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TANDAL POLDER FEASIBILITY STUDY

PREPARED FOR

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CH2M HILL

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Prepared for

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

November 1978

CH2M HILL, Inc.

ACKNOWLEDGEMENTS

The investigation of the feasibility of Tandal Polder was less than a 2-month effort. As such, it could only be completed with the assistance of many people who are located in Tchad. CH2M HILL appreciates the courtesies extended to each of our team members and it was only through the hospitality of these people and their willingness to cooperate that the effort was completed as planned.

We are particularly indebted to the people with SODELAC and the other agencies of the Government of Tchad who provided a great deal of background materials; to the engineers and technicians from SCET International who explained the Guini and Berim Projects; to the local officials in Bol and its surrounding villages who received us during our fieldwork; to the people at ORSTOM who provided numerous scientific publications and counsel; to various people within the Lake Tchad Basin Commission who made their knowledge available; and to people at the Institut National Tchadien des Sciences Humaines who provided input into the sociological studies.

Though our stay in Tchad was short, we are appreciative of the services provided by Ambassador Bradford and the staff of the U. S. Embassy.

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CURRENCY

Currency Unit = CFAF Franc
U. S. $1 = CFAF 230

WEIGHTS AND MEASURES

1 Kilometer (km)	=	0.6215 miles
1 Centimeter (cm)	=	0.033 feet
1 Meter (m)	=	3.3 feet
1 Hectare (ha)	=	2.47 acres
1 Liter (l)	=	.264 gallon
1 Kilogram (kg)	=	2.207 lbs
1 ton (metric)	=	2,207 lbs

ABBREVIATIONS

FAO	Food and Agriculture Organization of United Nations
GOT	Government of Tchad
LCBC	Lake Chad Basin Commission
ORSTOM	Office de la Recherche Scientifique et Technique Outre-mer
SCET	Société Centrale pour l'Equipement du Territoire-International
SODELAC	Société de Développement de Lac

Part 1A
DESCRIPTION OF THE PROJECT

In cooperation with a multidonor program for the Lac Region of Tchad, USAID is proposing to finance the construction of an irrigation development of the Tandal Polder near Bol (Figure 1A-1). The project consists of empoldering (diking) an area of approximately 800 hectares of Lake Tchad, providing facilities to irrigate the land by gravity and irrigation, and provide drainage facilities to ensure that the project continues to function as designed. The physical facilities include two intake structures with pumping facilities sufficient to assure a constant water supply during most years, a system of drainage canals and pumps to control seepage and surface runoff (Figure 1A-2).

Since the lands in the proposed Tandal Polder are presently inundated by Lake Tchad, persons to irrigate the proposed lands must be selected. The selection and subsequent assignment of lands and land rights must be carried out in a manner that will help ensure the success of the project. The method of selection that currently exists will be reviewed, and this report will suggest other methods that may assist the project in becoming socially acceptable to the neighboring Tchadian people. The availability of people and their cropping preferences will also be investigated.

Once implemented, the Tandal Polder Project becomes a part of the Bol Polder Development. Guini and Berim Polders are currently under construction using funds provided by the World Bank, and the Mamdi Polder Development is under study by the Arab Banque. If all four polders are eventually completed as planned, they will form an area of over 3,000 hectares of irrigated lands. Maintenance and operation of these projects will then become an integral part of ensuring that they will produce the desired benefits to the people of the Lac Region.

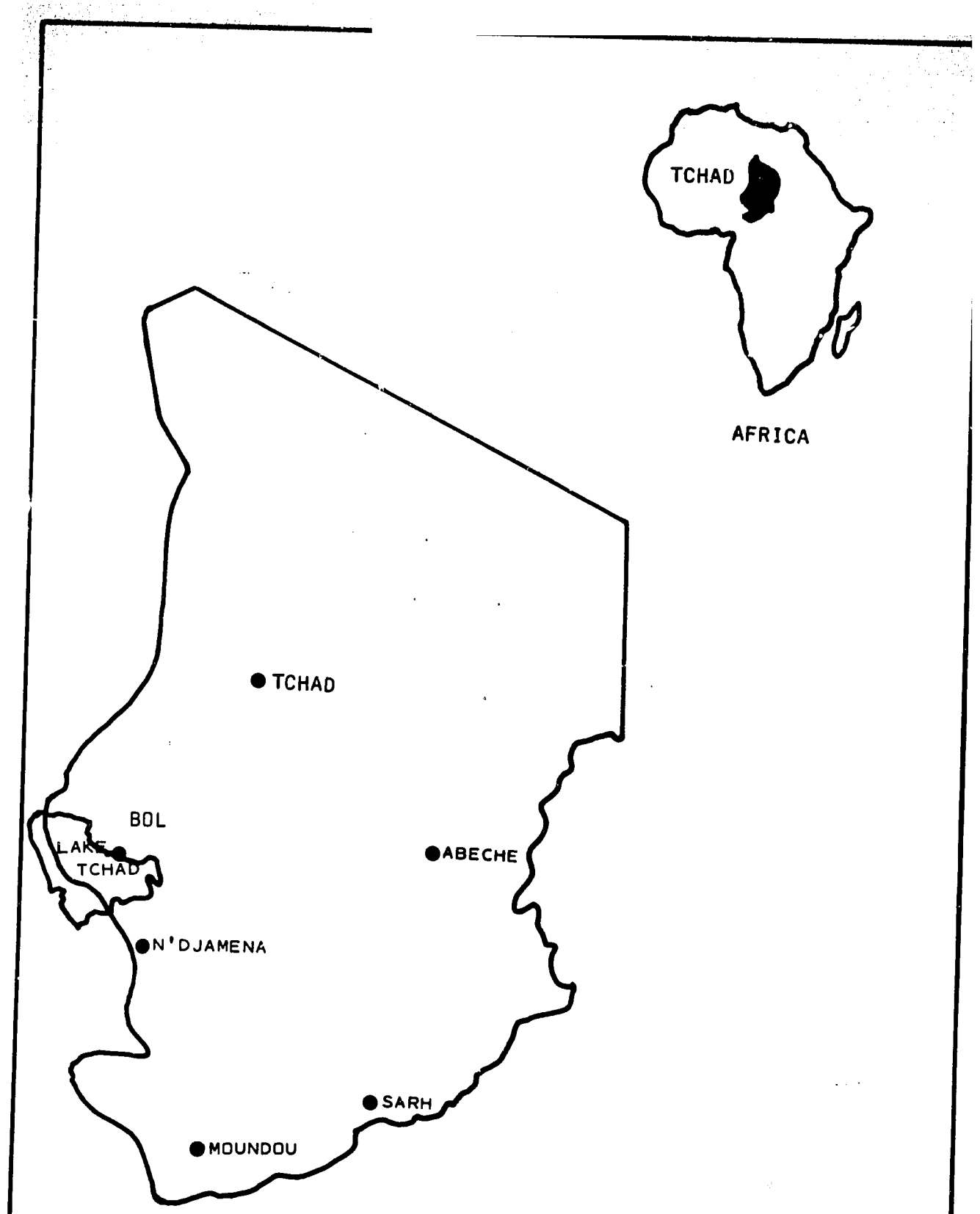


Figure 1A-1

LOCATION OF BOL IN TCHAD

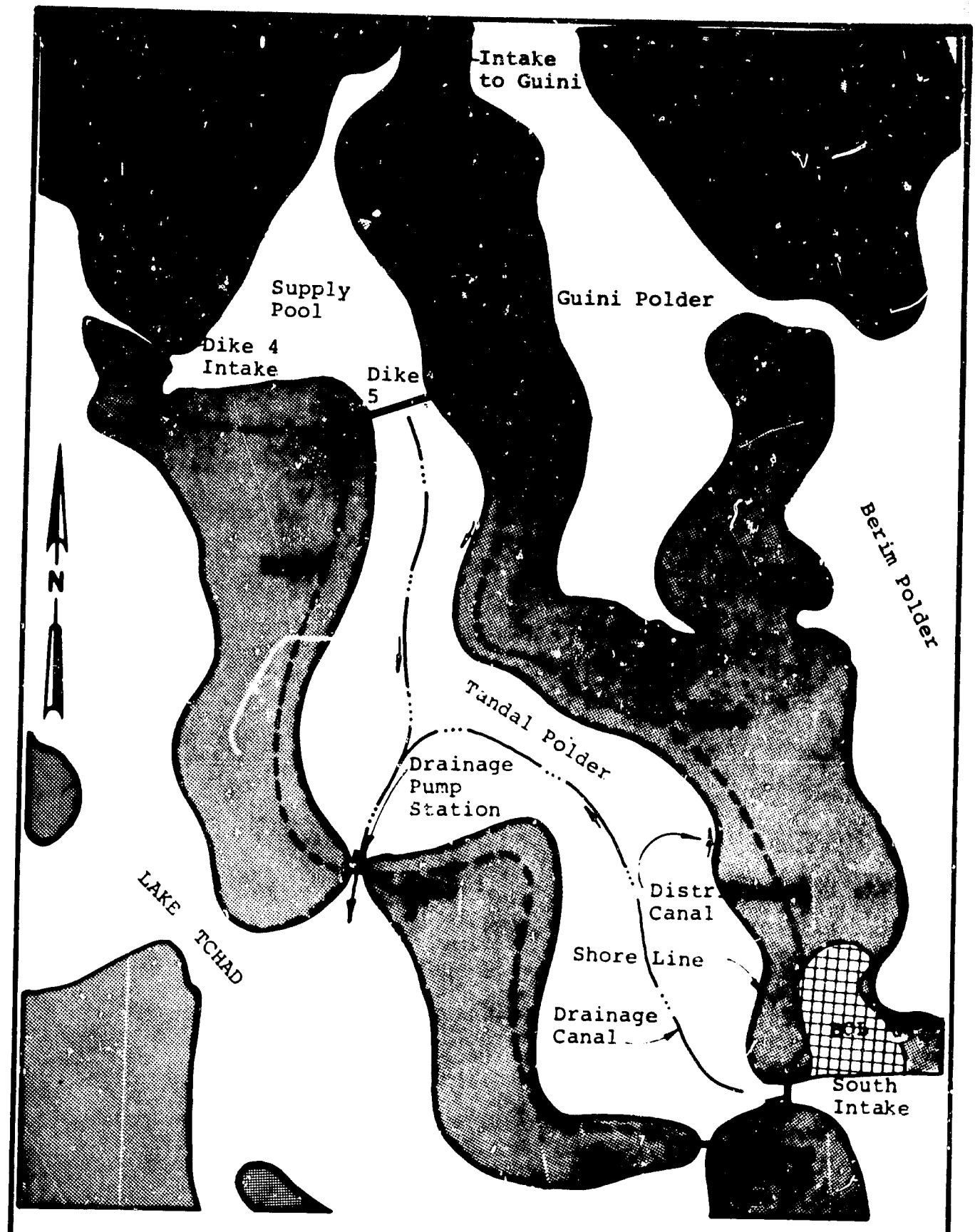


FIGURE 1A-2
TANDAL POLDER-DEVELOPMENT

Part 1B
SUMMARY FINDINGS

This study addresses seven separate but closely related aspects of the proposed Tandal Polder project and conditions in the nearby villages. The important conclusions concerning each of these elements are summarized below; each section of the report dealing with the specific topic contains other findings.

TECHNICAL

The design of Tandal Polder should follow the same general pattern presently being used on Guini and Berim Polders. However, some reservations are made concerning the ability to drain the polder soils and prevent salinization. Since earlier and more detailed soils reports did not anticipate significant drainage problems, on-going programs and the development of Guini and Berim Polders should provide definitive answers to the drainage and salinization question.

The low head differences between the polder ground surface and Lake Tchad requires that all facilities be oversized to reduce head losses. Consequently, the cost of development is high for the types of systems planned.

Transportation of construction materials and produce to market are impaired by lack of dependable transportation systems.

ECONOMICS

The total capital cost for the proposed Tandal Polder project is 1,820.0 million CFA ($7.9 million U.S.) for a development covering 600 hectares of irrigable lands. The cost is approximately 3.0 million CFA per ha ($13,200 per hectare or $5,300 per acre). Average annual costs for operation, maintenance and replacement of the system facilities is 77.1 million CFA ($335,000). The present worth cost of all expenditures over the estimated life of the project at a 10-percent discount rate for future expenditures is 2,752.1 million CFA ($12.0 million).

The benefits to be returned to Tandal Polder project beneficiaries is estimated to be 322.3 million CFA annually ($1.4 million) when full production is reached. The present worth value of these benefits is 2,282.5 million CFA ($9.92 million). The net rate of return on the investment

is about 6.0 percent and the project has a benefit/cost ratio of 0.83 at a 10 percent interest rate.

For each hectare farmed, net family income should be approximately 250,000 CFA annually.

Within 5 years, the farmers should generate sufficient revenue to make additional payments to SODELAC to cover a portion of the capital costs. This money could be used to finance other governmental programs or repay portions of the project loan.

ENVIRONMENTAL

The project will have a negligible effect on the Lake Tchad ecosystem though some minor local impacts will be noticed. Some changes in flora and fauna can be expected but are minute in comparison with seasonal and annual variations presently experienced.

SOCIO-CULTURAL

The construction of Tandal, Mamdi, Guini, and Berim Polders may have substantial impacts upon the socio-cultural systems present in Lac Prefecture. The major impacts on traditional systems will occur if a large number of workers from outside the region locate on the polders and if the farmers are not fully educated in the ways of money management. Future problems may be minimized by making modifications to the existing programs. These include modifications to the manner in which lands are "nationalized," the amount of land given to each family depending on size, the crops that can be grown, and the method of monitoring farming activities.

Effective communication between SODELAC and its agents and the farmers are a necessity if the polder project is to succeed.

HUMAN HEALTH

Health programs in the Bol area could be improved by providing additional drugs and supplies, trained staff in communicable diseases and sanitation, and laboratory diagnostic capability. The Tandal Polder project could worsen public health in the area if adequate provisions for quickly draining the empoldered area are not included.

ANIMAL HEALTH

The veterinary program at Bol could be strengthened by increasing the capability for surveying, diagnosing, and treating livestock, particularly if livestock populations increase. Additional research is warranted for vector identification,

diseases, and agronomics. Control of livestock populations may be necessary if the Tandal Polder project develops.

PLANT ECOLOGY

If crop production warrants the investment, additional staff should be added to provide advice on plant diseases and pests. The application of existing technology could significantly improve present programs.

Part 1C
RECOMMENDATIONS

The study has shown that there are no major technical, social, or environmental obstacles to the development of Tandal Polder. Though the effective rate of return on the investment is relatively low, 6 percent, and the cost of development is relatively high for this type of project, the decision to pursue the project is up to the agencies involved.

Though no major problems were discovered during this study, a number of factors need further consideration before the project is implemented. These factors are generally applicable to the entire Bol Polders project. The following recommendations are made:

1. A Bol Polders Project Commission should be established to oversee planning, design, construction, and operation of the project. The Commission would include representatives of each donor agency and the Government of Tchad. A coordinated effort is needed to ensure that the project will continue to function throughout its expected life.

2. Beginning with the third year of project operation, sufficient revenues should be generated by project farmers to repay about 2 percent of the invested capital cost annually. The generated revenues could be used by the Government of Tchad for other programs, to sponsor additional polder developments, or to repay the original grant or loan.

3. Consideration should be given to modifying the current SODELAC-farmer agreements to allow the people to eventually become land owners or share in the profits from the project. Furthermore, the farmers should have some preference as to the crops being grown and allowed to raise a small vegetable garden for their own use.

4. Improvements to the highway and water-borne transportation systems are a necessity for development of the Bol area. Cost-effective means of supplying materials to Bol and transporting produce to markets are a high priority item that needs immediate attention.

5. Prior to Tandal Polder construction, soil salinity, piezometric pressure, and permeability testing should be completed on the developed soils in Guini Polder. These tests are needed to confirm earlier studies and provide information needed for the design of the drainage system for Tandal.

6. Human and animal health programs will be affected by polder development, particularly during the drying phase and if substantial numbers of people migrate to the area. The project should finance improvements to the existing health programs.

7. From a socio-cultural standpoint, development of both Tandal and Mamdi Polders (in addition to Guini and Berim now under construction) may severely tax the ability of the local population to provide the necessary numbers of workers and farmers. Since the migration of large numbers of people from other ethnic backgrounds is undesirable, consideration should be given to developing an alternative polder where the social disruption will be less acute.

The above recommendations are felt to be the most important among those described throughout the report. It is recommended that USAID, other donor agencies, and the Government of Tchad consider them in light of improving and coordinating the development of the Bol Polders.

Part 2A
BACKGROUND

Development of the polders in the Lake Tchad area for agriculture began in the early 1900's. Polders were formed by the construction of sand embankments between fences of posts and small logs, the average length being 50 to 100 meters. Prior to 1950, there were approximately 23 dams in place with a reclaimed surface area of approximately 1,500 hectares.

During the period of 1950 to 1964, the lake underwent a series of floods which submerged most of the existing structures. After the flood of 1950, only 200 hectares of cultivatable land remained. At that time, the Administration of Bol undertook the construction of newer and larger dams in the polders region allowing farmers to recover their lands and intensify the exploitation of the area. By 1961, approximately 8,000 hectares of land within the polders area was being cultivated.

However, the floods of 1964 reached the highest mark in over a century and heavy damage ensued. Repairs to the damaged structures were accomplished with the help of the World Food Program and the European Development Fund. New techniques were used to avoid previous mistakes and increase yields from the polders. By 1966, the lake's isolated surfaces had reached 15,000 hectares. Several documents, including the AID Project Paper entitled "Lake Chad Irrigated Agriculture," give additional details concerning the history of polder development in Lake Tchad.

Present plans call for the reconstruction and initiation of four polders in the vicinity of Bol. These include: Guini and Berim Polders, being constructed with a loan from the World Bank; Mamdi Polder, being developed under the auspices of the Banque Arabe de Développement Économique de L'Afrique; and Tandal Polder, being proposed by USAID.

Part 2B
DETAILED DESCRIPTION

USAID has initiated a two-phased program for the development of agricultural production in Tchad. Phase 1 is comprised of four major activities and a series of subactivities. If the results of Phase 1 are favorable, Phase 2 would be the construction of irrigation facilities in Tandal Polder.

Phase 1 includes the following activities:

1. Strengthening of SODELAC as a regional development institution,
2. Research,
3. Health activities, and
4. Special studies.

The special studies, of which this report is a part, involves a technical review of the existing engineering practices being used in the adjacent polders, an environmental assessment of the reclamation of Tandal Polder, and a sociological study of the effect of Tandal Polder development on the human environment.

The objective of this report is to identify and analyze alternative schemes for increasing agricultural production in the polders area and select one for possible AID funding. Specifically, the report will address four areas of concern:

1. That sociological feasibility is established (or highly probable),
2. That the proposal is cost effective; that is, it will produce significant benefits for substantial numbers of AID's target group in relation to the cost of the proposal,
3. That the feasibility of technical design of the proposal selected be clearly established, and
4. That the proposal's impact upon the natural human and social environment be clearly understood with measures proposed as necessary to minimize environmental damage.

The proposed irrigation project involves the construction of five dikes around the periphery of Tandal Polder, draining the empoldered area through the use of pumps, and constructing intake structures, canals, laterals, and drainage facilities. Tandal Polder includes approximately 1,100 hectares (ha) of

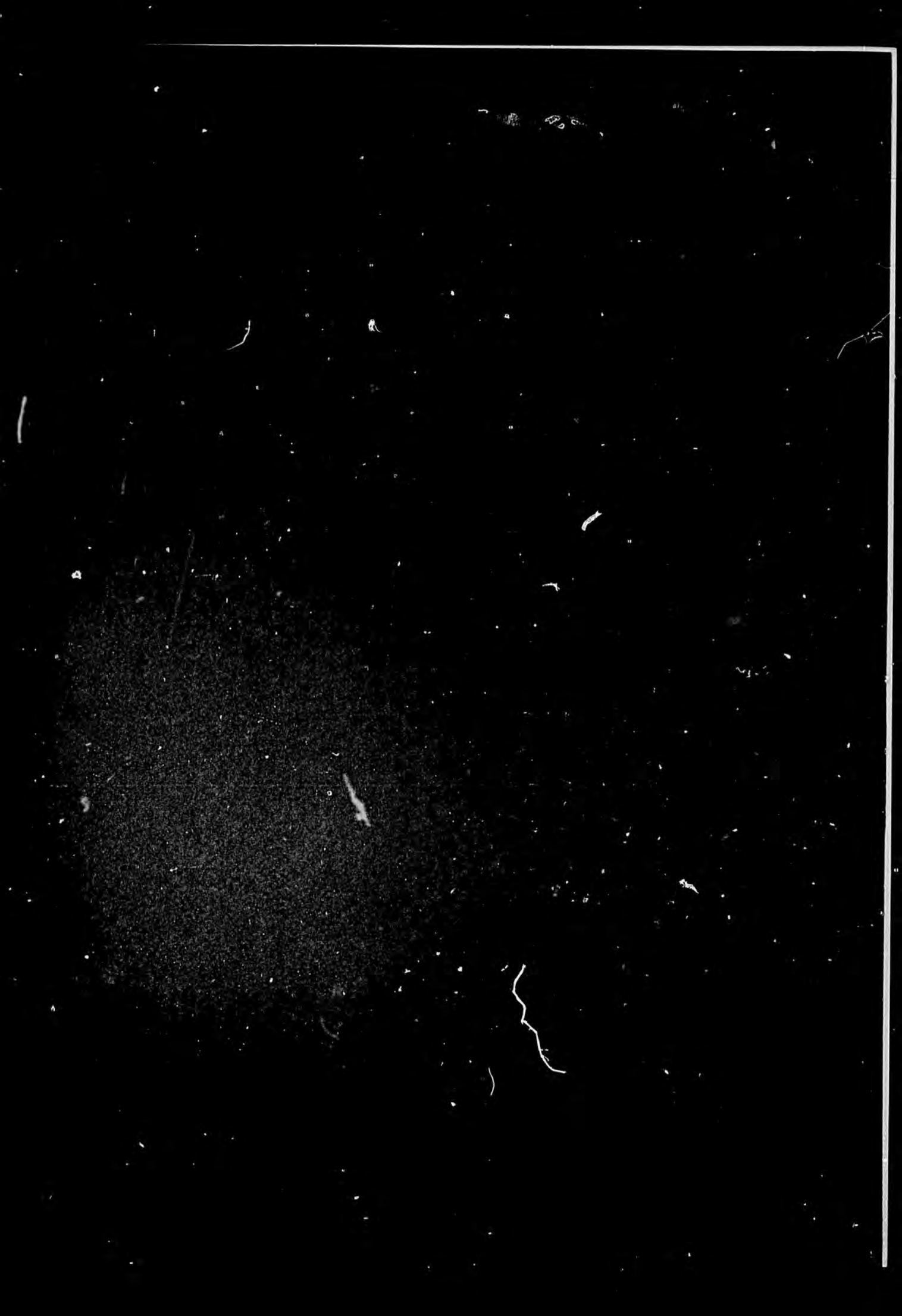
gross area of which about 600 ha can actually be put under cultivation. The intake structures would contain pumping provisions for periods when water cannot be delivered by gravity. The canals would be concrete lined and the lateral system would include buried pipe to deliver water to each hectare plot. The drainage system is designed to keep the water level below the root zone and includes a pump station to discharge the drainage water back into Lake Tchad.

An environmental assessment of the proposed project was conducted to determine the potential impacts on aquatic, terrestrial, and human resources.

Economic and financial analysis of the proposed project were performed to determine if sufficient revenues will be generated to recover the capital costs.

The creation of an extensive irrigation system near Bol will have a number of social implications to the village and surrounding villages. Though no people will be displaced by the project, the traditional ways of life will be modified if the project is to be successful. Factors which will facilitate or impair the establishment of Tandal Polder have been evaluated.

The status of current human, animal, and plant health programs near Bol have been analyzed. The impacts of the proposed project on these activities have been studied and recommendations are made to minimize the effects.



Part 3A
TECHNICAL ANALYSIS

I. WATER SUPPLY

The water supply to serve the proposed project on Tandal Polder will be Lake Tchad near Bol. Water will be taken from two locations in the archipelago of islands that comprise the eastern shore of Lake Tchad. This water is of suitable quality for all types of irrigated crops being considered for the area.

Lake Tchad is the remnant of a great inland lake which once covered nearly 350,000 square kilometers (km^2) and covered most of the area from south of N'Djamena to the Tibesti Mountains. A climatic change prior to 4000 BC reduced the lake to something near its present size. At the present time, the lake levels vary between 279 and 285 meters. At 279 meters, the lake contains approximately 20 billion cubic meters (m^3) of water at an area of approximately 5,000 km^2. At Elevation 285, the lake has a surface area of 30,000 km^2 and a volume of approximately 130 billion m^3.

The majority of the water flowing into Lake Tchad comes from the Chari River. The Chari River comprises approximately 33 percent of the average lake water supply of about 50 billion m^3. Rainfall and flow from other rivers comprise the remaining 17 percent. Since the drainage area for most of the Chari River is in an area of relatively high rainfall, a fairly constant water supply for the river is assured. Violent floods and large variations in flow are common. High flows follow the summer rainy season and occur in September and November, while low flows generally occur between March and June.

In the last 100 years, Lake Tchad has experienced significant fluctuations in elevation. During the late 1800's, the lake was constantly at high elevation, around 284. A drought in the early 1900's, however, dropped minimum levels in the lake down to approximately 280. Between 1920 and 1940, the lake remained at a level between approximately 281 and 283 until several successive dry years in the early 1940's dropped the lake to the 280 level again. In the late 1950's and early 1960's, the lake rose to a level approaching the levels that were reached in the late 1800's. However, a series of successively dry years followed and by 1973, the lake at Bol reached its lowest recorded level--approximately 278.3 meters. The lake has risen slightly since 1973, but has yet to return

to its previous levels. The history of the fluctuations of Lake Tchad are well documented in previous studies by ORSTOM and others.

It was not within the scope of this investigation to make a complete analysis of the hydrology of Lake Tchad. Consequently, past studies were reviewed and the results incorporated into this study. It is evident that Lake Tchad experiences a cyclic type of variation which makes it difficult to predict future water levels in the lake. It appears that the lake is experiencing a less than normal period of rainfall and inflow and that this cycle could continue for a number of years. Since other activities that affect the lake, such as the irrigation developments currently occurring in Nigeria and along the Chari and Lagone Rivers, will tend to reduce the water availability in the lake, it appears likely that the level of Lake Tchad may, in fact, stabilize at a level less than recorded historically. It appears probable that the maximum elevation reached by the lake may decrease by approximately 1 meter over the next 50 to 100 years.

If the 1 meter decrease in maximum lake elevation actually occurs in the coming years, then the frequency of lake elevations will be approximately as shown in Table 3A-1.

Table 3A-1
PROBABILITY OF LAKE LEVELS EXCEEDING
A GIVEN ELEVATION

Mean Annual Lake Elevation	Percent of Time Lake Exceeds Given Elevation
280.2	95
280.5	85
281.0	66
281.5	48
282.0	30
282.5	12
282.7	7

Table 3A-1 shows the elevations for the mean annual level of Lake Tchad at Bol. The maximum annual high elevation is approximately .4 meter above the annual mean level of the lake. Also, minimum levels are approximately .4 meter below the mean level. It would, therefore, appear that the maximum elevation that would normally be reached by Lake Tchad, as measured at Bol, would be approximately 283.5 meters. The minimum levels at Bol would remain approximately as they are today.

Since the design of the irrigation system for Tandal Polder is a function of the minimum lake elevation, several alternative elevations will be reviewed. Combinations of gravity flow and pumping will be investigated to determine the optimum elevation for the intake to Tandal Polder.

II. DESIGN ALTERNATIVES

Much of the information used in developing the design and cost analysis for this project was obtained from SCET, ORSTOM, LCBC, SODELAC, and Gannett, Fleming, Corddry & Carpenter, Inc., Engineers. This information was supplied by people working in the field and should, therefore, be quite accurate. Hopefully, all items have been interpreted correctly across the language barrier. Information that was not readily available was taken from past experiences and were adjusted for expected conditions in this area. Overall, the important information apparently was available though considerable effort was required. It is felt that the analysis and cost estimate for this project are reasonably accurate for this area.

The surface area of the polder was scaled from a 1:40000 aerial photograph. About 75 percent of the polder area was assumed to be the net usable area after roads and less productive areas are subtracted from the gross area.

The following values were used in investigating the system alternatives:

Manning n	
concrete canal	0.013
earth canal	0.060
pipelines	0.011
Canal slope	
irrigation	0.00005
drainage	0.00007
Intake Pump Station Capacity	
irrigation	2.5 l/s/ha
drainage	1.25 l/s/ha
Canal side slope	
irrigation (concrete)	vertical
irrigation (earth)	1 vertical to 1 horizontal
drainage	1 vertical to 3 horizontal
Dike side slope	1 vertical to 3 horizontal (minimum)

Inlet water surface to Tandal	**280 m elevation**
Irrigation canal water depth	1.1 m
Dike top elevation	
No. 1,2,3,4	285 m
No. 5	282 m
PVC pipe	660 mm or less

The alternatives investigated were a basic 600 net hectare area and an expanded 800 net hectare area. Modifications were made to these two systems by increasing the slopes of the inlet canal in order to decrease the size of the inlet canal and the distribution pipelines.

The basic 600-hectare area is shown on Figure 1A-2. It is composed of four exterior dikes (1, 2, 3, and 4) to isolate the polder area from the lake and an interior dike (5) to separate a permanent interior lake from the proposed polder area. A controlled inlet will be provided at Dike No. 4 so the interior lake level will not exceed 281 m elevation. The distribution canals will be located on the east side of the polder, one being fed from Pump Station No. 2 on the north end of the polder and one being fed from Pump Station No. 1 on the south end of the polder near Bol. The drainage canal generally traverses the center of the polder and will be discharged from the polder at Dike No. 3 located about mid-length of the polder. From the main distribution canal, pipelines will cross the polder distributing water to each hectare on a regularly scheduled basis.

Exterior roads for access to the polder will be constructed in locations generally shown on Figure 1A-2. Primary interior roads will generally follow the route of the main drainage canal. Secondary interior roads will provide access to the individual hectares from the primary interior road.

The 800-hectare area would be obtained by removing the interior dike (5) and utilizing the land that would have been inundated by the interior lake. The north half of the polder would then be served by a canal going down the west side of the polder and being served by a pump station at exterior dike (4). This scheme also would require a pump station to be built at the dike (4) and a canal built along the north edge of the polder to serve Guini Polder. The drainage for this system would be extended to the north end of the expanded polder but discharge at the same location as in the previous scheme.

Investigations were made into the feasibility of raising the canal inlet to several different levels, thus increasing the canal slope and thereby decreasing the canal size. This would also increase the head on the farm distribution pipelines and thereby decrease the size of these pipelines. It was found in these investigations that by raising the canal inlets about 2 meters, money could be saved in the construction of the project, but this would also entail increased power costs with the requirements that fuel and/or power be furnished to the site. This should be evaluated during final design to see if economies can be generated into the project with this method of construction. The anticipated cost of power at the time the project is constructed will influence the feasibility of this concept. Whereas pumping is required less than 5 percent of the time with the intake elevation at 280, pumping is required about 70 percent of the time at Elevation 282.

III. SOILS

Lake Tchad, as we know it today, lies in the southwest central portion of what was in recent times a large inland basin several hundred kilometers wide. It extends from the plateaus and mountain ranges associated with the Tibesti massif in northern Tchad to south of N'Djamena. The low point in this basin lies to the northeast of the lake near Largeau. Waters enter the lake principally through the Chari and Logone Rivers which flow throughout the year and by direct rainfall onto the lake. Lake Tchad does not have an outlet to the sea but during periods of very high rainfall, some water may leave the lake through Bahr el Ghazal to the northeast towards Largeau. The surface area of the lake varies between 10,000 and 25,000 square kilometers over a period of years.

The eastern shores of Lake Tchad are characterized by a series of ancient sand dunes and islands which extend into the lake. These elongated fingers and islands of sand may extend into the lake for several kilometers. The lake has submerged the depressions between the dunes to form shallow elongated bodies of water which may become little more than a swamp when the lake waters are at a low level. These shallow water areas support a floating swamp type of vegetation. Several centimeters to several meters of a dense water logged, lacustrine soil has accumulated in these shallow waters. This soil consists of decayed vegetation, diatoms, and clays which have been deposited in the lake over a long period of time. When empoldered, these areas expose relatively fertile soils which, in some areas, produced high yields of cultivated crops with little fertilization. The soils contain various amounts of salts, including sodium, which must be kept at a low level within the plant rooting zone. The waters of the lake contain relatively low amounts of dissolved salts.

Lake Tchad is located in the Sahelian or semi-arid climate--vegetative zone. An east-west line through Lake Tchad at approximately 14°N is the practical northern limit of the production of cultivated crops under rain-fed agriculture.

A. DEPRESSIONS (SITES FOR POLDERS)

The site of the proposed Tandal Polder near Bol on the eastern shores of Lake Tchad was visited between the 21st of March and 6th of April 1978. At that time the area was covered with a floating type of vegetation and had only a few bodies of open water. The proposed polder area covers approximately 800 hectares. Insofar as is known, the soils within the Tandal Polder have not been examined. A high intensity or very detailed soil survey will be necessary prior to finalizing of plans for development of this polder. Two polders, Guini and Berim, are adjacent and parallel to the eastern side of Tandal

Polder. The soils on these have been examined and described by a number of investigators and a systematic soil survey based on physical and chemical characteristics completed. The soils in the depression between the dunes in this area are assumed to have a similar mode of formation; however, specific soils and their relationship to each other may vary to some degree between depressions. The discussion of the soils in this report are based on those occurring on Guini and Berim Polders.

The upper horizon of the soil consists of a dark gray (10YR 4/2* when moist) or light brownish gray or grayish brown (10YR 6/2, 5/2 when dry) clay or clay loam which ranges from loose to hard when dry. It consists of decaying vegetation and strongly developed fine platy structure. This has a moderately developed coarse prismatic secondary structure when dry. It is said to contain 6 to 15 percent organic matter and ranges in thickness from 10 to 50 cm. It is generally nonsaline but the salinity may range to strongly saline or strongly alkaline in some small local areas.

The second and subsequent horizons consist of a gray or light brownish gray (10YR 6/1-6/2, when moist) or light gray (10YR 7/2, when dry) clay which is very hard when dry. The structure is similar to the upper horizon, except the primatic secondary structure is better developed. The structural faces may be coated with white and dark yellowish brown or yellowish brown oxides of iron. These horizons appear to have a low bulk density and contain an abundance of diatoms. They contain decreasing amounts of organic matter and increasing salinity and/or alkalinity and range in thickness up to 7 meters. The upper horizons are referred to in some of the literature as the "blocky, columnar, fissured (highly permeable) heavy clay." These upper horizons when dry and fissured take water at a relatively fast rate. When saturated, they become virtually impermeable.

Allison (1962), Salinity Consultant from the U. S. Salinity Laboratory, Riverside, California, U.S.A., made an appraisal of the salinity status of irrigation schemes in northern Nigeria for USAID in February-April 1962. He visited the marte area on the west bank of Lake Tchad. The soils there consist of 3 to 6 feet of highly colloidal clays. These "Ficki" plain soils are very impermeable and it was his opinion that "successful irrigation of 'Ficki' soils with Lake Tchad water over a prolonged period of time is improbable. Successful irrigation for a number of years may be possible but 'salting up' and sodium accumulation is inevitable without internal drainage sufficient to maintain a favorable salt balance within the root zone." It would appear that the same opinion can be drawn regarding the soils of the polders at Bol.

*as per the "Munsell soil color charts"

A thin horizon of a few to 5 cm in thickness may occur between the clayey horizons and fine sand which underlies the whole area. This thin horizon is a dark grayish brown or grayish brown (10YR 4/2, 5/2 when moist) or gray (10YR 6/1 when dry) sandy clay which is hard when dry. It has a well developed vesicular structure with a strong fine granular secondary structure. The structural faces may be coated with white and yellowish brown oxides of iron.

These upper "clayey" horizons are resting on a light grayish brown or grayish brown (10YR 4/2, 5/2 when moist) or light gray (10YR 7/2 when dry) loose, structureless fine sand. This sand which is in the 0.16 to 0.22 mm size range consists of more than 95 percent clear subrounded and frosted rounded quartz grains.

Other horizons which may occur consist of mucks, sandy, diatomaceous, or calcareous strata within the clays. In some areas the clays are very dark gray or black in color.

Subsidence will occur as the polder is developed. The amount will depend upon the amount of organic matter originally in the soil and compaction of the clayey diatomaceous horizons. It will probably be an uneven subsidence during the first few years of the polders development. This will require a releveling of the surface for uniform flood irrigation. ORSTOM (1975) suggests a subsidence in the magnitude of 30 to 35 percent. The maximum as observed on the polders since 1954 has been 1.2 meters. This movement of the soil may dislocate the network of irrigation and drainage canals.

The World Bank (1975) reported:

> "The soils of Guini and Berim polders are high in nutrient elements and in clay and in cation exchange capacity; their clays are largely montmorillonite (50-70%) with lesser amounts of koalinite (20-40%) and illite (trace-10%), are slightly to moderately saline, and are slightly to moderately calcareous. Chemical reducing conditions in the highly organic, waterlogged areas lead to formation of alkali soils in some locations and to acid soils in others."

1. Soil Salinity

When the land is placed under a polder, the saline water evaporates and unless the salts are leached from the soil, it will become increasingly saline and/or sodic. In addition to irrigation water which is applied to the soil, there is seepage of lake water through and under the sand dunes and possibly upwards from the sands under the clays. This possible upward movement of the water is an unknown factor.

The World Bank (1975) describes potential soil salinity problems as follows:

> "It is estimated that seepage amounts to about 2 m^3/ha/year. Thus, at a concentration of 400 mg/l, the salt content in the polders would increase 800 g/m^2/year. If all of this salt was concentrated in the surface two meters of soil, the average salt content in the polders' soil would increase 0.04% per year, and reach the danger level of 0.3% in less than eight years. The rate of salt accumulation is, however, decreased by (a) precipitation of much of the calcium and some of the magnesium in the soil mass as carbonates, (b) by diffusion of salts into the groundwater and/or deep subsoil, (c) the blowing away of loose surface deposits of salt by winds, (d) occasional submergence and desalinization of polders by lake water and (e) slow seepage of diffused underground salts away from some polders. Conversely, the rate of salt accumulation is increased by the capillarity process, which accumulates salt close to the soil surface, and on balance the danger level could be reached in less than eight years."

2. Soil Salinity--Guini and Berim Polders

Salinity studies in Guini and Berim Polders is summarized by the World Bank (1975).

> "Salinity surveys of Guini and Berim polders in 1966 showed that only a small portion of each had a damaging concentration in the surface half meter of soil where the salts tend to concentrate; furthermore, in contrast with other polders, the severity of the salinity problem has increased very slowly since the mid-1960s indicating almost certainly that some salt is being eliminated, probably by seepage from these polders. Alkali problems have developed only in a few spots where the soils are high in organic matter and waterlogged to the surface."

ORSTOM (Cheverry 1969) in a study of the salinity-alkalinity problem of several polders reported strong accumulation of salts; i.e., the conductivity of the saturated extract (LES) was as high as 24 micromhos and sodium-exchange capacity ratio (Na/T) as high as 40 percent in the surface and subsurface horizon in recently cleared areas with a high water table. In areas with lower water tables, there was a corresponding drop in salinity and/or alkalinity. In these areas the LES was less than 6 and Na/T under 10 percent. The polders must be leached prior to seeding. The water table must remain at all times below the rooting zone of the crop. A suggested depth is +1.2 m. Should the water table be allowed to rise within the rooting zone, crop damage may occur.

B. DUNES

The soils which occur on the dunes consist of a fine quartz sand similar to that which underlies the depression. In fact, these sands are believed to be continuous from the dune to under the depression to the next dune, etc.

The Peace Corps has sunk many wells on these dunes to provide domestic water for the local people. The log for 18 wells was examined and summarized. These wells were sunk to depths of 16 to 18 m. The ground-water table occurs at 11 to 14 m. In four of the wells thin strata of clays from a few centimeters to 1 m thick occurred in one well at 4 m and the rest below 8 m. The greatest variation noted was in the color of the fine sand; i.e., brown, yellow, white. The salt content of the water table which occurs in the sand dune soils is thought to remain relatively stable. Measurements at the western edge of Guini Polder in May 1970 shows a content of 463 mg/l and in May 1974, 467 mg/l.

C. WATER TABLE AND DRAINAGE

The control of ground water and the leaching process are the most important factors contributing to the success of the polder schemes. Nearly all of the soils on the polders consist of clays which extend to below 2 meters. The saturated permeability of these clays is virtually zero. In order to adequately drain the clay would require a very close network of drainage canals. A minimum water table of 1.2 m should be maintained.

The drainage design must take into account the need for initial reclamation and necessary requirements for periodic leaching to prevent subsequent resalinization. Careful control of the water table level is essential. A heavy concentration of roots develops immediately above the water table, and even a temporary rise into the root zone can result in asphxiation of roots and yield losses. If the water level can be carefully controlled, then the maintenance of a high water table (i.e., 1.2 m) may be successful.

The lake water at Bol is classified as C1S1 in the classification scheme of the U. S. Salinity Laboratory. The electrical conductivity (EC) of the lake water at Bol ranges from 110 to 140 micromhos or about 70 mg/l (ppm) of soluble salts. This is very good water for irrigation. If one assumes some mixing of the more saline waters of the depressions, the project irrigation water might have an average EC of 200 micromhos (about 150 mg/l of salts).

The salinity of the phreatic water table of the polders increases with development of the polder. In the Guini Polder drainage canal, the salt content went from 513 mg/l to 991 mg/l

between May 1970 and May 1974. In the west center of Berim Polder, it went from 686 mg/l to 1,202 mg/l.

The water from the ground-water table below the polders at depths of less than 1 m may be up to 80 times higher in salt content than the lake water. One sample contained 5,600 ppm of soluble salts and alkali characteristics. This is not suitable for irrigation. In the event the ground-water table is allowed to rise above 1.2 m, there will be a risk of salt accumulating on the surface through capillary rise.

One estimate places the leaching requirement to be about 40 percent of the irrigation requirement. This should be revised to correspond with the results observed in leaching the soils at Guini and Berim Polders.

1. Biological Drainage

One estimate places the lateral seepage from the adjacent sand dunes into the depression in the range of 0.25 l/s/ha. This is a rough estimate and could very well be too low. To reduce seepage into the depression and the resulting need to pump the water out, several rows of trees should be planted along the dune-depression boundary. It is suggested that eucalyptus be used as the center row with more salt-tolerant trees on the polder side and neem on the dune side. Care should be taken not to introduce species such as tamarix, which will become a pest and would be very difficult to eradicate. Several rows of neem could be planted on the dune side to extend up the dunes several tens of meters. The trees will serve as (a) biological drainage, (b) windbreak for the shifting sand, (c) if properly managed (i.e., selective cutting and replanting), the source of some firewood and poles, and (d) home for wildlife.

D. ENGINEERING USES OF THE SOILS

There are only two broad kinds of soils available in the area; namely, clayey (depressional soils) and fine sand (dune soils). There are no known deposits of gravel or rock. The following table (3A-2) shows the estimated soil properties significant to the construction of dikes, levees, and other embankments.

Embankments made of sand must be very wide. Even then, some seepage may occur when the lake is at a high level. The dike or levee core could be constructed from the clayey soils of the depressions; i.e., soil removed from the excavation of drainage canals. If this core remains wet and not allowed to dry and crack, such dikes or levees should be nearly impermeable. Since the sands will underlie the dikes or levees at relatively shallow depths, particularly near the dune soils, seepage under or around them may be a problem. When constructing embankments in narrow areas between the sand dune soils, there may be very little clay under these areas.

Table 3A-2
Estimated Soil Properties

	Depression Soils	Dune Soils
Texture	Clays	Fine sand
Unified(a)	MH or CH	SP
AASHO(b)	A-7	A-3
Shear strength(c)	Low to medium	Medium
Compressibility(d)	High	Low
Permeability of compacted soil(e)	Low	Medium to high
Susceptibility to piping(f)	Medium to low	Medium to high
Compaction characteristics(g)	Fair to poor	Fair to good

(a) This is adapted from the Standard-Unified Soil Classification System for roads, airfields, embankments, and foundations. Std-619B, 1968 USA.

(b) From AASHO Designation: M 145-66 I in Interim Specifications and Methods Adopted by the AASHO Committee on Materials 1966-1967, published by the American Association of State Highway Officials in 1968.

(c) The shear strength of a soil indicates the relative resistance of that soil to sliding when supporting a load. The highest resistance to sliding occurs in soils that are composed of clean gravel (less than 5 percent fines). Soil strength decreases as fines increase and is lowest in fine-grained organic soils (OL and OH).

(d) The compressibility of a soil pertains to the decrease in volume of the mass when supporting a load. Compressibility is lowest in coarse-grained soils having grains that are in contact; volume of the mass decreases very slightly when these soils support heavy load. Compressibility increases as fines increase and is highest in fine-grained soils containing organic matter.

(e) The permeability of compacted soil pertains to the rate at which water moves through soil after compaction. If a coarse-grained soil, after compaction, contains large continuous pores, the soil transmits water rapidly and is said to have "high" permeability. Because fine-grained soil transmits water very slowly, it is said to have "low" permeability.

Table 3A-2 (continued)

(f) Susceptibility to piping or to internal erosion applies to the likelihood of removal of soil particles by water moving through the pores (or cracks) in the compacted soil mass. Highly susceptible soil materials are those that have large pores through which water moves rapidly, yet in which soil grains are fine enough and sufficiently lacking in coherence so that the individual grains move readily. The most susceptible materials are fine sands and nonplastic silts (PI less than 5). Although coarse sands and gravel also may transmit water rapidly, they consist of large individual grains that, themselves, resist internal movement. Also, other soil materials of low susceptibility to piping are fine-grained, cohesive, and highly plastic; they transmit water very slowly and, thus, resist piping or internal erosion.

(g) Compaction characteristics indicate the relative response of soil to compactive effort. Where there is satisfactory moisture control and a soil can be compacted to a high degree with minimum effort, the compaction characteristics of that soil are evaluated as "good." The degrees to which compactive effort and construction control must be increased are reflected in the evaluations of "fair" and "poor."

E. ROADS

Road construction on the dune soils will be difficult due to the nature of the sands and lack of available materials from which to stabilize the sand base. The clay from the depression (drainage canals) may be added to the sand; however, they are poorly suited and the roads will require considerable maintenance. It is suggested to use about 40 percent clay and 60 percent sand well mixed for a 20-cm-thick road base. The addition of the most saline water in the construction of these roads would be beneficial.

Roads constructed on the clays should have sand incorporated in the surface 15 cm in a mixture similar to those on the sands until experience proves otherwise. These polder roads should be elevated approximately 15 to 20 cm and graded for drainage. This addition of sand will facilitate their compaction. Subsidence is likely to be uneven; therefore, the roads will require considerable maintenance.

Clay soils taken from the excavation of the drainage canals not used in road construction or other uses should be removed from the canal edges.

F. AGRONOMIC PRACTICES

The clayey soils, when first brought under irrigation, contains relatively large amounts of organic matter (i.e., 6 to 15 percent). With continued farming under irrigation, this will decrease. However, care must be taken to maintain the organic matter at a high level. With the prevalent high temperatures, this will be difficult. There should be no burning, grazing, or removal of crop residues; all should be returned to the soil. Alfalfa and similar crops may be grown to assist in maintaining the organic matter content and reclamation. The crop should be cut and fed outside the polder area; there should be no grazing within the polder.

Several alternative cropping systems have been suggested. In real life, however, the systems may change from time to time as the need arises. One simple cropping pattern includes 5 to 6 months for a wheat crop and 6 to 7 months for cotton. The initial average yields should be 3,000 kg/ha for wheat and 3,500 kg/ha for seed cotton. With the anticipated rise in salt and/or sodium content of the soils, this will start to decrease in a few years. Food crops are very scarse in Tchad. The polders may be better utilized to produce crops for human or animal consumption. A wide variety of crops are adapted to the climate and soils on the polders. These include maize, potatoes, tomatoes, okra, cabbage, onions, carrots, beans, and peppers to list just a few.

G. MATAFO RESEARCH STATION

This station has been in operation since 1970 and was established to cover the agronomic aspects of polder development in the Bol area. It should be continued and expanded. Improved methods of cultivation and water application need to be explored. Studies should be carried out on weed, insect, and disease control. Research in the past was predominantly most concerned with cotton and wheat; this should be expanded to include maize and vegetable crops adapted to the climate and soils.

Fertilizer and trace element studies will be needed to determine the deficiencies of such materials as zinc, manganese, sulfur, etc. Studies are needed to determine the long-term effects of cultivating these clayey polder soils, including the rotation that would maintain current fertility as well as irrigation and leaching requirements.

H. CONCLUSIONS

The soils underlying most of the polders consist of at least 2 meters of stratified lacustrine clays. These clays contain varying but relatively high amounts of organic matter. These clays are largely montmorillonite with lesser amounts of kaolonite and illite. They are slightly to moderately saline and are slightly to moderately calcareous. Under certain conditions they may become sodic and in others acidic. Some horizons or strata contain an abundance of diatoms and a relatively high amount of uneven subsidence may be expected. Portions of these soils are virtually impermeable when saturated. There are some doubts as to whether the internal drainage will be sufficient to maintain a favorable salt balance within the root zone.

H. RECOMMENDATIONS

1. Once the Guini and Berim Polders are complete and operational, tests should be made periodically to determine if the water table can be maintained at a satisfactory depth and the soils leached. Semi-annual checks should be made on the soils in order to determine their salinity and alkalinity levels. Tests should be made to determine permeability rates at various level in the soil profile.

2. Piezometers should be installed in Guini and Berim Polders and adjacent sands in order to determine if "semi-artesian" pressure will be a problem. This should provide information on the permeability when the lake is at a relatively high level.

3. Research in crops, fertilizer, and trace elements, insect and disease control, and irrigation practices should be continued at the Matafo Experiment Station. Studies should be made on the use of a high return vegetable cropping system such as potatoes, tomatoes, cabbage, onions, carrots, okra, melons, etc.

4. When work at Guini and Berim show that the polders may be irrigated with success, a high intensity or very detailed soil survey of Tandal Polder should be carried out after clearing away the overgrowth.

5. Windbreaks should be planted internally and around the perimeter of all polders.

6. All crop residues should be returned to the soil.

IV. DRAINAGE

The basic assumption of this study was that the reported drainability of the soils of the polders, as indicated in the various reports reviewed for this project, could be achieved. That is, a drainage channel down the center of the polder would be able to withdraw all the leaching and seepage water from the polder and maintain the water table at a minimum depth of 1.2 meters below the surface of the polder. After the polders are once put into operation, it may be found desirable to install lateral drains connecting to the main center drain to drain isolated problem areas in the polder. The validity of this assumption should be verified before construction of the project. Piezometric wells are soon to be installed at Guini Polder under a USAID contract. This information along with soils tests should provide valuable information for this evaluation.

One of the major problems with the central drainage canal will be the macrophytes which grow in the canals. These plants will restrict the flow in the canal and could have the potential of completely stopping flow in the drainage canal to the pump station.

When the drainage water is pumped back into Lake Tchad, there exists the possibility of short circuiting this water back to the intake for the north half of the polder. To reduce the potential of this higher salt content water from reaching the intake, additional dikes (especially at the lower lake levels) may be required exterior to the polder to reduce this possibility. Drainage of the polder after the dikes are completed was assumed to be accomplished in about 1 year by the use of pumps and engines already at the site or purchased for further use on the project.

V. MAINTENANCE

Supplying materials to the Bol area will be of major importance for the maintenance of the system. For efficient management of the project, an adequate supply of spare parts will be a necessity. A maintenance program should be instituted when the project is first put into operation and maintained at a high level of proficiency throughout the life of the project.

In the drainage canals, aquatic growth will present a major maintenance problem. An efficient herbicide or mechanical method will be required to control the growth of these materials in the canal so that adequate drainage can be obtained from the project.

As indicated in the various reports and studies previously made in the polder areas, there is a potential for settlement of the soils. Settlement will be a major problem for the

pipelines if settlement in some areas of the polder is greater than 1 meter, as has been experienced. Settlement of this magnitude can cause separation of pipe joints and/or breaking lengths of pipe, thus causing a major maintenance expense item. Money for this possibility was not included in the maintenance costs but should be given serious consideration.

The operation, maintenance, and replacement (OM&R) costs are estimated to be 77.1 million CFA per year. Replacement costs, as used here, are for yearly replacement and repair of equipment and materials and not for the complete replacement of these items.

VI. TRANSPORT

Transport in the local area will be over roads constructed of a clay-sand mixture. This includes both the interior and exterior roadways.

Surface transportation of construction materials from the N'Djamena area would probably be by a road connecting Bol to N'Djamena. The road would also transport crops grown on the Bol Polders to markets in N'Djamena. The majority of this road would be constructed of a clay-sand mixture. This road would be approximately 340 kilometers long and require relatively high maintenance cost each year, especially in the rainy season. In studies being done for the Africa Development Bank by Gannet, Fleming, Corddry, and Carpenter, Inc., the road costs from Bol to N'Djamena may range from 2,400 million CFA to 10,000 million CFA.

A preliminary study by the Ecole Nationale de Travaux Public on this type of road construction indicates that a clay with a liquid limit less than 40 and a plasticity index less than 10 would have about 20 to 35 percent clay mixed with sand and give a 50 CBR. The best clays are A6, and the plasticity determines the percent of clay in the sand-clay mixture. For best results, mechanical means under controlled conditions should be used to make the mixture.

An alternate method of transporting materials to the Bol area from N'Djamena would be by the over-water route. This requires dredging of the existing canal that leads to the open lake area through the archipelagos from Bol. It has been proposed by SCET that a dredge and dragline barge be purchased to straighten and deepen the canal. The estimated cost of this dredge is about 250 to 300 million CFA. It is estimated that the time required to dredge and clear this canal would be about 6 months and would take approximately 1 month each year. This dredge could also be used to clear the channel from the open lake waters to the lower Chari River, thus providing a year-round passage between Bol and N'Djamena.

VII. COST ESTIMATES

A cost summary for the basic 600-hectare development with an intake elevation of 280 is shown in Table 3A-3.

Table 3A-3
CONSTRUCTION COST ESTIMATE

Dikes	178.1	million CFA
Drainage of Tandal Polder	20.2	
Irrigation Facilities	956.1	
Drainage Facilities	66.5	
Roads	55.1	
Land Leveling	24.0	
Total	1,300.0	million CFA
Contingency (40%)	520.0	
Total Estimated Cost	1,820.0	million CFA
	or	
	7.9	million (U.S. $)

Increasing the area to the 800 hectares would require an additional 700 million CFA. This increases the cost per hectare and makes the alternative unattractive.

On the basis of the 600-hectare system, raising the intake elevation to 282 would increase the irrigation canal slope, thereby reducing the canal and pipeline sizes, and approximately 133 million CFA can be saved in the present worth value of construction and operation costs. This alternative would require pumping for longer periods of time each year and thus require larger quantities of fuel to be supplied to the Bol area. At present, the possibility of supplying large quantities of fuel to the Bol area would be questionable. But, if low cost fuel becomes available to the Bol area, this alternative should be considered. If the reported future cost of fuel in the Bol area is as stated in the SODELAC report on the Mamdi Polder (SCET 1978a) then even larger savings than those indicated above would be experienced. This alternative should be given further investigation during the final design of the project.

VIII. ALTERNATIVE PROJECTS

This investigation has centered on the proposed Tandal Polder Project near Bol. A number of other projects are currently under consideration in various geographical regions of Tchad. However, these are not really alternatives to Tandal Polder because Tandal is designed to specifically benefit the region around Bol. Consequently, little consideration is given to these as alternatives.

There are a number of potential projects in the vicinity of Bol which could be considered as viable alternatives to the Tandal Polder. Because of the large number of empolderable areas in the Lake Tchad archipelago, many other areas could be developed in the manner proposed for Tandal. Though each polder has its own unique situation, one would expect the per unit cost to be quite comparable because the major cost items are the canals and laterals which are generally based upon the size area being irrigated. Having several polder developments in close proximity (such as Guini, Berim, Mamdi, and Tandal) may reduce the cost of project management. Too many nearby developments, however, can compound drainage and supply problems and perhaps overburden the ability of the local area to furnish the needed supply of farmers. A development of 3,000 to 5,000 ha appears to be a reasonable area for implementation. Also, developments closer to the south shore of Lake Tchad would be closer to the existing transportation systems.

Another alternative development in the vicinity of Bol would be the reestablishment or modernization of polder areas which were developed in past years. A number of these polders exist within 50 km of Bol, and a detailed cost study of each would be necessary before the polders could be developed. Since only a minor cost saving would be incurred due to the existing polder dikes, the unit cost of development would be approximately the same as for Tandal.

Rather than empolder a large area, it is possible to construct low dikes parallel to the polder shore about 100 m or less out in the water. The dikes would be just high enough to protect the area from seasonal flooding and would only be constructed in shallow areas. This scheme is an extension of the methods presently being used, though small pumps or perhaps windmills could be used to lift the water over the low dike to the head of the field.

None of the above alternatives were investigated in any depth during this study. If the Tandal Polder Project is not pursued, development of these alternatives could be investigated as methods of adding new farmable lands to the Bol area.

IX. IMPLEMENTATION

If USAID decides to pursue the construction of Tandal Polder, the project will develop in several phases. A design phase will be followed by construction followed by operation and maintenance. As an independent project, Tandal Polder could be implemented in a fairly straightforward manner. However, Tandal should be considered as an integral part of the Bol Polders Development and fully integrated with Guini, Berim, and Mamdi projects. It would be extremely ineffective for each sponsoring agency to independently repeat the process, particularly the construction aspects.

An irrigation project is a difficult development to operate and maintain under normal conditions. The present lack of good maintenance, transportation, power, communications, and similar facilities will all contribute towards making projects at Bol exceptionally difficult to operate. This multidonor aspect may create additional problems if the installed equipment varies significantly from one project to another. Uniformity of equipment, materials, supplies, etc., will greatly improve the chances for successful operation.

It is imperative that the people of Tchad eventually assume complete responsibility for operation of the project. In the beginning, expatriot assistance is needed to train Tchadians in the complexities of operating the irrigation system. Within a 5- to 8-year period, however, the expatriots should be phased out and the responsibility turned over to Tchadians. As is described in the socio-cultural portion of this report, it is desirable that people from the Bol region be utilized to the maximum degree possible.

