicated losses ranging from 33 to 65 per cent, with an average of 47 per cent. Another investigation on 60 sections carried out in 1977 and 1978 by Water and Power Development Authority of Pakistan indicated similar losses. The magnitude of this problem can best be realised by consideraing the case of well-lined canals, which are expensive to construct and have operating efficiencies of 70 to 80 per cent. When the efficiency of the total system is considered, that is lined canals in conjunction with the inefficient section from canal outlets to farms, the total efficiency is of the order of 20 to 50 per cent, which means that even for expensive, lined and well-maintained canal systems, in many cases less than one-quarter of water released from a reservoir reaches the crops being irrigated. The Central Board of Irrigation and Power of India recommend (CBIP, 1975) that channels above 1,000 cusecs ($304.9\ m^3$/sec) should be lined.

A major consequence of this sad state of affairs is that engineers have accepted this inefficient system, at least implicitly. During planning of irrigation projects, total water requirements are generally calculated by multiplying the extent of total area to be irrigated by water required per hectare. The water requirement per hectare is generally estimated on the basis of existing systems, where major portions of water released from reservoirs are lost. Accordingly, overall estimates of irrigation water requirements are invariably high – certainly significantly higher than necessary – and the inefficient system is condoned and perpetuated. In other words, most irrigation systems designed so far are generally inefficient and use far more water than necessary. Unfortunately, instead of attempting to make irrigation systems more efficient and then maintaining them at such high levels, engineers are constantly looking for new sources of water for irrigation. They look for costly alternatives, like interbasin water transfer, when cheaper alternatives are available and which can be implemented within a significantly shorter timeframe with the indigenous labour force and expertise by simply improving existing systems. Furthermore, when new projects are developed, unless special efforts are made to maintain their efficiencies at high levels, their effectiveness will decline with time and the vicious circle continues to be perpetuated.

Viewed from a different standpoint, present irrigation systems are highly efficient in recharging groundwater!

While the potential for saving water is extremely high for irrigation, water can be used more efficiently in other sectors as well. For example, nearly 60 to 80 per cent of water required for industrial processing is for cooling and, by extensive recirculation, the total water requirements can be drastically reduced. Thus, water requirements per ton of soap manufactured varies from 960 to 37,000 tons. Similar savings in water can be achieved with other industrial processes.

Since more and more water will be required in the future, it is essential to promote more efficient use of water.

iii) *Water development on a sustainable basis* Water development, like any other type of development, must be sustainable over the long term and the social and environmental costs from such developments should be kept to a minimum.

Over-irrigation is endemic, and not an uncommon practice in both developed and developing countries. This not only means that much water brought to the field, after major capital expenditure, is wasted but also such practices contribute to the development of adverse environmental problems like increase in groundwater tables and salinity levels. Ultimately this reduces the yields of agricultural products, thus undermining the very objective for which the initial development took place.

There are cases where water development projects to increase irrigated agriculture have also contributed to problems which eventually reduced total food production. Among such problems are deterioration of soil fertility and eventual loss of good arable land, due to progressive development of salinity, alkalinity or waterlogging. For example, at one time Pakistan alone was losing 24,280 hectares of fertile cropland every year and currently nearly 10% of the total Peruvian agricultural area is affected by land degradation due to salinisation. Among other major areas affected by salinisation are the Helmud Valley in Afghanistan, the Punjab and Indus Valleys in the Indian sub-continent, Mexicali Valley in Northern Mexico and the Euphrates and Tigris basins in Syria and Iraq (M. R. Biswas, 1979a, 1979b).

Groundwater resources have been extensively developed in many countries in recent years primarily for irrigation purposes. If such developments are based on the fundamental hydrological principle that the rate of abstraction should be equal to or less than the rate of recharge, then such developments are sustainable. Unfortunately, in many instances, the rate of abstraction of groundwater far exceeds the rate of recharge, thus contributing to over-exploitation. Such practices result in not only continual lowering of the water table but also often contribute to decreased pressure in aquifers, changes in rate and direction of flow, salt water intrusion and land subsidence. Continued over-exploitation coupled with high energy costs could mean that the water table could be lowered to such an extent that it no longer remains economic to pump the water up for irrigation. Thus, agricultural developments in such instances can only be treated as temporary phenomena, since production declines significantly once the water availability is reduced. This situation has already occurred in many parts of the world. For example, recent data from groundwater monitoring in the province of Tamil Nadu in India indicate that at least 27 observation wells had a net fall of more than 6 metres during a period of only six years, between January 1973 and January 1979. One recorded a net fall of as high as 16.40 metres, which means an average lowering of 22.77 cms per month, a very high figure viewed from any direction (Srinivasan, 1979).

With increasing emphasis on the use of groundwater for further horizontal and vertical expansion of agriculture, it is imperative that the developments planned are sustainable.

iv) *Development of river and lake basins shared by more than one state* With increasing demands for water for agricultural, industrial and other purposes, conflicts between nations sharing the same river and lake basins are likely to intensify in the future. The magnitude of the problem of development of shared water resources has, unfortunately, not been realised so far. National boundaries frequently divide drainage basins and conflicts between nations often arise due to competing demands over limited supplies of available water and/or deterioration of water quality through waste discharges.

