RAPID HEALTH ASSESSMENT

MANANTALI ENERGY PROJECT

MARCH 1993

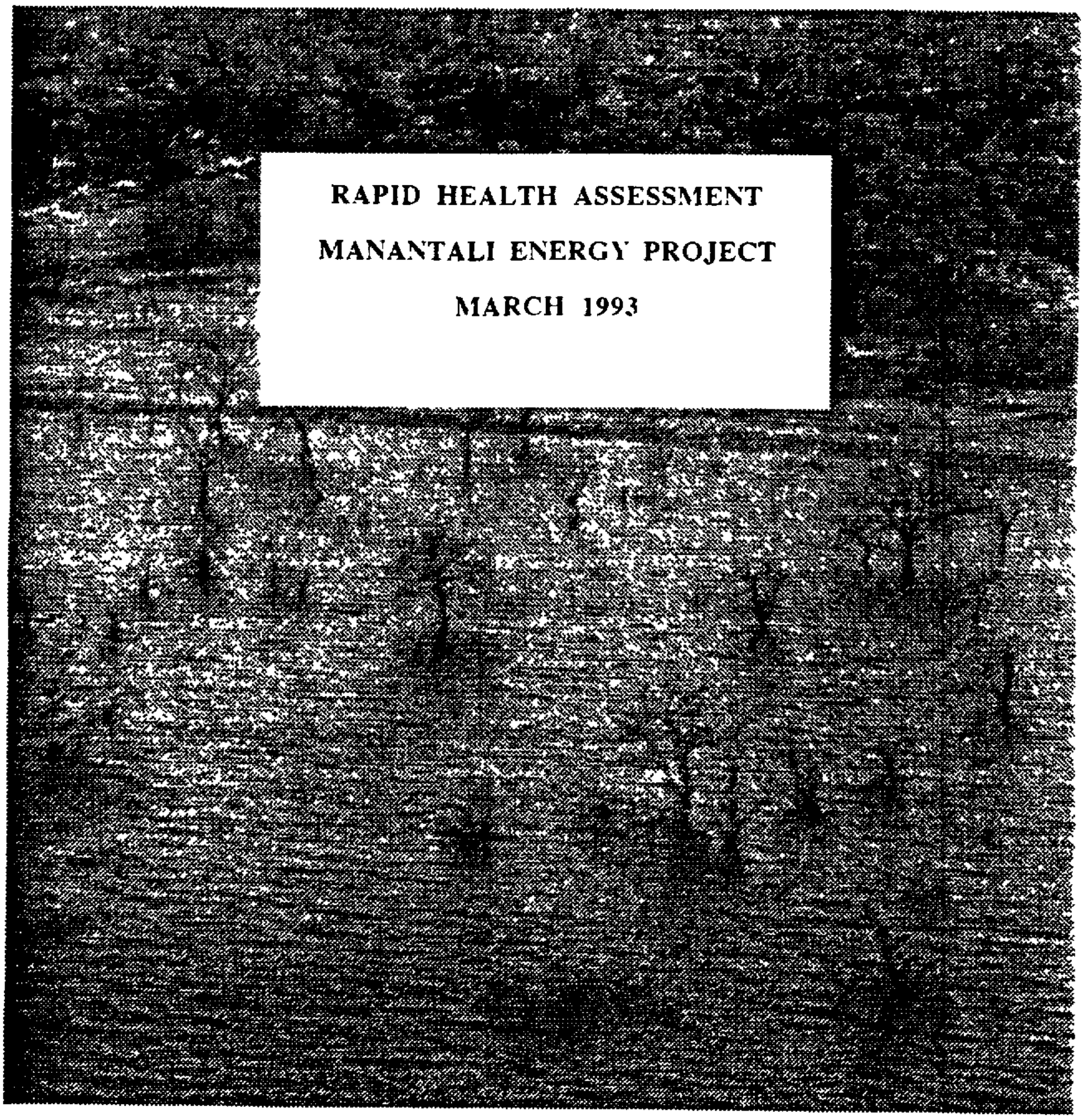
BLUE NILE ASSOCIATES

Consultants on tropical diseases in water resource development projects

RAPID HEALTH IMPACT ASSESSMENT OF MANANTALI DAM

OMVS ENERGY PROJECT

WEST AFRICA



Eastern shore of reservoir created by Manantali Dam in Mali, at water elevation of 203 meters. Cattle were grazing along shoreline, which could also be used for recession agriculture. However flooded trees and flat shoreline also provided protected habitats for malaria mosquitos and bilharzia snails, causing severe disease among lakeshore inhabitants. Photo by Leeds.

SUMMARY

This is a rapid evaluation of the health impact of the present stage of Manantali Dam in Mali, and an assessment of additional health issues to be addressed in completing the Environmental Impact Assessment for the proposed final stage of the Manantali Energy Project. Unfortunately we found that the first stage of the Manantali Dam Project and concurrent developments in the Senegal River Basin caused the same health problems which have afflicted every large dam in Africa. Except for an exemplary relocation program for the villages displaced by the reservoir, no design or operational modifications were made to avoid the outbreaks of Rift Valley Fever, malaria and bilharzia which occurred throughout the basin. Furthermore opportunities for eliminating other potential problems related to river blindness and malnutrition were ignored.

Fortunately the OMVS has made a good start in protecting health of the relocated villages around Manantali Dam, and also has a valuable and unique opportunity to extend this positive record. Because operation of the dam can be quite flexible during the next few years while the power generating facilities are being developed, the OMVS has an important and unique opportunity to adapt operational methods for control of insects and snails to local conditions, and apply them in the reservoir and in the river below the dam. The opportunity also exists to develop permanent environmental changes and encourage biological control measures, as part of development of the agricultural and fishing potential around the reservoir.

Important health benefits have occurred due to Manantali Dam, in the valley population and also among the people relocated to new villages downstream of the dam. In the middle valley and in the relocated villages there has been a decrease in death and disease from diarrhea, due to increased summer flow in the river. There was improvement in general health and nutrition of the relocated populations because of health campaigns and supplemental food supplies provided in the initial years after the move. The population which remained around the rising lake also had improved nutrition and lowered diarrheal diseases.

However there have also been several important health problems in the river basin since the dam was completed. These included epidemics of Rift Valley Fever and a severe and expanding outbreak of intestinal bilharzia. Malnutrition also continued at a serious level in the valley, partly due to modifications of the annual flood caused by dam operations. Our field study also determined that people around the new Manantali reservoir were suffering from severe malaria and urinary bilharzia, and were exposed to a new risk from intestinal bilharzia. This was also true for fishing communities which have migrated to the lake. These health problems were directly related to operational practices at the dam which keep the reservoir at a stable, nearly full level.

The critical health issues which remain to be addressed before completing the final phase of the Energy Project include development of mitigating measures to prevent further outbreaks of

Rift Valley Fever, to control malaria and bilharzia around the lake, to prevent further intestinal bilharzia outbreaks in large irrigation systems in the valley, and to prevent further malnutrition due to modifications of the annual flood which has been the basis for local agriculture.

To deal with these remaining issues, two additions are needed to the current Environmental Impact Assessment for the Energy Project. They are (1) adaptation of environmental management methods for use in the reservoir and in the lower valley for disease control, and (2) assessment of the impact of changes in the annual flood on malnutrition in the Senegal River Valley.

Firstly an experimental program of modified reservoir operation should be developed with the guidance of the World Health Organization, as part of the initial Environmental Impact Assessment. The current Energy Project offers a unique and important opportunity to adapt available environmental methods to deal with most of these water-associated diseases. There is an opportunity to experiment with Manantali Dam in the period prior to completion of the energy facilities, to develop operational methods such as small fluctuations in the lake level for control of disease-bearing mosquitos, blackflies and snails **(Figure 1)**.

These operational techniques for the reservoir can be complemented by shoreline modifications to reduce insect and snail habitats, and by biological measures to control these disease-bearing organisms. Disease control programs based solely on drugs and biocides are far too expensive for permanent control of these diseases in the Senegal River Basin, and should be added only where the more permanent environmental and operational measures are not cost-effective.

If these operational trials are conducted in cooperation with local and international health agencies, the results from the Manantali experiment could be applied to all the irrigation systems and dams in the Senegal River Basin, to Selingue Dam in Mali, and also throughout Africa.

Secondly the impact on malnutrition of current and potential modifications of the annual flood must be accurately determined. The current operating rules regarding the impact of the artificial flood on agricultural and fisheries productivity - and thus on malnutrition - should be thoroughly evaluated with this information.

These two additional evaluations should be started now and continued during the period prior to generation of electricity in the next 3-5 years. In addition, health conditions should be monitored annually thereafter for at least 10 years, to insure that the dam is operated in a manner which gives optimum health benefits. This is an essential requirement to counter the experience in the first six years of operating Manantali Dam, during which unnecessary disease and death has occurred.

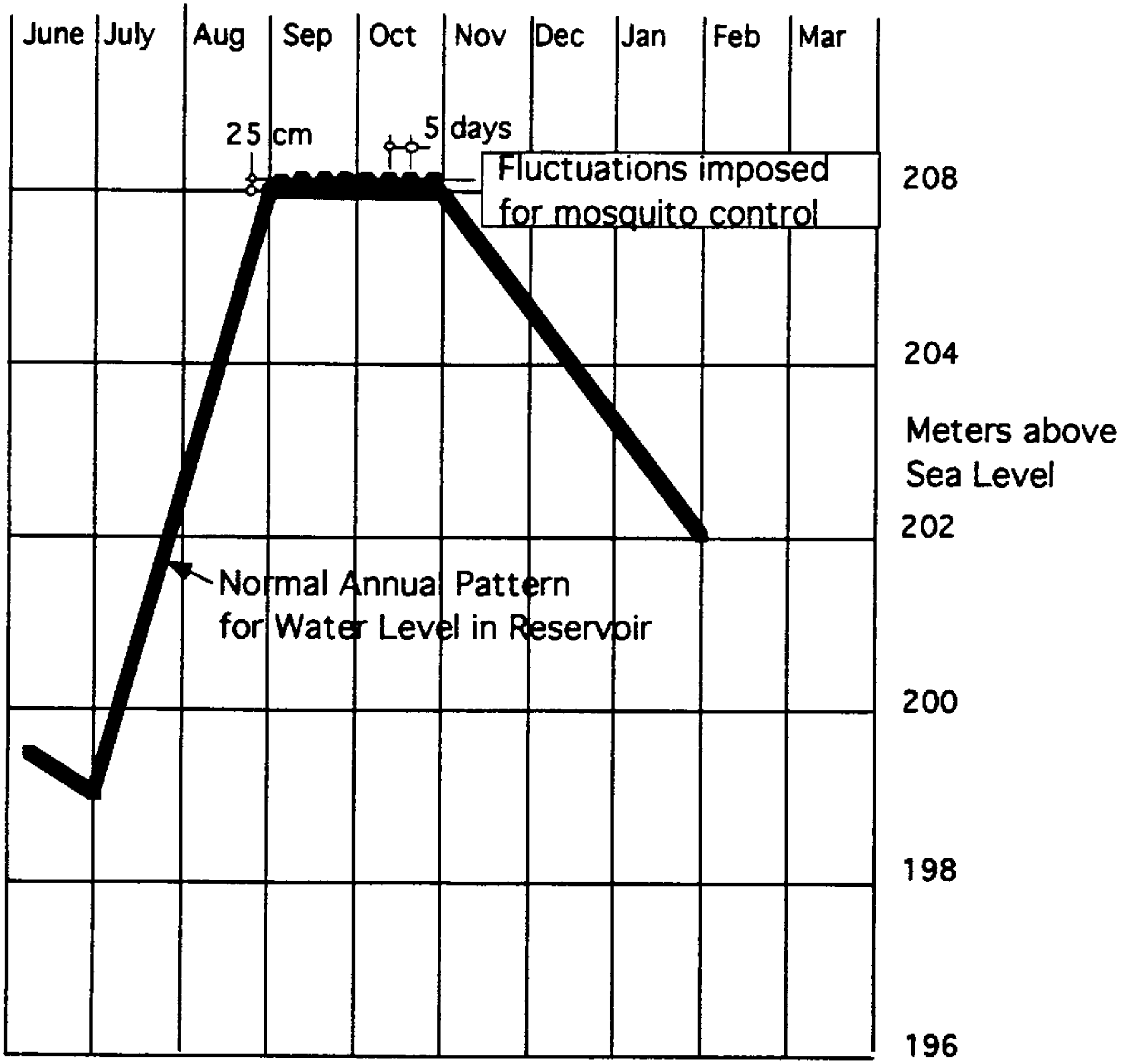


Figure 1. Proposed fluctuation pattern for water levels in Manantali Reservoir, to be adapted for mosquito and snail control under local conditions.

Based on experience in the Tennessee Valley Authority with malaria mosquito control and in Puerto Rico with bilharzia snail control, fluctuation patterns with a 3-10 day cycle and 25 to 50 centimeter amplitude should be evaluated for suitability to local conditions in the Senegal River Basin. The techniques should also be evaluated for prevention of Rift Valley Fever epidemics around reservoirs.

HEALTH IMPACT ASSESSMENT
OF MANANTALI DAM

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I. INTRODUCTION

This is the final report from a one month evaluation of the health impact of Manantali Dam in Mali, and an assessment of the remaining health issues to be evaluated in the Environmental Impact Assessment of the Manantali Energy Project proposed by OMVS *(Organisation de Mise en Valeur du Fleuve Senegal)*. The OMVS is responsible for developing the entire Senegal River Basin, including construction of Diama Dam near St. Louis, Senegal, and Manantali Dam in Western Mali **(Figure 2)**. Additional important developments by other agencies in the Senegal River Basin included the Richard Toll and other irrigation systems in the lower valley, the Gorgol Irrigation System in Mauritania based on Foum Gleita Dam in the middle valley, and the small irrigated perimeters near Bakel, Senegal (Senegal Consult, 1970; and Gibb et al, 1986).

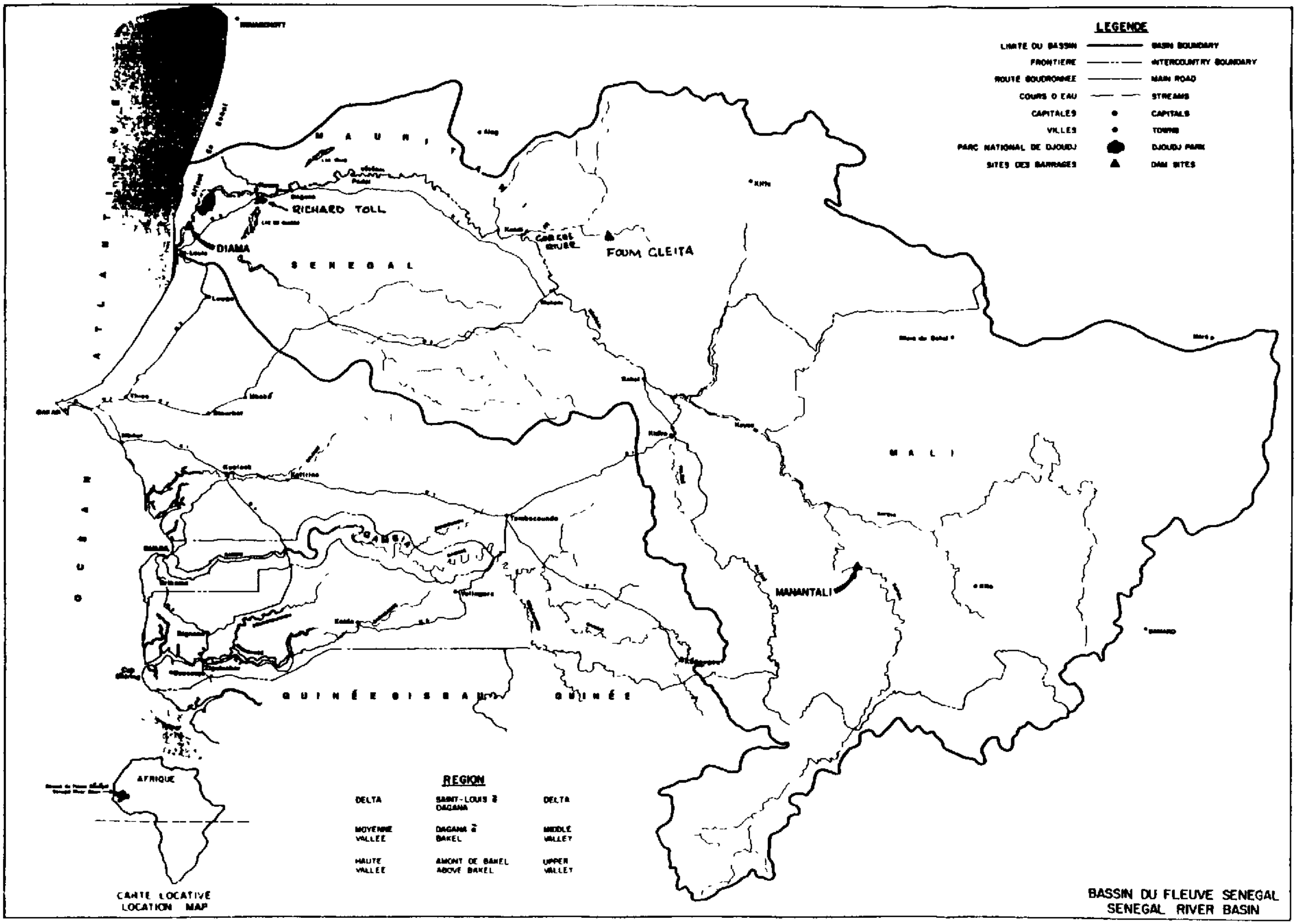
Physical characteristics of dams in the Senegal River Basin, 1993

Dam	Location	Purpose	Storage Capacity in cubic kilo- meters	Area of Reservoir in square kilo- meters	Spillway Elevation in meters above sea level
Diama	Mouth of Senegal River	Irrigation	0.5	367	1.0
Foum Gleita	Gorgol Blanc River in Mauritania	Irrigation	1.2	300	40
Manantali	Bafing River in Mali	800 MW Hydro- electric, irrigation, water supply, and navigation	11.3	400	208

The main structure of Manantali Dam was completed in 1988 without the hydroelectric power system. This study determined the health impact of the partially completed Project as of the beginning of 1993, and made predictions of the health impact expected from installation of the power system. Recommendations were made to take advantage of the unusual opportunity to turn the negative health impact into a positive one. There was an unusually large and pertinent body of literature on the subject, making this rapid assessment possible with minimal new field studies.