It is suggested that a Bol Polder Project Commission be considered to direct the design, construction, and initial operation of the project. Each multidonor agency would be represented as well as a representative of SODELAC. The Commission would make all major decisions concerning engineering, financing, equipment, and operations that will enable the project to develop smoothly. The Commission could choose to appoint a person experienced in large-scale irrigation development to work with SODELAC in implementing the project.

Though this approach may be difficult to establish because of political constraints placed by the donor nations, it may be the best way to implement the projects and ensure that they can be constructed and operated to the benefit of Tchad.

I. INTRODUCTION

An environmental assessment of the proposed Tandal Polder Project must consider its impact on surrounding ecological systems. These include the land, waters, aquatic species, wildlife, humans, social-economic systems, and others. Since the social, economic, human health, animal health, and plant ecology and agriculture are being considered in other parts of this report, only the aquatic and terrestrial wildlife systems are being considered in this section.

II. EXISTING AQUATIC CONDITIONS

The Tandal Polder portion of Lake Tchad is a portion of an entire lake ecosystem and is best viewed for its importance and relation to the system. This is particularly true in such a large lake where ecological differences in various portions of the lake may lend insight to changes resulting from the Tandal Polder development. The aquatic ecology section is therefor organized with a description of the lake as a whole first, followed by a description of the Tandal area.

A. LAKE TCHAD

1. Physical-Chemical Characteristics

Lake Tchad is the remnant of former Lake Mega-Tchad which had a surface area of 300,000 to 400,000 km^2 during the last 12,000 years (Beadle 1975). The lake area and volume continue to undergo large fluctuations, both on annual and longer term basis. Depth fluctuates approximately 1 m each year (Hopson 1967). During this century, the lake area has fluctuated between 6,000 and 25,000 km^2. The lake volume averaged 72×10^9 m^3 during the period from 1954 to 1972, with a peak in 1962 at 91×10^9 m^3 and a general decrease since that time (Carmouze 1971) to approximately 10×10^9 m^3 in 1973-74 (Durand 1977).

The reasons for the lake's erratic volume and surface area lie in the balance between the annual volume of inflowing water and losses through evaporation and percolation. The lake lies in a primordial continental basin which has undergone little tectonic modification during the past 12,000 years. The drainage basin covers some 2.5 million km^2, with

the majority of the inflow originating in the Central African Republic highlands via the Logone and Chari River systems and the Cameroun highlands via the Yobe River. From 1954 to 1972, inflows ranged from 20.25 x 10^9 m^3 in 1972 to 55.2 x 10^9 m^3 in 1961. Average inflow was 41.5 x 10^9 m^3/year. Eighty to ninety-five percent of the total inflow originated with the Chari River. Average inflow is 70 percent of the average lake volume (Carmouze 1976). Seasonally, 44 percent of the inflow occurs from October through November, 28 percent from July to September, 21.5 percent from December through February, and 6.5 percent from March to June (Carmouze 1976). Rainfall occurs during July through September, ranging from an average of 300 mm/year overall, to 200 mm in the north, and 500 mm in the south (Gras et al 1967).

Water loss from the lake is primarily through evaporation. Solar radiation is high (approximately 550 Langleys/day) (Leveque et al 1972) and relatively constant resulting in evaporation of about 2.2 m/year on an average basis. This accounts for 95 percent of the lake losses, and infiltration accounts for the remaining 5 percent of the losses. At most recent lake levels, losses by surface flow do not occur. At high levels, such as occurred from 1961-1964, water reportedly flowed overland through the Bahr-el-Ghazel leading towards the Bodele Depression, some 130 m lower than the lake elevation (Beadle 1975).

Despite the lack of surface outflow and high evaporation, Lake Tchad remains fresh, with salinities below 1,000 ppm (Beadle 1975). Three mechanisms have been proposed to account for the low salinity. The first, proposed by Tilho in 1910, is biochemical precipitation. Carmouze (1969) has shown this mechanism to remove 60 percent of the calcium, 54 percent of the magnesium, 36 percent of the potassium, 44 percent of the carbonates, and 84 percent of the silicates. The result is deposits of natron and a relative increase in sodium and chloride concentrations in the northern end of the lake which is farthest from the inflow.

A second salt removal mechanism is the entrapment of saline water in wadis of the northern archipelago (Roche 1970). By this scheme, water flowing in from the Chari River displaces more saline water to the north (Carmouze 1971) and at the same time raises the lake level. As the inflow diminishes, the lake level recedes and the more saline water is prevented from mixing with the main water mass by becoming entrapped amongst the archipelago's many bays and shallow wadis.

A third mechanism, proposed by Bouchardeau (1958) is by subterranean seepage of saline water around the lake's margin. Although the volume of water loss is small (~5 percent of the total), the salinity of this water is high (approximately 10 times the salinity of the inflowing Chari River), resulting in large salt losses.

The high solar radiation is reflected in the lake's temperatures which range from 13°C in the cool season (November through March) to 34°C in the warm period (June through September) (Hopson 1967). Stratification, however, is only weak and ephemeral. This is due to a combination of the lake's shallow depth (average approximately 4 meters, ranging from 2.5 to 4.5 in the southern area to 4.7 m in the north basin at volumes of approximately 75 x 10^9 m^3) and strong winds with a clear fetch on open areas. The lake is, therefore, polymictic with resulting low transparency largely due to resuspension of inorganic sediments (average Secchi depth = 0.7 m) (Lemoalle 1973).

The majority of the research efforts on lake chemistry were focused upon ions relating to salinity and conductivity (Carmouze 1976; 1973; 1971). Major nutrients (phosphorus and nitrogen) have received much less examination.

Salinity varies from 70 to 1,000 mg/l, with conductivities of 50 to 1,100 μmhos/cm^2 (corrected to 25°C), with concentrations increasing with distance from the mouth of the Chari. The pH range is alkaline, varying from 7 to 9, again generally increasing with distance from the river mouth. Ionic composition changes with salinity due to the precipitation of certain ions as salinity increases. Waters are predominantly calcium dominated in the south and become sodium dominated in the north. Calcium ranges from .2 to 2.5 meq/l, magnesium .17 to .35 meq/l, sodium .15 to 4.5 meq/l, potassium .06 to 2.5 meq/l, silica from .20 to 125 mg SiO_4/l, alkalinities from .6 to .13 meq/l, and chlorides from .3 to 7 mg/l. Phosphate, as PO_4, ranged from 0 to 1.5 mg/l. Inorganic nitrogen content is low, being .1 mg/l in the archipelago near Bol (Leveque et al 1972; Lemoalle 1969a). Several of these parameters are given in Table 3B-1 for various lake biotopes.

On the basis of surface physiognomy, the lake is divided into four major biotopes; open water occurring in the middle areas in the north and south basin, a patchy swamp belt of submerged sand dunes with emergent vegetation surrounding the open water, a raised area between north and south basins ("Grande Barriere"), and an archipelago of sand dunes with varying degrees of open waters and swamp occurring between islands along the northeastern shore of the north basin and northern shore of the south basin (Figure 3B-1). The archipelago forms a zone up to 45 kilometers wide, but the division of area between the different zones is transitory since water depth determines the amount of each biotope. If, for example, lake levels decrease, swamp area will shift inward, open water zones will decrease, and patchy swamp areas become archipelago regions. This is what happened during the 1973-1978 drought (Figure 3B-1).

Table 3B-1
PRINCIPAL CHARACTERISTICS OF THE LAKE COMMUNITIES AT A SURFACE ELEVATION OF 281.5 M

	Region	Surface Area	% Water of Total Surface	Depth (m)	Substrate
North Basin	North Patchy Marshes	3,560	83	5 to 8	Mud
	North Archipelago	2,200	52	4 to 6	Mud & Clay
	North Open Water	4,200	100	4 to 7	Mud & Clay
South Basin	Eastern Archipelago	1,050	49	2.5 to 4	Mud & Clay
	Southeastern Archipelago	1,470	62	2.5 to 4	Mud & Clay
	Southeast Open Water	1,850	100	3 to 4	Sand & Clay
	Southern Open Water	1,850	80	2 to 3	Sand & Mud
	Patchy Marsh in Southeast	1,200		2 to 3	Mud & Clay
	Patchy Marsh in South	1,450	85	2	Mud & Clay
	Grande Barriere	2,000	80	2 to 3	Mud

Table 3B-1 (Continued)

	Region	Secchi Depth (cm)	Conductivity (μmhos)	Relative Proportions of Salts	R
North Basin	North Patchy Marshes	60 to 80	500 to 1,500	$0.15<(SiO_2)/(A)<0.25$	
	North Archipelago	60 to 80	200 to 1,200	22<%Ca<27 25<%Mg<29 35<%Na<40 8.5<%K<40	40
	North Open Water	40 to 60	250 to 500		
South Basin	Eastern Archipelago	35 to 50	150 to 650	$0.50<(SiO_2)/(A)<0.35$; 35<%Ca<40 25<%Na<35; 24<%Mg<31; 7.5<%K<11	
	Southeastern Archipelago	20 to 50	70 to 200	$0.35<(SiO_2)/(A)<0.60$; 35<%Ca<40 22<%Na<35; 24<%Mg<31; 7.5<%K<11	
	Southeast Open Water	10 to 50	50 to 120	$0.25<(SiO_2)/(A)<0.75$	
	Southern Open Water	10 to 30	50 to 120	27<%Ca<40 22<%Na<35 25<%Mg<31 7.5<%K<10	85
	Patchy Marsh in Southeast	15 to 30	50 to 125		
	Patchy Marsh in South	15 to 30	50 to 250	$0.15<(SiO_2)/(A)<0.75$	
	Grande Barriere	50 to 30	50 to 400	27<%Na<40; 22<%Ca<35 24<%Mg<29; 8<% K<11	

R = average percent replacement

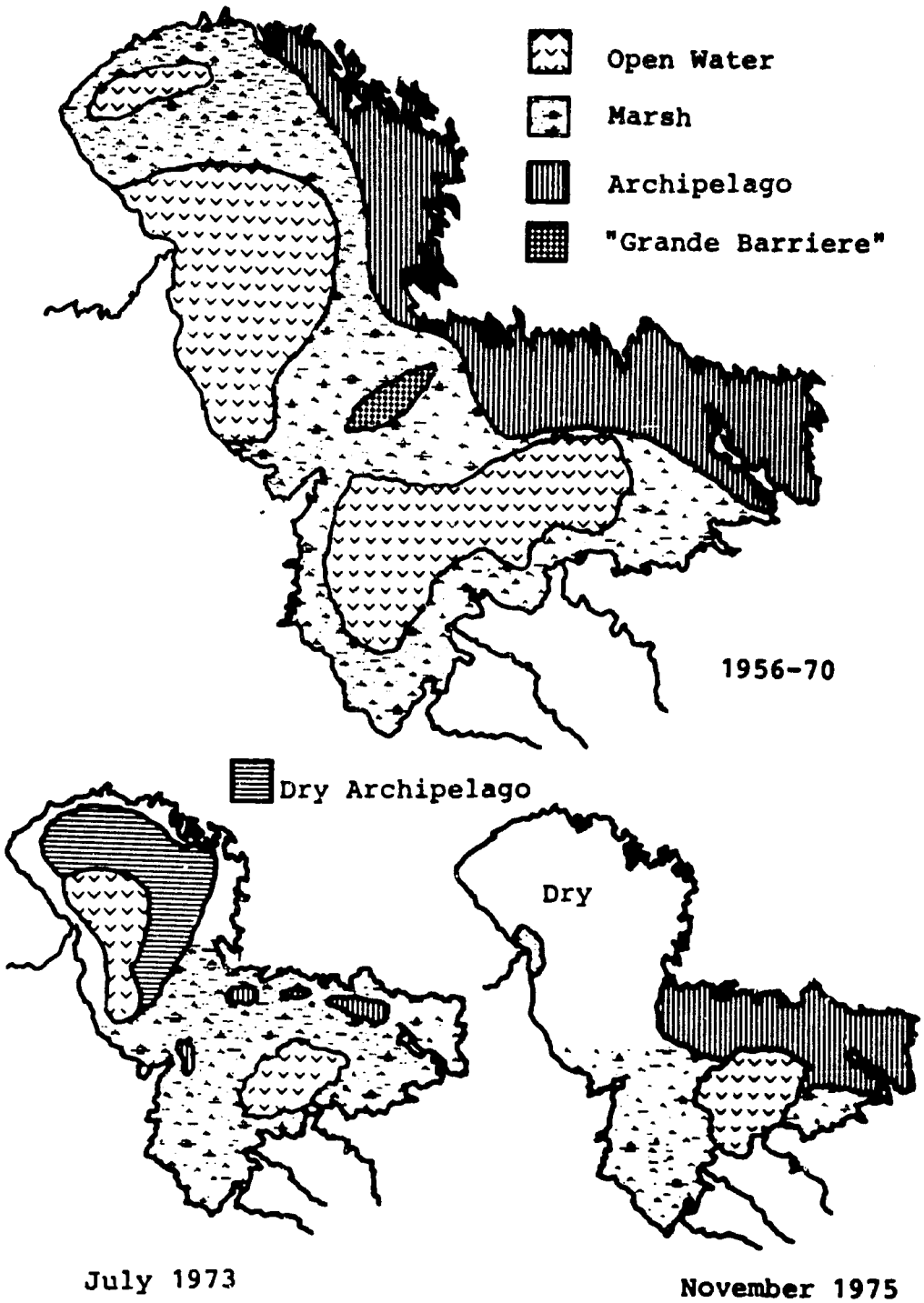


Figure 3B-1
MAJOR ECOLOGICAL ZONES IN LAKE TCHAD AT DIFFERENT DEPTHS

The changes in lake level have led to classifications of the lake by its surface area and volume. Mega-Tchad, or great Tchad, occurs when surface area exceeds 25,000 km^2 (Elevation 282 m or more). Normal, or mean, Tchad is the level encountered through most of the last century. Surface area varies from 10,000 to 24,000 km^2, with approximately a 50-percent reduction of maximum area (in December) to minimum (in July). Elevation varies from 282 to 280 m. Finally, mini-Tchad occurs during droughts. Lake area is reduced to below 9,000 km^2 and elevation to less than 280 m. With a reduction of area below 9,000 km^2, the basins become isolated. Mini-Tchad occurred in 1972 to present, with a slow recovery toward normal Tchad.

2. Algae and Macrophytes

Compere (1975 a,b) has identified 496 species of algae in the Lake Tchad area (including the river systems) exclusive of blue-green algae. A list of genera from Gras et al (1967) is given in Annex 2. The algal flora is dominated overall by blue-greens which account for 90 percent of the individuals observed. Microcystis, Aphanocapsa, and Anabaena are the dominant genera; but near the Chari, Melosira becomes more abundant. Cell densities are high, ranging from 6.4×10^6 to $1,284 \times 10^6$ liter (Gras et al 1967).

Algal distributions are heterogeneous over the lake's surface, but four algal biotopic zones have been identified (Figure 3B-2). An additional biotope, not shown here, is the periphytic flora of the emergent vegetation which is dominantly by Gomphonema, Rivularia, Calothrix, Microchaete, and Oedegoniun (Carmouze et al 1972).

Macrophytic biotopes are shown on Figure 3B-2. Dominant macrophytes are the reed Phragmites (60 to 80 tons/ha, freshweight above the waterline), papyrus (Cypreus) (150 to 180 tons/ha), bulrushes (Typha) (70 to 80 tons/ha), and aquatic grasses (Vossia) (40 tons/ha) (Leveque et al 1972). In calm waters, Potomogeton, Vallisneria, Najas, Ceratophyllum, Nymphea, Utricalaria, Lemnea, Azolla, and Spirodela are common. Vast prairies of Vossia cuspidata occur, particularly in the south, along with Cyperus papyrus and Pharagmites. This community shifts to C. papyrus, Pharagmites, and Typha in the central area of the "Grande Barriere." In the north, Pharagmites and Typha dominate (Leonard 1969; Carmouze et al 1972). Approximately one-third of the lake surface area is covered by marsh (Hobson 1967).

3. Invertebrate Fauna

The invertebrate fauna is conveniently separated into groups of zooplankton, benthic organisms, and insects. Detailed lists of these organisms found in Lake Tchad are presented in Annex 2.

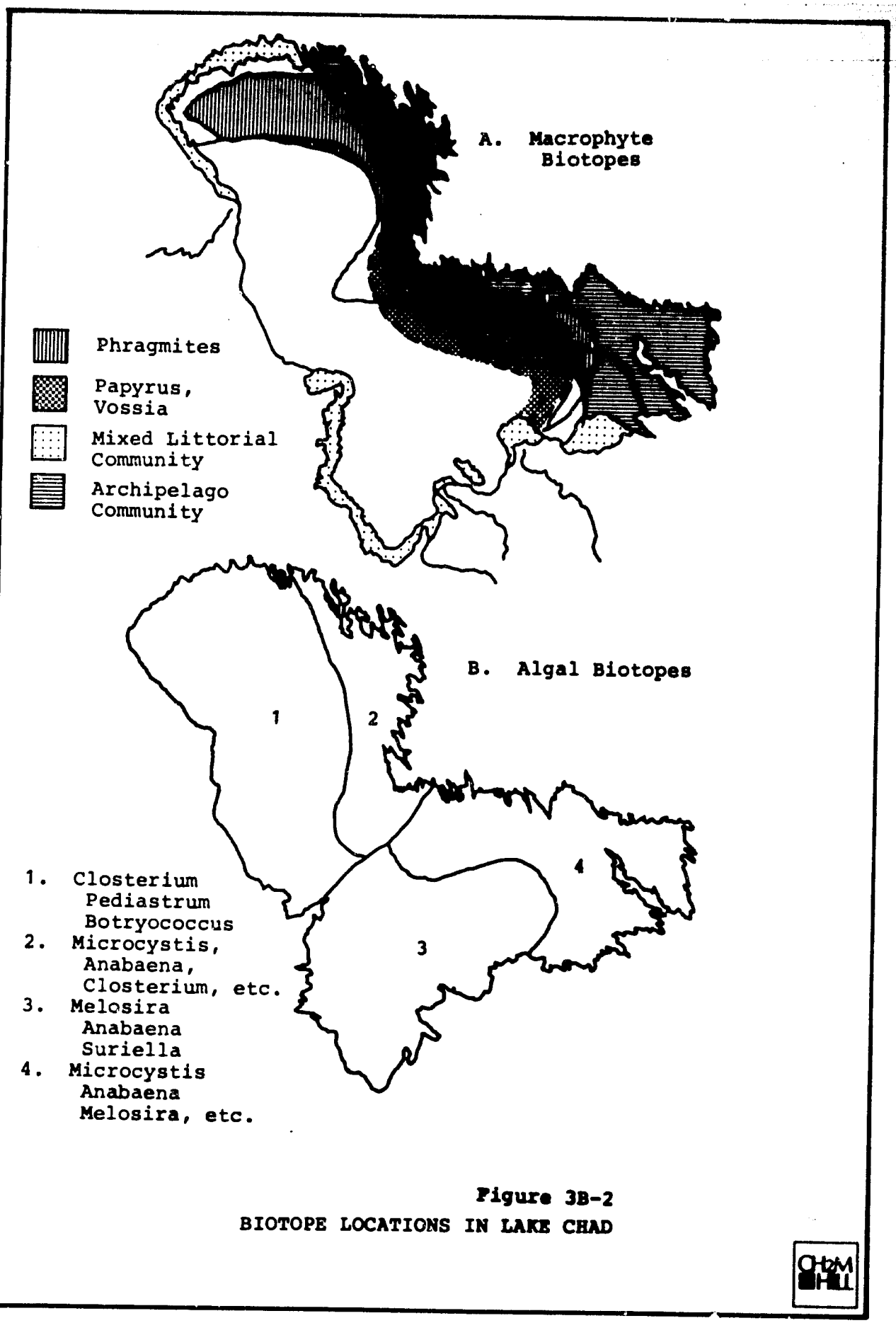


Figure 3B-2
BIOTOPE LOCATIONS IN LAKE CHAD

Average zooplankton biomass in the eastern portion of the lake was 140 kg/ha, 58 percent being Copepodes and 42 percent being Cladocera. Numerically, copepods are dominant (55 percent), followed by Cladocera (30 percent) and rotifers (15 percent) (Leveque et al 1972).

Dominant species are Mesocyclops leuckarti, Thermocyclops neglectus, T. incisus, Tropodiatomus incognitus, Daphnia barbata, Moina micrura, Ceriodaphnia corruta, Diaphanosom excisum, and Bosmina longistrostris. Rotifers are represented by a dozen species in the genera of Kenadella, Brachionus, Filinia, Tetramastyx, Trichocera, and Hexartha (Dussart and Gras 1967; Rey and Saint-Jean 1968; Lévêque et al 1972).

Clodoceran and diaptomids ate mostly algae, and largely Aphaecapsa; but not filamentous forms such as Anabaena. Adult Thermocyclops incisus and Mesocyclops leukarti were carnivorous on other zooplankton (Lévêque et al 1962).

Carmouze et al (1972) have outlined three major biotopes of zooplankton in the lake. The first zone was the open waters of the southern basin which respond directly to the influence of the Chari. This area had an average biomass of 150 mg/m^3, with dominant association of Moina, Diaphanosoma, and Ceriodaphnia. The second zone was the archipelago and patchy emergent vegetation areas with a biomass of 350 mg/m^3 during the months from February to March 1971, little fluctuations, but the same dominant organisms. The final area was the north basin with a lower biomass (240 mg/m^3). The primary factor in determining these zones was the effect of the Chari River.

Benthic invertebrates consist of oligochaetes, nematodes, molluscs, and insects. Dominant determinants of distribution and abundance are substrate type, conductivity, and macrophyte growth.

Oligochaete and nematode distribution is determined largely by the combination of substrate type and water salinity. Carmouze et al (1972) proposed four biotopes based on the biomass of nematodes and the oligochaete families Alluroididae, Tubificidae, and Naididae. Alluroididae are dominant by weight, and Tubificidae are dominant by numbers (Lauzanne 1968). The northern open water area with conductivities from 180 to 420 µmhos and muddy substrate formed a biotype rich in Tubificidae. The southern basin, open water area with conductivities less than 180 µmhos, and clay and "pseudo-sand" substrates had a biomass high in Alluroididae. The archipelago and patchy marsh areas of the north basin were grouped as one biotope by their lack of Alluroididae and conductivity over 420 µmhos, despite a great diversity of substrate types. The "Grande Barriere" and archipelago-patchy

marsh region of the southern basin was also classed as one biotope, abundant in Tubificidae in muddy areas and in Alluroididae in clay substrates. Biomass throughout the whole lake ranged from 2 to 39 kg/ha for both oligochaetes and nematodes combined, with minimum in July and maximum in December-February (Lévêque et al 1972).

Molluscs in the lake were studied extensively by Lévêque (1972). The lake fauna is of low diversity and have only 10 commonly found species. Dominant species are Bellamya unicolor, Cleopatra cyclostomoides, Melania tuberculata, Corbicula africana, and Caelatura aegyptiaca (Leveque 1972). Average biomass is low in the north (22 kg/ha) and east (150 kg/ha), but increases in the south (360 kg/ha) and is maximal in the central area between Baga Sola and Baga-Kawa (550 kg/ha). This central area is particularly high in Bellamya unicolor (Lévêque et al 1972).

The insect fauna is dominated by chirinomids, primarily Cladotantytarsus, Chirohomus, Cryptochironomus, Tantytarsus, and Polypedilum (Dejoux 1968; 1969). This family represents 85 to 90 percent of the insect numbers. Chirinomids are distributed in five biotopes around the lake, based on abundance of different species. Cladotantytarsus lewisi and Tantytarsus nigrocinctus are dominant in a small area in the north-eastern corner of the lake. Polypedilum fuscipenne is dominant in the north-east archipelago below the Cladotantytarsus-Tantytarsus region, extending almost to Bol in the cool season. The western portion of the north basin, extending south of Bega-Kawa in the cool season, is dominated by Clinotanypus claripennis. The southern basin is dominated by Cryptochironomus diceras, while Chironomus formosipennis dominates in the south-east (Carmouze et al 1972).

Ephemeroptera (primarily Cloeon fraudulentum, Eatonica schoutedeni, Coenomedes brevipes, and Povilla adusta), Trichoptera (Dipseudopsis capenis and Ecnomus ssp.), Diptera (Ceratopogoridae) and Odonata (Libellulidae) account for the remaining 10 to 15 percent of insects found in the benthos. Their distribution is determined primarily by substrate type and form two large biotopes in the North basin where insects are more plentiful and the South basin which has lower insect densities (Carmouze et al 1972). An additional subbiotope is the beds of Potamogeton where densities of 50,000 chirinomids per cubic meter are found with weights of 1.5 gm/m^2 (Lévêque et al 1972).

Insect abundance is maximal during the cool season. Annual average biomass range from 260 mg/m^2 in the north basin, 50 mg/m^2 in the southeast, and 15 mg/m^2 in the southern basin and western side of the north basin (Carmouze et al 1972).

4. Fish Community

This fish community of the Lake Tchad basin has fewer species when compared to the Niger River system nearby (Hobson 1967), although fish production is very high. Eighty seven species have been recorded from the lake itself (see Annex 2). Dominant species are Lates niloticus, Hydrocycon forskali, Eutropius niloticus, and Hydrocyon brevis. Commercially important species include the Alestes group, Lates niloticus, Citharinus citharus, C. distichodoides, Labeo coubie, L. senegalensis, Distichodus rostratus, and Heterotis niloticus. The last six species are large herbivores, while Lates and Alestes are carnivorous (Hobson 1967).

Carmouze et al (1972) distinguished six biotopes of fish in the lake. In the south, the open waters were represented by Schilbe mystus, Citharinus citharus, C. distechodoides, Labeo coubie, and Synodontis clarias. In the archipelago Ptetrocephalus bane, Marcusenius cyprihoides, and Chrysichthys auratus were found. These species are rare or absent from open water areas. The southern basin archipelago was divided into a south-eastern section, characterized by the presence of Alestes barmoze, A. dentex, Synodontis frontosus, S. batensoda, Heterotis niloticus, and Tilapia spp. The archipelago in the eastern corner of the lake had 62 species, with juvenile Schilbe mystus and Hyperopisus bebe and adult Ichthyborus besse, Siluranodon auritus, Polypterus bichir and P. senegalus.

The southern open water area (south of Malamfatori) in the north basin is very similar to the open water fauna of the south basin. North of Malamfatori, the fauna becomes less diverse. The northern archipelago has very high densities of Alestes baremose (Carmouze et al 1972).

Most of the fish species, except for Heterotis niloticus, Distichodus rostratus, and Lates niloticus breed in the marshes and flood plains of the inflowing rivers (Durand 1977; Hobson 1967; 1972). Some species may be adapting to breeding in the lake. Hobson (1972b) found two subpopulations of Alestes baremose in the north basin. The largest group bred in the Yobe River, but a smaller group bred in the lake.

Fish production in the Lake Tchad Basin is very high. Blache and Milton (1962) reported a catch of 60,000 to 80,000 tons per year for the basin, with only minor fishing pressure in the lake itself. Mann (1962) estimated production in the north basin at 10,000 tons in 1961.

Since the drought of 1972-73, fish production has plummeted. This is due to a combination of overfishing and habitat reduction by the decrease in lake size and the sizes of nursery grounds at confluence of the Chari and Lagone.

5. Fisheries

Originally, fisheries effort concentration on the Chari Delta River and the Lagone River system (Durand 1977). For purposes of this report, the fisheries effort in the lake itself will be emphasized, although the yield is generally reported for the basin in total (including the Chari and Yobe Rivers), and the production depends on the basin as a system.

The two fisheries can be distinguished on the basis of the species captured and processing. The first and more traditional to the lake is "banda." Lates niloticus, Heterotis niloticus, Citharinus citharus, C. distichoides, Labeo couble, and L. senegalis are the main catch for this trade. Banda is produced by cutting the fish in strips and drying in the sun for an hour or two, then smoking the fish, and then redrying it in the sun (Hobson 1967). Since 1960, gill nets of 6- to 8-inch mesh are used for banda, along with long lines of up to 2,000 hooks (Hobson 1967).

The second fishery, called "salanda," is comprised almost entirely of Alestes baremoses and A. dentex. This fishery is recent to the lake, having started in 1969-70 (Stauch 1976). These fish are processed just by drying in the sun. Dominant catch methods uses gill nets with two 2- to 3-inch mesh.

Yields in the basin were estimated at 20,000 to 24,000 tons per year from 1960-63 (Hobson 1967), 46,000 to 50,000 tons in 1969, 52,000 to 57,000 tons in 1970, 91,000 to 99,000 tons in 1971, and 130,000 to 141,000 tons in 1972 (Durand 1973). In the southern part of the lake, the annual catch increased from 3,856 tons in 1969-70 to 10,235 tons in 1973-74. A similar increase occurred in the northern part of the basin. The increase in fish catch was not, however, due to the increased yield but to increased effort. As the lake level diminished, fish populations became concentrated and easier to catch. This caused more fishermen to go north where the main concentration took place, and increased the fishing effort (Stauch 1976). The catch per unit effort from 1963-67 decreased (Durand 1973) indicating a diminishing fish production. Since 1974 yields have diminished sharply due to diminished stocks and/or diminished environmental quality for young fish. "Salanda" was particularly hard hit, with Alestes disappearing from the records in 1975 (although still being sold to some extent) (Stauch 1976).

An additional phenomena, reported by Benech et al (1976) is the death of fish in both the north basin and eastern archipelago due to anoxic conditions. The dissolved oxygen drops are associated with winds which remix decaying macrophytic vegetation in the water column. Additional growth

rates have diminished for Brachysynodontis batensoda, and younger age classes have been inhibited by competition in the poorer environment (Benech 1974). This phenomena is undoubtedly occurring in other species as well.

B. TANDAL POLDER

Tandal Polder has received direct scientific study by ORSTOM researchers working out of Bol. In addition, work on the eastern archipelago is useful in describing the existing conditions. The following condition summarizes much of this work and describes conditions under both normal and drought conditions.

1. Physical-Chemical Characteristics

Water circulation, even during the flood periods, is very low through the archipelago. Carmouze (1971) indicated water movement through the eastern archipelago by movement of sodium during November and December of 1970, but the isopleth of .25 meq/l did not reach the Tandal Polder area. The orientation of the islands inhibits mass water movement during the rainy season and diminishes wind-generated currents (Carmouze 1971).

During the drought of 1973-1977, the archipelago near Bol became isolated from the rest of the lake (Benech et al 1976, Figures 3B-3 and 3B-4). Figure 3B-3 shows the water depth at Bol during different years, and Figure 3B-4 shows the relation of water depth to total lake surface area, volume, and elevation.

Water exchange in the archipelago can be viewed like the effects of flood tide in a coastal bay. During high inflow periods, water enters the area while mixing with existing waters. There is no "ebb tide" and the cycle occurs only once per year, giving very little water replacement. During most of the year, there is a very slight movement of water into the area as water enters the lake via the Chari and evaporates.

During 1968 when water depth was 3 meters at Bol, temperatures ranged from 18°C to 33°C. Stratification was weak when it did occur, with a maximum of 4°C difference between the top and bottom (Lemoalle 1969b).

When connected with the rest of the lake, the water was dominated chemically by bicarbonates (to the order of 1.40 meq/l), sodium (.36 meq/l), potassium (.13 meq/l), calcium (.56 meq/l), and magnesium (.36 meq/l). Chlorides and sulfates are generally below 1 mg/l, and silicates were 36 mg/l. Relative proportions of dominant salts are shown in Table 3B-1 (Lemoalle 1969b).

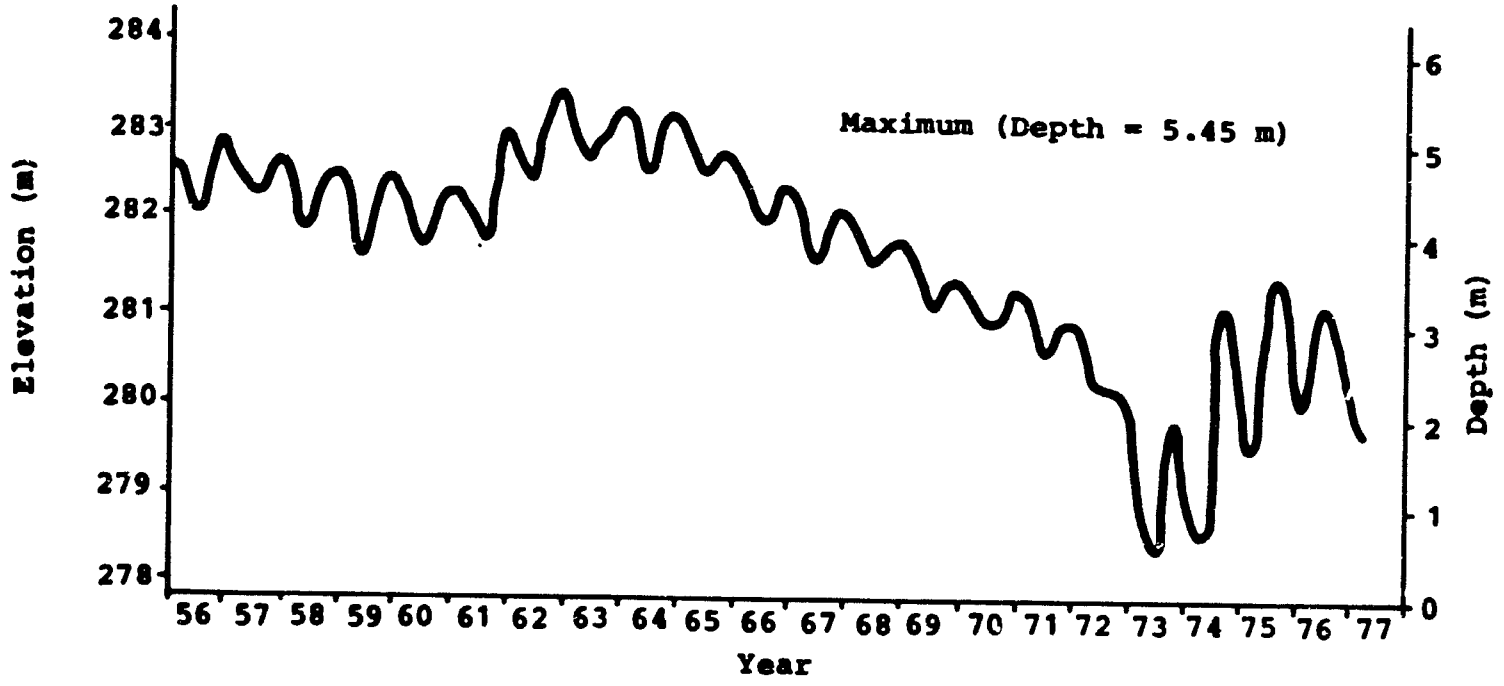


Figure 3B-3
LAKE LEVEL AND DEPTH AT BOL SINCE 1956
(FROM CHOURET 1977)

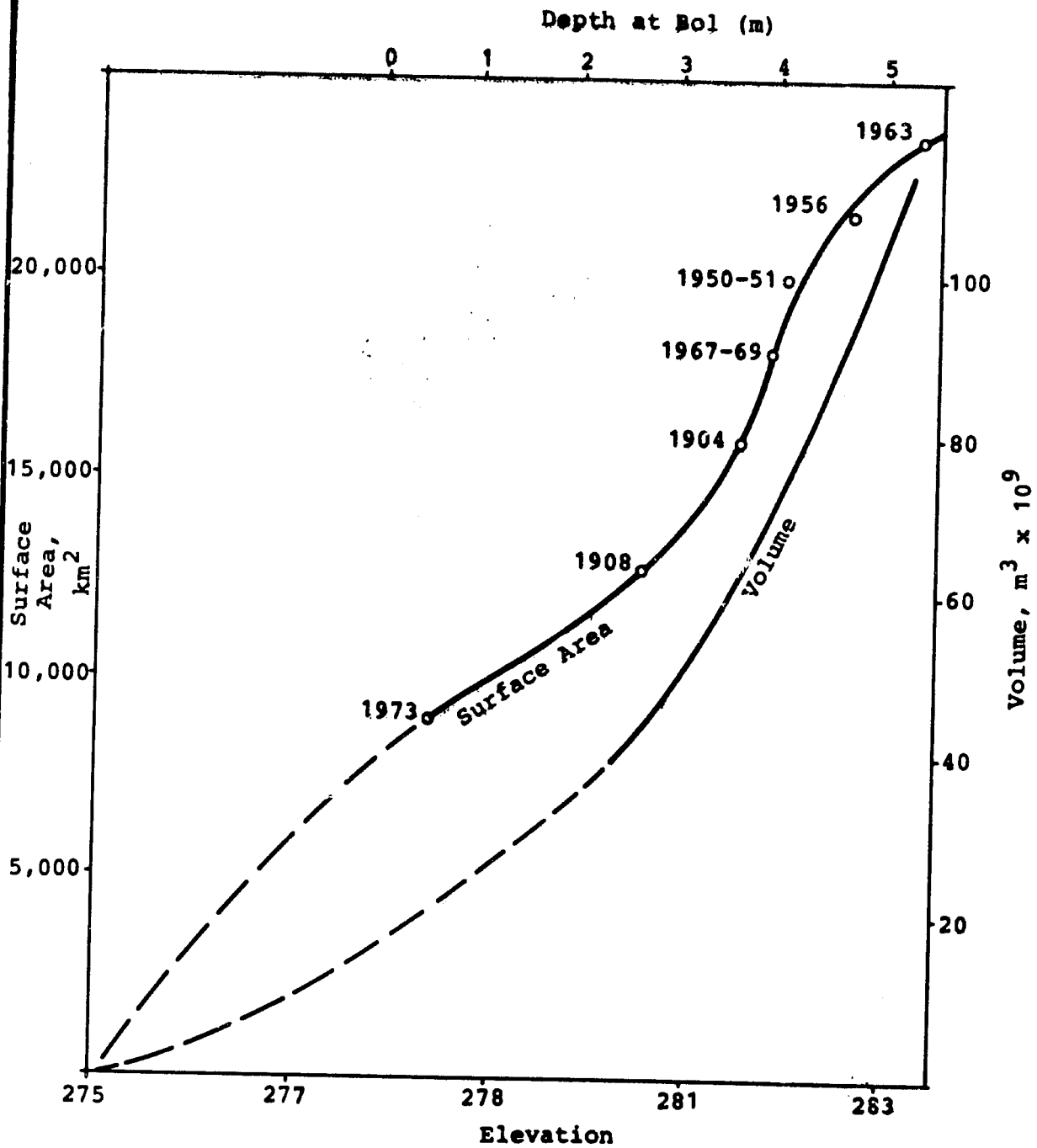


Figure 3B-4
VOLUME, SURFACE AREA, DEPTH AT BOL, AND ELEVATION OF THE SURFACE IN LAKE TCHAD (FROM CHOURET 1977)

Nutrient levels were high, with phosphates ranging from .1 to .4 mg/l, inorganic nitrogen at .1 mg/l, and organic nitrogen at .4 mg/l (Lemoalle 1969b). Carmouze et al (1972) noted an increase in phosphorus levels due to evaporative concentration in the north basin. A similar phenomena would be expected to occur in the archipelago area, particularly during the hot season.

Using the ratio of phosphorus to nitrogen, the system appears to be nitrogen limited, although these results must be viewed cautiously due to recycling rates of the nutrients and lack of information on the chemical analysis methods.

Transparency during higher water years (before 1973) ranged from 40 to 60 cm (Secchi depth) (Lemoalle 1969b). During 1973-1974 Secchi depth increased from 8 to 10 cm in September to 35 to 80 cm in July 1974. The increase in clarity was reportedly through sedimenation of inorganic material as the water passed through the dense aquatic vegetation (Benech et al 1976). This low clarity undoubtedly restricts macrophyte growth to shallower zones. The present brown water color occurred only after the drought. Before 1973-74, transparency was determined by phytoplankton and inorganic turbidity (V. Benech, personal communication). Conductivity during 1973-1974 remained below 500 μmhos/cm^2 (Benech et al 1976). During the years before the drought, conductivity ranged from 7 to 200 μmhos/cm^2 (Carmouze et al 1972), indicating a concentration of ions of 2.8x or more during the drought period.

Soluble iron decreased tremendously at alkalinities over 1.8 meq/l, and concentrations near Bol in 1968 were below 1.0 mg/l since alkalinity was over 1.5 meq/l. Going inland through the Tandal Polder, iron concentrations increased to approximately 2 mg/l as alkalinity decreased to below 1 meq/l (Lemoalle 1969b). Given these levels of iron, and organic nitrogen content as an approximate index of chelating capacity, it is quite likely iron is present in sufficient available quantities for photosynthesis. The decrease in alkalinity through the polder area was likely due to higher rates of photosynthesis and bicarbonate and carbonate uptake.

2. Algae and Macrophytes

According to the biotopes outlined in Carmouze et al (1972), the area around Bol is a region of primary production of 1.1 to 3.5 g $O_2/m^2/day$, with "optimal" productivities between 1.0 to .4 mg $O_2/l/hr$. The phytoplankton community is dominated by Microcystis and Anabaena, with abundant Melosira granulata, Surirella pseudospinifera, and Pediastrum clathratum.

Lemoalle (1969b) found a biomass of .586 mg/l in April of 1968, and 2.566 mg/l in June near Bol. Lévêque et al (1972)

reported production variations from 2 gm/m^2/day in December to 4.8 gm/m^2/day in July of 1969. Production rose with increasing water temperature, and chlorophyll ranged from 26 mg/m^3 during the warm season to 10 mg/m^3 in the cool season. During the drought, chlorophyll varied from 700 mg/m^3 in September 1973 to approximately 130 mg/m^3 (Benech et al 1976).

Phytoplankton production and biomass at Bol are very high, with seasonal changes typically of two- to four-fold increases as temperatures rise and water levels decrease. Dominant seasonal influences would probably be nutrient regeneration by high warm season decay rates and more wind mixing and/or more solar radiation. Given the low ratio of nitrogen to phosphorus, it is quite likely the blue-green algae are fixing nitrogen. Lemoalle (1969b) noted the presence of heterocysts at Bol. The high color and turbidity of the water may result in light limitation to the water column as a whole, grading to nitrogen limitation in upper levels during calm periods or lower turbidity.

Higher aquatic vegetation growth during April 1978 was extensive in the Tandal Polder, with few open water areas (see Figure 3B-5). Vegetation near the shore was dominated by emergents (Pharagmites, Cyperus) interwoven with Vossia, and with several Acacia trees with submerged trunks and roots. As the distance from shore increased, the emergents gave way to submerged vegetation (such as Ceratophyllum, Photomagetan schweinfurthi, Vallisneria, etc.) and floating mats of Vossia. Floating mats often had emergent vegetation growing out of them and appeared to be mats of dead reeds and papyrus woven together by Vossia.

Before the drought, Tandal Polder was largely open water with vegetation restricted to the shallow shoreline. The present extensive beds of vegetation occurred after 1973-74. During that period, the area dried out completely and upon receiving water during the 1974-75 flood season, was almost completely engulfed in vegetation (V. Benech, personal communication).

Gras et al (1967) identified these communities to consist largely of Cyperus papyrus, Vossia, Phragmites, Pycreus mundtii, Cyperus articulatus, Dryopteris gongylodes, and Polygonum mixed with Ceratophyllum, Lemna paucicoota, and Spirodella polyrhiza.

Dense beds of this vegetation were estimated to have from 60 to 80 tons/ha of Phragmites, 40 tons/ha Vossia, 70 to 80 tons/ha Typha, and 150 to 180 tons/ha papyrus above the water line (Lévêque et al 1972).

Open water areas of the lake are void of emergent and submerged higher aquatics even though the depth may be only 2 to 3 meters

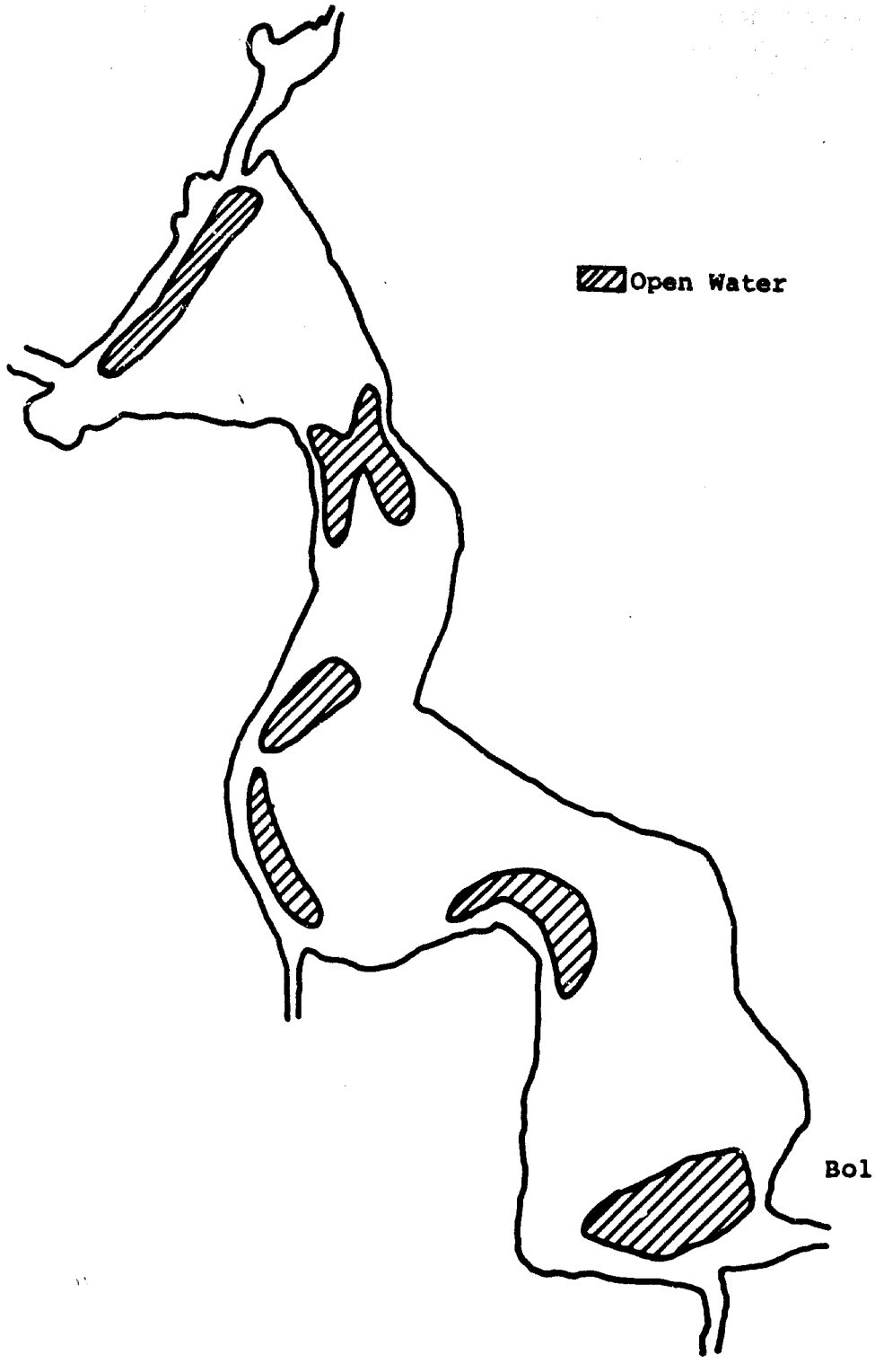


Figure 3B-5
AREAS OF OPEN WATER IN
TANDAL POLDER IN MAY 1978

during high-water years (Carmouze et al 1972). The limit to higher aquatic growth in the lake is probably determined by light penetration to the bottom. It appears, both from Secchi disk readings and the distribution of the plants, that sufficient light normally is present between 1 and 2 meters of depth. When the lake level decreased in 1973 and in later years, vegetation was able to encroach upon many open-water areas.

3. Invertebrate Fauna

Dejoux and Saint-Jean (1972) studied the distribution of invertebrates in various types of aquatic vegetation at Bol, and Dejoux et al (1971) reported the distribution of organisms on different substrates in the area. Their results are presented in Annex 2.

The substrate in the polder is dominated by mud in the central regions, bordered by peat in shallower areas and having patches of clay in the narrowest channels between islands (Dejoux et al 1971). Gras et al (1967) reported abundant vegetative debris on the substrate.

Dominant species on the mud were Cleopatra and Melania, with Melania replacing Cleopatra during the last several years (Leveque et al 1972). Associated invertebrates were included Clinotanypus and Aulodrilus (Dejoux et al 1971).

Zooplankton in these vegetated areas were the same as species found in adjacent open-water areas. Species found at Bol are given in Annex 2 (Dejoux and Saint-Jean 1972; Rey and Saint-Jean 1968; 1969). Zooplankton biomass in the archipelago was 350 mg/m^3 in February-March of 1971 with little season fluctuation (Carmouze et al 1972). This region had higher average zooplankton biomass than the open water in the south and northern basin.

4. Fish Community

From 1971 to 1974, V. Benech (unpublished) found a total of 63 species in the eastern archipelago with the number of species present diminishing with annual low water periods and following the drought. A number of new species appeared during the drought.

Lauzanne (1972) found 25 species of fish at Bol, with Synodontis batensoda, Alestes baremoze, and Alestes dentex dominant by numbers and Synodontis batensoda, Tilapia galilaea, Lates niloticus, and the Alestes species dominant by weight. Most of the dominant species were found to eat primarily insects and zooplankton, except for Tilapia, which is a detritvore, and Lates which is a piscivore (see Annex 2). Biomass in these sheltered areas was estimated at 600 kg/ha and 30,000 individuals/ha. Less sheltered areas had a biomass of 50 kg/ha (Lévêque et al 1972).

Since the drought, mass fish mortality has occurred near Bol. Lates niloticus, Hydrocynus forskalii, Hydrocynus brevis, Alestes, Citharinus citharus, and Synodontis membranaceus have essentially disappeared from the area. Clarias, Polypterus, Gymnarchus niloticus, and Brienomyrus niger continued to survive. The first three of these species can breathe air, and Brienomyrus is tolerant of low-dissolved oxygen. The die-offs apparently occurred when winds mixed low-dissolved oxygen water and organic debris high in oxygen demand through the water column, resulting in oxygen depletion (Benech et. al. 1976).

5. Fisheries

A local fishery exists in the Bol area. During site visits in March 1978, fishing activity was apparent in the open water reaches of the archipelago. Nets, as well as traditional gear, was involved and the head of several Clarias were observed.

During higher waters, the potential for both salanda and banda fisheries exists at the polder since Lates niloticus, Alestes, Citharinus citharus, Labeo senegalensis, and Heterotis niloticus were found (Lauzanne 1972). Biomass is also very high, ranging from 600 kg/ha in sheltered areas to 50 kg/ha in the open water (Loubens 1967). Fishing at Bol is for local consumption, with fishing for export being done in fishing camps away from the archipelago (V. Benech, personal communication).

In relation to the lake, the amount of fish production from the Tandal Polder area is negligible, since the contribution of the Tandal area would be approximately proportional to its surface area, and therefore amounts to less than 0.1 percent of the eastern archipelago's production. The majority of fishing is done along the shoreline from Baga Kawa to the Chari Delta, in the open water biotopes, the delta, and the river itself, making the contribution by the local Bol area fisheries miniscule.

Since the drought of 1973-77, the fish community has changed drastically in the Bol area due to die-off resulting from insufficient dissolved oxygen. All the usually commercially important species had disappeared, leaving Clarias as the main commercial species. This species, while acceptable to locals, is not valuable as an exported product (V. Benech, personal communication).

III. PROJECT IMPACTS ON AQUATIC CONDITIONS

Impacts of the Tandal project will occur to the aquatic system by two means. First are considerations of the effect of removing

the area from the lake ecosystem. Second, the agriculture and irrigation activities will affect the lake by removing water and adding nutrients, pesticides, herbicides, and/or more saline water.

The impact of any project must be viewed with natural ecological variability in mind. The Lake Tchad ecosystem is subject to strong perturbation annually due to the seasonality of inflow and salinity cycles. On a long-term basis, the area is subjected to even stronger changes as climatic change alters the lake's size and chemistry. All these changes result in variability in the ecosystem, and the organisms present are tolerant of certain degrees of changes and resilient enough to return after lake conditions have returned from an unfavorable episode. Organisms not having this resiliency perished long ago.

All this variability diminished the sensitivity to which ecologists can detect changes. Given the need of statistical proof to decipher significant changes from random ones, and the sensitivity of equipment available for detecting altered abundances and distributions, the minimum change must be to the order of 20 percent before it is detectable. So the magnitude of changes from man-made impact must surpass this level before we can assess it.

A. IMPACT OF REMOVING THE AREA FROM THE LAKE ECOSYSTEM

According to Carmouze et al (1972) the eastern archipelago covers approximately 1,050 km^2, 49 percent of which is water when the lake depth is 2.5 to 4.0 meters ("normal" Tchad). Water surface in the area therefor covers approximately 514 km^2. Tandal Polder represents approximately 0.15 percent of the water area. The removal of such a small proportion of the archipelago region would have no detectable effects to the system. Given the normal fluctuations due to seasonal volume changes, the change by removing the Tandal area is too small to be noticed. Even if we considered the polder area as the only protected area for fisheries, thereby having 12 times the biomass of the open areas on a per unit surface area basis, the resulting loss would only represent 1.3 percent of the total biomass. Again the effect would be negligible.

During the drought, this area dried out and hence does not represent a refuge during low water periods.

B. IMPACTS OF THE PROJECT ON WATER USE ON THE LAKE

No impact from this project will be felt on the whole lake due to the relatively minor amount of water used and discharged compared to the amount in the lake total. Local impacts will occur, however.

Circulation through the archipelago near Tandal is not quantitatively known but can reasonably be assumed as negligible. Water intake and discharge will create a circulation pattern as shown on Figure 3B-6. This circulation will be relatively strong and the impact of discharge water quality will also be strong due to the low amount of water in the polder adjacent to Tandal. The area depicted on Figure 3B-6 is between 800 and 900 ha. If we assume its average depth to vary between 1 and 4 m, the volume would vary from 8 million to 36 million cubic meters. The return flow from the project may reach 3 million cubic meters per year, thereby supplementing the volume in the neighboring polder. In reality, the return flows will replace the water in some portions of the affected polder, and mix to varying degrees in other areas. The average salinity in the polder area adjacent to Tandal will increase to approximately 500 mg/l within a 4-year period and then stabilize. The area adjacent to the Tandal discharge will reach approximately 1,000 mg/l salinity while the Tandal intake should average about 450 mg/l. Major impacts will occur in the region closest to the discharge, diminishing with increasing distance and dilution. The impacts may be quite strong, since discharge water will have salinities of approximately 1,000 mg/l. In addition to the dilution of discharge water, salinity patterns and concentrations will change during high inflow periods.

The combination of saline and enriched discharge water will likely result in a localized increase in algae in the area indicated on Figure 3B-6. The salinity balance will shift towards more sodium and chloride in this small region, simulating conditions in the northern archipelago. It is possible that species more abundant in the northern archipelago would become more abundant in this area of higher salinities. Possible changes would be an increase in Closterium, Phragmites, Typha, insects in general, and specifically Polypedilum foscipenne and decreases in Alluroidadae zooplankton and mollusc biomass. It is impossible to say if these changes will occur or not. Although the increased salinities and nutrient may favor such organisms, the climate is still one of more southernly nature than the northern archipelago, and the organisms present to continually colonize this area would be those typically found in the area.

During low water periods, the increased nutrients and likely increased algal growth may result in diurnal oxygen changes unfavorable to fish. Fish will avoid low oxygen areas if they can escape, and escape will depend upon the morphology of the basin receiving agricultural return water. The basin morphology is not presently known.

While having a definite local effect, the polder area affected still equals only a small proportion of the total eastern

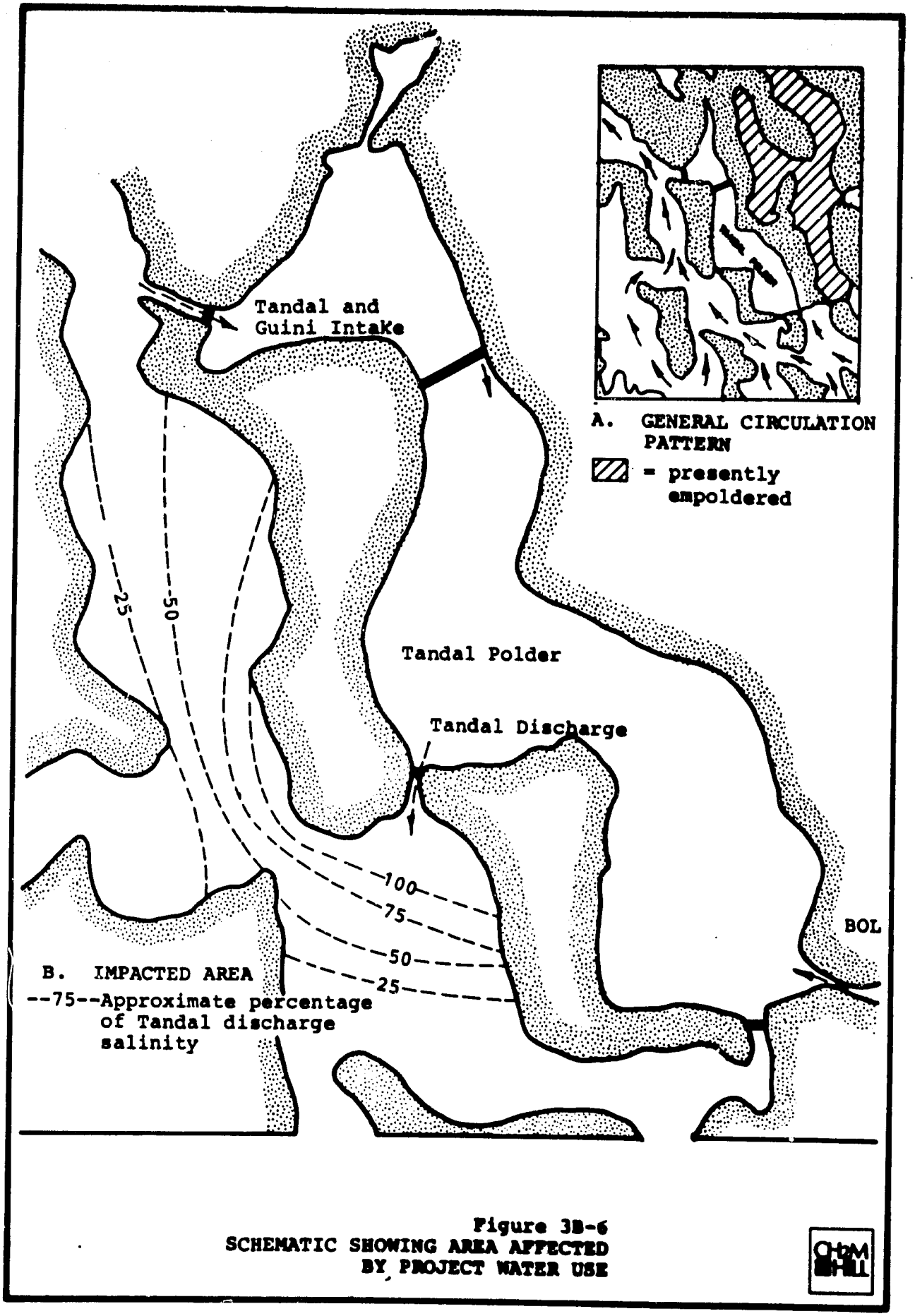


Figure 3B-6
SCHEMATIC SHOWING AREA AFFECTED
BY PROJECT WATER USE

archipelago habitat. Essentially, a definite effect will be seen locally, but the local area involved is small compared to the archipelago area.

