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SENEGAL RIVER BASIN PLANNING[1]

by J. Paul Riley[2]

Introduction

Physical characteristics

The Senegal River is truly an international stream. The river, which is 1800 km long, is one of the largest rivers in Africa (Senegal-Consult, 1970). As shown by Figure 1, the river rises in the north of Guinea, crosses the western part of Mali, then for the rest of its course to the Atlantic Ocean it follows the border between the Republics of Mauritania and Senegal. The drainage basin contains a total surface area of approximately 290,000 km^2 and this total is divided between the four riparian countries about as follows: Guinea 31,000 km^2, Mali 155,000 km^2, Mauritania 76,000 km^2, and Senegal 28,000 km^2. Situated between latitudes 10°30' and 17°30' north and longitudes 7° and 16°30' west, the basin consists of three distinct regions, namely, the upper basin, the valley, and the delta. The upper basin is the runoff or supply region, while the two lower regions are generally conceded to be the areas of consumptive water use. The highest point in the basin is 1372 meters above mean sea level. Average channel gradients vary from a maximum of about 2 m per km in the headwater streams to less than 1 cm per km in the delta region.

Precipitation (rainfall) is the source of supply for the river flows. Rainfall quantities vary considerably throughout the basin, ranging from an average of 2000 m per year on the southern portion to 250 mm per year in the northern section. At a particular location rainfall amounts also vary from season to season. Average rainfall quantities for the entire basin have been found to vary from one year to another by 20 percent. Average monthly precipitation quantities are high during the rainy season, and are practically nil outside this period. In the south rainfall occurs in the period from April to November, whereas in the north this season usually extends for the three months of July, August, and September. River flows reflect precipitation quantities, and thus vary considerably both throughout the year and from one season to the next. The average runoff coefficient at Bakel (approximately 800 km upstream from the river mouth and generally accepted as the point of division between the upper basin and the valley) is 18.2 percent, but this number varies considerably with rainfall characteristics and antecedent soil moisture conditions. The average annual discharge at Bakel is 771 m^3/s, while the 100-year peak flow at this location is 10,700 m^3/s. The average monthly discharge at Bakel is 3,423 m^3/s in September and 10 m^3/s in May.

Existing water uses

The Senegal River basin is inhabited essentially by farmers, herdsmen, and fishermen. Its current population is estimated to be 1.6 million, which represents about 16 percent of the overall population of the four states. To this population must be added people living in the adjacent regions who will in varying degrees be affected by any development within the basin. At