Figure 2. Map of the Senegal River Basin.

The map shows the location of the major dams and irrigation projects in the OMVS region.


LEGENDE
LIMITE DU BASSIN — BASIN BOUNDARY
FRONTIERE — INTERCOUNTRY BOUNDARY
ROUTE GOUDRONNEE — MAIN ROAD
COURS D EAU — STREAMS
CAPITALES — CAPITALS
VILLES — TOWNS
PARC NATIONAL DE DJOUDJ — DJOUDJ PARK
SITES DES BARRAGES — DAM SITES
M A U R I T
S E N E G A L
M A L I
G U I N É E B I S S A U
G U I N É E
A T L A N T
O C E A N
RICHARD TOLL
DIAMA
GORGES GOURE
FOUM GLEITA
MANANTALI
GAMBIA
REGION
DELTA | SAINT-LOUIS À DAGANA | DELTA
MOYENNE VALLEE | DAGANA À BAKEL | MIDDLE VALLEY
HAUTE VALLEE | AMONT DE BAKEL ABOVE BAKEL | UPPER VALLEY
AFRIQUE
CARTE LOCATIVE
LOCATION MAP
BASSIN DU FLEUVE SENEGAL
SENEGAL RIVER BASIN

II. BACKGROUND ON HEALTH IN SENEGAL RIVER BASIN

The Senegal River is one of the larger rivers in Africa, with a catchment basin of 290,000 square kilometers. Near Bakel, Senegal the river discharge reaches its highest values, thereafter losing water through evaporation and other causes as it flows to the ocean at St. Louis (**Figure 2**). Annual mean discharge at Bakel is 780 cubic meters per second with the peak flood occurring about September (**Figure 3**). The river is almost dry during May and June, and flood flows are extremely variable (Senegal Consult, 1970). Bakel also marks the change from the relatively steep Upper Basin to the flat Middle Valley.

The number of people in the Basin will approach 1,900,000 by the year 2000. Near the Ocean they are primarily of the Wolof ethnic group. In the Middle Valley there is a mixture of Haalpulaars and Maures, while the Upper Valley is inhabited

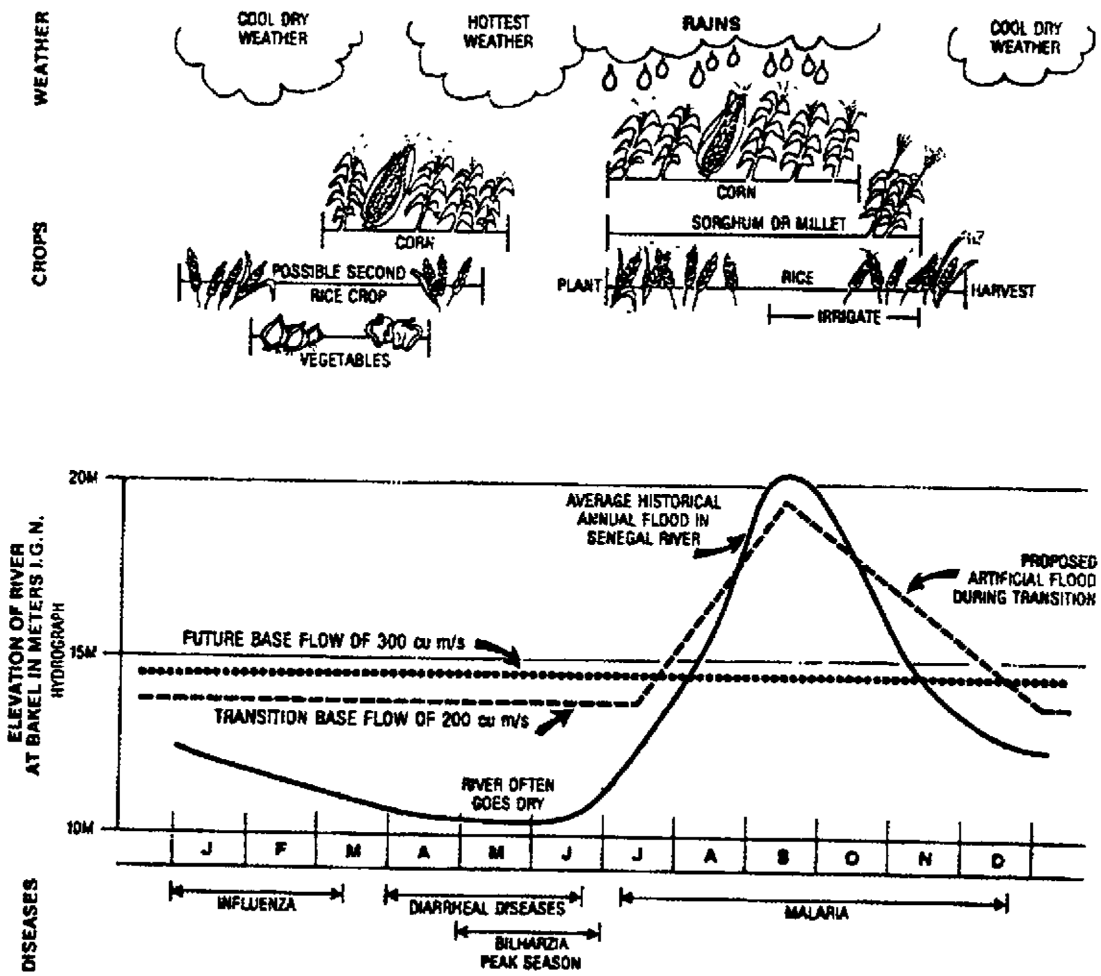


Figure 3. Seasonal patterns of hydrology, agriculture and disease near Bakel, Senegal in the middle valley of the Senegal River Basin (Jobin and Jamnback, 1988).

primarily by Sarakoles. In the Upper Basin around Manantali Dam the people are Malinkes, with some Bozo immigrants around the lake. The Haalpulaars of the Middle Valley are semi-nomadic, herding sheep in the immediate vicinity of the river. Most of the Maures are nomadic herders, covering a zone from central Mauritania down to central Senegal (IDA, 1991).

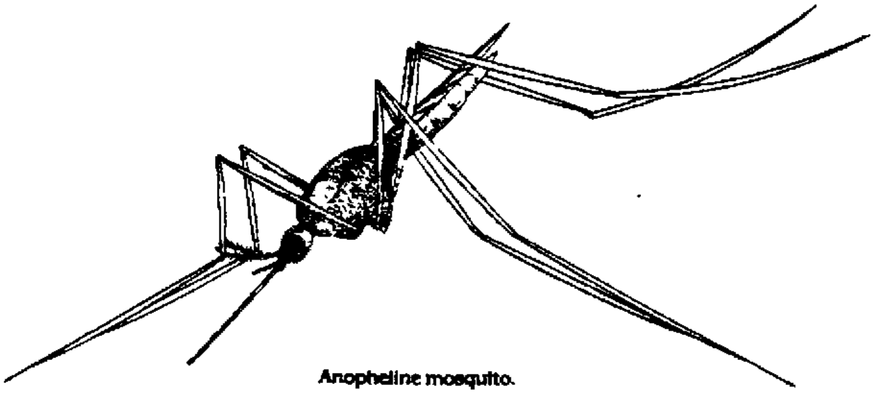
Agriculture in the valley has traditionally depended on the annual flood and the ephemeral rains, resulting in harvests during October and November **(Figure 3)**. With pump irrigation, a second crop is sometimes grown, with harvests in April and May. Agriculture has been severely hampered in the past few decades due to drought, and malnutrition has forced people to migrate out of the valley.

One of the key ecological features under discussion regarding operation of Manantali Dam has been the provision of an artificial flood during the initial years of operation of the dam. Its purpose is to allow farmers to continue their traditional agriculture, at least for a transition period while they evaluate the practical aspects of changing to pump irrigation. The artificial flood would occur on a pattern to simulate the natural annual flood which existed prior to Manantali Dam **(Figure 3)**.

The major diseases associated with water also follow the seasonal pattern of the river and rains **(Figures 3 and 4)**. Malaria and other mosquito-born diseases occur in September and October, almost disappearing by the hot, dry months of April and May. As the flow in the river ceases, the river breaks up into pools which become extremely contaminated, causing transmission of bilharzia and outbreaks of diarrheal disease just before the rains.

Large dams such as Manantali always present health problems in Africa. For over 40 years, hydroelectric reservoirs have been known to cause health problems in the tropics, especially malaria. The problems and integrated programs for their solutions have been described in detail (TVA, 1946). Large dams in Africa have an especially unfavorable history of health problems (Obeng, 1969). World-wide reviews have identified malaria, bilharzia and river blindness as diseases of particular concern in these reservoirs (Goldsmith and Hildyard, 1984; Oomen et al, 1988; and Jobin, 1992).

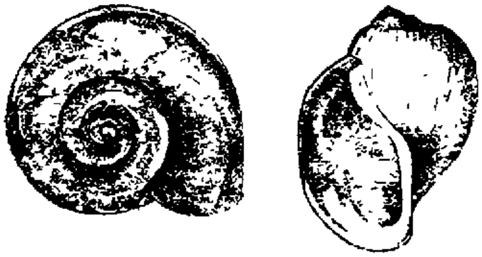
Control measures for all mosquito-borne diseases have been developed and published by international agencies, including environmental measures especially suited to large reservoirs and irrigation systems (WHO, 1982). This latter publication marked the beginning of a UN sponsored Panel of Experts which addresses the problems of water-associated diseases in large dams (PEEM, 1981-1992). For over a decade, the Panel and its predecessor committees have provided training courses for planners and engineers, and have also published documents with guidelines for design and operation of large water resource systems to avoid these disease problems. Their work is especially suited to large dams such as the one constructed at Manantali.



Anopheline mosquito.

MALARIA

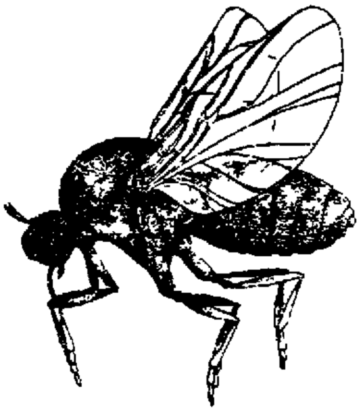
The most common of the tropical diseases related to water, malaria is transmitted throughout the tropics by anopheline mosquitoes which are often found infesting reservoirs, irrigation canals and drains. Due to resistance to insecticides and drugs, prevention by environmental modification is becoming a necessity in water resource developments. These environmental control measures are best implemented in the design stages of a project.



Shells of planorbid snails.

BILHARZIA

Bilharzia is a parasitic disease transmitted in a complex cycle by fresh water snails, an infection closely linked with irrigation and classically associated with the Nile River. It is also found, however, in the Caribbean area and Brazil, in China, the Philippines and the Middle East. The disease is also known academically as schistosomiasis.



Blackfly.

RIVER BLINDNESS

This disease, prevalent in Africa and tropical America, is spread through the bite of the blackfly. The biting blackfly breeds in rapids or whitewater on spillways and water control structures, and is responsible for impeding agricultural development in much of West Africa. The disease is also known as onchocerciasis to parasitologists.

Figure 4. Major diseases associated with water around Manantali Dam, and the insects and snails which cause their transmission.

Manantali Dam started to fill in July 1987 on the Bafing River in Western Mali. It was designed primarily to generate hydroelectric energy but can be operated to produce multiple benefits (**Figure 5**). The reservoir took several years to fill, reaching spillway elevation in late 1991. At present the reservoir is being kept almost full, with a minimal base flow released for agricultural purposes.

Operation of the dam has a direct effect on flow downstream since the Bafing River supplies half of the river flow at Bakel. The effect of the dam at present is to moderate the floods and droughts normally experienced. This has an impact on health, as well as agriculture, fisheries and general ecology.

Field surveys showed that general health conditions were very unfavorable in the valley of the Senegal River and especially in the area of the Manantali Dam, prior to construction of the dam. Three major health surveys in 1977-78, 1981 and 1986 gave detailed and precise indications of the existing health conditions, especially diseases associated with water and malnutrition. After construction of Diama and Manantali Dams, several additional reports were published regarding epidemics of Rift Valley Fever, Yellow Fever and bilharzia, all related to ecological changes caused by the dams. These outbreaks have been the object of a great deal of international scientific attention because of their severity.

Prior to construction of the dams, a comprehensive health survey was conducted throughout the Senegal River Basin as part of an environmental impact assessment for the entire integrated development plan of the OMVS (Gannett et al, 1980). In this report, published in 1980, it was indicated that the principle burden of disease in communities of the Senegal River Basin was on infants and young children. The vital statistics given in the 1980 report seemed to be erroneous (see table C.2.1 of Partial Report on Health), but a World Bank report indicated that in 1992 mortality rates for children under 5 varied between 125 and 222, some of the highest in the world (**Table 1**). Life expectancy at birth was also extremely low, around 48 years.

Table 1. Selected vital statistics for countries in the Senegal River Basin (taken from World Bank Atlas, 1992).

