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Monchon

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# FEASIBILITY REPORT ON RICELAND RECLAMATION IN GUINEA

6750013

# MONCHON PROJECT

BY THE

HARZA ENGINEERING COMPANY

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A.I.D. HISTORICAL AND
TECHNICAL REFERENCE
ROOM 1656 NS

PREPARED FOR

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

OCTOBER 1963

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SUMMARY LETTER

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# SUMMARY LETTER

HARZA ENGINEERING COMPANY
CONSULTING ENGINEERS
RIVER PROJECTS
400 WEST MADISON STREET
CABLE ADDRESS 'HARZENG CHICAGO CHICAGO 6, ILLINOIS TELEPHONE RANDOLPH 6-3451

October 15, 1963

Agency for International Development
State Department
Washington 25, D.C.

Subject: Monchon Project
Feasibility of Riceland Reclamation

Gentlemen:

We are pleased to submit our feasibility report on the Monchon Project. This report contains the results of the engineering, agronomic, and economic studies of the Monchon Project which we have made in compliance with the terms of our contract AID/afe-93, dated April 3, 1963. This contract provides for feasibility studies in connection with the reclamation of a series of four project areas totaling about 17,500 hectares in the Republic of Guinea. The Monchon Report is the first of the series.

Our findings indicate that a drainage and agricultural improvement project covering about 2500 hectares at Monchon is economically and financially feasible. This project will make an important increase in the supply of locally produced rice and thus reduce significantly dependence on foreign food sources.

## Introduction

The Republic of Guinea presently has an agricultural economy, heavily dependent upon rice. Although rice is staple food in Guinea, domestic production has been insufficient to meet the ever-increasing needs of a growing population.

The Monchon area has long been a rice producing region, but land use and crop yields have been far below their potential because of inadequate

drainage, salt intrusion, and the lack of supporting agricultural improvement programs.

## Reclamation Plans

Several plans have been developed since 1930 for reclaiming the 3000 hectares of arable land located in the vicinity of the village of Monchon. One of these plans, consisting of a system of canals draining the plains toward the north, was constructed in the 1940's. However, this project soon became ineffective because of the silting of the Diberedi River, the tidal stream used as outlet for the canals.

More recently, another outlet was found on the southwest, suitable to drain water from the plains. This outlet is the Sonie Koure River, a tributary of the Koumba River. Dredging of a main canal to the Sonie Koure from the Dentema dune was started in 1957, but was left uncompleted upon the departure of the French Colonial Administration in 1958.

The government of Guinea is now considering the resumption of this project with the assistance of international financing agencies. Our assignment has included both field and office studies to determine the feasibility of reclaiming the Monchon Area for rice production.

## Present Studies

We have sent to Guinea a team of six engineers and agronomists who, from April to July, 1963, reviewed all available data pertaining to the Monchon Project. This team carried out the field investigations related to hydrology, topography, soils, hydraulics, agronomy, and economics, and collected the data for the development of a comprehensive plan for reclamation. Analysis of the data and preparation of the plan were then completed in our Chicago office.

## Project Description

The Monchon Project will consist of an enclosed system of surface canals designed to drain into the Sonie Koure the excess runoff that would otherwise remain in the paddies for a prolonged period. The previously

constructed reach of the main canal will be deepened by dredging, and extended in a northeastern direction for an additional distance of about 2600 meters. The main canal will have a bottom width of 16 meters. Secondary canals, excavated to a bottom width of 13 meters at their widest sections, will empty into the main canal along its course. A network of tertiary and quaternary canals will collect excess runoff from the fields and empty into the secondary canals. These canals will have a bottom width of 0.8 meters. The proposed canals have been located so as to take full advantage of existing drains.

The project area will be surrounded by dikes designed to prevent the entrance onto the plains of flood waters from adjoining watersheds. A control structure provided with five timber flap gates will be located across the main canal near the Dentema dune to control the entrance of salt water into the canal system during high tides.

A number of bridges have been included in the project, for operation and maintenance access and for use by the local populations.

A total of about 220,000 cubic meters will be excavated by a suction dredge for construction of the main canal. Draglines will be used to excavate about 630,000 cubic meters for construction of the secondary and tertiary canals. Quaternary canals will include about 25,000 cubic meters, to be excavated by the individual farmers with hand labor. Construction of the project is estimated to take two years.

## Project Costs

We have estimated the construction cost of the civil works including canals, dikes, and structures, to be US $1,300,000 and GF 185,000,000. The cost of land preparation, including minor leveling and planing, is estimated to be an additional GF 35,000,000. Funding arrangements should include additional allowances for interest during construction and possible cost escalation. Financing requirements are estimated to be US$1,350,000 and GF 250 million, equivalent to a total of US $2,350,000, not including interest during construction. The rate of exchange used is GF 248 equal US $1.00.

The average annual cost of operation and maintenance is estimated to be GF 6,000,000. This amount includes the average cost of a comprehensive agricultural extension (improvement) program.

## Project Benefits

The presently cultivated area of about 950 hectares can be increased to about 2400 hectares with reclamation. From our studies of the agricultural potential of the soils in the project area, we estimate that the present average annual production of about 520 tons of rice paddy can be increased to about 1600 tons immediately upon completion of the project. This production can be progressively increased to 3850 tons in about ten years, and to an ultimate amount of 6100 tons 20 years after project completion. These increases in production will require from the very beginning a comprehensive support program for the improvement of farming practices.

The potential increase in production will make a sizeable contribution to the Guinean economy, which is presently deficient in rice. Annual imports have increased steadily in the last few years, to about 35,000 tons in 1963. Rice imports now cost about $2.5 million yearly, or ten percent of the present deficit in the balance of payments.

## Economic Value

The economic value of this project has been measured by benefit-cost relationships. Capital costs have been based on an interest rate of six percent and an economic life of 50 years. Included are both direct and indirect benefits that will accrue to the project and for which a monetary value could be assigned. The results obtained are as follows:

All Amounts in GF 1000

| Annual Benefits | Upon Completion of Project | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|
| Direct Benefits | 19,500 | 43,000 | 55,000 | 93,000 |
| Indirect Benefits | 1,500 | 7,500 | 10,000 | 15,000 |
| Public Benefits | 5,000 | 6,500 | 7,000 | 9,000 |
| Total Annual Benefits | 26,000 | 57,000 | 72,000 | 117,000 |
| **Annual Costs** | | | | |
| Capital Costs | 37,000 | 37,000 | 37,000 | 37,000 |
| Operating Costs | 5,000 | 6,000 | 6,000 | 6,000 |
| Total Annual Costs | 42,000 | 43,000 | 43,000 | 43,000 |
| **Benefit-Cost Ratios** | | | | |
| With Direct Benefits Only | 0.5 to 1.0 | 1.0 to 1.0 | 1.3 to 1.0 | 2.2 to 1.0 |
| With Total Benefits | 0.6 to 1.0 | 1.3 to 1.0 | 1.7 to 1.0 | 2.7 to 1.0 |

We consider that the project is economically justified, with satisfactory benefit-cost ratios to be reached after five years of project operation. For achievement of the potential benefits from the drainage of the lands, a supporting program of agricultural extension services will be required.

## Financial Analysis

The source and terms of project funds are not yet known. For sake of analysis we have assumed loans bearing interest at an annual rate of 0.75 percent, to be repaid in 40 years, with the first amortization payment due ten years after the completion of construction.