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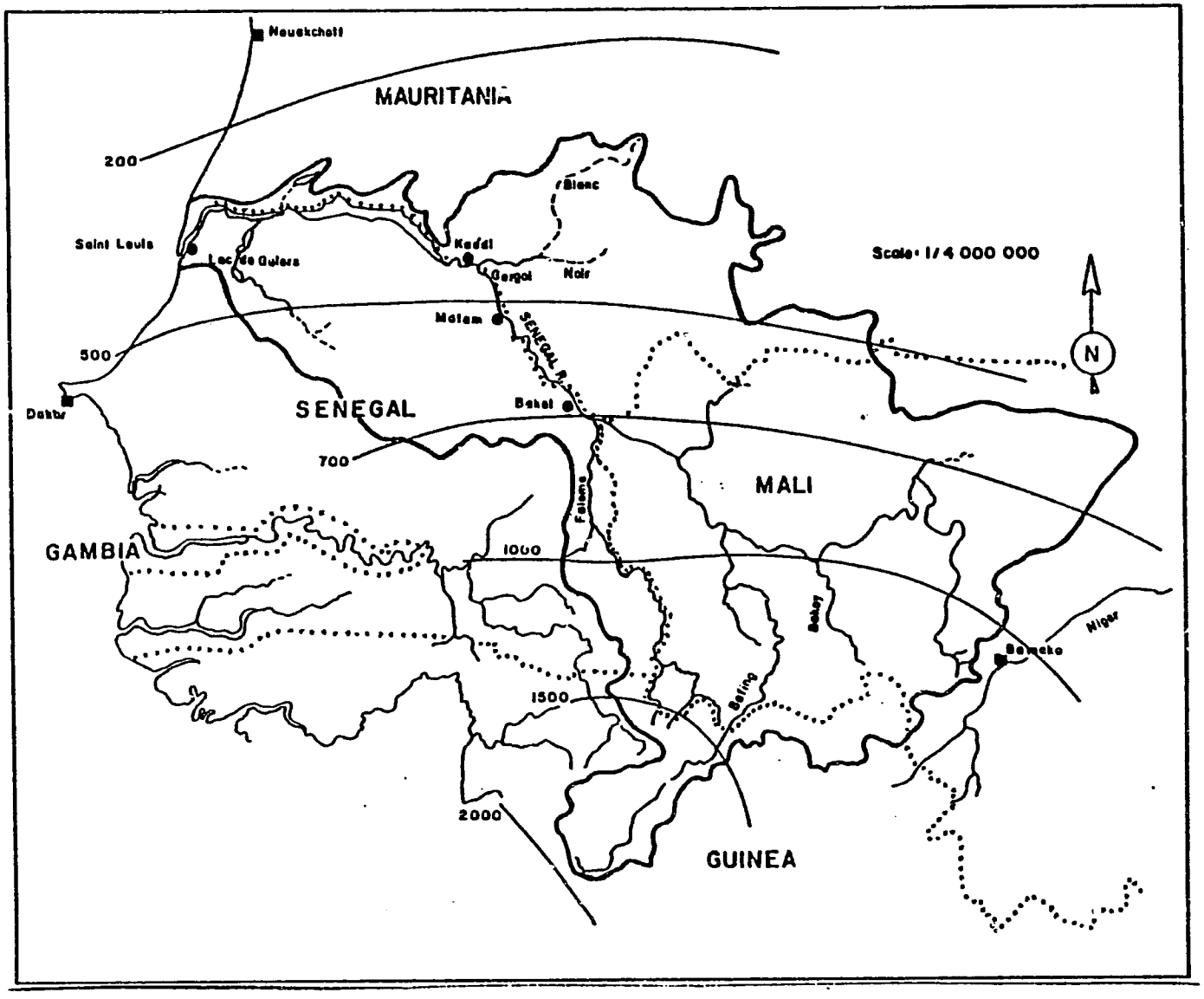

Figure 1. Map showing the location of the Senegal River Basin and isohyetal lines of average annual precipitation (in millimeters).

present the waters of the Senegal River are used for agriculture, navigation, and in a limited way for municipal and industrial purposes.

1. Agriculture - The present level of agricultural development within the basin is limited by both climatological and technological factors, including transportation facilities. Most of the culivated lands lie in the valley and delta regions downstream from Bakel and comprise a total of approximately 120,000 ha of "recession" crops. These crops are grown on the river flood planes after the recession of high river flows each year. In addition, controlled irrigation now is being practiced on some small pilot projects in the valley and on an area of about 20,000 ha in the delta region. Of this total, 1,100 ha in Mauritania and 11,000 ha in Senegal are being irrigated by controlled surface flooding techniques and one crop is being produced each year. The remaining area of approximately 5,000 ha are in sugar cane, and are under fully controlled pumped irrigation in the Richard Toll area of Senegal.

2. Navigation - Partly because of the inadequacy of the existing road and rail transportation networks within the basin, navigation on the river is an important means of transportation. The navigability of the lower portions of the Senegal River channel is dependent upon water stage. Thus, during periods of high flow the river is commercially navigable as far upstream as Kayes in Mali. During periods of low flow, navigation on the river is limited to the portion of the river between Podor, a distance of 275 km upstream from St. Louis, and the river mouth.

3. Municipal and Industrial - Present demands upon the river for municipal and industrial supplies are very low. In addition to supplying small communities situated along the channel, the stream does provide water for Kayes in Mali, for Rosso, Rogue, and Kaedi in Mauritania, and for the Senegalese communities of Bakel, Matam, Podor, Richard Toll, St. Louis, and Dakar.