More persuasive effects will occur if persistent pesticides (chlorinated hydrocarbons) or heavy metal fungicides are used on the fields. Both material groups have bio-magnification properties and should not be used.

IV. EXISTING WILDLIFE CONDITIONS

Data on wildlife in the Bol region are very scant. Some bird reports exist, but no systematic surveys for mammals, reptiles, or amphibians were available. The following discussion is severely limited in both scope and depth by this lack of data.

The archipelago region near Bol had a rich avifauna involving both migrant and resident species. The list in Table 3B-2 is a partial compilation of bird species reported to occur in archipelago habitat. This list was extracted from Veillard (1971, 1972a, b, c) and K. Belyo (personal communication), with distribution and abundance data provided largely by Williams (1964) and Serle et al (1977). As such, the information is general in nature and should be viewed as a cross section of species occurring near Bol.

No species in the Tchadian Basin avifauna checklist supplied by Veillard (1972a) is on the endangered and threatened species list (National Wildlife Federation 1977), so none are assumed to occur near Bol. The Tchadian Government has several local species on a protected list, including the cattle egret (Bubulcus ibis) whale headed stork (Balaniceps rex), little egret (Egretta garzetta), grand egret (Casmerodius albus), all pelicans, longtail shag (Phalacorax africanus), and sacred ibis (Threskiornis oethiopicus). With the exception of the whale headed stork and grand egret, all of these species have wide regional distributions and are fairly common. The whale headed stork has only local distributions and is rare and distribution data for the grand egret are unavailable.

No scientific data on mammals in the Bol area were available. The Parks and Reserves Service reported two species of otter (Lutra maculicollis and Aonyx capensis), a warthog (Phacochaerus acthiopicus), ground squirrels (Euxerus erythropus), and two jackal species (possibly Canis aureus and C. adustus) in the area (K. Belyo, personal communication). The local veterinarian reported a poisoning campaign against jackals and wild dogs, possibly either feral dogs, Lycaon spp. or a cross breed. Local Peace Corps volunteers reported that a band of elephants (Loxodonta africana) occasionally passed through Bol. They

(Pg-1

LIST OF BIRD SPECIES

TO OCCUR NEAR BOL

WILLIAMS 1972a, 1972b; 1971a, 1971c;

ET AL 1974; SERLE ET AL 1977;

WILLIAMS 1964; BELYO, PERSONAL COMMUNICATON)

Scientific Name	Common Name	Resident/ migrant	Distrib	Abundance	Habitat
Actophilorus africana	Lily troter	U	W	LC	Ag
Acrocephalus rufescens	Rufus crane warbler	M	W	C	Ag
Alopochen aegyptiacus	Egyptian goose	R	W	C	Tr
Anas acuta	Pintail	M	W	C	AgM
Anas capensis	Cape wigeon	U	WL	C	Ag
Anas crecca	European teal	M	U	UC	Ag
Anas querquedula	Garganey	M	U	C	Ag
Ardea goliath	Goliath heron	R	W	UC	Ag
Ardea cinera	Grey heron	M	W	C	Tr-Ag
Asio flammeus	African marsh owl	R	W	C	Tr-Ag
Balaeniceps rex	White headed stork	R	L	R	Ag
Balearica regulorum	Crested crane	R	W	C	Tr-Ag
Bubulcus ibis	Cattle egret	R-M	W	C	Ag-Tr
Burhinus senegalensis	Senegal thick-knee	R	W	LC	Tr-Ag
Butorides striatus	Green backed heron	R	W	C	Tr-Ag
Calidris alpina	Dunlin	M	U	UC	Ag
Centropus monachus	Blue-headed coucal	R	W	LC	Tr
Charadrius pecuarius	Kittlitz's sand plover	M	W	C	Ag
Ciconia ciconia	White stork	M	W	UC	Tr-Ag
Cisticola ruficeps	Redpate cisticola	R	W	UC	Tr
Corythornis cistata	Malachite kingfisher	R	W	LC	Ag
Cossypha niveicapilla	Snowy-crowned robin-chat		W	LC	Tr
Dendrocygna viduata	White faced tree duck	R-M	W	LC	Ag-Tr
Dendrocygna fulua	Fulvous tree duck	R-M	W	LC	Ag
Egretta garzetta	Little egret	R	W	C	Tr-Ag
Ephippiorhgnchus senegalensis	Saddlebill stork	M	W	C	Ag
Falco subbuteo	European hobby	M	W	R	Tr
Fulica atra	European coot	M	W	UC	Ag
Gallinula chloropus	Moorhen	M	W	LC	Ag
Glareola nuchalis	Collared pratincole	M	W	LC	Tr-Ag
Glareola pratincola	Pratincole	R-M	W	LC	Tr-Ag
Gyophierax angolensis	Palmnut vulture	R	W	C	Tr

Table 3B-2 (Continued)

Scientific Name	Common Name	Resident/ migrant	Distrib	Abundance	Habitat
Gyps ruppellii	Ruppell's giffon vulture	R	W	C	Tr
Haliaetus vocifer	W. African river eagle	R	W	LC	Ag-Tr
Himanotopus himantopus	Black winged stilt	M	W	LC	Ag
Ixobrychus minutus	Little bittern	R-M	W	C	Ag
Jynx torquilla	European wryneck	M	W	UC	Tr-Ag
Lanianus erythrogaster	Barbary shrike	R	W	LC	Tr
Larus ridibundus	Black headed gull	M	W	UC	Tr-Ag
Limnocorax flavirostra	Black crake	U	W	C	Ag
Merops superciliosus	Blue cheeked bee-eater	M	W	LC	Tr
Micropara capensis	Lesser lily-trotter	U	L	UC	Ag
Mirafra javanica	Singing bush-lark	R	W	LC	Tr
Pelecanus onocrotalus	White pelican	R-M	W	LC	Ag
Pelecanus rufescens	Pink back pelican	R-M	W	LA	Ag
Phalacorax africanus	Longtail shag	U	W	C	Ag-Tr
Platalea alba	African spoonbill	U	W	LC	Ag-Tr
Platalea leucorodia	European spoonbill	M	U	R	Ag-Tr
Plectropterus gambensis	Spurwinged goose		W	C	Ag
Plegadis falcinellus	Glossy ibis	R-M	W	C	Ag
Podiceps ruficollis	Dabchick	R	W	LC	Ag
Porphyrio porphyrio	King reed-hen	R	W	LC	Ag
Recurvirostra avosetta	Avocet	M	L	UC	Ag
Riparia cincta	Banded martin	M	L	LC	Tr
Sarkidornis melanonotus	Knob-billed goose	R	WL	C	Ag
Scopus umbretta	Hammerkop	R	WL	C	Ag
Sterna nigra	Black tern	M	W	R	Tr
Sylvietta brachyura	Nuthatch warbler	R	W	C	Tr
Threskiornis aethiopicus	Sacred ibis	R	W	C	Tr-Ag
Turtur tympanistria	Tambourine dove	R	W	C	Tr

also reported mice, rats, ground squirrels, a larger cheetah (possibly Acinyx jubatus) and a smaller cat (likely a member of the Felis group), a small gazelle (possibly Gazella dorcas or G. rufifrons), and an occasional hippopotamus (Hippopotamus amphibius).

No data were available on reptilian or amphibian species. Peace Corps volunteers and the Parks and Reserve Service (K. Belyo) reported a crocodile in the area. The species was unknown, but all crocodiles are protected by the Tchadian Government. An endangered crocodile, Crocodylus catapharctus, occurs in Central Africa (National Wildlife Federation 1977) and may be the species reported for Lake Tchad. However, it is impossible to establish the identity of the crocodile species reported in Lake Tchad at this time.

V. IMPACTS ON WILDLIFE

Project impacts on wildlife populations will be species specific although several species may be affected in the same manner. Each species population numbers and distribution is determined by factors specific to that species. For example, one bird species may be limited by food availability, while another could be limited by nesting sites. Increased food through crop availability would only help the species which is food limited.

A. IMPACT OF REMOVING EXISTING AREA

No major impact on the majority of bird species existing in the area is likely. Most species are widespread and highly mobile making destruction of this small area negligible when viewed against the larger habitat of equivalent suitability which is available.

A more serious impact on the whale headed stork (Balaniceps rex) is possible, since this species is not widespread, is rare, and is a resident, nonmigratory species. The reduction in habitat will not be serious, but accumulation of pesticides with resulting reproduction decreases is likely if persistent pesticides are used.

Mammalian wildlife in the area should also not be significantly affected. The aquatic species (otters and hippopotamus) are mobile and have ample nearby habitat. Their populations also must have been resilient enough to survive the lake level changes which determines the amount of available habitat.

A serious impact is very possible if the reported crocodile is Crocodylus cataphractus, the endangered species. Endangered species populations are in a highly vulnerable state, and environmental changes which would be survived by a healthy population can be devastating to an endangered species. Typically,

either their populations have been reduced to the point where they can barely maintain themselves against normal or manmade mortality factors, or their habitat has been reduced to the point where any further reduction leaves them too little area in which to survive. The removal of the Tandal area could potentially harm the crocodile species by further diminishing the population's ability to maintain itself. At present, no information is available on the reported animals identification, so we cannot indicate the suitability of the Tandal area as habitat or the population's resiliency.

B. IMPACT OF CREATING NEW HABITAT

Arboreal birds will be provided new habitat by windbreak trees, thus enhancing their populations. Since the amount of this type of habitat is small in the area, the enhancement will be large relative to the existing population but will be small in total numbers.

Species which are commensurate with agriculture and/or human habitation will be somewhat enhanced. Rats of the genera Rattus, Cricettomys, and Thryonomys would be favored, and the blue-cheeked bee eater may be enhanced. The quelea bird (Quelea quelea) may be more attracted to the area if wheat is grown. Elephants may also be more attracted to the area by the crops and windbreaks. If acacia trees are planted, the gazelle (G. dorcas or G. rufifrons) may be attracted, and it is likely that predators such as wild dog, jackals, or cheetahs will follow. None of these changes are significant for their impact on wildlife, but are more important for wildlife impacts on the project.

C. RECOMMENDATIONS

1. The identity of any crocodile species in the Bol area should be determined and steps taken to protect it. If the species is C. cataphractus, a review of the entire project's impact on the species survival should be conducted. Steps should also be taken to protect the whale headed stork (Balaniceps rex).

2. No persistent pesticides should be used on the project. The devastation of DDT and related compounds on bird populations is well documented, and this easily avoided tragedy should not be repeated. Use of nonpersistent pesticides should be strictly controlled and used in an integrated manner with other pest control measures. Fungicide covered seeds should also be used in a manner to avoid consumption by birds and rodents.

Part 3C
ECONOMIC ANALYSIS

I. INTRODUCTION

This section discusses the economic feasibility of the proposed project to develop Tandal Polder for intensive agricultural production. The objectives of the economic analysis are to:

1. Determine, within the time and budget constraints, the benefits of the project and their incidence among the parties affected, at both the local and national levels.

2. Determine costs, under the same constraints as affect benefit calculations, resulting from project planning, design, and implementation necessary to achieve agricultural production on the project and deliver such production to appropriate markets.

3. Compare benefits to costs and calculate feasibility measures including ratios of benefits to costs and internal rates of return, including likely variations in critical factors and resulting sensitivity of feasibility measures to such variations.

The scope of the study is necessarily limited by time and budget. The economic study was conducted over a 6-week period from 11 March to 20 April 1978 by a single economist. Given this time constraint, the information for the analysis is principally information already available from previous studies supplemented by data obtained locally from Government of Tchad (GOT) agencies and from persons at the project site. The latter are primarily SODELAC and SCET personnel developing Guini and Berim Polders near Bol. The level of accuracy of information used is not well known, although it is believed to be adequate to reach reliable conclusions on project feasibility. The primative nature of data gathering activities in Tchad is a recognized limitation, however.

Procedures used are for the most part conventional benefit-cost techniques. A 30-year period of analysis is used, all costs and benefits are expressed in constant 1978 CFA or dollar terms, and thus indicate real resource and product values. The benefits and costs are discounted to 1978 to calculate the benefit to cost ratio. The rate of return

calculation estimates the return on all costs incurred to produce and sell the products which result when revenues are accounted for. Some benefits and costs are not quantifiable and are discussed, but do not enter the benefit-cost calculation. While important, such benefits would likely also result from alternative investments in Tchad and thus are not net gains to this project at the national level.

Certain assumptions, some of which are evaluated in other parts of the study, are made for the economic analysis:

1. It is assumed that project progress will not be adversely affected by political conditions in Tchad.

2. SODELAC will be reorganized in such a manner and receive adequate financing to be an effective farm management, extension, marketing, and credit agency.

3. Appropriate motivation to produce will be provided to settlement farmers by policies and practices of SODELAC and farm policy measures of GOT (see the Social Analysis Section).

4. An adequate number of settlement farmers will be attracted to settle in the project lands (see Social Analysis Section).

5. Adequate financing of the project and necessary infrastructure will be obtained (see also Financial Analysis).

II. NATIONAL AGRICULTURAL SITUATION

Gross National Product (GNP) per capita in Tchad is estimated to have been $73 (U.S.) in 1976 (U.S. Foreign Service, American Embassy N'Djamena 1977). This ranks the country as one of the lowest in income in the world. While the country has been self-sufficient in food in many recent years, there has also been a shortage in some years due to unfavorable weather conditions. The drought in the late sixties and early seventies resulted in the need to import food. The balance of trade is unfavorable, with the deficit financed by foreign assistance and internal deficit financing. Agricultural products, especially cotton, are the principal exports of the country. These products account for about 80 percent of exported value; cotton alone for over 60 percent (The Secretary International Monetary Fund 1976). The country's adverse financial condition is worsened by expenditures for military purposes due to internal security problems.

The rural sector of the country, including crops, livestock, and fish is estimated to supply 50 percent of GNP and provide a livelihood for 80 percent of the population (World Bank 1977). The majority of agricultural population and production is in the south of the country below N'Djamena on dryland farms. The Government of Tchad has programs to improve productivity on the drylands, especially cotton production for export. GOT also has programs to develop and improve agriculture in the Lake Tchad area. Part of this program is the development and irrigation of polders, such as Tandal.

Some of the benefits to irrigation development in Tchad are (World Bank 1975a):

1. Greater diversity of crop production,
2. Greater utilization of the country's livestock resources,
3. Evolution of a high technology agriculture, and
4. Insurance against disruptive effects of drought.

To these might be added the following advantages to increased irrigated production:

5. Greater production of food to meet the needs of a growing population,

6. Reduction in foreign exchange deficit through reduced importation of food and increased exports, and

7. Possibility of improved efficiency in use of labor and other resources in the dominant economic sector of the country.

On the other side of the balance must be placed the significant cost of irrigation development to a country with limited capital and the need to import most of the material necessary to build irrigation works. Cost of developing Guini and Berim Polders (1,170 ha) was estimated by the World Bank (1975) at $4,700 per hectare just for construction and supervision and $11,100 when associated settlement, research, overhead, and contingencies are added. About 80 percent of the cost would be foreign imports.

Societe de Developpement du Lac (SODELAC) is a government corporation established in 1967 to assist in development of the Lake Tchad region. Its responsibilities include provision of credit, extension, and marketing services to farmers. Because of the low volume and high transportation costs, marketing activities of SODELAC have generally been unprofitable. This fact plus the net cost of activities other than marketing have placed SODELAC in a difficult financial situation. The financial structure together with questionable organization to perform its functions have resulted in suggestions to

reorganize SODELAC (World Bank 1975, USAID 1977b). A management study sponsored by USAID is currently being conducted to evaluat and recommend changes in the organization of SODELAC. It is generally conceded by agencies donating to development of the Lake Tchad polders that funds for additional development should not be approved without suitable reorganization of SODELAC (World Bank 1975a).

III. PRODUCTION, VALUE, AND INCOME

Production from Tandal Polder is estimated for a double cropping program of cotton and wheat. Reasons for choosing this cropping plan are 1) there are research results from the Matafo Experiment Station at Bol (SCET International 1972) indicating these crops are well adapted and suitable cultural practices are known, 2) there are agreements between SODELAC and COTONTCHAD and SODELAC and Grands Moulin du Tchad (GMT) for marketing of the cotton and wheat in N'Djamena, and 3) the seasons between planting and harvest do not overlap, allowing double cropping. Other crops are being grown on the polders and experimentation should be continued with periodic review of their adaptability to production, handling, and marketing. Potatoes and other vegetables are being grown, but inadequate storage and transportation to their principal market--N'Djamena--currently pose severe limitations to large-scale production. Other crops with potential include forages for livestock, maize, millet, and sorghum.

Yields assumed are 3,500 kg/ha for seed cotton and 3,000 kg/ha for wheat. These yields are based on experimental results at Matafo and discussions with SODELAC personnel at Bol. They are lower than experimental yields to allow for field conditions. Because of the possibility of inadequate soil drainage and the consequent buildup of salts in the soil after a few years of irrigation, yields may decline (see Technical Analysis, Soils). It is assumed here, however, that yields will be maintained throughout the 30-year evaluation period. Seeding rates assumed are 80 kg/ha for wheat and 30 kg/ha for cotton. Other cultural practices should be based on experimental results and actual experience on Guini Polder (SCET International 1972).

Selecting prices to use in valuing the products pose considerable difficulty. The official government price for wheat in Lac Prefecture is 40 CFA/kg (Ministère du Dévelopment Agricole 1978). This is likely to be the price offered cultivators (or a similar official price set at time of development of Tandal). Open market prices have often exceeded the official price and provide an incentive for farmers to sell their wheat outside the government system (Center for Research on Economic Development, University of Michigan, 1977). If continued, this practice can be expected to result in considerable friction

between SODELAC management and cultivators. Assuming open market prices reflect demand and supply conditions, payment of the fixed price 40 CFA/kg reflects an income transfer from cultivators to consumers of wheat. For determination of value of production, a price of 60 CFA/kg is assumed for wheat. This is an import substitution price assuming a U.S. wheat price of $3.00 per bushel (25 CFA per kilogram) and cost of importation of 35 CFA per kilogram.

Virtually the entire production of cotton in Tchad is sold to COTONTCHAD and processed in one of their gins for export. In 1971, COTONTCHAD was granted a monopoly for the purchase, ginning and marketing of cotton. The official government price for cotton (white) is currently 45 CFA/kg (COTONTCHAD 1977). Although the price received by Tchadian producers is lower than that received by producers in neighboring countries (Secretary, International Monetary Fund 1976), it is not known what price would prevail in Tchad in a free market. World prices, CIF Europe, were in the $0.80's in early 1977. They declined to the $0.60's by late 1977 (USDA, FAS 1978). We assume a world price of $0.60 per pound, and consider ginning, transport, and export costs to Europe. A price of 80 CFA/kg is used to value production.

The cropping plan assumes a 3-year development period (Table 3C-1). A "project unit" as suggested by World Bank (1975 a) is adopted for this analysis. The project unit would produce the crops the first year, with cultivators assuming operation in the second year. Two hundred hectares would be added each year until the total cultivatable area of 600 hectares was under production. Seed would be purchased the first year, then produced on the experimental farm in succeeding years. For uniform seed quality, all seed would be produced and provided by the experimental farm. The acreage in the experimental farm is slightly in excess of seed requirements, allowing areas for experimentation with crops other than cotton or wheat.

Production, under the above conditions and assumptions, would be 700 tons of cotton seed in the first year and stabilize at 2,044 tons in 1986 and after (Table 3C-2). Wheat production would be 600 tons the first year and build to 1,752 tons by 1986. Production is maintained at that level until 2013.

Value of production from the cotton-wheat plan would be 92.0 million CFA in the first year of production and 268.6 million CFA in 1986 and subsequent years (Table 3C-3).

Table 3C-1
COTTON-WHEAT CROPPING PLAN--TANDAL POLDER

	1984	1985	1986	1987-201
Cotton (area, ha)				
Cultivators	--	200	400	584
Exper. Farm(seed)[1]	11	16	16	16
Project Unit	200	200	184	--
Total Area	211	416	600	600
Wheat (area, ha)				
Cultivators	--	200	400	584
Exper. Farm(seed)[2]	11	16	16	16
Project Unit	200	200	184	--
Total Area	211	416	600	600

[1]Assumes 40 kg/ha seed required, yield of 3,500 kg/ha and 60 percent seed recovery. Seed purchased first year. Four hectares available for other purposes after 1986.

[2]Assumes 80 kg/ha seed required, yield of 3,000 kg/ha and seed furnished by experimental farm. Seed purchased first year. Rounded up to next hectare.

Table 3C-2
COTTON AND WHEAT PRODUCTION--TANDAL POLDER

	1984	1985	1986	1987-2013
Cotton Production (tons)[1]				
Cultivators	--	700	1,400	2,044
Project Unit	700	700	644	--
Total	700	1,400	2,044	2,044
Wheat Production (tons)[2]				
Cultivators	--	600	1,200	1,752
Project Unit	600	600	522	--
Total	600	1,200	1,752	1,752

[1]Assumed yield of 3,500 kg/ha, acreage net of seed production.
[2]Assumed yield of 3,000 kg/ha, acreage net of seed production.

Table 3C-3
VALUE OF PRODUCTION--TANDAL POLDER

	Million CFA			
	1984	1985	1986	1987-2013
Cotton[1]				
Cultivators	--	56.0	112.0	163.5
Project Unit	56.0	56.0	51.5	--
Total	56.0	112.0	163.5	163.5
Wheat[2]				
Cultivators	--	36.0	72.0	105.1
Project Unit	36.0	36.0	33.1	--
Total	36.0	72.0	105.1	105.1
Total, all (CFA)	92.0	184.0	268.6	268.6
Total, all (million US$)[3]	.40	.80	1.17	1.17

[1]Assumes price per unit of 80 CFA/KS.
[2]Assumes price per unit of 60 CFA/KS.
[3]At the conversion rate of 230 CFA per dollar, 1978.

IV. BENEFITS

The principal benefit of the proposed project is the increase in value of agricultural production. Because the polder is not under production now, and there is a ready use for the proposed products at the assumed prices, the entire value of production after polderization is counted as a benefit.

Additional factors indicate benefits to Tchad in addition to value of production of cotton and wheat. In the case of cotton, nearly all of the production is exported as lint and provides a major source of foreign exchange earnings. For wheat, there are two factors: foreign exchange savings through less importation of food and better utilization of the GMT flour mill at N'Djamena. For these reasons, a shadow price factor of 20 percent is used to increase the value of production of these crops as a benefit. This factor is somewhat arbitrary, but information is inadequate for a refined analysis of shadow price. Annual benefits are illustrated in Table 3C-4.

Secondary benefits were mentioned in an earlier part of this report. They are not quantified, with the exception of the shadow price factor, because by and large they are not attributable to this project alone. Other shadow price adjustments are applied to project costs below.

A. COSTS

Several categories of costs are considered here. In pricing the resources used in developing and operating the project, the guiding principle is that the value of the resources committed should reflect the benefit foregone in their most productive alternative use. All costs are in present day 1978 terms.

The categories of costs considered include the following:

1. Construction--all costs of construction of the irrigation and drainage works, including contingencies. The source is the engineering studies (Section 3A).

2. Operation, maintenance, and replacement of irrigation system--annual costs of operating and maintaining the irrigation and drainage works. The source is the engineering studies.

3. Farm production--the cost of producing the farm crops--wheat and cotton--by the farm development unit (first year) and by the cultivators. Cultivator labor cost is excluded since its return is treated as a residual income to farm production. The source of these costs is World Bank (1975, Annex 3, Table 3), with inflation of 8 percent per

Table 3C-4
ANNUAL BENEFITS AND COSTS OF OPERATION, TANDAL POLDER

Benefits	Million 1978 CFA				
	1984	1985	1986	1987	2013
Farm Production					
Cotton	56.0	112.0	163.5	163.5	163.5
Wheat	36.0	72.0	105.1	105.1	105.1
Total	92.0	184.0	268.6	268.6	268.6
Shadow Price Adj.	18.4	36.8	53.7	53.7	53.7
Total Benefits	110.4	220.8	322.3	322.3	322.3
Costs					
Operation, Maint., & Replace.	26.0	52.1	77.1	77.1	77.1
Farm Production	19.8	41.3	59.6	59.6	59.6
Farmer Investment (including foregone income)	13.9	24.4	26.8	14.8	14.8
Project Overhead	11.9	23.8	34.8	34.8	20.4
Labor Price Adjustment[1]	(1.2)	(2.4)	(3.5)	(3.5)	(4.4)
Operating Costs	70.4	139.2	194.8	182.8	176.3

[1]Applied to operation, maintenance, and replacement and project overhead only.

year since 1975 (based on recent rates of inflation in Tchad. See U.S. Foreign Service, American Embassy N'Djamena 1977; Secretary, International Monetary Fund 1976; and World Bank, 1977). Farm production costs are estimated to be 93,700 CFA/ha for the first year of cultivation and 99,265 CFA/ha subsequently.

4. Farmer investment costs--costs incurred by the farmer for food (first year only), for equipment, and for foregone income. The food cost is assumed to be 1,000 kg of wheat per family at 52 CFA. In subsequent years, food is purchased from labor income. Equipment needed and its cost is from World Bank (1975 a, Annex 3, Table 3) indexed up to 1978 at 8 percent per year. It is assumed that equipment will be shared among farmers. Income foregone is assumed to be 113 kg of both wheat and maize grown under traditional polder cultivation (World Bank 1975 a, Annex 3, Table 2), priced at 52 CFA and 20 CFA per kilogram, respectively. Farmer investment for equipment is estimated to be 53,500 CFA and includes a sprayer, cultivator, seeder, cart, and oxen. Replacement is required every 3 to 5 years.

5. Project overhead--this cost is based on data in the World Bank report (1975a, Annex 7, Table 1). Included are costs of the farm development unit and project unit overhead costs. It is assumed that the land of the new settlers will be cultivated, seeded, and harvested by the farm development personnel the first year. The project unit includes storage for fertilizer and supplies, extension service, and administration. Project overhead is high during the development period because of high salaries of expatriot personnel. Overhead costs are reduced by about one-half after development when it is assumed most expatriots leave the project. As before, costs from the World Bank study (1975a) are inflated by 8 percent per year for 1975-1978. For this study, these costs are further reduced by one-half on a hectare basis because of stated overcapacity in the World Bank report. Project overhead costs are estimated to be 59,600 CFA/ha during development and 35,000 CFA/ha after development.

6. Infrastructure--these costs, although they may be sizable, are not estimated here. A major infrastructure cost may entail improvement in transportation from Bol to N'Djamena. Without this improvement, it may be necessary to store crops during

the rainy season. If well stored, the planned crops, wheat and cotton, are not perishable. Information available and time constraints of this study precluded evaluation of infrastructure costs.

When there is a high degree of unemployment or underemployment of labor or other resources in a country, the social cost of bringing such resources into use may deviate from their market prices (Howe 1971). For example, part of the shadow price adjustment in the valuation of the crop products was due to underemployment of the flour mill in N'Djamena. Similarly, labor resources in Tchad are believed to be underemployed. In this case, the wage rate of labor does not reflect the opportunity cost of using unemployed or underemployed labor. An approach for valuing such labor is to multiply the wage rate by one minus the probability of drawing on the unemployed labor force (Howe 1971). Data are not available on the degree of underemployment or unemployment of labor so a detailed analysis is not possible. For present purposes, an unemployment rate of 20 percent is assumed and Tchadian labor used for project construction and other purposes, except farm production, is multiplied by .80 to estimate its social cost (shadow price). It is assumed further that adequate skills are available for project job requirements among Tchadian unemployed.

The following estimates were made of labor components of costs:

	Total Labor % of Cost	Tchadian Labor % of Cost
Construction	20	10
Operation, maintenance, replacement	33	20
Project overhead:		
development period	45	6
full operation period (after 1987)	33	33

Operational costs, with associated labor price adjustments are shown in Table 3C-4. Costs of construction, less Tchadian labor price adjustments and net construction costs, are shown in Table 3C-5.

V. PROJECT FEASIBILITY

Project feasibility is measured in two ways: 1) by comparing benefits to costs on a discounted basis and 2) by calculating an internal rate of return. The rate of discount used to estimate present values was 10 percent, approximating the opportunity cost of capital.

Table 3C-5
CONSTRUCTION COSTS AND TCHADIAN LABOR PRICE ADJUSTMENT

	Million CFA		
Year	Total Construction Cost	Labor Price Adjustment	Net Construction Cost
1981	235.9	4.7	231.2
1982	180.7	3.6	177.1
1983	475.4	9.5	465.9
1984	465.2	9.3	455.9
1985	439.3	8.8	430.5
1986	23.5	.5	23.0
	1,820.0	35.9	1,783.6

The present value (1981) of benefits is 2,282.5 million CFA ($9.92 million), the present value of costs is 2,752.1 million CFA ($12.0 million) (Table 3C-6). Therefore, the benefit to cost ratio at a 10-percent interest rate is 0.83.

The analysis of internal rate of return indicates, given the benefits and costs used, the project would yield about 5 percent return on the invested costs.

These results indicate the project is marginal under the objective of economic efficiency. If money indeed will yield 10 percent, each dollar invested in this project would on the average result in a return of $0.83.

Regardless of the outcome of the economic feasibility analysis, certain qualifications should be recognized. Considerable reliance has been placed on data from other studies, the validity of which is not completely known. For example, much of the cost information is from the World Bank report on the feasibility of Guini and Berim Polders (1975a) updated by estimated rates of inflation. The seeming thoroughness of that study gives confidence but appearance is sometimes deceiving. Experience on the new polders will provide information on the validity of the World Bank costs. Guini begins production of cotton and wheat by cultivators only this year on a scale adequate to begin testing costs.

Costs of farm production, farmer investment, and project overhead should be recorded and evaluated thoroughly on the newly developing polders. It is worth noting, however, that farm production, farmer investment, and project overhead (disregarding the labor price adjustment) are only 26 percent of all costs during the project analysis period. Further, if these costs are disregarded entirely, the project yield is greater than 10 percent (benefit to cost ratio of 1.12 at 10 percent discount rate).

Estimated costs of construction, and operation, maintenance, and repairs are based on somewhat incomplete information (see Technical Analysis Section). The effect of inaccurate estimates (they could be high or low) of these items may be significant to project feasibility. For example, removal of the 40 percent contingency on construction costs which is considered appropriate for a study of this nature would increase the benefit to cost ratio to 1.00. That is, the project would then yield a rate of return of about 10 percent rather than 6 percent.

Crop yields and prices of farm crops used here, while not invulnerable to criticism, are based on data considered to be relatively up-to-date and reliable. If anything, crop

Table XC-6
COMPARISON OF BENEFITS AND COSTS OF DEVELOPMENT OF TANDAL POLDER

	Present Value, 1981[1] (Mill CFA)	(Mill $)[2]
Benefits	2,282.5	9.92
Costs		
Construction	1,457.2	6.34
Replacements	56.7	.25
Operation, Maintenance, Repairs	545.2	2.37
Farm Production	421.9	1.83
Farmer Investment	128.6	.56
Project Overhead	171.9	.75
Labor Price Adjustment	(29.4)	(.13)
Total	2,752.1	11.97

Ratio of Benefits to Cost

$$\frac{2,282.5}{2,752.1} = .83$$

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[1]The discount rate used was 10%

[2]Conversion rate of 230 CFA to one dollar

production may be overstated if difficulties in obtaining adequate drainage reduce projected yields. A different cropping pattern with higher value products would enhance benefits, but also raise costs.

The effects of some possible changes in critical variables on the benefit to cost relationship are indicated below.

Variable	Benefit-Cost Ratio +20%	Benefit-Cost Ratio -20%
Value of crop produced	1.00	.66
Construction Cost	.75	.93
Operation & Maint. Cost	.80	.86
Farmers Costs	.80	.86
Project Overhead	.82	.84

It is apparent that, in percentage terms, project feasibility is most sensitive to value of crop production and construction cost. For these variables there is an 8 to 17 percent change in the benefit-cost ratio for a 20 percent change in value of the variable. Changes in values of other variables change the benefit to cost ratio by only a few points.

Part 3D
SOCIO-CULTURAL AND SOCIO-ECONOMIC CONSIDERATIONS

I. INTRODUCTION

This section of the report has been prepared to present the socio-cultural parameters which exist in the Bol area and to give considerations to some socio-economic traditional and modern features which affect the Tandal project.

The facts presented and discussed were collected from the available documentation examined in Paris, at N'Djamena, and at Bol.[1] Because the resources in documentation were limited and the time available for the project short (60 days, including 2 in Paris, 38 in N'Djamena, and 16 at Bol), the data collected cannot be considered exhaustive. Some time was spent doing field work at Bol and in the villages surrounding the periphery of the Tandal basin and the data collected by means of questionnaires was sorted out both manually and by computer permitting a sound analysis of the materials gathered. This presentation, though limited to the salient features of the materials researched, may be viewed with a fair degree of confidence in regard to the bearings it has on the Tandal project. Because most of the recent work, and often the only work, done on the Kanembu, Buduma, Kuri, and Haddad societies were made by Christian Bouquet, much data and some considerations were drawn from his works.

Since much of the engineering, climatic, geographical, faunal and floral, and otherwise environmental data are presented fully elsewhere in this report, these factors are only alluded to when necessary. Annexes are presented to introduce data pertinent to this section.

Here, considerations are given first to the main aspects of Bol and the traditional society of the area; this is followed by an examination of the present polder situation and its managerial aspects; an analysis of the demographic data and of the attitudes of the villagers of the region to be affected by Tandal is presented; some comments are made on which factors might facilitate or impair the establishment of the Tandal basin as a polder; conclusions are in the form of a series of recommendations.

[1] At the Sorbonne's Center for African Research, Paris; at the National Tchadian Institute of Human Sciences and University of Tchad in N'Djamena; at the Prefecture in Bol.

II. THE SOCIO-CULTURAL BACKGROUND: TRADITIONAL SOCIETY AND ITS NETWORKS

A. BOL: ITS ADMINISTRATIVE AND SOCIO-ECONOMIC ASPECTS

In 1962,[1] Bol became the administrative capital of the Prefecture du Lac, a Tchadian state created out of the former District du Lac, the area of southern shores and island archipelago of the Prefecture of Kanem. This newly created prefecture (equivalent of a state) includes two sous-prefectures (an administrative unit below the level of the state). The western half is that of Bol, which contains the Administrative Post (A.P.) of Liwa; the eastern half that of Ngouri including the Administrative Post of Doum-Doum (see Figures 3D-1 and 3D-2).

As a further division, the Prefecture du Lac is composed of 14 cantons (counties) and three groupements (corporation of villages). Bol (sous-prefecture) is composed of seven cantons and the A.P. of Liwa contains three; Ngouri is also composed of seven cantons with the A.P. of Doum-Doum incorporating two cantons and three groupements. See Annex 3A for the list of ethnic groups that comprise Lac Prefecture.

The Prefecture du Lac is administered by a prefet (governor) and his assistant, two sous-prefets, and two Administrative Post Chiefs. Contingents of the National Guard are stationed at Liwa, Bol, Ngouri, and Doum-Doum; police posts are established at Bol, Liwa, and Ngouri; and the customs at Baga-Sola. Various services exist for the population: schools include about 17 grade schools but there are no secondary schools. Health is centered around a hospital in Bol with a French cooperant medical doctor and his Tchadian assistant and several dispensaries in the outlying districts (about 20 male nurses). The Water and Forest Departments are supervised by a chief assisted by guards and some prospectors (for arabic gum). There is a Service de l'Elevage directed by a Chief for l'Elevage,[2] including veterinary services at Bol and at Ngouri. A large government supervised company, SODELAC (Societé de Dévelopment du Lac) has an important involvement in the prefecture related to the agricultural production of the polders. It employs one agency chief at Bol and two chiefs for subagencies in Bol and Ngouri; it also employs a large number of various technical specialists, agriculturalists, monitors, and assistants. It must be noted, however, that most leadership positions in the prefecture, and thus at Bol, are filled by people who are strangers to the region. These people have come from other areas

[1] Edict No. 38/PR issued October 12, 1962.
[2] "Elevage" meaning animal husbandry and health care.

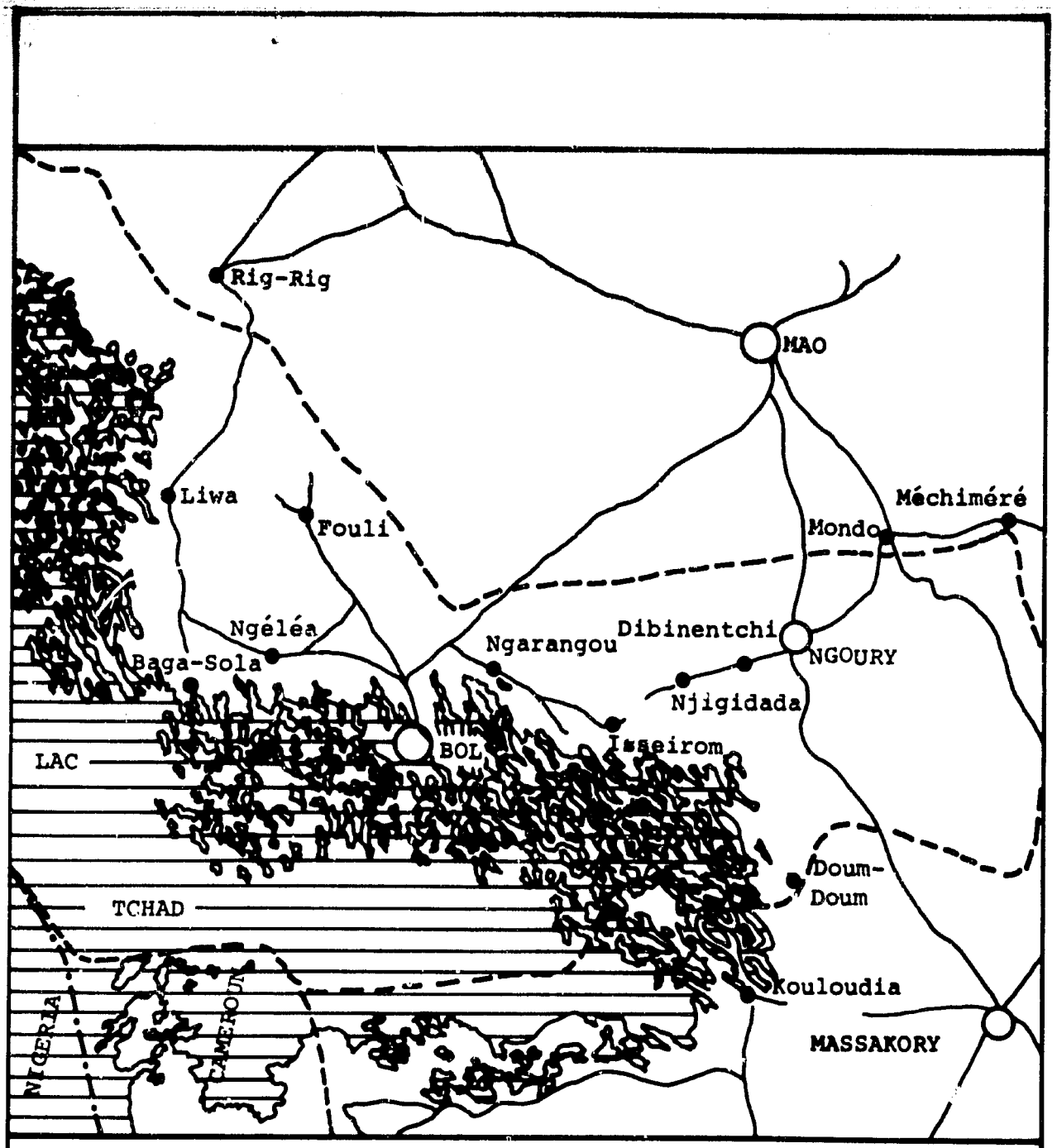

Figure 3D-1
THE PREFECTURE DU LAC AREA
(LAKE CHAD: EASTERN SHORE)

C. Bouquet:1974

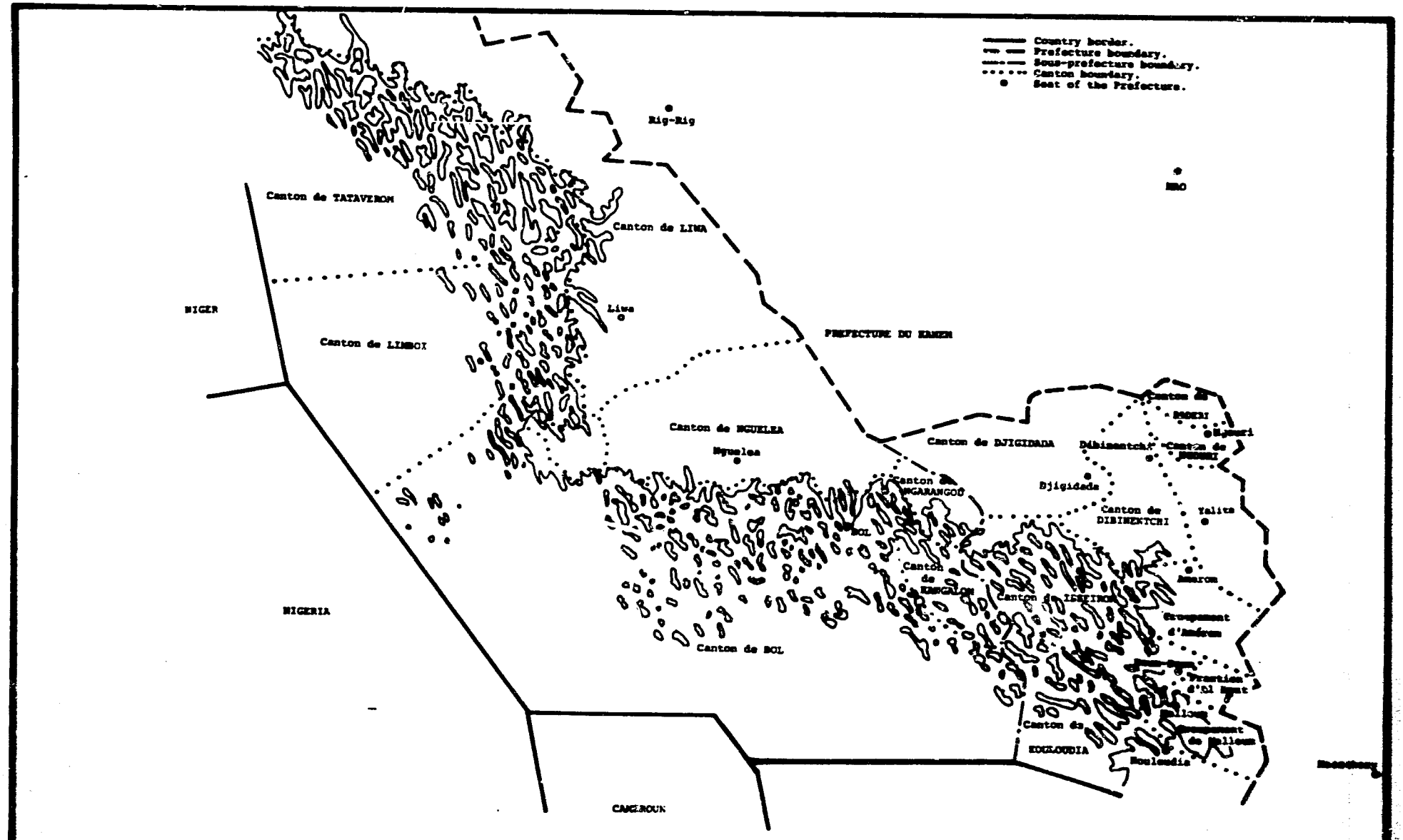

Figure 3D-2
ADMINISTRATIVE DIVISION FOR
THE BOL PREFECTURE

© Bouquet:1974

(80 percent are Sara or Ngambaye) or are foreigners, French cooperants and SCET specialists. Similarly, over 50 percent of the National Guard units are composed of members who came from outside the region.

Altogether, the prefecture appears to have about 175,000 people though accurate figures are not available and censuses are usually biased. The 1968 census indicated 94,738 people but there actually were 116,000 at the time. The number of villagers also vary greatly depending upon which statistical sources one uses. The 1970 census shows 871 villages for the Bol sous-prefecture with 620 being in the cantons of Bol, Nguelea, and Liwa.

Most of the population of the prefecture tends to be sedentary and agricultural with cattle raising. There are also fishermen and traders. People are not afraid to move from their villages, either temporarily so as to fish on the southern shores of the lake or to seek employment on the polders and even in N'Djamena (a minority). In their agricultural enterprises and fishing/cattle raising activities, the people do not hesitate to move, at times over 20 to 30 kilometers, though the average move is about 5 to 8 kilometers. The move is to take advantage of pastoral opportunities, access to new cultivations, or fishing grounds. Thus there is in the prefecture a fairly sedentary and stable population but at the same time a flexible one. The various demographic surveys from the Bol area have also indicated that one deals with a fairly young population. Seventy percent are less than 30 years old and 40 percent less than 40 years old. Men tend to be outnumbered by women at the rate of 100 men to 110 women or more. Most people are employed in a variety of agricultural, pastoral, fishing, and commercial (a minority) activities which permits each to carry out a series of subsidiary activities on the side as well. A farmer will also fish and tend cattle, etc.

The agglomeration of Bol, called by some a town and by others a large village, contains about 3,800 inhabitants. Statistics lists Bol at 4,000, but this number is inflated by counting the nearby villages within the agglomeration. Because it is the prefecture's seat, it differs in appearance from other agglomerations, having a large number of lanes which cut at right angles (a grid system). These are bordered by sun-dried mud-brick buildings (called poto-poto) with inner courtyards in which one finds one or several typical grass huts for women's quarters or for cooking. There are also some larger colonial-type residences surrounded by green trees, such as the Prefet's house. Whereas the town's lanes are narrow, the administrative quarter is well spaced and shaded. Other public buildings include the police station, the sous-prefecture, and the post office. A broad tree-lined avenue

leads south to the harbor with the garage SODELAC nearby. To the east, along the polder of Berim, a large number of round grass huts have been built, breaking off the grid pattern. To the north beyond the market, a series of modern, air-conditioned screened buildings were constructed by the World Bank and today shelter the SCET specialists, and their Tchadian counterparts, who are managing the Guini and Berim Polders for SODELAC.

Aside from its administrative and living quarters, Bol includes a series of shops which are supplied by goods brought across the lake by means of motorized barges, a business which is owned locally. Bol possesses the only gasoline supply in the whole prefecture, shipped by truck from N'Djamena. It boasts one hospital, a veterinary center, a mosque, and a school. By its size, it is really but a large village; due to its administrative and commercial/agricultural activities, it may be called a town. See Annex 3B for details of Bol's wards.

Bol's main problem is its isolation. There is a small air-strip (only 800 m long) on Berim on which small planes can land, but it is insufficient to bring supplies in by air, though it facilitates officials who visit N'Djamena and allows medical emergency cases to be evacuated. There are only two services per week through Air Tchad. The lake also provides a workable link to the outside. However, the many fingers of water which extend between the islands of the archipelago and the peninsulas of the shore are often clogged with both floating and anchored vegetation making access to the open waters difficult. The motor barges follow a canal cut through this vegetation but the canal is often blocked for several days. Finally, there is the road. Large Berliet or Mercedes trucks are used between N'Djamena and Bol, via Massakory and Doum-Doum to transport goods. The problems of truck and road maintenance and the difficulty of keeping schedules are so enormous that much commercial profit is lost in transport.

The two main assets of Bol are (a) its weekly market carried out on the traditional level, and (b) the exploitation of the polders which permits a certain degree of commercialization and provides a labor market for the region. See Annex 3B for further discussion of the market at Bol. The polders and SODELAC will be discussed below.

B. TRADITIONAL SOCIETIES (ETHNIC GROUPS) OF THE BOL REGION

There are four traditional societies of the Prefecture du Lac: the Kanembu who live on shore and along the peninsulas from Ngouri to Liwa and from Ngarangou to Amerom; they include about 30 named clans and originally resided in the region of Mao; the Kuri are island dwellers who occupy the

eastern part of the archipelago; they also include several named clans; the Buduma occuply mostly the islands in the center and western area of the archipelago; they also recognize named clans and are more numberous than the Kuri; the Haddad are not really an ethnic group but rather a social caste of artisans, rendering mostly services to all the groups existing in the region; they have their own communities but speak the language of the people with which they coexist. There are also a few minor ethnic groups represented mostly in Bol, but sometimes in villages. These are: Kanuri, Fulbe (Fulani), Gorane (Toubou), and some Kotoko from the Chari Basin.

In general, these ethnic groups occupy the shorelines, peninsulas, and archipelago islands, and dwell within small villages containing circular huts that dot the landscape at fairly close intervals. Bouquet's several surveys have demonstrated that among the island Buduma and Kuri, half of the villages have less than 52 people and comprise 26 percent of the local population. They also show that 50 percent of the population live in villages of less than 76 inhabitants. On land, among the Kanembu, half of the villages have less than 42 people comprising 22 percent of the local population. Half of the population live in villages of less than 82 inhabitants. Bouquet questions the use of the term "village" because these communities are fairly flexible in their makeup, spliting seasonally when they need to fish, pasture cattle, or send people to work on the polders or ouaddis. Furthermore, with the water of the lake fluctuating, some communities abandon their villages to create new ones or they may split in half when quarrels occur or move altogether when new cultivations are open.

By and large among these ethnic groups, the Kanembu are the more numerous (about twice as many as Buduma) and composed of 34 clans; the Buduma have 7 clans; the Kuri, with 9 clans, are the less numerous, about one-third in number when compared to Buduma. The Haddad, forming but one caste, are only half as numerous as the Buduma or one-quarter as numerous as the Kanembu.

The Kanembu, whose name is derived from Anem (south) and Bou (those from), claim ancestry from Baghdad. They say their clans were established by the sons of a sultan's daughter. They were chased south by northerners and moved close to the islands where they could hide if attacked. They agree that the Buduma already occupied the islands prior to their arrival.

The Kuri claim to be descended from the sons of a Kanembu chief who ran afoul of his father and took refuge in the islands of the eastern archipelago. Thus, they are called Kuri, "those who live in the islands." This accounts for their claim to have originally come from Yemen.

The Buduma, a name which means "those who dwell in the grass," claim to be the original inhabitants of the islands of the archipelago. The original ancestors took refuge on the island to escape the wrath of an irrate husband. Later, he crossed the lake in a calabash and intermarried with the legendary Sao. He then returned to his homeland with cattle and Haddad artisans.

The Haddad, which is derived from Haddid--"iron," have always been a caste of their own, never intermarrying with other people. They are said to be originally from the Fada region and to have accompanied Gorane (Toubou) and Kanembu in their migration. They may have been the first to specialize in fishing on the lake (the Buduma were then strictly cattle herders). They usually take the name of the group to which they render service; i.e., Kanembu Haddad; Buduma Haddad.

These ethnic groups are all now Muslim in religion, the Kanembu being the most faithful. The Buduma, recently converted by the zealous Kanembu, are said not to know the Quran (Koran) well. Islam has an important role in the whole area as witnessed by the established mosques, the role of the marabouts (Muslim Saints), and the influence of Quranic education. Many leave the village to attend Quranic schools at Maiduguri, Nigeria, and some go to the haj (pilgrimage) to Mecca. Most of the festivals celebrated during the year are Islamic. However, many traditional beliefs are still followed: there are sacred trees, fetishism is practiced, and so are exorcism and divination.

All Kanembu tend to speak the same language, follow the same customs, and practice the same activites. They built their village on top of sand dunes to avoid the lower areas because of mosquitos and practice agriculture within the periphery of the village or in the depressions of the sand dunes (ouaddis). Penicillum millet is their favorite crop, along with sorghum and corn. They plant these on the dunes near the huts and they irrigate the depression by means of the "chadouf," a structure which permits one to draw water from the ground and disperse it through shallow channels to the prepared squares of cultivation. There he cultivates corn, wheat, vegetables, and sometimes fruit trees. They practice a sedentary form of cattle raising, their small herds being used to fertilize the sand dunes in preparation for the millet planting at the beginning of the rains.

The Haddad have no language of their own, though some contend they do sometimes use a northern dialect among them, but speak the language of the group they serve. They live on the margin of the Kanembu society, each group being recognized as to its particular occupation. They are said to form 40 such occupational clans consisting of iron-working, weaving, leather

working, tanning hides, making baskets, extracting the natron (natural salt), and other such servile and otherwise despised activities. They never intermarry with other groups, but only among themselves. This is contrary to the Kanembu who will intermarry readily with Buduma, Kuri, Toubou, and arabs.

The Haddad are the only ones who practice hunting. They are also said to have been the traditional fishermen, this activity having now been usurped by the Buduma. It is the Haddad who are called to circumcize Kanembu and Buduma young boys during their initiations.

The Buduma, differing from Kanembu by their height and darkness of skin, have traditionally been cattle herders on the islands. Their ancestors despised fishing but recently have turned towards fishing activities. This came after the disaster of 1962 when half of their islands were submerged by the rising water of the lake and they lost a considerable amount of cattle pastures. They build their villages on the heights of the islands and move their cattle about in small groups from island to island along traditional pastures. Each clan owns rights on specific islands. They also cultivate millet and corn but today emphasize fishing, drying, and smoking their catches for illegal export to Nigeria.

The Kuri, who speak the same language as the Buduma, an Afro-asiatic group, are also cultivators and cattle herders. But they are far more sedentarized than their neighbors because their islands are not affected by the lake's fluctuation and because some reside on the peninsulas. They built their villages at the top of the islands where they cultivate millet, wheat, corn, and some vegetables. They also practice some fishing. Kuri and Buduma will readily intermarry as well as with Kanembu and arabs. It must be noted that often in the villages the husband will be Kanembu and have one Buduma wife and a Kuri wife; or a Buduma husband may have a Kanembu wife. The children follow their father's ethnic group.

Because these four ethnic groups have lived together and/or in proximity of each other so long, they have adopted similar, if not the same, customary practices. Thus whether one be among Buduma or Kanembu, Kuri or Haddad, he observes exactly the same kind of constructions, village agglomerations, garments, and festivals. As a result, one may generalize about their social and structural arrangements.

Villages consist of as little as 5 or 6 conical huts to as many as 50 or 60. There is no real order as to where one builds his hut, but all huts face west. In the past, there used to be a certain order within each compound as to the location of the male, female, cooking huts, but no longer. Even compounds are hard to distinguish. Thus a village

appears as a loose clustering of huts, with an open area somewhere within the village square. A mosque, constructed under a tree, is a simple fence enclosure made of doum palms. Nearby is a rectangular structure covered by a thatch roof, but without walls, which is the public meeting place where men discuss and pray. If the village is important, it will boast a small market on its outskirts.

The family group lives within a compound called fado. The compound takes the shape its builder fancies. However, customs require that a man's first wife must build her hut to the north of the family head and each following wife to build in line to the south of this first hut. The huts vary between 3 to 5 meters in diameter. There are no cooking huts or graneries as those are left in the fields.

The village is built in a customary location. When a new village is to be built, a location is chosen prior to requesting the approval of the Chef-de-Canton.

Families usually consist of a man and his wife (wives), their children (there can be four to seven), sometimes an oldster or a widow, and at times a visiting stranger (usually a man). Thus, statistically, families vary in size between 2.3 and 5.6, the mean being about 4.2.

One marries either within or outside of one's village, there are no strict rules, but a wife always comes to live in her husband's village and compound. The children receive their status from their father because their mothers may be from different ethnic groups. One chooses his wife preferably from among the daughters of an uncle, either paternal or maternal. A usual Islamic practice is to keep inheritance within the family group. It is often one's father who selects the first wife for his son. Among Kanembu and Haddad, a bride-wealth, given to the girl's family, consists of between CFA 5,000 to 50,000. Whereas among Kuri and Buduma, the bride-wealth varies between CFA 30,000 and 200,000, the Kuri being lower than Buduma. Women among Buduma are considered a wealth. They work hard and often replace Haddads in their occupational roles; thus the bride-wealth is high. Furthermore, a young man seeking a bride (the young man averages 20 years--the girl about 12 to 13) must enter in competition with other suitors who might produce a larger bride-wealth. Usually this is paid in money, but at times either gold or cattle may be used. Note that divorce is both easy and frequent. Yet, polygamous practices tend to stabilize marriages (it is costly to divorce). There are about 20 divorces to each 100 marriages.

Villages are usually composed of the same ethnic group in terms of the males though their wives may be from several

ethnic groups. When there are several ethnic groups represented, the village chief, selected for each village by the Chief-of-Canton from among the chiefly clan, is their representative. If the village is a large one, there may be chiefs of wards, each ward representing an ethnic group.

The village chief is assisted by his village council, composed of the major family heads and advised by a marabout (Islamic holy man) if there is one in residence. Each family group within the village is controlled by the family head, usually the oldest man within the family group. Such groups may be large if the family is poor for a married son will then live within his father's compound, always a cause for tension between the generations.

The village chief is responsible to the canton's administration for his village. He must collect the taxes, CFA 1,000 for each adult over 15 years of age, and remit these to the Chief-of-Canton. The chief must be wealthier than most villagers for he needs to pay the tax for those who cannot afford to do so. He also settles village disputes and distributes the land. It is his duty to inform the villagers about any administrative decisions.

The Chief-of-Canton is a traditional administrative officer who answers directly to the sous-prefet. It is he who decides who may pasture cattle where and cultivate which land in the canton, either on polders or in ouaddis. He has the responsibility to collect taxes from the village chiefs, calls them into councils, and applies customary law.

The Chief-of-Canton holds court in the same manner as that of the former sultans. He is advised by marabouts, important men, and has a body guard. The marabouts play an important role because they are the Quranic experts: they teach maraboutic schools and officiate at religious ceremonies; they practice divination and provide amulets (gris-gris); they act as medical healers; and they function as judicial officers. They also assist the sous-prefet in assessing land.

