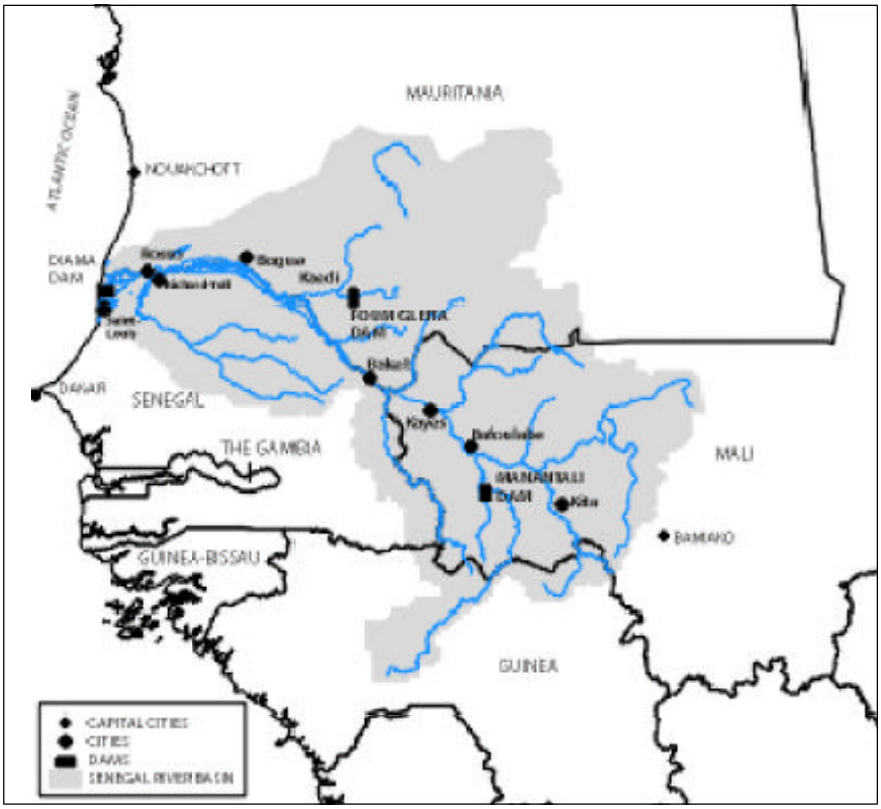
Regional Profile | Damming The Senegal River

A regional effort to harness the waters of the Senegal River for hydropower, irrigation, and transportation has resulted in profound environmental changes in the river basin. These environmental changes have, in turn, caused severe health and general welfare problems for the river basin's residents. This case study illustrates the complex relationships that can unfold between people and their environment as societies work to meet their growing needs for energy, agricultural production, and industrial development. Although many of the harmful effects were predicted before the project began, the project's purported benefits—water storage for irrigation, drought, and domestic supply; electrical power for urban areas and industry; and a transportation channel to the sea for land-locked Mali—were deemed too important to forgo. Now, years later, the river basin management authority, national ministries in three riparian countries (Mali, Mauritania, and Senegal), and international agencies financing the project are trying to mitigate some of the most severe problems as they continue work to realize the project's potential benefits.



Background

The Senegal River is the second longest river in West Africa (1). Its principal tributary, the Bafing River, rises in the highlands of Guinea's Fouta Djallon and runs north into Mali, where it joins the Bakoye River at Bafoulabe to form the Senegal River. From Bafoulabe, the Senegal River flows northwest through Mali and down to Kayes, receives waters from the Faleme River, and then flows onto the flood plain starting at Bakel in Senegal. For its remaining length from Bakel to the Atlantic Ocean, the Senegal River forms the border between Mauritania to the north and Senegal to the south.