4. Power - At present no use is being made of the Senegal River to generate hydro-electric power and the very high cost of thermal energy is precluding the development of the appreciable mineral resources of the basin. In addition, hydropower is needed to support agricultural, municipal and industrial development in the basin. For this reason, the three OMVS countries are interested in the hydro-electric power potential of the river. Except for a few limited exceptions involving specialty crops such as tomatoes and sugar cane, at present levels of water development within the basin it is not possible to maintain a state of self-sufficiency with any increase in population within the basin. The result has been a rural exodus and an influx of people to major centers of population, such as Dakar.

Potential additional water use in the basin

The waters of the Senegal River represent a common and highly valuable resource to each of the three states of Mali, Mauritania, and Senegal, and yet each state views the development potential of this resource in terms of its own particular needs. These needs are based largely on geographic location, the availability of other resources within the country (including human resources), and social goals and aspirations. The major development potentials of the river as viewed by each country are discussed in brief and general terms by the following paragraphs.

MALI

1. Navigation - Because Mali is a landlocked country it regards the Senegal River (an international stream) as a means of access to the Atlantic Ocean without crossing international boundaries. It is estimated that a regulated minimum flow of 300 m^3/sec at Bakel would enable vessels with draughts not exceeding 1.5 meters to reach Kayes in Mali during the entire year. Even so, channel improvements and a continuous dredging program would be necessary. The alternatives to river transportation are improved road and rail systems, both of which would involve agreements with other countries.

2. Power - Mali is interested in hydro-electric power to foster municipal and industrial development. Large iron deposits exist between the Baging and Bankeye River and on the Foleme River. In addition, there are apparently large reserves of bauxites in the south-west portion of the country. Mali views the hydro-electric potential of the Senegal River as a logical source of power for the development of its mineral reserves. The generating sites would be situated within Mali. Fossil fuel or nuclear plants are the primary alternatives to hydro-electric power.

3. Irrigation - The use of the river for irrigation represents a very limited potential for Mali. For example, construction of the proposed Manantali dam would enable about 40,000 ha in Mali (upstream from Bakel) to be brought under controlled irrigation. The primary alternative available to Mali is to further develop the irrigation potential of its Niger River basin.

MAURITANIA

1. Navigation - Regulation of the Senegal River would improve the year-round navigability of the river upstream from Podor. However, it is doubtful that Mauritania, with its improving road network, regards the river navigation potential with a high priority in the basin development program.

2. Power - Mauritania has significant untapped deposits of phosphates and copper, and power will be needed to develop these. However, the possibility of obtaining hydro-power from the Senegal River, at least for some considerable time, seems remote. Thus, it is believed that Mauritania presently regards the power potential of the river development program with a low priority, unless the power were to be utilized to drive pumps associated with the irrigation development. The energy alternatives available to Mauritania are fossil fuel, nuclear, and perhaps solar.

3. Irrigation - The irrigation potential of the basin and delta regions is the aspect of the river development program which currently is of most interest to Mauritania. Mauritania includes about 130,000 ha of arable land within the flood plane of the river below Bakel. Irrigation offers the prospect for stabilizing the incomes of those who live along the river, and also could provide supplemental feed for the migratory herds in the Sahara. Mauritania has no other major river which could provide an alternative source of irrigation water. However, the groundwater potential of the Senegal River basin could be a viable source of supply. Fossil groundwater supplies have been tapped at various other locations throughout the country, but on the basis of present knowledge this potential is minimal.

SENEGAL

1. Navigation - Like Mauritania, the value of improved river navigation to Senegal is probably marginal. Improved rail and road transportation facilities represent very viable alternatives.

2. Power - Senegal is very interested in the power potential of the river in order to provide for both municipal and industrial demands. Tapping the large iron-ore deposits in eastern Senegal will require a large block of energy. In addition, Senegal views the river as a potential source of power for (a) Dakar and other urban centers of the country, and (b) pumps associated with agricultural development on the river. Alternatives to power from the upper Senegal basin include hydro-electric sites on the Gambia River (the Samban-Galou development, for example), fossil fuel generation, nuclear, and perhaps solar.