The sous-prefet is an administrative officer appointed by the central government. He acts as justice of the peace and he must be able to decide on cases through either customary law or codified law. He assesses the land with the help of several assessors and has a municipal guard (goumiers) who can enforce his decisions. Within the sous-prefecture, he arbitrates all divorce cases, litigations with regard to debts or land disputes, rights of succession within families, and he deals with theft of cattle and fights, crimes, and frauds. He is responsible to the prefet who has final authority and represents the central government.

Because Kanembu and Buduma have a tradition of being warriors (raiders for cattle) as well as cultivators, the ideas held by villagers are those of honor; be a good warrior; cultivate millet with care; raise beautiful horses (men); and women must be good housewives. These values place these groups hierarchically above the Haddad who are service castes. Since these populations are Islamic, most of the virtues advocated by the Quran are held in high esteem and the marabouts have much clout.

A final note needs to be given. All villagers, aside from the municipal tax, pay "redevances" (dues). These must be paid to the village chiefs, to the Chief-of-Canton, and to the marabouts. There are two kinds of dues: the dues owed by the administered to his chief, and the dues owed by the cultivators to the owner of his land.

The Zakka is a Quranic dues. Usual payment is one-tenth of the family harvest to the marabouts. This must be added the sadaka--almsgiving--a sum paid to the Mai (Chef-de-Canton) in protection for the poor.

Other payments include the "moud" (related to millet fields on the dunes) and the "kiski" (related to cultivation in the ouaddis or polders). These consist of paying 6 zacca (or koro = 2.5 kilograms per zacca) of millet per adult. Since wheat and corn are also harvested, one may have to pay the moud or kiski as many as three times a year (once per each harvest).

The cultivating practices and cattle herding pattern of these ethnic groups will be discussed in later sections.

III. THE PRESENT SITUATION ON THE POLDER PROJECT

A. THE HISTORY OF WHEAT CULTIVATION ON THE POLDERS OF LAKE TCHAD

Wheat cultivation around Lake Tchad is not new. Beginning in the late 1800's, when wheat had been introduced from the Fezzan, it has been cultivated within ouaddis (fertile depressions between sand dunes which have ceased to receive water from the lake) by the local populations. They discovered that the many finger-shaped bodies of water running between sand dunes and islands could be isolated from the lake by simple earthen dike construction. When dried up for cultivation, the local inhabitants created polders, the first being the Souya and Bilidoa basins.

By 1924 they had errected a large number of earthen dikes and by 1950 about 30 polders were existing with cultivation of 1,500 ha. The traditional dikes were constructed by

setting two rows of wooden posts in the ground, interweaving doum palm fronds, and adding sand between the rows of posts. The flimsy structures, however, did neither withstand the fluctuation of the lake nor the forrays of hippopotami. In 1950 the water level rose and destroyed almost all dikes, leaving only 200 ha to cultivation. From this period onward, the colonial administration, and later the Tchadian Government, stepped in to both develop and improve this imaginative method of cultivating wheat. Annex 3C details the traditional method used to cultivate the polders.

Bouquet (1974) summarizes the developments which led to the present concept of commercial agriculture on the Lake Tchad polders. The establishment of SEMABLE--Secteur Experimental de Modernization Agricole du Blé--in 1961 created a monopoly on purchase and sale of wheat. This agency was replaced in 1967 by SODELAC--Societé pour le Development du Lac. Bouquet demonstrates that from the time when polders were first constructed by means of traditional methods to the present, there has been a constant acceleration in the number of polder areas isolated from the lake. But, there has been a very slow increase in the areas actually made ready for cultivation. Furthermore, even though crop production increased steadily, neither SEMABLE nor SODELAC could compete with the traditional wheat market between the polder cultivators and the Libyan/Fezzanese traders who purchased wheat and millet at a much higher price. In spite of having a monopoly on the purchase and sale, SODELAC is still meeting some resistance due to the power of the now illegal traditional market.

B. SODELAC AND SCET

SODELAC, constituted in 1967 to replace SEMABLE, is a small corporation which is owned by the government and has been given the responsibility to oversee the development of the Lake region. One of its activities is to direct the commercialization of wheat and other crop productions on the polders of Lake Tchad. It was organized as an agency with a P.D.G. (President-Directeur-General) or managerial director at its head. He acts in behalf of the Bol sous-prefecture but resides in N'Djamena. He is assisted by a technical director (also at N'Djamena), an agency chief at Bol, and two subagency chiefs who provide regional supervision. Furthermore, SODELAC uses agricultural and technical agents for the polder cultivation. Within the plots open to agricultural use, there are monitors to advise the farmers and supervisors in the field to watch over the farmer's planting and harvesting. They weigh the harvested products for SODELAC and keep tally of each farmer's yield. This type of monitoring and supervision is modeled upon the French system of developing "Cadres" (i.e., technical leaders and/or supervisory assistants). SODELAC is financed by government funds and partly by minority stockholders.

The SODELAC "PROJECT" was constituted when the U. S., French, World Bank, and Arab loans were established to develop the polders in the Lake Tchad region. It aimed at isolating 3,000 ha of land from the lake and irrigating it by modern technological means at the estimated cost of about $12 million (U. S.). Three polders close to Bol were initially selected:[1] Guini, 320 ha; Berim, 1,000 ha; and Mamdi, 2,000 ha.

To accomplish this purpose, SODELAC selected the French International Company (SCET--Societé Centrale pour l'Equipement du Territoire, International). The project, though operating under the directorship of the agency, is almost entirely manned by French specialists. It has a director assisted by a number of highly skilled technological specialists. Tchadians are on the project as counterpart to the French. They will take over operation of the project once the technical aspect is completed and the contract with SCET fulfilled.

The SODELAC Project, aside from preparing the polders for cultivation, diking, draining, and irrigating, is also experimenting with irrigation techniques and with various crops. The traditional mode of irrigation by means of the native chadouf is being eliminated because salinity in the water would cause eventual damages to the crops. Such water salinity would eventually "natronize" (i.e., deposit a natron film on the soil) the cultivated area. To remedy this problem, the project will bring lake water with minimal salinity by means of gravity canals. To avoid salinity deposits, the project will use pumps to drain the polders. The traditional method was to dry the polders by simple evaporation, leaving a film of natron. Because of the rich organic content of the soil, no fertilizers are presently being used though some may be needed within the next 5 years.

The commerical crops grown on the polders are mostly cotton, wheat, potatoes, and corn. At the experimental level, such products as hops, peanuts, vegetables of all kinds, and fruits are being investigated in the hope of later commercial development.

For a calendar of crop rotation on the polders as compared to the traditional agricultural calendar of the local population, see Annex 3C.

C. MATAFO EXPERIMENTAL STATION AND THE PILOT PEASANT PROJECT -

The Matafo experimental station, established in 1970 on the Polder of Guini (6 km north of Bol), was created to conduct tests on the feasibility and yields of polder agriculture and

[1] A fourth one, Tandal, is the subject of this report.

to gather facts about the human, economic, and agricultural factors related to the crops being produced. Experiments with a variety of crops under varying conditions are being conducted to create a credibility study.

The station is directed by a project chief from SCET, assisted by a deputy and his Tchadian counterpart, with farming and garage managers. Attached to the project are two Peace Corps volunteers experimenting with various species of trees to be used as windbreaks. There are also several workshops for carpentry and reinforced steel for concrete structures. This project is jointly financed through SCET, FAC, and USAID.

Aside from experiments in irrigation practices, brush and weed removal, fertilizer use, bird control, crop yields, etc., the most important aspect of the project has been its experimenting with "pilot-peasants." It was initiated to determine to what extent and under what conditions the farmers would work with new and old crops using innovative techniques. The farm manager trains and guides these farmers (pilot-peasants) in new modes of cultivation. The farmers are given a plot of irrigated land to cultivate a given crop and promise to give 25 percent of his harvest yield to the experimental station. Note that the traditional system was for a farmer to pay dues to a landowner for the use of the cultivated plot.

By and large the experiment attracted many farmers who established themselves at Matafo or at Lafia Kafia, thereby creating large villages composed of several ethnic groups (i.e., Matafo with Kanembu, Arabs, Kuri, and Bornu, the village chief is an Arab from Djimtilo). People came from as far away as Nguelea and Mao to participate on the project. The cadre for the project are people from the south. These farmers have shown more willingness to use modern methods in the sowing and harvesting of cotton (a new crop to the region) than to wheat or corn, their traditional crop. Potatoes have been grown since 1967 and are presently quite successful. Today, the experimental methods have been extended to other parts of the polder. In 1972 plots were distributed to 35 farmers over 26 ha; today 144 farmers are working 90 ha (Mahmat Doungous, personal communication). Pending the opening of another hundred hectares or so in June, 800 applicants have volunteered to participate on the Guini project (George Badot, personal communication).

However, some problems have arisen. In spite of a good yield in crops, farmers have twice recently gone on strike. The causes apparently relate to the fact that after working hard at the harvests, SODELAC was very slow in paying them. Consequently, the French technicians who administer the farm have

taken the blame. Similarly, the project workers (manoeuvres) also went on strike recently. This brought about an intervention of the sous-prefet, the police chief, and the project supervisors. It is hoped that such current problems will be resolved satisfactorily for the project to continue successfully. The pilot-peasants must be trained with an eye toward transmitting their knowledge to other farmers and to stand as an example to traditional farmers as to what modern methods may yield in the future.

D. SOME SOCIO-ECONOMIC CONSIDERATIONS IN TERMS OF THE PRESENT INFRASTRUCTURE

SODELAC as an Agency and as a Project is a sound concept but the application of the principles involved may fall short of the ideal situation. Commercial concern, government owned or otherwise, given a monopoly over both the production and the sale of a product is bound to encounter disfavor. The human factors attached to such an enterprise, as well as the many technical difficulties, are bound to create friction and distrust by everyone. Neither the Agency nor the Project have escaped these pitfalls. The stress and strain of the operation, therefore, have created at times serious setbacks in production and distribution of the products as well as in the timetable set by the corporation.

One of the most crucial problems is that of resolving the distribution of the products once they have been harvested. Transportation by road with a limited number of supply trucks and along a badly maintained sand track between Massakory and Bol poses serious problems. Likewise, water-borne transport along a narrow canal which constantly needs dredging and is clogged for days at a time with fast growing aquatic vegetation poses similar serious problems for perishable goods. Potatoes and vegetables must reach market in time to be sold prior to their spoiling. Also, they must be removed from the harvest field on schedule or they may stand under the hot sun for several days. In a commercial enterprise with an eye to profit, such setbacks can be costly.

Another factor affecting the operation is the sensitive area of human relations. Here, an operation under government sponsorship is making use of foreign expertise and agricultural leaders from distant Tchadian prefectures. Both the differing language barriers and conceptual frameworks tend to create obstacles in the mind and in the behavior of those who interact together. Such human parameters need to be analyzed carefully for the group dynamics to function smoothly. It is important that proper means of communication between all concerned be established for the project to operate smoothly. These human parameters can be costly to a profit making corporation if they are not resolved in common understanding.

A final aspect with respect to human relationships is that of the common use of field supervisors (moniteurs) who are working with the farmers on their plots. This practice has been strongly censured by S. P. Reyna (1964) in his report to USAID. It must be considered that such an overseeing function may lead to more inefficiency than to constructive practices as it engenders repressive attitudes in the mind of those who are overseen. It is hoped that field supervisors may be carefully trained in a manner that they will not develop into "moniteurs" in the sense of the Reyna report.

IV. THE SOCIO-DEMOGRAPHIC STUDY AND FIELD SURVEY AT BOL AND AROUND TANDAL

A. THE FEASIBILITY STUDIES

A series of field studies were carried out, under SODELAC and the University of Tchad sponsorship, in 1977 prior to the arrival of the CH2M HILL team (Wilcox at Matafo;[1] Bouquet on Berim, Guini, Mamdi). The following summary is drawn from the yet unpublished materials (Bouquet 1977, manuscripts) relating to these field studies.

A first study surveyed the villages included in the Cantons of Isseirom, Ngarengu, and Nguelea (Figure 3D-2: Administrative Divisions for the Bol Prefecture) with an eye to evaluate which percentage of their population might be attracted to work on the polders near Bol (Guini, Berim, Mamdi). It was reported that Isseirom already owned 9 traditional polders whereas Ngarengu 3 and Nguelea 11. Farmers living on the mainland appeared more interested to participate on polder cultivation than do people living on the islands. Thus, among Kanembu in Isseirom, 97 percent of the mainland population farms on polders whereas only 30 percent of the island population does so; they travel as much as 6.1 km to do so on the mainland and 10.2 km in the islands. Among the Kuri, 100 percent of the shore dwellers participate in polder cultivations traveling 2.8 km to reach them; on the islands, 40 percent of the population does so, traveling 8 km to reach them. Of the Haddad population, 60 percent participate in cultivation traveling 2.7 km to reach their polders. A similar ratio can be seen for the two other cantons, but with some variance in Nguelea where a large number of ouaddis are also cultivated traditionally. One notes, however, that the large polder of Tchingam has attracted many farmers, even though it is now becoming saline and is ready to be voluntarily reflooded for a period of years. This study also indicates that in many cases, farmers work on several traditional polders simultaneously. Some

[1] Though several references were made in conversation about Mrs. Wilcox (an American Sociologist) by people in Bol and in N'Djamena, no institutions or individuals possessed a copy of the results of her work.

abandoned ouaddi cultivation to do so, moving between 6 km to 20 km away to participate on polder cultivation.

The conclusions drawn from the study emphasize that: (a) When a polder is available within less than 10 to 12 km of the surrounding villages, farmers are willing to commute daily to work on the polder. During harvest, they camp on the polder's rim for up to 10 days at a time and their own villages remain undisturbed. When polders are more distant, they may come and camp longer, from planting to harvest, leaving their cattle to be kept by relatives who remained in the village. At times, though, farmers bring their own cattle with them. All farmers return, however, once a week to their village to participate in the weekly market. It would, therefore, be possible that such polders as Guini, Berim, and Mamdi would attract a fair number of cultivators from a reasonable distance (b) In spite of the fact that some Kuri have participated in traditional dike constructions to isolate polders, it is by and large the Kanembu who are most interested in polder cultivation and generally better at it. (c) Some cultivators (in Nguelea) indicated a willingness to abandon their inland ouaddis in favor of riverine polders. (d) The need for space to allow for cattle grazing and millet cultivation on the dunes was ennunciated. When new villages are established around a newly opened polder, there is a need to space them in a manner to allow for sufficient pastures and millet fields to which the farmers are both necessarily and emotionally attached. (e) There were some problems mentioned, including: that of the traditional dues paid to village chiefs (6 koro of grain per harvest per family head, 4 koro to be paid to the canton chief, and 2 koro to the village chief; if the harvest is poor, the farmer needs to borrow money to fulfill his obligations; and over and above this, the Quranic tithe (Sadøka), prescribed by the marabouts and levied by the Chef-de-Canton, to care for the poor, takes away one-tenth of a harvest per individual. In this manner, traditional chiefdoms may, by insisting on revenue payment, dampen the enthusiasm of farmers working on polders.

The second study seeks to document the behavior and attitude of the farmers cultivating the polders around Bol (Guini and Berim). The field work was carried out within 14 villages with samples of 503 family heads accounting for 2,423 people located on the rims of Guini and Berim Polders. These villages are almost entirely Kanembu though a strong minority of Kuri and Buduma are found at Matafo, the old pioneer village for the Guini Polder. Bol-Guini boasts a few Gorane (Toubou) who migrated there from South Kanem during the 1973 drought. When one looks at the average age for family heads, one is surprised to find only one-third are less than 30 years of age and another one-third between 40 and 60. This is important

to remember if modern innovations in agriculture are introduced. In relation to ownership, Kanembu own more land (polder and dunes) than Buduma but Buduma own more cattle, about 8.5 head per family head. In comparing the land/cattle ownership to the family size, one notes that the larger the family, the more work one can furnish. A family head with three wives cultivates 2.32 ha and owns 13.6 cattle, and he may have between 8 to 10 children.

Two salient features are emphasized: (a) All family heads (100 percent) cultivate a millet field on the dunes during the rains; and (b) 63 percent of the family heads (farmers) own cattle and must have pastures available around the villages. The question of space is therefore crucial. Since it is necessary to live close to one's field, once modern irrigation is introduced, one needs to establish the ratio between villages, millet fields, and pastures prior to expecting success on the polders. Some villages (like Lafia Kafia) own over 900 head of cattle which are brought back to the village every night, even though 31.6 percent of them graze seasonally 10 km away from the village. Furthermore, to own cattle is proven a necessity to those farmers who cultivate millet on the dunes since cattle dung is the fertilizing agent.

In regard to whether or not there are enough people to profitably cultivate the three polders, the author hypothesizes that it might be well to attract Kanembu from South Kanem to move towards the polders. Emphasis is placed on the fact that Kanembu populations are flexible and do not hesitate to migrate; 30 percent of the villagers were born in the village; 36 percent born in the canton where the village is located; and 34 percent have come from another canton.

Finally, it is pointed out that all farmers on the polders also have subsidiary activities. They are also marabouts, fishermen, day laborers, cattle herders, etc. Village chiefs and marabouts tend to be older than fishermen and day laborers and the village chiefs have more wives and cultivate more than the average farmer. Fishermen and day laborers own small plots on the polders and have very few cattle. Thus, revenues derived from a subsidiary occupation are at a subsistence level, not for a profit.

The last study addresses the rate of emmigration for the Bol Prefecture population. The purpose of the study was to evaluate the rate of traditional migration, such as: Kanembu who move to attend Quranic School at Maidugiri, or Buduma who move to the western shores during the dry season to fish in open waters and sell their products to Nigeria. This is in contrast to that of accidental migration such as those who left because of the drought to look for pastures elsewhere or salaried work in towns. There is a flow of younger people

moving towards the Nigerian and Camerounian side of the lake. The study revealed that about 100 young people between 15 to 25 years old move yearly for religious studies. There are also now about 1,500 Tchadian Buduma established permanently between Malam-Fatori and Mulgo where they smoke fish and sell it commercially. Some return to Tchad with money they will use as bride-wealth or to buy a few head of cattle. The study of Kanembu who left during the drought to seek pasture in Nigeria and in Niger was inconclusive. Of 700 to 800 young Kanembu who left to seek salaried work, within a 2-year period, about 40 percent eventually returned to Tchad. It would appear that the Nigerian region attracts newcomers. Furthermore, the large-scale irrigation projects being prepared at Baga Kawa (20,000 ha) and New Marte (55,000 ha) is also a strong factor in drawing young people towards an attractive pay.

The CH2M HILL socio-demographic study in the region of Bol and Tandal basin is similar to the field studies carried out in 1977. The procedures used have been reported in Annex 3D, with the data analyzed and categorized in the same annex.

B. THE SURVEY AT BOL

The CH2M HILL team sent an enqueteur (data collector) to Bol with questionnaires to sample each block (about 86) of the town. Within each block one family head was selected to answer the questions. The sample of population surveyed was in the order of one-eighth (462) of the total Bol population (about 3,800). The questions asked related to: (a) statistics bearing upon the composition, age, and activities of the family groups; (b) the permanance and origin of the family; (c) the attitude of these family heads in regard to participating in the cultivation of Tandal basin if it were to be prepared as a polder and their preferences as to what they would prefer to cultivate; and (d) what advantages and inconveniences they would anticipate if Tandal was made a polder. The range of answers were either manually sorted or entered into the computer for statistical breakdowns. See Annex 3D for details of the methodology and data procedures. An analysis of the data provides the following information.

The Bol population, estimated to be 3,800 people, is a heterogeneous one, represented by about 50 percent Kanembu, 19 percent Kanuri, 15 percent Buduma, 3 percent Kuri, 3 percent Fulbe, 6 percent Kotoko, and only 3 percent of other ethnic groups from Tchad (exclusive of the administration). Thus numerically, local people still predominate, and the impact of other groups are still slight. As has been noted above, the impact from outside groups is being felt mostly through the administrative structure of the prefecture.

Family statistics are average for the region: men have 1.0 wife, 2.6 children, and the family totals 4.6. On the average, the family heads have resided for 22.7 years in Bol, cultivates 82.5 ares (100 ares = 1 ha), and the millet fields on the dunes are more important than the polder plots and they have a small subsidiary garden on the edge of the water. The average family owns 4.1 cattle which are sent to distant pastures. About 51 percent of them own a polder plot and 44 percent of those who do would not abandon them if Tandal Polder were available. If Tandal is made into a polder, 98 percent of them would volunteer for a plot; 100 percent would grow corn, 97 percent would also favor wheat, and 68 percent might consider cotton.

To the Bol villagers, cotton appears to be the most time consuming in its care, and they are familiar with wheat and corn. Their feelings are mixed as to whether or not they would abandon the millet cultivation. But, on the whole, more would than would not. However, if they were permitted to grow sorghum on the new polder, 75 percent would drop their millet field on the dune. As for the cattle, about 50 percent might accept feeding them fodder from polder cultivation rather than let them pasture in the fields.

The cause of mobility (moving to Bol or leaving it) is usually related to seeking employment on the polders or to work for wages. As a subsidiary crop, Bol farmers tend to favor either potatoes or gombo. They usually refuse to discuss the advantages or disadvantages that Tandal would bring as a polder.

Thus, it appears that at Bol the heterogeneity of the population causes it to be more innovative and possibly more ambitious than in the villages. However, since most are local people, a strong traditional orientation is still present regarding what to farm and how to farm it and about keeping millet and cattle as social security. Yet money and wages have an attraction, and generally people would welcome Tandal to be open as a polder.

For the most part, the modern and urban aspects of Bol are strictly related to administrative and a few commercial enterprises. But, people remain agricultural villagers at heart.

C. SURVEY OF THE VILLAGES EAST OF TANDAL (ZONE B)

A series of villages lie to the east of the Tandal Basin on top of the sand dunes. From north to south they are: Matafo 3 (population 176); Matafo 2 (population 276); Matafo 1 (population 451); Bol-Fartchari (population 115); Tchaitchairom (population 102); and Bol-Tandal (population (77). These villages already participate in polder cultivation on

the Guini Polder which is adjacent to the west. The CH2M HILL team sent several enquêteurs, with questionnaires, to personally interview each family head. The team leaders visited the village chiefs to inform them of the purpose of the survey. Altogether, 248 family heads were consulted, their average age being 36.9, fairly old as local standards go.

A number of questions similar to those asked in Bol were asked of them. The information is important since, if Tandal Basin becomes cultivated, they will have to decide on which polder to work.

Though the majority of the villagers are Kanembu, each village (except for Tchaitchairom which is exclusively Kanembu) also has another ethnic minority. There are 6 percent Buduma at Matafo 2 and Bol-Tandal; 20, 10, and 28 percent Kanuri at Matafo 3, 2, 1, respectively; and 13 percent Haddad at Matafo 1. This distribution reflects the general pattern for ethnic groups in the region; Kanembu on the peninsulas, Buduma on the islands. It also emphasizes the nature of Matafo villages which were pioneers in working experimentally on the polders (Kanuri came from afar).

Family heads tend to have either one or two wives (average 1.1), two or three children (average 2.2), and belong to families of three to six members (average 4.3). However, families may actually have children away with the cattle in distant pastures during the dry season and these were not always reported to the enquêteurs. In regard to people's stability, these villages indicate that they are recently established in the region, probably since the polders were first put into cultivation. The average time of the family head in the village is 17.9 years. Each family tends to cultivate a total of 182.5 ares (1.825 ha) with the millet field on the dune being larger in area than their polder holdings. They own about 5.2 cattle per family with a variation from 2.2 to 11.9.

In relation to Tandal Basin, they wish to cultivate about twice as much as they cultivate now. This may reflect an ambition to earn more money but may not be realistic in view of the size of their families and the fact that they wish to retain their present holdings as well. A large majority of them would prefer to work on Tandal rather than Mamdi if both were to be cultivated. Similarly to the people in Bol, corn is preferred to wheat which is preferred to cotton. This reflects their experience with crops on the present polders--cotton demands more work and sells for less.

They are evenly split (50 percent to 50 percent) concerning abandoning the millet cultivation on the dunes. If they

were given leeway to cultivate sorghum on the polder, 69 percent would forego their millet fields. However, a large majority of them would prefer to continue to pasture their cattle on the dunes rather than to feed them fodder cultivated on the polders. Most people (85.2 percent) who moved into the area have come specifically to work on the polders. As a secondary crop, they prefer to raise gombo (though potato is favored as well due to their recent experience with an unusual harvest).

As for the advantages and inconveniences of Tandal Basin being open to cultivation, they emphasize that it would bring them additional cash and that they already cultivate gardens on the edges of the basin. However, they fear that it will restrict their fishing activities, curtail water for cattle, and are worried about being pressed into labor to construct the dikes. They also fear that cattle thieves will increase with better access to the fields due to the dikes.

D. SURVEY OF THE ISLAND VILLAGES WEST AND SOUTH OF TANDAL (ZONE C)

The Tandal Basin is bordered to the west by a series of islands. These are, north to south; Somi, Ika, and Tandal (across from Bol). Further to the south are Koremirom and Yakoua. The villages surveyed on these islands were Somi 1 and Somi 2, Ika 1 and Ika 2, Tandal, Koremirom 1 and 2, Gambaru, and Kudubul. Villagers in Kudubul, who refused to answer to the enquêteurs, are Kanembu who split away from Bol-Guini in a quarrel with the village chief. The split into No. 1 and No. 2 in some villages is a reflection of the fact that Kanembu people are slowly migrating south towards the islands and among the Buduma.

The island villages have smaller populations than those on the dunes east of Tandal with 112 family heads representing 536 people in 8 villages. The family heads tend to be slightly older than those of Zone B--average 38.5 years. The ethnic groups are distributed at a ratio of 38 percent Kanembu, 49 percent Buduma, 13 percent Kuri, and no Haddad. Families are of the same size and composition as those examined in Zone B, but the population is more permanent. The family heads have resided in their own villages for an average of 26.8 years. Iga I, a new Kanembu village, has a residence average of 8.4 years. Kudubul, also Kanembu, was created 5 years ago.

The islanders are traditional cultivators and till an average of 207.5 ares (8.3 ha) per family, their millet dune fields being twice as important as their gardens on the edge of the basin. Their polder holdings are usually minimal. This is a reflection of the fair number of cattle owned (average 5.5 per family) and used to fertilize their millet field.

In regard to Tandal Basin becoming cultivatable, they wish to obtain almost four times as much polder land as they now traditionally cultivate. This is a reflection of their inexperience with polder cultivation which they usually forego to either tend cattle or fish. They indicate they would not abandon their present holdings on polders, but one must consider that 62 percent of them do not have any now. Aside from Gambaru, on Yakoua Island adjacent to Mamdi, they would favor working on Tandal which is next door to them. As for the commercial crop, they would prefer corn first followed by wheat and then cotton. They decidedly would not forego their millet fields on the dunes; but if sorghum could be grown on the polder, they might relent. Few are interested in fodder to feed their cattle as they prefer grazing them on island pastures.

Among people who leave the villages, the reasons are participation in polder cultivation, fishing, and to look for new pastures. The subsidiary crop they prefer to raise is emphatically the gombo, then the potato, pimentos, and vegetables. As for advantages they see in Tandal Basin being cultivated, they see it as a means to earn lots of money, obtain good moist land, take advantage of a nearby opportunity, prove that Buduma can be good cultivators, and to lift the standard of the villages. They, however, fear the loss of fish.

E. CONCLUSIONS FROM THE VILLAGE SURVEYS

Based upon the survey results, several conclusions can be drawn about cultivating Tandal Polder:

1. It is towards the Kanembu (and a few Haddad and Kuri) that one must turn to find cultivators for the polders. They view polder work as a means to obtain cash which otherwise is very scarce.

2. The Buduma, though not disinterested in the polders, are really too occupied with their cattle, traditional cultivations, and in fishing to be depended upon as a source of labor in the polders. By drying and smoking fish, they readily obtain cash through its illegal exportation to Nigeria.

3. Both main ethnic groups, Kanembu and Buduma, prove to be flexible in their activity behavior. Kanembu do not hesitate to move temporarily or even permanently to seek new opportunities in cultivating polders. The Buduma, who were mostly cattle herders, have proven flexible when they turned towards fishing activities after the disaster of 1962. However, this flexibility is restricted to specific opportunities.

4. In their carefully balanced mode of adaptation through agriculture/cattle herding/fishing, these local groups show both intelligence and sensitivity to their environment and circumstances by living on an adequate subsistence basis and being generally self-sufficient.

5. The fact that all groups still strongly emphasize their attachment to both millet cultivation and cattle herding on pastures is indicative of a possible barrier to change. This area is filled with emotion and, as in the study made on cattle herders of the Sahelian zone in Tchad,[1] it is feared that any attempt at modernization in this sphere would hit against a solid wall.

6. The size of the families and cultivations already engaged into would indicate that a new polder could be opened up to cultivation with a certain amount of success as the desire is certainly present. But, one needs to be cautious about going too fast in this endeavor. Both the Chef-de-Canton for Bol and for Nguelea assured the CH2M HILL team leaders that there would be enough villagers interested in work on a new polder and willingness to move there. They, however, cautioned that because other traditional polders were in cultivation to the east and west, only those villagers within a radius of about 20 km would participate. The opening of two polders at the same time (i.e., Tandal and Mamdi) might prove catastrophic population wise because it would put too much pressure on too few people.

7. The order of choice of commercial crops that the villagers wish to cultivate indicates that they are not yet ready to readily use modern methods of cultivation. Corn is preferred, followed by wheat and then cotton, with a strong orientation towards gombo as a subsidiary. They prefer to deal with crops with which they are familiar and the less demanding crops as far as care and maintenance is concerned. On the other hand, the willingness to grow potatoes, vegetables, and fruit trees indicates an interest in projects that may profit local villagers as well as commercial enterprises.

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[1]Note Sur l'Approche a la Formation des Eleveurs de la Zone Sahelienne du Tchad (USAID Library, no author).

8. The strong perference of cattle herders to pasture their herds on the dunes or in the polder, rather than feed them with fodder, may shed a new light on the Kuri Ranch experiment at Matafo.

V. FACTORS WHICH MIGHT FACILITATE/IMPAIR THE ESTABLISHMENT OF THE TANDAL POLDER

A. SOCIO-ECONOMIC TRADITIONAL PATTERNS

Among Kanembu and Buduma/Kuri, there is a direct correlation between millet agriculture on the sand dunes and the movement of their cattle. The cattle are always brought back to the vicinity of the village in the evening where their droppings fertilize the sand dune, setting a limit as to where millet will be cultivated. One does not sow millet where the cattle has not dwelled. The practice of fertilizing the otherwise sterile sand dunes starts immediately upon the end of the hot season. Millet is planted in June, when the rain starts, and harvested in September once the rains stop. The millet fields are always in the vicinity of the villages.

Another kind of traditional agriculture is practiced in narrow fields along the edge of the water basins. These fields, under water when the lake rises, are rich in organic materials and are used only when the water recedes. The farmers plant corn, some sorghum, some manioc, and grow papaya trees on the edge of the field. These amount to gardens and produce a needed subsidiary set of foods.

The ouaddis, depressions between sand dunes which were once arms of the lake, are rich in alluvium and permit permanent cultivations. Traditional polders are, in fact, artificially created ouaddis. The water table lies only about 1 meter below ground and fluctuates with the lake level. It is easy to be tapped by digging a shallow well, thus being able to irrigate by means of a chadouf or simply with a bucket. Ouaddis can bear up to three harvests a year with wheat the most common crop.

These cultivation practices, and herding, are done on a well balanced schedule during the year. They from the backbone of the tradition of Kanembu/Buduma life. Tradition has it that the land belongs to whosoever cultivates it, but it also belongs to Allah and must be shared with the community.

Cattle are important to both Kanembu and Buduma, but it is the Buduma who are the most likely to attach an enormous value to their cattle. They raise Kuri cattle (Bos taurus), which are becoming extinct, as well as two types of Zebu cattle (Bos indicus). The Fulbe (peul) is characterized by long horns in the shape of a lyre and the Arab zebu by short

horns. The Buduma follow a very strict seasonal schedule and specific daily practices with their cattle. In the cold season, cattle are kept in the millet fields; in the warm season, they are moved to other islands for new pastures; in the rainy season, they pasture on the dunes near the lake coast. Even this small scale transhumance disperses the Buduma society throughout its environment.

The horse is raised, but used only by the chiefs and their retenues. It is used for travel but is not part of the economy (a luxury item). Sheep and goats are also kept and play an important role in the economy.

Other traditional resources are fishing and the extraction of natron from various depressions (particularly near Liwa). Natron, a sodium carbonate, is used as salt in cooking and as a tonic/laxative to heal. It is in great demand in the markets of Tchad (white natron) and Nigeria (black natron). Natron pits are said to belong to Allah, but are distributed to the Haddad for exploitation by the canton chief. In exchange, they pay him dues of 20 percent of what they extract.

The marabouts and faki (muslim practitioners) traditionally sacrifice cattle when a new pit is open to exploitation. In 1949 there were 26 such depressions exploited, producing about 120,000 tons from 744 hectares.

The Tchadian Government, through SONACOT (Societe Nationale de Commercialization du Tchad) attempted to control the export and sale of natron. However, they failed due to the tenacity of the traditional system, abandoning the natron exploitation to the traditional markets.

Finally, fishing has become one of the most important and lucrative activities of the Buduma. Originally they ignored the fish, since they were warriors, and only their slaves--the Haddad--were permitted to do the fishing. Where most ethnic groups practice fishing only as a subsidiary activity, the Buduma have now specialized in open water fishing. Using either their Kadei (reed boats) or purchasing Kotoko dugout canoes at CFA 60,000 each, they harvest and dry or smoke fish using the Banda technique learned from the Kanuri. Banda in Haussa language means smoking table. They have developed a commercial enterprise with Nigeria which, though illegal, bring them considerable revenues in money. As a result, they are not really interested in polder cultivation and earn more through fishing than through commercial agriculture. This has, in fact, produced a quasi migration of Buduma fishermen to the shores of Nigeria and Cameroun. These practices, if properly directed, may develop some valuable commercial links between Tchad and Nigeria in the future.

These traditionally developed systems have permitted the local population to reach a fairly stable equilibrium in their own environment. Having judiciously resolved the basic problems encountered, the systems stand in the balance when weighed against modern development. This is no doubt that the polders, as presently commercialized, have attraction for some. However, a system needs to be established that will facilitate the entry of a yet very traditional people into the world of commercial enterprises. It is obvious that modernization and the present political realities cannot be ignored. There are many aspects of the traditional way of life that may be tapped usefully to the advantage of a development program. There are also some basic values which will stand firm against new teachings and technological methods. These must be accounted for if successful goals are to be reached.

B. THE VALUE SYSTEM AS RELATED TO TRADITIONAL REVENUES

As seen earlier, the ideas of the Muslim religion (as expressed by the marabouts and practiced by the Chef-de-Canton) and the customary dues to be paid to the village chief tend to produce some problems when a large piece of land is declared nationalized. In the case of the polders, managed by SODELAC for development, they are said to be national land.

Farmers who volunteer to work for the commercial company (SODELAC) at a given unit rate for their harvest pay for their seed and for the use of irrigation water. But, they still face the traditional "redevances" (dues) which are required by their faith and paid to their chiefs. The survey clearly indicates such fears; "there will be too many village chiefs." For farmers already on a mediocre income, these produce a real hardship. When donor countries plan schedules of repayment for government investments and predict certain rates of interest (USAID 1975), they should be aware of traditional factors or their plans may falter under a burden of iniquities. Such practices as the payment of religious alms and traditional dues cannot be dismissed easily nor transformed overnight.

On the other side of the balance sheet, one needs to remember that in dealing with human societies which have shown in the past both intelligence and flexibility in their adaptation to various circumstances, these same societies have demonstrated that they are industrious, hard working, and face life with many positive attitudes. These characteristics will assist in the establishment of new methods and in developing new patterns of behavior if one is willing to patiently provide the information needed for cultivators to understand the meaning of the experiments on the polders. The survey tends to demonstrate that most villagers have little notion of what commercialization and money management means in relation to polder agriculture.

VI. CONCLUSIONS AND RECOMMENDATIONS FOR SOCIO-CULTURAL SYSTEM

Based upon the studies conducted for the proposed Tandal Polder, the following conclusions and recommendations are presented.

1. At present, SODELAC governs the nationalization of polder lands. The expropriation of tennants who own traditional gardens and fields along the edges of the lake are taken for granted and promises are made that they will be given priority in the selection of plots on the new polder. Since one must then pay fees to SODELAC for the seed received, for land, and water use prior to being paid a unit rate for the crop harvested, one does not have an opportunity to invest into the land. The only incentive is that by hard work one can obtain greater crop yields and earn more money. It is recommended that a system be developed whereby each polder farmer, if he so wishes, receive an option to own the land individually or jointly with the company. That is, by applying some of the fees paid, he buys shares in the company. If the farmers can be trusted to become shareholders, this incentive will then be increased as they shall not only work for a cash gain, but they will be making an investment which ultimately will turn into profit. Share holders could receive dividends or take losses in a manner similar to the company.

2. Because farmers have an interest in several crops and because several villages are located close to several polders, it is recommended that a farmer be allowed to cultivate several plots and share in several kinds of crops. He may do this by dividing his land area into several crops, or he may cultivate plots on several polders at the same time. The farmers are accustomed to scheduling their activities between several endeavors.

3. In relation to crops the farmers prefer to raise, the survey made it clear that cotton is not presently favored by the local population. It is considered too labor intensive for the profit it generates. Local farmers prefer to grow corn, wheat, and potatoes for commercial purposes and gombo for their own use. The survey emphasized that farmers, even if they work on the polders for commercial purposes, are not ready to abandon their millet fields. The survey indicated that they liked to cultivate vegetable gardens for their own family use. It appears that farmers tend to trust the crops they know traditionally and that farmers show flexibility as they have readily accepted potato and vegetable crops for their personal uses. It is recommended that labor intensive crops as cotton be abandoned on the polder in favor of corn, potatoes, and wheat, and that

farmers and families should be employed, but not at the exclusion of being able to tend their cattle and millet fields. It is important to mesh carefully the commercial endeavors with the traditional calendar. They also should be allowed about 1/4 hectare on which they may cultivate vegetables to replace their ebb fields. This incentive may prove worthwhile as a reward for their interest in commercialization.

4. The CH2M HILL survey in the villages and on the islands revealed that most villagers live rather isolated lives at the traditional level. They have heard about the polders, but their knowledge of social and economical implications is grossly distorted. It is recommended that prior to construction at Tandal, a socio-economic team be established to initiate communication with the local farmers and provide adequate information on the project and secure additional data about the local situation. At the present time, a socio-economic unit does not exist within the framework of SODELAC. It is important that the company have a permanent unit and that new project endeavors should not be undertaken prior to more socio-anthropological investigations.

5. In relation to the cash earned by farmers on the polders, the survey has shown that money earned is usually gone quickly. Traditional people entering a money economy need to be taught the proper use, management, and power of money. They need to be led into a situation where money can be saved and invested for profit. It is recommended that an educational program be established so that farmers are taught the principles of sound economics and money management. They must understand the company's goals and purposes so that they have the incentive to cooperate and invest their gains in return.

6. The Matafo pilot-peasants project uses "monitors" to supervise the farmers while they cultivate and harvest. This system of "encadrement" has some merits. However, it easily lends to a hierarchy which tends to be oppressive. Though there are complaints that farmers sell some of their products rather than keep the total harvest for SODELAC, such practices could easily be curtailed if the field hierarchy were replaced by a system of cooperative understanding. Since monitors frequently belong to ethnic groups different than the farmers, this only increases the problem. It is recommended that these suppressive activities be remedied so that the pilot farmers become trustworthy advocates of the program since it will be duplicated on other polders.

7. The Kuri Ranch feeds Massakori cattle polder-grown fodder. Under carefully controlled conditions, it is an excellent concept in terms of western economics. The survey has shown, however, that the local population owns cattle

strictly as a prestigious item. Because of their strong traditional values, it is recommended that the Matafo Ranch experiment be reconsidered in light of ethno-economics rather than pure western economics.

8. Finally, in regard to ethnic and population density considerations, it would appear from this study that the polderization of Tandal is feasible, but only under certain conditions: (1) The Kanembu/Haddad and perhaps the Buduma should be used on the project rather than importing different ethnic groups from distant regions; (2) if Tandal, Mamdi, Guini, and Berim are all polderized, an undue strain would be placed upon the local population to provide the labor force, inevitably leading to the import of distant laborers; if this occurs, a program should be initiated whereby the "tribesman" will be made a "citizen"; and (3) considering the above factors, it may be a better policy to abandon polderization of either Tandal or Mamdi and consider shifting the development to adjacent polders further to the east and the west. In this manner, the local population would be in a better position to participate in the program with a minimal problem of displacement. It would also distribute the burden of development throughout the whole Lac region.

As has been already noted, the Prefecture du Lac population is essentially a traditional one, with villages quite isolated from the maintstreams of modernization. It is an intelligent and imaginative population, flexible enough to adjust to unusual circumstances and adapt to a variety of conditions. The judicious manner in which the development program is imposed upon these ethnic groups that are just now emerging into the realities of the Tchadian Republic and its modernizing goals will either make or break the polder program.

Part 3E
FINANCIAL ANALYSIS

In this section, the project revenues and costs are evaluated and distributed by the party affected. Revenues and costs are inflated the amount expected in nominal terms in the year they occur. An inflation rate of 8 percent is assumed, approximately the rate which has prevailed in Tchad in recent years. The analysis begins at the project level and subsequently considers effects on farmer cultivators, SODELAC, and Government of Tchad. The analysis is limited to the first 10 years of project operation.

I. PROJECT COSTS AND CASH FLOW

The total cash required for the project during the first 10 years of operation is 5,284.1 million CFA ($23.0 million) (Table 3E-1). The requirements for construction are 3,118.9 million CFA ($13.6 million) assuming that construction begins in 1981.

II. SOURCES OF FUNDS

Funds required for constructing and operating the project are expected to come from donor grants (USAID, World Bank, African Development Fund, etc.), from revenue from sale of products, and from the Government of Tchad (GOT). The proportional allocation of initial construction cost and operating deficits the first few years of operation are not known at this time. It is assumed that GOT would contribute only a minor amount (2 percent) because of its weak financial condition and that donors would provide the remainder (98 percent).

Assuming the project were funded in this manner, the distribution of investment capital would be as follows:

	Mill CFA	Mill $
Donors (98%)	3,056.5	13.3
GOT (2%)	62.4	.3
Total (100%)	3,118.9	13.6

Table 3E-1
CASH FLOW FOR PROJECT CAPITAL REQUIREMENTS FOR CONSTRUCTION AND OPERATION (MILLION CFA AND DOLLARS)[1]

Year	Construction Costs	Operating Costs	Total CFA	Total Dollars
1981	297.2	--	297.2	1.29
1982	245.8	--	245.8	1.07
1983	698.5	--	698.5	3.04
1984	738.2	60.1	798.3	3.47
1985	752.9	130.1	883.0	3.84
1986	43.5	207.1	250.6	1.09
1987	--	223.7	223.7	0.97
1988	--	210.5	210.5	0.92
1989	--	227.3	227.3	0.99
1990	--	245.5	245.5	1.07
1991	--	265.2	265.2	1.15
1992	342.8	286.4	629.2	2.74
1993	--	309.3	309.3	1.34
TOTAL	3,118.9 ($13.6 million)	2,165.2 ($9.4 million)	5,284.1	23.0

[1]All 1978 CFA are inflated at a rate of 8 percent per year.

III. DISTRIBUTION OF REVENUES AND COSTS

A possible financial plan for determining rental rates for irrigated land is illustrated in Table 3E-2. In this scheme, the farmers would pay all operating costs of SODELAC, 1 percent of invested construction capital in 1986 and 1987, and 2 percent of invested construction capital in 1988 and subsequent years. There would be no payment on invested capital during the first 2 years of operation--1984 and 1985.

Revenues from crop sales would be distributed as follows for the 10-year period:

	Million CFA	%
Farmers	1,402.3	24.4
Farm suppliers	1,653.0	28.8
SODELAC	529.0	9.2
Project suppliers & labor	2,165.2	37.6
Total Crop Sales	5,749.5	100.0

Total economic activity resulting from the crop production might well be double the payments illustrated here due to operation of the economic multiplier. Areas of impact would depend on where the money received was spent. Thus, the second and subsequent round of spending due to money received by the farmers would primarily be in the Bol area and could stimulate consumer activities there. Money spent in N'Djamena, say for project supplies, would stimulate increased economic activity there.

A particular advantage of the proposed scheme is the provision of a capital fund for SODELAC, which is in financial distress due to limited sources of capital. SODELAC's project operation and overhead expenses would, of course, be met through the rental payment.

The transportation, processing, and sale of project products would have further effects. Even if transportation charges only covered costs, the service would provide employment and sales of gasoline and equipment. Processing would likewise provide employment and stimulate economic activities. Taxes and duties on exports would, in addition, provide additional government revenue.

IV. CONSEQUENCES OF PLAN ON FARMERS

If the proposed plan were adopted, project farmers could meet rental payments proposed and have a significant net income. For example, the following incomes would accrue to farm families for the given years, assuming 1 hectare per family.

Year	Net Income (Mill CFA)	No. Families	Income/Family CFA	$
1984	32.4	200	162,000	704
1986	93.4	584	159,900	695
1988	135.2	584	231,500	1,007
1990	169.9	584	290,900	1,265

These incomes would be a significant improvement over present family incomes in the Bol area, estimated by World Bank (1975) at 32,900 CFA ($146).

Table 3E-2
SCHEDULE OF CROP SALES AND PLAN
FOR THEIR DISTRIBUTION--TANDAL POLDER

Year	Crop Sales[1]	Farmer Costs[2]	Residual to Farmer	Project Operating Costs[3]	Farmer Rent[4]	Available for Fixed Costs
1984	146.0	53.5	92.5	60.1	60.1	--
1985	315.3	112.6	202.7	130.1	130.1	--
1986	497.2	159.9	337.3	207.1	243.9	36.8
1987	536.9	148.7	388.2	223.7	260.5	36.8
1988	579.9	160.6	419.3	210.5	284.1	73.6
1989	626.3	173.5	452.8	227.3	300.9	73.6
1990	676.4	187.4	489.0	245.5	319.1	73.6
1991	730.5	202.3	528.2	265.2	338.8	73.6
1992	788.9	218.5	570.4	286.4	366.9	80.5
1993	852.1	236.0	616.1	309.3	389.8	80.5
TOTALS	5,749.5	1,653.0	4,096.5	2,165.2	2,694.2	529.0

[1]Inflated at 8% from 1978.

[2]Includes farmer investment and farm production costs, inflated at 8% from 1978.

[3]Includes operation, maintenance, and replacements and project overhead, inflated at 8% from 1978.

[4]Assumed to cover operating costs each year and 1 percent on construction investment in 1986 and 1987 and 2% thereafter.

I. DEMOGRAPHY

Bol is the capital of Lac Prefecture and a center for health services, commerce, and administration. The area to the east quickly becomes arid; e.g., the sahel a transition zone between desert to the north and savannah to the south. Along the lake there is a green zone of significant biological productivity. Bol sits on one of a series of archipelago islands and peninsulas along the eastern shore. These are actually a series of very large fine sand dunes of a previous drier period. Because of the recent drought, normal water areas between the islands are now mostly marsh or swamp.

Bol has approximately 2,800 residents and has several surrounding villages (4,000 in general vicinity). In recent years, the town has had an influx of population associated with polder projects including a number of Europeans. The Prefecture generally has had accelerated growth that is about twice that of Tchad as a whole. This could be associated with the drought and the green border areas where the lake has receded. A great number of cattle can be seen grazing along this belt from the air. In 1971 Lac Prefecture had a population estimated at 125,000, a density of 5.6 persons per square kilometer. The 1976 estimate is 139,000 or 6.2 person per square kilometer. This is a growth rate of 0.12 persons per square kilometer per year (about 2 percent per year).

In contrast, Tchad has gone from 3,715,000 to 4,121,000 persons from 1971 to 1976 (from 2.9 persons per square kilometer to 3.2 persons per square kilometer). The growth rate was 0.06 person per square kilometer per year.

By 1980 the population of Lac Prefecture is forecasted to grow to 151,000 (6.8 persons per square kilometer per year) (Annuaire De Statistique Sanitaires Du Tchad 1976).

Malan et al (1977) surveyed approximately 10 percent of the households in Bol. At the time of the survey, 62 percent of the dwellers were female, 38 percent male. This is a high female proportion, but females generally outnumber males in Tchad villages. Malan felt that the sex ratio was an artifact of the timing of the survey since the population tends to be transient. Nineteen percent of the population had lived in Bol less than 1 year, and 26 percent from 1 to 5 years. Though good age structure information is scanty,

84 percent of the men at home were 15 to 45 years, and 13 percent were over 45 during the survey. The age structure in Tchad in 1976 is as follows:

0 to 14, 41%
15 to 59, 55%
60+, 4%

Buck et al (1970) found significant differences in age structure of males and females at Djimtilo (southwestern Lake Tchad area). There were many more males over 40 than females. Females in the village, however, were much more abundant than males in the 11- to 40-year category and overall (1.3x). They found that many males temporarily leave the village to work at N'Djamena or to avoid paying a head tax. Thus, the disparity in sex ratio appears to be a valid demographic statistic (e.g., a transience in the male population is characteristic).

Early marriage is characteristic of the Tchadian people as is a high divorce rate. Polygamy is not uncommon. The transience of the males plus the high divorce rate results in a surplus of unmarried females residing in the villages.

More background information about the Bol area people appears in the Social Analysis section.

II. PUBLIC HEALTH SERVICES AND STRUCTURE

A diagram summarizing the health services for the Bol area appears as Figure 3F-1. Bol, the administrative health center for Lac Prefecture, has a 27-bed medical clinic which includes facilities for minor and emergency surgery, x-rays, delivery room, a treatment room, a small separate pharmacy and dispensary, an isolation area for tuberculoid patients, a separate kitchen for the patients, and a separate small building for the doctor's office and medical records.

The full-time staff at Bol consists of one medical doctor, one registered nurse (infirmier d'etat), seven licensed attendants (infirmier brevite), one midwife, four orderlies, and one secretary.

Six village dispensaries report to the medical center at Bol, each staffed by a licensed nurse and orderly. The doctor routinely visits the villages and offers assistance and consultation.

There are four religious missionary dispensaries also operating in the province. They do not report to the Bol (and Lac Prefecture) medical administrative system, but primarily serve the island people and are more mobile. Specific information on level or numbers of staff is unavailable.

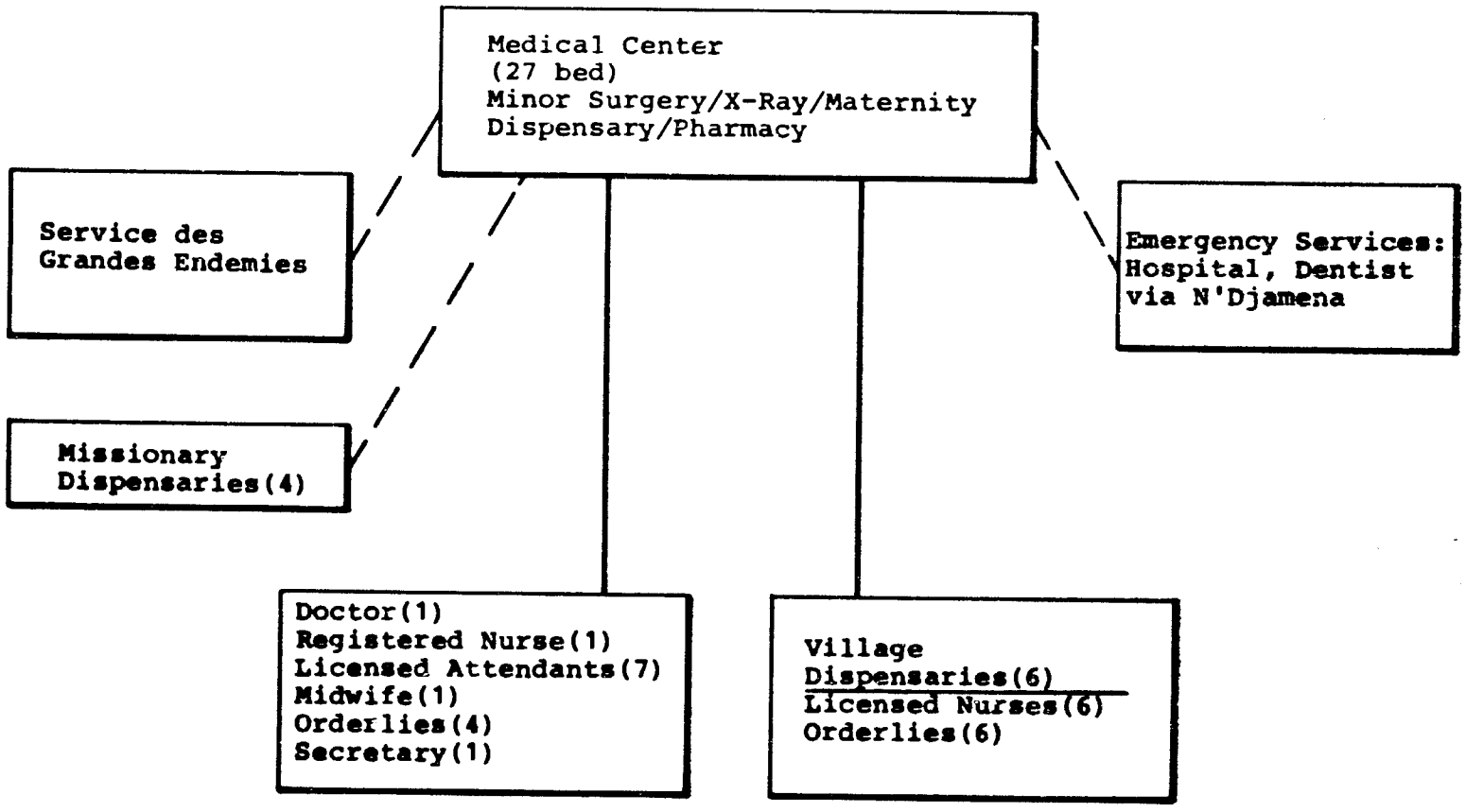


Figure 3F-1
DIAGRAM OF HEALTH SERVICES
FOR THE BOL AREA

In addition to the line functions, the area is also served by the Service des Grandes Endémies, a mobile service group originally organized to combat trypanosomiasis (in 1932). Its primary purpose today is preventative medicine in rural areas, especially to try to prevent vector-borne epidemics. The Service performs epidemiological analysis, coordinates vaccination programs, coordinates vector control programs, etc. The Lac Prefécture falls under the Subsector I group headquartered in Mao which covers Kanem and Lac Prefectures. The Service is independent of the medical structure at Bol (which reports to the Ministry of Public Health in N'Djamena). Lac Prefécture apparently does not receive the attention that Kanem Prefecture does from the Service.

Backup emergency, hospital, laboratory-diagnostic, and dental services can be provided at N'Djamena. A commercial airline (Air Tchad) links Bol to N'Djamena with twice-weekly scheduled flights and emergency or chartered flights are available. However, most people in the Bol area lack sufficient funds to make use of these services, and a 2-day overland trip is the alternative. On a routine practical basis, laboratory diagnostic services are available and could be used more frequently (i.e., blood and tissue samples, etc., could be sent for laboratory diagnosis). The hospital has its own staffing and funding problems, however.

The major shortcomings of the health services for the Bol area are:

1. Insufficient drugs, vaccines, and medical supplies.

2. Insufficient number of trained staff needed to attack the levels of communicable disease problems being experienced in the area.

3. Lack of trained staff to provide basic sanitation and hygiene education.

4. Lack of attention from the Service des Grandes Endémies for vaccination program assistance and assistance in malarial vector control.

5. Lack of general and specific laboratory diagnostic equipment and supplies.

6. Lack of out-reach services and followup ability to track down specific carriers who do not reappear for treatment.

III. ENDEMIC DISEASES AND RELATIVE IMPORTANCE

An informative overview of disease problems in Tchad can be obtained through statistical records of Service des Statistique

Sanitaires and Service des Grandes Endémies. The former's records now appear as annual reports.

A good summary of information from the Service des Grandes Endémies for 1970-1976 appears in the 1976 Service des Statistique Sanitaires report. Buck et al (1970) compiled similar information for 1966 which, unfortunately, did not include venereal diseases. Selected data (not all diseases were covered) for 1969 appear in Schneider et al (1977). These reviews can be combined and a relative baseline obtained for the major communicable diseases in Tchad (Table 3F-1). These data should not be used as absolutes but as reasonable estimates. In the near future, more complete data will be available from the Service des Statistique Sanitaires. The data are subject to error because many people will not report some illnesses and others will simply not request any treatment. The statistical records contain many diagnoses based solely on symptoms, and the depth of medical training and staffing is not uniform geographically or in time. In spite of these limitations, the data are very useful.

There are four apparent diseases trends in the data. These "trends" should be observed cautiously for reasons previously mentioned. Gonorrhea and leprosy appear to be declining slowly, but intestinal schistosomiasis and amebiasis appear to be increasing. The two declines could well reflect relative treatability (gonorrhea and leprosy respond to antibiotic treatment). Intestinal schistosomiasis is more of a problem in southern Tchad, but the range of infection appears to be spreading northward. Schistosomiasis is very difficult to treat and localized amebiasis resistance is known to exist. If population migrations occur, local epidemics can occur and treatment is difficult. The apparent trends are graphed on Figures 3F-2 and 3F-3.

The other major statistical change is a striking difference in apparent incidence of dysentery which appears in 1971, a 40-fold increase! Only 197 cases and 138 cases were reported in 1966 and 1969, respectively. This jumped to 6,274 in 1971, 23,742 in 1973, and 42,657 in 1976. This could well be a reporting change as many individual District Monthly Reports had crossed off bacillary or added diarrhea. It would probably be better to consider this illness as acute diarrhea without clinical verification of cause. If only 1973-1976 data are used, the mean is 23,000 cases of acute diarrhea per annum.