Vital Statistic	Mali	Mauritania	Senegal
Under-five mortality rate per 1,000 live births	222	200	125
Life expectancy at birth, in years	48	47	48

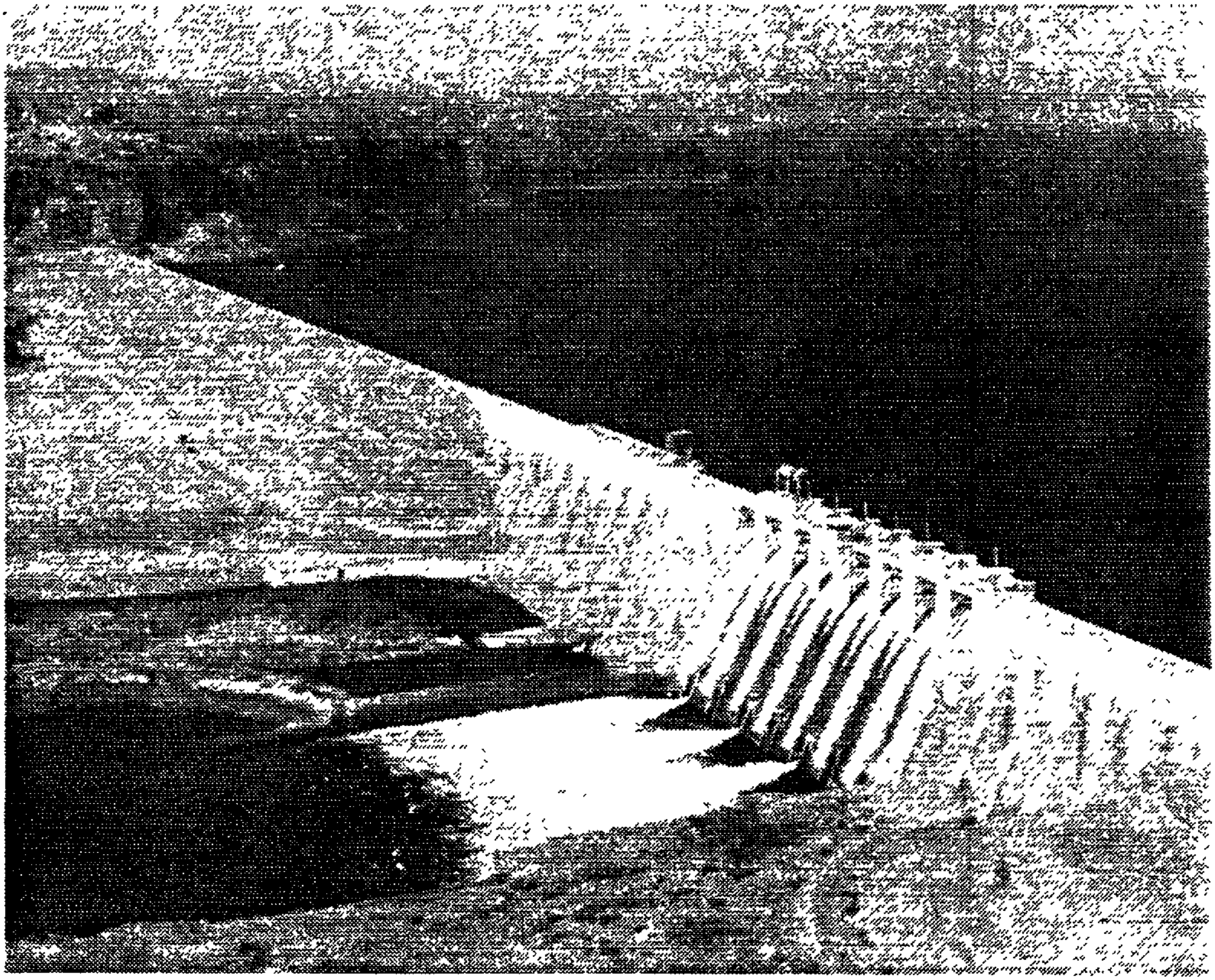


Figure 5. Manantali Dam on the Bafing River in Western Mali. The dam began to fill in July 1987 and reached spillway elevation about November 1991. In this view from the Western or left abutment, the water surface in the reservoir was at 203 meters above sea level, 5 meters below the spillway crest. Photo by Leeds.

In the 1980 report malaria was identified as an important health problem in the basin, closely linked to the rainy season and to the amount of rainfall. The malaria intensity, as measured by the spleen rate, was highest in the upper basin and lowest in the delta **(Table 2)**.

Table 2. Malaria spleen rates by geographic area, for children from 2-10 years of age (taken from Gannett, et al 1980).

Area	Number examined	Number positive	Spleen rate %
Delta	64	2	3
Lower Middle Basin	208	12	6
Upper Middle Basin	235	43	18
Upper Basin	149	60	40

Another important disease related to rainfall was malnutrition in children. Of 1,000 children examined in the river basin during the 1977-78 field survey, one-quarter to one-half of the children under 5 years of age suffered some degree of malnutrition. The type of malnutrition was mainly energy-deficiency, and because of its correlation with rainfall, was assumed to be related to the frequent crop failures in the valley.

Other than these few factual observations, the general predictions of health impact in the 1980 report were not well related to the specific ecological changes expected from the proposed developments in the Senegal River Basin. In fact the rather complacent predictions regarding expected health conditions have proved to be highly inaccurate (Gannett et al, 1980).

However an extremely useful study for assessing the impact of the proposed Energy Project was completed in 1981 in Western Mali by the National School of Medicine in Bamako and the World Bank (Duflo et al, 1986). This covered the Cercles of Kita, Bafoulabe and Kenieba, and included a summary of the productive days lost from each disease **(Table 3)**, and the number of deaths per year for the diseases associated with water and malnutrition **(Table 4)**. From this analysis it can be seen that malaria, diarrheal diseases and malnutrition ranked very high in importance in the Senegal River Basin, prior to construction of Diama and Manantali Dams.

Table 3. Number of productive days lost due to disease in Western Mali during the year 1981*, in a population of 1,000 persons (taken from Duflo et al, 1986).

Rank	Disease	Days Lost*
1	**Malaria**	**82,000**
2	**Diarrheal Diseases****	**51,100**
3	Lung disease (not tuberculosis)	39,400
4	Miscarriages	37,000
5	Neonatal disease	34,000
6	Measles	31,000
7	**Malnutrition**	**27,700**
8	Anemia	27,500
9	Complications at birth	23,200
10	Liver disease	16,100
11	Tetanus	12,400
12	Trauma	10,600
13	**Salmonellosis****	**9,800**
14	Heart disease	8,000
15	Hypertension	6,800
16	Eye disease (not trachoma or river blindness)	6,800
17	**Hepatitis****	**6,000**
18	**Bilharzia**	**5,900**
19	Meningitis	5,900
20	Neural disease (not tetanus)	5,600
21	Whooping cough	5,300
22	Tuberculosis	4,400
23	Gynecological disease	4,300
24	Urinary tract (not bilharzia)	4,000
25	**River blindness**	**3,500**
26	Trachoma	3,200
27	Tumors	2,800
28	Diabetes	2,500
29	Thyroid disease	2,300
30	Guinea worm	1,800
31	Leprosy	900
32	Syphilis	800
33	Polio	700
34	Rheumatic fever	700
35	ORL	600
36	Skin disease	500
37	**Hookworm****	**300**
Total		**485,400***

* The projected days lost includes days lost because of premature death, thus this is a projection into the immediate future, not just for the year in which the person dies.
** In subsequent discussion, all of these diseases are considered diarrheal diseases.

Table 4. Annual deaths due to diseases related to water and malnutrition in Western Mali in 1981, for a population of 1,000 persons (taken from Duflo et al, 1986).

Rank (see Table 1)	Disease	Annual Incidence per thousand	Mortality rate per case	Deaths per year
1	Malaria	37.2*	0.462	17.2
2	Diarrheal diseases**	130	0.019	2.5
7	Malnutrition	25*	0.060	1.5
13	Salmonellosis**	28	0.025	0.7
17	Hepatitis**	6.5	0.01	0.06
18	Bilharzia	26	0.01	0.26
25	River blindness	158*	0.005	0.8
37	Hookworm**	278	0.001	0.3

* These prevalences apply to Western Mali but are not representative of the entire Senegal River Basin because they are closely related to rainfall which is highest in the upper valley.

** In subsequent discussion, all of these diseases are considered to be diarrheal diseases.

Table 5. Simplified grouping of annual deaths due to diseases related to water and malnutrition in Senegal River Basin in 1981, for 1,000 people (taken from Duflo et al, 1986).

Disease	Annual Incidence per thousand	Mortality rate per case	Deaths per year	
Malaria by zones				
-Upper Valley	37.2	0.126	4.69	
-Middle Valley	17.0	0.126	2.14	
-Delta	4.0	0.12	0.48	
Malaria subtotal				7.31
Diarrheal Disease	442.5*	0.008*		3.56
Malnutrition	25	0.06		1.50
Bilharzia	26	0.01		0.26
River blindness	158	0.005		0.79

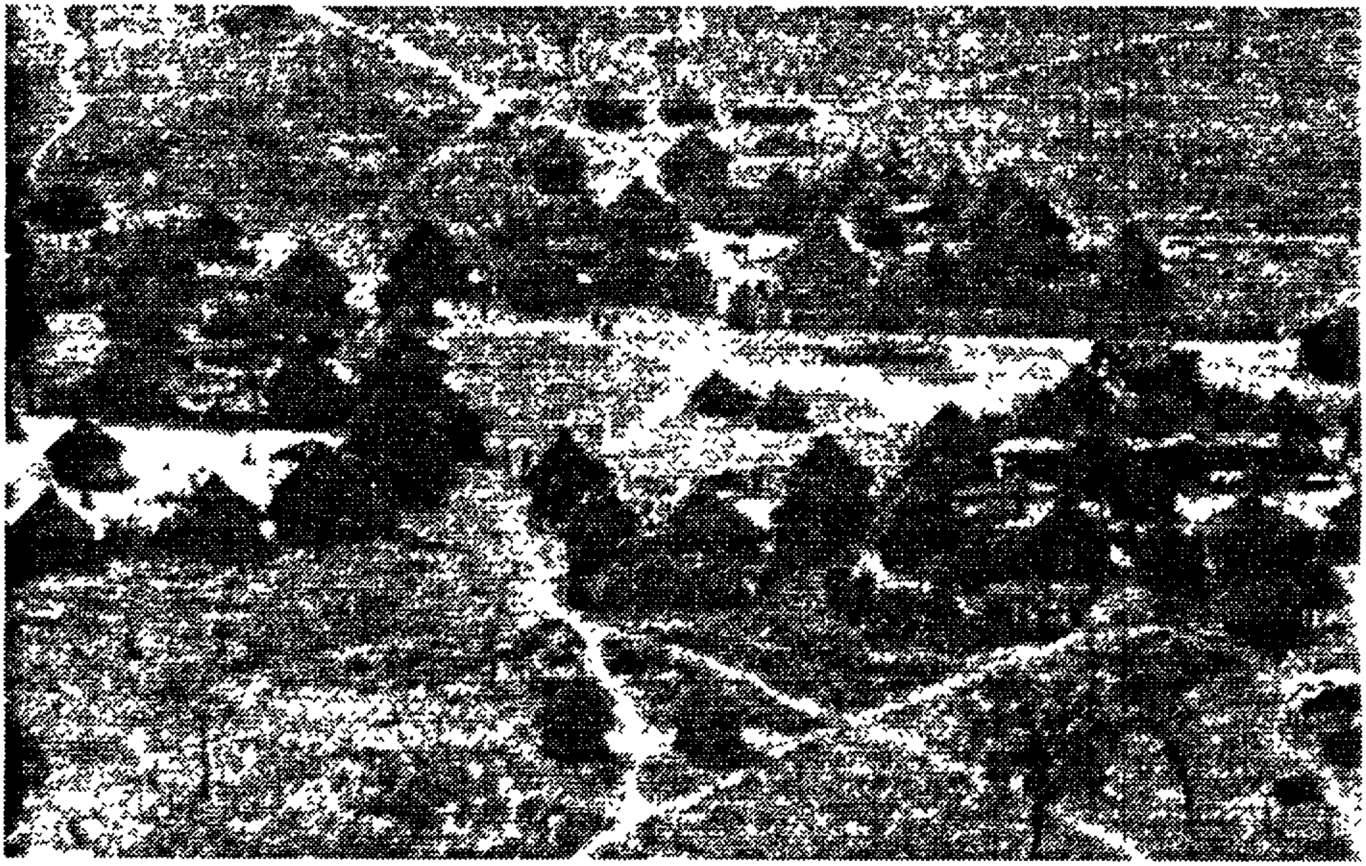
Most recently, and specifically related to the proposed construction of Manantali Dam, a pair of health assessments were conducted in the immediate vicinity of the dam site, before and after its construction, giving highly specific and accurate indications of its health impact (INRSP 1986 and 1989).

The pre-construction survey was based on a large sample of about one-third of the 10,000 people in the villages to be affected by the dam (**Figure 6**). Preconstruction vital statistics indicated that health conditions were very unfavorable, with high death rates among children (**Table 6**). The most commonly used figure is the Infant Mortality Rate which was 149 per year, per 1,000 live births.

Table 6. Pre-construction vital statistics for communities in area of Manantali Dam during 1986 (taken from INRSP, 1986).

Mortality Rates per 1,000 live births	
Neo-natal 0-27 days	71
Post neo-natal 28 days - 12 months	78
Overall Infant less than 1 year	**149**
Children up to 2 years	184

Figure 6. Firia village is on the north-eastern shore of Manantali Reservoir in Western Mali. Their crops are dependent on rainfall. Photo by Leeds.



It was found that water supplies were inadequate in the existing villages, with a correspondingly high incidence of diarrheal disease of 66%. Malnutrition was also high, affecting about one-third of the children. The malaria spleen rate was 20% in 1-9 year old children **(Table 7)**.

Table 7. Pre-construction prevalence of water associated diseases during 1986, in area of Manantali Dam (taken from INRSP, 1986).

Disease	Measure	Rate
Malaria	Spleen rate	20%
	Parasite rate	55%
Diarrheal Disease	Incidence in children	66%
Malnutrition	Weight-age in children	34%
Bilharzia		
urinary	Prevalence	20%
intestinal	Prevalence	3%
River blindness*		
infection	Skin-snip prevalence	50%
blindness		1-2%

* quoted from a 1972 survey

This thorough pre-construction survey was followed by a similar post-construction survey in 1989. The lake had begun filling in August 1987 and was not completely full until November 1991, thus it was only half full by the time of the 1989 survey, in terms of volume. However most of the villages had been moved by this time, and the effects of the resettlement were already noticeable. Ten of the resettled villages studied in the pre-construction survey, were resurveyed in 1989, along with five stable villages which had not been relocated. The five stable villages served as comparisons for the relocated villages **(Figure 6)**. A total of 10,459 people were displaced by the rising water, including 31 villages and 17 hamlets (INRSP, 1989)

The most noticeable improvement in health was due to the provision of good water supplies for the resettled villages, and the corresponding decrease in diarrheal disease and infant mortality. The annual death rate among children less than 1 year old dropped to less than half its pre-construction value, decreasing from 149 per 1,000 live births in 1986 to 63 per 1,000 in 1989 **(Table 8)**.

Malnutrition also decreased noticeably, due to a temporary feeding program provided during the first two years of the resettlement. General malnutrition among children in these re-settled villages decreased from 34% in 1986 to 23% in 1989.

These improvements in health were largely due to the considerable expenditure of money and effort during the relocation period. Besides construction of new homes, provision of supplemental food, and provision of safe drinking water supplies, the resettlement process also include vaccination of children and treatment of infected persons with bilharzia drugs, as well as a spraying program in the river to kill larvae of the blackflies which spread river blindness. These efforts had a large impact on the 1989 survey data, but were discontinued immediately thereafter. Thus the improvements noted in 1989 were largely temporary.

The resettled villagers complained of insufficient land for cultivation, not enough pasturage, and not enough water for their vegetable gardens. Contrary to the improvements in health noted above, there were some important increases in disease, notably malaria and bilharzia.

The comparison villages which were slightly uphill of the lake shore and thus were not relocated, showed increases in both malaria and urinary bilharzia. In addition, the newly established fishing villages, which were estimated to include about 2,000 people, were not measured in the post-construction survey. These people would have been at the highest risk for water-associated diseases.

Table 8. Comparison of pre-construction and post-construction disease rates in villages around Manantali Dam (taken from INRSP 1986 and 1989).

Disease (See Figure 4)	Measure	Pre-construction 1986	Post-construction 1989
Decreased disease			
Annual Mortality	Children under 1 year per 1,000 live births	149	63
Diarrhea	Incidence in children	66%	53%
Malnutrition	Weight-age in children	34%	23%
River blindness	Parasite prevalence	50%	30%
Increased disease			
Malaria	Parasite rate	55%	64%-75%
Bilharzia	Resettled villages	20%	20%
	Stable villages	20%	26%

Malaria

Foum Gleita dam, constructed near Kaedi on the Gorgol river in Mauritania, may provide useful indications of what could be accomplished by environmental control measures against malaria in Diama and Manantali Reservoirs. In a pre-construction health impact study in 1974, we recommended structural and operational modifications for the reservoir to prevent malaria and bilharzia transmission (Jobin and Jamnback, 1974). Water level fluctuations were recommended to interrupt breeding of bilharzia snails and malaria mosquitos (**Figure 7**). Foum Gleita Reservoir filled in 1985, and observations during the first year indicated that malaria mosquitos were not breeding in the reservoir (Baudon et al, 1986). Although the low rainfall during the first few years may have contributed to the lack of mosquitos, the preventive measures which we proposed also may have been important.