Agency for International
Development

October 15, 1963

Our analysis of future revenues and costs shows that after only three years residual revenues will be greater than the interest, amortization, and operation costs of the project. In fact, substantial surpluses will occur in future years, indicating that even less liberal financing terms can be met by the project.

## Timing of the Project

This project being the first of a series to be studied by us and, we understand, by the Food and Agricultural Organization of the United Nations, we cannot determine at present whether the Monchon Project is more- or less- economical than other potential riceland reclamation projects. However, it appears that all projects which are economically feasible will be needed, if Guinea is to become self-sufficient in rice. Consequently, we believe that the Monchon Project should be undertaken as the initial step in a major agricultural program.

## Recommendations

We recommend that negotiation be started by the Government of Guinea for financing of the project, and that committments be obtained for all necessary funds, both in foreign and domestic currency, before construction begins.

The Government of Guinea should engage an experienced consulting firm to prepare contract documents and detailed drawings, and to supervise and inspect construction of the works.

Bids should be taken from qualified contractors for construction of the civil works. Preparation of the project lands for agricultural use can be carried out by the Center of Rural Mechanization.

We recommend that a rice agronomist be engaged by the Government of Guinea to direct a program of agricultural extension service and to assist farmers in improving their production.

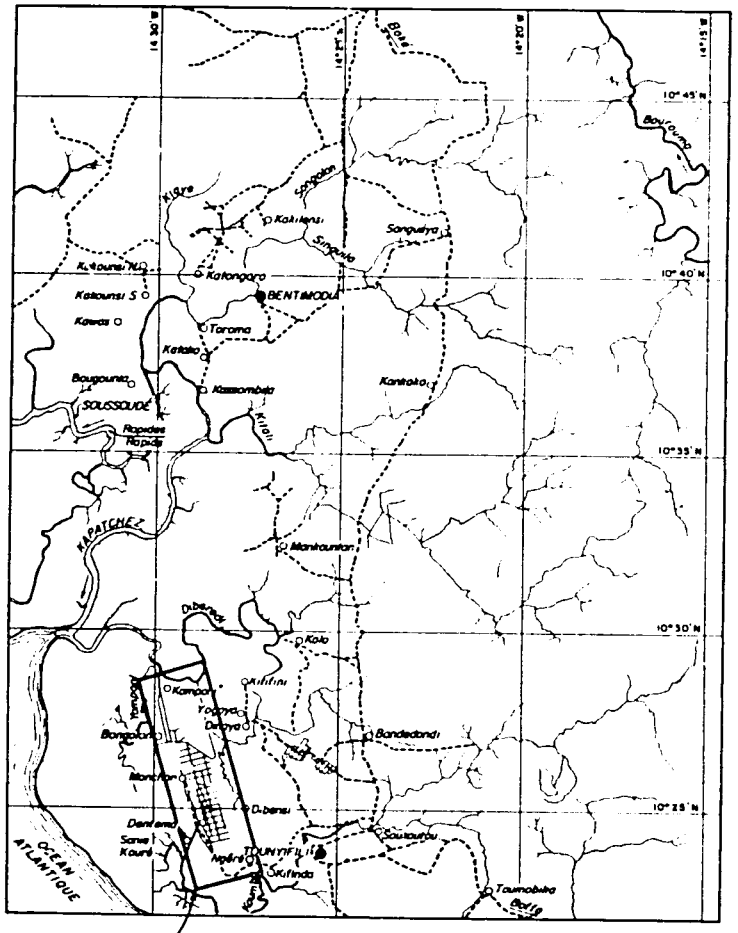
Very truly yours,

HARZA ENGINEERING COMPANY

Richard D. Harza

Richard D. Harza
Vice President

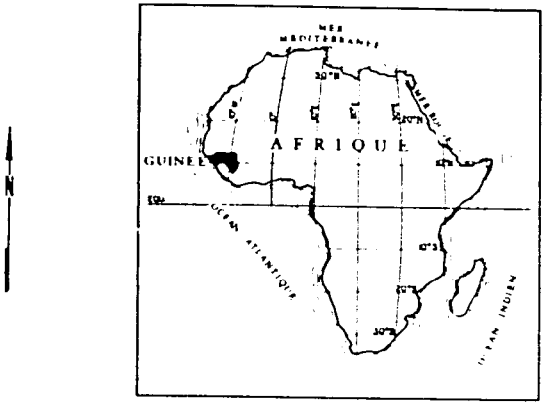
PLANCHE
EXHIBIT




PROJET DE MÔNCHON
MONCHON PROJECT

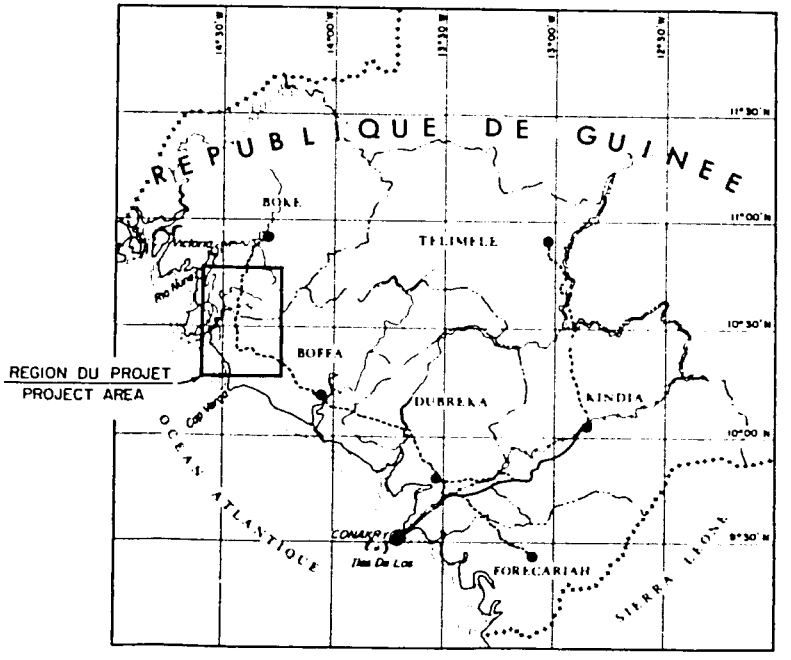
CARTE REGIONALE
PROJECT AREA

Echelle 0 1 2 3 4 5 Kilomètres
Scale Kilometers




SITUATION
KEY MAP

Echelle 0 1000 2000 3000 Kilomètres
Scale Kilometers




REGION DU PROJET
PROJECT AREA

BASSE GUINEE
LOWER GUINEA

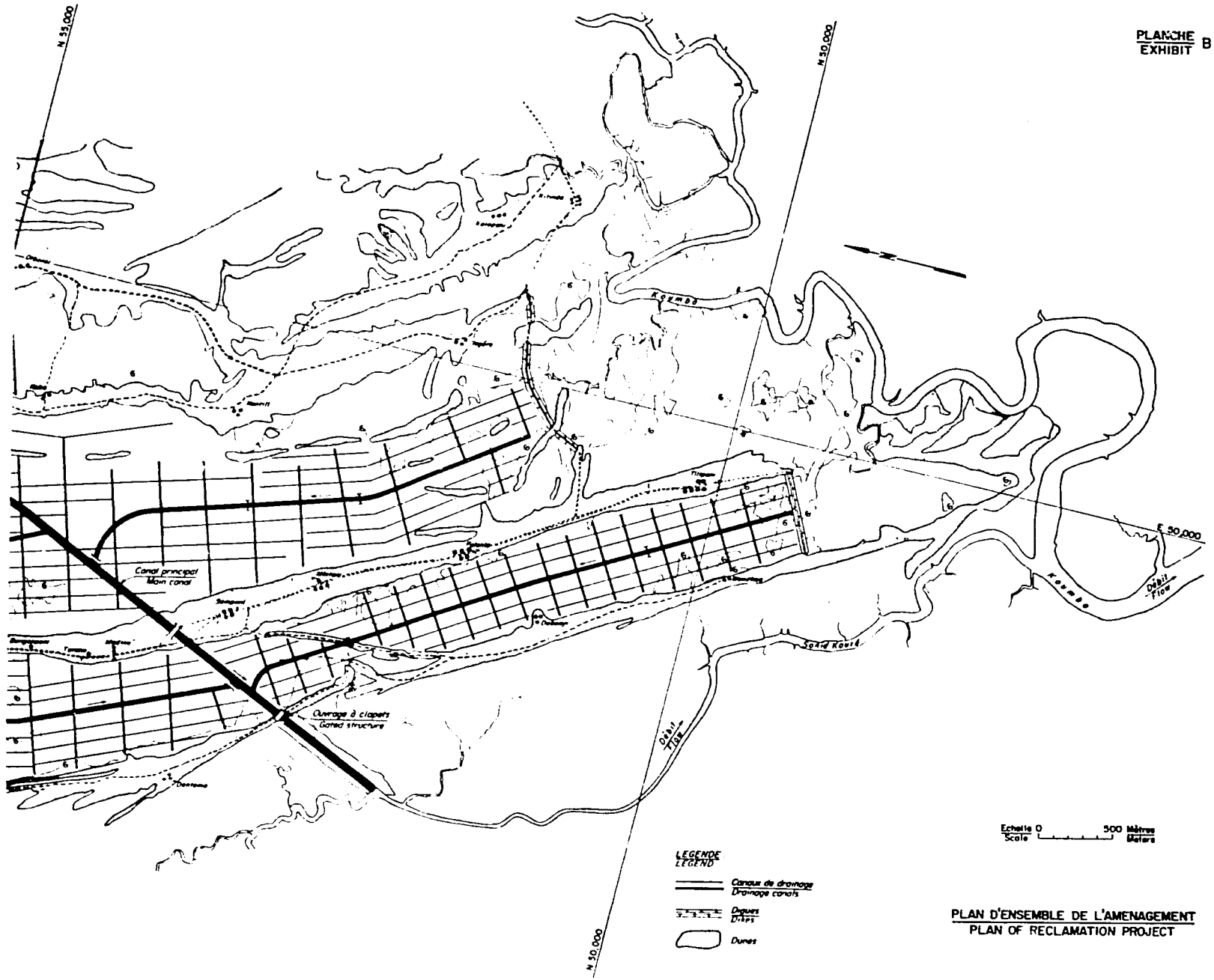
Echelle 0 10 20 30 40 50 Kilomètres
Scale Kilometers

LEGENDE
LEGEND

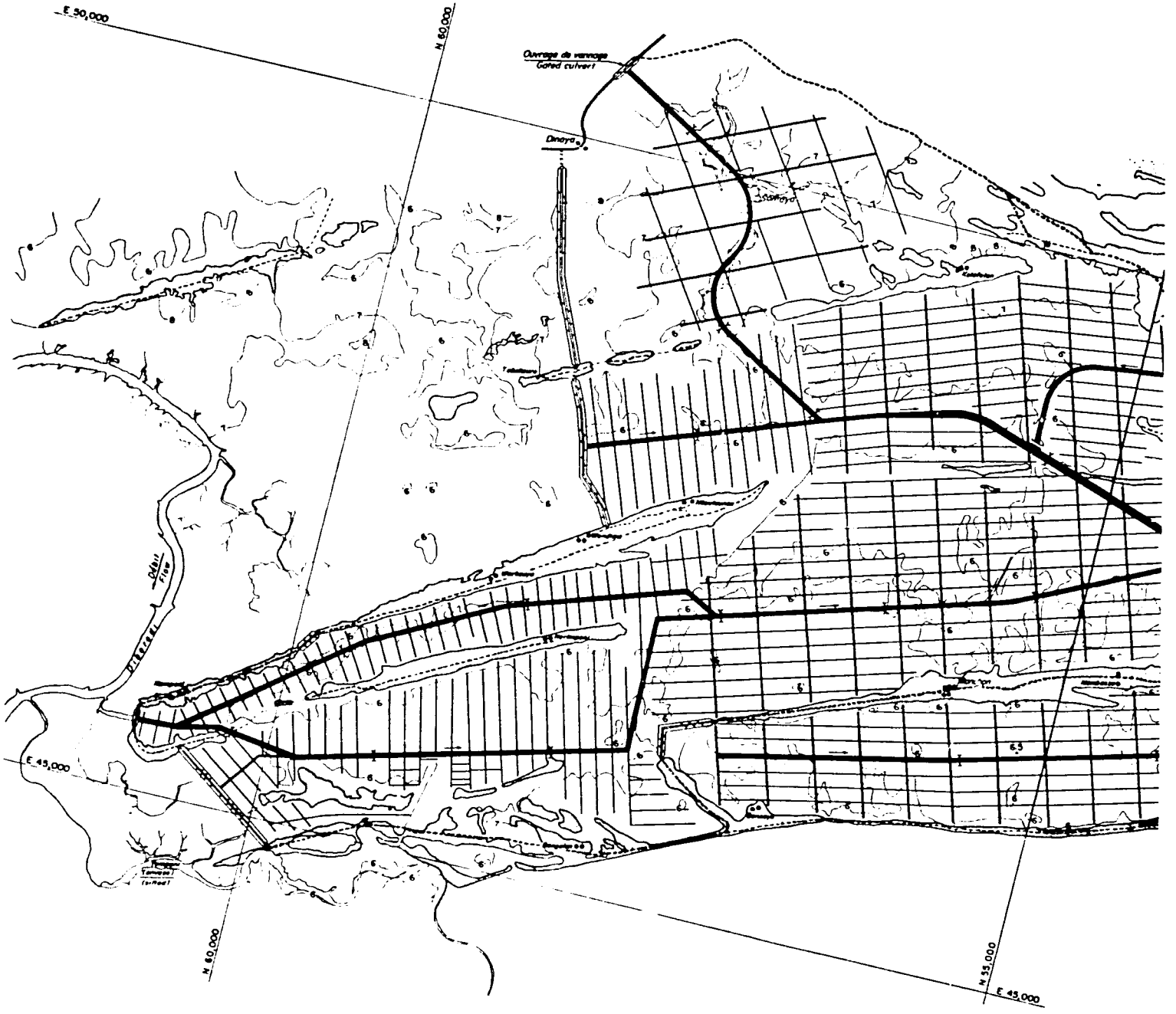
- Route / Paved road
- Piste / Unpaved road
- Chemin de fer / Railroad
- Villes et villages / Main cities and villages
- Frontière / National boundary
- Limite de region administrative / Regional boundary
- Réseau de canaux de drainage / Drainage canal system
- Cours d'eau / Streams

CARTES D'ENSEMBLE
GENERAL MAPS

PLANCHE / EXHIBIT B




PLAN D'ENSEMBLE DE L'AMENAGEMENT
PLAN OF RECLAMATION PROJECT


E 50,000
N 60,000
Ouvrage de vannage
Gated culvert
Dinaye
Jabbinaye
Kadhaw
Debi River
Tomato
(Wheat)
E 45,000
N 60,000
N 55,000
E 45,000