On a global basis there are 214 river or lake basins that are shared by two or more countries. These are distributed as follows: Africa – 57; Asia – 40; Europe – 48; North and Central America – 33; South America – 36.

There are nine river and lake basins which are shared by six or more countries:

Danube	(12 countries – Romania, Yugoslavia, Hungary, Czechoslovakia, Federal Republic of Germany, Bulgaria, Austria, USSR, Switzerland, Italy, Poland, Albania).
Niger	(10 countries – Mali, Nigeria, Niger, Algeria, Guinea, Cameroon, Upper Volta, Benin, Ivory Coast, Chad)
Nile	(9 countries – Sudan, Ethiopia, Egypt, Uganda, Tanzania, Kenya, Zaire, Rwanda, Burundi)
Zaire	(9 countries – Zaire, Central African Republic, Angola, Congo, Zambia, Tanzania, Cameroon, Burundi, Rwanda)
Rhine	(8 countries – Federal Republic of Germany, Switzerland, France, Netherlands, Austria, Luxembourg, Belgium, Liechtenstein)
Zambezi	(7 countries – Zambia, Angola, Zimbabwe, Mozambique, Malawi, Tanzania, Namibia)
Amazon	(7 countries – Brazil, Peru, Bolivia, Columbia, Ecuador, Venezuela, Guyana)
Lake Chad	(6 countries – Chad, Niger, Central African Republic, Nigeria, Sudan, Cameroon)

Mekong (6 countries – Laos, Thailand, China, Kampuchea, Vietnam, Burma)

The countries listed in brackets are arranged on the basis of the share of the total basin area per country. For example, for the Mekong River, the total area of the river basin is 786,000 km^2 and it is shared by countries listed in Table 1.

Table 1. Countries sharing the Mekong River Basin.

Country	Share of River Basin	
	km^2	Percentage
Laos	199,500	25.4
Thailand	180,000	22.9
China	174,000	22.2
Kampuchea	149,000	18.9
Vietnam	60,500	7.7
Burma	22,500	2.9

Viewed from a different perspective, there are at least 40 countries where at least 80 per cent of the total area falls within international river basisn. These are shown in Table 2.

During the past decade several long-standing conflicts have emerged over the development of international rivers like Colorado (United States and Mexico), Euphrates (Syria and Iraq), Ganges (India and Bangladesh), Indus (India and Pakistan), Jordan (Israel and Jordan) and La Plata (Brazil and Argentina). With increasing population and need for further economic development, pressures for further water resources development will become more critical. For example, the Ganges Basin alone may have to support some 500 million people by the year 2000. With such pressures, the potential for conflicts between nations will, in all probability, increase dramatically.

There is an urgent need to identify existing and emerging conflicts, and to develop guidelines and processes for the resolution of such conflicts. International organisations like the United Nations have not made serious attempts or studies for the resolution of such conflicts. During the United Nations Water Conference held at Mar del Plata, Argentina in 1977, a low-key approach was taken for shared water resources because of the conflict between the host country, Argentina, and Brazil. The Conference did, however, pass a resolution on international river basins (Biswas, 1978). For all practical purposes, United Nations has not addressed itself to such problems and this is one area where the United Nations University, because of its unique position, can and should make a major contribution.

Conclusion

Four priority areas have been identified in this paper, but it should be noted the order of the areas is not based on their relative importance. This is because all four areas need immediate emphasis and all require simultaneous attention. While water resources of the world are undoubtedly an extremely valuable commodity, insufficient attention is being paid at present as to how to develop and manage them efficiently for the good of all mankind. This situation has to be changed.

Table 2. Countries where at least 80 per cent of total area falls within international basins.

Countries	Total Area (km^2)	Area within International Basin (km^2)	Percentage of Country within International Basins
Africa			
Benin	112,622	104,800	93
Burundi	27,834	27,834	100
Central African Republic	622,984	622,984	100
Congo	342,000	283,500	83
Equatorial Guinea	28,051	28,051	100
Ethiopia	1,221,900	972,100	80
Gabon	267,667	229,700	86
Gambia	10,260	9,500	91
Guinea	245,587	198,200	81
Lesotho	30,355	30,355	100
Malawi	118,484	113,500	96
Nigeria	923,768	805,000	87
Rwanda	26,388	26,388	100
Sudan	2,505,813	2,035,900	81
Swaziland	17,363	17,363	100
Uganda	236,036	236,036	100
Upper Volta	274,200	274,200	100
Zaire	2,345,409	2,339,800	99
Zambia	752,614	752,614	100
Zimbabwe	390,580	389,360	100
Asia			
Afghanistan	647,497	587,000	91
Bangladesh	142,776	123,300	86
Bhutan	47,000	47,000	100
Iraq	434,924	362,500	83
Kampuchea	181,035	158,000	87
Laos	236,800	222,900	94
Nepal	140,797	140,797	100
Europe			
Andorra	465	465	100
Austria	83,849	83,849	100
Belgium	30,513	29,300	96
Bulgaria	110,912	88,000	80
Czechoslovakia	127,869	127,869	100
G.D.R.	108,178	100,300	93
Hungary	93,030	93,030	100
Liechtenstein	157	157	100
Luxembourg	2,586	2,586	100
Poland	312,677	298,564	95
Romania	237,500	233,000	98
Switzerland	41,288	41,288	100
Yugoslavia	255,804	211,850	83

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