This fluctuation technique was developed in the USA by the Tennessee River Authority and further promoted by the World Health Organization (TVA, 1946, and WHO, 1982). Mosquito eggs are usually deposited in protected areas of reservoir shores, often floating among vegetation or floating debris. The proposed pattern of a rising and falling water level would strand them on the shore, or flush the floating mosquito larvae into open water, making them easy targets for predatory fish.

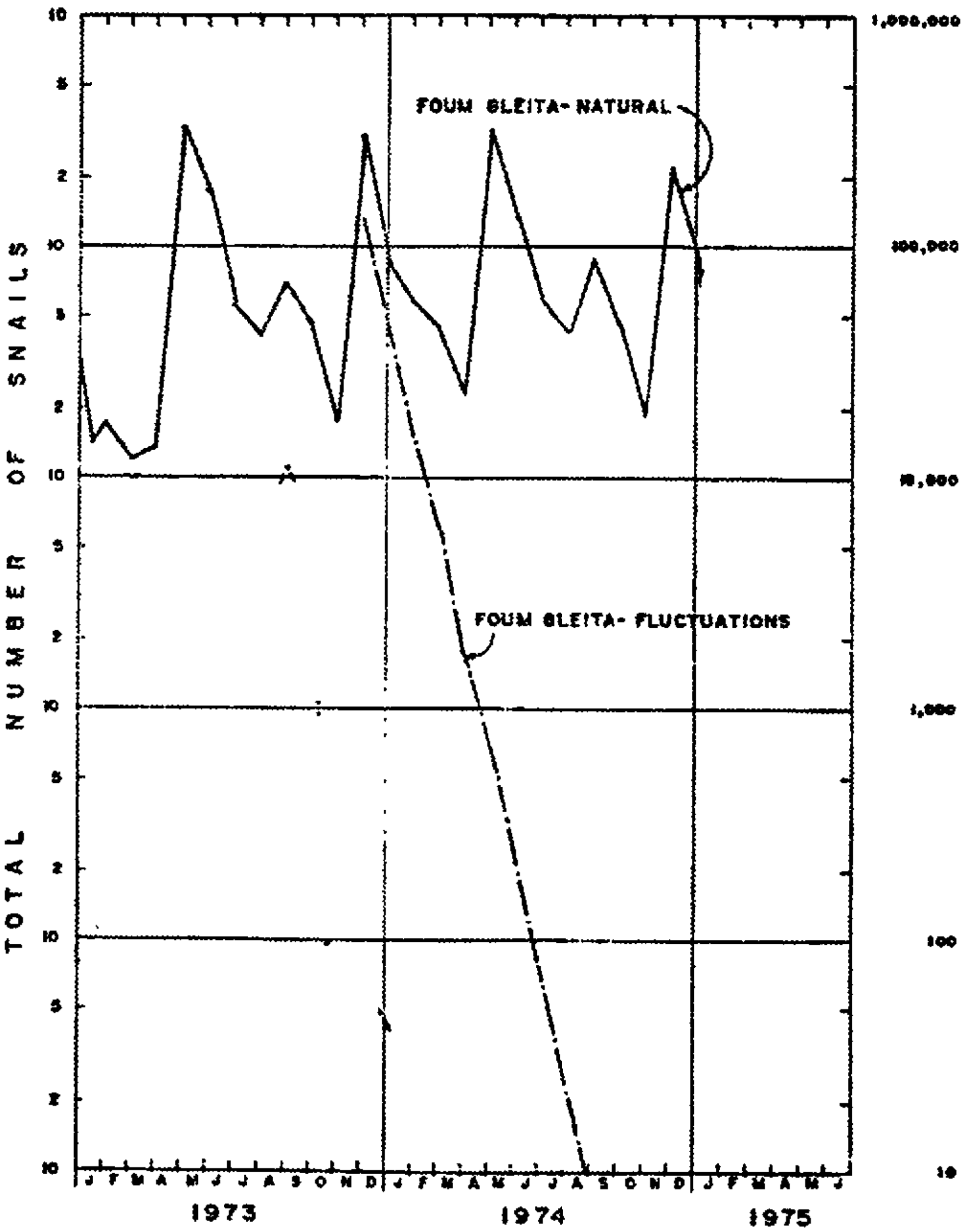
In the TVA reservoirs a fluctuation pattern of 30 centimeters amplitude and 7-10 day periods was effective in controlling the local malaria mosquito. It may be necessary to shorten the period by a few days to control *Anopheles gambiae or Anopheles funestus*, the malaria mosquitos in Mali. Also the mosquito species which transmits Rift Valley Fever, *Aedes macintoshi*, is quite different and variations in the TVA pattern should be investigated for effectiveness against this species also.

Because large inflows are required to cause the rise in water level during the fluctuation cycle, the fluctuations can be used primarily during the flood season when the reservoir is full. Fortunately this is also the time when mosquito breeding usually starts. In addition to fluctuations at maximum reservoir level, they can also be incorporated into the recession phase when the reservoir level is being drawn down by power generation, if river flow conditions permit.

These same fluctuation patterns are effective in controlling bilharzia snails from Puerto Rico, with the recession phase being more important than the maximum pool phase. Again the effectiveness of fluctuations needs to be evaluated against the local species of bilharzia snails which have greater resistance to drying. Restrictions on large-scale changes in water level can also be used to encourage fish populations, increasing the predation pressure on the snails and the mosquito larvae, another very effective control method.

Shoreline modifications to reduce the shallow, protected areas are another effective way of reducing aquatic habitats of both mosquitos and snails. These include straightening and steepening of irregular shorelines by simple earthmoving operations, and also removal of submerged trees offshore, to increase wave action against the shores. These environmental methods have been used successfully on hydroelectric and irrigation reservoirs in the USA and Puerto Rico, and should be effective in Mali (Jobin, 1992).

Figure 7. Water level fluctuation patterns which were recommended for operation of Foum Gleita Reservoir on the Gorgol River in Mauritania to control bilharzia snails and malaria mosquitos (Jobin and Jamnback, 1974). The upper line shows the expected number of bilharzia snails in the reservoir, the bottom line showing the predicted elimination of the snails with periodic fluctuations.



Malnutrition

In 1991 a thorough assessment of malnutrition in the Middle and Lower Valley was conducted by ORANA in Senegal. In comparison with similar data from the 1978 malnutrition survey, the measure of height for age showed evidence of continuing high prevalences of malnutrition in the population (ORANA, 1992).

The prevalence of malnutrition in Bakel was 29% in 1991, slightly higher than the 27% prevalence in 1978 (**Table 9**). In the middle valley the prevalence in 1991 was 39%, compared to 37% in 1978, and in the lower valley malnutrition prevalence in 1991 was 33%, compared to 37% in 1978. These small changes between 1978 and 1991 were not statistically significant, thus there was no real improvement in the state of malnutrition over this 13 year period, despite considerable efforts by SAED and OMVS to improve irrigation and agriculture.

Table 9. Comparison of malnutrition in Senegal River Basin between 1978 and 1991.

Region	1978 (taken from Gannett et al, 1980)	1991 (taken from ORANA, 1992)
Delta (Dagana and Podor)	37%	33%
Middle Valley (Matam)	37%	39%
Upper Valley (Bakel)	27%	29%

Rift Valley Fever

Perhaps the most spectacular impact of early OMVS projects in the Senegal River Basin was the occurrence of Rift Valley Fever in two or three separate outbreaks during the rainy season of 1987. These outbreaks appeared to occur around the new reservoirs at Diama and Foum Gleita dams in the lower valley, and perhaps around Manantali Dam as well (Jobin, 1989).

The virus is usually found in sheep and goats, causing large numbers of aborted births in these animals. However when very large mosquito populations occur in areas where sheep, goats and people are congregated, such as the perimeter of a newly filled reservoir, the virus is transmitted to people with lethal effect. The particular species of mosquito involved (*Aedes macintoshi*) lays its eggs above the water line of rivers in the Sahel Zone.

Often these eggs contain the virus, and both egg and virus can endure several years of desert conditions. Thus a long drought, broken by heavy rains would produce enormous numbers of this mosquito. If a new reservoir has been completed during the drought, it would quite likely be ringed with herders and their animals while it was filling, and a heavy rainy season would then produce all the conditions necessary for an epidemic of this animal disease in people (**Figure 8**).

Figure 8. Herds congregated around scarce water in the Gorgol River Valley of Mauritania in May 1974 near the end of a long drought. This same combination of water, herds and people precipitated the disastrous epidemics of Rift Valley Fever throughout the Senegal River Basin in the rainy season of 1987.

The Rift Valley Fever epidemics in the lower valley were centered around Rosso and Kaedi, Mauritania, and over 200 deaths were reported, although the actual figure was probably closer to 1,000 (Saluzo et al, 1987; Walsh, 1988; and Jouan et al, 1990). Geographically the first area coincided with backwater from Diama dam, and the second with Foum Gleita reservoir, the location of most of the deaths in the Kaedi region (**Figure 2**). In a personal communication Jouan stated that the deaths near Foum Gleita were primarily Maure camel herders. Abortion rates due to the viral infection among sheep and goats congregated around Foum Gleita reservoir were about 80% during the episode, which occurred during a season of very heavy rains. The first human deaths reported at the hospital in Rosso were identified as Yellow Fever on the basis of gross symptoms. It was not until the Pasteur Institute did virological studies later that year that the virus was identified as that of Rift Valley Fever.

A similar epidemic occurred in Western Mali at the same time, probably Rift Valley Fever, although it was reported as Yellow Fever, without virological confirmation (Kurz, 1990). The epidemic occurred from September to November 1987 and although 145 deaths were notified officially, the author estimated that the true figure was about 700 deaths. Yellow Fever had not been reported in this area since 1960, but there were many reports of Rift Valley Fever virus in herds migrating through the area. Manantali reservoir began filling in August 1987, one month before the epidemic started. An epidemic of severe disease occurred at this time among animals of the people dislocated by the filling of the reservoir, resulting in many deaths of the animals (INRSP, 1989). Although it had filled only partially during the first rainy season, the ecological conditions around Manantali Reservoir were thus consistent with the requirements for an epidemic of Rift Valley Fever.

Bilharzia

Although never previously reported from the delta or lower valley of the Senegal River, intestinal bilharzia has become a major health problem in the irrigated fields in the lower valley around Richard Toll since Manantali and Diama Dams were completed in 1987.

The first cases of intestinal bilharzia were reported in 1988 with a prevalence of 2%, and by 1989 the prevalence of disease reached 72% (Talla et al, 1990). More recent studies in the area confirmed that intense infections are occurring, and that the snails and disease are spreading along the left bank (Senegal side), toward Diama Dam (Diaw et al, 1991; Diallo et al, 1991; and Handschumacher et al, 1992). It is likely that this outbreak is a result of both the exclusion of salt water during the dry season because of Diama Dam, and the provision of substantial fresh water flow throughout the dry season from Manantali Dam.

Another relevant outbreak of bilharzia occurred immediately after construction of Selingue Dam in the adjacent watershed of the Niger River in Mali. Selingue reservoir filled in 1986 and fishermen began colonizing the shores soon afterwards because of the large fish population. These immigrants soon became infected with urinary bilharzia, reaching a prevalence of 58%, compared to local villagers with a prevalence of 12%, and resettled villages where the prevalence was 21% (Traore, 1989). Prior to construction of Selingue Dam, the local prevalence of urinary bilharzia had been only 2%. It should have been fairly clear from this experience that similar problems would occur in Manantali Reservoir, due to their close proximity and similar ecology. Selingue Dam was also constructed for hydroelectric power. Another study covering water resource developments all over Mali, confirmed the findings around Selingue Dam and further concluded that bilharzia transmission was even more intense around irrigation systems (Brinkman et al, 1988).

III. FIELD ASSESSMENT

In January 1993 we visited health authorities and scientists at the World Health Organization in Switzerland, in Senegal and in Mali, to obtain more recent information on malnutrition and water-associated diseases around Manantali Dam and in the rest of the Senegal River Valley. We also made a short field visit to Manantali dam and surrounding communities, interviewing lakeshore residents and local authorities involved with the resettled villages (**Figure 9**).

From the information we assembled, it was clear that severe health problems caused by Manantali and Diama dam are now occurring around the lake and in communities in the valley and delta. Many of the health problems are being created by the operation of the dam, and could be avoided.

Although some international groups are beginning to apply remedial disease control measures in the lower valley on an experimental basis, national authorities have no resources to apply to the increasing disease related to the OMVS developments.

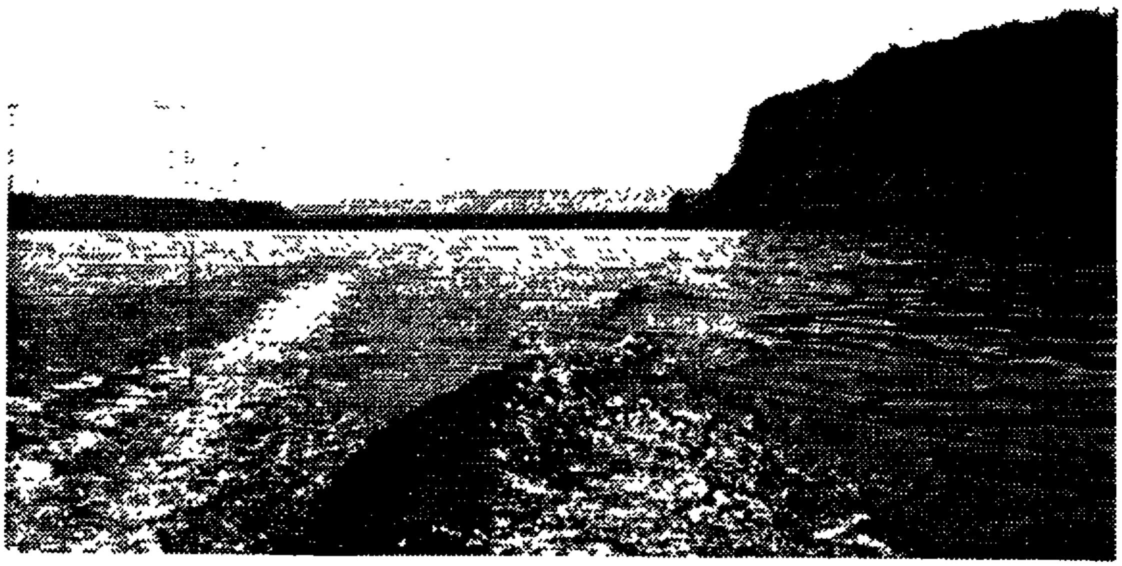


Figure 9. Right abutment of Manantali Dam from upstream, along northeastern shore of reservoir. Also see Figure 10. Photo by Leeds.

A. World Health Organization in Geneva, Switzerland

Several scientists involved in research and control of water-associated diseases in West Africa were able to add considerable recent information to that already published about the Senegal River Basin.

Bilharzia

The epidemic of intestinal bilharzia in the lower Senegal River Basin is the subject of intense study by several European groups related to WHO in Geneva. Bilharzia prevalences in 1991 were exceeding 90% in villages around the irrigation system of Richard Toll, with very high intensity infections, according to personal communications from Dr. Bruno Grysells at WHO in Geneva.

The outbreak of urinary bilharzia around Selingue Reservoir was also confirmed by Dr. Kenneth Mott at WHO Headquarters, who further indicated that the data collected at Selingue was of high quality.

River Blindness

Although initially identified as an important region of river blindness during the 1980's, when they conducted detailed investigations, the Onchocerciasis Control Program (OCP), a joint effort of WHO, the World Bank, USAID and many other donors, found that the infected blackflies were carrying a parasite of cattle, not humans. In discussions at WHO Geneva with the Executive Director of the OCP, Dr. Ebrahim Samba, he indicated that the Bafing River below Manantali Dam was a source of blackfly breeding, down to the Senegal border, but the disease was not being transmitted to people in this area. Thus the OCP decreased their interest in the Senegal River Basin below Manantali Dam. Also the breeding sites flooded by the dam were permanently eliminated due to submersion. The Bafing River upstream of the dam however is an important site of breeding, and larval control operations are carried out on foot or by air, as needed. The OCP continues to monitor blackfly populations along the entire Bafing River. This is especially important because operation of Manantali Dam and further agricultural development along the Bafing River could increase the potential for transmission of River Blindness in the future.