# ANNUAL BUDGET OF 4-HECTARE FARM UNIT

| Item | Unit | Without Reclamation Project | With Reclamation Project: Upon Completion | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|---|---|
| **Farm Production and Cash Value** | | | | | | |
| Average rice yield | kg/ha | 545 | 1,000 | 1,800 | 2,400 | 3,800 |
| Farm production, rice (paddy) | kg | 1,472 | 2,700 | 4,860 | 6,480 | 10,260 |
| Part of rice production consumed (paddy) | kg | 1,200 | 1,500 | 1,500 | 1,500 | 1,500 |
| Part of rice production used for seed | kg | 120 | 154 | 154 | 154 | 154 |
| Total amount of rice used on farm | kg | 1,320 | 1,654 | 1,671 | 1,671 | 1,671 |
| Total amount of rice available for sale | kg | 152 | 1,046 | 3,189 | 4,826 | 18,589 |
| Amount available for sale (polished) | kg | 106 | 732 | 2,232 | 3,378 | 6,012 |
| Cash receipts from rice sales, at GF 45/kg | GF | 4,770 | 32,940 | 100,440 | 152,010 | 270,540 |
| Equivalent net income from other crops | GF | - | - | 3,300 | 11,065 | 49,745 |
| Value of rice used on farm, at GF 32/kg | GF | 42,240 | 52,928 | 52,928 | 52,928 | 52,928 |
| **Farm Investments** | GF | | | | | |
| Land development | | - | 29,625 | 29,625 | 29,625 | 29,625 |
| Dwelling (farm share) | | 50,000 | 50,000 | 87,500 | 87,500 | 87,500 |
| Other developments | | 15,000 | 20,000 | 25,000 | 30,250 | 35,500 |
| Equipment and supplies | | 15,600 | 15,600 | 19,700 | 25,265 | 32,000 |
| Livestock | | - | - | - | 22,500 | 45,000 |
| Miscellaneous | | 4,030 | 5,760 | 8,590 | 9,760 | 11,460 |
| Total Farm Investments | GF | 84,630 | 120,985 | 170,415 | 204,900 | 240,725 |
| **Current Farm Expenses** | GF | | | | | |
| Interest on investments | | 5,080 | 7,259 | 10,225 | 12,295 | 14,445 |
| Taxes | | 3,500 | 3,500 | 7,000 | 7,000 | 7,000 |
| Depreciation and repairs: buildings & improv. | | 7,120 | 7,665 | 12,320 | 12,895 | 13,500 |
| equipment | | 2,230 | 2,230 | 3,630 | 4,185 | 4,740 |
| Rice processing | | 4,056 | 7,638 | 14,067 | 18,980 | 30,320 |
| Hired labor | | 6,000 | 7,500 | 9,000 | 10,000 | 15,000 |
| Marketing (hauling) | | 265 | 1,830 | 5,580 | 8,415 | 15,030 |
| Fertilizers | | - | 3,350 | 6,700 | 8,770 | 12,655 |
| Equipment rental | | - | - | - | 10,200 | 12,000 |
| Crop seed | | - | - | 667 | 1,000 | 2,545 |
| Plant protection | | - | - | - | 1,550 | 4,265 |
| Livestock expenses | | - | - | - | 400 | 1,000 |
| Miscellaneous | | 1,413 | 2,049 | 3,459 | 4,790 | 6,625 |
| Total Current Farm Expenses | GF | 29,664 | 43,021 | 72,648 | 100,580 | 139,125 |
| **Financial Statement** | GF | | | | | |
| Cash sales | | 4,770 | 32,950 | 103,700 | 163,075 | 320,285 |
| Farm privileges: used on farm | | 38,400 | 48,000 | 51,295 | 56,030 | 59,695 |
| rental value of house | | 5,475 | 5,475 | 9,375 | 9,375 | 9,375 |
| Total income | | 48,645 | 86,425 | 164,370 | 228,480 | 389,355 |
| Total expenses | | 29,664 | 43,021 | 72,648 | 100,580 | 139,125 |
| Net income | | 18,981 | 43,404 | 91,722 | 127,900 | 250,230 |
| Return to family labor and management | | 18,981 | 43,404 | 54,750 | 57,970 | 74,215 |
| Repayment capacity | | - | - | 36,972 | 69,930 | 176,015 |

## MONCHON PROJECT - DIRECT BENEFITS

| Item | Unit | Without Reclamation Project | With Reclamation Project: Upon Completion | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|---|---|
| Reclaimed area | ha | 950 | 2,400 | 2,400 | 2,400 | 2,400 |
| Equivalent number of farm units | | 355 | 600 | 600 | 600 | 600 |
| Net project income | GF 1000 | 6,738 | 26,042 | 55,033 | 76,740 | 150,138 |
| Increase in net income | GF 1000 | - | 19,304 | 48,295 | 70,002 | 143,400 |
| Direct project benefits (discounted) | GF 1000 | - | 19,304 | 42,983 | 54,602 | 93,210 |
| Indirect benefits | | | 1,734 | 7,448 | 9,975 | 14,916 |
| Public benefits | | | 5,165 | 6,349 | 6,930 | 8,860 |
| Total Annual Benefits | | | 26,203 | 56,780 | 71,507 | 116,986 |
| use | | | 26,000 | 57,000 | 72,000 | 117,000 |
| Average annual project cost | | | 43,000 | 43,000 | 43,000 | 43,000 |
| Project benefit-cost ratios | | | | | | |
| Direct benefits | | | 0.5 to 1 | 1.0 to 1 | 1.3 to 1 | 2.2 to 1 |
| Total benefits | | | 0.6 to 1 | 1.3 to 1 | 1.7 to 1 | 2.7 to 1 |

# TABLE OF EQUIVALENTS

## Length

| | |
|---|---|
| 1 - Millimeter (mm) | 0.039 Inches |
| 1 - Centimeter (cm) | 0.394 Inches |
| 1 - Meter (m) | 3.281 Feet |
| 1 - Kilometer (km) | 0.621 Miles |

## Area

| | |
|---|---|
| 1 - Square meter ($m^2$) | 1.196 Square yards |
| 1 - Hectare (ha) | 10,000 Square meters |
| 1 - Hectare | 2.471 Acres |
| 1 - Square Kilometer ($km^2$) | 0.386 Square miles |

## Volume

| | |
|---|---|
| 1 - Cubic meter ($m^3$) | 35.31 Cubic feet |
| 1 - Cubic meter | 1.308 Cubic yards |
| 1 - Million cubic meters (MCM) | 810.7 Acre-feet |

## Weight

| | |
|---|---|
| 1 - Kilogram (kg) | 2.205 Pounds |
| 1 - Metric ton (mT) | 1,000 Kilograms |
| 1 - Metric ton | 2,205 Pounds |
| 1 - Metric ton | 1.102 Tons (short) |

## Flow

| | |
|---|---|
| 1 - Cubic meter/second ($m^3$/sec.) | 35.31 Cubic feet/second |
| 1 - Cubic meter/second | 70 Acre-feet/day |

## Agriculture

| | |
|---|---|
| 1 - Ton/hectare (paddy) | 20 Bushels per acre |
| 1 - Ton of paddy rice | 49 Bushels (paddy) |
| 1 - Bushel of rice (U.S.A.) | 45 Pounds of rice paddy |

## Currency

| | |
|---|---|
| 1 - Guinean Franc (GF) | 0.004 US Dollars |
| 1 - U.S. Dollar | 248 Guinean Francs |
| 1 - CFA Franc | 0.004 US Dollars |

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# PART I

# THE MONCHON PROJECT

# THE MONCHON PROJECT

## The Reclamation Works

### The Project Area

The Monchon Project is located near the northern coast of Guinea, within the Adminstrative Region of Boffa, and about 50 kilometers northwest of the town of Boffa. The relationship of the Project to the country of Guinea is shown on Exhibit A, and details of the area are shown on Exhibit B.