3. Irrigation - This aspect of the river development program offers considerable potential for Senegal. In fact, the government of Senegal has categorized the Senegal River basin as one of the three major planning regions of the country, with the other two being (a) the Casamance in the south and (b) the region lying between. At the present time emphasis is being placed on agricultural development in the river delta area where upstream salt intrusion is a problem during river low flow stages. Ways being considered to solve this problem include flow regulation and/or a barrier structure near the river mouth. The government, however, is officially committed to the development of controlled irrigation (and drainage) on the entire area of arable land (about 230,000 ha of Senegal) within the flood plane of the river (below Bakel). Alternatives available to Senegal for food production include the interior basin with irrigation from groundwater supplies and also the Gambia River, and the Casamance area where little or no irrigation is needed.

A Planning Strategy for the River Basin

The OMVS

In 1964 an international organization was formed to facilitate the formulation of an integrated development plan for the river. This organization, called "The Senegal River Basin Development Inter-States Committee," included the four riparian states of Guinea, Mali, Mauritania, and Senegal. In 1968 the organization became "The Senegal River States Organization" (denoted OERS from its French title). In 1972 the OERS was dissolved when Guinea withdrew, and a new organization consisting of the remaining three states was formed called "The Senegal River Basin Development Organization" (OMVS from its French title, "Organisation pour la Mise en Valeur due fleuve Senegal"). The OMVS organization has broad planning authority, and under its direction many studies of the Senegal River basin have been undertaken which involve a wide range of physical and socio-economic disciplines. Although much broader in its scope of activity, the OMVS is roughly equivalent to the International Columbia River Engineering Board (ICREB) which formulated the Columbia River Treaty between the U. S. and Canada and which was signed in 1961.

The governing body of the OMVS is a Council of Ministers which consists of members of the government from each of the member states. The chief officer is a High Commissioner and the day-to-day executive function is conducted by the Secretary-General. Both of these positions are filled by appointments from the Council of Ministers. Although the stated mission of the OMVS is to formulate and coordinate an integrated development plan for the Senegal River basin, its relationship with national development organizations (such as SAED in Senegal) has been only loosely coordinated. The relationship of the OMVS to national development corporations and to other international authorities which might in the future be established to fulfill specific functions (such as a river navigation authority) is depicted by Figure 2.