Rift Valley Fever

Because of its spreading occurrence throughout Africa and especially because of the well documented epidemics near Rosso and Kaedi in 1987, WHO and several US organizations have taken a strong interest in clarifying the epidemiology of RVF. Remote sensing of rainfall, river flooding and vegetation are being used to track and perhaps to predict outbreaks of RVF, according to Dr.

James LeDuc of WHO in Geneva. Satellite images and thematic mapping can also be used to assess and perhaps predict transmission of malaria and other water-associated diseases occurring in remote areas.

B. Ministry of Health in Mali

The Division of Epidemiology of the Ministry of Health in Mali prepared a current summary of health statistics from their units in the three Cercles of Kita, Bafoulabe and Kenieba, surrounding the reservoir and resettled communities. Although their data were not collected by random sampling and thus cannot be compared with the INRSP studies, their general analysis of the situation around the reservoir was extremely negative.

They listed a series of negative effects, including the creation of biotopes favorable to the mosquitos and snails which spread malaria, bilharzia and other parasitic diseases, the aggravation of conditions favoring continuous and massive transmission of malaria, and the increase in new diseases. Most dramatic of these was an epidemic in 1987 which was either Yellow Fever or Rift Valley Fever, killing several hundred people.

C. Interviews around Manantali Dam and Reservoir

We made an aerial tour of the entire shoreline of Manantali Reservoir during late January 1993, when the lake level was at 203 meters above sea level (**Figure 9**). At this level the storage capacity of the reservoir was about 9 cubic kilometers (see table below).

Most of the western shore of the reservoir was steep and rocky, with few places hospitable to people, cattle or mosquitos and snails. However the eastern shore, especially in the north-eastern quadrant, contained many areas of flat slope where cattle were grazing, and where small villages had been started. In this area the large village of Firia contained hundreds of people involved in agriculture, and the village of Tondidji had been moved to an elevation slightly above the lake level, rather than moving it to the resettlement sites (**Figure 10**). Most of the eastern and southern shores of the reservoir were lined with large numbers of partially submerged trees, interfering with fishing, and also protecting the shores from wave erosion.

Summary of Reservoir Storage Capacity vs. Elevation of Water Level

Elevation in meters	Storage in cubic kilometers	Elevation in meters	Storage in cubic kilometers
160	0.026	185	3.103
165	0.125	190	4.400
170	0.395	200	7.800
175	1.300	208 spillway	11.300
180	2.200	212 design maximum level	

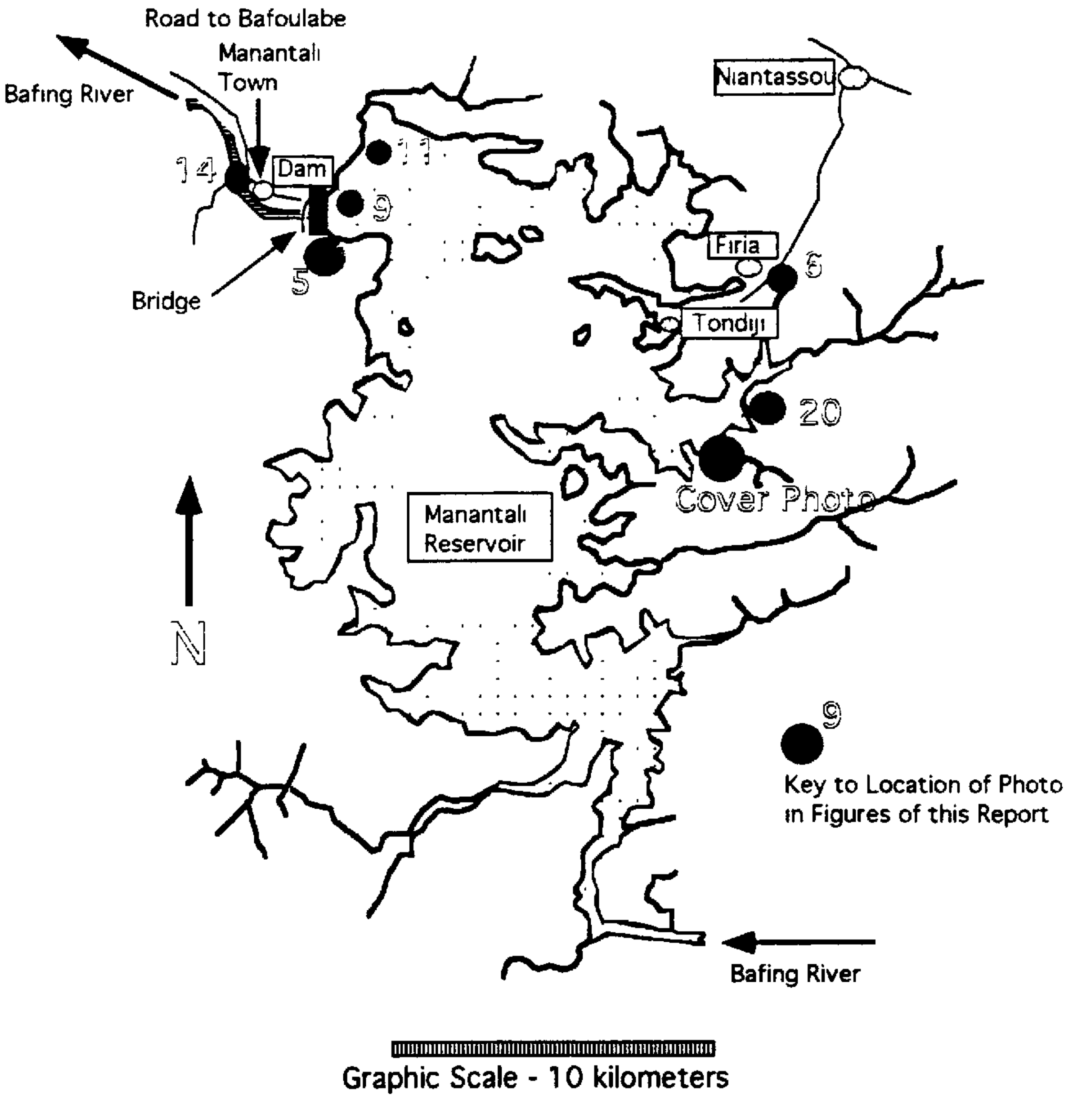


Figure 10. Corrected map of Manantali Reservoir, also showing locations of photos in various figures in this report.

Although the biological productivity of the lake seemed low, there were already 25 fishing villages established along the north-eastern shores, and about 30 metric tons of fish were being harvested each month (Anne, 1992). Shoreline habitats in the north-eastern sector were favorable for malaria mosquitos and bilharzia snails due to the highly irregular shoreline and the large numbers of trees remaining in the flooded zone. Along flat shorelines these factors combine to prevent wave erosion along the shores, allowing mosquitos and snails to breed **(Cover photo)**.

Because the lake had only been full for two years, the patterns of shore deposition and erosion had not been established in 1993, and very little emergent or floating vegetation had appeared. As the shoreline vegetation grows, this will provide additional habitat for the malaria mosquitos and bilharzia snails.

The mosquitos which transmit Rift Valley Fever do not lay eggs in the lake, but lay them in the soil above the water line. Thus conditions for large numbers of this species of mosquito would require several years of drought and low lake level, followed by a year of heavy rains and high lake level. This sequence would produce a large number of these mosquitos during the rainy season.

Our interviews with immigrant Bozo fishing people around the shores of Manantali Reservoir in January 1993 elicited complaints of severe malaria throughout the year, and occurrence of blood in urine of almost everyone in the fishing communities **(Figure 11)**.

These same indications of endemic malaria and widespread transmission of urinary bilharzia were supported by surveys of the Limnology Unit based at Manantali, during their studies related to fisheries.

The Limnology Unit estimated the number of Bozo immigrants at 1,000, based on their census of 25 fishing camps in July 1992 (Anne, 1992). The Bozo fishermen are part of a cooperative group which moved up from the adjacent Niger River Basin.

Both the mosquito and snail populations along the shores of Manantali Reservoir have reached high numbers because of the highly conservative tendency of the dam operators to keep the reservoir at a stable and nearly full level. This stability encourages breeding of these disease-spreading organisms. Since the reservoir contained several species of snails including those capable of transmitting both urinary bilharzia (*Bulinus* species), and intestinal bilharzia (*Biomphalaria* species), it serves as a gigantic snail nursery, contaminating the entire Senegal River downstream with both kinds of bilharzia snails.

Downstream of Manantali Dam, personnel involved with the resettled villages indicated that there were severe problems in the villages with a lack of reliable irrigation water for agriculture, and a shortage of fish, vegetables and other local food crops.

Figure 11. Upper photo shows fishing settlement on rocky and steep shore of reservoir about 5 kilometers East of the right abutment of the dam. Lower photo shows Bozo family from this settlement, part of fishing cooperative who moved up from Segou area of Niger River Valley. Also see Figure 1[illegible] Photo by Leeds.

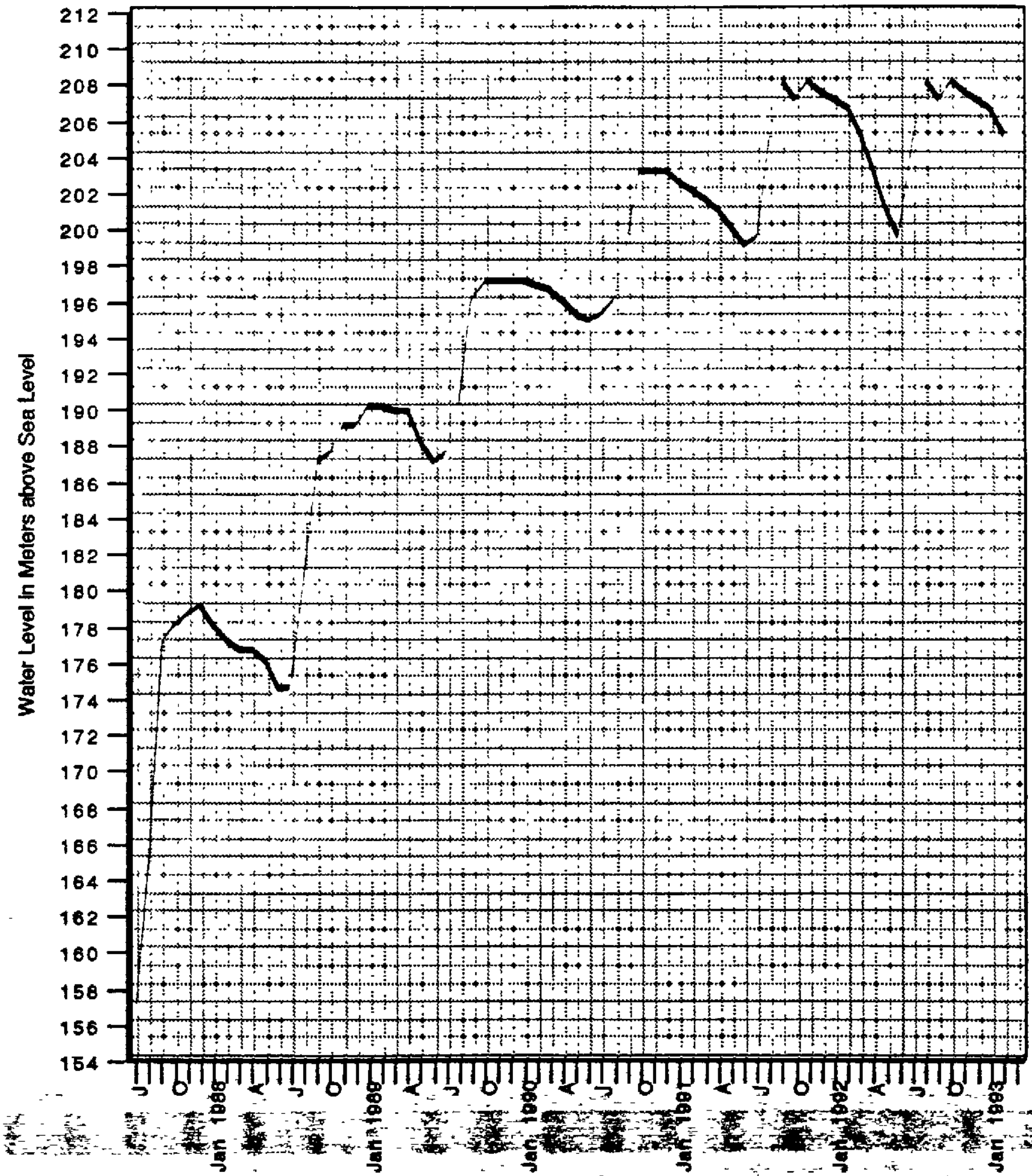
The OMVS personnel operating Manantali Dam indicated that the reservoir had filled rather slowly, starting in August 1987 and reaching full level of 208 meters above sea level in late 1991 **(Figure 12)**. During the first few years, no artificial flood was released. Only in 1988 was the expected flood seen by the farmers in the valley, probably because it was a very wet year and the Bakoy and Faleme Rivers contributed substantial flow. The current pattern of discharge from the dam involved delivery of an artificial flood of about 2,000 cubic meters per second at Bakel, Senegal for 15 days. The flood was delivered in September or October of 1991, somewhat later than desired, and it was also late in 1992 **(Figures 13 and 14)**. A base flow of 200 cubic meters per second was maintained during the rest of the year, except that the flow was cut to 90 cubic meters per second during December and January, and also in May and June. The dam operator said this was done because the farmers downstream didn't need the water during those months. However it did not appear to be part of any approved operational procedures, nor has its environmental impact ever been assessed.

Recent engineering and economic analyses by the OMVS consultants have evaluated and then recommended significant changes in the artificial flood originally proposed. Instead of the gradual artificial flood which peaked in August, the new flood occurs a month later, and lasts only 10-15 days instead of two months **(Figure 15)**. This modification saves a great deal of water for hydroelectric use, and improves the economics of power generation (Gibb et al, Report 1B, August 1987). However it was unfortunate that the same effort devoted to improving power generation was not devoted to improving agriculture and nutrition. Also it was disturbing to see this change in the flood, discarding previous plans and analyses based on a much larger artificial flood. Such a change in the artificial flood should not be made without a complete re-evaluation of the previous environmental impact analyses (Gannett et al, 1980).

Despite the opinion of OMVS personnel managing the dam that they were improving conditions downstream for the farmers, it appeared that in fact the dam was being operated as if hydroelectric power generation were the primary and over-riding consideration. If this attitude continues when the turbines are actually installed, considerable additional damage to health could occur.