Diseases that cause mortalities are another important statistic. Table 3F-2 lists the 10 primary causes of death in Tchad in 1976 (most recent data available) compared to respective case numbers. Year-to-year variability in death causes is shown in Table 3F-3, a 5-year matrix. These later data can be combined by straight line weighting to rank the 10 most

Table 3F-1
CASES OF MAJOR COMMUNICABLE DISEASES IN TCHAD 1966, 1969-1976
(FROM LE SERVICE DES GRANDES ENDEMIES)

Rank	Disease	Annual Average	Range
1	Malaria	141,000	101,000-218,000
2	Amebiasis⁻	42,000	23,000- 53,000
3	Schistosomiasis	25,000	19,000- 33,000
4	Gonorrhea*	25,000	19,000- 31,000
5	Dysentery/Diarrhea⁺	12,000	100- 43,000
6	Syphilis, Primary*	11,000	8,000- 14,000
7	Hepatitis, Infectious	10,000	5,000- 12,000
8	Pneumonia⁺	9,000	1,000- 38,000
9	Measles⁺	6,000	1,000- 12,000
10	Whooping Cough⁺	6,000	3,000- 12,000
11	Trachoma	5,000	1,000- 6,000
12	Influenza⁺	4,000	1,000- 10,000
13	Tuberculosis	2,000	1,000- 2,000
14	Leprosy	2,000	1,000- 3,000

*No data 1966 ⁺No data 1969 ⁻No data 1976

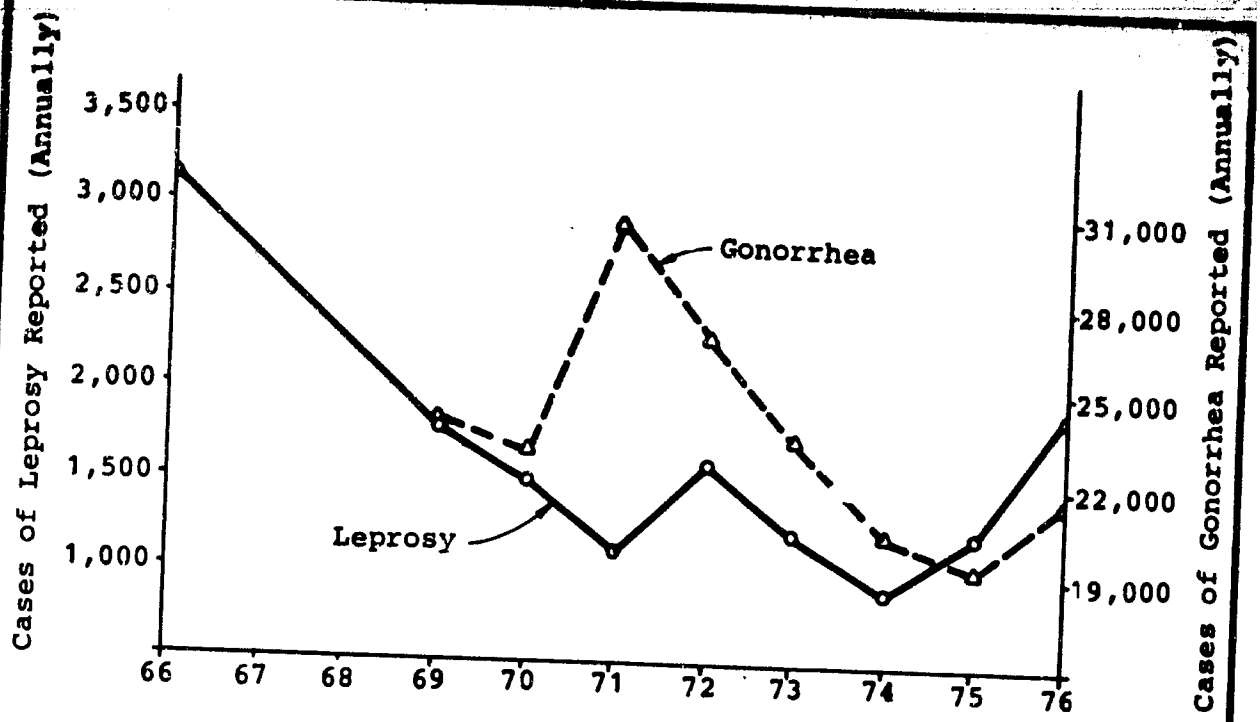


Figure 3F-2
TRENDS IN LEPROSY AND GONORRHEA
IN TCHAD 1966 AND 1969-1976

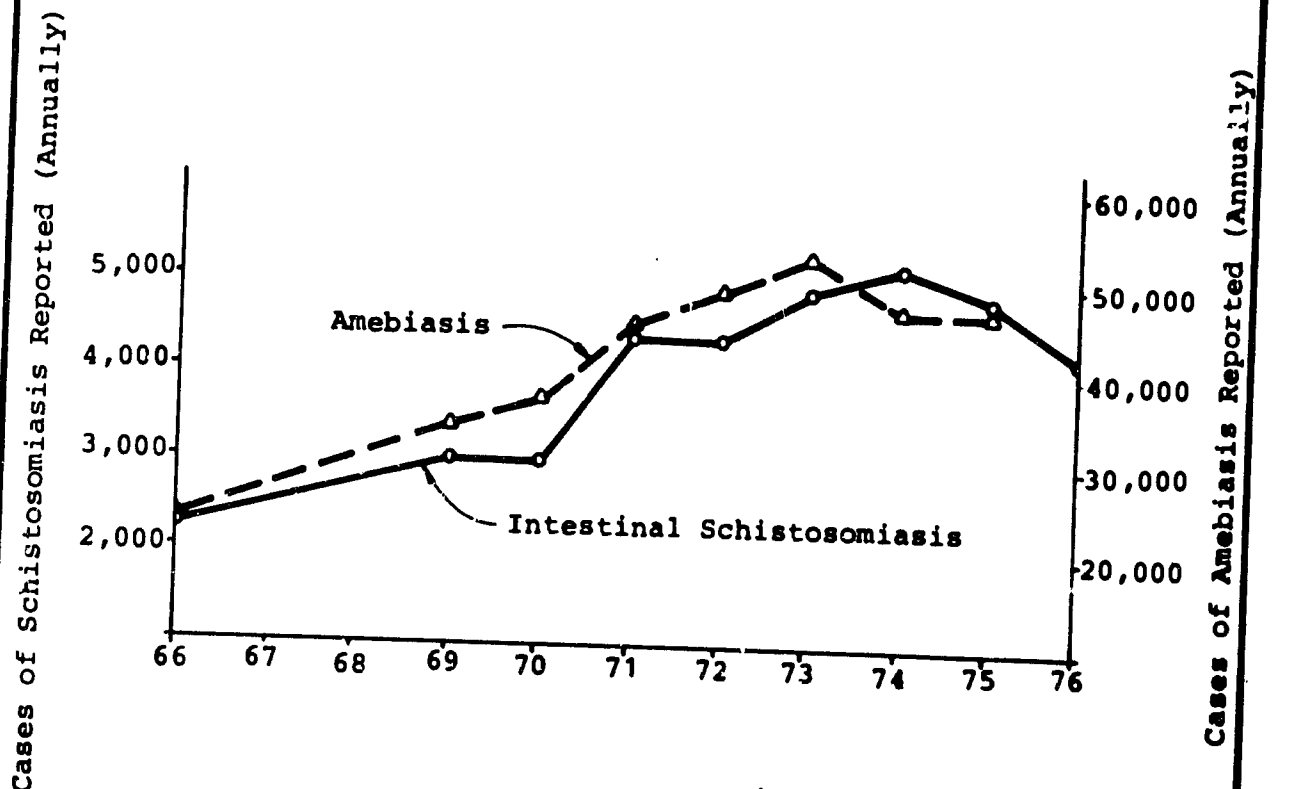


Figure 3F-3
TRENDS IN INTESTINAL SCHISTOSOMIASIS AND
AMEBIASIS IN TCHAD 1966 AND 1969-1976

Table 3F-2
TEN PRIMARY CAUSES OF DEATH IN TCHAD IN 1976
(FROM ANNUAIRE DE STATISTIQUE SANITAIRES DU TCHAD 1976)

Rank	Cause	Deaths (#)	Cases (#)
1	Malaria	501	374,000
2	Tetanus	466	1,700
3	Measles	406	6,000
4	Hepatitis	287	4,000
5	Bronchial-Pulmonary	217	100,000
6	Meningitis-coccal	134	500
7	Tuberculosis	131	4,500
8	Diarrhea/Dysentery	102	114,000
9	Amebiasis	72	97,000
10	Leprosy	42	4,000

Table 3F-3
FIVE-YEAR MATRIX OF PRIMARY CAUSES OF DEATH, 1972-1976
(FROM ANNUAIRE DE STATISTIQUE SANITAIRES DU TCHAD 1976)

Rank	Year				
	1972	1973	1974	1975	1976
1	Meningitis	Malaria	Tetanus	Tetanus	Malaria
2	Malaria	Tetanus	Measles	Malaria	Tetanus
3	Hepatitis	Hepatitis	Malaria	Hepatitis	Measles
4	Diarrhea*	Measles	Hepatitis	Meningitis	Hepatitis
5	Tetanus	Amebiasis	Meningitis	Amebiasis	Pneumonia
6	Amebiasis	Meningitis	Pneumonia	Tuberculosis	Meningitis
7	Measles	Tuberculosis	Amebiasis	Pneumonia	Tuberculosis
8	Pneumonia	Pneumonia	Infant Death**	Dysentery	Dysentery
9	Grippe	Dysentery	Tuberculosis	Rage	Amebiasis
10	Tuberculosis	Pertussis	Chloera	Pertussis	Leprosy

*Note 1972 = Diar & Gas-Ent des nourris.
** 1974 = Inf. ombilic.

significant causes of death in Tchad in recent years (1972-1976). Table 3F-4 lists the results and compares these to primary disease causes.

Seven diseases appear on both lists: malaria (obviously Tchad's primary problem), amebiasis, acute diarrhea/dysentery, infectious hepatitis, pneumonia, measles, and whooping cough. Three of these diseases are transmitted by the fecal-oral route (amebiasis, diarrhea, hepatitis), three by droplet or direct contact with nasal or throat secretions (pneumonia, measles, and whooping cough, all highly communicable), and one by mosquito vector (malaria). Also, transmission of measles by the urine-oral route is known, and the fecal-oral route is suspected.

Comparative data can be derived for the Bol area (Table 3F-5, main causes of disease). The data should be viewed as reasonable estimates and not as absolutes. Ranking of disease, outbreak incidents, seasonal trends, etc., are obtainable and useful.

Table 3F-6 compares the 10 primary disease problems in Bol to those in Tchad in recent years. There is considerable similarity as expected but a few notable differences. Malaria is the primary problem in the Bol area as it is in Tchad as a whole. Dysentery/acute diarrhea becomes more important at Bol, amebiasis less important, and venereal disease is much more important. Schistosomiasis appears to be relatively less important, but its ratio to malaria is much higher at Bol than in the whole of Tchad. Schistosomiasis remains a major problem in Bol, more so than in Tchad generally, pointing out the severity of venereal infections in the area. Mumps are locally a problem at Bol, and measles became a problem in 1977 and thus do not appear in the ranking yet. Leishmaniasis is notable for its importance at Bol. This was surprising as previous epidemiological surveys did not pick this up as a problem. Hepatitis, whooping cough, and trachoma maintain their relative importance as problems (although trachoma was displaced at Bol by mumps and leishmaniasis).

A similar ranking of disease problems was found in northeastern Nigeria (southwestern Lake Tchad area); eye infections, malaria, gonorrhea, diarrhea, syphilis, urinary schistosomiasis, and low incidence of intestinal schistosomiasis (Menn et al 1973, Noamesi and Morcos 1974).

The diagnosed presence of intestinal schistosomiasis at Bol which appears in 1976 and 1977 is noteworthy and agrees with observations elsewhere around the lake. Relative low incidence is also in agreement.

Several occasional communicable disease cases appear in the Lac Prefecture medical records: hookworm, onchocerciasis,

Table 3F-4
RANKING OF TEN PRIMARY CAUSES OF DEATH IN TCHAD IN RECENT YEARS AND COMPARISONS TO PRIMARY CAUSES OF DISEASE

Rank	Death	Disease
1	Malaria	Malaria
2	Tetanus	Amebiasis
3	Hepatitis, Infectious	Schistosomiasis
4	Meningitis	Gonorrhea
5	Measles	Dysentery/Diarrhea
6	Amebiasis	Syphilis, Primary
7	Pneumonia	Hepatitis, Infectious
		Pneumonia
8	Tuberculosis	Measles
9	Dysentery/Diarrhea	Whooping Cough
10	Whooping Cough	

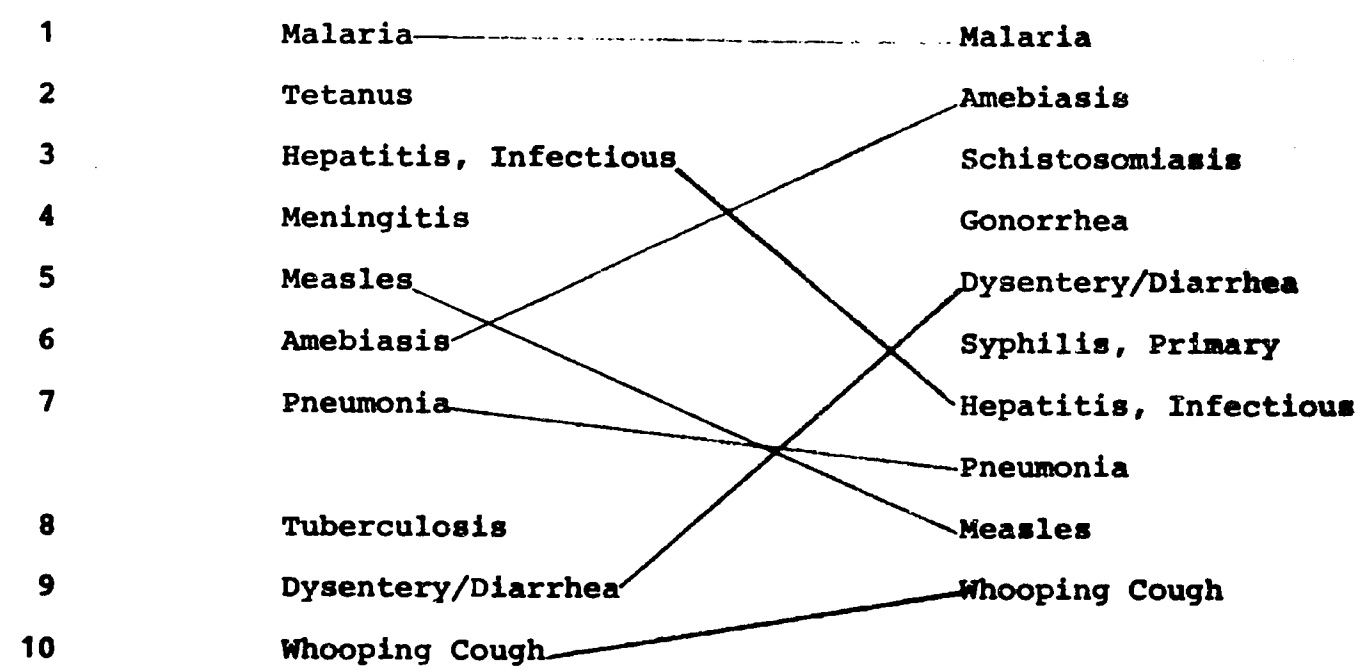
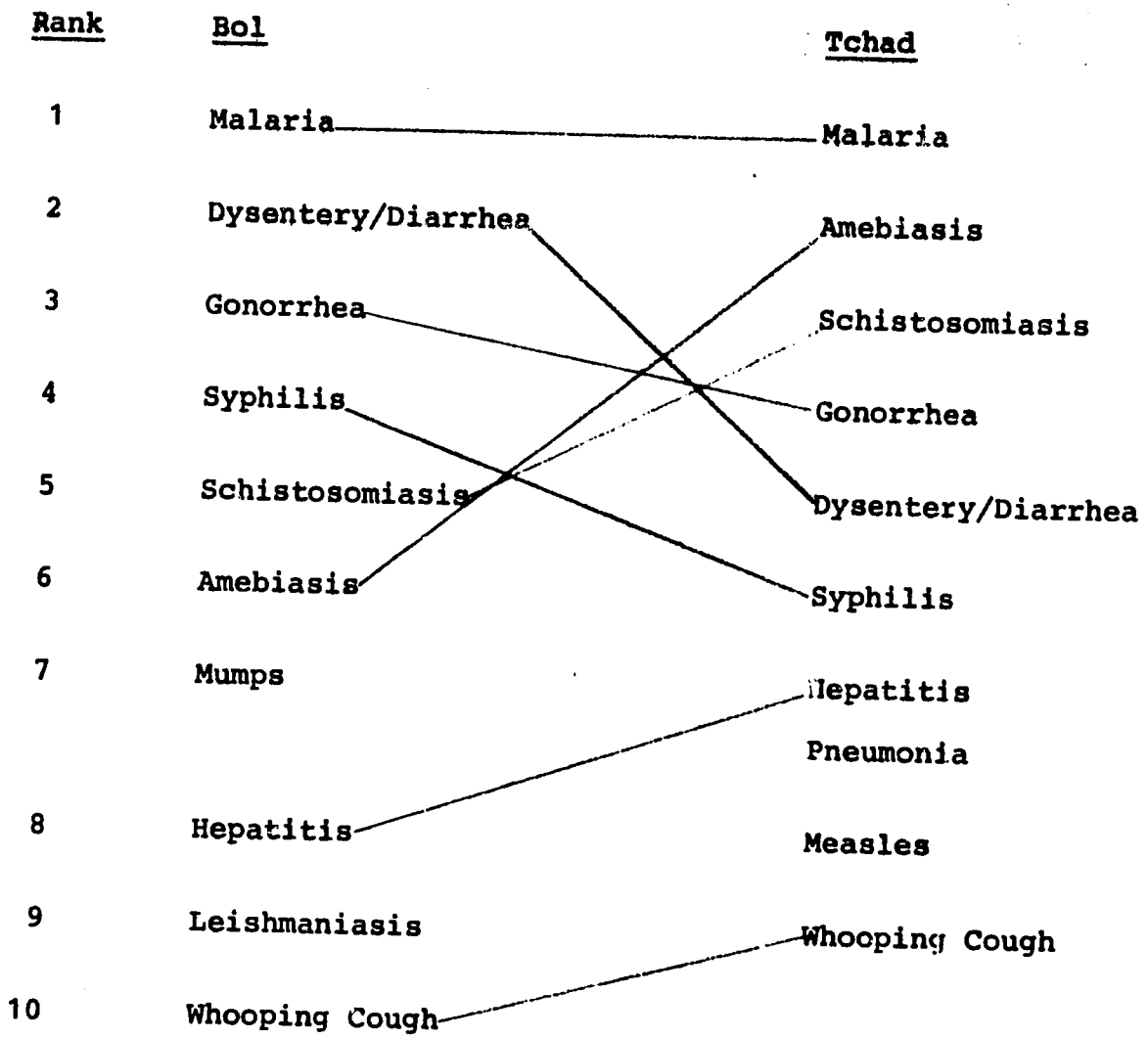


Table 3F-5
MAIN CAUSES OF RECENT DISEASE IN BOL AREA
1975-1977, AVERAGE MONTHLY CASES

Rank	Disease	1975	1976	1977
1	Malaria	112	239	235
2	Dysentery/Diarrhea	134	355	85
3	Gonorrhea	100	135	107
4	Syphilis	90	111	102
5	Schistosomiasis-urinary	53	70	77
	Schistosomiasis-intest.	...	2	2
6	Amebiasis	21	21	35
7	Mumps	20	29	5
8	Hepatitis, Infectious	...	15	14
9	Leishmaniasis, Cut.	...	13	9
10	Whooping Cough	20	9	2
11	Pneumonia	...	12	7
12	Measles	...	0+	17
13	Trachoma	5	5	6
14	Tuberculosis	4	4	6

Table 3F-6
COMPARISON OF TEN PRIMARY DISEASES IN TCHAD
TO BOL IN RECENT YEARS



chicken pox, and yaws. The data for these are spotty and not with enough regularity to suggest established local disease but could reflect a transient disease problem since all of the diseases are known in Tchad. A recording of several cases of trypanosomiasis was found for April 1976, but this was a typographical error; actual case tallies showed no incidence. A single verified case appeared in a boy in 1978, but he had recently returned after 1 year in Cameroun.

A complete discussion of major disease problems in the vicinity of Bol is included in Annex 4.

IV. RELATION OF DISEASES TO ENVIRONMENTAL CONDITIONS AND CULTURE

The vast area of closeby marshy waters surrounding Bol provides mosquitos (including anophelines) with good breeding habitat. Standing waters in the polders (including the native polders built since the turn of the century) increase the potential for high local mosquito populations. Ponded surface waters and stagnant drainage canals are the problems in the polders (e.g., good mosquito habitat). The intake sluices are not considered mosquito habitat. The local practice of building villages on the dunes lessens the human blood meal potential because most mosquito species do not tend to fly uphill and tend to prefer a more moist atmosphere (e.g., lower). Lack of vegetation there also helps.

Female mosquitos generally remain active, mostly crepuscular or nocturnal, until they have found a blood meal. The presence of game or livestock between mosquito breeding areas and human habitation may act as a blood meal buffer for humans. There are enough mosquitos in the general area, however, that a problem exists, and conditions are such that they will remain a problem (with or without the polder projects).

If the Bol area populations are isolated long enough, the degree of virulence of the local malaria strains will decrease. That is, through genetic selection both humans and plasmodia would adapt somewhat to each other. The relative transience of the population, especially the male population, prevents this. The transients are moving through areas endemic to malaria and some percentage are acting as carriers (based on Tchad statistics, about 30%) introducing new strains of malaria to the Bol area. There will always be a risk of an especially virulent strain of one of the three local Plasmodium species being introduced into the Bol area with increased mortality the result.

Local housing (mud adobe, woven mat, and thatch) varies in susceptibility to nocturnal mosquito attack. Many of the mud adobe type have screened windows and some have solid doors or

woven mat doors. The use of mosquito or flour sack netting over sleeping facilities is common (along with screened windows) and appears to be related to the serious local pest status of Mansonia (Malan et al 1977). The pests seem to discourage unsheltered sleeping in general. The woven mat and thatch housing are more susceptible to mosquitos, and smudge fires are commonly used at night as a deterrent.

There are no active mosquito control programs nor routine residual spray programs in residences at this time and there are no records of such programs in the past. These topics will be covered in the Recommendations section.

The presence of three major fecal-oral transmitted diseases (dysentery/acute diarrhea, amebiasis, and infectious hepatitis) at serious incidence levels indicates a problem with either personal hygiene, defecation practices, water supply, or all three. Malan et al (1977) felt that defecation practices outside villages and the hot arid climate minimized this hazard. The common practice is to go outside the compound area and squat. This is apparently true in the dry season, but it contains risk. In the wet season, it certainly is not recommended.

The Peace Corps well program in Bol is a very progressive step forward towards a safe drinking water supply. However, because of the very porous sandy nature of the local soil, sanitation practices, and population density, the ground-water supply can become contaminated. Virtually none of the Peace Corps wells penetrated a substantial clay layer that would safely seal the ground-water supply against contamination. Also, none of the casings themselves were sealed. The existence of drilled cased wells is certainly a quantum health jump from previous water supplies and should not be forgotten. Lake water next to the village is still being used for water supply and waste disposal. There was a significant decrease in dysentery/diarrhea cases in 1977 at Bol (although any quantitative treatment of these data must be approached very cautiously), and this might reflect a change to cased-well supplied water.

Traditional water supplies still being used in the surrounding villages include lake water (now mere marsh water) and open dug wells. Treatment of the water does not occur in the villages or at Bol.

Personal hygiene is involved in the high incidences of fecal-oral transmitted diseases. The left hand is used as a wiping agent and water is only sometimes available to rinse the hand. Although Moslem custom states that the left hand is unclean and the people will not eat with it, both hands are used to handle water vessels, raw foods, etc. The high density of Musca sorbens also certainly contributes to the problem.

Schistosomiasis is an endemic problem throughout the Lake Tchad Basin and will remain a problem in the foreseeable future. Some poor drainage practices in the polder projects locally increase risk of incidence (no drainage in the early ones). This results because of the increased probability of infecting host snails through increased human densities in the polders. Workers defecate and urinate close to their work, and thus increase the probability of schistosomiasis in the host snails in the poorly drained areas (and drainage ditches with poor slope). The probability is higher than in the lake proper simply because of the lake's greater relative volume.

The intake sluices of the modern polders are not snail habitats. The water velocity and lack of substrate are not appropriate for most snail species, especially Bulinus and Biomphalaria, lotic snails. It is unknown whether cercaria can attach and penetrate (or even survive) at the current velocities present in the sluices. This information is needed because it is becoming a common practice for polder workers to bathe in the intake sluices. If the currents are too great for cercaria to be infective, the bathing practice could be encouraged. There is no known literature data on cercaria penetration effectiveness and water current speeds. As a generality, schistosomiasis is not associated with flowing waters (at least in part because host snails are not present).

The crowding of people that occurs during markets, meetings, play, and the closeness of sleeping quarters for large families contributes directly to the spread of diseases like mumps, whooping cough, pneumonia, measles, tuberculosis, trachoma, and secondarily to diarrhea, amebiasis, and hepatitis. This is important because Bol is a very dense community.

Measles are a hot, dry season disease in Tchad and recently has become important in the Bol area. Crowding and poor hygiene certainly play a major role in measles communicability.

V. IMPACT OF PROJECT ON HUMAN HEALTH

The Tandal Polder Project has the potential to either improve or worsen public health in the Bol area. In simplistic terms the project will:

- Remove some 800 hectares of natural marshy embayment, most of which is now fair to good mosquito breeding habitat(s) and good snail habitat(s).
- Create 800 hectares of temporary new mosquito and snail habitats until the area is properly drained.
- If the project can be effectively designed and constructed and good drainage accomplished, approximately

40 hectares of mosquito and snail habitat would remain. These would be restricted to undrainable terrain and portions of the area that are economically or logistically difficult to pump dry (the undrained area could remain as high as 200 hectares).

- Pump 1,500 liters per second of lake water and deliver it in concrete sluices for irrigation at a velocity of 1 m/second.
- Pump 750 liters per second of drainage water back to the lake.
- Increase the local labor force by 300 temporary construction workers, 30 permanent project workers, and 800 permanent agricultural workers (and their families).
- Require living accommodations, water supply, etc., for these temporary and permanent employees and their families. Population levels at Bol of the local villages could increase.
- Provide agricultural products for revenue (and food) locally and nationally.

In terms of public health, the project could temporarily increase local populations of vector mosquitos (of malaria) and host snails (of schistosomiasis) until the polder is properly drained, filled, and graded. It might establish additional sandfly habitat temporarily as well; this is uncertain. It is virtually impossible to compare these (mosquito, snail, sandfly populations in temporary habitats during draining) to the levels naturally present in the marshy embayment. There certainly will be changes in individual species abundances during this temporary period. Because people will be working in the area, increased exposure to malaria and schistosomiasis will occur during this temporary construction period.

Some 40 to 200 hectares of small ponds and marshy areas will remain, including drainage ditches which will be pumped and have some flow. The actual area will depend on bottom topography of the drained embayment. Experience on the other polders has revealed that the bottom is irregular (sand dune topography including ripples, slip off faces, etc.) and some low spots have proven difficult to drain and prepare for agriculture. Thus, there will be some permanent acreage of mosquito and snail habitats; it might be wet-meadow-like and best be planted as pasturage.

Outside workers could introduce a more locally virulent strain of malaria. However, transience is already a demographic characteristic of the area and new strains are being introduced now. A fair amount of construction labor and permanent farmers

will be local. Intestinal schistosomiasis is already present at low incidence and haematobial at a high incidence. This low level of intestinal incidence and higher level of urinary incidence is approximately the same throughout the Lake Tchad Basin. Thus, unless newcomers come from southernmost Tchad where mansonial incidence is higher, the risk of raising the incidence of schistosomiasis is overall not increased. However, a few heavily infected mansonial newcomers could change local incidence rate. Similarily, newcomers could well be more susceptible to local strains of malaria.

Long term, the project, if designed to maximize drainage and minimize standing water (including the drainage ditches), should overall lower the present risk of malaria and schistosomiasis infection (and probably leishmaniasis) locally.

There is no health risk involved in pumping drainage water back into the lake. In fact, this is a very high public health benefit as it reduces mosquito and snail habitats in the polders.

There is a public health danger in increasing population levels in Bol and any of the villages. The lower the population density, the lower the probability of spreading communicable diseases. Bol has no sanitary waste disposal system, and it is getting large enough for this to be of serious concern. Very serious efforts need to be made to limit Bol's further development until steps are taken to provide a sanitary waste disposal system or improved drinking water source.

The recent availability of Peace Corps drilled wells in the area is admirable as this is a great improvement over previous systems. However, local soil conditions are such that groundwater contamination has a relatively high risk. These wells are relatively much safer for the scattered villages at low population densities than they are for Bol. Bol needs to start planning for a central (treated) water supply system as this has much higher priority than a waste treatment system. At a minimum, Bol should go to deeper cased and sealed wells that have penetrated the self-sealing clay layer.

The project also has potential to improve public health in an indirect way. This revolves around SODELAC as a potential commerical agent for supplying chloroquine-treated block salt, window screening, and mosquito bed netting for local commerce. Consideration should be given to including public health improvement as part of the project.

VI. RECOMMENDATIONS

The Tandal Polder Project can improve public health in the Bol area. Several things, including design considerations, can be done directly and indirectly to help maximize human health aspects.

A. DESIGN AND CONSTRUCTION

1. Intake Structure and Water Delivery Sluices

Little can be done regarding the location of the water intake though from a health standpoint, it would be best offshore (to minimize entrainment of schistosome cercaria). This is probably impractical economically and is one of the lower priorities. However, if salt recirculation is a problem, health concerns would reinforce an offshore intake or canal system.

The water delivery sluices in the World Bank Guini Polder Project are good from a health standpoint. Surface area has been minimized, there is a good water velocity in them, and they are concrete, not dirt. Similar structures are planned for the Tandal Project, and these would be good. As a generality, water velocity is good and if possible, the design should maximize velocity in these sluices within good engineering and economical constraints. This will minimize (effectively prevent) sluices as mosquito and snail habitats and probably will minimize cercaria skin penetration.

2. Drainage System

This system should be designed to minimize (optimally eliminate) standing water anywhere in the polder to minimize mosquito and snail habitats. This is complementary to minimizing ponded surface waters and salt concentrations which are poor for agricultural purposes. Design consideration should be given to maximizing gradients in the drainage ditch systems within engineering and economical constraints. Perhaps multiple or stepped drain ditches might be close in cost to one long drain ditch. If these provided better field drainage and less standing water in the drainage ditches, they would be preferable. A lined deep sump at the end of the drainlines would certainly help. Two-stage drainage lines (one subsurface of drain tiles or plastic pipe for chronic drainage, plus a shallow wide-V surface drain for acute rainfall drainage) would be desirable from a health viewpoint. With high transportation costs and lack of a local pipe manufacturer, however, this might be cost prohibitive.

The agricultural field layouts should be surveyed and graded carefully to ensure slope for surface drainage and to minimize low spots where ponding could occur. Careful layout and construction management will be very important.

Maximizing drainage is of much higher health priority than intake location.

B. CONTRACTUAL LOAN CONDITIONS

It would be reasonable to contractually specify, as conditions for accepting a grant or loan, several health considerations. In fact, WHO (1974) specifies the following:

> "Action to be taken in minor projects
>
> In minor projects employing a few hundred immigrants that are generally not assisted by bilateral or international agencies and whose budget is insufficient to develop even a small antimalaria service within the project area, the least that should be done is to make attempts to prevent deaths and to minimize the clinical effects of the disease. The contractor should be compelled by law to announce the future project to the national health authority or its provincial office, if any, and to obtain a stock of antimalarial drugs sufficient for the treatment and weekly mass prophylaxis of all employees, labourers, and their families. He should be instructed by a physician from the national health service on dosages for clinical treatment and weekly prophylaxis for different age groups, as well as on minor larval control activities to be carried out by his men, particularly as regards source reduction. He should particularly set up a centre where one of his employees, in addition to carrying out his normal duties, would distribute 3-day chloroquine treatment to every fever case and each week on pay-days administer weekly doses of chloroquine or pyrimethamine. The contractor himself, in the interests of a successful outcome of the work, should adequately brief all employees and labourers about the malaria danger and the need to take the drugs supplied to them. Non-immune expatriates employed by the project might publicly take the weekly dose to serve as a good example to other employees - after all, they will have more need of the drug than the labourers, who probably have some degree of immunity."

Considering the problem status of malaria in the area, this type of requirement is not at all out of line for this project. WHO goes so far as to specify a malaria control officer and staff, with suitable annual budget, be part of contractual conditions for major projects. This does not appear fully warranted here; however, a basic health education program for workers is warranted and should try to be secured. Some of the health education topics would include personal malaria protection (do not spend nights outdoors, mosquitos cause malaria, importance of taking weekly drugs, importance of reporting to the clinic if fever develops, importance of screens on windows, netting over bedding, etc.); personal hygiene (improper disposal of urine or faeces causes disease, go in dry sandy areas, dry sand "washing" of hand, importance of soap washing when possible, strengthen practices of the Koran, etc.).

C. MUTUAL PROJECT OPPORTUNITIES

The Tandal Polder Project by itself does not economically justify a health or malaria officer (and staff and budget). However, together the four planned polder projects do. Also, the four projects are jointly causing some temporary health problems and if designed or constructed poorly, some long-term problems. It makes sense from a health impact viewpoint to combine these responsibilities into one integrated health program. This might not be politically feasible, but it is meritorious enough to be tried. Then, a major program to significantly drop incidence of malaria in the Bol area would be feasible. Eradication is not practical yet because of the relatively high incidence rates in surrounding areas and the transience of the population. Local health education programs, vaccination programs, etc., could be ensured. Further, this type of program could cost effectively act as a training program for Tchad staff thus benefiting the country as a whole.

D. INDIRECT METHODS

1. Peace Corps Well Program

This is a good program though locally porous soil conditions, sanitation practices, and population densities could mean that ground water could become contaminated. There is much less contamination risk if villages are kept small and spaced apart. A planned drilling program would help accomplish this since villages would locate where these pumps are located. Villagers tend to like to keep together in small family units.

Some malaria control can be accomplished by choosing well sites (and thus village sites) that increase the distance from mosquito breeding areas. Since mosquitos do not tend to fly uphill, do not do well in windy places, and prefer a damper atmosphere, well sites should be selected to maximize distance from standing water and be on as high an elevation as possible. This obviously means the dunes, the traditional village sites.

2. Bol Wells

The population at Bol is exceptionally large now for not having sanitary waste disposal. The risk of contaminating shallow ground-water wells there is high. Deeper sealed wells may be needed that have penetrated an impervious clay layer. A testing program is needed to determine the degree of present contamination and to determine if future contamination occurs.

3. Well Monitoring Program

All new wells should be monitored quarterly for contamination (the *E. coli* test). Contaminated wells could be treated or abandoned.

4. SODELAC As an Agent of Trade

Because SODELAC is already established as a commercial agent to purchase and sell agricultural products and manage the polder water works, an opportunity exists for them to be agents of trade for some goods that would benefit the health of the Bol area residents. These goods include medicated block salt (WHO 1974, but this should be carefully reviewed as to case history success and danger of Plasmodium strains becoming resistant if dosage is too low) (especially if sources of regular salt were restricted or priced at a disadvantage), window screening, and mosquito netting for sleeping areas. It is in SODELAC's best interest that their employees remain productive and healthy. Perhaps special at-cost pricing could be arranged for employees, while nominal profits could be added for area residents.

E. INSECT CONTROL PROGRAM

1. Malaria Control

We do not recommend routine mosquito control programs except for residual spray programs in village houses. A special eradication program which is well planned and supervised is, of course, different. Larviciding, broadcost spraying, and aerial spraying are too costly relative to the local economy for routine application, and there simply is too much area to cover. Also, there is a real danger in local mosquito strains developing resistance to insecticides used. Large-scale programs should be reserved for epidemic emergencies or for special eradication program(s).

Because of the dangers of insecticide resistance in health vectors, we do not recommend routine agricultural insecticide usage for health reasons. This topic is covered in more detail in the plant pests section.

Residual sprays for mosquito control in residences is recommended, acknowledging the difficulties mentioned by Malan et al (1977) for adobe and thatch residences. However, we strongly feel this is the best place to attempt to break the malaria cycle. This, in conjunction with a good medical prophylactic program, will achieve results.

DDT is recommended by WHO (1974) and APHA for mosquito control in domestic residences in problem malaria areas (for which Bol and all of Tchad qualify). DDT is not only an effective residual spray, but it also is a strong irritant to anopheline mosquitos and they tend to avoid residences so sprayed. DDT further is very safe for humans and such limited usage in no way endangers the important commercial fishery in Lake Tchad. Solid vaporizing insecticides (such as Vapona) also offer promise in the adobe domiciles, less in thatch or woven structures.

I. LIVESTOCK SITUATION

Livestock numbers in Tchad increased gradually from 1968 to 1972, then decreased drastically in 1973 (drought), followed by slow recovery to date. Cattle decreased from 4.5 million to less than 3 million and are now just over 4 million. Goats and sheep peaked at over 5 million and are now about 4.5 million.

Livestock are very important economically and socially to the peoples of the Bol polders region. The latest census (1971) produced the following count for the Bol "Cheptel" area: 127,714 cattle, 1,379 camels, 39,164 goats and sheep, 1,036 horses, and 3,469 asses. However, only a small percent of animals were counted. C. de Leusse (1974) gives an estimate for the same year and place: 350,000 cattle, 70,000 camels, 650,000 goats and sheep, 20,000 horses, and 50,000 asses. Dogs are abundant but their numbers are unknown. There are no swine in this muslim area, but wild pigs and warthogs are hunted. Direction L'Elevage, for Lac Préfecture, estimated 300,000 cattle, 150,000 goats and sheep, 20,000 horses, 20,000 asses, 3,000 camels, and no pigs (Direction de L'Élevage 1977).

The herds move in a fairly regular pattern among the islands and to the mainland, depending on rainfall. On the dunes, starting usually in July, annual grasses grow profusely, providing good grazing. Land use of the dunes is a competition between this grazing and the most important crop of the region, millet. The vegetation on these never-inundated dunes includes scattered Acacia raddiana (low trees), Callotropis procera (a woody milkweed, Asclepiadacae), Leptadenia spartium or pyrotechnica (camel feed bush), a few doum palms (Hyphaene thebaica) which are often "palmetto-like" as regrowth after cutting, and the annual grasses and millet fields. At the same time, the low profile sandy islands (inundated in some years) are grazed. Annual grasses grow here also. The vegetation is less xerophytic.[1] The scattered tree growth is mostly doum palm, with some Acacia and less "milkweed" than on the dunes. Feeding by cattle, goats, sheep, and camels on the above areas includes browsing as well as grazing.

[1]Plants acclimated to dry environments.

The above statement is based upon personal observation in early April (very dry season). A complete botanical summary as recorded prior to 1967 is presented in Annex 5.

The length of time that livestock can graze on these lands depends on length and intensity of the rains. Before February, the annual grasses are dead and eaten. Most of the cattle move off the mainland to the islands and graze on lands that are inundated annually during the rainy season. Inundation lasts well beyond the end of the rains, depending on timing of the Chari River flood. The botany of these areas and more information on migration of cattle and man was presented in earlier sections.

A minor number of cattle, goats, and sheep are kept year-round at villages on the dunes near Bol, spending the night near the villages. Manure from these animals, as well as the seasonal stock, is used to fertilize millet fields.

It is difficult to assess this grazing and movement pattern based upon observation made late in the dry season when most of the uplands appear like bare sand. Nevertheless, it appears that the upland areas near Bol are grazed and browsed up to their carrying capacity and possibly beyond.

Improved nutrition is being tested at the Matafo Experiment Station, particularly the use of Pennisetum grass on polders and supplementation with crop residues such as cotton seed.

The livestock-man association is intimate as older cattle are usually herded by men, and calf and goat herds by children. Raw milk, usually soured, is regularly consumed by man, and meat is utilized even from sick and dying beasts. Local cooking often does not sterilize the meat. The primitive slaughtering facilities include no veterinary nor medical inspection and the raw hides can spread contagion. Livestock immigration and emigration are extensive, including some long-distance seasonal migration as detailed in earlier sections. Thus, livestock diseases and zoonoses[1] can fulminate in the area, and new inoculum[2] may appear during livestock immigrations.

II. GOVERNMENT SERVICES IN VETERINARY AND ANIMAL SCIENCES

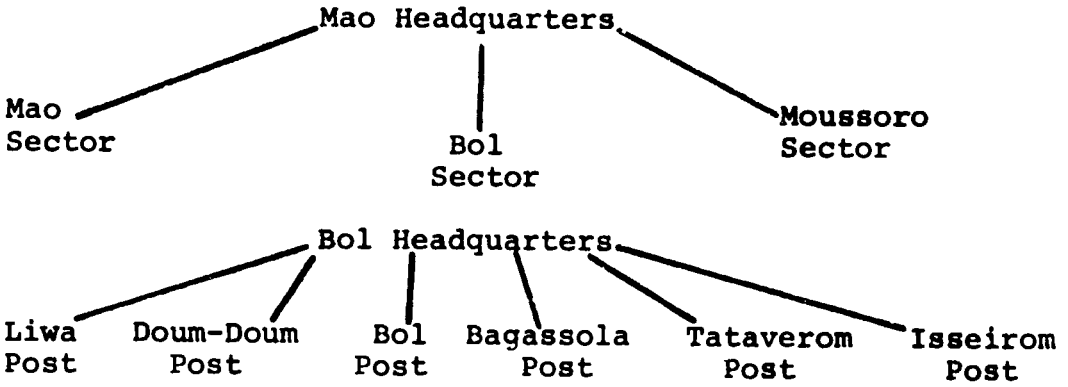
Veterinary and Animal Sciences are centered in the Direction de L'Élevage et des Industries Animales, Direction Générale, Ministère du Developpement Agricole et Pastoral, Charge de la Lutte Contre les Calamites Naturelles, headquartered at Farcha, N'Djamena.

[1]Diseases of animals that are transmissible to man.
[2]Introduction of infectious material.

This "Direction de L'Élevage" comprises departments in Administration, Technique, Projects, and Education-Research. The Technique Department includes Animal Health, Production and Animal Industry, Tsetse Control, Cell Research, and Maintenance sections. The Projects Department includes: Conducting Projects, Supervision, and Checking Projects sections. The Education-Research Department includes: National School for Veterinary Technicians ("Agents Techniques") (ENATE), Experimental Pasture Center at Bedaye, and Veterinary Stations (temporarily closed) including N'gouri Stud Farm, Ouaddi-Rime Ranch, Fianga Veterinary and Zootechnique Research Center.

Direction D'Élevage divides Tchad into six "Circonscriptions" to administer field veterinary services: Central-West headquartered at N'Djamena, North-West at Mao, Central at Ati, East at Abeche, South-East at Sarh, and South-West headquartered at Bongor. The Circonscriptions are divided into Sectors and the Sectors into Posts. Bol is in the North-West "Circonscription" (includes Kanem and Lac Préfectures.

NORTH-WEST CIRCONSCRIPTION



The Bol Sector staff totals 25: Head of Sector (1), Agent Techniques (6), Infirmier brete (6), Infermier veterinaire (4), Interpreter (2), Driver (1), Boatman (1), and Laborers (4). The Bol Sector headquarters at Bol are primitive. There is no real diagnostic laboratory, only an office and some cabinet storage space for drugs. There is but one operational vehicle. This travels infrequently as petrol is chronically in short supply. Drugs are in short supply and the bulk of activity is in vaccination campaigns. No surveys of disease are conducted. All data are based upon "cases that come to the attention of Direction L'Élevage."

Veterinary and agronomic research is centered in the Laboratory of Veterinary Research and Zootechnique of Farcha, which is part of the Institut D'Elevage et de Medecine Veterinaire des Pays Tropicaux, Maisons-Alfort France. The Pathology Division conducts research on viral and bacterial diseases and on entomological and helminthological problems. This division produces vaccines against viral and bacteriological diseases. This is a major operation, producing almost 10 million doses of vaccines for use in most of Francophone West and Central Africa, as well as in Tchad. Diagnostic work is also done by the Pathology Division. The Zootechnique-Nutrition Division works on animal science related to small animals (goats and sheep), on agronomic problems, and on zootechniques and applied biochemistry.

The 1977 budget totalled 239,322,500 CFA to support a staff of 411. The staff included 9 veterinary doctors, 1 agronomist, 1 ingenieur agronome, 1 biochemist, 1 pharmacist, and 156 lower-level employees. Staffing is almost complete except for the post of entomologist.

The developing University of Tchad teaches some courses in animal science, diseases, and agronomy. Research and extension activities are very limited to date.

III. DISEASES AND THEIR RELATIVE IMPORTANCE

A. INFECTIOUS DISEASES

Campaigns against the great viral diseases of livestock, such as rinderpest and contagious bovine pleuropneumonia (CBPP), are not completed in Tchad. Currently, no cases of rinderpest are known in Tchad (Bertin, personal communication), and the vaccination program is continuing. However, there is lack of knowledge of the rinderpest situation in some neighboring countries so that new infections in Tchad are possible by international livestock movements. There was rinderpest in Nigeria and in Cameroun in 1975 (Bertin, personal communication). Rinderpest presents no foreseeable threat to the Bol polder area as long as security continues.

Contagious bovine pleuropneumonia (Mycoplasma mycoides), however, remains enzootic[1] in the Bol Sector despite the vaccination program. The disease is chronic and recurrent and affects only cattle. Actual number of cases is unknown because of difficulty of transport among the islands and because of the chronic nature of most cases. Vaccination of Kouri cattle on the islands is very incomplete because vaccinators from Direction L'Elevage have inadequate water transport. Some island cattle swim to the mainland, perpetuating the infection. Many Kouri cattle died on the islands

[1]Enzootic is the veterinary equivalent of the medical term "endemic."

during 1951, probably from an epizootic of pleuropneumonia, but exact diagnosis was not accomplished.

Foot and mouth disease remains enzootic and causes some losses, but it is not a limiting factor to successful husbandry with indigenous livestock.

The usual nonvectored diseases of African livestock are common in the Bol Sector. Direction L'Élevage records infections and mortality as such come to their notice, but exact survey is nonexistent. Vaccinations are given annually to combat rinderpest, contagious bovine pleuropneumonia, hemorrhagic septicemia, blackleg, and anthrax. No charge is made for these vaccinations (except rabies). Disease incidence and vaccination data are presented in Table 3G-1. Tables 3G-2, 3, and 4 present comparison data for the North-West Circonscription and Tchad as a whole.

Anthrax is serious in the Bol polder area, with considerable death losses. Infections increase dramatically during the rainy season, May to October. Spores remain viable for long periods in soils. During 1971 an epizootic[1] of anthrax killed many cattle and goats. Vaccination had been suspended. Since then, vaccination has been fairly rigorous, and the disease is now of sporadic occurrence. Human infections and deaths do occur from eating meat from diseased animals (intestinal anthrax). Many deaths occurred in Tchad in 1970 and 1971 (Bertin, personal communication). Human dermal anthrax occurs from hides of infected animals, but this disease is seldom fatal.

Blackleg exists in the Bol Sector, but the annual vaccination program minimizes losses among cattle. Camel infections occur also, but no exact data exist. There were only 174 camel vaccinations in the whole North-West Circonscription. Infections in goats are not known.

Hemorrhagic septicemia can be a serious disease of cattle in Tchad. It is noted as particularly serious by Lake Tchad and in the low, humid parts of the country. There is no general annual vaccination campaign. Vaccinations are done by request or against outbreaks in specific areas. During 1975 hemorrhagic septicemia was a problem in the Bol Sector. Vaccination was done in 1975 subsequent to diagnosing initiation of the outbreak, and again in 1976. No cases were reported in 1977.

Brucellosis (Brucella abortus, B. melitensis, and probably B. canis, B. suis) is enzootic in Tchad. No survey has been

[1]Epizootic is the veterinary equivalent of the medical term "epidemic."

Table 3G-1
INCIDENCE OF AND TREATMENTS FOR LIVESTOCK DISEASES, BOL SECTOR. 1977[1,2]

Disease	Livestock	Cases	Deaths	Vaccinations	Treatments
Rinderpest[3]	Cattle	0	0	214,667	0
Pleuropneumonia CBPP[3]	Cattle	--[4]	--	214,667	0
Foot & Mouth Disease	Cattle	--	--	0	0
Anthrax	Cattle & goat	--	--	126,415	0
Blackleg	Cattle	38	4	218,216	0
Histoplasmosis	?	14	--	0	14
Streptothricosis	Cattle	10	--	0	10
Hemorrhagic septicemia	Cattle	0	0	0	0
Trypanosomiasis	Cattle	642	--	0	642
Trypanosomiasis	Camels	300	--	0	300
Trypanosomiasis	Horses/asses	27	--	0	27
Piroplasmosis	Cattle	6	--	0	6
Rabies	Dogs	--	--	4	0

[1]Data from Bol Sector Annual Report 1977, Direction D'Elevage.
[2]Data are cases of disease and deaths that are brought to the attention of Direction L'Elevage. No survey data are available of general incidence in the sector.
[3]Vaccinations are the same for rinderpest and pleuropneumonia because a bivalent vaccine is used.
[4]Dashes mean cases and deaths do occur but number is unknown.

Table 3G-2
INCIDENCE OF AND TREATMENTS FOR LIVESTOCK DISEASES,
NORTH-WEST CIRCONSCRIPTION. 1976.[1]

Disease	Livestock	Locations	Cases	Deaths	Vaccinations	Treatments
Rinderpest	Cattle[2]	0	0	0	389,179	
Pleuropneumonia CBPP	Cattle[2]	5	--[3]	--	391,617	
Foot & Mouth Disease	Cattle	2	--	--		
Blackleg	Cattle	--	--	--	385,702	
Blackleg	Camel	--	--	--	174	
Anthrax	Cattle	2	--	--	376,978	
Anthrax	Camel	--	--	--	357	
Anthrax	Goat/sheep	--	--	--	--	
Anthrax	Horse/ass	--	--	--	--	
Hemorrhagic septicemia	Cattle	1	--	--	90,817	
Rabies	Dog	--	--	--	27	
Trypanosomiasis	Cattle	--	--	--		998
Trypanosomiasis	Camel	--	--	--		2,278
Trypanosomiasis	Other species	--	--	--		83
Streptothricosis	Cattle	--	--	--		4
Piroplasmosis	Cattle	--	--	--		17
Piroplasmosis	Other species	--	--	--		16
Helminthiasis	All species	--	--	--		55,492
Mange	Camel	--	--	--		89
Mange	Other species	--	--	--		35
Histoplasmosis	?	--	--	--		47
Pleuropneumonia	Goats/sheep	--	--	--		--

[1]Data are from Bol Sector Annual Report 1977, Direction D'Elevage.
[2]Bivalent vaccine.
[3]Dashes mean cases and deaths do occur but number is unknown.

Table 3G-3
INCIDENCE OF EPIZOOTIC DISEASES OF LIVESTOCK
IN TCHAD 1976

Disease	Locations	Cases	Deaths
Rinderpest	0	0	0
Foot & Mouth Disease	6	32	25
Pleuropneumonia CBPP	10	114	71
Anthrax of cattle	18	Many	380
Anthrax of camel	Many	6	6
Anthrax of goats/sheep	Enzootic	58	52
Anthrax of horses/asses	6	5	--
Blackleg of cattle	11	324	230
Blackleg of camel	--	--	--
Trypanosomiasis of cattle	Enzootic	22,843	1,155
Trypanosomiasis of camel	Enzootic	2,471	64
Trypanosomiasis of other species	Enzootic	966	14
Piroplasmosis of cattle	Enzootic	2,420	207
Piroplasmosis of other species	Enzootic	61	
Hemorrhagic septicemia of cattle	4	69	46
Streptothricosis of cattle	Enzootic	Enzootic	--
Histoplasmosis	Enzootic	269	--
Mange of camels	Enzootic	1,363	
Mange of other species	Enzootic	1,293	
Internal parasites	Many	Many	--
Pleuropneumonia of goats/sheep	Enzootic	Many	Many

Table 3G-4
ACTIONS AGAINST LIVESTOCK DISEASES IN TCHAD

Disease	VACCINATIONS				
	1976	1975	1974	1973	1972
Rinderpest	1,674,940	1,713,995	1,539,464	1,744,869	1,633,915
Pleuropneumonia CBPP	1,689,309	1,747,039	1,546,783	1,746,730	1,436,076
Blackleg (cattle)	1,598,089	1,309,418	1,114,772	1,178,218	726,355
Blackleg (camel)	2,027	16,258	11,149	9,153	--
Anthrax (cattle)	1,733,049	1,233,223	1,017,219	819,768	716,428
Anthrax (camel)	6,195	23,671	12,269	7,858	676
Anthrax (goat/sheep)	75,766	28,692	--	--	--
Anthrax (horse/ass)	6,938	258	--	--	--
Hemorrhagic septicemia	130,733	11,846	52,795	35,213	
Rabies	2,418	2,326	2,041	1,164	1,397

Disease	TREATMENTS				
	1976	1975	1974	1973	1972
Trypanosomiasis (cattle)	102,881	55,168	66,390	262,952	169,156
Trypanosomiasis (camel)	10,216	20,188	13,963	9,150	15,627
Trypanosomiasis (other sp.)	4,457	2,799	2,040	4,661	5,351
Piroplasmosis (cattle)	4,273	2,937	4,243	650	1,665
Piroplasmosis (other sp.)	1,006	205	332	229	260
Streptothricosis (cattle)	18,998	11,992	5,847	17,715	5,787
Helminthiasis	506,271	517,912	512,502	406,785	58,279
Mange (camel)	2,259	1,454	20,511	34,253	26,254
Mange (other sp.)	94,837	2,618	4,952	2,866	1,285
Histoplasmosis	664	610	563	841	648
Pleuropneumonia (goat/ sheep)	4,312	3,522	818	150	
Other treatments		338,678			

conducted on man or livestock at Bol but it is undoubtedly present and may be important to livestock production. At Karal on the south shore of Lake Tchad, cattle were found to be 20 percent infected. At Massakory the cattle infection rate was 24.2 percent. This location is about 120 kilometers east of Bol on the N'Djamena to Bol road. Losses are considerable (abortion, sterility, loss of milk and meat), estimated at Karal to be 5.8 to 9.5 million CFA/10,000 head/annum (Lab. Vet. Res. Zootech. Farcha 1978). Brucellosis affects cattle, goats, man, and other species. Human infections arise mainly through contact with cattle and by drinking unboiled milk.

Diseases present at Bol, for which data are inadequate to assess importance, include tuberculosis, histoplasmosis, streptothricosis, small animal pneumopathies, and rabies. Tables 3G-1, 2, 3, and 4 give data for Bol, North-West Circonscription, and Tchad in general. These diseases are discussed more completely in Annex 5, Animal Health. Treatment with neoarsphenamin for histoplasmosis was given to 14 cattle at Bol in 1977. Treatment with injectable penicillin plus streptomycin for streptothricosis was given to 10 cattle at Bol in 1977. Diseases probably present at Bol but for which there are no data include actinomycosis, trichophytosis, leptospirosis, Q fever, tetanus, toxoplasmosis, cowpox, and orf virus. These diseases affect man as well as animals. Further information is presented in Annex 5, Animal Health.

Calfhood diseases are an important problem at Bol, causing losses through stunted, poor growth and death. Diarrhoes are common, but no study of causative agents has been conducted. Malnutrition is a contributory factor, as the dam's milk is used for human consumption with the calf getting the remainder. Complication with tick-borne disease problems of calves is discussed subsequently (Section B). The abundant filth flies of Bol, Musca sorbens, are mechanical vectors of diarrhoes of calves and mastitis of cows.

In general, disease problems are most serious during the rainy season, May to October. Time lag for infection development produces peak problem from August through October. This is particularly true for parasitic problems requiring moisture for hatching of eggs, soil-borne pathogens such as that of anthrax, and vectored diseases with vector population peaks dependent on water for breeding or moisture for survival (trypanosomiasis, tick-borne diseases, arbor viruses, etc.).

B. VECTORED DISEASES AND EXTERNAL PARASITES

Arthropod-vectored diseases are limiting factors to livestock production in most of Africa. However, the aridity of Tchad north of 13°N latitude prevents reproduction of many vector

arthropods. At Bol, none of the vectored diseases are limiting factors, but several reduce productivity of livestock.

Trypanosomiasis of cattle, goats, sheep, camels, horses, and asses is common in the Bol Sector. Species probably present include Trypanosoma congolense, T. vivax, T. brucei, T. evansi, T. simiae and possibly others, and also T. equiperdum (spread by contact). There have been no recent surveys to determine trypanosome species or relative abundance. However, cyclic transmission by tsetse flies (Glossina) does not occur in the Bol polder area. Shade is required for tsetse reproduction, and savannah tsetses require trees for resting sites prior to flying toward hosts from which they obtain a blood meal. The Bol polder area is ecologically unsuited to tsetse. None have been seen for many years.

Acyclic transmission of trypanosomiasis by Tabanidae (horseflies and deerflies) is implicated. No research has been done in Tchad to substantiate tabanid transmission, but Direction L'Elevage believes Tabanidae to be the vectors. Tabanidae are proven vectors in the Sudan and Venezuela, particularly for Trypanosoma vivax. Tabanidae are not implicated as vectors of human sleeping sickness (Trypanosoma gambiense), and this form of trypanosomiasis is not present in the Bol area. Tabanidae are reported to be abundant in the Bol area, particularly during the rainy season (Direction L'Élevage, personal communication). The Tabanidae species of Africa are fairly well known, but no references could be found to specific data on Tabanidae of the Bol area. Buck et al (1970) found Atylotus agrestis (abundant) and Tabanus taeniola variatus (few) at Djimtilo on Lake Tchad in the Chari Delta. Most Tabanidae are aquatic in the larval and pupal stages but a few breed in soil. To our knowledge, no studies on tabanid larval habitats have been conducted in the Lake Tchad area. The ORSTOM Lake Tchad hydrobiological research plan excluded Tabanidae.

Cases of animal trypanosomiasis that come to the attention of Direction L'Élevage, Bol Sector, are treated with chemotherapeutants including Berenil, Trepamidium, Morganyl, or Naganol.

The tick-borne diseases piroplasmosis (Babesia, many species), anaplasmosis (Anaplasma, several species), heartwater (Rickettsia ruminantium) and other rickettsioses, and benign theileriosis (Theileria, certain species) most likely are all present in livestock in the Bol Sector. There are no exact data on incidence as no survey has been done. Annual summaries by Direction L'Élevage suffer from inadequate equipment and personnel rendering differential diagnosis impossible. Undoubtedly, tick-borne virus diseases occur also, but diagnosis

is impossible under current conditions. Death from piroplasmosis is most common among calves. Poor nutrition (competing with man for milk), helminthic, diarrhoeic, and other diseases lower the natural resistance of calves to piroplasmosis. Survivors become premune, but recurrence and death can occur in older animals, again frequently because of presence of other diseases.