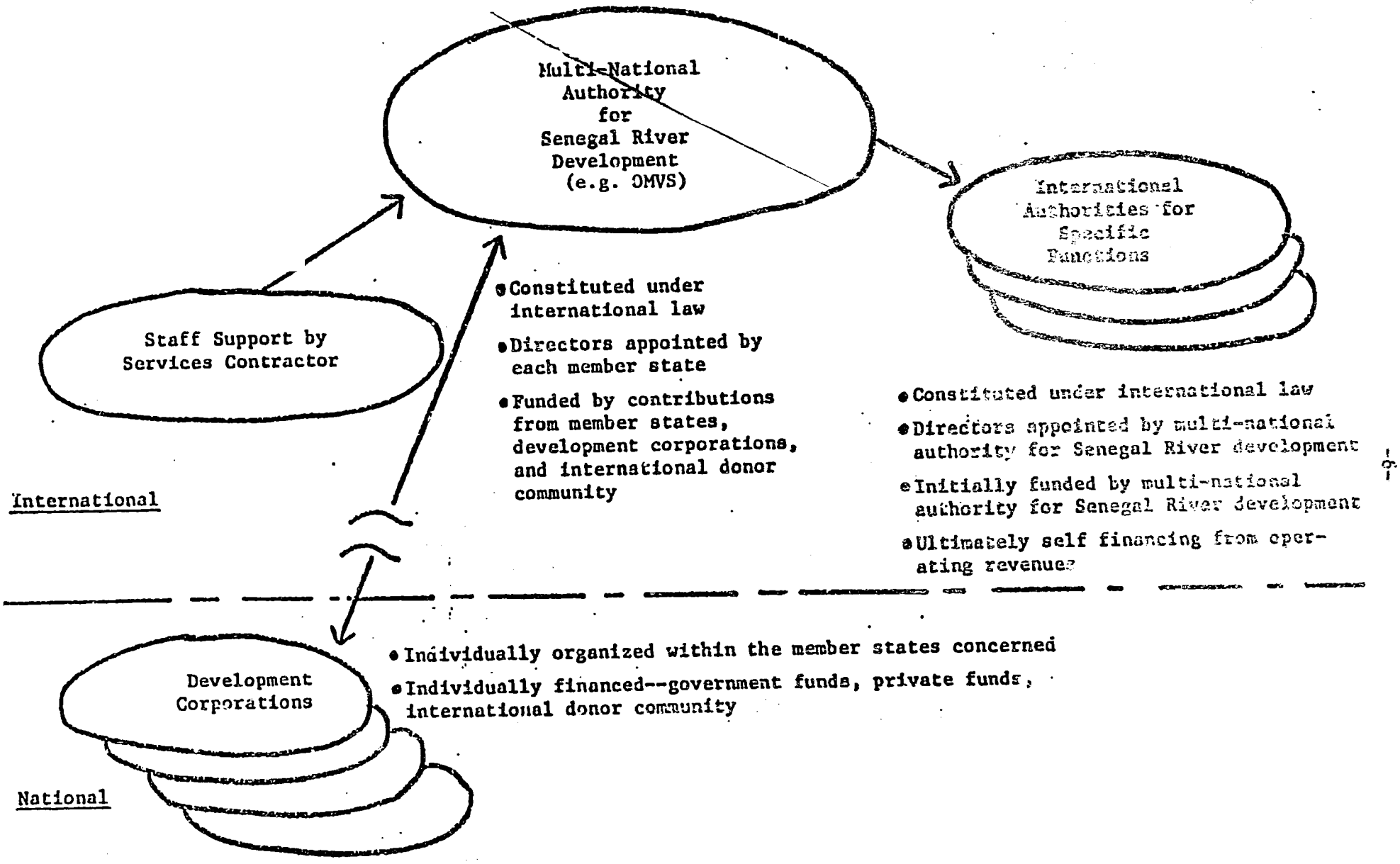

Figure 2. The basic institutional components of a general management plan for the proposed Senegal River Development Project.

Basin-wide planning

Water is an essential ingredient of life. Included among its use sectors are agriculture, navigation, power generation, municipal and industrial uses, and recreation. As water resource utilization becomes more intense, interactions and conflicts between the various uses become more pronounced. For this reason, the proper management of the water resources of a region so as to achieve maximum public benefit is a matter of increasing importance.

The effective management of the water resources of the Senegal River basin is a question of utmost importance to the riparian countries of Mali, Mauritania, and Senegal. The manner in which the available water supplies eventually are allocated and used will have a long-term impact on the economic and social development of the entire region. Thus, the question of how the water resources of the Senegal River can be utilized to best serve the needs of the people of the basin is one of paramount importance, and the answer will require a well-integrated and cooperative approach by all groups and countries concerned with the welfare of Western Africa.

Clearly, the starting point in the formulation of a planning and management strategy is a precise definition of the management objectives and of the kinds of problems which might be encountered in achieving these objectives. Without this essential first step, a meaningful and effective management strategy cannot be formulated and implemented.

By definition, a problem is associated with a characteristic of a physical or social system which is in some way detrimental to, or perhaps not amenable to, a particular social use. The problem for the particular social use is solved by modification of the system so as to better accommodate the use. For example, a dam is constructed to provide flood control and so reduce the risks associated with flood plain development. However, the construction of the dam might well have adverse affects on other social uses, such as transportation and farming within the reservoir area. A modification at any point in a system initiates a whole series of adjustments throughout the entire system until anew equilibrium condition is reached. These adjustments produce both physical and social impacts, some of which are positive and others of which are negative, but all of which need to be anticipated and assessed by a program of efficient system management.

A system is managed in order to accommodate particular social uses which are identified with specific social goals and objectives. For this reason, the first step in identifying possible problems associated with the management of a particular system is to delineate the various potential social uses for the system. In the case of the Senegal River basin the major social uses of the water resources system are identified with the following areas of activity.