FIGURE 12

WATER LEVEL IN MANANTALI RESERVOIR, 1987 - 1993 page 32



Elevations for 1992 are estimated

Figure 13

Historical and proposed flood hydrographs for Senegal River at Bakel (from Le Bloas, 1983)

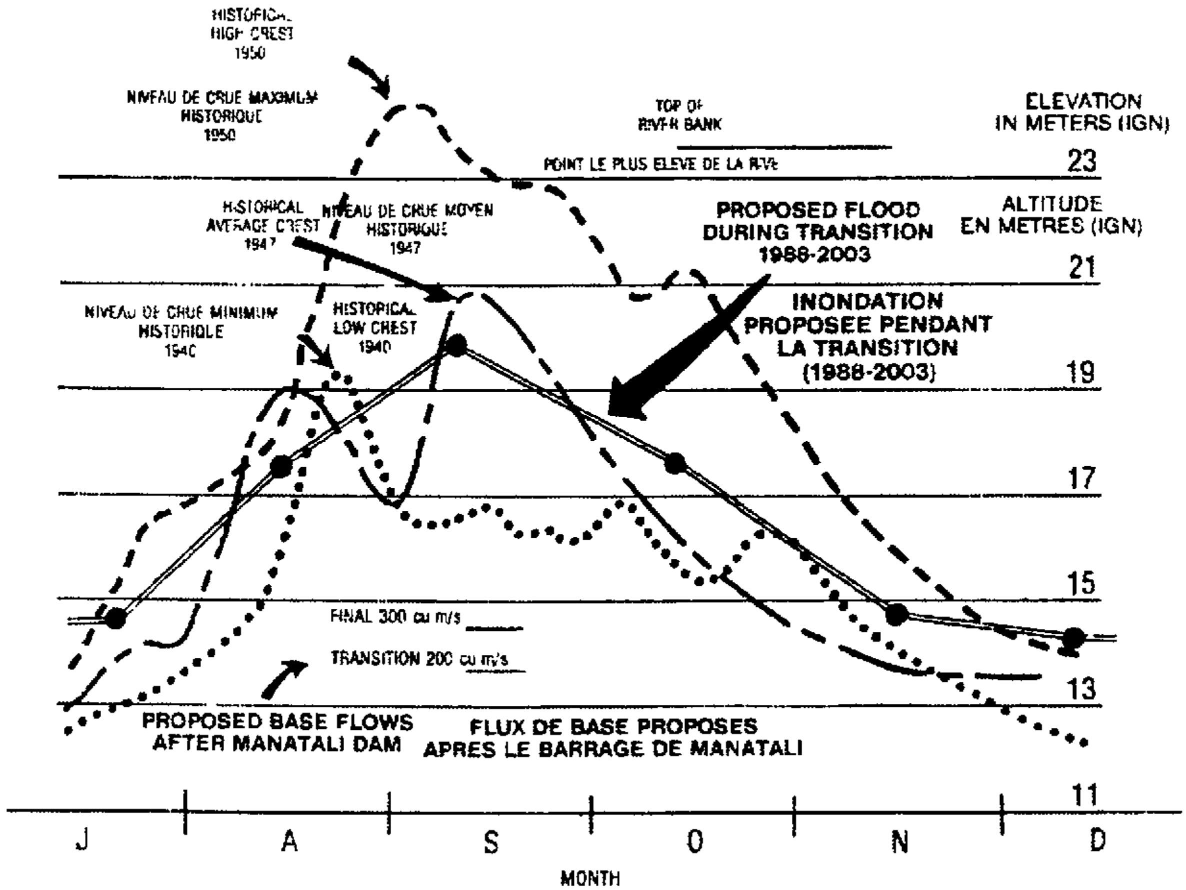
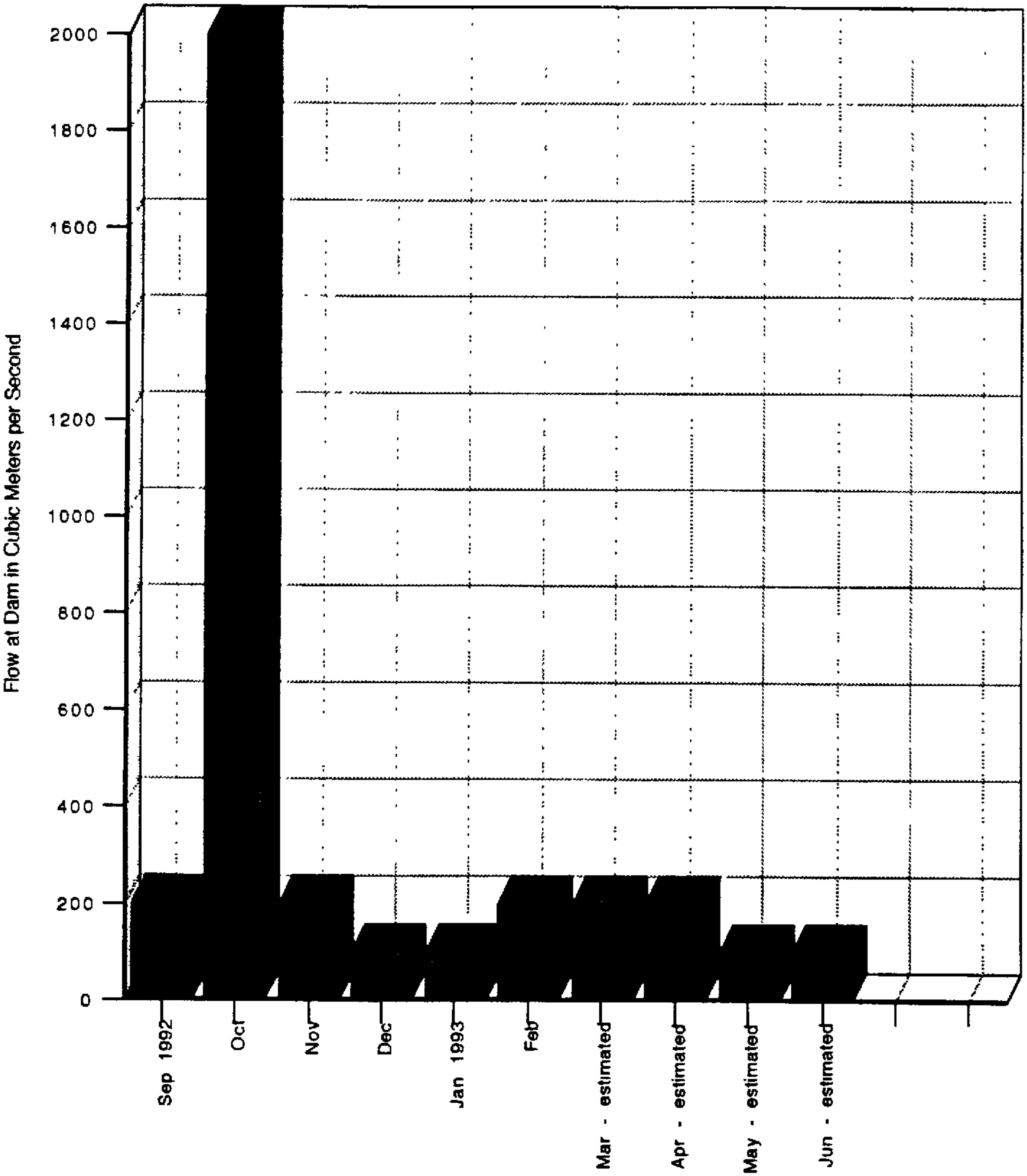


Figure 14

Monthly discharges released at Manantali Dam - page 34



Data taken verbally from dam operator at Manantali

The river immediately downstream of Manantali Dam was flowing at 90 cubic meters per second during our visit in late January, and offered conditions suitable for blackfly breeding (**Figure 15**). The blackfly require rapids and "white-water" to lay their eggs. The larvae which hatch from the eggs attach themselves to rocks and overhanging vegetation for about 10 days, until they become adults.

Prior to construction of Manantali Dam, blackfly breeding occurred only in the rainy season, and was not extensive enough to cause significant transmission of the blinding parasite among the people living within 30 kilometers of the river. That is the normal limit of the blackfly biting range. However after construction of the dam, a base flow occurs throughout the year, and the number of blackflies may increase significantly. In addition the number of people living near the river may increase. Thus the biting rates will increase and so will the potential for parasite transmission. This may be a severe problem in the portion of the Bafing River downstream of Manantali Dam, and near the rapids of the upper Senegal River.

Figure 15. Birds flying upstream on Bafing River below Manantali Dam in January 1993. Rock outcrops and rapids provide breeding sites for blackflies which spread River Blindness. Also see Figure 10. Photo by Leeds.

Because of the slow rate of transmission of this blinding parasite, the effect of Manantali Dam in terms of increased blindness of the people in the area may not appear for another decade. Thus preventive measures should be developed now, even though the current prevalence of blindness is still low.

D. Interviews in the Middle Senegal River Valley

Information from our own studies in 1988 and from more recent studies by USAID indicated that slow development of agriculture throughout the Senegal River Basin is a major source of continued malnutrition (IDA, 1991). A sociologist who had conducted surveys throughout the lower and middle Senegal River Valley for USAID confirmed the severe agricultural problems, partly due to inadequacy of the artificial floods provided by operation of Manantali Dam during the last six years **(Figure 12)**. According to farmers along the river, there was no artificial flood in 1987 or 1990, the flood was inadequate in 1989 and 1991 with a second peak which washed out planted seeds, and the flood was too late in 1992. Only the artificial flood provided in 1988 was adequate. Thus agricultural conditions throughout the Senegal River Valley remained precarious, and malnutrition continued to be a serious problem. This improper delivery of the artificial flood during the last six years caused serious health problems and appeared to be contrary to recommendations of OMVS consultants (Gibb et al, 1987).

A study we conducted in Bakel, Senegal in September and October of 1988 for USAID and SAED in the middle valley pointed out the difficulties with plans for expanding the irrigated perimeters in the middle valley, and thus the need for a regular and dependable artificial flood (Jobin and Jamnback, 1988). Our survey in the Bakel area was conducted just before harvest time in 1988, the one year in which OMVS had provided a reasonable artificial flood. Nonetheless the small irrigated perimeters were not heavily utilized that year, because the farmers did not wish to take the extra risks required **(Figures 16 and 17)**. People preferred to harvest their rainfed and recession crops because of lower investment requirements, and lower labor needs. The final report to USAID concluded that rice irrigation in the small perimeters of Bakel was not economical.

Pump irrigation in small bunded fields or "perimeters" had been initiated in the Bakel area in the mid-1970's. By 1984 about 700 hectares were thus irrigated, and plans were made to develop irrigation for the potentially irrigable area of 10,000 hectares. However by 1988 the SAED Director for Bakel reported only 1,842 hectares were developed for irrigation and only 1,556 hectares were planted. The irrigated fields were neglected in 1988 because of good rainfall and the preference for cultivation of rainfed crops.

Thus the true situation in the Bakel area was in fact even less optimistic than the figures reported by SAED. According to verbal reports from villagers we interviewed during field visits to 23 of the 31 perimeters, only 40% of the area reported by SAED was actually planted. This was 600 hectares, not 1,600.

Thus the amount of irrigated land had decreased by 100 hectares since 1984, and was nowhere near sufficient to satisfy local needs, let alone provide rice or other crops for export. Only 6% of the potentially irrigable land was cultivated after 4 years of heavy investment from USAID and SAED.

Figure 16

Section through riverbank showing typical village and irrigated perimeter – no scale

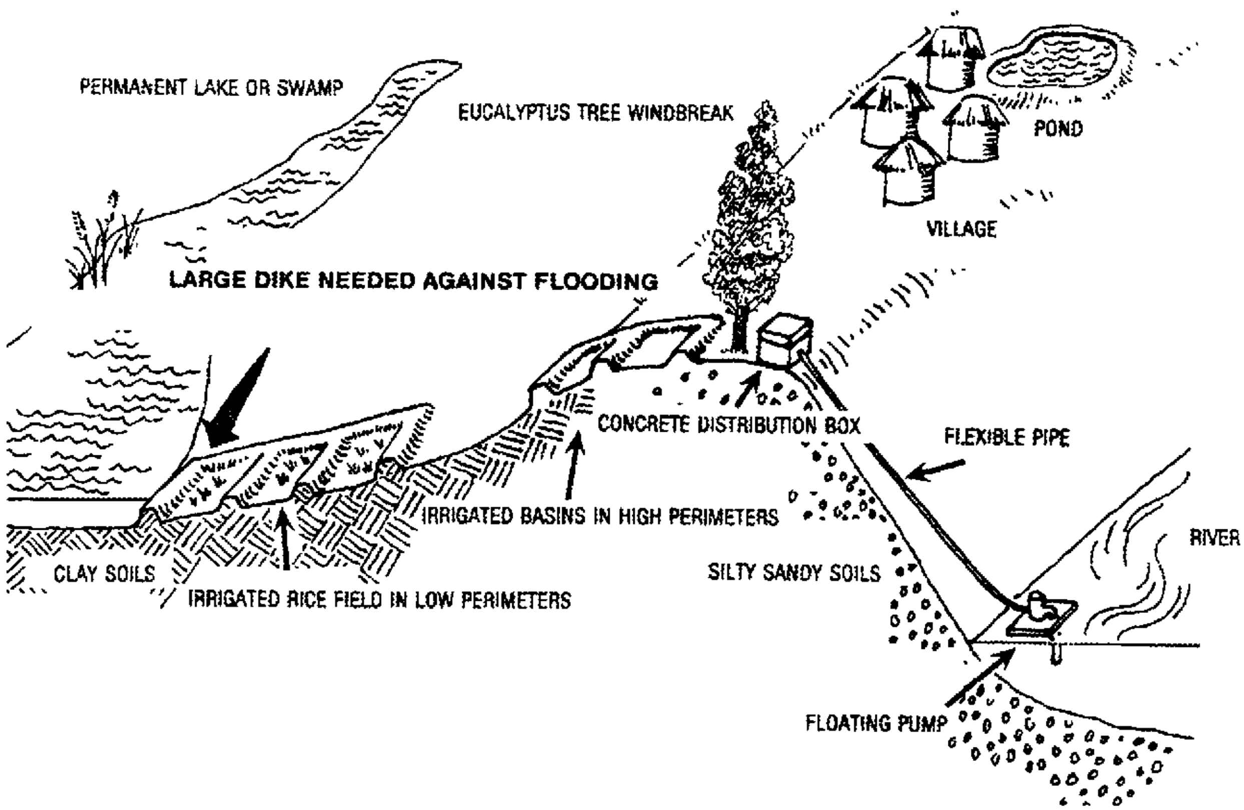


Figure 17. Upper photo shows author searching for bilharzia snails in one of few rice field at Balou, near Bakel, Senegal in October 1988. Lower photo is of woman cultivating recession crops along bank of river, also October 1988. This type of cultivation will disappear along more than 1,000 kilometers of river bank if the artificial flood is not maintained. Photos by Jamnback

This serious discrepancy between the plans, the reported figures and the reality, explained the continuing presence of malnutrition in the river basin. It also indicated that the optimistic expectations of reaching self-sufficiency in food through pumped irrigation were false. After a decade of effort by SAED to promote pump irrigation, local people continued to rely instead on rainfed and flood agriculture, and resorted to the more difficult and expensive pumped irrigation only in severe drought years. The irrigation might thus dampen serious fluctuations in the food supply, but would not be able to keep up with the caloric needs of the local population, even in the immediate future.

A recent review of small-scale irrigation in the Sahel Zone of Africa confirmed this analysis (Brown and Nooter, 1992). In this World Bank report it was pointed out that the original justification for construction of Diama and Manantali Dams required SAED to bring 5,000 hectares per year under development, to be double-cropped. However in one of their largest projects, SAED

> "...constructed canals on only about 1,250 hectares per year, of which it developed only 50% for irrigation. Only 75% of the area was actually farmed and only 5% double cropped...."(page 26).

If one multiplies these factors, it can be calculated that they achieved only 5% of the required development. In smaller perimeters such as those around Matam,

> "...farmers sold only 8% of their rice production. By 1983 the World Bank considered that rice alone was not profitable;...."(page 27).

Based on these observations, we concluded that malnutrition will continue to be a severe problem in the Senegal River Basin, and that elimination of the artificial flood, as proposed for the future in the Manantali Energy Project, would increase the present malnutrition to unacceptably high levels. This was detailed by the calculations reported in the following section on analysis.

IV. ANALYSIS

Utilizing the death rates for various diseases provided by the study in Western Mali, projections were made for conditions to expect with completion of the Energy Project and generation of electricity. Additional situations were analyzed, including permanent provision of an artificial flood, and integrated operation of Manantali Reservoir in a manner which includes health needs.

To refine the predictions, the calculations were conducted for three separate zones, the Senegal River Delta, the Middle Valley, and the Upper Valley which was the portion of the river in Mali **(Table 10)**. The major adjustment for the separate zones was the differential prevalence rates of malaria in the three zones. Malaria was most common in Mali, and least common in the Delta. Thus the prevalence rates reported in Mali (Duflo et al, 1986) were adjusted in proportion to the parasite prevalence rates reported in the 1978 longitudinal study (Gannett et al, 1980).

The total population assumed for the Senegal River Basin for the year 2,000 was 1,900,000. This total was divided among the three zones, with 580,000 in the Delta, 1,285,000 in the Middle Valley, and 35,000 in Upper Valley of Mali and Guinea **(Table 10)**. In addition, the population in Upper Mali assumed to inhabit the shores of Manantali Reservoir was 5,000 for the year 2,000.