Cases of piroplasmosis that come to the attention of Direction L'Elevage, Bol Sector, are treated with the chemotherapeutants Omidine or Pentamidine.

The tick species and their distributions in Tchad are well known through the work of P. C. Morel and his coworkers (Morel 1958, Morel and Magimel 1959, Morel and Graber 1961). Amblyomma lepidum and A. variegatum (important vectors of diseases of cattle, sheep, goats, camels, horses, asses) have been found in the north of Tchad, the latter at Bol, but have not established continuing populations. Amblyomma species are the important vectors of heartwater (Rickettsia rumimantium) of cattle and sheep.

Boophilus annulatus and B. decoloratus are present at Bol, vectoring piroplasmosis, anaplasmosis, and possibly other diseases to all classes of livestock. B. decoloratus is the more important since it is better adapted to low rainfall zones.

Hyalomma impeltatum, H. impressum, and H. truncatum are recorded at Bol and H. dromedarii and H. rufipes are probably present as they have been found in similar ecological zones near Ngouri, Mao, Moussoro, and Ati. Hyalommas are the common ticks of arid Africa, attacking camels in particular, but also other classes of livestock. Quoting Morel and Graber (1961), "They are distributed abundantly in the Sahel and the North Sudanese Savannah." Morel and Magimel (1959) note H. impetatum, H. truncatum, and H. rufipes as the most abundant species. Hyalomma species transmit piroplasmosis and anaplasmosis to livestock but are particularly important in vectoring tick-borne diseases among camels. They transmit tick paralysis, Q fever, and possibly boutonneuse fever.

Rhipicephalus simus (early collections may include R. muhsamae, see Morel and Vassiliades 1964) and R. appendiculatus have been collected at Bol and R. evertsi and R. sanguineus complex (Morel and Vassiliades 1962) at Moussoro and Ati so that they likely occur at Bol. R. sanguineus (very abundant all around Lake Tchad) and R. simus (uncommon) are vectors of diseases of dogs and of human rickettsioses (Rickettsia conori, boutonneuse fever) but are of little importance to livestock. They are capable of transmitting livestock diseases, but their life cycles and host predilections make them unimportant. R. evertsi is an efficient vector of piroplasmosis and

anaplasmosis, but populations on livestock are very small in the Lake Tchad region.

R. appendiculatus is the most important tick in Africa since it is the vector of East Coast fever (Theileria parva) as well as other diseases, but it is not present in Tchad so far as known. A single collection of R. appendiculatus at Bol undoubtedly resulted from long-distance migration or importation of livestock, or possibly movement of a wild host. Bol is ecologically unsuited to R. appendiculatus so that development of populations of this tick is most unlikely. Nevertheless, this tick should be watched for as any development of a population could cause devastating death losses of cattle by an East Coast fever epizootic.

Ornithodoros savignyi, found at Mao, is abundant in all terrain of Tchad receiving less than 500 mm annual rainfall (Morel and Magimel 1959). This argasid tick is a specific pest of camels, vectoring camel diseases, but will feed on other livestock. It lives in the walls, floors, and ground of the locations where camels rest. It is present in the Bol area where Buck et al (1970) collected 54 specimens.

Many tick species are present in Tchad that are of no significance to livestock at Bol. Also, tick-borne virus diseases of livestock are undoubtedly present in the environs of Lake Tchad, but no studies have ever been done.

This discussion of ticks and their importance at Bol is based on data collected more than 17 years ago. No surveys have been done since then.

A negligible amount of tick control is done in the North-West "Circonscription D'Élevage." In the Bol Veterinary Sector there are no dip tanks nor sprayers. Some hand treatment is done using insecticide from Direction L'Élevage. Seventy-five liters of "Procigam" (benzene hexachloride) and "Procibam" (carbaryl) formulation was used in 1977. This quantity could have no effect on tick population in the area in general, nor have an appreciable effect on tick-borne disease incidence. Far less than 1 percent of the livestock of the Bol Sector could have been treated with 75 liters of insecticide concentrate. L'Élevage Farcha reports that there is some resistance to benzene hexachloride in ticks in Tchad, likely in Boophilus species only.

Mites of the families Sarcoptidae, Psoroptidae, and Demodicidae cause mange and scabies of all classes of African livestock. In Tchad, mange is most serious on camels but is of lesser importance on cattle, goats, and sheep. Demodex causes serious losses to hides by downgrading leather. Demodicosis is particularly severe on dogs. All these manges and scabies are present in the Bol Sector.

Mosquitos, probably Mansonia sp., were reported as causing severe losses in the 1973 rainy season during a cattle fattening experiment at Bol after the lake receded due to the drought. The likely cause was vegetation involved with additional breeding loci. When the lake returned to higher level, the mosquito outbreak subsided (McGahuey 1975). Amopheles, Aedes Culex, Aedomyia, Ficalbia, and Urotaenia undoubtedly add to the Mansonia sp. mosquito problem. Mosquitos also transmit Germiston and Congo fever which are zoonotic African viruses of unknown status in Tchad.

Graber (1964) has published on species and incidence of cattle, sheep, and poultry helminths in Tchad, and the annual reports of the Veterinary Research Laboratory, Farcha, update this information. Their helminth research was closed down until July 1977. Now they plan to investigate the situation subsequent to the drought.

Direction L'Élevage considers helminths to be a major problem in Tchad. Several people have stressed the importance of liver flukes, intestinal roundworms and flatworms, stomach roundworms, and distomatose in cattle and goats of the Bol Sector. Treatment is done with Exhelf 11 (Morantil tartrate) for roundworms, Disto 5 cogla and Ranide for flatworms, applied without charge. Impact is worst on young animals, and this is the most frequently treated age. Tapeworm cystocerci are frequent in meat in the area, resulting in cases of beef tapeworm in man.

IV. IMPACT OF TANDAL POLDER PROJECT ON ANIMAL HEALTH

Two phases of ecological change, occasioned by the Tandal Polder Project, must be discussed separately for impact on animal health. During the first phase, development of Tandal from virgin Lake Tchad ecology to the cropping stage, there will be extensive ecological changes that will affect animal health, mainly by population fluctuations of aquatic and semi-aquatic vector arthropods. Subsequently in Phase 2, fully developed cropping, there will be a minimum of aquatic and semi-aquatic habitat on the Tandal Polder. During Phase 2, possible deleterious effects on animal health will relate mainly to changes in number of livestock in the area and their movement patterns.

Phase 1 is projected as requiring between 1 and 2 years. The gradual drying process will produce temporary stagnant water areas and exposed muddy habitats conducive to breeding of certain vector arthropods with aquatic or semi-aquatic immature stages. These include mosquitos, Tabanidae, Ceratopogonidae, and Psychodidae.

During Phase 1, it is predicted that an increase in mosquito annoyance to livestock with probable minor direct production loss and an increase in mosquito-borne arbovirus diseases will occur. Outbreaks of ceratopogonids or psychodids should have but a minor effect on livestock as direct annoyance is not very important, and they carry few diseases to livestock. Bluetongue could be worsened, but too little is known about this disease in Lac Préfecture to allow prediction.

The most important vectors to be considered are Tabanidae. Unfortunately, the prediction of effects on population is hampered by lack of knowledge of larval habitats. The drying polder area will probably provide breeding grounds for one or more species. However, tabanid larvae and pupae require many months to mature so that survival will be minimize by rapid drying out of the polder. Therefore, it is possible that tabanid transmitted diseases will increase during Phase 1, but such increase should not be great. Trypanosomiasis is the most important livestock disease transmitted by Tabanidae.

Other diseases possibly aggravated during Phase 1 are anthrax, streptothricosis, leptospirosis, calfhood dirrahoes, and helminthic infections. These are diseases of higher incidence when cattle utilize wet grounds or humidity is high or in the rainy season. If cattle are grazed extensively on the Tandal Polder during the first phase, one or more of these diseases could worsen. No increase should occur if the polder was not grazed.

There is no reason to expect an increase in the contagious diseases such as rinderpest, contagious bovine pleuropneumonia, blackleg, hemorrhagic septicemia, brucellosis, tuberculosis, or small animal pneumopathies.

Tick-borne diseases may be affected by better survival of ticks on the damp ground in the polder during the dry season. However, the Sahel ticks are adapted to the dry environment so that population change should not be great. Sahel ticks would be unlikely to survive on very wet ground. Hyalomma, Rhipicephalus, and Amblyomma ticks in the Sahel probably require a full year for one generation (Strickland 1961). An increase in tick numbers might occur toward the end of Phase 1, but not likely. Boophilus ticks reproduce more rapidly so that these would be the most likely to increase if cattle are grazed on the drying polder. Thus, piroplasmosis and anaplasmosis, Boophilus vectored, are the most likely tick-borne disease complexes to increase during Phase 1, but even this is questionable.

Phase 2 should be beneficial by reducing the area of aquatic and semi-aquatic habitats that breed vectors of livestock

diseases. Some aquatic and semi-aquatic habitats will remain, perhaps 40 to 200 hectares (including drainage canals), but it is difficult to predict the relative importance of this small area in comparison to the 1,100 hectares of virgin Tandal. The conclusion of beneficial effect is based on the assumption that, during normal functioning of the developed polder, the cropland will never be flooded for more than a short period during irrigations or unusual rains. Aquatic and semi-aquatic vector arthropods should not breed on the croplands. The irrigation and drainage canals will breed a minimum of vector insects so long as these canals are maintained clean, free of emergent vegetation, and free running with no stagnant water. This projection is predicted on planting of upland crops. Lowland rice, however, would encourage aquatic insect vectors and inundation during Phase 2 of part or all of the polder could result in breeding a large number of vectors of livestock diseases. Foreseeable causes are above-normal lake level, protracted unusual heavy rains, unforeseen seepage, upwellings, or breakdown of the drainage system.

Phase 2 could aggravate livestock disease problems by increasing the number of livestock in the Bol polders area. Increased human population is necessary for agricultural labor to ultimately use the total area of Guini, Berim, and Tandal Polders. Normally, the peoples of northern Tchad take their livestock with them when they move. However, the grazing land in use now is fully grazed near Bol and additional livestock will require feedstuffs or grazing from the polders. Kanembu and Buduma peoples may be willing to migrate in while leaving their herds in their home area with part of the family. Southern Tchadian peoples, on the other hand, would come without livestock. No exact forecast of livestock numbers can be made until human population increase is estimated, the tribal composition is known, and administrative actions are planned to prevent overgrazing in the Bol area.

If the livestock population is allowed to increase significantly, there will be overgrazing, poor nutrition, crowding, increased use of paths, etc. There is jeopardy of increased incidence of contagious diseases as well as vectored diseases and parasites. By contrast, the polders could increase productivity of livestock by providing by-product feed supplements (e.g., cottonseed) and nutritious forage from lands not being cropped. No significant increase in livestock numbers would then be necessary for greater production of meat and animal by-products. Better nutrition would help to alleviate impact of disease.

Thus, correct polder utilization and Bol area management should allow little or no significant livestock population increase. Thereby, no significant disease problem should result from Phase 2 utilization of the Tandal Polder.

In further summary, the area of Tandal Polder is extremely small in contrast to the many square kilometers of Lac Prefecture over which the livestock move. Annual movements, island to island and island to mainland and back, are done in an area of well over 500 square kilometers for livestock that appear in the Bol polders area at one or another time of year. Thus, it is difficult to conceive that changes in the less than 1,100 hectares of Tandal could have a major health effect. In opposition, the "nidus of infection" principle could be pertinent. Changes wrought by the project might cause a disease organism and its vectors and intermediate hosts to increase simultaneously. The result would be an outbreak of disease. We know of no predictable "nidus of infection" effect.

V. RECOMMENDATIONS

1. Bol headquarters veterinary personnel, facilities, supplies, and direction should be drastically improved. The present emphasis on vaccination should not be slackened. In addition, the necessities should be provided for survey of diseases and vectors, for differential diagnosis, for obtaining specimens from diseased animals, and for storage and shipment of specimens to Farcha for examination. Additional trained personnel and labor is necessary to implement survey, as well as equipment such as vehicles, paraffin (kerosene) fueled refrigerator and freezer, microscopes, glassware, and miscellaneous laboratory equipment; supplies of petrol, reagents, slides, collecting bottles, preservative, labels, notebooks, pencils; equipment maintenance. Drugs and insecticides should be available on a continuing basis for treating livestock.

The present lack of commercial production of meat and by-products from the herds may not warrant such expenditures. However, livestock population increase in the Bol area, with concomitant threat of disease increase, should be impetus for improvement of Bol headquarters. If improved animal husbandry, including improved pasture and feeding is accomplished, livestock production may support the expenditures noted above.

2. The same recommendation is made for Central Headquarters of Direction L'Élevage at Farcha. No strong recommendations can be made, however, since Bol Sector is but a small portion of Direction L'Élevage's responsibility. Two suggestions are paramount. First, Farcha should include expertise and incidentals to do adequate examination of specimens sent from the Bol Sector. Second, an extension type section of Direction L'Elevage should be organized and personnel trained to give livestock owners instruction in improved animal husbandry, disease control, and agronomics. This suggestion will be difficult to implement but a start should be attempted.

3. Concerning the Laboratory of Veterinary Research and Zootechnique at Farcha, the excellent contribution of vaccine production and long history of good research is to be commended. It is to be hoped that future trend of research will be toward certain practical problems of epizootiology and vector biology. Entomological and helminthological survey and biology should be brought up to date. An entomologist should be recruited soon. Identification and incidence of arbovirus diseases should be studied and vectors identified.

For the Bol area, differential diagnosis of trypanosomiasis is necessary, particularly the relative incidence of Trypanosoma vivax (the trypanosome best adapted to acyclic transmission by Tabanidae). Studies of tabanid species, relative abundance, and larval habitats are necessary to understand the trypanosomiasis situation in the Basin of Lake Tchad and the impact of polder development on trypanosomiasis. The tick survey should be renewed and biological studies commenced to determine life cycles, including number of generations a year (probably one at Bol for most species). Such information will determine period of infectivity to livestock, providing a basis for an inexpensive, practical program for control of tick-borne diseases in the Lake Tchad Basin as well as north Tchad in general.

There should be expanded agronomic research, emphasizing testing of grasses other than Pennisetum. It is possible that species of grasses within the genera Cenchrus, Panicum, Passpalum, Andropogon, Chloris, Hyparrhemia, etc., may be better adapted to environments such as that of Bol. Productivity, feeding value, and labor requirements (planting, replanting, direct use by livestock rather than cutting) may be better. Research on cattle feeds should include evaluation of crop residues and by-products of current crops as well as new crops. Adaptability of cattle breeds to Bol conditions could be studied, emphasizing other African breeds such as the highly productive Boran cattle of Somalia and Kenya.

Cooperation with ORSTOM and with the Ministry of Public Health and Social Welfare could expedite research on disease problems. ORSTOM hydrobiological research could include Tabanidae taxonomy, distribution, and biology. The important problems of brucellosis and tuberculosis incidence in man, related to incidence in livestock, could involve Farcha serological and immunological facilities and personnel. Obviously, zoonoses should involve medical and veterinary experts in concert.

Cooperation with the West African Virus Research Organization in Nigeria could aid greatly in elucidating the arbovirus problem in livestock.

4. Eradication of trypanosomiasis in the Bol Sector should be considered. Over 35 years ago it was standard practice

to halt acyclic transmission of trypanosomiasis by chemotherapy. Cattle that developed trypanosomiasis by movement into a tsetse belt and subsequently back to tsetse-free grazing were sources for acyclic transmission to uninfected cattle. Treatment of all cattle in the tsetse-free area sufficed to terminate the outbreak (Northern Rhodesia Government Annual Report 1950-1954). The scheme is successful because acyclic transmission from wild hosts occurs rarely or never, and Tabanidae harbor trypanosomiasis for minutes only.

The suggestion, therefore, is trypanocidal drug treatment of all cattle in the Bol Sector, accomplished in as short a time as possible. Subsequently, there should be monitoring for trypanosomiasis and repeated general treatment if incidence rises greatly. Recurrence should be slow so that retreatment should be necessary only after an interval of several years, depending on cattle movement from tsetse infested zones. Drug resistance should not arise as acyclic transmission allows only asexual reproduction of the parasite.

5. The contagious bovine pleuropneumonia vaccination program should be reevaluated. More than 10 years ago there was controversy over the best approach to control of this disease (National Academy Sciences, U.S.A. 1965). The alternative approach is testing, elimination of reactors, and restricted movement of animals from infected herds. Required is large-scale rapid serological diagnosis, possibly using mobile field equipment. Considerable local adaptation would be necessary because of difficulty of transport in the Tchad sands, mud, and interisland waters, as well as the difficulty of herd control.

6. No large-scale tick-borne disease control campaign should be attempted. Dips and spray races for tick control are too difficult to manage correctly. Poorly operating dips can worsen tick populations by concentrating cattle at treatment locations as well as causing heavy, repeated use of trails from normal herd locations to treatment points. Such situations are ideal for tick reproduction. Hand-spraying, using bucket pumps, is preferable but too laborious for good results in large-scale campaigns. Also, death losses from tick-borne diseases will occur if control campaigns reduce tick numbers to the point that calves do not develop premunity. Such calves are likely to die if infected later as older animals. Tick control should involve grazing and movement management designed to minimize the opportunity for ticks to complete their life cycle. The question of perennial versus annual grasses also has meaning in regard to tick survival on the ground.

Differential diagnosis is required to determine incidence and importance of the various tick-borne diseases. Recommendations 1, 2, and 3 address this question.

7. Livestock population in the Bol polders region should not be increased. Production should be raised by improved pasturing and forage growth on the polders without a significant livestock population increase. Also, crop by-products should be utilized for fattening cattle and improved dry season nutrition.

8. The Tandal Polder area could be used for grazing during Phase 1 (from diking to inception of cropping). Livestock owners should be forewarned that there is danger of disease. Surveillance must be continuous to diagnose any disease outbreak at its onset. Susceptible livestock species should then be kept off the polder.

9. The Tandal Polder development scheme should attempt to dry off the polder as quickly as possible. Final leveling should be the best practical, with a minimum of low areas remaining. These engineering details related to vector insect breeding were thoroughly discussed in an earlier section.

10. Grazing on the dunes should be better managed including prevention of overgrazing. Education through extension activities (Recommendation 2) may be the best approach. Tree species of maximum utility for lumber, firewood, and charcoal (not Neem) should be planted for shade and to stabilize the dunes for better grass and browse reproduction.

11. Tree species should be planted that will provide nutritious leaves or fruits on which livestock will feed. There are several local Leguminosae that could be encouraged and exotics that could be tested (see Annex).

12. Reforestation to the point of producing a tsetse habitat must be absolutely avoided.

I. PRESENT CROPS AND ASSOCIATED HABITATS

A. GENERAL

The area of Tandal, west of Bol, is one of sand dunes surrounded by marsh and shallow water channels filled with reeds. It adjoins the already formed polders of Guini and Berim, east of Bol.

B. DUNE HABITAT

The dunes, often settled by one or more villages of Buduma (depending on island size), have typical Sahelian vegetation of low formation.

1. Natural Growth

Dominant are species of Aristida longiflora, Cymbopogon proximus, and C. giganteus, and others of the Graminae (Cabot, Bouquet 1972). The larger islands may have a few native date palms, Borassus aethiopum (Ronier), on the high ground. Away from the village, scattered Acacia (A. senegal, A. raddiana) and Balanites occur. These thorny shrubs may also grow larger when they occur in gulleys which have seasonal inundation. Callotropis sp. and ground-cover xerophytes are also found, generally on the dunes and slopes. A zone of low fan palms, Hyphaene thebaica (doum), occur in all dune habits at high water level.

2. Gardens

Around villages there are plantations of Neem trees, Melia azadarach and/or Salvadora (Fry et. al. 1972). These have been introduced in other areas (e.g., N'Djamena) where wood for charcoal is becoming scarce. However, Neem is not a good charcoal producer being a soft wood. They are also good shade trees.

On the slopes of the dunes, millet is planted at the beginning of the rainy season and harvested at the end. Corn is cultivated in small patches at water edge in the ebb fields (Section C). The ground is usually cleared by burning prior to planting. Sorghum is also cultivated.

The polders formed by the Buduma in earlier times continue to be cultivated by villagers in or near the new polders. Where the water table is high enough, buckets are used to pour water, from the lake edge, onto these old village plots. In several parts of Berim Polder, there are small onion and millet gardens watered by a chadouf. These plots may be protected by thorn-bush barriers and wind breaks of Parkinsonia sp. The drainage ditches form another area for garden produce where peppers, squash, and castor plants are grown in the bank, with one or two banana trees and/or papaya on the top of the ditch.

C. EBB FIELDS

Below the high water mark is a region of ground which is seasonally inundated. When the waters recede through the dry season, Eragrostis pilosa, Chloris prieurii, and Panicum laetum emerge (Lamarque & Gaston 1967). Left untouched, they form pasturage both on the high dunes and the treeless, flat islands which are uninhabited except for herding animals in the dry season and are submerged during the floods. Exposed areas where some water remains produce Carex spp. which multiply by seed and vegetative rhizome growth.

D. MARSH AND LOW-DEPTH WATER (SHALLOWS)

Below the slopes of the dunes and the ebb zone, the marsh and the shallows have a variety of monocotyledons such as Vossia cuspidata, Aeschynomene elaphroxylon, Cyperus papyrus, Typha domingensis, and Phragmites australis (Fry 1972; Gaston & Dulieu 1976). To distinguish the zone between waters edge and shallows is impossible. They are interwoven because of rapid growth of flora and variations and fluctuations of the lake water from season to season and year to year.

These plants of natural growth, like the pasture, are utilized by the villagers for building huts and boats and weaving baskets. They are, therefore, an essential crop for the native way of life.

E. PRESENT POLDERS OF GUINI AND BERIM

The large modern polders have experimental cultivation of potatoes, cotton, and wheat. Several varieties of the latter are being tested.

Commercial garden plots of vegetables are also being grown. Cabbage, onions, tomatoes, peppers, carrots, and squash are some of the species produced. This agricultural enterprise is all under the direction of SODELAC.

An experimental tree nursery is also maintained. This is in the process of producing trees to provide wind breaks across the polders for crop protection against the northeastern wind, the harmattan. Eucalyptus spp. have been planted over the past 8 to 10 years, and Parkinsonia sp. are also being used effectively. Seed beds of Eucalyptus and Parkinsonia are in production, and an experimental grove of guava is also under observation. This forestry project is under the direction of the Peace Corps.

II. AGRICULTURAL SERVICES

Agricultural services in Tchad are under the Director General for Agriculture in the Ministère du Développement Agricole et Pastoral, Charge de la Lutte Contre les Calamites Naturelles. Crop protection (entomology, plant pathology, nematology, weeds, rodents, and bird pests) is the responsibility of the Crop Protection Service within the Division of Agricultural Production. Personnel of the Crop Protection Service include the Chef du Service and two assistants to the Chef and an AID expert, plus drivers and laborers. There are no field offices or field personnel.

Extension work is in the semi-autonomous Organization Nationale Développement Rurale of the Ministry.

Much of the work of these organizations relates to cotton. COTONTCHAD, independently, conducts research and services cotton production.

The polder crops and research at Bol are handled independently by SODELAC.

Pesticides are imported by the Crop Protection Service for general use, by COTONTCHAD for cotton, and by SODELAC for the Bol Polders Project. Decisions on pesticides and their application are made independently by these organizations. A pesticide use law is under consideration, but no regulations have been promulgated as yet.

III. PLANT PESTS AND DISEASES

A brief examination was made of crops on the polders in the March and early April late dry season. Vegetables, potatoes, wheat, and maize were seen. Further information sources were SCET, SODELAC, COTONTCHAD, Crop Protection Service, and AID personnel. Information on cotton pests in Tchad is available, but information is almost nonexistent on potential pests of the various crops on the Bol polders.

In general, insect pest problems to date have not been serious. Aphids as virus vectors may be the most important pests of

potatoes and vegetables. Several cotton insects have become established, but the overall problem is minor compared to the serious losses occasioned by pests on cotton throughout Africa. Insects are unimportant on wheat in comparison to severe losses of grain by quelea attack (weaver birds, Ploecus species). The importance of insects on millet in dryland farming at Bol is unknown. Equally little is recorded concerning fungal, bacterial, and virus pathogens in the Bol Tandal Polder area.

The isolation of the Bol polders from other agricultural areas probably has protected the crops from major insect invasion to date (except for millet). The aridity of the region and length of the dry season will prevent establishment of most potential pests acclimated to regions far south and west of Lake Tchad. Nevertheless, there are a number of potential pests that could affect crop yield on the polders if these pests invade and/or became established. The following discussion is based mainly on insects that are well known in Nigeria as pests of crops in the Sahel of Northern Nigeria (Libby 1968). Further sources are pest information from other Sahel countries summarized in Sasser et. al. (1972), Schmutterer (1969), Hill (1975), and Smith and Schlegel (1974).

A. GENERAL INSECT PESTS

General insect pests that feed on all kinds of crops include: locusts (Locusta migratoria, Schistocerca gregaria, Anacridium, and Nomadacris), grasshoppers (Aelopus, Cataloipus, Oedaleus, Kraussaria, Zonocerus, Heiroglyphus, and Catantops), and crickets (Brachytropes) chewing up all above-ground plant parts; scarab beetles (several species of Scarabaeidae including Pachnoda) adults chewing up above-ground plant parts, larvae ("white grubs") chewing up below-ground plant parts; termites (many species of Isoptera) tunneling out roots and stems; leaf worms (particularly Spodoptera littoralis) chewing up leaves; shield bugs (Pentatomidae, particularly Nezara, Agonosceles, and Aspavia) sucking sap from above-ground plant parts; blister beetles (Cantharidae) chewing flowers and leaves; cutworms (Agrotis) cutting off young plants and chewing roots; and Armyworms (Spodoptera) chewing leaves and stems.

Locusts have not appeared in Tchad for many years. There is a possibility of damage in 1978 because locust populations are developing in Arabia and northeastern Africa. Some of these may fly southwest as far as Tchad, but it is too early for definite predictions (Mapatta 1978). OCLALAV is the locust control organization in Tchad. OICMA, headquartered in Bamako, Mali is also involved.

1. Cotton

Considering the specific crops grown on the polders now, the worst pest attack is likely to be on cotton. In Tchad as a whole, there are two basic problems, yellow bacteriose (blackarm) and nematodes. The former is controlled to some extent by seed treatment with sulfuric acid and the latter by crop rotation (Dr. B. Wood, personal communication). There is also Chad Mosaic Disease which is being studied with respect to cotton varietal resistance (Dussart 1973). Cotton is notorious for the variety of insects that feed on all vegetative and reproductive parts. To date, there has been relatively little damage to the crop at Bol, but an increased pest problem must be anticipated. A current problem exists with pests of flowers, squares, and bolls including the bollworms Heliothis, Diparopsis, Earias, and Pectinophora gossypiella (Mady, personal communication). The first two are considered to be serious pests while Pectinophora and Earias are of little importance. The cotton stainer (Dysdercus) is present but not serious. Aphids (probably mostly Aphis gossypii) are present and could be serious as virus vectors. Scarabaeidae are the worst pests with adult feeding above ground and larvae below (Mady, personal communication). Cotton pests could be worsened by planting other crops or ornamentals that harbor cotton insects, by allowing volunteer cotton to develop or by allowing indigenous Malvaceous plants to grow. Maize, several vegetables, and Hibiscus are attacked by some cotton insects.

2. Grain Crops on the Polders

Grain crops, particularly wheat, are second in importance on the polders. The only insect pest on wheat reported by Bol personnel was a black "grasshopper," species unknown, found on the polders in the rainy season. Damage was not severe. Redden (1977) noticed slight stem borer (species not identified) damage on Bol polder wheat. Injury was confined to field margins. DeLeuss (undated) noted that the 1972 wheat crop on the polders gave a poor yield, partly because of "caterpillars." Probably serious insect pest problems will rarely occur on wheat, but experience with this crop is limited even in neighboring countries. No control measure has been used on wheat and none are envisioned. Stored grain pests may be a problem.

Among some of the experimental wheat plots at Guini, a chlorotic leaf streak is most likely to be caused by virus. The other main economic problem is weaver birds, Ploceus spp., which reduce the crop at harvest time.

Maize (corn) is being grown on a small scale on the polders. No insect pest problem was noted during the dry season of late March, nor were insect problems reported by Bol polder development personnel. There are serious potential insect problems known from neighboring countries and from southern Tchad.

Of utmost importance on maize are the stored grain pests, which also attack grains of millet and sorghum. The grain weevils, Sitophilus oryzae and S. zea mais are primary, but many other beetles and caterpillars may be involved. Storage pests are almost certain to be a problem unless the crops are sold immediately on harvest. However, by proper construction and management of storages, plus pesticide use, long storage is feasible.

No control of maize pests has been necessary at Bol. Pesticide use on maize is of doubtful effect and economics. Any pest problem that arises, other than in storages, should be controlled by cultural practices where feasible.

Barley has been mentioned as a possible crop for Bol. No information on pests of barley under Sahel conditions was found.

3. Potatoes

The crop of third importance currently on the Bol polders is Irish or white potatoes. This has been a very successful crop. No major insect problems have occurred to date. Aphids (Aphididae) and leafhoppers (Jassidae) have been seen by Matafo personnel but have not increased enough to cause direct damage.

On Bol Guini Polder at the present time there are a few fungal plant diseases. Fusarium is said to be a serious problem in potatotes but there is little damage to other crops. Thus preventive measures by crop dusting or spraying are not a large part of the management routine at this stage of development. However, appropriate chemicals are available should the need arise.

There has been considerable research in Nigeria on potato diseases. One of the problems has been identified as virus infection. In Bol it has been difficult to demonstrate virus as a cause of leaf necrosis since drying out of leaves occurs rapidly and could be due to natural desiccation. The aforementioned Fusarium could be the sole cause of destruction.

4. Vegetables

The major problem among the vegetable crops of Bol Guini Polder appears to be virus diseases. These have been seen on peppers as chlorotic leaf spots and distortions and on tomatoes as spot necrosis of the leaves. There is a general chlorosis in bean leaves which could also be due to virus; nutrient deficiency is unlikely with the good growth of other vegetables in the area. Nematodes are also found to be pathogenic in some vegetables, but these are not an economic problem.

A complete list of possible insect pests of potential vegetable crops on the polders would be voluminous and of little use. Several species of aphids (Aphididae), leafhoppers (Jassidae),

and whiteflies (Aleyrodidae) may be the most serious problems, particularly as virus vectors. Aphids were the only insect problem on vegetables mentioned by personnel at Bol.

No insect pests have occurred to date on the leguminous crops grown at Bol, green beans and peas. Peppers are also grown on the polders but no pests were seen or reported. Cucumbers, root and bulb crops, and crucifers appeared similarly clean.

Potential insect pests of Bol polder crops are listed in Table 3H-1.

5. Garden Crops

There are village crops which are susceptible to some plant pathogens and other plants which could act as secondary hosts to carry disease from one season to another. Millet, which is grown on the dunes and is susceptible to green ear disease, Sclerospora graminicola and to ergot, Balansia sp., is one example. Maize is another cereal grown in village gardens and known to be susceptible to fungal and virus pathogens. Vegetables which are known to be susceptible to various diseases in Nigeria (Table 3H-2) are okra, peppers, tomatoes, onions, small striped cucumbers, and melons. These are all grown in village gardens for home use or to barter for fish. A wild Hibiscus sp. is perpetuated for its petals with which to make herbal tea. This and four or five other Malvaceae are short lived perennials. Some or all of these village plants could be a potential secondary host for major crop diseases also known in Nigeria and West Africa as well as southern Tchad. None of these plants in the Bol area, however, were observed to have pathological problems. On Guini Polder naturally occurring plants in the families Solanaceae and Cruciferae have few representatives which might serve as secondary hosts to vegetable crop diseases. Millet and sorghum will continue to be grown on the sandlands adjacent to the polders. An AID report on millet and sorghum in Tchad (1/17/78 typescript) notes grasshoppers, stalk borers, and blister beetles as insect pests.

Plant pathogens found in southwestern Tchad on sorghum, millet, rice, and peanuts, are listed in Table 3H-3.

B. STORAGE INSECT PROBLEMS

A major problem for all grain crops and dried seed crops is insects in storage. The continuously warm climate of Tchad is conducive to severe losses. Low moisture content of grains and seeds in arid areas reduces attack but by no means eliminates it. Besides the maize pests noted previously,

Table 3H-1
POTENTIAL INSECT PESTS OF BOL POLDER CROPS

Insect	Crops Attacked
Plant bugs *Taylorilygus* *Campylomma* *Halticus* *Helopeltis*	Cotton, green beans, peas, okra
Leafhoppers *Empoasca*	Cotton, green beans, peas, okra
Mealybugs *Ferrisiana*	Cotton
Aphids *Rhopalosiphum* *Aphis*	Maize, cucurbits, okra, cabbage, cauliflower
Cotton stainer *Dysdercus*	Maize, tomato, okra, millet, sorghum
Cotton seed bugs *Oxycaraenus*	Cotton
Thrips *Frankliniella* *Thrips*	Cotton, onion
Blue bugs *Calidea*	Cotton
Spittle bugs *Locris* *Poophilus*	Maize, millet, sorghum, grasses
Plant bug *Leptoglossus*	Cucurbits
Stalk borers *Sesamia* *Busseola* *Eldana* *Coniesta*	Wheat, maize, millet, sorghum
Caterpillars in ears and on silks *Mussidia* *Argyroploce*	Maize

Table 3H-1 (Continued)

Insect	Crops Attacked
Shoot fly *Atherigonia*	Wheat, sorghum
Stemgall midge *Thomasiella*	Sorghum
Sorghum midge *Contarina*	Sorghum
Armyworms *Spodoptera*	Maize, wheat, millet, sorghum, grasses, and other crops
Earworm *Heliothis*	Maize, tomato, okra
Caterpillars *Maruca* *Laspeyresia*	Green beans, peas
Beetles in ears *Carpophilus* *Brachypeplus*	Maize
Leaf beetles *Epilachna* *Aspidomorpha* *Copa* *Aulacophora*	Wheat, potato, tomato, eggplant, cucurbits, okra
Leaf rollers *Sylepta*	Cotton, eggplant, tomato, potato, okra
Flea beetles *Podagrica* *Syagrus*	Cotton, potato, tomato, eggplant, okra
Weevils *Apion*	Green beans, peas
Mole crickets *Gryllotalpa*	Potatoes

Table 3H-2
PLANT DISEASES OF NIGERIA

Host	Disease		Notes	Unobtainable References
	Common Name	Latin Name		
Cotton	Boron deficiency			Smithson, J. B. & R. G. Heathcote 1974 Exp. Agric. 10.(3). 199-208.
	Boron deficiency			Smithson, J. B. & R. G. Heathcote 1974 Exp. Agric. 10.(3). 209-218.
Cowpea	Virus disease		Aphid-borne.	Raheja, A. K. & O. I. Leleji 1974. Plant Dis. Rep. 58.(12). 1080-1084.
Vigna sinensis			N. Nigeria-irrigated	
	Wilt	Fusarium oxysporum f. sp. tracheiphilum		Oyekan, P. O. 1975. Plant Dis. Rep. 59. (6). 488-490.
	Smut	Entyloma vignae		Da Ponte, J. J., I. Vasconcelos, J. B. Paiva, F. E. De Castro, & C. A. Sobral 1976. Summa. Phytopathol. 2.(1). 50-52.
	Leaf spot	Cercospora cruenta		Schneider, R. W., R. J. Williams, & J. B. Sinclair 1976. Phytopathology 66. (4). 384-388.

Table 3H-2 (Continued)

Host	Disease		Notes	Unobtainable References
	Common Name	Latin Name		
Wheat	Fungal Foot & root rot		Irrigated Northern States	Giha, O. H. 1976. Pest Artic. News Summ. 22.(4). 479-487.
Maize	Streak virus		Epiphytotic	Fajemisin, J. M., G. E. Cook, F. Okusanya, & S. A. Shoyinka 1976. Plant Dis. Rep. 60.(5). 433-447.
	Rust	Puccinia polyspora	Epiphytotic in 1949.	Fajemisin, J. M. & S. A. Shoyinka 1976. Proc. Internat. Maize Virus Dis. Colloq. & Workshop. Ohio Agric. Res. & Dev. Center, Wooster Ohio. Aug 16-19. p. 52-61.
	Leaf blight	Biopolaris (Helminthosporium)	West Africa	
	Leaf spot Streak Smut	Curvulania	West Africa	
	Brown spot	Physodium	West Africa	
	Fungal & bacterial stalk rots			
	Nematode	Pratylenchus brachyurus		Egunjobi, O. A. Nematologica 20.(2). 181-186.

Table 3H-2 (Continued)

Host	Disease		Notes	Unobtainable References
	Common Name	Latin Name		
Okra	Mosaic virus			Lana, A. O. & T. A. Taylor 1975. Proc. Am. Phytopathol. 2. 71-72.
	Mosaic virus		Insect transmission	Lana, A. O. & T. A. Taylor 1976. Ann. Appl. Biol. 82.(2). 361-364.
	Mosaic & leaf curl			Lana, A. F. 1976. Pest. Artic. News Summ. 22.(4). 474-478.
			Also in Ivory Coast	Bozarth, R. F. A. O. Lana, R. Koeni, J. Reese 1977. Phytopathology 67.(6). 735-737.
				Lana, A. F. & R. Bozarth 1976. Proc. Am. Phytopathol. Soc. 3. 235.
	Mosaic virus			Givard, L. 1977. Ann. Phytopathol. 53-70.

Table 3H-2 (Continued)

Host	Disease		Notes	Unobtainable References
	Common Name	Latin Name		
Tomato	Bunchy top virus disease			Ladipo, J. L. 1973. Nigerian Agric. J. 10.(1). 99-105.
	Leaf blotch	Septoria lycopersia		Okpala, E. U. 1977. Octa Hortic. (The Hague) 53. 64-70.
	A new virus-like disease			Lana, A. F. & G. F. Wilson 1976. Plant Dis. Rep. 60.(4). 296-298.
Egg Plant Solanum melongena	Green mosaic			Ladipo, J. L. 1976. Plant Dis. Rep. 60.(12). 1068-1072.
Cucurbitaceae Telfairia occidentalis	Mosaic virus			Nwauzo, E. E. & W. M. Brown, Jr. 1975. Plant Dis. Rep. 59.(5). 430-432.
Yams	Rot fungi		In storage	Ogundana, S. K., S. H. Z. Naqvi, & J. A. Ekundayo 1975. Int. Biodeterior. Bull. 11.(2). 36-40.

Table 3H-2 (Continued)

Host	Disease		Notes	Unobtainable References
	Common Name	Latin Name		
Yams (continued)	Yam nematode	Scutellonema bradys		Adesiyan, S. O., R. A. Odihirin, & M. O. Adeniji 1975 Plant Dis. Rep. 59.(6). 477-486.
Sweet potato	Sweet potato disease—— ? virus		Insect transmission	Schaefers, G. A. & E. R. Terry 1976. Phytopathology 66.(5). 642-645.
Sorghum Bicolor	Witchweed	Strixga hermonthica		King, S. B. 1975. Proc. Am. Phytopathol. Soc. 2. 136.
	Long smut	Tolyposporium ehrenbergii		Manzo, S. K. 1976. Plant Dis. Rep. 60.(11). 948-962.
Peanuts (Groundnuts) Arachis hypogaer	Leaf disease	Cercospora sp.		Elston, J., C. Harkness, & D. McDonald 1976. Ann. Appl. Biol. 83.(1). 39-51.
	Rust			Akrokoyo, J. O., A. M. Emechebe, A. M. Fowlers, M. H. Gumel, C. Harkness, & D. McDonald 1977. Samaru Misc. Pap. 68. 1-14.

Table 3H-2 (Continued)

Host	Disease		Notes	Unobtainable Reference
	Common Name	Latin Name		
Peanuts (continued)	Nematode, Endo-parasite	Aphelenchoides arachides		Bos, W. S. 1977. z. Pflanzenkr. Pflanzenschutz. 84.(2). 95-99.
		A. arachidis	Seed borne	Bridge, J., S. W. Bos, L. J. Page, & D. McDonald 1977. 253-259.
Cashew	Kernel rot fungi			Esuruoso, O. F. 1974. Int. Biodeterior. Bull. 10.(2). 57-59.
Anacardium occidentale	Floral shoot dieback	Lasiodiplodia theobromae		Olunloyo, O. A. & O. F. Esuruoso 1975. Plant Dis. Rep. 59.(2). 176-179.

Table 3H-3
CROP PATHOGENS OF SOUTH-WEST TCHAD
(ADAPTED, SACCAS 1953)

Sorghum	Millet	Rice	Peanuts
Sphacelotheca spp.	Tolyposporium	Piricularia	Rosette (virus)
Sorosporium	Sclerospora	Fusarium spp.	Cercospora
Phoma	Balansia	Helminthosporium	Batryodiplodia
Fusarium spp.	Puccinia	Cercospora	Corticium
Gonatobotrys	Phyllachora	Curvularia	
Helminthosporium	Phyllosticta	Nigrospora	
Colletotrichum		Chactophoma	
Ascochyta		Ophiobolus	
Glococercospora			
Ramulispora			
Cercospora spp.			
Puccinia			
Phyllosticta spp.			
Ophiobolus spp.			
Mycosphaerella			
Leptosphaeria spp.			
Physalospora			
Didymella			
Curvularia spp.			
Gibberella spp.			
Macrophomina			
Sclerotium			

the following genera of insects may be involved: Tribolium, Sitotroga, Trogoderma, Cryptolestes, Oryzaephilus, Caryedon, and Callosobruchus.

C. WEED PESTS

Weed pests introduced with impure seed may also become a problem by their competition with the crops, for water and nutrients. Portulacca sp. is one such plant seen in the potato fields of the Bol area. Naturally occurring plants of the polder may also provide a nuisance factor. Cyperus spp. (sedges) are plants which may be reintroduced by seed or stolons in irrigation water or may not have been completely removed when the polder was cleared. Irrigation water on polder soil will provide an adequate habitat for regrowth, especially if drainage should be poor. Witchweed, Striga hermontheca, is another native plant present in village millet plantings. Hand labor is able to reduce but not control these pests.

D. PESTICIDES

Pesticide use on the polders is minimal at present and should not rise unless a larger area is planted to cotton.

Currently, the cotton crop is supposed to be treated every 15 days with a spray of Peprothion containing DDT, endosulfan and methyl parathion, or Nuvacron containing azodrin and DDT. Machinery used is either 20-liter back-pack knapsack hand sprayers or ultra low volume battery-electric hand sprayers. Both perform well, but workers prefer the battery-electric hand sprayers. They are much easier to work and require carrying little water. However, they require care and expertise in application, including restricting work time to periods of proper atmospheric conditions, particularly with reference to wind. Since a concentrate is sprayed, it can injure cotton or yield poor pest control unless applied properly. However, pesticide use should be based on level of infestation. Specific pesticides prescribed should depend on the insect pests involved. Excessive or unnecessary pesticide application results in increased pest problems in the long run. Biological control agents are reduced so that alternate or incipient pests become damaging. Resistance to pesticides is encouraged and unnecessary pesticide pollution may occur. In relation to the malaria problems of Bol, unnecessary agricultural pesticide use should be eliminated because resistance may be developed in mosquito larvae.

Trained personnel should be employed to make accurate observations of the growing crop, from planting to harvest. Then incipient pest infestations could be treated appropriately.

Pesticides should not be applied to grain, potato, or vegetable crops except when developing pest populations threaten serious loss of yield. Then only specific pesticides, known to be effective on that pest, should be used. Mammalian toxicity of the specific pesticides should be known by supervisory personnel. The more toxic pesticides are not safe for use by untrained workers without protective masks and clothing. Hand application of the more toxic pesticides should not be permitted. To prevent toxic residues on food, pesticides should not be used near harvest time, particularly on vegetables. Recommended cautions on pesticide use should be followed exactly.

Pesticides and sprayers were observed at Matafo. Some were in a locked room under fairly good storage conditions. Others were in an open shed among machinery, which is a poor practice for toxic chemicals.

The Crop Protection Service of Tchad has prepared mimeographed sheets (1 to 2 pages) on a few pesticides now in use or planned: Benzene hexachloride (Hexachlorocyclohexane) dry powder for dusting and spraying against grasshoppers and weevils. Lindane (Gamactif) 0.6 percent as dry powder against "altises," thrips, "negrils," weevils, caterpillars, bugs, ants, leaf beetles, potato beetles, and "hannetons." Malathion 200 g/l liquid formulation against aphids, mites, insects on vegetables, "altises," stored grain pests, and bruchid weevils of legumes. Carbaryl (Sevin)(Prosevor) 85 percent powder in a spray against fruit insects, leafhoppers, psyllids, weevils, aphids, caterpillars, flies, stem borers, pink bollworm, and Earias. Parathion (Oleoparaphene or Typholene D) 3 percent emulsifiable sprayed for aphids, budworms, "Cheimatobies," mites, and scales. Dimethoate (Systoate) 400 g/l liquid against thrips, psyllids, aphids, mites, leafhoppers, leaf miners, scales, and fruit worms. Carbofuran (Furadan 3G) granular against rice stem borers, leaf feeding caterpillars, beetles and flies, and aphids, leafhoppers, and "poux." "Actelic" (active ingredients not stated) 8 percent to 25 percent spray, 1 to 2 percent dust, fumigant, or aerosol on plants, stored grain, in buildings, and on water. Kills caterpillars, "trips vers gris," aphids, mites, white flies, scales, "lanigeres," beetles, weevils, grasshoppers, Eurygaster, legume flies, mushroom flies, fruit flies, date moths, and cotton bugs. Methylithiophanate (Pelt 44) 70 percent active, diluted as a spray for "travalure" of stone fruits, Oidium grey rot of salad greens, Septoria, Fusarium "Pietin," "verse," "rouille," Cercospora. Also for seed treatment. Copper oxychloride plus zineb (Cuprosan)(37.5 percent, 15 percent) emulsifiable as a spray for mildew, anthracnose, Alternaria, Septoria, Oidium. Chlorophacinone (Quick) rodenticide. Defecanum (Ratak) rodenticide. Coumachlore (Tomorin) rodenticide. "Ratilan Block Bait" agricultural rodenticide.

Concerning toxicity, the practice at Bol of using Peprothion and Nuvacron on cotton is questionable because they contain three very toxic insecticides: methyl parathion, endosulfan, and monocrotophos. Workers use hand sprayers without protective equipment. This is a health hazard.

DDT, however, is acceptable as this is one of the safest and most effective insecticides, considering mammalian toxicity and pest control. So long as use remains small, there should be no significant pollution effect. Large-scale use could adversely affect fish and wildlife. DDT alone will not control the pest complex on Bol polder crops.

If insect outbreaks occur, there are many good insecticides available that should be considered for use on cotton and other crops. Among the least toxic to man and animals are carbaryl, fenitrothion, tetrachlorvinphos, malathion, trichlorphon, formothion, iodofenphos, phoxim, and pirimphos-methyl. Somewhat more toxic, but still relatively safe, are diazinon, dimethoate, fenthion, phenthoate, phosalone, pirimiphos-ethyl, pirimicarb, promecarb, and propoxur. These are all organophosphorus or carbamate compounds that degrade rapidly, so that long lasting environmental pollution is minimized. Insecticide companies in Germany, Netherlands, England, France, Italy, Switzerland, Japan, and the United States produce these chemicals. They should be contacted for data, use experience, cautions, and recommendations. The pesticide information available in Tchad is inadequate. FAO and WHO have published comprehensive information on most pesticides giving authoritative toxicity data and hazards of residues on crops and of environmental pollution (WHO 1965-?).

E. NEW CROPS FOR TRIAL

We suggest several new crops for trial at Bol. Cowpeas (Vigna unguiculata) are a highly nutritious crop, particularly for vegetable protein as well as carbohydrates. Cowpeas are eaten by some of the peoples of Tchad and are a preferred food in Nigeria. They are in demand for export. Experience in Northern Nigeria presages good yields for lands such as the Bol polders. There is a very extensive background of research and experience with this crop in Nigeria. The pest problems outlined previously for beans and peas might occur on cowpeas also. Cowpea yields are adversely affected by numerous insect pests in Nigeria, but good varieties and pest control practices are known by Nigerian research at IITA, University of Ibadan, University of Ife, Federal Ministry of Agricultural Research at Ibadan, and Samaru Experiment Station in Zaria.

Peanuts should grow well at Bol, producing a dry food and oil crop for local consumption and export. The remarks made for

cowpea are pertinent to this crop also, except that Nigerian experience is limited to Northern Nigeria and its institutions. Peanuts have a serious problem in Northern Nigeria, rosette virus disease, transmitted by aphids.

Peppers are grown on old polders and ebb fields and could be expanded as a profitable crop with good local demand.

Sweet potatoes should grow well on polders, producing a very large volume of food per hectare. This is a sturdy crop requiring little care for reproduction by vegetative means so that labor and costs should be low. However, the peoples of Tchad may not convert readily to sweet potatoes in their diet. The sweet potato weevil is a major pest in both field and storage. Virus disease is a threat with transmission by aphid and other insect vectors. IITA has done extensive research on this crop in Nigeria.

Rice could be grown on the polders but would require complete reevaluation of the development and irrigation scheme. Rice poses the problem of breeding vectors of diseases of man and livestock during flooding.

Cassava is a comparatively insect pest-free crop but does have serious phytopathological problems. It is doubtful that this relatively low value, starchy, root crop would be economical relative to polder costs.

Citrus could be grown but has a multitude of pest and disease problems. Tree crops require several years' growth before yield commences which may not be practical for the polder farming peoples. Transportation of this perishable fruit may well be uneconomical.

IV. POLLUTION DUE TO CHEMICALS

At present, only a minimal amount of pesticide is being used on the polders. Pests are not serious. The only crop being sprayed is cotton, using combinations including methyl parathion, endosulfan, azodrin, and DDT. The two organophosphates will kill mammals, fish, and invertebrates on contact or by ingestion but are rapidly degraded. Long-term pollution effects will not occur. DDT and endosulfan are more lasting in pollution effect. DDT offers no real hazard to vertebrates by acute poisoning whereas endosulfan is more toxic. It would be a questionable practice to grow a large area of cotton on the border of Lake Tchad and use these insecticides on a 15-day spray schedule. Fish and wildlife might be adversely affected. This is particularly true for waters near Tandal Polder if good circulation to the lake proper does not occur. However, the amount being sprayed now, on a small area of cotton, offers little or no hazard.

V. ECOLOGICAL IMPACT OF TANDAL POLDER PROJECT

The project removes less than 1,100 ha of aquatic and semi-aquatic plants. Considering the vast area of similar ecology in the Lake Tchad Basin, this loss is insignificant.

With polder formation, some parts of the island dunes, close to the polder, are denuded of vegetation to permit canal and road construction and equipment installation. Land leveling and pipe laying on the polder ground also disturbs soil and sand. These factors leave free sand exposed and it blows easily in any wind (especially the Harmmatan). In turn, this occurrence could cause erosion, corrosion of installations, and destruction of crops. To prevent these detrimental effects, trees and shrubs should be planted for sand retention and windbreaks as well as biological drainage (Soils Section). Some species which might be used, besides those already mentioned, are Balanites and Acacia which occur naturally on the dunes. These should be pruned (grazing by animals was the ancient method) to retain low growing, shrub formation.

The presence of unlined drainage canals provides an excellent habitat for Phragmites and other aquatic macrophytes growing naturally in the archipelago. These plants are readily reintroduced on the polders by wind-blown seed and fragmented stems and roots. Left untended they grow rapidly, filling the canals and reducing water flow. Removal of these plants must be done with care. Cut debris left floating in the canal water will become rooted in new locations on the canal surfaces thus increasing the problem.

When the polder is in production, the increase in human population and activity will affect some parts of the natural vegetation.

VI. RECOMMENDATIONS

1. Crop protection expertise, research, and survey should be increased. As soon as crop production warrants the investment, an applied entomologist or plant pathologist should be added to the staff. An expert with wide knowledge of crop pests and diseases is needed to advise on all disciplines within crop protection. He should develop experiments on pest biology, control and varietal resistance under Bol polder conditions. Laboratory facilities and supplies will be necessary. Survey is vital to develop the most effective pest and disease control with minimum use of pesticides. Survey must also be a warning system. Economics of crop production at Bol is dependent on the present isolation from crop pests. As crop pests invade the area, warning will be necessary for rapid development of control systems required to prevent major losses.

2. The extensive agricultural information available in neighboring countries should be utilized. For example, there is a tremendous body of excellent information in Nigeria on pests of the crops growing on or projected for the Bol polders. Much of this information is from Northern Nigeria, where climate and pest problems approximate that of Lac Prefecture. Some is even from extensive polder development on Nigerian Lake Tchad. Sources include Samaru Experiment Station (Zaria), Ahmadu Bello University (Zaria), Universities of Ibadan and Ife, Ministry of Agricultural Research (Ibadan), IITA and CIMMYT. Sudanese information is also extensive and pertinent. Personnel at Bol and N'Djamena should visit these locations, with interpreters, and attend short courses including the IITA extension courses. Cooperation should be stimulated, including requests for visits to Bol and N'Djamena by IITA, CIMMYT, and other personnel. USAID should help by obtaining publications and reports from the above organization and translating and distributing them.

3. Clean, tested seed and planting pieces should be the basis of all crops grown on the polders. This has been practiced at the beginning of the SODELAC project and should be continued seasonally. Introduction of new pests and diseases to Bol should be prevented. Seed and planting piece sources should be known and necessary steps taken to examine and/or treat against plant pests. For some crops, seed testing may be necessary to determine diseases present, particularly viruses. Insect vectors must be excluded from such test areas. If seed is retained from each crop for the next sowing, there is probability not only of chance contamination but hydridization from native species. This could introduce varieties with lower resistance than the parent plant.

4. High yielding crops must be grown, considering the economics of Bol polder irrigation. Important factors are:

Resistant Varieties. Research around the world is producing varieties of such crops as wheat and maize which have high yield in grain and low susceptibility to a number of pathogens. Nigeria, also, has worked on this subject and cooperation would benefit both Tchad and her neighbor in the prevention of disease proliferation. Potatoes and cotton have also received attention in the area of resistant varieties.

Crop Rotation. This method of eliminating plant pests is already practiced by alternating wheat and cotton on Guini Polder. Cowpeas and peanuts, both of which are accepted and used as food by the village peoples, would also make good alternate crops with wheat in place of cotton. These items would also increase the nutrition and provide animal fodder. Different crops susceptible to the same pests should not be planted side by side, nor in rotation. In particular,

care should be taken to prevent survival of pests through the dry season by avoiding the planting of alternate hosts at that time. Volunteer crop plants should be removed.

Weed Removal. Regular hoeing is adequate for most introduced weeds. After seed planting and 30 cm of crop growth is achieved, manual labor can lift weeds which die rapidly in the hot sun. Fast crop growth soon crowds out additional weeds.

Burning and Field Sanitation. The burning of crop residues, which may or may not be contaminated with pests or disease, should be considered. It is a rapid method of disinfection but may also destroy organic materials in the soil. It should be practiced judiciously, but may be the only method of pest control in some instances.

Indigenous alternate hosts for crop pests should be removed from the vicinity of the polders. Some research is necessary to prove that certain plants are alternate hosts for crop pests. For example, is the common milkweed of Bol (Callotropis procera) an alternate host for cotton stainer and mirids?

5. The pesticide knowledge and procurement base should be broadened. There are many effective insecticides of low mammalian toxicity and minimum environmental pollution hazard. Chemical companies and international organizations should be canvassed. Sources should include companies in England, France, Netherlands, Germany, Switzerland, Italy, Japan, and the United States.

6. Pesticides with high toxicity to man should not be used.

7. The area planted to cotton should not be increased until pest control programs are developed that offer low-hazard, nonpolluting, minimum pesticide use. Spraying cotton on a regular schedule from sprouting to harvest is not a good practice. A scouting program should be instituted with pesticide treatment based on pest population data.

8. Alternative crops and other plants should be considered. This subject was begun briefly under Crop Rotation with the suggested alternatives of cowpeas and peanuts for cotton. Other cereals that should be considered are maize and sorghum, both of which are grown in village gardens but not as field crops. Care must be taken in introducing the species listed in Table 3H-2 since pathogens as yet absent in the Bol region are known in Nigeria and other West African countries, and in the southwestern area of Tchad (Tables 3H-3 and 3H-4) (Saccas 1953).

Other tree crops that might be grown in the irrigated polder region are cashew nuts (known to be salt tolerant) and

better fruiting palms. Both would provide good food products. Mangos might also be introduced. Bananas and papaya could also be produced in greater quantity.

Acacia spp., already part of the natural vegetation, should also be used. Almost all species provide some useful material. A. arbeda is a good source of livestock food. A. neolitica and A. senegal both provide edible beans for man and livestock.

9. Construction and operation of grain storages should include provisions to minimize rat and insect damage. Pesticide treatment of maize and possibly other grains will be necessary for storage periods longer than a few weeks.

10. Standard precautions should be taken to prevent human and animal poisonings by pesticides. Precautions include prevention of toxic residues on edible crops, proper pesticide storage, and correct disposal of unused formulations and sprays.

Table 3H-4
PROTECTIVE MEASURES AGAINST CROP DISEASE
(ADAPTED, SACCAS 1953)

	Seed Disinfection	Burning & Uprooting	Crop Rotation	Resistant Varieties	Notes
Sorghum vulgare	(Formaldehyde, copper solution, Mercurial pdr.)				
	Sphacelotheca			Ramulispora	
	Sorosporium			Puccinia (several in USA)	
	Fusarium	Fusarium			
	Helminthosporium	Helminthosporium		Helminthosporium	
	Colletotrichum		Colletotrichum	Colletotrichum*	
	Gloeocercospora	Gloeocercospora		Gloeocercospora**	
	Gibberella	Gibberella		Gibberella*	
		Ascochyta	Ascochyta	Ascochyta	
		Cercospora		Cercospora	
		Phyllosticta			
		Macrophoma		Macrophoma*	& richer soil
		Ophiobolus			

Table 3H-4 (Continued)

	Seed Disinfection	Burning & Uprooting	Crop Rotation	Resistant Varieties	Notes
Rice	Piricularia			Pinicularia**	
Oryza Sativa	Fusarium	Fusarium			
	Helminthosporium	Helminthosporium			
		Cercospora		Cercospora*	
	Tolyposporium	Tolyposporium	Tolyposporium		
Millet		Sclerospora		Sclerospora*	
Pennisetum typhoideum		Balansia			
		Puccinia		Puccinia	
		Phylachora			
		Phyllosticta			

*Only some less susceptible varieties.
**Resistant varieties not known.