The upland areas above Bakel, and particularly those in Guinea, receive 700 to 2,000 millimeters of rainfall annually and provide virtually all of the flow in the Senegal River. Annual rainfall below Bakel is typically between 150 and 300 millimeters. Tributaries to the Senegal River are temporary, seasonal systems that function as distributaries when flow is high in the main channel. In its natural state, the Senegal River's annual flood inundated approximately 150,000 hectares in an average year and up to 350,000 hectares in high-flow years. In the dry season, freshwater flow stopped in the lower reaches of the river, and saltwater flow traveling upstream created estuarine conditions from the Atlantic coast to Dagana, approximately 250 kilometers inland. These conditions created a natural division of the river basin into three zones: an upper basin above Bakel; the middle valley from Bakel to Dagana; and the delta, or lower valley, from Dagana to the Atlantic coast.

Approximately 2 million people of several ethnic groups live in the river basin. The predominant groups are the Malinke in the upper basin, the Soninke around Bakel, the Pulaar and Maures in the middle valley, and the Wolof in the delta. All of these groups are agropastoralists, relying for their livelihood on a combination of agriculture, small animal husbandry, and fishing. Herders have historically traveled with their cattle from the valley floor in the dry season to the adjacent Sahelian fringe areas in the rainy season and floods.

Because of their dependence on the river, residents' fortunes have risen and fallen through the years in relation to the availability of water from rainfall and floods. From 1968 to 1973, the region experienced a prolonged and severe great drought that caused extensive famine and focused international attention on the Sahel region.

Development Projects on the Senegal River

Because of its size and regional importance, the Senegal River has long been a target for development projects. There were two international efforts to develop agriculture, navigation, and hydroelectric projects in the four riparian states (including Guinea) during the colonial period in the 1930s and early 1940s. In the 1960s, after gaining independence, the riparian countries created an Inter-Country Committee and a successor organization to pursue an integrated development program for the river basin. However, most of the early attempts at developing the river's resources failed, either for technical reasons or because of tension among the participating states.

In the early 1970s, circumstances finally combined to favor mounting several large-scale projects. In 1970, a U.N.-sponsored study identified several potential sites for hydroelectric dams in western Mali and northeastern Guinea. In 1972, partially in response to the great drought and the resulting attention from international agencies, the governments of Mali, Mauritania, and Senegal created a regional river basin authority, the Organisation pour la Mise en Valeur du Fleuve Senegal (OMVS). Guinea was not included in the OMVS because of its lack of interest and effective participation in the earlier regional organizations. The three member states of the OMVS thought a regional organization would be the best way to prioritize economic objectives for developing resources in the basin, to organize a cooperative effort, and to reach agreement on common responsibilities for financing and managing the major works. Arab oil states also took an interest in financing projects on the Senegal River, a reflection of their prosperity during the oil boom of the 1970s and of their desire to assist other members of the Islamic community and increase Islamic economic and cultural influence in the region.

The OMVS members developed an integrated plan for development of the Senegal River, designed to stimulate economic growth in the three member countries and to moderate the effects of drought on people living in the basin. The plan had six components:

- an upland hydroelectric dam on the Bafing River at Manantali, Mali, for water storage and power production;
- a lowland dam on the Senegal River near Diama, Senegal, to limit saltwater intrusion, regulate water levels in the middle valley, and store water for domestic water supplies;
- facilities and conditions (i.e., locks, channel dredging, and water-level management) to ensure navigability from the Atlantic coast at Saint-Louis, Senegal, to Kayes, Mali;
- irrigation projects and agricultural development in the middle and lower valley;
- urban water supplies using the reservoir created by Diama Dam; and
- development of agroindustry.

The OMVS was given direct authority for building and operating the two dams and responsibility for developing the navigation project. The member states retained responsibility for developing irrigation, water supply, and agroindustrial projects within their own territories.

Politically, the major selling points of the plan were that it would lessen the impact of future droughts and help close the food gap that was emerging as rapid population growth outpaced domestic food production. The OMVS was directed to manage the river's water resources to achieve two objectives that related primarily to agriculture: first, to reduce the large seasonal and annual fluctuations in water availability; and second, to control flooding so that land in the valley could be developed for irrigated agriculture. Senegal and Mauritania would realize most of the benefits from meeting these objectives: of the 375,000 hectares of land that were to be developed for irrigation, all but 9,000 hectares were in these two countries. The hydropower and navigation components were included in the plan primarily to meet Mali's interests.