The normal number of deaths annually in a population of 1,900,000 people in the Senegal River Basin without the Manantali Energy Project would be about 38,000 per year at a Crude Death Rate of 2%. Of these 38,000 deaths it was estimated that about 12,000 were due to malnutrition and water-associated diseases, based on the previously cited sources **(Table 10)**. Changes in water flow and amount caused by changes in the Manantali Energy Project of the OMVS would have an impact on these 12,000 deaths. Thus they formed the basis for our comparison of various situations, with and without the Project. It would also be possible to make this evaluation on the basis of productive days lost due to these diseases, but the conclusions are clear enough based on the number of deaths (Duflo, 1986).

These calculations are a refinement of those given in the preliminary report of 2 February 1993. The differential rates of disease incidence for three separate zones of the Senegal River Basin have been used here, to be more precise, but the conclusions remain the same. Thus under existing conditions, without the Energy Project, diarrheal diseases would be the major cause of death, resulting in over 5,000 deaths per year, compared to malaria and malnutrition which would each cause about 3,000 deaths per year **(Table 10)**. Bilharzia would cause about 500 deaths but River blindness would cause only about 30, if one includes the fact that the flat slope of the middle valley and delta preclude breeding of the blackflies in the river.

Table 10. Estimated annual number of deaths due to malnutrition and water associated diseases predicted for three zones of the Senegal River Basin for the year 2,000 and a total population of 1,900,000. but without the Manantali Energy Project. (See Table 5 for mortality rates for each disease).

Zone Population	Delta 580,000	Middle Valley 1,285,000	Upper Valley 35,000	Total 1,900,000
Malaria	278	2,750	164	3,192
Diarrhea	2,064	3,574	125	5,763
Malnutrition	870	1,928	52	2,850
Bilharzia	151	334	9	494
River Blindness	0	0	28	28
Total				**12,327**

By making simple adjustments to these numbers, it was possible to compare alternative situations in the future with and without the Project **(Table 11, variations 1 and 2).** Additional alternatives considered were the permanent addition of an annual artificial flood to the discharge requirements for Manantali Dam **(variation 3)**, and finally the further addition of water-level fluctuations to the reservoir operation during the rainy season **(variation 4).** These measures are detailed in the section on Recommendations.

Four increases in the number of deaths were expected if the Project were implemented as presently planned. It was assumed that epidemics of Rift Valley Fever would continue to occur near the three reservoirs in the Senegal River Basin, at a frequency of once every 5 years. If the combined deaths caused by epidemics around all 3 reservoirs were 1,500, then the annual average would be 300 deaths **(Table 11, variation 2).**

The second increase was assumed to be a doubling of the malnutrition rate when the annual flood is completely eliminated. This implies that the current situation with agriculture in the basin will continue, with little utilization of pumped irrigation. Thus the consequent loss of drawdown and flood agriculture, as well as the present fish population, would be a major blow to nutrition.

There would also be increases in intestinal bilharzia due to continuous irrigation in the large systems of the lower valley. River blindness would also increase because of the continuous breeding by the blackflies below Manantali Dam.

On the positive side, the base flow provided during the dry season would reduce diarrheal disease in half, eliminating 2,900 deaths per year. Thus under this variation, the Project as presently conceived would cause a net addition of 2,000 deaths per year **(Table 11, variation 2).**

If the artificial flood were maintained properly every year, it was estimated that the rate of malnutrition would remain at its present level and there would be a net decrease in deaths, primarily due to decreases in the summer diarrheal disease epidemic **(Table 11, variation 3)**. Under this condition the Project would result in a decrease of abut 600 deaths per year, due to the improved nutrition.

The final variation examined assumed that the mosquitos, snails and blackflies around Manantali Dam could be controlled by simple changes in reservoir operation such as fluctuation of the water level during the breeding season of these organisms.

Under this situation it was estimated that the Project would result in considerably improved health for the entire valley, and a decrease in the number of deaths annually by almost 3,000 (Table 11, variation 4).

Table 11. Approximate annual number of deaths related to the Manantali Energy Project of the OMVS, predicted for the year 2,000 and a population of 1,900,000 in the Senegal River Basin, for three variations of the proposed Project, and for conditions without the Project.

Variation / Disease	(1) Without Project	(2) With Project	(3) With Project and artificial flood	(4) With Project plus artificial flood and reservoir management
RVF	0	300	300	0
Malnutrition	2,800	5,600	2,800	2,800
Malaria	3,000	3,000	3,000	2,800
Bilharzia	500	1,500	1,500	750
Diarrhea	5,800	2,900	2,900	2,900
River Blindness	30	1,000	1,000	30
Total Deaths	12,130	14,300	11,500	9,280
Change from conditions without Project	0	+ 2,170	- 630	-2,850

Such calculations are highly approximate, but they illustrate the importance of proper design and operation of Manantali Dam. If its operation is integrated with health and other needs, the Project could provide multiple benefits for the people of the Senegal River Basin.

V. CONCLUSIONS

Since Manantali dam was completed and began filling, several important health impacts have been observed, including epidemics of Rift Valley Fever and a severe outbreak of intestinal bilharzia in the sugar cane irrigation system at Richard Toll. Malnutrition remained high in the river valley, as expected improvements due to agricultural programs did not occur. This was partly due to improper modifications of the annual flood by operation of Manantali Dam during the six years since the dam started filling.

Some health benefits did occur in the valley population and among the people inhabiting the area flooded by the dam. Among the people displaced by the dam to relocated villages, there was a decrease in diarrheal disease due to improved water supplies and a generally good relocation program. There was also an improvement in nutrition, primarily because of supplemental food supplies provided in the initial years after the move. The small population which remained around the rising lake also had improved nutrition due to good fishing, and lowered diarrheal diseases due to the large dilution of wastes by the lake waters. However they were suffering from severe malaria and intense transmission of urinary bilharzia.

The stable level of the lake created ideal conditions for breeding of malaria mosquitos and bilharzia snail populations, especially along the north-eastern shorelines where the larger original villages remained. This was also true for the villages of fishing people who recently migrated to the lake.

Experience in the last few decades has shown that diseases transmitted by mosquitos and aquatic snails can be controlled by operational measures involving water-level fluctuations, and by physically decreasing the amount of protected shoreline habitat. The present period, before the final Energy Project is completed at Manantali Dam offers a unique and valuable opportunity to adapt these environmental methods to conditions in the Senegal River Basin.

As presently operated, Manantali Dam will continue to have a major negative effect on health conditions in the Senegal River Basin. Thus for the final Energy Project it is imperative that operational guidelines should be developed to include provisions to maximize health and other benefits, in addition to hydroelectric power.

VI. RECOMMENDATIONS

The remaining health issues which need to be addressed regarding the final phase of the Energy Project include adaptation of available environmental methods for Manantali Dam and Reservoir to prevent new outbreaks of Rift Valley Fever, to control present malaria and bilharzia transmission around the lake, and to prevent further intestinal bilharzia transmission in large irrigation systems in the valley. The final major issue which must be dealt with is the prevention of further malnutrition due to modifications of the annual flood which has been the basis of traditional agriculture throughout the river valley.

The first four of the following six recommendations require establishment of an International Steering Committee consisting of representatives from the World Health Organization and the Ministries of Health of Mali, Mauritania and Senegal. This committee should guide the Limnology Unit of OMVS at Manantali, the international OCP, and the INRSP of Mali to carry out the experimental program. The first four recommendations should be initiated immediately as part of the current Environmental Impact Assessment.

Adaptation of water level fluctuation techniques and shoreline modifications to Manantali Reservoir for disease control.

1. An International Steering Committee should plan and evaluate manipulation of water levels in Manantali Reservoir for control of the insects and snails which spread Rift Valley Fever, malaria, bilharzia and river blindness (**Figure 18**). Fluctuation patterns developed in the TVA and in Puerto Rico should be evaluated in short field trials and adapted to conditions in the Senegal River Basin.

After the rains when the reservoir level would normally be receding due to generation of electricity, a staggered recession pattern should also be evaluated as a means of controlling the bilharzia snails.

Physical modifications of the shoreline should be evaluated on a pilot basis, near villages along the shore of Manantali Reservoir. Straightening shorelines and creating steeper shores near the villages should be evaluated for cost-effectiveness in reducing mosquito and snail habitats. Cutting of submerged trees near lakeside villages should be evaluated as a means of reducing protected habitats, dependent on patterns of wind and wave action.

The International Steering Committee should also evaluate changes in operation of Diama Dam and the Richard Toll irrigation system to eliminate the conditions favoring intestinal bilharzia in the lower valley. Perhaps fluctuations, periodic drying, or modified irrigation techniques can be used to eliminate the *Biomphalaria* snails which invaded the area after the dams began to function.

Disease control programs based solely on drugs and biocides are far too expensive for permanent control of these diseases in the Senegal River Basin, and should be integrated with the more permanent environmental methods only when more cost-effective in a long range analysis.

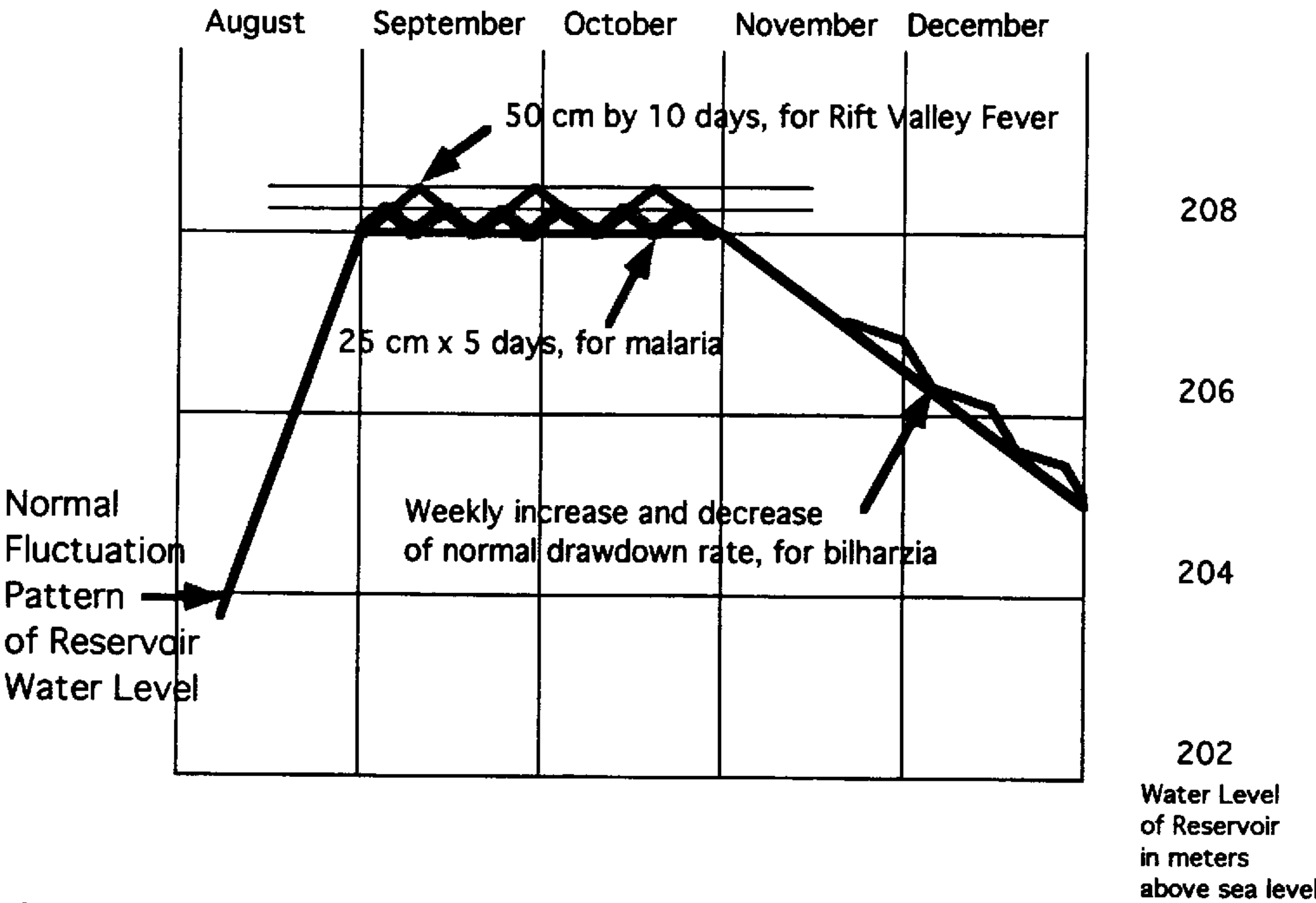


Figure 18. Proposed guidelines to be evaluated for water-level management on Manantali Reservoir.

One reason why the present OMVS Limnology Group at Manantali should play a central role in carrying out the field work related to developing methods for control of mosquitos and snails, is that predation by fish should be encouraged as another control method. Cichlid fish are especially good predators on snails, and other groups are effective against mosquito larvae. The focus of the Limnology Unit on fish should be expanded and encouraged to study this aspect as well. They might also find fish which prey on the blackfly larvae in the river below the dam.

2. The evaluation of mosquito, blackfly and snail populations should be carried out by the Limnology Unit at Manantali, or the OCP, with the assistance of biologists from INRSP. All of these modifications in the fluctuation pattern should be evaluated downstream as well, primarily to measure their effect on larvae of the blackflies. Slight changes in river discharge could easily eliminate the blackfly breeding sites, if closely coordinated with climate and geographical conditions along the river (**Figure 19**). It is also necessary to evaluate safety considerations for people along the river. Rapid rises in river flow could result in loss of life through drowning, especially in the river just below Manantali Dam.

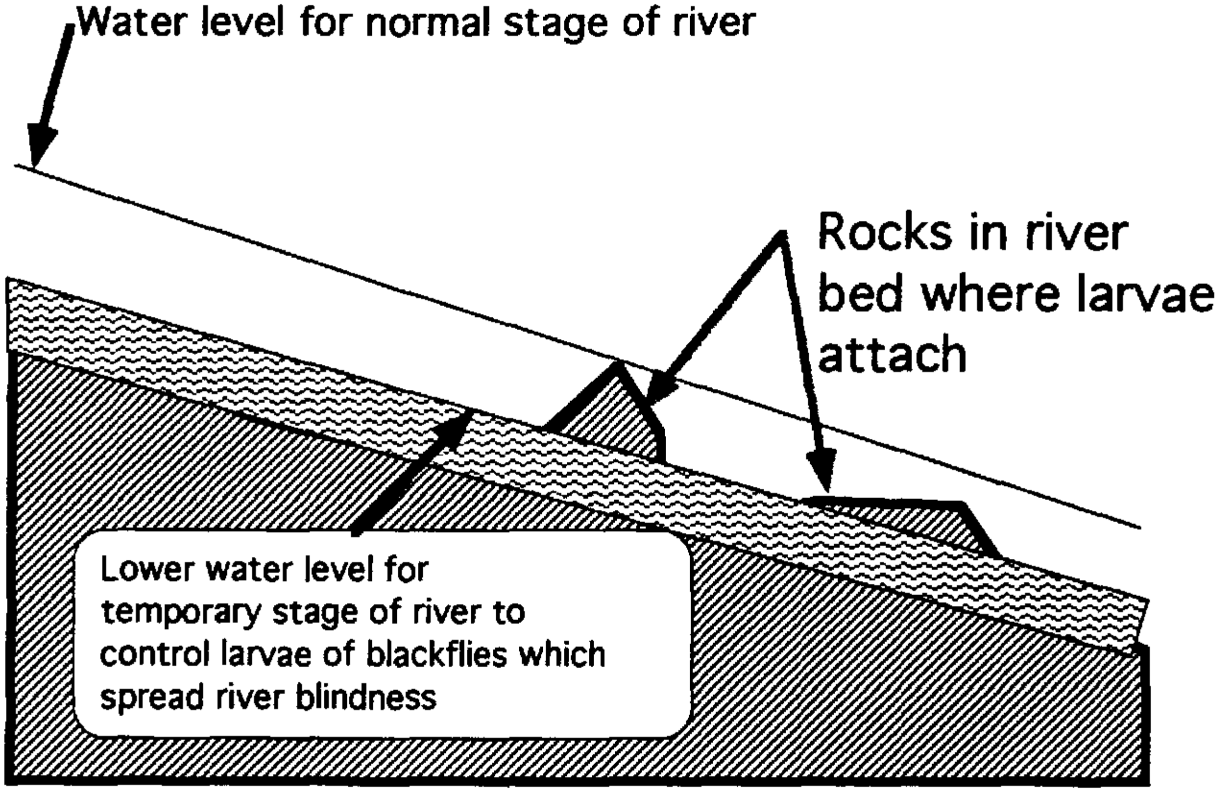
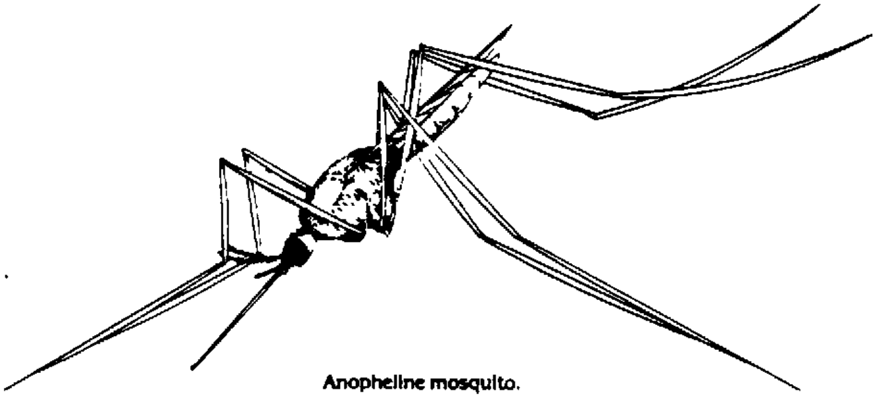


Figure 19. Schematic profile along Bafing River downstream of dam, showing effect of slightly lower river flows in drying of blackfly larvae.