1. Irrigation agriculture
2. River navigation
3. Hydro-power generation
4. Community development
5. Municipal and industrial water supplies
6. Mining activities
7. Fishing
8. Dryland agriculture, including grazing
9. Forest production

Of the nine social uses involving the water resource system of the basin listed above not all are independent, and some, such as the last two, are probably little influenced by the water resources system. The dependency between uses is illustrated by mining activities which require both electric energy and transportation.

The general management concept for a natural resource system, such as that of the Senegal River basin, is illustrated by Figure 3. As indicated by this diagram, there is first the need to understand and describe the physical component of the system through basic information and data. Next to be considered are the social demands or use options which might be implemented in varying degrees through management measures (both technical and non-technical) which alter certain characteristics of the physical system. Any management policy is imposed upon the physical system in order to produce a particular set of conditions. In turn these conditions are interpreted in terms of the needs of a particular social objective or set of objectives. Thus, while an achieved set of conditions might be desirable in terms of a given social objective, these same conditions might represent disadvantages to other social uses or objectives. For this reason a particular management plan is necessarily selected by means of some form of optimizing process which usually is based on cost and value factors. The selection, or optimizing, procedure often involves "trade-offs" between value functions, but hopefully the management plan which is ultimately selected is able to provide the optimal resource use in terms of the needs, objectives, and goals of the society as a whole. Frequently, the plan which is adopted does not provide the optimal resource use in terms of economics alone. Finally, through the input of labor and capital, the physical system is modified to accommodate to some degree the requirements of the various resource use options which are emphasized by the management plan being implemented.

As previously mentioned, under the auspices of the OMVS many planning studies have been conducted in the Senegal River basin. In general, however, each of these studies has been based on very limited information or data about the physical and social (including economic) systems under investigation. Understandably, the OMVS and its member states are anxious to implement a program of development. Accordingly, the OMVS has adopted the very logical policy of "continuous planning, advancing by successive approximations." Under this policy, an initial phase of a long-range program is identified and implemented. As the results of this implementation and other information become available, the long-range program is re-evaluated and modified, and the next step in the development process thus is identified and implemented. On the basis of this procedure, the member states in OMVS have agreed to develop the Manantali dam on the Bafing River in order to provide a minimal regulated flow at Bakel of 300 m^2/second, and ultimately to generate 200 MW of "firm power". The agreement also refers to the construction of a salt water barrier dam (called Diama) near St. Louis at the mouth of the river. However, there is some justifiable concern regarding the imediate implementation of this step. The basis of these concerns are as follows:

1. The studies which led to the recommendation of this step are rather cursory, primarily because they are founded on weak formation bases. In short, additional physical data are needed.
2. The step requires a very high level of capital investment.

Recommendations

1. There are three obvious and important aspects concerning the utilization of the Senegal River:
   a. It is an international stream.