Peanuts Three pathogens were found: Rosette, virus disease Potryodiplodia & Corticum. No good control methods. Chemical treatments have no pre ise action. To reduce reinfection uprooting and burning of diseased plants is helpful.

ANNEX 1
CONSTRUCTION COST ESTIMATE

Construction Item	Units	Total Price Million CFA
Dikes:		
Interior (5)	750 m	42.3
Inlet through (5)	1 ea	11.6
Exterior (1,2,3,4)	1,040 m	124.2
Drainage of Tandal Polder:	--	20.2
Irrigation Facilities:		
Main distribution canal	6,000 m	353.0
Pipe inlets	16 ea	3.9
Pipe (PVC)	22,722 m	454.0
Farm outlets	300 ea	105.8
Secondary ditches	35,000 m	8.2
Pump stations (1&2):		
Structure and gate	2 ea	19.0
Pump and engine	2 ea	12.2
Drainage Facilities:		
Drainage canal	7,600 m	47.5
Pump station:		
Structure	1 ea	6.1
Pump and engine	1 ea	12.9
Roads:		
Internal:		
Primary	6,800 m	1.2
Secondary	16,000 m	1.1
External	21,120 m	52.8
Land Leveling:	120 ha	24.0
Subtotal:		1,300.0
Contingency (40%)		520.0
TOTAL CONSTRUCTION COST		1,820.0

CONSTRUCTION SCHEDULE OF COSTS

Construction Item	Millions CFA						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Dikes:							
Interior (5)	42.3						42.3
Inlet through (5)		11.6					11.6
Exterior (1,2,3,4)	124.2						124.2
Drainage of Tandal Polder:	2.0	18.2					20.2
Irrigation Facilities:							
Main distribution canal		53.0	100.0	100.0	100.0		353.0
Pipe inlets			1.9	1.0	1.0		3.9
Pipe			155.0	155.0	144.0		454.0
Farm outlets			35.8	35.0	35.0		105.8
Secondary ditches			2.2	3.0	3.0		8.2
Pump stations:							
Structure and gate		19.0					19.0
Pump and engine		12.2					12.2
Drainage Facilities:							
Drainage canal			20.0	17.5	10.0		47.5
Pump station:							
Structure		2.2	3.9				5.1
Pump and engine		12.9					12.9
Roads:							
Interior:							
Primary			0.4	0.4	0.4		1.2
Secondary			0.4	0.4	0.3		1.1
Exterior			12.0	12.0	12.0	16.8	52.8
Land Leveling:			8.0	8.0	8.0		24.0
Subtotal:	168.5	129.1	339.6	332.3	313.7	16.8	1,300.0
Contingency(40%):	67.4	51.6	135.8	132.9	125.6	6.7	520.0
TOTAL COST:	235.9	180.7	475.4	465.2	439.3	23.5	1,820.0

ANNEX 2
ENVIRONMENTAL ASSESSMENT

ALGAL GENERA IN LAKE TCHAD FROM GRAS ET AL (1967)

CHLOROPHYTES

Chlorophyciae

Volvocales
- Chlamydomonas
- Eudorina
- Pandorina
- Volvox

Tetrasporales
- Gloeocystis
- Sphaerocystis

Ulothricales
- Ulothrix
- Hormidium
- Gleotila

Chlorococcales
- Shroederia
- Oocystis
- Chodatella
- Franceia
- Tetraedron
- Selenastrum
- Kirchneriella
- Nephrocytium
- Ankistrodesmus
- Quadrigula
- Golenkinia
- Micractinium
- Dictyosphaerium
- Dimorphococcus
- Botryococcus
- Coelastrum
- Crucigenia
- Tetrastrum

Euglenophycia
- Euglena
- Phacus
- Trachelomonas
- Scenedesmus
- Actinastrum
- Tetrallantos
- Pediastrum
- Dispora

Oedogoniales
- Oedogonium
- Bulbochaete

Zygnemales
- Mougeotia
- Spriogyra
- Zygnema
- Actinotaenium
- Cylindrocystis
- Gonatozygon
- Pleurotaenium
- Closterium
- Cosmarium
- Arthrodesmus
- Xanthidium
- Euastrum
- Micrasterias
- Staurastrum
- Spondylosium
- Sphaerozosma
- Onychonema
- Gymnozyga
- Desmidium
- Hyalotheca
- Phymatodocis
- Cosmocladium

Algal Genera (Continued)

Charophyciae
- Chara
- Nitella

Pyrrhophytes

Perindiniales
- Peridinium

Chrysophyciae

Xanthophycees
- Ophiocytium
- Heterodendron

Chrysophycees
- Dinobryon
- Mallomonas
- Synura

Diatomees
- Cyclotella
- Melosira
- Rhizosolenia
- Chaetoceros

Cyanophyciae

Chroocccccales
- Dactylococcopsis
- Tetrarcus
- Microcystis
- Aphanocapsa
- Aphanothece
- Chroococcus
- Merismopedia
- Coelosphaerium

Fragilaria
Asterionella
Synedra
Tabellaria
Cocconeis
Eunotia
Navicula
Gyrosigma
Cymbella
Pinnularia
Gomphonema
Amphora
Nitzschia
Surirella
Cymatopleura

Hemogonales
- Hapalosiphon
- Rivularia
- Calothrix
- Anabaena
- Anabaenopsis
- Aphanizomenon
- Oscillatoria
- Spriulina
- Lyngbya
- Phormidium
- Scytonema

ZOOPLANKTON GENERA

Rotifers

- Conochiloides
- Filinia
- Tetramastix
- Hexarthra (= Pedalia)
- Pompholyx
- Testudinella
- Collotheca
- Monommata
- Scaridium
- Polyarthra
- Synchaeta
- Trichocerca
- Asplancha
- Anuraeopsis
- Brachionus
- Epiphanes
- Euchlanis
- Keratella
- Macrochaetus
- Mytilina
- Platyias
- Lecane

Cladocers

Sididae
- Diaphanosoma

Daphnidae
- Ceriodaphnia
- Daphnia
- Moina
- Simocephalus
- Simosa

Bosminidae
- Bosmina
- Bosminopsis

Macrothricidae
- Ilyocryptus
- Macrothrix

Chydoridae
- Alona
- Alonella
- Chydorus
- Euryalona
- Graptoleberis
- Leydigia

Copepods

Calanoida, Diaptomidae
- Thermodiaptomus
- Tropodiaptomus

Cyclopoida, Cyclopidae
- Ectocyclops
- Eucyclops
- Paracyclops
- Tropocyclops
- Cryptocyclops
- Afrocyclops
- Microcyclops
- Mesocyclops
- Thermocyclops

BENTHIC ORGANISMS
(FROM CARMOUZE ET AL 1972)

WORMS

Oligochaetes

Alluroididae
Alluroides

Tubificidae
Aulodrilus
Euilodrilus

Naididae
Branchiodrilus
Allonais

Nematodes

MOLLUSCS

Prosobranches
Melania
Cleopatra
Bellamya

Lamellibranches
Corbicula
Caelatura
Pisidium
Byssanodonta

AQUATIC INSECTS FOR THE LAKE TCHAD BASIN
(FROM DEJOUX 1968)

DIPTERA

- Chirinomidae
  - Chironomus
  - Nilodorum
  - Dicrotendipes
  - Endrochironomus
  - Cryptochironomus
  - Polypedium
  - Stichochironomus
  - Paratendipes
  - Tanytarsus
  - Cladotantytarsus
  - Nilodosis
  - Lauterborniella
  - Nilothauma
- Tanypodinae
  - Pentaneura (subgenera Ablabesmyia)
  - Tanypus
  - Clinotanypus
  - Procladium
- Chaoboridae
  - Chaoborus

ODONATA

- Libellulidae
  - Diplacodes
  - Urothemis
  - Brachythemis
  - Pantala
  - Tholymis
  - Trithemis
  - Trapezoshyma
  - Hemistigma
  - Crocothermis
  - Orthetrum
  - Olpogastra
  - Acisoma
  - Philonomon
  - Palpopleura
- Cordullidae
  - Macromia
- Aeschnidae
  - Anax
  - Hemiana
- Gomphidae
  - Ictinogomphus
  - Lestinogomphus
  - Paragomphus
- Lestidae
  - Lestes
- Coenagriidae
  - Pseudagrion
  - Agriochemis

TRICHOPTERA

- Ecnomidae
  - Ecnomus
  - Psychomyellodes
- Leptoceridae
  - Oecetis
  - Hemileptocerus
  - Parasetodes
  - Pseudoleptocerus
  - Trichosetodes
- Polycentropodidae
  - Dipseudopsis
- Hydroptilidae
  - Orthotrichia
- Hydropsychidae
  - Amphysyche

HEMIPTERA

- Nepidae
  - Laccotrephes
  - Ranatra
- Belostomidae
  - Diplonychus
  - Hydrocyrius
  - Lethocerus
- Corixidae
  - Micronecta
  - Sigara
- Pleidae
  - Plea
- Notonectidae
  - Enithares
  - Anisops
  - Nconychia
- Naucoridae
  - Macrocoris
- Gerridae
  - Limnogonus
  - Naboandelus

EPHEMEROPTERA

- Baetidae
  - Procloeon
- Ephemeridae
  - Eatonica
- Polymitarcyidae
  - Povilla
  - Ephoron
- Caenidae
  - Coenomedes

FISH SPECIES IN LAKE TCHAD
(FROM HOBSON 1967)

Species	Abundance
Alestes dentex	C
Alestes baremose	R
Alestes macrolepidotus	C
Alestes nurse	AC
Alestes dageti	TC
Aplocheilichthys schoelleri	AC
Aplocheilichthys kingi	AC
Aplocheilichthys gambiensis	TC
Auchenoglanis biscutatus	TC
Auchenoglanis occidentalis	C
Barbus anema	AR
Barbus cf. callipterus	C
Barbus pleuropholis	NIL
Barbus lawrae	NL
Barbus wernei	C
Barbus leonensis	TC
Barbus stigmatopygus	NL
Bargus bayad	
Barilius niloticus	NIL
Barilius loati	AC
Barilius senegalensis	C
Citharinus citharus	C
Citharinus latus	C
Citharinus distichodoides	C
Clarias angularis	TC
Clarias lazera	C
Clarotes laticeps	C
Clarotes macrocephalus	AR
Ctenopoma petherici	AE
Distichodus rostratus	AC
Distichodus brauipinnis	C
Epiplaxys senegalensis	C
Epiplaxys bifasciatus	TC
Eutropius niloticus	AR

Fish Species in Lake Tchad (Continued)

Species	Abundance
Gnathonemus niger	NIL
Gnathonemus senegalensis	AR
Gnathonemus cyprinoides	AR
Gymuarchus niloticus	C
Haplochromis wingah	C
Hemichromis fasciatus	AC
Hemichromis bimaculatus	C
Heterotis niloticus	C
Heterobranchus bidorsalis	AC
Hydrocynus (Hydrocyon) forskali	C
Hydrocynus (Hydrocyon) brevis	AC
Hyperopisus occidentalis	R
Hyperopisus bebe	R
Ichthyoborus besse	NL
Kribia nana	C
Labeo senegalensis	C
Labeo coubie	C
Labeo pseudocoubic	C
Lates niloticus	AC
Malapterurus electricus	C
Marcusenius isidori	AR
Malacembalus loennbergi	AR
Micralestes acutidens	TC
Mochochus niloticus	C
Mochochus brevis	NIL
Mormyrus rome	AR
Mormyrus deliciosus	NL

Species	Abundance
Nannaethiops unitaeniatus	C
Ophiocephalus obscurus	
Paradistichodus dimidiatus	
Petersius brevidorsalis	C
Petrocephalus simus	NIL
Petrocephalus bovei	AR
Petrocephalus bane	C
Polypterus senegalus	C
Polypterus bichir	C
Polypterus endlicheri	R
Protopterus annectens	?
Schilbe mystus	AR
Silurandon auritus	C
Syndontis batensoda	C
Syndontis clarias	AC
Syndontis membranaceus	TC
Syndontis eupterus	TC
Syndontis frontosus	AR
Syndontis schall	TC
Synodontis gambiensis	C
Tetraodon tanaka	C
Tilapia galilaea	C
Tilapia nilohea	TC
Tilapia monodi	AR
Tilapia billi	TC
Tilapia melanopleura	AC
Xenomystus nigri	NL M

Key

Abundance (from Blache 1964)

TC	Very abundant
C	Abundant
AC	Common
AR	Uncommon
R	Rare
TR	Very rare
NL	Species not listed in Blache 1964
NIL	Species not listed in Lake Chad by Blache 1964

PRESENCE OF ORGANISMS IN TYPES OF AQUATIC VEGETATION AT BOL (FROM DEJOUX AND SAINT-JEAN 1972)

Organisms Found	P	C	V	TP	RP
Oligochetes	+	+	+	+	+
Nematodes	+		+		
Hirudinees				+	+
Agrionides	+	+	+		
Libellulides		+	+		
Baetidae	+	+	+	+	+
Povilla	+	+	+	+	+
Ecnomus	+	+	+	+	+
Orthotrichia	+	+	+	+	+
Dipseudopsis		+			
Diptonychus		+			
Plea	+	+			
Hydrocyrius					
Micronecta	+	+			
Naboandelus		+			
Lepidoptera		+			
Coleoptera					
Musicidae	+		+		
Cullicidae		+			
Ceratopogonidae					
Hydra		+	+		+
Bulinus	+	+	+		
Ferrissia	+				
Biomphalaria		+			
Anisus		+			
Gabbia					
Bellamia		+			

+ = Presence of species; P = Potamogeton; C = Ceratophyllum; V = Vallisneria; TP = stalks of Cyperus papyrus; RP = roots of C. papyrus

SPECIES CHARACTERISTIC OF DIFFERENT SUBSTRATES AT BOL (FROM DEJOUX ET AL 1971)

\- Absence

\+ - significant at P = .05
++ -- significant at P = .01
+++ --- significant at P = .001

Taxa	Coarse Clay	Fine Clay	Mud	Peat	Sand
Insects					
Ecnomus dispar	+++		--		
Cloeon fraudulentum	+++		---		
Povilla adusta	+				
Eatonica schoutedeni					
Orthoirichia					
Chaoborus ceratopogones					
Ceratopogonides		+			
Ablabesmyia dusoleili		-		+++	--
Chironomus formisipennis	+				
Chironomus sp. I		+++			
Cladotanytarsus lewisi			--		+++
Cladontanytarsus sp. I		+			
Clinotanypus claripennis			+++		
Cryptochironomus stilifer			++		---
Cryptochironomus diceras			--		
Cryptochironomus sp. I			--		+++
Cryptochironomus sp. II					+++
Cryptochironomus sp. III					++
Cryptochironomus sp. IV					
Nilodorum rugosum		+++	-		
Polypedilum fuscipenne	--		++		
Polypedilum sp. I		++			
Polypedilum sp. II			+		
Polypedilum sp. III			--		+++
Procladius brevipetiolatus					
Stictochironomus sp. I	+				
Stictochironomus sp. II	++		-	+++	
Tanytarsus nigrocinctus	+				
Tanytarsus sp. I	+		---	+++	-
Worms					
Aulodrilus		---	+++	---	++
Euilyodrilus	++			--	+
Alluroides	+++	+++	---	---	

Species Characteristics (Continued)

Taxa	Coarse Clay	Fine Clay	Mud	Peat	Sand
Branchiodrilus	+			-	
Pristina	+++				
Nais	-	-	-	-	+++
Aulophorus					+++
Nematodes	+	++	-	---	+
Molluscs					
Melania	-	---	+++		
Cleopatra		+	---		+
Bellamya	+++		-	-	
Corbicula	+++	+++		---	
Caelatura	+++	+++	---	--	
Pisidium					
Byssanodonia	+++		--	-	

ZOOPLANKTON AT BOL
(FROM DEJOUX AND SAINT-JEAN 1972)

Cyclopods	Cladocera
T. incognitus	M. triserialis
B. longirostris	M. goeldii
M. micrura	I. spinifer
C. c. rigaudi	A. guttata
D. excisum	A. monacantha
A. norae zelandiae	A. pulchella
A. diaphana	A. verrucosa
A. Karuz	Ch. eurynotus
A. monacaytha	
A. pulchella	
A. verrucosa	
Ch. eurynotus	
Ch. globosus	
M. goeldii	
I. spinifer	

DIETARY COMPOSITION OF FISH NEAR BOL
(FROM LAUZANNE 1972)

Species	Fish		Prawns		Aquatic Insects		Ostracods		Molluscs	
	%OC	%V	%OC	%V	%OC	%V	%OC	%V	%OC	%V
Hydrocyon forskalii	61.5	31.4	61.5	68.4	9.2	0.1				
Hydrocyon brevis	100	100					25.0	3.4		
Lates niloticus	100	100					12.5	1.9		
Schilbe mystus	39.3	66.2	50.0	29.4	39.2	1.0				
Eutropius niloticus	66.2	62.1	7.1	1.5	16.0	3.1	60.0	23.3	80.0	19.8
Bagrus bayad	41.0	69.3	79.5	27.3	48.7	3.4	55.5	0.4	61.1	48.3
Heterotis niloticus	5.0	2.2	10.0	9.1	80.0	19.3	82.7	40.8	27.6	34.0
Hyperopisus bebe					66.6	41.2				
Synodontis cf. schall					55.1	25.1				
Synodontis batensoda					42.8	5.9				
Synodontis membraneceus										
Alestes baremose										
Alestes dentex					22.2	16.6				
Alestes macrolepidotus					85.7	16.9				
Labeo senegalensis										
Citharinus citharus										
Tilapia galilaea										

Dietary Composition (Continued)

Species	Detritus %OC	Detritus %V	Zooplankton %OC	Zooplankton %V	Seeds %OC	Seeds %V	Higher Aquatics %OC	Higher Aquatics %V	Terrestrial Insects %OC	Terrestrial Insects %V
Hydrocyon forskalii										
Hydrocyon brevis										
Lates niloticus										
Schilbe mystus										
Eutropius niloticus									17.8	31.4
Bagrus bayad										
Heterotis niloticus			25.0	11.3	75.0	14.7				
Hyperopisus bebe					13.8	17.9				
Synodontis cf. schall										
Synodontis batensoda			100	94.0						
Synodontis membranaceus			100	100						
Alestes baremoze			100	100						
Alestes dentex			92.5	70.0	14.8	13.3				
Alestes macrolepidotus							100	60.3	71.4	22.6
Labeo senegalensis	100	100								
Citharinus citharus	100	100								
Tilapia galilaea	100	100								

ANNEX 3A
ETHNIC GROUPS FOUND WITHIN THE CANTON OF THE SOUS-PREFECTURES OF BOL AND NGOURI[1]

Cantons	Ethnic Groups (Clans)
1a. Bol Sous-Préfecture (seven cantons)	
Kangalloum	Buduma (Kella)
Bol	Buduma (Gouria, Maidjigodia, Dallas)
Nguelea	Kanembu (Ngalla, Kadjidia)
Ngarengu	Kouri (Koura)
1b. Administrative Post of Liwa (three cantons)	
Liwa	Kanembu (Koubri, Guim, Haddad)
Kiskra	Buduma (Maibouloua)
Tataverom	Buduma (Budja)
2a. Ngouri Sous-Préfecture (seven cantons)	
Ngouri	Kanembu Haddad
Baderi	Kanembu
Yalita	Kanembu Haddad
Djibinentchi	Kanembu
Djiguidada	Kanembu
2b. Administrative Post of Doum-Doum	
Isseirom	Kuri (Koura)
Kouloudia	Kuri (Kalla)
2c. Groupement of Amerom	Kanembu (Kenguena)
Groupement of Malloum	Kanembu (Ngalna)
Groupement of Albout	Kanembu (Ngalna)

[1]Data from de Leusse 1974. See also Map #2 (Bouquet 1974)

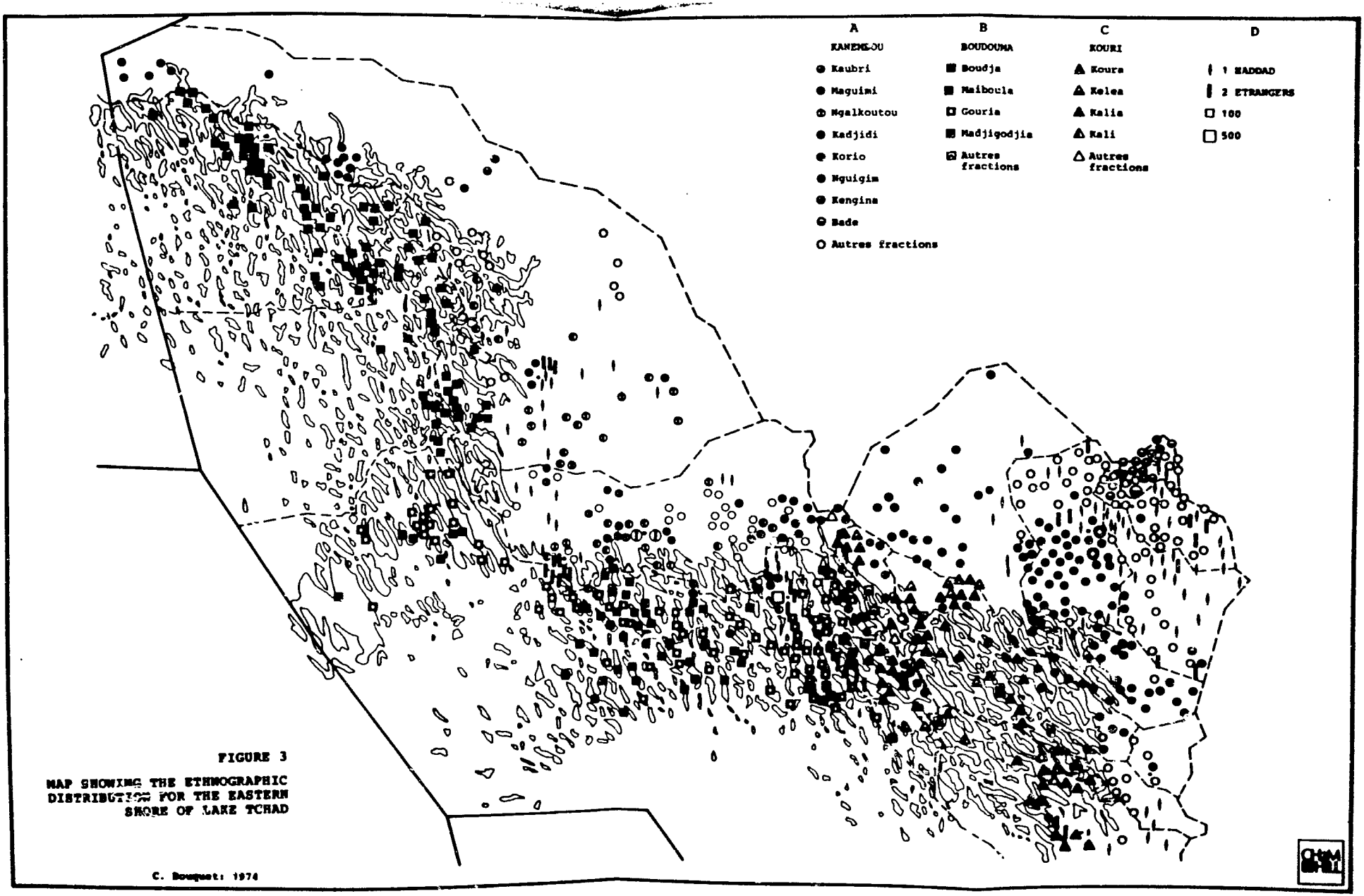


FIGURE 3

MAP SHOWING THE ETHNOGRAPHIC DISTRIBUTION FOR THE EASTERN SHORE OF LAKE TCHAD

C. Bouquet: 1974

ANNEX 3B

BOL, THE AGGLOMERATION

Bol is divided into a series of wards (quarters). There are eight wards, each under a chief of their own. The population may be statistically expressed as about 40 percent Kanembu, 35 percent Buduma, 20 percent Haddad, and 5 percent represented by various other groups; i.e., Toubou (called Gorane), Fulbe (Fulani), Kanouri, the officials from the south, and the technicians from abroad.

BOL, THE MARKET

The Bol market is located north of town. It covers an area of about 3,000 m^2 and meets on Wednesday. Traders and merchants arrive by small and large camel and donkey caravans about mid-morning, occupying traditionally located low palm roofed stands (see Figure 3-2 for location of various goods). It quickly becomes a busy dusty place as everyone spreads their wares on the ground for passersby to examine. Very little of these goods will actually be sold or traded. It would appear that the most important function of the market (as it often is in Africa) is contained in the breaking of the daily monotony of village life. One likes to travel to and from, meets relatives, and takes care of legal obligations. In the evening, most of the goods will be collected and taken back to where they came, people arriving at their own village very late at night. Some have traveled as much as 25 to 30 kilometers to come to Bol.

Bouquet (1974:154-157) tried to analyze the price structure of the goods at the market. He reports the difficulty in doing so because prices fluctuate during the day; expensive in the morning, cheaper in the afternoon. Furthermore, prices fluctuate from week to week and fluctuate with customers. Another difficulty comes from the fact that measures (Koro or Zacca) are not standardized. A Koro of corn is not equivalent to a Koro of millet, the latter being heavier in density. In a traditional market, prices do not follow an established price structure and barter exchanges never follow specific rules. The exchanges are more in terms of placing value on social intercourse than on gaining profit.

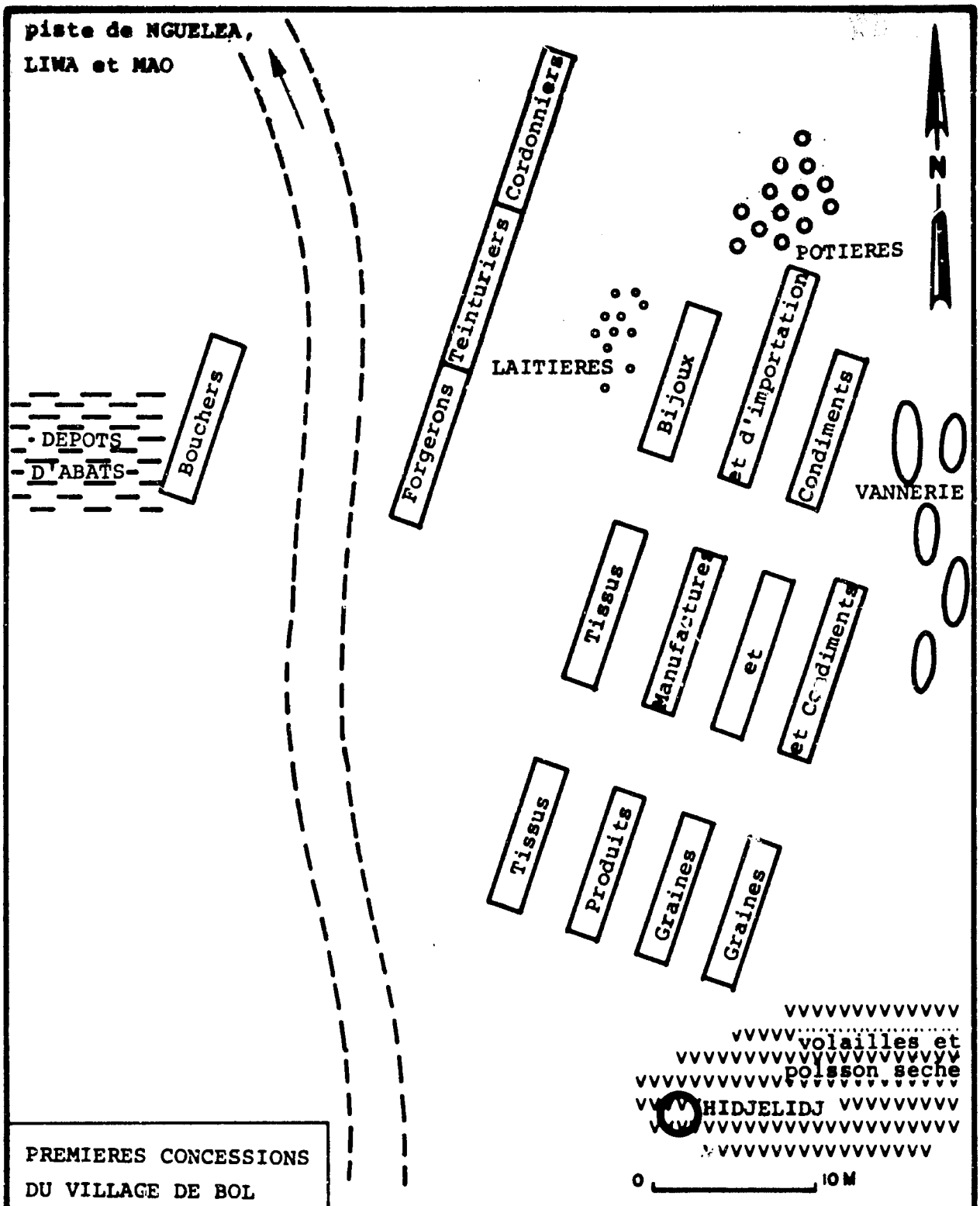


Figure 3-2
SKETCH OF THE BOL MARKET

C. Bouquet:1974

ANNEX 3C

AGRICULTURAL CALENDAR FOLLOWED ON THE POLDERS (FROM DE LEUSSE 1974)

cold-dry→	←warm-dry→		first rains	←Rains→		←cold-dry
Jan-Feb	March	April	May-June	July	Sept-Oct	Nov-Dec
Vegetables are harvested. Potatoes are harvested.	Wheat harvest	Vegetables are harvested	Cotton is planted	Millet is planted	Cotton harvest. Potatoes are planted. Vegetables are planted. Millet is harvested.	Wheat harvest

TRADITIONAL ACTIVITY CALENDAR FOLLOWED BY BUDUMA/KURI GROUPS DURING THE YEAR (AGRICULTURE-HERDING-FISHING)

Cold dry season: Nov-Feb	Hot dry season: March-June	Rainy season: July-October
1. Wheat is cultivated on the polders by some family members.	1. Corn is cultivated on polders by part of the family.	1. Millet is cultivated around permanent villages.
2. Fishing is done locally by others.	Fishing is done on the lake's western shore by other members of the family.	2. Cattle pasture on polders, lakeshores, and northern islands.
3. The cattle stays on the islands (the water is too cold for crossing.	3. The cattle is taken on transhumance to the mainland.	3. Millet is harvested and cattle brought back to the southern islands.

EVOLUTION OF WHEAT PRODUCTION ON THE POLDERS OF LAKE TCHAD (FROM BOUQUET 1969)

Year	Areas Isolated (in ha)	Areas Actually Dried Out (in ha)	Areas Cultivated (in ha)	Yield per ha	Production in tons	Purchases in tons by Semable-Sodelac
1962	5,480	1,500	1,056	14	1,600	900
1963	5,480	1,730	988	15	1,500	826
1964	8,000	2,080	1,511	20	2,600	600
1965	12,000	2,588	1,932	20	3,800	1,300
1966	15,000	3,250	2,422	20	4,800	1,100
1967	--	--	2,280	20	3,500	350
1968	--	--	3,600	21	9,000	600
1969	22,000	7,000	3,250	19	6,000	200

NOTE ON THE RECENT PRACTICES OF EMPLOYMENT OF PILOT-PEASANTS (FARMERS)ON THE POLDER PROJECT (BASED ON VERBAL COMMUNICATION WITH THE PRODUCT MANAGER, GEORGE BADOT)

The distribution of land on the polder is administered by the director of the project, implementing decisions made by a commission that includes representatives of SODELAC, local administrative authorities, and delegates elected by the farmers. There is no private property as the polder is declared national land. The order of priority for distributing land to those who volunteered to cultivate the polder is on the following basis. Those who owned land on the traditional polder are given first priority. Second priority is to those who have applied and have the size family warranting the land area they request. Those who are known locally to be industrious are considered next.

Those who receive a hectare, or a half hectare in the case of a widow, cultivate the crop SODELAC requests. They purchase seeds with a loan from the company and obtain land and irrigation water for CFA 65,000 per harvest. If they need money during the period of time between sowing and harvesting, they can borrow from SODELAC against their harvest wages. When harvest is done, the yield is weighed and they are paid. Thus there is an incentive to carefully till, irrigate, weed, and tend their crop. On payday, they are paid their wages minus the seed money, the "Redevance" (the charge for land/water use), and what they have borrowed. The balance is a clear gain for them. Last year, a man harvesting 1 hectare of potatoes could clear between CFA 25,000 to CFA 120,000, depending on his yield and indebtedness. This year, the potato harvest being excellent, most farmers are clearing CFA 120,000 to CFA 200,000. Since they usually participate in at least two harvests a year and sometimes three, their monetary gain is significant.

Most of the money cleared, aside from their daily maintenance, goes to gather a bride-wealth, to purchase a horse, to obtain cattle, and finally to improve their dwelling.

ANNEX 3D
RESULTS OF VILLAGE SURVEY

This appendix contains a summary of the data gathered during the project fieldwork. A survey of Bol (samples taken in each block of the town) and of its surrounding villages (east, west, and south of Tandal) was carried out by means of sending out a team of young people, with questionnaires, selected and trained for this purpose.

Samples were taken on 86 blocks in Bol and across 14 villages (6 on sand dunes and 8 on islands) surrounding Tandal. Each block and village was cross checked carefully and the questionnaires analyzed both manually and by computer (SCET-SODELAC Project, Bol).

The range of data and results are reported here summarily, but the totality of the analysis may be obtained from the files left with the Faculté des Lettres et des Sciences Humaines at the Université du Tchad in N'Djamena.

A. NOTE REGARDING THE VILLAGE SURVEY

The fieldwork for the village survey was carried out between March 14 and April 6, 1978. It encompassed most of the family heads (chefs de famille) within Bol and 14 villages which we divided into three zones (strate):

1. A survey was carried out in Bol, sampling one family within each block (86 family heads, 462 people), called Zone A.

2. The zone constituting the villages located on the sand dunes east of Tandal (6 villages, 248 family heads, 1,197 people), called Zone B.

3. The zone constituting the villages located west of Tandal (islands of Souri and Iga) and south (islands of Tandal, Konenrirom and Yakoua) (8 villages, 112 family heads, 536 people), called Zone C.

Taking into account the lack of adequate statistics, it is neither possible to determine what exact percentage of the Bol population was actually surveyed, nor to establish solid projections for surrounding villages. However, for most of the questions asked and answered within each zone, the answers given can be considered significant.

For each zone a questionnaire was prepared and a copy is included.

B. ENQUETEURS (DATA COLLECTOR) USED IN THE VILLAGE SURVEY WITH NOTES ABOUT THEIR SELECTION AND TRAINING

Ten young people present in Bol were interviewed for us as field workers in the villages to be surveyed. They were expected to speak and read French as well as to be able to converse in Kanembu and Buduma. Explanations were given as to the purpose of the survey and about the Tandal project. The questionnaires were explained in detail and information given about the rate of pay. The young people were informed that five of them would be selected and five rejected. They were each interviewed personally as to their background, education, work experience, etc. Finally, advice was taken from the foreman we hired, Mr. Delley Moussa (who also carried out the survey in Bol), who knew the young people. Those selected for the survey were:

Seid Adam, Kanembu from Bol
Mamat Moussa, Buduma from Bol
Idris Mahamat, Kanembu from Lafia Kafia
Momadu Boukar, Kanembu from Ngarengu
Ismeila Malloum, Kanembu from Bol

Adequate instruction in use of the questionnaire was given before sending them out to the villages by landrovers, dugout canoes, or by motor launch. They were expected to return on their own. Once a village was surveyed, it was cross checked by sending back another enqueteur to verify the answer given.

The CH2M HILL project leaders visited each village and met personally with the village chiefs to explain the purpose of the survey.

D. SURVEY FORMS

Enquête TANDAL Date:

Strate A (Bol, The Town) Enquêteur:

ilôt numéro:_____

I. Nom du chef de famille:

Ethnie:_____ Age:_____

Famille: épouse(s)_____ Age_____ Ethnie_____

_____ _____ _____

_____ _____ _____

Enfant(s)_____

Total famille:_____ Autres personnes_____

Date d'installation à Bol:_____

Domicile précédent:_____

Cause de la venue à Bol:_____

_____

_____

II. Activités

Le chef de famille a-t-il une activité rémunérée?

[Oui] [Non]

Laquelle?_____

Revenu annuel approximatif lié à cette activité:_____

Pratique-t-il des activités rurales? [Oui] [Non]

Quelle est l'activité dominante?

[Emploi rémunéré] [Agriculture] [Pêche] [Autre ( )]

III. Exploitation agricole et élevage

	Superficie sima	Localisation	Récolte moyenne
Champ de dune mil			
———	———	———	———
parcelle de polder blé maïs			
———	———	———	———
culture de décrue maïs sorgho			

Troupeau (nombre têtes bovins):

	Saison des pluies	Saison fraîche	Saison chaude
Localisation des pâturages			

IV. Perspective TANDAL

Si le polder de Tandal est créé

Accepterez vous d'y travailler? Oui Non Ne sait pas

Sur quelle superficie? [illegible]

Abandonnerez vous votre parcelle de polder ?

Guini: Oui Non Ne sait pas

Berim: Oui Non Ne sait pas

Autre polder: Oui Non Ne sait pas

( ): [illegible]

Pourquoi? _____

_____

_____

Prefereriez vous travailler à Tandal ou à Mamdi?

└┘ [Ne sait pas] [Tandal] [Mamdi] [les deux]

Pourquoi? _____

_____

_____

Quelles cultures aimeriez vous pratiquer sur Tandal?

└┘└┘└┘└┘ [Coton] [Blé] [Maïs] [Légumes] [Sorgho mil] [Autre ( )]

Seriez vous prêt à abandonner la culture de dune pour travailler uniquement sur le polder?

└┘ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à abandonner la culture de dune si on vous attribuait une parcelle de polder pour y cultiver le mil ou le sorgho?

└┘ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à garder les vaches à l'étable en les nourrissant avec du fourrage récolté sur le polder?

└┘ [Oui] [Non] [Ne sait pas]

Quels avantages et quels incouvénients voyez vous dans l'aménagement du polder de Tandal?

_____

_____

_____

Enquête TANDAL Date:

Strate B (Villages on Dunes East of Tandal) Enquêteur:
Village: _____

I. Nom du chef de famille:

Ethnie: _____ Age: _____

Famille: épouse(s) _____ Age _____ Ethnie _____

_____ _____ _____

_____ _____ _____

Enfant(s) _____

Total famille: _____ Autres personnes _____

Date d'installation dans le village: _____

Village précédent: _____

Village d'origine: _____

Cause du déplacement: _____

_____

_____

II. Perspective TANDAL

Si le polder de Tandal est créé

Accepterez vous d'y travailler? Oui Non Ne sait pas

Sur quelle superficie? [illegible]

Abandonnerez vous votre parcelle de polder

Guini: Oui Non Ne sait pas

Berim: Oui Non Ne sait pas

Autre polder: Oui Non Ne sait pas

( ): [illegible]

Pourquoi? _____

_____

_____

Prefereriez vous travailler à Tandal ou à Mamdi?

⌊_⌋ [Ne sait pas] [Tandal] [Mamdi] [les deux]

Pourquoi? _____

_____

_____

Quelles cultures aimeriez vous pratiquer sur Tandal?

⌊_⌋⌊_⌋⌊_⌋ [Coton] [Blé] [Maïs] [Légumes] [Sorgho mil] [Autre ( )]

Seriez vous prêt à abandonner la culture de dune pour travailler uniquement sur le polder?

⌊_⌋ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à abandonner la culture de dune si on vous attribuait une parcelle de polder pour y cultiver le mil ou le sorgho?

⌊_⌋ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à garder les vaches à l'étable en les nourrissant avec du fourrage récolté sur le polder?

⌊_⌋ [Oui] [Non] [Ne sait pas]

Quels avantages et quels inconvénients voyez vous dans l'aménagement du polder de Tandal?

_____

_____

_____

Enquête TANDAL Date:

Strate C (Villages on Islands West and South of Tandal) Enquêteur:
Village: _____

I. Nom du chef de famille:

Ethnie: _____ Age: _____

Famille: épouse(s) _____ Age _____ Ethnie _____

_____ _____ _____

_____ _____ _____

Enfant(s) _____

Total famille: _____ Autres personnes _____

Date d'installation dans le village: _____

Village précédent: _____

Village d'origine: _____

Cause du déplacement: _____

_____

_____

II. Activités et calendrier

	Saison des pluies	Saison fraîche	Saison chaude	Tempor-aire	Toute l'année
Agriculture Elvage Pêche Autre ( )					

III. Exploitation agricole et élevage

	Superficie sima	Localisation	Récolte moyenne
Champ de dune mil			
———	———	———	———
parcelle de polder blé maïs			
———	———	———	———
culture de décrue maïs sorgho			

Troupeau (nombre têtes bovins):

	Saison des pluies	Saison fraîche	Saison chaude
Localisation des pâturages			

IV. Perspective TANDAL

Si le polder de Tandal est créé

Accepterez vous d'y travailler? [Oui] [Non] [Ne sait pas]

Sur quelle superficie? [illegible]

Abandonnerez vous votre parcelle de polder

Guini: [Oui] [Non] [Ne sait pas]

Berim: [Oui] [Non] [Ne sait pas]

Autre polder: [Oui] [Non] [Ne sait pas]

( ): [illegible]

Pourquoi?_____

_____

_____

Prefereriez vous travailler à Tandal ou à Mamdi?

└┘ [Ne sait pas] [Tandal] [Mamdi] [les deux]

Pourquoi?_____

_____

_____

Quelles cultures aimeriez vous pratiquer sur Tandal?

└┘└┘└┘ [Coton] [Blé] [Maïs] [Légumes] [Sorgho mil] [Autre ( )]

Seriez vous prêt à abandonner la culture de dune pour travailler uniquement sur le polder?

└┘ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à abandonner la culture de dune si on vous attribuait une parcelle de polder pour y cultiver le mil ou le sorgho?

└┘ [Oui] [Non] [Ne sait pas]

Seriez vous prêt à garder les vaches à l'étable en les nourrissant avec du fourrage récolté sur le polder?

└┘ [Oui] [Non] [Ne sait pas]

Quels avantages et quels inconvénients voyez-vous dans l'aménagement du polder de Tandal?

_____

_____

_____

C. LIST OF THE VILLAGES SURVEY BY CH2M HILL TEAM IN THE REGION OF TANDAL (BOL, DIST. DU LAC, TCHAD) BETWEEN MARCH 14 AND APRIL 6, 1978

Zone of Investigation	Village Name	Number of Family Heads Contacted		Total Population Surveyed	
			total:		total:
A. Town	Bol (The Agglomeration)	86	86	462	462
B. Villages east of Tandal (sand dunes)	Matafo 3	55		176	
	Matafo 2	49		276	
	Matafo 1	79		451	
	Bol Farchari	24		115	
	Tchaitchairom	25		102	
	Bol Tandal	16	248	77	1,197
C. Villages west of Tandal (islands)	Gumbaru	15		95	
	Kudubul	Refused to answer questionnaires			
	Koremirom 1 and 2	27		145	
	Tandal	26		90	
	Iga 1	7		39	
	Iga 2	8		21	
	Somi 1	17		75	
	Somi 2	12	446	71	2,195

(See Figure 3D-3 for locations.)

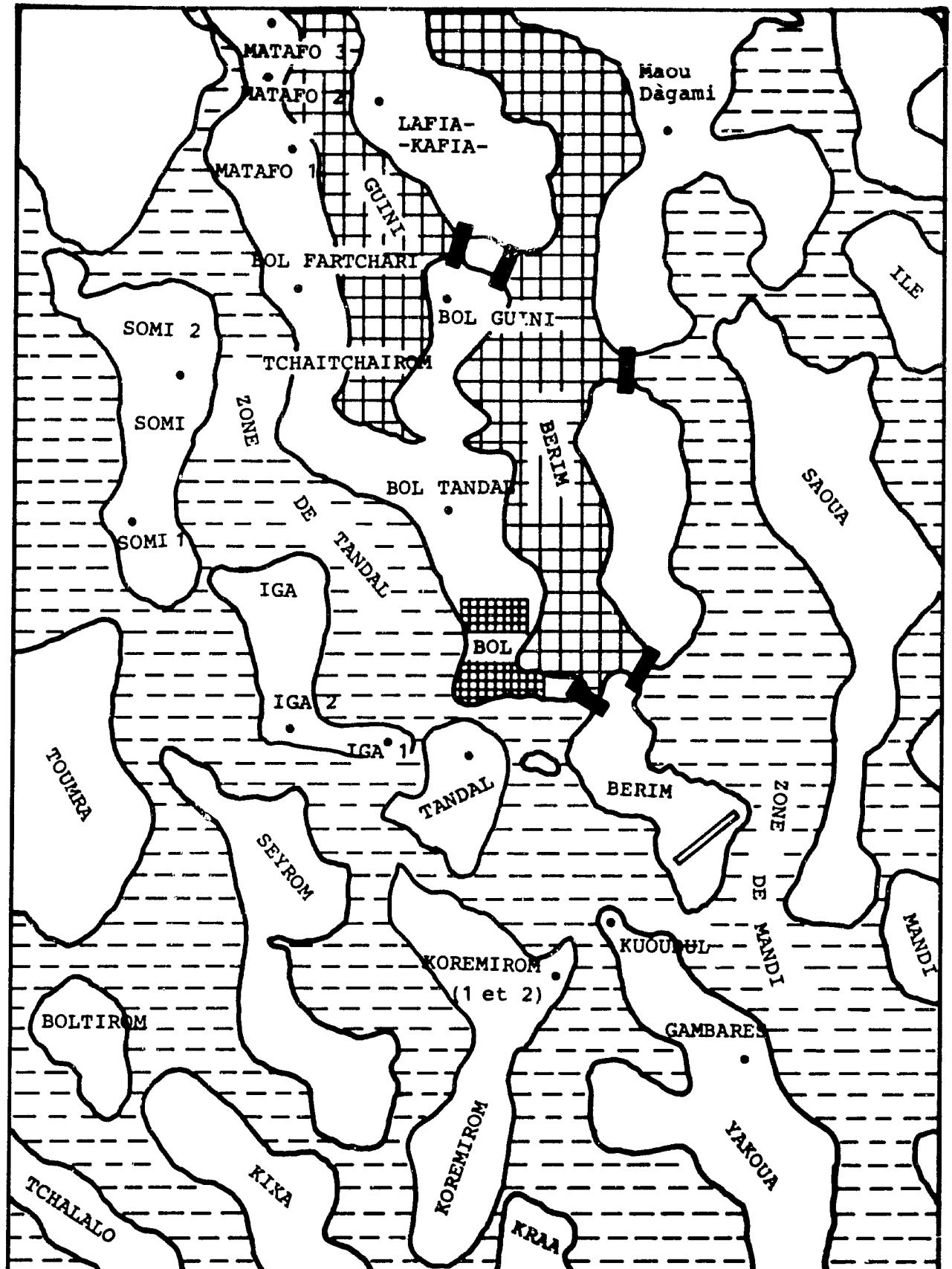


Figure 3-3
GENERAL AREA MAP
BOL AND THE POLDERS TANDAL BASIN

C. Bouquet:1978

E. COMMENTS ON THE AGE DISTRIBUTION

Taking the data in its totality, one notices a slightly larger number of males, this in spite of the noticeable lesser number of males in the age group between 20 and 40 years old. This larger total of males is the result of the manner in which the survey was carried out, accounting not only for the male family members who actually lived on the compound, but also recorded the visitors. Visitors to villages are usually males rather than females.

The age distribution appears to follow the usual profile, which one obtains in this region. The lesser number of males in the 20 to 40 year old group is related to temporary emigration which is noted elsewhere. The gap in age between married men and their wives is expressed by a larger number of females in the age group of the 15 to 35 years old. On the other hand, one notes the scarcity of women older than 40. This is the result of wives who have been repudiated and left the village, or who live there alone and are not accounted for in the census.

Age Distribution Tables Resulting from the Survey

1. For the totality of the sample surveyed (1,982 persons):

Males	Age	Females
91	70	5
40	60	4
59	50	24
105	40	50
127	30	130
154	20	237
198	10	209
301	birth	318
Total: 1,005		977

2. For each of the zones investigated:

Zone A (410 persons) Bol (Town)		
Male	Age	Female
7	70	0
5	60	0
21	50	5
28	40	17
22	30	23
23	20	54
43	10	29
57	Birth	76
258 ← Totals →		272

Zone B (1,042 persons) Villages on Dunes		
Male	Age	Female
8	70	1
23	60	1
25	50	10
53	40	24
69	30	72
89	20	110
122	10	124
152	Birth	159
541 ← Totals →		501

Zone C (530 persons) Islands		
Male	Age	Female
6	70	4
12	60	3
13	50	9
24	40	9
36	30	35
42	20	73
33	10	56
92	Birth	83
258 ← Totals →		272

F. COMMENTS ON POPULATION MOVEMENTS

For Zone A (Bol agglomeration), one notes a large population of immigrants who come to the town to seek nonagricultural work. It represents a development towards urbanization.

We need to note that within Zone B (villages east of Tandal) the people who followed their village chief in his moving were considered as if they were born in the village. Within this zone, the reasons most people moved are directly related to polders cultivation and/or work.

To the contrary, the family heads within Zone C (the islands), who generally tend to move less, attribute their movement to securing new pastures for their herds or for increasing their fishing grounds.

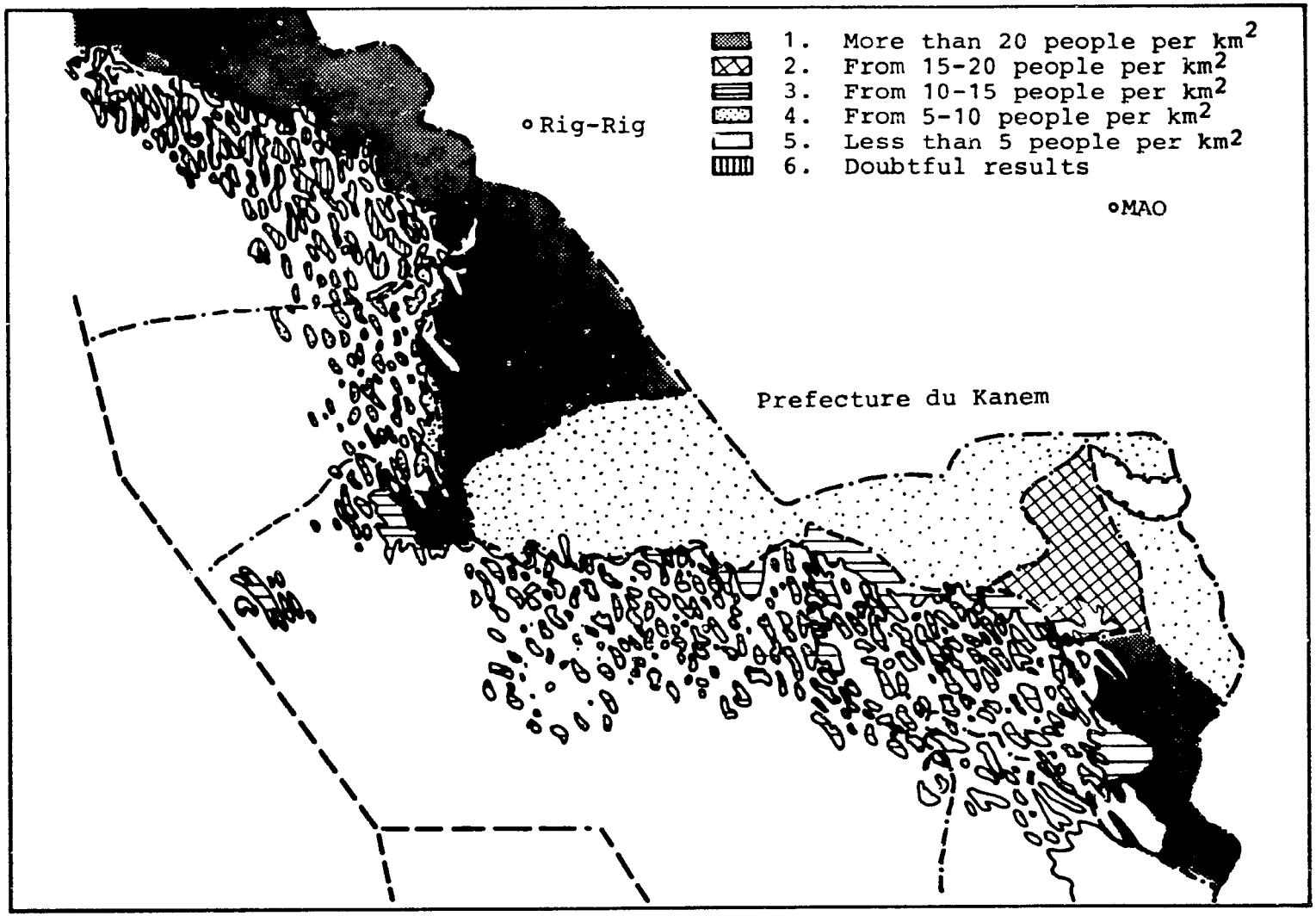


Figure 3-4
POPULATION DENSITY MAP

C. Bouquet:1974

This may be diagrammed as follows:

Reasons for Moving	Zone A Bol %	Zone B Dunes %	Zone C Islands %
To cultivate a polder	38.8	85.3	49.2
To seek a new job	29.0	0	0
To fish	0	0	17.6
To seek new pastures	0	0	12.3
To attend Koranic school or to become a Marabout	3.2	2.2	8.7
Because parents moved	8.0	2.2	5.2
Due to "fate"	6.5	6.1	7.0
Because of administrative edicts	8.0	0	0
Other reasons	6.5	4.2	0
	100	100	100

G. NOTE ON TRADITIONAL CULTIVATION YIELDS

The survey provided data which allows one to estimate the yields for both the millet cultivated on the sand dunes and the corn cultivated on the water edge (champs de decrue). The survey also confirmed the yields already known in relation to wheat and corn grown in the polders.

Millet cultivated on the sand dunes (by traditional means) yields about 660 kg/ha during an average year. One may note, however, a very distinct difference between the yields obtained by the Bol farmers (597 kg/ha) and those of the island villages (730 kg/ha), in spite of the fact that the latter, most of them Buduma, are not better farmers. One may assume, therefore, that the practice of letting the cattle drop their dung on the dunes around the villages in the islands, where there is an abundance of cattle, creates the difference (natural fertilizer). On the other hand, the Bol farmers own little or no cattle. Otherwise, it may be that the latter being town dwellers, they keep their own cattle away from their own fields in a nearby village.

Cultivation of corn on the edge of the water (in ebb fields) produces lower yields than that cultivated on the polders. The average is 775 kg/ha.

Having obtained these figures, it is therefore possible to evaluate the yield for each family head's harvest; a simple diagrammatic computation of the areas each individual cultivates in each crop may thus easily provide the average yield per compound.

H. RESULTS OF THE ANSWERS GIVEN TO THE QUESTION: "WHICH CROP WOULD YOU PREFER TO CULTIVATE ON TANDAL IF IT WERE MADE INTO A POLDER?"

The most interesting answers to this question concern the last (and open) entry. There, the farmers freely express their own views about which crop (as a secondary crop) they would prefer to grow, since they have already answered what they think about cotton, wheat, and corn.

1. Zone C (island villages: 112 family heads). They would prefer to cultivate gombo (okra)(36), followed by potatoes (28), pimento (18), peanuts (11), and tomatoes (9). A few isolated answers indicate a preference for cucumber (3), melon (2), sugar cane and leeks (1), and lettuce. Two farmers indicated they would like to start fruit trees (mangoes, lemons).

2. Zone B (dune villages with fields on the water edge: 248 family heads). These farmers are already cultivating Guini Polder; they therefore favor potatoes (66); however, most of the farmers expressing this live in Matafo 3, whose villages will experience an unusually excellent potato harvest this year, or they are farmers from Tchaitchairom where the data collector, himself involved in the potato harvest, may have influenced their answers. As a result, one may wish to pay more attention to the other wishes: gombo (okra)(45), pimento (32), onion (17), garlic (10), peanuts (8), tomato (8), manioc (6), lettuce (6), and green beans (5). Only one farmer wishes to start a fruit orchard (lemons).

3. Zone A (Bol agglomeration). There is some difficulty in accepting the data here because the data collector was prejudiced as to the kind of crop one should grow. The results were: potatoes (40), gombo (15), and peanuts (6).

I. RESULTS TO THE QUESTION: WHAT ADVANTAGES AND/OR WHAT INCONVENIENCES DO YOU CONSIDER TANDAL POLDER TO BRING YOU?

1. Zone B (villages on dunes east of Tandal). These are villagers who, for the most part, are already involved with Guini Polder, Berim, or Ngambia. Their answers on the whole seem to indicate they see more advantages than inconveniences.

   (a) Advantages exist on two levels:

      (1) Individual: "We shall be able to eat and buy clothes with the products of Tandal's harvests."

(2) Regional/economic: "Bol will become the largest city in the region."

"Tandal Polder is both near the dune and not far from Bol where we can sell our products."

"Tandal Polder is large; it will retain moisture, it will be easy to come dwell here and avoid disputes with Guini."

"With the money earned on Tandal, we shall be able to increase our cattle herds."

"We already cultivate the edges of Tandal (ebb fields)."

(b) Inconveniences:

"With the drying up of Tandal 'River,' the fish will vanish; it will be a disaster for our sauces" (fish is important to prepare sauces).

"Once the dams will be built, surely the cattle will wander away--there are many cattle thieves."

On the whole, the farmers worry a lot about the construction of dams for they remember having suffered a great deal in the past on such construction. They also fear that there will be too many volunteers who come and cultivate the polder and fear that the number of village chiefs will increase, therefore multiplying their traditional dues. They also say that many people will be hurt by the manner the land will be distributed.

Those who have cattle fear that there will not be enough pastures once newcomers arrive and they are anxious to know where the cattle will obtain their water.

A large number of those questioned indicated they feared an invasion of mosquitos (a remembrance of the years 1973-75 when Tandal went dry).

One Tchaitchairom farmer inquired about the manner in which Guini would be receiving its water from Tandal once it is dried up.

2. Zone C (the island villages). People of the islands are much concerned about Tandal being "polderized." These people are cattle herders, cultivators of

millet on the sand dunes, fishermen; they also engage in cultivation of fields on the edge of Tandal when the lake waters subside. They call these holdings their "garden."

Gamburu villagers are not concerned about Tandal, they are waiting for Mamdi to be polderized.

(a) Advantages seen:

(1) The hope to earn lots of money.

(2) The polder will be at their doorstep (closer than those existing now--but where they do not work).

(3) The satisfaction to own moist land. "It is good to cultivate a garden which is newly created."

(4) Those who do not have cattle will be able to cultivate land.