The plains of Monchon are about five kilometers wide by ten kilometers long, and consist of relatively flat lands, only 5.5 to 7.5 meters above mean sea level. The area is traversed by a series of long narrow sand dunes on which are located numerous villages. One of the larger villages is Monchon, from which the project name was derived.

The most westerly of the sand dunes separates the plains from the tidal cost of the ocean. On the east, the boundary of the Project area follows the road connecting the villages of Ngere and Dinaya. On the north, the plains extend to the tributaries of the Kapatchez River -- the Diberedi River and the now silted-in channel of what was once the Yomponi River. The Koumba River and its tributary, the Sonie Koure, form the southern edge of the Project area.

About 3000 hectares of fertile land are included within the area, one-third of which have had limited cultivation of paddy rice for many decades. As early as 1935, the French Colonial Administration had studied the area with the purpose of increasing the rice production. It was obvious even then, that excessive salinity and inadequate drainage were obstacles to the achievement of full potential use of the land.

The first attempt to improve the area was made in the 1940's, with an investment of about five million CFA francs. Canals were cut towards the Diberedi and Yomponi rivers, which was the natural direction of drainage. Unfortunately, the Kapatchez River, of which these streams were tributaries, had seriously aggraded through siltation. As a result, the Diberedi and Yomponi were obstructed, their levels were raised, and this initial attempt at drainage proved totally ineffective.

A second development was undertaken in 1957. This time the drainage was directed towards the Sonie Koure and the Koumba River. Although these rivers are in the opposite direction from natural drainage of the plains, they are not subject to the silting that has obstructed the Kapatchez River. Also, the plains are so flat, that reverse drainage is not difficult. After an expenditure of about 40 million CFA francs, the project was halted upon the departure of the French Administration. A main canal had by then been excavated from the Sonie Koure for a distance of about 1900 meters. Much was left to be done, but no further construction has been carried out. These works benefited only a limited portion of the total area.

At the time of the first project, dikes were constructed across the open ends of the dunes. Some of these have settled and have been breached.

## The Project Plan

The present plan for reclamation of the Monchon Plains is similar to the one proposed in 1957 with some modification. Much better information is now available concerning the hydrology, topography, and agricultural potential of the area, due to the field surveys recently conducted.

These surveys and subsequent analyses have served to define the lands worth reclaiming, and to permit designs of a complete canal and levee system.

As in 1957, drainage will be directed toward the Sonie Koure. The previously excavated canal will be cleaned of its sediment accumulation, enlarged to a 16-meter bottom width, and deepened at its upper end.

In addition to improvement of the existing canal, new construction will include upstream extension of the main canal, a series of secondary branch canals, and a comprehensive network of tertiary and quaternary drains. Around the perimeter of the Project area levees will also be constructed as barriers against encroachment of flood and tidal waters from adjacent rivers.

The sand dunes which traverse the Project divide it into a number of isolated areas, each of which must be drained individually. However, the dunes also offer protection against outside flooding along much of the project boundary, and will serve as convenient abutments for levees across their openings.

The canal and levee arrangements are shown on Exhibit B. The length and typical dimensions of the canals are given in Table 1.

TABLE 1

Typical Canal Dimensions

| | Main Canal | Secondary Canals | Tertiary Canals | Quarternary Canals |
|---|---|---|---|---|
| Total length (km) | 4.5 | 28 | 84 | 90 |
| Bottom width (m) | 13-16 | 1-13 | 0.8 | 0.8 |
| Normal water depth (m) | 2.4 | 2.4 | 0.8 | 0.8 |
| Gradient (m per km) | 0.2 | 0.1-0.2 | 0.1-0.8 | nominal |

Side slopes will be excavated at 2.0 horizontal to 1.0 vertical. The banks of the main and secondary canals are expected to slough to a final slope of 6.0 to 1.0, for which the capacities were designed.

The Sonie Koure, into which the Project will drain, is subject to tidal fluctuations. Salt water could back into the canal system during high tides, unless a barrier is provided. To control salt water intrusion from this source, a concrete structure is proposed on the main canal at the Dentema dune crossing. Five automatic flap gates, each 3.5 meters wide by 2.5 meters high, will permit flood waters within the area to discharge into the Sonie Koure during low tides or when a positive gradient exists. However, the gates will bar saline waters from entering from the outside during high tides.

The levees to be constructed across openings in the sand dunes will keep the surrounding rivers such as the Diberedi and the Koumba from inundating the project lands. A total length of about 6.5 kilometers of existing and new levees will be required, but none of these need exceed two meters in height.

Near the village of Dinaya, on the northeastern edge of the Project, a small stream will be reversed from its natural flow and drained into the main canal. The levee blocking this stream will have controlled relief gates which can be opened when water levels in the Project area are low and levels outside are high. In such circumstances, the drainage capacity of the Project can benefit the lands northeast of Dinaya which are beyond the Project boundaries.

To the maximum extent possible, the proposed canals and levees will make use of existing works. New canals will follow the alignment of present channels and excavations. New levees will be built over the older dikes, which must be raised and have their breaches plugged.

Access roads and bridges are an important adjunct to the Project. At present, roads follow the ridges of the sand dunes which are above the reach of flooding waters. These roads will continue to serve as the principal access route to the area. Major vehicular bridges are included in the plans for the main canal at the control structure and at the Mintani dune crossing. Several single-lane bridges will be constructed across the secondary canals, to carry construction and maintenance equipment. An economical and simple design is proposed for these secondary bridges, using precast concrete cribs for abutments, and creosoted timber decks. Some 16 foot-bridges of lighter design are also proposed for foot traffic across the secondary canals to permit farm access. The lesser canals are so narrow that no special bridges are required.

Drainage Design

It is neither practical nor economic that agricultural land be protected against maximum rainfall or flooding. In the case of the Monchon Project, we believe that the optimum benefits to the use of the land will result with control of rainfall and surplus waters which might occur once in ten years.

From our examination of precipitation records in Guinea, and analysis of the meteorologic conditions in the Monchon area, we have concluded that a total rainfall of 730 millimeters in 15 days is probable at a ten-year frequency. The drainage system has been designed to cope with this intensity, taking into account groundwater percolation, evaporation, and field retention.

During rainfall less than the design intensity, the canal system can rapidly and effectively remove excess waters. With full design intensity,

some ponding of surplus waters would occur on the rice paddies. However, our calculations indicate that this ponding would reach no more than eight centimeters above the youngest rice plants, and would endure no longer than six days.

Subsequently, the water levels in the fields could be lowered to about one-half of plant height and held at this level for several days before another severe rain might be expected. With these limitations on inundation, and with water level control, the production of rice should not be adversely affected.

Adequate drainage and control of salt water intrusion can be achieved by the proposed works, sufficient to protect the fields against all but the most infrequent and severe conditions.

## Agricultural Production

The lands of the Monchon plains are fertile and well suited to agriculture, rainfall is ample, and increased rice production is needed in Guinea. The Monchon Project can convert the potentials of the area into positive contributions to the regional and national economy.