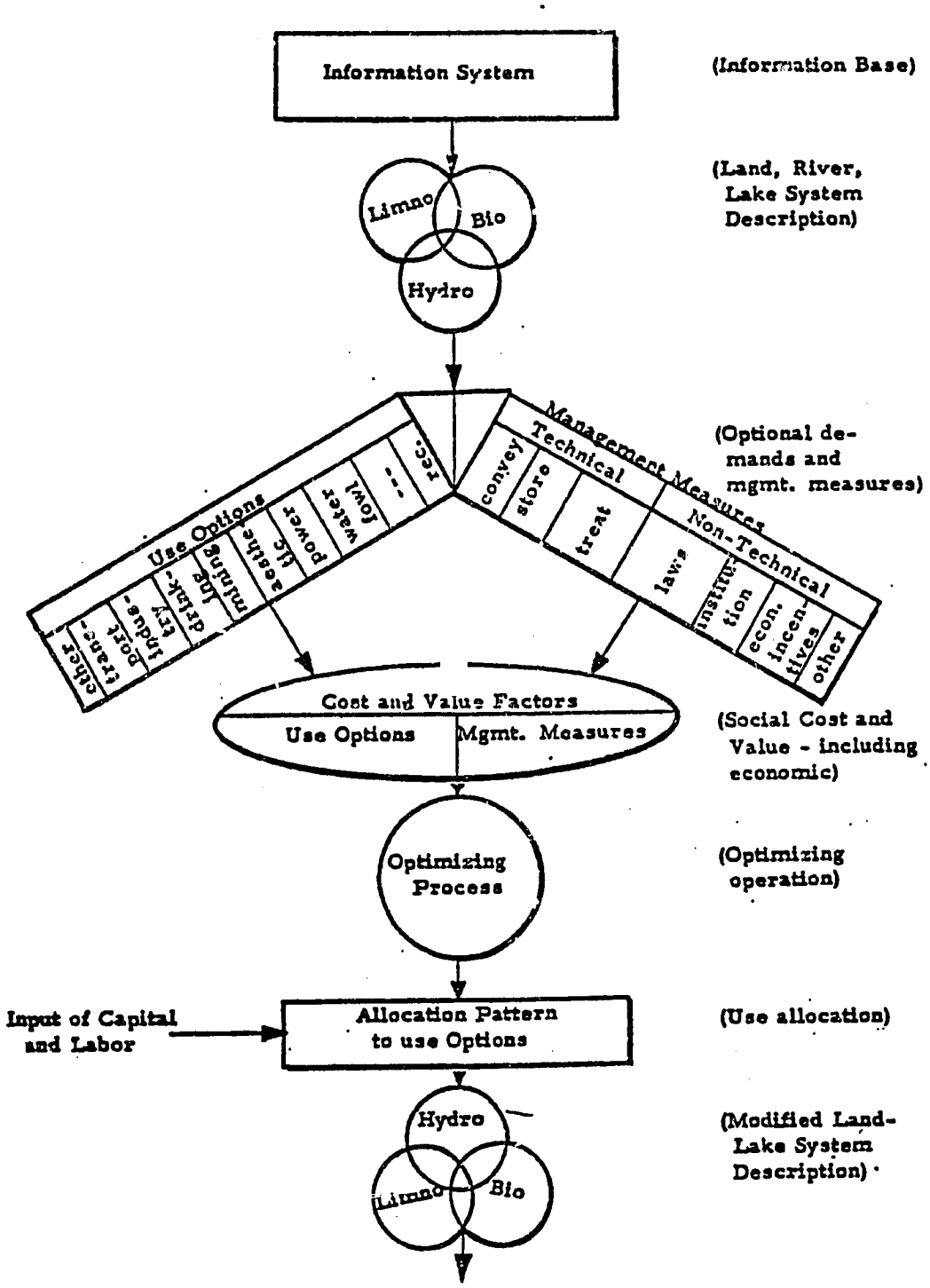

Figure 3. A conceptual diagram of the processes involved in the optimal management of a physical system.

b. It has considerable development potential from the standpoint of both food and energy production.

c. Its development both in a planning and management sense requires careful and effective coordination, not only across a spectrum of potential uses, but also between three separate national states.

In the past, the OMVS has functioned very effectively in the role of an international river basin authority. There is a need for an organization such as the OMVS to exist, and an obvious course of action would be to support and strengthen as needed the OMVS in its present role.

2. Development of the water resources of the basin requires (a) the establishment of a configuration of water control structures on the river, and (b) construction of the irrigation systems and development of the associated complex social infrastructures within the valley. At the present time the U. S. assistance in addressing the valley development, including such facets as:

a. Pilot development areas

b. Training and extension activities at various levels of expertise

c. Experimental farms

d. The meeting of basic research needs associated with the development

This is a highly important area of activity regardless of the system configuration which might be adopted. This role of the U. S. should be continued and expanded. Other donor countries currently are studying the two major structures on the river proposed by the OMVS (the Diama and Manantali dams) and the proposed river navigation system.

3. As indicated earlier, the OMVS has proposed a particular configuration for the initial phase of the river basin development program. There is a possibility that the current investigations will reveal some major obstacles to the construction of the Diama and/or Manantali dams. In this event (and perhaps in any case), other alternatives should be carefully evaluated using adequate and sound information bases. The U. S. could perform a very useful role in these evaluations. However, it is submitted that the U. S. role always should be supportive of the OMVS functions in the Senegal River development program.