The expectations of mutual benefit and accelerated development, coupled with the crisis conditions created by the great drought and realistic prospects of international financing, enabled the three countries to overcome entrenched suspicions and proceed with the project. The three member states have maintained a level of cooperation sufficient to complete construction of both dams. Diama Dam was completed and began storing water in 1986. The reservoir behind Manantali Dam began filling in 1987 and reached spillway level in 1991. Other portions of the plan have developed more slowly than first envisioned. Irrigation projects have been completed in the middle valley, and rice and sugar cane production have increased, although not as rapidly as originally predicted. Financing was recently arranged for the hydropower component, which involves installation of turbines and generators at Manantali Dam and building transmission lines to the three capitals (Dakar, Nouakchott, and Bamako) and several points in the basin. Plans for the navigation component have been modified to reflect more realistic water management conditions, shipping systems, and associated development of sea and river ports. Some critics maintain that the navigation project is still unrealistic and will likely never be built. Plans are being developed for water supply projects in Senegal. Most recently, a small amount of industrial development has occurred in the valley, primarily connected with the agricultural sector.

Although the OMVS has implemented portions of its development plan, the projects have not yet generated substantial economic benefits for the member states. Agricultural development has proceeded more slowly than expected, in part because of inappropriate plans for irrigation projects, low yields being experienced in existing projects, and (until recently) centralized control over agricultural planning, production, distribution, and marketing. The power and navigation projects have not yet been implemented. There is some question whether the full plan, even if completed, will ever generate the level

of economic benefit originally predicted. The Senegal River dams were initiated in a global economic climate that favored large development projects and a political climate in which the major donors exerted little influence—too little, maintain some critics—over project planning and implementation (2)(3)(4).

Whatever balance may eventually be realized between the economic benefits and costs of the projects for the region and for each country, it is also important to consider the distribution of those costs and benefits and, particularly, the situation of people most directly affected by the projects— those living in the river basin. The completed projects and the OMVS' practices to date in managing water levels in the basin have provided few benefits and serious negative consequences for the basin's residents—some anticipated, and some unanticipated. The ecological, health, and social consequences will be explored in the following sections.

Ecosystem Changes in the Senegal River Basin

The Manantali and Diama dams have changed the river basin ecosystem in several obvious and profound ways. The annual flood has been reduced substantially, because the flow from the Bafing River has been impounded at Manantali Dam. The amount of water available from other tributaries is considerably less than that from the Bafing River. Water has been released from Manantali Dam to provide a managed flood every year since 1987. Unfortunately, the volume of water released each year has been far less than would have been available under natural conditions. And during several years, the period chosen for a water release was poorly timed.

The Senegal River now flows yearround. The region above Diama Dam is now a stable freshwater lake and no longer shifts to estuarine conditions during the dry season. The area below Diama Dam now has a relatively constant estuarine status, as opposed to the previous shifts between freshwater and estuarine conditions that occurred as a result of high freshwater flows in the flood season and low-to-nonexistent freshwater flows in the dry season. The shoreline is increasing as irrigation canals are developed. Weeds and grasses characteristic of a freshwater lake are growing along the banks of the river and canals from Diama Dam to Dagana and could eventually reach another 100 kilometers inland to Bogué. The vegetation, partially submerged along the river's edge, is favorable habitat for the snails that carry schistosomiasis; increasing vegetation is the primary cause of the growing disease problem among the population of the lower basin.

The changes in aquatic habitat and the physical barrier of Diama Dam have greatly affected fisheries in the lower valley, delta, and coastal waters. Before the dams were built, the sediments carried by the annual flood were an important source of nutrients for coastal fisheries, and the flood plains in the upper delta were spawning and feeding grounds for saltwater and freshwater species. A major coastal fishing industry was centered around Saint-Louis, and fish were an important source of protein for people living in the valley. Although the prolonged drought had already reduced annual catches in the valley before the dams were built, a study in 1994 concluded that the dams have generally had a detrimental effect on fish production both in the valley and in the upper part of the delta. People living in the valley maintain that fish consumption has decreased since 1988. They say that the fish now consumed are almost exclusively saltwater species, trucked in from the Senegalese and Mauritanian coastal areas.