### The Soils and Land

The soils of the Monchon plains are predominantly alluvial clays of recent geologic origin, and only slightly permeable. However, these soils are well adapted to rice culture, if surplus water is removed.

The soils in areas of present cultivation are low in organic content, while the other lands are richer in their top surface. Saline concentrations exist through much of the area, due to original marine deposits and to inadequate drainage. The natural phosphorus content of the soils is

below normal in many sections. Drainage, leaching, and the use of natural and chemical fertilizers can correct the deficiencies of the soils and restore their full fertility.

Certain precautions are necessary when the project lands are drained. Lowering of the groundwater table could encourage excessive oxidation, the creation of free iron and aluminum in the soil, and an acidity level which might be toxic to the crops. The outlet gates of the main drainage canal should be operated in a manner that will prevent the groundwater level from being lowered more than is necessary.

The lands of the area have been classified according to their suitability for agriculture, taking into account soil quality, topography, and present drainage. With the improvements of the proposed project,much of the land will be upgraded. A summary of the land classification within the reclaimable area of the Project is given in Table 2.

TABLE 2

Summary of Land Classification

| Land Class | Quality | Total area - hectares Present | Total area - hectares Future |
|---|---|---|---|
| 1 | Very Good | - | 1464 |
| 2 | Good | - | 940 |
| 3 | Fair | 988 | 125 |
| 4 | Presently unsuited | 1541 | - |
| | Total | 2529 | 2529 1/ |

1/ A five percent allowance for canals and dikes results in a cultivated area of 2400 hectares.

## Crop Yields

About 950 hectares within the Project area are presently under rice cultivation. Annual production is estimated to average about 520 tons of rice paddy,[1/] or only 0.55 tons per hectare.

Very substantial increases in rice yield should result from the reclamation program. Our estimates of the yield from the various land classes are shown in Table 3.

TABLE 3

Anticipated Rice Yields

| Land Class | Annual Yield Tons per hectare |
|---|---|
| 1 | 2.5-4.0 |
| 2 | 2.0-3.5 |
| 3 | 0.5-3.0 |
| 4 | 0 -0.4 |

The conversion of land from one class to the next higher class, and the achievement of higher yields will take place gradually over a period of 20 years, after the lands have been reclaimed.

## Cropping Pattern

The Project area is predominantly suited for rice. However, continuous rice cropping would not be proper, and one-third of the land should be left fallow each year or devoted to some other crop. With drainage of the lands, several other crops could be introduced to the area over an extended period of time.

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1/ 100 kilograms of unpolished rice, or rice paddy, yields about 70 kilograms of polished rice.

A three-year rotation of rice on two-thirds of the reclaimed land is anticipated for the first five years of operation. Thereafter, other crops such as lespedeza (clover), maize, and grain sorghum could be advantageously introduced on the remaining one-third of the land. A cropping intensity of 100 percent should be feasible after 20 years of project operation. The projections of crop land use and cropping intensity are shown in Table 4. The intensities shown could be advanced, if sufficient technical and financial assistance were made available to the farmers.

TABLE 4

Projected Crop Land Use and Cropping Intensity
(In Percent of Reclaimed Land)

| Crops | Number of Years After Reclamation | | | |
|---|---|---|---|---|
| | 0 | 5 | 10 | 20 |
| Rice | 67 | 67 | 67 | 67 |
| Lespedeza (clover) | - | 8 | 15 | 20 |
| Maize | - | - | 3 | 9 |
| Grain Sorghum | - | - | - | 4 |
| Cropping Intensity | 67 | 75 | 85 | 100 |

## Total Crop Production

The cropping patterns and anticipated yields have been combined for estimates of future agricultural production, as shown in Table 5.

TABLE 5

Estimated Annual Agricultural Production
in the Monchon Area

(Metric Tons)

| Crops | Number of Years after Reclamation | | | | |
|---|---|---|---|---|---|
| | Present | 0 | 5 | 10 | 20 |
| Rice (paddy) | 520 | 1600 | 2900 | 3850 | 6100 |
| Lespedeza | - | - | 190 | 360 | 480 |
| Maize | - | - | - | 70 | 220 |
| Grain Sorghum | - | | - | - | 100 |
| Total | 520 | 1600 | 3090 | 4280 | 6900 |

## Project Costs

### Construction Costs

The construction costs of civil works and land preparation are based on the quantities of work indicated by the preliminary project plans. Appropriate unit costs or lump sums have been applied to these quantities, using price levels of June, 1963.

Costs have been segregated into foreign and domestic expenditures. The foreign component has been estimated in U.S. Dollars and the domestic component in Guinean Francs (GF), with an exchange rate of GF 248 equal to one U.S. Dollar.

The construction of the Monchon Project will require the services of a foreign contractor. Although the project is of only moderate size, facilities available locally are not considered sufficient to have the project constructed either by a local contractor, or under force account by

the Guinean government. We have assumed that the construction contract will be awarded, after public advertising and submittal of sealed competitive bids, to a private American or European contractor with the required experience, equipment, and working capital. Most of the construction equipment, and such materials as steel, timber, cement, and fuel will need to be imported. Skilled labor is also expected to come from abroad. Common labor, however, should be available locally. Local labor rates used in the estimates conform with wages now officially in force, and liberal fringe benefits customary in Guinea have been taken into account. The construction prices include allowances for contractor's plant, equipment, labor, home office and local overhead, profit, performance bond, insurance and taxes. Customs duties and taxes on imported equipment and materials have not been included.

A contingency allowance of 15 percent was added to the subtotal of direct costs obtained from the quantities and unit prices. This allowance is intended to cover possible unforeseen difficulties of construction, omissions from the estimates, and possible variations in unit prices. The contingencies provided should be adequate in view of the detailed field information now available and the conservative values used in the individual estimates.

The addition of the contingency allowance established the total direct cost. An allowance of 15 percent was then applied for such indirect costs as engineering, supervision of construction, and owner's overhead. The addition of this allowance to the total direct cost gives the estimate of total construction cost. The total construction cost of the civil works is estimated to be U.S. $1,300,000 and GF 185,000,000, or a total equivalent to U.S. $2,050,000.

We have not included the prior investment by the French Administration for the construction of the lower reach of the main canal, about 40 million CFA francs. Some benefits have already been derived from that investment. The cost of rehabilitation of this canal reach has been included as part of the proposed project.

The cost of land preparation allows for a limited amount of leveling and planing required in the rice fields. These operations can be carried out by the local government with mechanized facilities, and with local common labor. The cost of land preparation is estimated to be GF 35,000,000. The cost of excavating the quaternary canals is not included in this amount.

## Project Investment

The project investment includes interest during construction in addition to the construction costs of civil works and land preparation. Since financing terms are not yet established, net interest during construction can only be assumed. We have used for this purpose an annual interest rate of six percent, to be applied as funds are withdrawn for construction.

TABLE 6

Monchon Project Investment

| | Foreign Currency (U.S.$) | | Domestic Currency (GF) |
|---|---|---|---|
| Civil Engineering Works | 1,300,000 | | 185,000,000 |
| Land Preparation | - | | 35,000,000 |
| Total Construction Cost | 1,300,000 | | 220,000,000 |
| Interest during Construction | 80,000 | | 15,000,000 |
| Project Investment | $1,380,000 | GF | 235,000,000 |

Total equivalent to U.S. $2,320,000 or GF 580 million.