(5) To show that Buduma are able to work the land.

(6) As a bonus, they will be able to have a hayday of miraculous fishing once the water recedes: "When the water will vanish, we will catch huge amounts of fish. Then we shall work only on the polders."

(7) It will upgrade village life.

(b) Inconveniences:

The island villagers see none. They are new to polder cultivation and consider the opening of Tandal to cultivation as conducive only to advantages. Yet, they do fear that fishing will die out.

3. Zone A (Bol, the town). People in Bol are more reflective; they tend to answer glibbly with: "I cannot anticipate anything for I cannot imagine it," or "I don't know anything about advantages or inconveniences for it is Allah who creates the polders."

Yet, some advantages/inconveniences were voiced.

(a) Advantages:

(1) Wealth is considered first. "Everything will cost less and commerce will prosper." To be noted, however, is the fact that modernization is not a concern of the people of Bol whereas the dune villagers did anticipate it.

(2) Famine will vanish.

(3) One will be able to purchase cattle.

(4) Cultivators will be able to buy moto-pumps (which only indicates ignorance on the part of Bol's people about how to operate on a polder).

(b) Inconveniences:

(1) Fish will vanish and it is a serious matter in preparing sauces.

(2) There will be less pasture for cattle.

(3) There will be more cattle thieves.

(4) There will be too many mosquitos.

(5) Farmers from other regions will come and settle.

(6) There probably will not be enough land but there will arise too many village chiefs.

J. DATA TABULATIONS

The following pages present the summarized data collected during the village surveys.

EXTENT OF THE CH2M HILL SURVEY

Villages and Code Numbers	Number of Family Heads Surveyed	Total Population Surveyed	Observations
1. Bol Agglomeration: Zone A	86	462	1 sample taken in each city block
2. Matafo 3	55	176	Survey of October 1977: 50/255
3. Matafo 2	49	276	43/225
4. Matafo 1	79	451	33/414
5. Bol-Fartchari	24	115	22/92
6. Tchaitchairom	25	102	33/189
7. Bol-Tandal	16	77	18/76
Totals for Zone B (villages on dunes)	248	1,197	
8. Somi 1	17	75	Area never surveyed before 1978
9. Somi 2	12	71	
10. Iga 1	7	39	
11. Iga 2	8	21	
12. Tandal	26	30	
13. Koremirom 1	11	66	
14. Koremirom 2	16	79	
15. Gambaru	15	95	
Totals for Zone C (island villages)	112	536	
GRAND TOTAL	446	2,195	

COMMENTS:

1. The sample taken in Bol represents about one-eighth of its total population. Thus Bol's population may be about 3,800.

2. When one compares the survey statistics of October 1977 for Zone B to those obtained March-April 1978, one notes how mobile the population has been during the year. This fact was confirmed at Tchaitchairom when in March 1978, its people left in groups to go to Ngambia where they have plots of land.

DISTRIBUTION OF VILLAGERS BY ETHNIC GROUPS

Village	Percentage								
	Kanembu	Buduma	Kuri	Haddad	Kanuri	Fulbe	Southern Ethnic	Northern Ethnic	Kotoko
1. Bol Agglomeration: Zone A	50	15	3	--	19	3	1	2	6
2. Matafo 3	78	--	20	--	--	--	--	2	--
3. Matafo 2	74	6	10	--	--	--	4	6	--
4. Matafo 1	46	--	28	13	1	--	6	--	--
5. Bol-Fartchari	36	--	4	--	--	--	--	--	--
6. Tchaitchairom	100	--	--	--	--	--	--	--	--
7. Bol-Tandal	81	6	13	--	--	--	--	--	--
Total for Zone B (villages on dunes)	71	2	17	6			1	3	
8. Somi 1	[illegible]	94	--	--	--	--	--	--	--
9. Somi 2	[illegible]	34	8	--	--	--	--	--	--
10. Iga 1	[illegible]	--	86	--	--	--	--	--	--
11. Iga 2	75	--	25	--	--	--	--	--	--
12. Tandal	100	--	--	--	--	--	--	--	--
13. Koremirom 1	--	100	--	--	--	--	--	--	--
14. Koremirom 2	--	63	37	--	--	--	--	--	--
15. Gambaru	7	93	--	--	--	--	--	--	--
Total for Zone C (island villages)	38	49	13	--	--	--	--	--	--
TOTALS:	59	16	13	3	4	1	1	2	1

Note: All numbers represent % of the population.

(1) The ethnic composition of the population is mixed in Bol and to a lesser degree in the pioneering villages of Matafo. On the other hand, there is homogeneity for the villages--Zone B (dunes) Kanembu and Zone C (island) Buduma/Kuri.
(2) The division of the villages of Somi and Iga (1-2) is a recent feature which reflects the arrival of Kanembu on the islands.
(3) One must note the very small percentage of ethnic groups external to the region (Fulbe, Southern and Northern, Kotoko). Only 5% altogether, thus denoting a very weak impact of external migrations.

TABULATION GIVING THE AGE OF FAMILY HEADS

Villages	Average Age	Comments
1. Bol Agglomeration: Zone A	43.6	(1) The rather advanced age of the family head confirms a characteristic already observed in the 1977 survey. In October 1977, the survey was carried out on a sample of 503 family heads with an average age of 38.9. This corroboration seems to validate the new survey.
2. Matafo 3	39.9	
3. Matafo 2	36.2	
4. Matafo 1	38.7	
5. Bol-Fartchari	35.6	
6. Tchaitchairom	34.4	
7. Bol-Tandal	39.0	
Average Age in Zone B	36.9	(2) The size of the sample for Zone B tends to hide the age profile within this zone (see table on age profile following).
8. Somi 1	29.4	
9. Somi 2	37.5	
10. Iga 1	48.6	
11. Iga 2	35.0	(3) These figures tend to confirm previous conclusions in regard to the open-mindedness of family heads (farmers) towards technological and social innovations, as discussed by Bouquet (1977 b,c).
12. Tandal	43.8	
13. Koremirom 1	42.7	
14. Koremirom 2	30.0	
15. Gambaru	43.3	
Average Age in Zone	38.5	
TOTALS:	38.6	

AVERAGE SIZE OF THE FAMILY

Village	Average Number of Spouses	Average Number of Children	Total for the Family
1. Bol Agglomeration: Zone A	1.0	2.6	4.6
2. Matafo 3	0.9	1.0	2.9
3. Matafo 2	1.2	2.5	4.7
4. Matafo 1	1.2	2.9	5.1
5. Bol-Fartchari	0.9	1.8	3.7
6. Tchaitchairom	1.2	1.9	4.1
7. Bol-Tandal	1.1	2.1	4.2
Total for Zone B (villages on dunes)	1.1	2.2	4.3
8. Somi 1	1.2	2.1	4.3
9. Somi 2	1.3	3.6	5.9
10. Iga 1	1.1	3.3	5.4
11. Iga 2	0.9	0.8	2.7
12. Tandal	1.0	1.5	3.5
13. Koremirom 1	1.5	3.1	5.6
14. Koremirom 2	1.0	2.8	4.8
15. Gambaru	1.3	2.9	5.2
Total for Zone C (island villages)	1.1	2.4	4.5
TOTALS:	1.1	2.3	4.4

COMMENTS:

(1) The average number of spouses was calculated counting each family head and including as well bachelors. Thus there is a slight skewing. This explains the anomalous figures for villages 2, 5, and 11.

(2) The socio-demographic structure differs categorically obtained by Bouquet in 1977. This is the result that children leave the village to tend cattle during the hot season. This factor confirms that during the year, family mobility is evident within a margin of 10%.

Village	Number of Years in the Village	Comments
1. Bol Agglomeration: Zone A	22.7	(1) The island people are the oldest in place; then come the people of Bol, and then the more recently established people dwelling on the dunes east of Tandal.
2. Matafo 3	12.6	
3. Matafo 2	20.9	
4. Matafo 1	10.9	
5. Bol-Fartchari	21.1	
6. Tchaitchairom	34.4	
7. Bol-Tandal	31.3	(2) There are no villages recently established on the islands (exception made of Kudubul, created by Kanembu on Yakoua Island 5 years ago, but not included in the survey). Many of the villages appear to have been established about 15 to 30 years ago. The polders must be considered as being the major reason for people moving into the region.
Total for Zone B (villages on dunes)	17.9	
8. Somi 1	18.8	
9. Somi 2	25.7	
10. Iga 1	8.4	
11. Iga 2	27.9	
12. Tandal	39.0	
13. Koremirom 1	22.2	
14. Koremirom 2	27.0	
15. Gambaru	26.8	
Total for Zone C (island villages)	26.8	
TOTALS:	21.1	

AVERAGE AREA CULTIVATED BY A FAMILY HEAD

Village		Millet Field On The Dune	Polder Plot	Cultivation On Edge Of Lake	Total Cultivated
1.	Bol Agglomeration: Zone A	1.7 ha	1.3 ha	0.3 ha	3.3 ha
2.	Matafo 3	3.8	2.1	↑	
3.	Matafo 2	4.3	2.9		
4.	Matafo 1	4.9	2.1	Not	
5.	Bol-Fartchari	4.8	2.1	Surveyed	
6.	Tchaitchairom	3.7	2.6		
7.	Bol-Tandal	4.0	1.6	↓	
Total for Zone B (villages on dunes)		4.5	2.8		7.3
8.	Somi 1	3.8	2.4	1.1	
9.	Somi 2	6.1	3.2	1.8	
10.	Iga 1	4.4	7.1	2.6	
11.	Iga 2	5.5	2.0	1.9	
12.	Tandal	4.6	2.3	2.5	
13.	Koremirom 1	1.9	0.0	1.4	
14.	Koremirom 2	3.3	0.0	3.4	
15.	Gambaru	4.7	0.2	2.8	
Total for Zone C (island villages)		4.3	1.8	2.2	8.3
TOTALS:		3.9	2.3	1.4	7.6

Results of 1977 survey (Oct)

COMMENTS:

(1) The sample taken at Bol indicates that the town's people practice little agriculture. Even though polder work pays more, they still favor millet on the dune when they cultivate.
(2) For notes on the result of Zone B, see the text where Bouquet's survey and samples are reported.
(3) The percentages obtained in Zone C may need to be corroborated by a future survey. They indicate that the three true island villages (#13, 14, 15), inhabited mostly by Buduma, attach more importance to dune cultivation than to the polders.

SIZE OF THE CATTLE HERD

Village	Average Size of the Herd by Each Farmer	Comments
1. Bol Agglomeration: Zone A	4.1	(1) It is customary, among cattle herders to declare less heads of cattle than they actually have.
2. Matafo 3	5.7	(2) The Buduma/Kuri villages (9, 10, 13, 14, 15) own the most cattle. The Nov. 1977 survey already noted the strong attachment of villages 5, 6 to their cattle herds. They are customarily providing Bol with milk products.
3. Matafo 2	2.2	
4. Matafo 1	2.4	
5. Bol-Fartchari	9.3	
6. Tchaitchairom	11.9	
7. Bol-Tandal	5.2	
Total for Zone B (villages on dunes)	5.2	(3) Particular attention should be paid to the manner that Buduma/Kuri villagers have answered the question relating to using cattle feed rather than pasuturing the dunes.
8. Somi 1	1.8	
9. Somi 2	6.3	
10. Iga 1	6.9	
11. Iga 2	3.4	
12. Tandal	3.5	
13. Koremirom 1	8.9	(4) The figures obtained for Bol result from the fact that the town's people have the means to send their cattle to pasture in far away fields.
14. Koremirom 2	8.8	
15. Gambaru	6.9	
Total for Zone C (island villages)	5.5	
TOTALS:	5.1	

Results obtained from Oct. 1977 survey

ANSWER TO THE QUESTION: "HOW MUCH LAND AREA WOULD YOU WISH TO CULTIVATE ON TANDAL?"

Villages	Area Wished Expressed in ha per Farmer	Area Presently Cultivated on a Polder (ha)	Comments
1. Bol Agglomeration: Zone A	1.1	(1.3)	(1) The villages of Gambaru, on Yakoua Island, wish polder holdings on Mamdi, not Tandal.
2. Matafo 3	1.2	(2.1)	
3. Matafo 2	1.2	(2.3)	(2) The request for holdings cover in general twice as much as a farmer already cultivates, which may be wishful thinking.
4. Matafo 1	1.6	(2.1)	
5. Bol-Fartchari	1.3	(2.1)	
6. Tchaitchairom	1.4	(2.6)	
7. Bol-Tandal	0.7	(1.6)	
Total for Zone B (villages on dunes)	1.3	(2.8)	(3) One may observe high ambition among those who do not yet cultivate polders. Caution need be taken.
8. Somi 1	1.3	(2.4)	
9. Somi 2	2.2	(3.2)	
10. Iga 1	1.2	(7.1)	(4) The villages which show the most interest for Tandal Polder cultivation are Somi 2, Iga 1, and Matafo 1; those that are the least interested in Tandal are Bol, Bol-Tandal, and Koremirom 1 and 2.
11. Iga 2	1.8	(2.0)	
12. Tandal	1.3	(2.3)	
13. Koremirom 1	0.8	(0.0)	
14. Koremirom 2	1.1	(0.0)	
15. Gambaru	1.3	(0.2)	
Total for Zone C (island villages)	1.3	(1.8)	
TOTALS:	1.3	2.25	(5) If one were to add the area of polder already cultivated to that also wished for,

ATTITUDES EXPRESSED IN RELATION TO PRESENTLY CULTIVATED POLDER PLOTS VERSUS OPTING FOR A PLOT ON TANDAL

Villages	Percentage			
	Would Abandon Present Holding	Would Not Abandon Present Holding	Do Not Know (Undecided)	Do Not Own a Polder Plot at Present
1. Bol Agglomeration: Zone A	7	44	--	49
2. Matafo 3	51	47	2	--
3. Matafo 2	41	55	4	--
4. Matafo 1	24	75	1	--
5. Bol-Fartchari	--	100	--	--
6. Tchaitchairom	32	64	4	--
7. Bol-Tandal	--	100	--	--
Total for Zone B (villages on dunes)	30	68	2	
8. Somi 1	35	18	--	47
9. Somi 2	8	50	--	42
10. Iga 1	14	86	--	--
11. Iga 2	12	38	--	50
12. Tandal	8	50	--	42
13. Koremirom 1	--	--	--	100
14. Koremirom 2	--	--	--	100
15. Gambaru	8	--	--	93
Total for Zone C (island villages)	15	23	--	62
TOTALS:	22	52	1	25

COMMENTS:

(1) The Bol farmers are the most attached to their polder holdings, but about half do not have plots on the polder.
(2) About one-third of the polder farmers living in villages on the east side of Tandal would leave their plots to work on Tandal. One must note, however, that Guini and Berim are not the only polders cultivated.
(3) The island dwellers, not particularly concerned about polder development, are not attached to their holdings when they have some. This raises doubts about their expressed desires to farm Tandal or Mamdi with the large expenses.
(4) Note that the majority in Matafo 3, which was affected by the engineering works on Guini, express a wish to abandon it.

CHOICES EXPRESSED BETWEEN WORKING ON TANDAL OR MAMDI IN THE FUTURE

Villages	Percentage			
	Tandal	Mamdi	Both	Undecided
1. Bol Agglomeration: Zone A	98	1	--	1
2. Matafo 3	67	16	13	4
3. Matafo 2	98	--	2	--
4. Matafo 1	90	10	--	--
5. Bol-Fartchari	100	--	--	--
6. Tchaitchairom	100	--	--	--
7. Bol-Tandal	100	--	--	--
Total for Zone B (villages on dunes)	89	7	3	1
8. Somi 1	100	--	--	--
9. Somi 2	100	--	--	--
10. Iga 1	100	--	--	--
11. Iga 2	100	--	--	--
12. Tandal	100	--	--	--
13. Koremirom 1	100	--	--	--
14. Koremirom 2	94	--	6	--
15. Gambaru	--	100	--	--
Total for Zone C (island villages)	86	13	1	0
TOTALS:	90	7	2	1

COMMENTS:

(1) The percentage of those who did not make a choice is small.
(2) The village of Gambaru, located on the east side of Yakoua Island facing Mamdi, chose it.
(3) The villagers of Matafo 3 are ready to leave their present holdings on Guini and are attracted by Tandal, being the closest to it among the villages east of Tandal.

ATTITUDES EXPRESSED RELATED TO COMMERICAL CROPS THE FARMERS WOULD AGREE TO CULTIVATE

Villages	Percentage					
	Cotton		Wheat		Corn	
	Yes	No	Yes	No	Yes	No
1. Bol Agglomeration: Zone A	68	31	97	3	100	--
2. Matafo 3	62	38	100	--	100	--
3. Matafo 2	100	--	98	2	96	4
4. Matafo 1	24	76	81	19	94	6
5. Bol-Fartchari	75	25	75	25	88	12
6. Tchaitchairom	84	16	100	--	100	--
7. Bol-Tandal	37	63	100	--	100	--
Total for Zone B (villages on dunes)	59	41	91	9	96	4
8. Somi 1	100	--	94	6	100	--
9. Somi 2	75	25	92	8	100	--
10. Iga 1	--	100	86	14	100	--
11. Iga 2	12	88	100	--	100	--
12. Tandal	73	27	77	23	85	15
13. Koremirom 1	100	--	100	--	100	--
14. Koremirom 2	100	--	100	--	94	6
15. Gambaru	100	--	100	--	100	--
Total for Zone C (island villages)	79	21	92	8	96	4
TOTALS:	66	34	92	8	97	3

COMMENTS:

(1) Cotton is not in high favor. Four villages (Matafo 1, Bol-Tandal, Ika 1, Ika 2) are quite negative about it. Zone B generally presents a mixed opinion. These villagers produced cotton recently for SODELAC whereas the island people have no experience with cotton.
(2) Both wheat and corn are favored and the three zones are in agreement.

ATTITUDE REGARDING HOW FARMERS WOULD FEEL ABOUT ABANDONING THEIR SAND-DUNE FIELDS (MILLET CULTIVATION) IF TANDAL WERE TO BE AVAILABLE FOR CULTIVATION

Villages	Percentage		
	Would Abandon The Dune Fields	Would Not Abandon Them	Undecided
1. Bol Agglomeration: Zone A	58	41	1
2. Matafo 3	85	15	--
3. Matafo 2	16	84	--
4. Matafo 1	86	14	--
5. Bol-Fartchari	4	96	--
6. Tchaitchairom	0	100	--
7. Bol-Tandal	6	94	--
Total for Zone B (villages on dunes)	50	50	--
8. Somi 1	--	100	--
9. Somi 2	25	75	--
10. Iga 1	57	43	--
11. Iga 2	100	--	--
12. Tandal	31	69	--
13. Koremirom 1	--	91	9
14. Koremirom 2	6	94	--
15. Gambaru	7	83	7
Total for Zone C (island villages)	22	76	2
TOTALS:	45	54	1

COMMENTS:

(1) With the exception of two island villages, abandoning millet dune fields is considered mostly by Matafo farmers who already have experience with the polders.
(2) Since 36% of the Bol family heads have no dune field, one understands clearly the Bol figures.

ATTITUDE REGARDING HOW FARMER WOULD FEEL ABOUT THEIR SAND DUNE MILLET FIELDS IF THEY WERE AUTHORISED TO PLANT SORGHUM ON TANDAL POLDER

Villages	Percentage		
	Would Abandon It	Would Not Let It Go	Undecided
1. Bol Agglomeration: Zone A	74+	25	1
2. Matafo 3	45-	53	2+
3. Matafo 2	12-	88	--
4. Matafo 1	97+	3	--
5. Bol-Fartchari	100	--	--
6. Tchaitchalrom	100	--	--
7. Bol-Tandal	100	--	--
Total for Zone B (villages on dunes)	69	30	1
8. Somi 1	12+	88	--
9. Somi 2	33+	67	--
10. Iga 1	100	--	--
11. Iga 2	100	--	--
12. Tandal	85+	15	--
13. Koremirom 1	9+	82	9
14. Koremirom 2	50+	50	--
15. Gambaru	20+	73	7
Total for Zone C (island villages)	49	49	2
TOTALS:	65	34	1

COMMENTS:

(1) Generally speaking, a promise made to authorize sorghum to be cultivated on the polder does not necessarily mean that the farmers would abandon their millet fields.
(2) In six villages, on the contrary, farmers would welcome this solution (abandon the dune field in favor of sorghum on the polder).
(3) Two villages would oppose this proposal. They are not sorghum eaters, but prefer their millet. The Matafo farmers also know that sorghum does not grow well when planted on polder earth.

ATTITUDES CONCERNING OBTAINING A PLOT ON THE POLDER TO GROW CATTLE FEED: "WOULD YOU BE WILLING TO KEEP YOUR CATTLE STABLED?"

Villages	Percentage		
	Would Accept	Would Refuse	Undecided
1. Bol Agglomeration: Zone A	48	51	1
2. Matafo 3	--	98+	2
3. Matafo 2	8	92	--
4. Matafo 1	65	35	--
5. Bol-Fartchari	100	--	--
6. Tchaitchairom	100	--	--
7. Bol-Tandal	100	--	--
Total for Zone B (villages on dunes)	36	63	1
8. Somi 1	6	94	
9. Somi 2	8	92	
10. Iga 1	--	100	
11. Iga 2	--	100	
12. Tandal	73	27	
13. Koremirom 1	82	--	18
14. Koremirom 2	69	19	12
15. Gambaru	20	60	20
Total for Zone C (island villages)	40	54	6
TOTALS:	39	59	2

COMMENTS:

(1) It is interesting to note that Matafo 3, within Zone B, refuses categorically. It is the village located the closest to the Kuri Ranch experiment where cattle are fed fodder without roaming the fields.
(2) Island cattle herders have mixed feelings. They probably do not grasp what this question means.
(3) One notes a rather suspicious attitude expressed by cattle herders in regard to an innovative method which would greatly transform traditional habits.

ANNEX 4
ENDEMIC DISEASES

A. MALARIA

1. General

Malaria in Tchad is endemic (always present). It is the country's and Bol's most significant disease and death problem. Malaria is a human blood parasite disease transmitted by female anopheline mosquitos taking a blood meal. Three blood parasites have been identified in Tchad (primarily Plasmodium falciparum followed by P. malariae, and then P. ovale). All three have been identified at Bol. Falciparum malaria is usually a more serious disease. Symptomatically, it is characterized by fever, chills and sweating, severe headache, shock, renal failure, and finally even choma and death can occur; disorientation and delirium are often present. The other malaria (quartan and ovale) are usually not considered fatal. They are characterized by chills, rapidly rising temperatures accompanied by headache and nausea, finally ending in profuse sweating and relief. This is often repeated in cycles from several hours to several days. Laboratory confirmation is desirable but often will not reveal malaria parasites in the bloodstream except during peak infection seasons. Seasonal malady is common when infection rates go up; localized tolerances are known to occur.

Seasonal peaks of malaria are evident in the Bol Préfecture annual statistics. These occur during the rainy season. In 1975 and 1976, symptomatic complaints and subsequent treatment began rising in June and peaked in October. The pattern in 1977 was similar. Malan et al (1977) conducted an epidemiological survey in the Bol area (nine towns) during March-April 1977 but failed to find malaria blood parasites in 239 children, aged 3 to 15. This is not altogether surprising as blood parasite incidence (parasitemia) usually varies in proportion to infection rate. Based on clinical statistics, this should begin increasing after June (e.g., the rainy season). Also, gametocytes usually appear in blood in sufficient numbers to be found 3 to 14 days after symptoms appear.

Delfini (1968) diagnostically surveyed children (blood smears) in the Bol area in November 1967 and found a parasitemia rate of 27 percent falciparum, 5 percent quartan, and 1 percent ovale malaria. This ratio is similar to that found elsewhere

in the Lake Tchad Basin. Clinically verified cases (microscopic examination of blood smears) are reported for falciparum, quartan, and ovale malaria nearby (Ochrymowics et al 1969, Buck et al 1970, Menu et al 1973, Ngamesi and Morcos 1974) and later at Bol (personal communication, Dr. J-P. Daupnier, but no differentiation of parasite species).

As long as infective malaria gametocytes are present in human blood and vectors are present (female anopheline mosquitos), communicable infections can occur. Infective gametocytes in man can last up to 1 year for falciparum and up to 3 years for quartan malaria (APHA 1975). A danger of large construction projects is the introduction of new, more locally virulent malarial strains brought in by outside workers, resulting in epidemic outbreaks or the susceptibility of newcomers to local malarial strains (WHO 1974).

Because of the high symptomatic and clinically verified rates of malaria in the Bol area specifically, Lake Tchad Basin generally, plus the documented presence of a host of vectors (discussed below), there can be no doubt that malaria is a serious problem here, and precautions should be taken to minimize the hazard.

2. Important Vectors and Hosts

Only infected adult female mosquitos of the genus Anopheles transmit malaria. Man is the disease reservoir (although other primates are known to be minor harborers for P. malariae). Then anopheline species are recorded for Tchad, seven for the Lake Tchad Basin, and all are known or suspected vectors (Buck et. al. 1970). A. gambiae and A. funestus are the two most dangerous vectors. A. gambiae usually breeds in small ponds and pools, while A. funestus is a larger water breeder. Eggs are usually deposited along vegetation or debris. The eggs are adapted for flotation. Aquatic larvae hatch from the eggs and feed actively. Then individuals pupate, are relatively inactive, and transform into emergent adults. A. gambiae is usually more seasonal (small pockets of water) while A. funestus is annually more stable.

Malan et al (1977) found abundant A. gambiae larvae in shallow pools in the Bol area (adobe pit, polder seepage pools, drainage ditches, inlet are for Guini Polder, pool near Matafo inlet, and small pool of water next to Bol hospital pump). Surprisingly, after significant effort, no Anopheles mosquito larvae were found in the lake proper, but the authors note that "Potential predators [of mosquito larvae and pupae] were everywhere abundant." A. gambiae and A. coustani adults were found.

Many pest mosquitos were also reported at Bol. This appears to be related to the drought:

> "The area inhabitants can pinpoint the incredible increase in mosquitos to August of 1973. Before, there were few mosquitos for most of the year. Now after sundown the mosquitos make any activity... intolerable." (S. McGahuey, preliminary AID report- 12 p.).

Culex, Ficalbia, Uranotaenia, and Mansonia mosquitos were identified in addition to Anopheles (Malan et al 1977). Mansonia is a very serious pest problem at Bol.

Menu et al (1973) identified A. gambiae, A. funestus, and A. pharoensis across Lake Tchad in northeastern Nigeria. Culex and Aedes were also collected. Noamesi and Morcos (1974) also identified A. gambiae, A. funestus, A. pharoensis, plus A. rufipes. They suspected the presence of A. coustani, A. wellcomei, and A. squamosus. Noamesi and Morcos (1974) reported A. funestus as abundant along the edge of Lake Tchad. Buck et al (1970) captured A. funestus, A. pharoensis, A. wellcomei, and A. coustani var. tenebrosus at Djimtilo in the Chari River Delta.

It is not inconceivable that all seven of the Anopheles species reported for the Lake Tchad Basin could be encountered at times in the Bol area.

B. DYSENTERY/ACUTE DIARRHEA

Dysentery is a human bacterial disease of the colon. Its symptoms are diarrhea and fever; vomiting and cramps often are present. Blood, mucus, and pus may be passed with the stool. The presence of pus is usually considered indicative of the disease. The more serious forms are caused by Shigella bacillus, and fatalities can result if untreated. Clinical diagnosis is highly desirable because of the possible confusion with cholera, salmonella, amebiasis, viral infections, miscellaneous helminths and protozoa, and even new strains of Escherichia coli (until resistance builds up). Medical authorities at Bol have recognized this problem and in their notes they refer to this disease as dysentery-diarrhea. This was not always caught when statistical summaries were made. It would be much better to designate the problem as dysentery/acute diarrhea. We have separated amebiasis as a separate problem because it is listed separately in local medical records. However, it would be safer to combine it into acute diarrhea as well because laboratory verification is not usually made.

Fecal-oral transmission is necessary. Food and vessel handling without proper cleansing is the usual route. Fecally contaminated water or dairy products can also pass the disease, and fly passage is known. In general, any possible way of passing infected bits of faeces, even very minute, will transmit the disease. Personal hygiene is critical to breaking the cycle. Moslem cultural practices here should be encouraged and strengthened if possible. Sanitary water supply will also help.

C. GONORRHEA (GONOCCAL DISEASE)

Gonorrhea is a gonococcus bacterial disease of man which is venerealy transmitted. The agent is the bacterim Neisseria gonorrhea which attacks moist epithelium. Thus, it can infect mouth, eyes, anus, uretha, and vagina. Because of the site of infection (and male and female differences), the disease differs in seriousness and symptoms. The disease is not deadly but can lead to prostratitis, sterility, secondary infection, and serious complications including blindness (eye associated). Usually the disease is sexually transmitted, and only the sex organs are involved (though anal infections are common). Venereal infection is the type referred to in Tchad and Bol medical statistics. It is a very serious problem at Bol.

Males are usually easier to diagnose than females. A discharge exudes from the penis, and urination is painful. In females, the disease symptoms may be unnoticeable, and chronic carrier infection may result. This is one of the major problems in trying to control the disease. Bacterial culture for specific identification is recommended; female infections may be hard to verify even clinically. The disease is communicable from months to years and virtually only as a result of sexual activities. Several similar diseases complicate diagnosis.

The disease responds well generally to penicillin or other antibiotic treatment. The disease can be controlled by intensive local education programs to promote treatment and tracking down sexual contacts so they can be treated.

Treatment and control is similar to that for syphilis. Because of the high incidence rate of both diseases at Bol (and in Tchad), priority should be given this problem.

D. SYPHILIS

This is a human venereal disease caused by a spirochete bacterium Treponema pallidum. Skin lesion transmission has also been documented (especially mucous membranes), but this is rare and is limited to geographical areas where very poor personal hygiene is practiced. Primary syphilis is

characterized by a lesion (sore, chancre) at a site of sexual contact about 3 weeks after exposure. This is often followed by temporary healing and then general secondary eruption (weeks to months). Long-term latency may then occur. Skin and mucous membrane sores can reappear. Or later, very serious secondary invasions of nervous and/or muscle tissue can occur. The former can cause blindness, crippling, insanity, and death.

Serological blood tests are the surest verification (or diagnosis) of disease. Syphilis is communicable during the primary stage from lesions and later whenever lesions reappear. Internal epithelial lesions may be unnoticed. Infection can then occur from discharges (semen, vaginal fluid, menstrual fluid).

Because of the incidence rate at Bol, its response to treatment, its similarity to gonorrhea (venereal infection and responsiveness to treatment), very serious efforts should be made to control the disease in the Bol area.

E. SCHISTOSOMIASIS

1. General

Schistosomiasis (also called Bilharzia) is generally regarded as the second most important health problem in Africa. It statistically ranks third in Tchad and fifth in the Bol area. Schistosomiasis is a trematode worm (fluke) which infects the bloodstream (veins) of its host. Two types infecting man have been identified for the Lake Tchad Basin: Schistosoma haematobium and S. mansoni. These are the urinary and intestinal forms, respectively. A third species, S. intercalatum, is suspect; this will be discussed below. The urinary or hematobic form is much more prevalent, but an apparent increase in intestinal schistosomiasis is occurring in Tchad from the south. Watson (1970) concluded that both forms are endemic throughout the Lake Tchad Basin, and this is supported.

Urinary schistosomiasis has more visible symptoms: blood in the urine, secondary infection (pus), or even blockage. Intestinal schistosomiasis has less outward signs: liver disfunction and enlargement, enlargement of the spleen, portal hypertension, and sometimes blood in the stool. Allergic reactions usually occur initially in humans, but these could easily be confused with a common cold. Debilitation is common, and infection rate is usually highest in children about 10 years old; and then incidence progressively trails off with age. (Buck et al 1970 nicely shows this for southern Lake Tchad area.) Two factors would explain this age/incidence pattern: eventual death of infected individuals and resistance (genetic or behavioral) in the remainder of

the population (acquired resistance with age). It is known that there is less risk of vulnerability to cercariae with age because of toughening of skin (WHO 1967).

There is no apparent seasonality to incidence of schistosomiasis at Bol from medical records. Barkhuus (1976) reported 100 percent occurrence of urinary schistosomiasis in the people at Bol and 85 to 90 percent for the coastal areas of Lake Tchad. These figures appear high but may be correct. Malan et al (1977) conducted a specific Schistosoma haematobium survey in the Bol area. An overall incidence of 25 percent was found in 118 children ages 4 to 15. Specific incidence rate per village varied from 0 to 58 percent and probably reflects environmental susceptibility. Higher incidence was generally associated with villages in the polder region.

Buck et al (1970) found an infection rate (ova present in urine or faeces) of 26 percent (362 residents examined) for urinary and less than 1 percent (368 examined) for intestinal schistosomiasis at Djimtilo (southern Lake Tchad). Serological reaction rates were even higher (61 percent). Serological reaction can occur because of past or present infections but without the fluke actively passing eggs.

Watson (1970) found that both urinal and intestinal schistosomiasis were endemic throughout the Lake Tchad Basin (foci was Lake Tchad itself). He reported a minimum of 10 percent and maximum 80 percent incidence rate for S. haematobium. Menu et al (1973) found an overall 27 percent (range 0 to 71 percent) incidence rate in 1,436 examinations in the southwestern area of Lake Tchad for the urinary form. Two out of 610 stool examinations were positive for S. mansoni. The authors also reported previously unpublished study results done in the western side of Lake Tchad at Yau: 17 percent haematobium infection rate (ova present in urine) for 400 persons sampled. Noamesi and Morcos (1974) did a followup study in the southwestern sector (northwestern Nigeria). They found an overall 30 percent haematobium infection rate with a range of 9 to 66 percent. Some age groups were 100 percent positive (ova present)! Positive stool examinations for S. mansoni were much lower as expected--2 percent (220 examined). However, this 2 percent of the total came from one locality, raising the local incidence rate to 12 percent (5 out of 41). In addition, they found one incident of a schistosome egg with a terminal spine which could be S. intercalatum. Malan et. al. (1977) regarded S. intercalatum as "cow schistosome" which is curious. S. intercalatum is usually considered to be a human disease, although it can be present in cattle (Benenson 1975).

In summary, S. haematobium and S. mansoni are certainly endemic in the Lake Tchad area. S. haematobium has been positively

identified in the Bol area at a high incidence rate. S. mansoni has been reported at Bol at a low incidence rate. Snails that are intermediate hosts of S. haematobium, S. mansoni, and S. intercalatum are all present in the area (see below). Like malaria, schistosomiasis is a serious problem, and the potential is there for the situation to worsen through an increase in intestinal form(s).

2. Important Hosts

Man is the reservoir of Schistosoma haematobium, S. mansoni, and S. intercalatum, although S. intercalatum also is found in cattle. The disease infects man through direct water contact. Larvae (cercariae) in the water burrow into the skin and enter the bloodstream, migrate to the liver and mature into males and females, and then migrate to either the veins of the abdominal cavity (S. mansoni and S. intercalatum) or to the pelvic veins (S. haematobium). Operculated eggs pass out with urine (S. haematobium) or with faeces (S. mansoni and S. intercalatum). If the eggs get to water within a few days (temperature dependent), they will hatch into larval miracidia which can infect host snails of the genus Biomphalaria for S. mansoni and Bulinus for S. haematobium and S. intercalatum. After a period of development in the snails the cercariae leave the snails and can infect man directly by skin penetration, completing the cycle.

Biomphalaria pfeifferi and B. sudanica have been positively identified as common along fringe vegetation in Lake Tchad in the Bol area and elsewhere (Leveque 1967). They are well established native snail species. B. pfeifferi and B. sudanica are both intermediate hosts of intestinal schistosomiasis. B. pfeifferi is regarded as the main host.

Bulinus truncatus, B. forskali, and B. joursseaumei are also present in good numbers in the Bol area (Leveque 1967). All three will serve as hosts for Schistosoma haematobium, while only B. forskali is known to host S. intercalatum. B. truncatus generally is regarded as the main intermediate host for urinary schistosomiasis. Bulinus (Physopsis) globosus is also reported present in the lake and is common in temporary ponds and irrigation ditches (S. W. sector: Menu et al 1973, Noamesi and Morcos 1974). B. globsus is a host for nonhuman schistosomiasis.

Also positively identified is the snail Lymnaea natalensis, a known host of the giant liver fluke Fasciola gigantica, which infects livestock (Leveque 1967, Menu et al 1973, Noamesi and Morcos 1974).

F. AMEBIASIS

Amebiasis is a serious infection of the digestive system with a protozoan Entamoeba histolytica. Its symptoms are very

similar and the methods of passage identical to bacterial dysentery, except that an infective cyst can also be involved here. Death can result from this disease. Diarrhea is almost always present and usually contains blood and mucus; fever and chills are common. Microscopic identification is desirable because of similarity to bacterial dysentery, Giardia infection, ulcers, etc. Although relative incidence is lower at Bol than that for Tchad as a whole, it is still a serious problem.

Once again fecal-oral transmission is involved, and sanitary disposal of faeces (no water contamination) and personal hygiene will go a long way in reducing incidence. Sanitary water supply will also help immensely.

G. MUMPS

A myxovirus, related to influenza and responsible for mumps, is locally important at Bol (seventh disease ranking). Swelling and tenderness in the salivary glands are the characteristics of this communicable disease. Secondary pancreatitis, neuritis, arthritis, mastitis, and pericarditis (heart) can occur. The disease often results in hearing loss (temporary to permanent).

At Bol, there is an apparent slight tendency for mumps to be more prevalent from December to March, but the disease also occurs year-round. Transmission is via infected droplet spray or direct salival contact (e.g., mouth to mouth or nose route). The disease has a 3-week incubation period (especially just before gland swelling and tenderness appear). Once the disease occurs, lifelong immunity exists.

Attenuated live virus vaccine is available, often in combination with measles live virus vaccine. This usually is 95 percent effective and gives long-term protection. Vaccine offers the best potential for disease control.

H. INFECTIOUS HEPATITIS

1. Hepatitis (Viral A)

Viral infectious hepatitis is endemic in Bol. It is the eighth most common disease at Bol. Hepatitis is the top third killer in Tchad and ranks seventh overall in disease incidence. Malan et al (1977) did not consider infectious hepatitis in their epidemiological study of the Bol area. Buck et al (1970) recognized hepatitis as a serious health problem in Tchad but were unable to determine specific incidence rates because of lack of antibody information.

The disease is characterized by sudden onset of fever, nausea, abdominal discomfort, and then jaundice. Enlargement of the liver is not uncommon. It has an incubation period of several weeks.

Infection is usually via the fecal-oral route like dysentery and amebiasis, but infectious viral particles have been found in blood and urine as well. Water supplies can become contaminated and so can food. Because of the long incubation period, the disease can be carried and spread for a significant period without a community being aware of the problem. No known vaccine for active immunization exists. Improved sanitation and personal hygiene offer the only practical way to reduce incidence. This disease will continue to be a problem at Bol.

2. Hepatitis (Viral B)

This viral disease has similar symptoms. No differentiation exists at Bol (or Tchad) between A and B. It is impossible to routinely separate the two. Viral particles have been identified in blood, saliva, semen, and urine. This disease is often associated with the medical profession: contaminated needles, syringes, etc. Man (and possibly chimpanzees) is the disease reservoir. The disease requires the passage of infected blood or objects soiled by infected blood (or possibly saliva, semen, or urine). Transmission by vector mosquitos is highly suspect but has not been proven. This latter route could be very important locally, but nothing more can be said at this time.

I. LEISHMANIASIS, CULTANEOUS

This is a vector transmitted (sandfly) disease of the skin; e.g., ulcerated skin lesions. These can be single or spread by aggravation. If the naries are involved, the disease can be fatal. This disease was low but surprisingly common at Bol; it ranked ninth in importance. No seasonality was evident.

The infectious organism is Leishmania tropica, a flagellated protozoan. Man is the primary reservoir, but dogs and rodents are known secondary reservoirs. Transmission is through the bite of infected female sandflies (family Psychodidae, subfamily Phlebotominae, usually genus Phlebotomus, probably genus Sergentomyia locally). Buck et al (1970) captured S. africana and S. squamipleuris at Djimtilo (Chari Delta).

Biology of these biting gnat vectors is not well known. Adults usually hide in the daytime in animal burrows, holes, hollow trees, or buttresses of trees in swamps. They are weak fliers. Mouthparts are adapted for piercing-sucking. Eggs are usually laid in cracks and crevices in damp ground. Eggs, larvae, and pupae must remain moist; they cannot tolerate desiccation. Larvae are known to feed on molds, excreta, and dead insects. Development time from egg to adult is 4 to 8 weeks (temperature dependent).

J. WHOOPING COUGH (PERTUSSIS)

This is an irritating highly communicable cough of the throat and bronchial tubes. The coughing often becomes uncontrollable and violent. The "whoop" develops when patients try to recover their breath. The disease is caused by the bacterium Bordetella pertussis (a similar but milder disease by B. parapertussis). Whooping cough is one of the top 10 communicable diseases and causes of death in Tchad and at Bol. It is a lethal child's disease (and for some reason more so for girls than boys).

Infection is by airborne droplets of infected mucous secretion (mouth to mouth or nose) or by contact with soiled articles which must reach the mouth or nose. Incubation is for several days, and it is during this period that the disease is highly communicable. The disease remains communicable through much of the coughing stage but seems to lose its early virulence. An attack usually confers indefinite immunity. The disease responds well to antibiotics (erythromycin, ampicillin).

A series of vaccinations (suspended or killed bacteria) in early childhood are recommended, and this gives several years of protection. In areas where the disease is not especially virulent, many medical authorities do not recommend vaccination. This does not appear to be the case for Tchad (and Bol). The standard vaccination today is DPT, which also gives diptheria and tetanus protection. In lieu of the high local tetanus mortality rate, this combination vaccine is highly recommended. Education of partents to remove infants from other whooping youngsters can be effective in many cultures.

K. PNEUMONIA

Pneumonia can be caused by several viruses and bacteria (and interactions between these). It is the seventh most important cause of death in Tchad and the eleventh most important disease in the Bol area.

1. Pneumoccal Pneumonia

This is a serious bacterial disease (Streptococcus pneumoniae) involving the lungs and/or bronchial passages. Vomiting and convulsions are often the first signs, or a sudden acute chill with fever. Pain in the chest and a deep cough often develop. Infants and aged are usually affected the worst, especially as a mortality factor. The disease is best confirmed by the presence of gram positive diplococci from the lower respiratory tract. Susceptibility seems to increase after viral infections of the respiratory tract. Several bacteria can cause similar pneumonia, especially after viral infections. Diagnostic x-rays are recommended.

Man is the reservoir, and the bacteria is generally common; most people are resistant while healthy. Transmission is by infected droplets (mouth to mouth or nose route) or via soiled articles.

The disease usually responds well to penicillin or erythromycin.

2. Viral Pneumonia

This is an upper respiratory infection which often leads to bronchial or lobar pneumonia. Symptoms are not as severe as bacterial pneumonia: headache, fever, general fatigue, cough, and some pain (not usually deep chest pain; usually higher). Death is infrequent. X-ray examination is very helpful to spot patchy infiltrations.

Transmission is also by air droplet infection or freshly soiled articles.

L. MEASLES (RUBEOLA)

Measles is a highly communicable and locally dangerous virus disease. Fever usually appears about 10 days after infection. Fever is universal. The characteristic red blotchy spots and rash appear 3 to 7 days after fever. Conjunctivitis and bronchitis are common. The disease symptoms last for several days and are more severe in adults. Secondary pneumonia can develop. Death can occur and, in fact, measles death is fifth in importance in Tchad. A seasonal outbreak just occurred in Bol in March-June 1977, and cases trailed off into November. Similar seasonal outbreaks (hot months) have been noted previously throughout Tchad (Buck et al 1970). Measles virus is one of the top 10 causes of disease as well as mortality in Tchad.

Measles virus only affects man but is known to be related to distemper virus in dogs and cats. It is transmitted primarily by droplet spray of mucous secretions (mouth to mouth or nose). The virus can also be transmitted by soiled article contact. Urine transmission has been verified and faeces transmission is suspect. Dust transmission in Tchad has to be suspect in the hot, dry seasonal outbreaks. The disease is highly communicable soon after infection, through the rash stage. Permanent immunity is usually acquired. Community control programs are difficult in the best situations and are impractical here at this time. Live virus vaccines usually give at least a decade of protection. Inactive virus vaccines are not recommended. Vaccination offers the best control potential.

M. TRACHOMA

This communicable eye disease of man is characterised by redness of the eye, invasion of the cornea with blood vessels, lymphoid follicles (lesions) of the conjunctivia, and in later stages gross deformation of the eyelids, visual impairment, and blindness. Clinically, scrapings of conjunctivial epithelium will show cytoplasmic inclusions (fluorescent staining technique). The infectious agent Chlamydia trachomatis can also be cultured and identified.

Buck et al (1970) found significant north-south differences in disease incidence. The Sahel (which includes Bol) had a much higher incidence rate. Twenty-three percent of the population at Djimtilo had acute conjunctivities. Benenson (1975) notes that worldwide the disease is often a problem in dry, dusty regions (i.e., Bol), especially with crowded living conditions.

The disease is transmitted by direct contact with infected discharges of the eye; discharges from the nose of infected people are suspect. Soiled materials can also transmit trachoma. The fly Musca sorbens, a serious nuisance at Bol, is also known to transmit the disease. Exposure to dry wind, dust, and sand aggravate the condition (cause rubbing, etc.). The disease remains communicable indefinitely whenever infected discharges occur.

Improving basic sanitation and personal hygiene will go a long way in lowering incidence. Routine washing of face and hands with clean water and soap (and avoiding common towels and other toilet articles) is highly recommended. These procedures (i.e., soap washing) would also dramatically lower incidence of diarrhea infections.

N. TUBERCULOSIS

This bacterial disease is slightly more important overall in Tchad than at Bol area. Nationwide it is the eighth most important cause of death. At Djimtilo (Chari Delta), 2 percent incidence was found by chest x-ray (n=215). However, 57 percent and 77 percent showed positive reactions to PPD-S and PPD-G tuberculin skin tests, respectively (n=358, Buck et. al. 1970). The authors found several complicating factors in the skin tests, but even with a conservation correction, at least 50 percent of the Djimtilo population was tuberculosis positive.

The high positive reaction rate with low x-ray diagnosis is not altogether surprising. Tuberculosis infection can be asymptomatic for long periods of time. Pulmonary or bronchial lesions often are very minor and become inactive. Later, remissions can occur and possibly serious secondary infections develop (pulmonary, meningeal), especially in youth. The symptoms that the public is familiar with (cough, fatigue, fever, weight loss, chest pain, hoarseness) are usually

associated with advanced tuberculosis. Diagnosis is best confirmed by microscopic smear examination for Mycobacterium tuberculosis or M. bovis in sputum.

Man is the primary reservoir for M. tuberculosis, while diseased cattle carry M. bovis. Both can infect man or cattle. Airborne droplets from sputum of infected persons is the usual route for man (e.g., mouth-mouth or naries route). This is the same route as measles and whooping cough. Infected, unpasteurized or unfermented milk products are the route from cattle to man. Infected sputum from cattle can infect man. A 4-to 12-week infection period in man is required before lesions appear. A carrier can transmit the disease for years (although often intermittently). Children are most susceptible.

Tuberculosis (along with measles and whooping cough) is most difficult to control. In fact, control for Tchad or even Bol is probably not practical at this time. Massive skin test programs would have to be carried out to identify carriers and initiate treatment. Public awareness and change of habits would have to accompany treatment. Treatment by antimicrobial drugs usually has to continue for a minimum of 12 months.

Tuberculosis transfer from cattle is a little more controllable. Elimination of diseased cattle is probably impractical now but should be looked at for long term. Encouraging fermentation of milk products or boiling before consumption by man is practical and is recommended. Eventually, pasteurization should be included in development of urban milk supplies.

O. MISCELLANEOUS DISEASES

Leprosy is also found at Bol. Cases in 1977 ranged from a high of eight in May to zero in June and averaged two per month. Leprosy is a chronic disease caused by the bacillus Mycobacterium leprae. Ulcerated lesions of the skin are the first sign. Long-term cases can exhibit nerve, muscle, and bone degredation, and the upper respiratory tract can be attacked (tubercular symptom). Diagnosis is best confirmed by the presence of acid-fast bacilli in lesions. Transmission is by direct contact, possibly by aerial droplets of infected mouth or nose discharges, or by soiled articles. Rodents can harbor the disease (footpads) and are a secondary disease reservoir. Long-term incubation (months to years) is characteristic. Treatment is successful but presently takes years.

Yaws, a spirochete bacterial disease (Yersinia pseudotuberculosis) attacking skin then cartilage and bone, is occasionally reported at Bol. Laboratory confirmation of this diagnosis should be

made if it is reported again. Raspberry skin lesions are often characteristic; these last several months. Serological syphilis tests will usually be positive in yaws. Transmission is by direct skin contact (as in syphilis); fly transmission, however, is highly suspect in yaws (not in syphilis). The disease usually responds well to penicillin treatment.

Hookworm (ancylostomiasis) is occasionally found at Bol. When present, this nematode (Ancylostoma duodenale) parasite can be very debilitating and lead to malnutrition and mental retardation in children. Man, dogs, and cats are the reservoir. Eggs are discharged in the faeces. If the soil is moist, larvae hatch and can be infective (bare skin-soil contact). The larvae bore through the skin, go through the lymphatic and blood system to the lungs, migrate up the trachea, and are swallowed into the stomach to the small intestine where they attach (i.e., hookworm), mature, and lay eggs. Incidence of hookworm could possibly increase in the polder areas because of the more damp irrigated soils.

Brucellosis was not reported as a human disease for the Bol area (nor has it been reported in livestock of the area). There is a very low reporting rate generally for Tchad. Two percent incidence, however, was found at Djimtilo (Buck et al 1970). We suspect that a low incidence may well be present at Bol. Diagnosis is difficult, death is rare in uncomplicated cases. The symptoms can be easily confused with other diseases present in the Bol area: fever, chills, sweating, depression, and generalized ache (i.e., similar to influenza, malaria at times, and others). The reservoir for the disease is livestock and the disease is contracted by contact with infected discharges, tissues, meat, raw milk, and contaminated dairy products. Brucellosis in cattle is not routinely checked. It has been present virtually in all areas of Tchad tested (see Animal Health Section).

P. ANIMAL BITES AND MISCELLANEOUS

The epidemiological survey conducted by Malan et al (1977) did not cover the relative importance of animal bites to the health of Bol's people. However, Buck et al (1970) points out that 1 percent of the reported fatalities from communicable diseases in Tchad in 1966 resulted from rabies. Because of the probable very low reporting rate, they considered this a very important health problem in Tchad. In their interview surveys at Djimtilo, a community near the mouth of the Chari River, they found a frequency of 19 percent of population had been bitten by dogs and 12 percent by rats.

Snakes may also be a potential problem in the area (especially in polder reclamation). Four genera of poisonous snakes could

be present: Bitis, Cerastes, Echis, and Naja. The only other probable terrestrial concerns are scorpia (genera Leiurus and Androctonus).

Fish bites from Tetradon in Lake Tchad have been reported to have caused serious gangrene. Electric fish are also present in the lake (the dangerous Malapterus electricus, the milder shocking Mormyrops deliciosus, and Gymnarchus niloticus). Fishermen at Bol are aware of these hazards, but newcomers are not.

DISEASES OF UNKNOWN STATUS IN BOL

Information on tuberculosis is most inadequate in Tchad. Abattoir observations indicate that infections are limited. No immunological testing has been done. No information exists on tuberculosis of cattle or other animals in the Bol Sector. Whether or not bovine tuberculosis is a problem in man at Bol is unknown.

The importance of histoplasmosis (Histoplasma capsulatum or duboisii fungus) in livestock at Bol is unknown. Fourteen cases came to the attention of Direction L'Élevage in the Bol Sector during 1977. Histoplasmosis is transmissble to man. All were treated with Novarsenobenzol "Billion" (neoarsphenamin). Actinomycosis and trichophytosis are also African fungus diseases of livestock, particularly cattle, and are transmissible to man. We found no data on status in Tchad.

Streptothricosis is an important disease of cattle over much of Africa. Dermal streptothricosis is debilitating, but systemic streptothricosis is frequently fatal. It affects goats to a lesser degree and can infect man. There is evidence of vectoring by ticks. Streptothricosis is common in Tchad, but action to combat it is limited. Only four treatments were done during 1976 in the whole North-West Circonscription (Table 3G-2). In the two South Conscriptions there were 18,118 treatments during 1976. During 1977, 10 cases came to the attention of Direction L'Élevage in the Bol Sector. All were treated with injectable penicillin plus streptomycin. Streptothricosis has not been serious to date in the Bol polder area. It is more serious in regions of higher humidity. Farcha Veterinary Laboratory is attempting to make a vaccine. They consider success likely and thereby will improve control of this disease in Tchad (Bertin, personal communication).

Leptospirosis is present in Tchad. This disease, caused by Leptospira, infects cattle, goats, sheep, horses, swine, and rats but is seldom very important. There are no data available as it is not diagnosed. Leptospirosis is zoonotic with transmission to man by contact with infected livestock or exposure to urine contaminated water (swimming, bathing, drinking), vegetation, and soil. Rat urine is a frequent source of inoculum.

Another zoonotic disease of little importance to livestock is the rickettsial disease Q fever caused by Coxiella burneti. Veterinarians and animal husbandmen are infected most

frequently. Excreta, birth fluids and placenta, milk, and airborne material from livestock can be infective. Ticks are implicated in transmission. There are no data on incidence in livestock in Tchad. Buck et al (1970) associated Q fever in man in Tchad with camel caravans. Q fever in man can cause chronic hepatitis and endocarditis.

Toxoplasma gondii (Coccidia, Sporozoa) infects cattle, sheep, swine, and other animals as well as man. There is some evidence of tick transmission. We know of no data on incidence in Tchad.

Cowpox and orf virus of livestock are transmissible to man by contact. Status in Tchad are unknown.

Livestock are important factors in tetanus (Clostridium tetani) incidence in man as horse and ass faeces are prime sources of the bacteria. Camel, cattle, sheep, and goat faeces augment the problem. However, the disease is of no significance to livestock.

Pneumonic diseases of small animals is a considerable problem. There are no data of incidence or causative agent at Bol. The Veterinary Research Laboratory, Farcha (1978) includes small animal "peste" (related to rinderpest), parainfluenza type B, Pasteurella multocida A, and P. hemolytica in their vaccine against small animal pneumopathologies.

Pox virus of small animals and lumpy skin disease of cattle are also problems in Tchad of undetermined importance.

Rabies is present in domestic carnivores and wild mammals of the Bol Sector but poses no serious threat to livestock. Perhaps 50 jackals are poisoned with strychnine each year by Direction L'Elevage. That program has been terminated. Rabies control in the North-West Circonscription in 1976 included poisoning 163 hyenas and 699 jackals. One hundred and sixty-two baits were put out. One hundred and six animals (mammals and birds) of other species were poisoned. Very few dogs are immunized because there is a charge for vaccination.

Other biting flies of importance are Ceratopogonidae and Psychodidae. The former are extremely small flies (sand-flies) that vector several viruses to livestock and man. The most important may be bluetongue (Culicoides sp. vector) of cattle, goats, and sheep. Bluetongue is present in Tchad, but distribution and incidence is unknown (Bertin, personal communication). The Culicoides species and their vectoring potential is better known in Nigeria through extensive research. Psychodidae are probably unimportant as these small flies are seldom abundant enough for bloodsucking to affect livestock, and they do not transmit important diseases. Psychodidae are important vectors of leishmaniasis of man.

We have seen no reports mentioning the blood sucking Muscidae, Stomoxys several species, which can be severe in most of Africa, and are possible acyclic disease vectors. Stomoxys breeds in dung and in rotting vegetation, so that lake level changes and poldering could produce these flies.

PLANT COMMUNITIES AND LIVESTOCK GRAZING PATTERN

Bouquet (1974), referring to Gaston (1967), distinguishes two sandy zones in the Bol region, the Sudanese Sahel meadow and the Saharan Sahel. The Sudanese Sahel meadow is a savannah with a few bushes, mainly Leptadenia spartium or pyrotechnica ("war," false broom, or sand broom). Acacia albida or Faidherbia albida is found occasionally ("haraz"). This tree loses its leaves in the dry season, thus providing important nourishment for livestock. In turn, the animals fertilize the small area under these trees with their dung. However, this tree is very thinly spread and does not form a parklike savannah. "Milkweed" (Asclepiadacea) Callotropis procera is present. Livestock do not feed on this poisonous shrub. Leptadenia is an important food for camels.

The perennial herbaceous stratus, mainly Cyperus conglomeratus, is about 50 percent of the grassy carpet. C. conglomeratus is important as it sprouts shoots a little before the rains, justifying by itself, where it is abundant, the beginning of the transhumance of the summer as early as May. Other perennials persent are Aristida longiflora, Cymbopogon giganteus, and Andropogon gayanus. In clear areas, Hyparrhenia dissoluta is abundant ("Chigou," tall grass used for hut construction). Annual grasses are poorly represented, including Aristida mutabilis (utilized by camels), Eragrostis tremula, and Ctenium elegans. These sandy plateaus are routes of transhumance.

Trees and bushes are more abundant on the Saharan Sahel. Principal species are Balanites aegyptiaca, Leptadenia spartium, and Acacia raddiana or scorpioides, Commiphora africana, Acacia senegal, and Callotropis procera. Annual grasses are predominant in this zone, with Aristida mutabilis and A. funiculata covering three-fourths of the grass sward. There are a few perennial grasses, mainly Cyperus conglomerata and Aristida longiflora.

Closer to the lake, wadis ("ouadi") become common. These wetter areas have an abundant flora. On the slopes of the wadis, the trees and shrubs include Balanites aegyptiaca, Acacia raddiana, A. senegal, Zizyphus mauritiana, Hyphaene thebatica (doum palm), and Maerua crassifolia. There are no perennial grasses. Annual grasses flourish on the slopes. Species include Aristida mutabilis, A. adscencionis, Cenchrus biflorus or catharticus, Chloris prieurii, and Eragrostis pilosus.

Further tree and shrub species occur in the beds of the wadis, including: Acacia nilotica, A. laeta, A. segal, Boscia senegalensis, Salvadora persica, and Capparis decidua. C. decidua furnishes important camel and horse feed starting while it is still very dry in April by means of new growth. Cattle will not feed on it. The bed of the wadi has the following new annual grasses: Eragrostis pilosa and Chloris prieurii. There are also hydrophytic plants such as Nymphaea lotus, Abutilon fruticosum, Trianthema polysperma, and Scipus praelongatus. Imperata cylindrica and Cynadon dactylon are found at the transition between bed and slope.

ANNEX 6
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