Above Manantali Dam, a large, deep freshwater lake now exists in what was previously a forested valley. The dam was designed to store 11 billion cubic meters of water, enough to supply 2 years' flow during a drought. The surface of Lake Manantali now covers 447 square kilometers; its shoreline is approximately 150 kilometers, and it is 65 meters deep at the dam. Studies conducted before the dams were built predicted that fish populations would increase in the lake behind Manantali Dam (stabilizing at around 3,000 metric tons annual production) and decrease below the dam (5). Although the fish population in Lake Manantali did increase after the reservoir was filled, the annual catch has never reached predicted levels and has fallen sharply in subsequent years, to 420 metric tons in 1991 and 285 metric tons in 1993. The decreased catch reflects in part the techniques and equipment used by the fisherman, who were accustomed to fishing in rivers rather than in a deep lake, and also the movement of people away from the area.

Environmental Changes and Health Problems

People living in the Senegal River basin have long suffered from schistosomiasis, malaria, and other infectious and vector-borne diseases endemic in large areas of sub-Saharan Africa. Before dams were constructed, malnutrition was widespread in the valley, and infant and child mortality rates were high, especially during the extended drought. The development plan endorsed by the member states of the OMVS predicted that residents' well-being would improve as agriculture and transportation expanded and people had more income and greater access to food, water, and health care.

The reality has been different. Agriculture is developing, but more slowly than anticipated and in a manner that stretches the financial and human resources of existing landholders. Transportation has not improved. Although some indicators of health have improved in the region, health risks from certain diseases—most notably schistosomiasis, diarrheal diseases, and malaria—have increased, in some cases dramatically. The net impact of the Senegal River development projects on people's health has clearly been negative to this point.

SCHISTOSOMIASIS

Schistosomiasis results from infection by species of the trematode *Schistosoma*. The parasite has a complex life cycle with a stage that infects freshwater snails, which then release larvae into the water. Humans come into contact with the larvae when they wade in shallow waters (for example, when collecting water, washing clothes, or, for children, playing); they become infected when larvae penetrate the skin. Larvae migrate through the host's circulatory system and lungs while developing into mature male and female worms; they eventually migrate to blood vessels in the abdomen and form permanent reproductive pairs, after which the females may produce large numbers of eggs for many years.

There are two main species of *Schistosoma* that infect humans in Africa; they rely on different snail hosts, settle in different tissues of their human hosts, and produce different forms of the disease. *S. mansoni* settle in blood vessels near the liver or intestines and cause intestinal schistosomiasis; *S. haematobium* settle near the bladder and cause urinary schistosomiasis. The severity of the disease in each individual depends on the position and size of the egg load and the host's cellular response to it. Intestinal schistosomiasis causes diarrhea and bloody stools in moderate cases and, in heavy infections, permanent organ damage that can lead to death. Urinary schistosomiasis causes blood in the urine; severe cases involve serious damage to the urinary tract, sometimes leading to bladder cancer.

Before 1986, urinary schistosomiasis was endemic in the Senegal River basin, with relatively low rates of infection in the lower valley and moderate to high rates in the middle and upper valleys. Since the construction of Diama Dam, the snail hosts of *S. haematobium* have extended their range and increased their number in the lower valley, especially along the Lampsar River (a southern branch of the Senegal River in Senegal). Infection rates in humans have also increased. A 1994 survey found the prevalence of urinary schistosomiasis was moderate (11 to 12 percent) among schoolchildren surveyed along the Mauritanian shore of the Senegal River at Rosso, Baghdad, and Jidrel Moghuen. That year, the snail host was found for the first time in the Taouey canal in Senegal, near its outfall to Lake Guiers. There was no evidence at that time of infection among schoolchildren in Mbane, a town on the eastern shore of the lake, although the presence of the snail host suggests that future increases in disease rates in this area are possible.