## Operating Costs

Annual operating costs will be incurred for normal operation and maintenance of the project, and for renewals and replacements beyond normal maintenance. Annual operating costs for the civil works are estimated to be about one percent of construction cost, or about GF 5 million.

Other annual costs will be incurred for the agricultural extension services to the farmers. These costs may be greater during the early years of project operation, but the long-term average should be about GF 1 million per year.

Total annual operating costs, not including interest and amortization of the initial investment, will be about GF 6 million.

## Average Annual Costs

Interest, amortization, and operating costs together represent the annual costs of the Project. The total investment in the Project has been estimated as the equivalent of GF 580 million. At six percent annual interest and 50-year amortization, the annual costs would be as shown on Table 7.

TABLE 7

Average Annual Costs

| | GF Million |
|---|---|
| Interest and Amortization | 37 |
| Operating Costs | 6 |
| Total Annual Costs | 43 |

## Project Benefits

The Project will result in substantial direct agricultural benefits to the farmers due to increased crop production. Other indirect benefits will accrue to the regional and national economy.

### Direct Agricultural Benefits

The direct agricultural benefits are equal to the net increase in farm income due to the effects of the Project. Thus, the values of future production with the Project must be reduced by the values that could be achieved without the Project. Also, farm costs which are needed to obtain the increased production must be deducted.

For estimates of the direct benefits, we have analyzed the future budgets of a typical four-hectare farm, as shown on Exhibit C. In general, we have used the procedures of the U.S. Bureau of Reclamation. Some modifications were necessary due to the lack of agricultural statistics, and to the unusual conditions of a non-private land tenure system, a nomadic and shifting system of farming, and a government controlled price-wage structure.

Land tenure practices in Guinea do not recognize the right of private sale of agricultural land. Any land, not being cultivated, may be occupied and developed by new settlers. Also, improvements made during occupancy may not be sold or transferred. Thus, it is impossible to assign a value to land in an economic analysis.

Gross income to the individual farm units will include cash receipts from rice sales and the value of rice consumed on the farm. The price of rice is now set by the government at GF 45 per kilogram for polished

rice, and GF 32 per kilogram of paddy rice. Our budgets are based on these set prices without regard to free-market values or long-term variations.

Farm costs are related to capital investments and operating expenses. The investment to be made by the individual farmer start with his land developments, which include the excavation of quaternary canals to drain his own paddies, the small levees surrounding each paddy, and some minor levelling. In addition, the farmer must provide his own buildings, equipment and supplies, livestock, and other miscellaneous investments.

These improvements will take place over a period of years as the farmer increases his earnings. As at present, the farmers of the Monchon area will be able to grow pineapples, bananas, palms for oil, and other crops on the sand dunes and outside of the reclaimed areas. Some increase in these crops will result as more people are attracted to the reclaimed area. Although the value of agricultural production outside of the reclaimed areas is not included in the farm budgets, one-half of future on-farm investments has been allocated to use outside the Project.

Operating expenses in the budgets include interest on farm investments, taxes, depreciation, and the annual costs of maintenance, supplies, and hired labor. These expenses will increase with time, as greater investments are made, more equipment and labor are employed, and the use of fertilizers and other agricultural aids are extended. Hired labor has been estimated at the present government-controlled rate of GF 28 per hour.

Net income to a typical farm unit is equal to the receipts from cash sales, plus the value of food consumed on the farm and the rental value of the farm home, less farm expenses.

Budgets were made, as shown on Exhibit C, for intervals following completion of the Project. An additional budget was made to show what net farm income would be, if the Project were not constructed.

Total income to the Project will be proportional to the farm-unit income and the number of farms. However, an early investment must be made in the Monchon Project, while the income will not be realized until future years. In recognition of the time lag between investment and benefits, we have discounted the future income on the basis of present worth factors at six percent interest.

The estimated income to the Project in future years is shown in Table 8.

TABLE 8

Annual Income to Project

(in GF 1000)

| | Without Project | With Project | | | |
|---|---|---|---|---|---|
| | | Year 0 | Year 5 | Year 10 | Year 20 |
| Typical Farm Unit | 19.0 | 43.4 | 91.7 | 127.9 | 250.2 |
| Number of Units | (355) | (600) | (600) | (600) | (600) |
| Theoretical Income | 6,700 | 26,000 | 55,000 | 76,500 | 150,000 |
| Net Increase | - | 19,500 | 48,500 | 70,000 | 143,500 |
| Discount Factor | - | 1.0 | 0.89 | 0.78 | 0.65 |
| Net Income | - | 19,500 | 43,000 | 55,000 | 93,000 |

Direct agricultural benefits from the Project have been taken equal to the net income shown above.

## Other Benefits

Indirect benefits from the Project will accrue to those persons, other than the farmer, who participate in the marketing of the cash crops. We have estimated the unit value of these benefits to be equal to the difference between farm prices and retail prices of polished rice, or about GF 5 per kilogram. The total value is proportional to the increased sale of rice due to the Project.

Further public benefits will result to the regional and national economy, through the increased employment during construction and operation of the Project, and through the stimulation of other economic activities. Estimates of these public benefits are based on an annual employment value equal to six percent of the construction labor cost of GF 70 million, plus an annual economic value of five percent of direct benefits.

Benefits will also arise from the opportunity to settle more people in the region as more land is available for cultivation. These, however, are difficult to evaluate and have not been included in the analyses.

## Total Benefits

The net benefits due to the Monchon Project are summarized on Table 9.

TABLE 9

Net Annual Benefits

(GF 1000)

| Years after Completion | Direct | Indirect | Public | Total |
|---|---|---|---|---|
| 0 | 19,500 | 1,500 | 5,000 | 26,000 |
| 5 | 43,000 | 7,500 | 6,500 | 57,000 |
| 10 | 55,000 | 10,000 | 7,000 | 72,000 |
| 15 | 93,000 | 15,000 | 9,000 | 117,000 |

## Contribution to the National Economy

The Monchon Project will increase rice production by about 1100 tons in the first year of operation, 1400 tons five years later, and ultimately by more than 5000 tons. These increases will make significant contributions to the national economy of Guinea.

The present population of the Republic is estimated to be about three million and increasing by about three percent per annum. At this rate, which is expected to be maintained or possibly exceeded in the future, the total population will reach nearly six million in about 20 years.

Food production per capita in Guinea has been declining since 1958. Production of the major subsistence crops, cassava and rice, have not kept pace with the population increase. The annual production of cassava has been maintained around 350,000 tons, and the production of rice has averaged about 310,000 tons of paddy, equivalent to about 220,000 tons of polished rice.

In the past, the country has generally been self-sufficient in most subsistence crops, except rice. The rice shortages stem from the fact that, in addition to the population increase, the average per capita consumption of rice has been increasing consistently. It went from about 170 grams of polished rice per day in 1948, to 220 grams per day in 1953, and to 230 grams per day in 1962.

Consequently, Guinea, which is the third largest rice producer in Africa after Egypt and Madagascar, since 1958 has had to import increasing amounts of rice, as shown in Table 10.

TABLE 10

Rice Imports

| | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 |
|---|---|---|---|---|---|---|
| Metric tons (polished rice) | 7,000 | 25,000 | 20,000 | 25,000 | 30,000* | 35,000* |
| Cost, equiv. U. S. $ million | 1.0 | 2.2 | 1.7 | 2.1 | (Not available) | |

* Estimated on the basis of present trade agreements.

The projected increase of rice production in the Monchon Area, as small as it is when compared to the total deficiency, will nevertheless help to reduce imports and save foreign exchange.