Monitoring of Malnutrition in Middle Valley in relation to Artificial Flood released from Manantali Dam.

3. Each year the timing and peak flow of the artificial flood should be recorded as it passes through the river valley. The response of the farmers to the flood should be determined, as well as their crop yields for each of the three types of cultivation practiced, and the harvest of fresh-water fish. This information should be correlated with measurements of malnutrition made every 3-5 years, in order to assess the advisability of discontinuing the artificial flood at the end of the transition period.

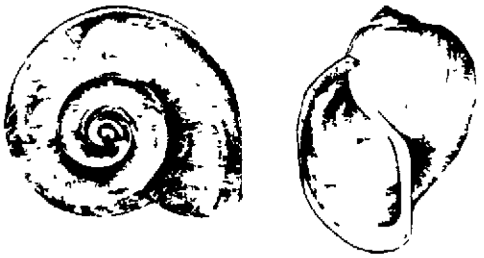
The primary method for monitoring the area of land cultivated each year should be remote sensing from satellites or specific aerial photography surveys (Rosema, 1990; and Cooley and Turner, 1975). These surveys should take place just before harvests. They should determine the area of land under pump irrigation, under recession planting, and under rainfed cultivation. Crop types and yields should also be estimated, using field measurements to calibrate the remote data. The principal aspects of the artificial flood to be evaluated are the amount and date of the peak release at Manantali, and the shape of the flood at Bakel and Podor.



Anopheline mosquito.

MALARIA

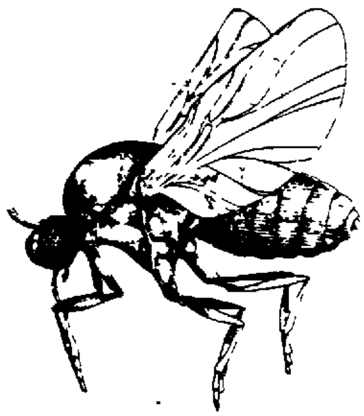
The most common of the tropical diseases related to water, malaria is transmitted throughout the tropics by anopheline mosquitoes which are often found infesting reservoirs, irrigation canals and drains Due to resistance to insecticides and drugs, prevention by environmental modification is becoming a necessity in water resource developments. These environmental control measures are best implemented in the design stages of a project.



Shells of planorbid snails

BILHARZIA

Bilharzia is a parasitic disease transmitted in a complex cycle by fresh water snails, an infection closely linked with irrigation and classically associated with the Nile River. It is also found, however, in the Caribbean area and Brazil, in China, the Philippines and the Middle East. The disease is also known academically as schistosomiasis



Blackfly

RIVER BLINDNESS

This disease, prevalent in Africa and tropical America, is spread through the bite of the blackfly. The biting blackfly breeds in rapids or whitewater on spillways and water control structures, and is responsible for impeding agricultural development in much of West Africa. The disease is also known as onchocerciasis to parasitologists.

Major Diseases Related to Water Resource Projects

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X. LIST OF GRAPHICS

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Table: Le nombre de décès prévus dus au projet d'Energie Manantali dans la région de l'OMVS, pour l'année 2000 et une population de 1.900.000

Maladie	Sans projet	Avec projet	Avec Projet et des améliorations
FVR	0	200	
Malnutrition *	2.800	5.700	
Paludisme	2.000	1.000	
Bilharziose **	400	1.500	
Diarrhée	4.200	2.500	
Cécité du fleuve ***	1.300	1.000	
Autres	26.700	26.700	26.700
Total	37.400	38.600	37.400
Change		+ 1.160	ZERO

* Dans le rapport final, on donnera une explication en détail des calculs et des hypothèses sur l'importance de la crue et l'agriculture de décrue pour la nutrition dans la vallée du fleuve Sénégal.

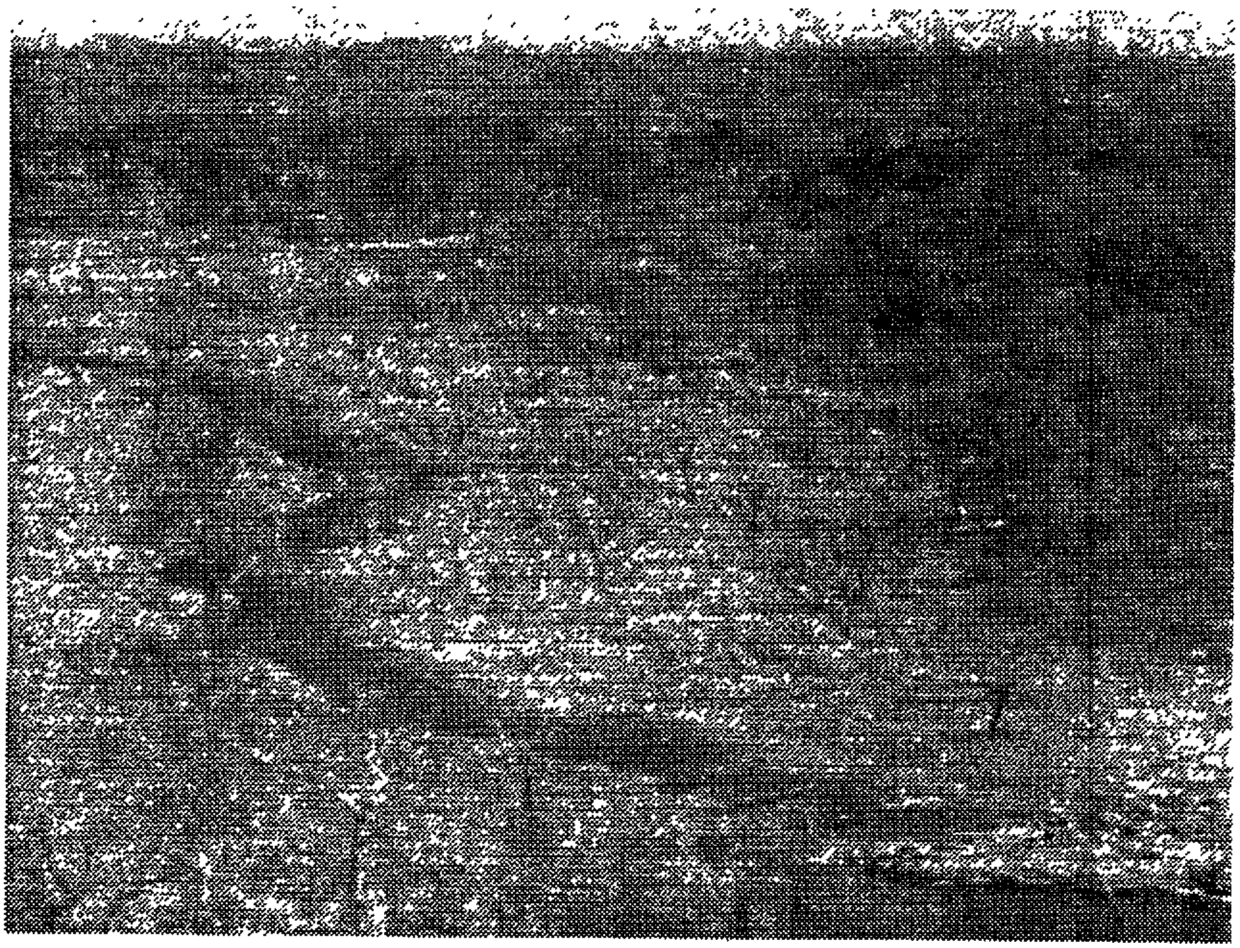
** Il faut diviser le chiffre en deux parts, l'une en relation au barrage de Diama, l'autre correspond au projet d'Energie.

*** Peut-être on peut calculer plus exactement la quantité des gîtes pour les mouches noires de la cécité des rivières avec les modèles hydrologiques pour le fleuve Bafing de Kayes jusqu'à Manantali.

12. Il existe la possibilité de réduire le nombre de décès dus au projet Energie Manantali avec le programme expérimental de gestion du niveau de retenue, avec les modifications sanitaires au lieu des villages des pêcheurs sur le lac, et avec d'autres méthodes sanitaires, sans interférence avec les objectifs primaires du projet d'Energie et de l'OMVS.

4. Around Manantali Reservoir an inventory of flat land should be conducted, perhaps by remote sensing methods, with soil surveys to determine potential agricultural productivity. This land could then be used for recession agriculture and thus improve local nutrition. With a regularly scheduled reservoir drawdown, the farmers would be able to plant and harvest appropriate crops.

Figure 20. Considerable flat land suitable for recession agriculture existed along the north-eastern shores of Manantali Reservoir at nearly full level. Photo by Leeds.



As the length of reservoir shoreline is roughly 100 kilometers, of which 25% may be flat enough for agriculture, and the drawdown zone of 23 meters vertically could expose a horizontal shoreline of 2,300 meters on a 1:100 slope, thus there are potentially 6,000 hectares of land available for recession agriculture around the lake.(**Figure 20**).

In areas favorable to shoreline settlements, permanent measures should be evaluated for mosquito and and snail habitat reduction. Straighter and steeper shores should be created by simple earth-moving measures. Removal of submerged trees in areas where wave action could thus be increased, should also be evaluated.

Utilization of experience with Manantali Dam to prevent problems with other dams in Africa.

5. United Nations agencies have jointly formed a panel to deal with water resource developments, and they should be closely involved with the experimental work recommended for Manantali Dam. This UN group is called the Panel of Experts on Environmental Management for control of water-associated diseases (PEEM), and has its Secretariat at WHO Headquarters in Geneva. PEEM includes representatives from WHO, FAO, the UN Environment Program and the UN Center for Human Settlements. PEEM could also monitor health conditions in other major dams in Africa and apply the techniques learned at Manantali. These techniques could immediately be applied at Selingue, Kainji and Bandama dams, all in West Africa.

6. In cooperation with the World Bank and other funding agencies, PEEM could review plans for new dams in Africa, and assure that the disease prevention measures developed for Manantali Dam are incorporated in the early planning stages. Such dams now being planned include Batoka Gorge Dam on the upper Zambezi River and Merowe Dam on the Nile River in northern Sudan.

The current director of PEEM is:

Dr. Robert Bos
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1211 GENEVA 27
Switzerland.

7. The initial evaluations of the proposed control methods should be started now and continued during the period prior to generation of electricity, the next 3-5 years. In addition, OMVS, with the help of PEEM or the OCP, should monitor health conditions annually thereafter for at least 10 more years, to insure that the dam is operated in a manner which gives optimum health benefits. This is an essential requirement to counter the experience in the first six years of its operation, during which Manantali Dam has caused unnecessary disease and death in the Senegal River Basin.

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VIII. PRELIMINARY REPORT IN FRENCH

This report was delivered to Mr. Konate of the Energy Project in the OMVS headquarters in Dakar, immediately after our field trip to Manantali Dam. Naturally it is of a preliminary nature, and has been considerably expanded by this final report in english.

Rapport préliminaire sur l'Impact du
Projet d'Energie Manantali sur la Santé

le 2 février 1993

Dr. William Jobin
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Consultant pour la Banque Mondiale
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CONCLUSIONS ET RECOMMANDATIONS

1. La Mise en valeur de la vallée du fleuve Sénégal et le projet Energie de Manantali, ne différent des autres grands barrages de l'Afrique de l'Ouest en ce qui concerne l'impact dans le domaine sanitaire. Il y a et aura des impacts positifs et négatifs sur les maladies endémiques suivantes :

- le paludisme
- la Fièvre de la Vallée Rift (FVR)
- la malnutrition
- la bilharziose
- la diarrhée
- la cécité des rivières (onchocercose).

2. On trouve de nombreuses données et des rapports sur la santé des personnes dans toute la région de l'OMVS et en particulier dans la zone du barrage de Manantali depuis les années 1978 jusqu'en 1992. Les données étant de très bonne qualité et on peut faire des prédictions pour chacune des maladies.

3. Due à la période transitoire et à une période de plusieurs années avant l'installation des turbines, une opportunité existe avec le projet de Manantali pour essayer les préventions des maladies plus importantes en utilisant les méthodes de gestion de l'eau et d'autres méthodes à coût faible. Pour cela, on peut calculer les bénéfices de santé pour le projet, et les ajouter aux autres bénéfices.

4. Un programme de prévention des maladies de la Fièvre de la Vallée du Rift, du paludisme et les autres maladies doit être basé sur la gestion du niveau de la retenue de Manantali. Il existe plus de 3 ans pour faire les essais à petite échelle dans le lac, avant la production d'énergie.

5. La gestion du niveau de la retenue Manantali doit être évaluée pour le contrôle des gîtes des moustiques dans le lac, pour éviter le développement des moustiques, du paludisme et du FVR. Il faut faire ces études en rapport avec l'Institut National de Recherches en Santé Publique (INRSP) à Bamako, et l'Institut Pasteur à Dakar.

6. La période pour évaluer les méthodes principales dans le lac devrait être quand la retenue est remplie au niveau de 208 m et quand il y a un grand débit du fleuve Bafing vers le lac. En principe, c'est aux mois de Septembre, d'Octobre et de Novembre.

a. Fièvre de la Vallée du Rift (FVR)

Changement cyclique du niveau du lac avec une amplitude de 50 centimètres et une période de 10 jours. Il y aura chute de 50 centimètres pendant 5 jours et une montée de 50 centimètres pendant les prochains 5 jours.

b. Paludisme

Changement cyclique du niveau du lac avec une amplitude de 25 centimètres et une période de 5 jours.

7. Il faut observer les effets en aval dus à ce programme sanitaire de gestion du niveau du retenue, inclusif les effets hydrologiques et biologiques.

8. Le groupe de limnologie en Manantali doit travailler en coordination avec le Chef de l'hydrologie pour faire l'évaluation du programme sanitaire sur la productivité générale du lac, sur les poissons et sur l'écologie aquatique.

9. Il faut installer aussi des postes d'observation spéciaux en aval, pendant les mois d'expérimentation (Septembre - Novembre) à Bakel, Kaedi et Richard-Toll.

10. La seconde méthode sanitaire pour évaluer sur le lac est la modification géographique des points de contact avec l'eau autour des villages de pêcheurs. Il y a la possibilité de changer la forme de la plage (plus grande pente, ligne plus droite). Aussi il faut installer des puits pour chaque village, loin de la plage pour éviter les gîtes des moustiques et mollusques.

11. Le projet d'Energie Manantali aura des effets positifs et négatifs sur la santé. Les calculs préliminaires montrent que le projet d'énergie modifiera le nombre de décès par ans dans la zone de l'OMVS par rapport aux maladies suivantes: (cf. table)

a. Une augmentation de 2.900 décès dus à la malnutrition *
b. Une baisse de 1.000 décès dus au paludisme
c. Une augmentation de 1.100 décès dus à la bilharziose **
d. Une baisse de 1.700 décès dus à la diarrhée
e. Une augmentation de 200 décès dus à la FVR
f. Une baisse de 300 décès dus à la cécité des rivières ***