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In the upper valley around Lake Manantali, the prevalence of urinary schistosomiasis was high (69 to 95 percent) in several lake shore villages and in a village just downstream of the dam, according to the 1994 survey. Prevalence decreased with greater distance from the dam (to 49 percent and 7 percent in two villages further downstream). In at least one place in the middle valley, in the irrigation projects around the Foum Gleita Dam in Mauritania, the prevalence of urinary schistosomiasis has been reduced to less than 5 percent by a combination of mitigation measures and natural conditions. The former includes switching from rice to other crops on some of the land and keeping irrigation canals free of weeds. These efforts are aided by the naturally flat terrain of the lake bed behind the dam, which results in large fluctuations in the location of the water line along the shore as water levels fluctuate in the lake. These fluctuations disturb the growth of marginal vegetation along the lake shore and reduce the amount of favorable habitat for snails.

The most dramatic health impact of the Diama and Manantali dams and the new water management regime has been the introduction and rapid spread of intestinal schistosomiasis in the lower valley. Before 1986, *S. mansoni* was not present in the lower and middle valleys and had been reported at only a few locations in the upper valley. In 1988, soon after the completion of Diama Dam, a new focus of intestinal schistosomiasis was reported in a sugar cane project area in Richard-Toll, on the Senegal side of the river. Prevalence reached epidemic levels the following year in Richard-Toll and, by 1993, had climbed to nearly 100 percent in the nearby village of Ndombo and 70 percent in Ngnith, a village on Lake Guiers. In 1994, disease prevalence was 82 percent among schoolchildren at Mbane on Lake Guiers and 47 percent at Dagana, the easternmost boundary of Lake Diama. These Senegalese children had heavy infections with very high egg counts.

In the Mauritanian portion of the lower valley, intestinal schistosomiasis was first reported in 1994 with prevalence rates of 25 to 32 percent in children in three towns from Rosso to Jidrel Moghuen; these children had infections of light to moderate severity. However, the snail host of *S. mansoni* was found in large numbers with high infection rates along the Mauritanian shore of the Senegal River and spreading northward into the Garak canal at Tougene and the Sokam canal near Lake Rkiz. These findings suggest that the extent and intensity of the epidemic will likely increase in Mauritania, possibly following the same course as in Senegal.

As of 1994, the problem with intestinal schistosomiasis had not extended into the middle valley and had not increased greatly in the upper valley. Under the current operating regime, Lake Diama ends at Dagana; above Dagana, the Senegal River is still within its original banks. There is little or no growth of marginal weeds in this region and, therefore, no habitat for the snails.

The introduction of intestinal schistosomiasis and the increases in urinary schistosomiasis are due to a combination of human factors. First, Diama Dam eliminated saltwater intrusion into the lower river and maintained nearly constant water levels, creating conditions fa-

voring the growth of marginal vegetation along the river edges and the spread of the snail hosts of *Schistosoma* species. Second, *S. mansoni* was probably introduced to the lower valley by people migrating into the region, possibly from the upper valley. Population in the region has increased rapidly, especially around the irrigation projects at Richard-Toll, as people move there to take advantage of new jobs. Water supply and sanitation facilities have not kept up with this rapid growth. As a result, the increased contamination of surface waters, and their greater use by residents, has contributed to higher transmission rates for schistosomiasis and increased risks for other waterborne diseases as well. The increased prevalence of urinary schistosomiasis around Lake Manantali—as well as the increased number of the type of snails associated with intestinal schistosomiasis—are due to the year-round presence of water in the lake and its nearly constant water level.

RIFT VALLEY FEVER

Rift Valley Fever is a mosquito-borne viral disease that is most often benign in humans but can occasionally lead to blindness, encephalitis, and fatal hemorrhagic fever. Epidemics are common in livestock and can cause high rates of stillbirths and abortions. The virus is transmitted to humans by biting insects (mosquitoes, sand flies, and, possibly, ticks) or by direct contact with blood or organs of infected animals after slaughter.

An outbreak of Rift Valley Fever occurred near Rosso, Mauritania, in 1987 soon after the completion of Diama Dam and the initial filling of Lake Diama. It began during the rainy season in pastoralist groups in Mauritania and spread to Rosso, eventually appearing on both sides of the river. The outbreak was the first known epidemic of Rift Valley Fever in humans west of Uganda and reportedly killed more than 200 people (6). The disease had been observed only once before in epidemic form in humans, in Egypt in 1977 near the Aswan High Dam on the Nile River. Although the exact ecological conditions conducive to rapid transmission of Rift Valley Fever remain unclear, the initial filling of a nearby reservoir may be a factor, since this was a common condition in the events at Aswan in 1977 and Mauritania in 1987 (7). Filling the Diama reservoir created more standing water—a location preferred by the *Aedes* mosquito, the probable vector of Rift Valley Fever in Mauritania (8).

The potential for such an outbreak in the Senegal River basin had been identified in pre-dam construction health assessments in 1980, 1984, and just before the onset of the rainy season in 1987 (9). Despite these warnings, authorities in the basin did not take necessary precautions to prevent an outbreak.

MALARIA

Malaria occurs in most parts of the Senegal River basin. Most reported cases are due to malaria tropica (*Plasmodium falciparum*), which can cause severe disease and death. The risk of infection is greater in the upper valley than in the lower areas because the rainy season is longer and the amount of rainfall is higher, creating better conditions for the mosquito vector (*Anopheles* species). *Falciparum* malaria has become a serious concern in Africa because of the parasite's growing resistance to antimalarial drugs.

Evidence is conflicting regarding whether the new water management regime on the Senegal River and the expansion of irrigated areas in the lower valley are causing an increase in malaria infection rates. Reliable evidence shows that *A. gambiae* population densities have increased during the rainy season (August to December) in the middle valley, and that malaria transmission is continuing later into the dry season (December to April). Routine surveillance data from health service facilities in Rosso, Richard-Toll, and Podor reflect an overall increase in the number of malaria cases, although most of the reported cases were not confirmed by microscopic analysis. In contrast, longitudinal studies conducted in the delta region at Kasak-Nord and the middle valley at Podor, and an unpublished study performed in 1991 by the OMVS throughout the basin, do not show increased malaria.

MALNUTRITION

Malnutrition has been widespread in the Senegal River valley for a long time; it was particularly severe during the droughts before construction of the dams. The Senegal River development projects were expected to improve the nutritional status of valley residents as irrigated agriculture catalyzed economic development and brought significant improvements in peoples' socioeconomic status, giving them more income to spend on nutrition and health. Although the situation is complex and no authoritative studies exist with which to compare nutritional status before and after dam construction, the available information suggests that overall, the quality of peoples' diet and their nutritional status have not improved significantly, and may have declined, since construction of the dams.

Before the dams were built, valley residents grew and consumed a wide variety of food crops grown in family plots and small fields in the river's flood plain. Construction of the dams, interruption of the annual flood, and expansion of irrigation projects has reduced traditional agriculture and has increased rice and sugar cane cultivation. In the lower and middle valley, residents' diets now appear to include more rice, a smaller variety of vegetables in most villages, and lower consumption of meat, dairy products, and freshwater fish. This change may reflect the financial strain on family resources caused by low rice yields and farmers' attempts to grow two crops of rice each year, and also the reduced livestock production and fish catch in the valley. For rice-producing families, rice is the predominant food in the diet and is usually eaten at least once or twice a day. Rice is less nutritious than millet and sorghum, which used to be staples in the diet but are now more difficult to find in the markets.

Several studies of nutritional status in towns along the Senegalese shore of the Senegal River in 1990–91 found the

prevalence of chronic malnutrition in children at levels between 20 percent and 36 percent. One study concluded that levels of malnutrition observed in 1992 were comparable to those in 1983, before construction of the dams (10). The same study found the prevalence of nutritional stunting to be 22 percent and wasting to be 11 percent in 1990 among children aged 0 to 5 years old, with somewhat lower levels observed in 1992 (16 percent and 5 percent, respectively). On the Mauritanian side of the river, a 1986 study in the Trarza district (around Rosso) found chronic malnutrition to exist among 25 percent of children younger than 5 years of age. In a 1994 study, rates of chronic malnutrition among children in the same region were estimated at 36 percent, with 11 percent of children showing evidence of nutritional wasting.

DIARRHEAL DISEASES

Changes in water management practices and voluntary migration into the lower valley have affected the rates of diarrheal diseases in basin residents. Development plans for the region called for improvements in water supply, sanitation, and health services, but few improvements have been made to date.

In the lower valley, modest improvements have been insufficient to deal with population movements. In Richard-Toll, an influx of workers to serve the sugar cane industry added an additional 50,000 people to the population, overwhelming improvements in the town's water supply and sanitation facilities. There is an increased risk of cholera and other waterborne diseases in the Richard-Toll area, and there was a cholera epidemic near Rosso, Mauritania, in 1987. Because future improvements to the water supply systems of Dakar and Saint-Louis will draw on water from Lake Diama and Lake Guiers, the quality of those water bodies may soon affect these large population centers as well.

In the middle valley, the regulation of water levels in the river has allowed the development of wind-powered water pumps. These pumps draw water from aquifers bordering the river, resulting in an improvement of water supplies for these villages. Further away from the river, however, the absence of the annual flood has interrupted the previous cycle of aquifer recharging, resulting in a gradual decline in the water table and reduced water availability. The result has been a rise in the reported rates of diarrheal disease. Along the river in the upper valley, diarrheal disease has continued to be a severe problem despite regulation of the river, and health authorities in Kayes, Mali, report that conditions have worsened.

Social Changes and Conflict

The environmental and health changes seen in the Senegal River basin have not happened in isolation; the change in water management and the growth of irrigated agriculture have also brought broad-based social changes, including tensions between pastoralists and farmers and among ethnic groups as well. The dam projects resulted in the relocation of roughly 10,000 people in more than 40 villages and hamlets in Mali. The Malian government, the U.S. Agency for International Development (USAID), and the World Health Organization moved these populations from the area inundated by the Manantali Dam and resettled them in new sites on the plateau above the lake and downstream along the Bafing River. One year after being resettled, villagers reported in a 1989 USAID study that they had insufficient land for cultivation and grazing and insufficient water for gardening. Housing and personal water supplies were considered adequate at that time, because the additional external funding that accompanied the dam projects ensured that these basic items were supplied to the displaced populations. Health problems are common in resettled populations, and increases in diarrheal illnesses and allergies, a measles epidemic, and an outbreak of livestock disease were reported among some of the resettled villages. Some health indicators did improve for the residents of some resettled villages, where residents had been guaranteed health centers and one water point for every 100 inhabitants. Two years after their displacement, residents continued to receive additional support, such as supplemental nutrition programs funded by the donor governments.

Traditional systems of livestock production have been altered in the middle valley. Construction of the dams was expected to foster an increase in livestock production, but herders have had to cope with a decrease in pastureland due to the persistent drought, the reduction in the annual flood, and the expansion of irrigated land. The increased difficulty of gaining access to the river for watering animals and the reduction in grazing land has led to tensions between pastoralists and farmers.

The development of irrigation along the Senegal River also disturbed patterns of land use and land tenure, exacerbating ethnic conflict among groups in the region. Tens of thousands of people lost their property rights, and massacres occurred in both Mauritania and Senegal (11).

Looking Forward

Dam building will continue to be an important element of economic development plans in many countries. The potential benefits for agriculture, water supply, power production, transportation, industrial development, and flood control are obvious and desirable. Given this expectation, what lessons can be drawn from the experience of Mali, Mauritania, and Senegal in developing the Senegal River?

This case study illustrates the many secondary impacts that a dam project may have on the health, livelihood, social structure, and general welfare of people living in the area. Many of these impacts can be predicted—indeed, most of the impacts of the Senegal River dams were predicted in preconstruction studies.

If many of the negative impacts of the Senegal River dams were predicted, then why were they not avoided? The answer is complicated. First, the financing consortium could have required changes in the

project's design but did not. The financing agreements for the dams were reached in the late 1970s, at a time when most participants were not especially sensitive to environmental impacts and, in any case, were eager to participate in the project and would not have been inclined to force changes to which the borrowing countries objected.

Second, the people who have been hurt by the project lack political power and were not represented effectively either in the project design or in its operation. Measures that would have reduced the project's negative impacts on valley residents were not implemented because they were perceived to be adverse to the project's objectives. In the Senegal River basin, more attention should have been paid to how benefits and costs would be distributed among various groups. Generally speaking, even when the overall balance of benefits to risks is positive and a project is justifiable at the level of national interest, the distribution of benefits and costs may be quite unfair. This situation was certainly apparent with the Senegal River dams project. The benefits of the project—income from irrigated agriculture and electrical power from Manantali Dam—will be enjoyed primarily by the people living in the capital cities, while people living in the valley pay the price for the project in terms of poorer health, changed livelihoods, relocation, and disrupted social relationships.

Third, even if the OMVS had the political will to reduce the negative impacts resulting from construction of the Senegal River dams, the organization does not have the technical capability to do so. Many of the negative impacts could be reduced even now by making operational changes in the project. For example, more water could be released to restore an annual flood. Planned variations in the water levels of Lake Manantali and Lake Diama could be used to control snail populations and reduce the spread of schistosomiasis. Yet, if the OMVS were to decide that such measures have merit, it would need greater capabilities in terms of water resource modeling, planning, and operations; genuine expertise in other disciplines (e.g., health and social sciences); and improved mechanisms for communicating with national agencies of its member states.

The experience with the Senegal River dams, therefore, points to at least the following five lessons:

- More effort is needed to evaluate the environmental, health, and social impacts of dams systematically in order to predict their varied impacts more accurately and with greater certainty.
- The design reviews and evaluations conducted by international funding agencies represent a critical juncture at which to make modifications that would reduce negative impacts.
- Dam projects should include funding for measures needed to mitigate their environmental, health, and social impacts as an integral part of the project.
- Institutional arrangements created for managing such projects should include representatives of affected populations in positions of real authority.
- These institutions need funding and technical assistance to develop adequate technical capacity and a multidisciplinary staff that understands and can address the broad range of potential negative impacts.

There is some hope that conditions will improve in the Senegal River valley as a result of international attention to the problems. An international consortium has recently concluded negotiations with the OMVS for the purchase and installation of turbines and hydroelectric generators at Manantali Dam and power distribution lines from Manantali to the national capitals and several locations in the valley. The project includes funding for a study of alternative water management regimes at Manantali Dam and, specifically, for evaluating options for manipulating water levels to reduce schistosomiasis transmission and other impacts. The World Bank, which is a member of the power project consortium, is also developing health sector projects in Senegal and Mauritania that will improve health services and disease surveillance. The World Bank is also developing water supply and sanitation projects in Senegal that will improve facilities and reduce the population's exposure to schistosomiasis.

References and Notes

1. Unless noted otherwise, information in this article is taken from Diop *et al.*, *Senegal River Basin Health Master Plan Study* (Water and Sanitation for Health (WASH) Field Report No. 453, December 1994, reprint ed.).
2. Construction costs for the two dams amounted to US$637 million. The funds came principally from the governments of Saudi Arabia, Kuwait, Abu Dhabi, the Federal Republic of Germany, France, Iran, and the African Development Bank. The United States (U.S.Agency for International Development) and the World Bank declined to provide capital funds for the projects, but supported environmental assessments and other research related to the projects and provided financial and technical assistance for relocating villages that were displaced by the Manantali Dam.
3. Anne Guest, "Conflict and Cooperation in a Context of Change: A Case Study of the Senegal River Basin," in *Boundaries in Question: New Directions in International Relations*, John Macmillan and Andrew Linklater, eds.(Pinter Publishers, London, 1993), pp. 163–173.
4. *Ibid.*
5. Gannett Fleming Corddry and Carpenter, Inc., "Assessment of Environmental Effects of Proposed Developments in the Senegal River Basin," prepared for the Organisation Pour La Mise en Valeur du Fleuve Senegal, 1977.
6. John Walsh, "Rift Valley Fever Rears Its Head," *Science*, Vol. 240 (June 10, 1988), pp. 1397–1399.
7. William R. Jobin, "Rift Valley Fever: A Problem for Dam Builders in Africa," *Water Power and Dam Construction* (August 1989), pp. 32–34.
8. *Op. cit.* 3.
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