The production of rice at the Monchon Project should be dependable, as great fluctuations in rainfall are not common in the area. This is not true in many other areas of Guinea, particularly in the highlands. During the extreme dry year of 1962, national production of rice paddy dropped to only 220,000 tons, or 30 percent below average.

## Economic and Financial Analyses

### Benefit-Cost Ratios

The economic value of the Project can best be measured by a comparison of its annual benefits and annual costs. The ratios shown in Table 11 have been derived from benefits and costs previously described.

TABLE 11

Benefit-Cost Ratios

| | Upon Completion of Project | After Five Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|
| Average Annual Total Benefits, GF million | 26 | 57 | 72 | 117 |
| Average Annual Costs, GF million | 43 | 43 | 43 | 43 |
| Benefit-Cost Ratio | 0.6 to 1 | 1.3 to 1 | 1.7 to 1 | 2.7 to 1 |

The ratios given in Table 11 indicate that construction of the Project will be justified by the benefits which are anticipated after the first five years of operation. The reclamation works will not alone be sufficient to justify the initial investment, on the basis of increased production which would result solely from the drainage of the lands and control of salt water intrusions. However, the additional benefits that can be achieved during the following five years of operation will require only a modest program of land management and agricultural assistance. Such a program can be simple enough to be easily accepted and put in practice by the local farmers, with the guidance of trained personnel of the regional administration.

## Financial Requirements

The construction costs of the Monchon Project amount to U.S.$1,300,000 in foreign expenditures and GF 220 million in domestic expenditures. Neither the local communities nor the Regional Administration could obtain such funds.

The national government could finance the Project from appropriations. However, this is only one of several reclamation works being considered, all of which together would reclaim about 40,000 hectares. Collectively, these projects could not be financed out of current income without very adverse effects upon an already serious deficit in the nation's balance of payments. It is probable, therefore, that loans will be sought from sources outside Guinea.

The source and terms of such financing are not now known. For the purpose of our analysis, we have assumed that liberal terms can be obtained, such as are currently offered for this class of project by the International Development Agency (IDA) and by the United States' Agency for International Development (AID). These institutions have been making agricultural development loans to national governments with a 0.75 percent annual service or interest rate and repayable over 40 years following a 10-year initial moratorium period.

With such terms, and including interest during construction, investments of U.S. $1,320,000 and GF 223,000,000 have been used in our financial analyses.

## Effect on Foreign Exchange

Loans received to finance foreign expenditures would probably require repayment in foreign currency. Under the terms cited above, annual repayments and interest after ten years would be about U.S. $64,000. At the same time the increased rice production alone would reach over 3000 tons per year, reducing annual imports by a value of more than U.S.$300,000. Even at far less favorable terms, a positive saving in foreign exchange would result.

## Financial Feasibility

In the case of the Monchon Project, the financial obligations to be incurred will probably be made by the national government with international lending institutions. Part of these obligations may require repayment in foreign currency, which only the national government could guarantee. Any assessments against the farmers of the Project will be set by the sponsoring government agency, and will be payable in domestic currency.

Although the credit of the national government is ultimate assurance of financial repayment, the economy of the Project gives a measure of financial feasibility. The best measure is the relationship between the residual income of the Project beneficiaries and the total annual costs of the Project.

The farm budgets, shown on Exhibit C, have included an allowance for the return to family labor and management in the computation of residual income available for profit and repayment. The total residual income to the Project is equal to that of a typical four-hectare unit times 600 such units.

The annual costs used previously in the benefit-cost analysis were long-term averages based on a six percent return on capital. For a financial analysis, the anticipated year-by-year expenditures should be used, including specific values for interest and amortization, and considering moratorium periods. In the case of the Monchon Project, our financial evaluation is based on the liberal terms of agricultural loans. However, we have recognized that expenditures for agricultural extension services should be greater in the early years.

The computed values of residual income and annual costs are given in Table 12.

TABLE 12

Financial Analysis

(Amounts in GF Million)

| Years after Completion | Residual Income Available for Profit and Repayment | Annual Costs | | | |
|---|---|---|---|---|---|
| | | Interest and Amortization | Operating Costs | Extension Services | Total |
| 0 | 0 | 4 | 5 | 4 | 13 |
| 1 | 4 | 4 | 5 | 4 | 13 |
| 2 | 8 | 4 | 5 | 4 | 13 |
| 3 | 12 | 4 | 5 | 1 | 10 |
| 4 | 17 | 4 | 5 | 1 | 10 |
| 5 | 21 | 4 | 5 | 1 | 10 |
| 6 | 25 | 4 | 5 | 1 | 10 |
| 7 | 29 | 4 | 5 | 1 | 10 |
| 8 | 34 | 4 | 5 | 1 | 10 |
| 9 | 38 | 4 | 5 | 1 | 10 |
| 10 | 43 | 16 | 5 | 1 | 22 |
| 15 | 71 | 16 | 5 | 1 | 22 |
| 20 | 104 | 16 | 5 | 1 | 22 |

Only during the first three years of Project operation will residual income of the farmers be less than the total annual costs of the Project. From then afterward income becomes substantially greater than Project costs. The comparison indicates that the Project has financial merit, even if the interest and amortization terms were less liberal than has been assumed.

## Project Repayment

Agricultural and reclamation developments such as the Monchon Project must yield sufficient financial return to the beneficiaries as an incentive for private investment and for increased production. Thus, it is not always advisable that the entire cost of the common works be borne by the farmer, even if residual income should indicate such a possibility.

The extent to which the farmers are required to repay project costs is a matter of national policy. For example, in the United States water rates are frequently set at 15 to 25 percent of the computed repayment ability. The term "repayment ability" is usually taken to mean the net income to the farmer less an adequate return for his family's labor and management effort, or what we have herein defined as residual income.

Repayment requirements which are less than project costs amount to a national subsidy. Justification for such subsidy is usually based upon the indirect and public benefits which result from the project.

It will be important, particularly in the early years of operation that farmers be given the incentive and opportunity to make the best possible use of the reclaimed land. Assessments which are initially too great will discourage new settlers or siphon off the capital needed for on-farm improvements. Yet, little or no assessment in future years will encourage indolence on the part of those settlers who are satisfied with only a subsistence living.

A flexible policy on repayment is indicated, beginning at a minimum level and increasing as the productivity of the area reaches its true potential.

## Implementation of the Project

The Monchon Project can be economically valuable and is financially feasible. However, its success will depend upon prudent arrangements for financing, engineering, construction, administration, fiscal control and operation, and upon an adequate agricultural extension program.

### Financing Arrangements

Twice previously the Monchon Project has been undertaken with insufficient funds and guarantees to complete the necessary civil works. A new start should only be made if the full financial needs of the Project are firmly committed in advance, including both foreign and domestic currency.

The terms of the Project loans should, of course, be as liberal as are possible to obtain, but most important is the assurance of sufficient funds, available as needed and in the proper currencies.

To insure that funds will be adequate, loan authorizations should include a supplemental financing contingency to allow for possible cost increases during any delayed negotiations and during the subsequent construction period. This financing contingency should be about five percent of foreign currency requirements and 15 percent of local currency requirements. Loan applications should be made for U. S. $1,350,000 and GF 250 million, not including interest during construction.

### Engineering

Although a thorough plan has been prepared for the Monchon Project, final designs, specifications for bidding, construction drawings, and inspection of construction are still needed to insure the technical adequacy of the civil works. For these, a competent and independent consulting

engineering firm should be retained, which can give professional direction to the work, unbiased by any association with contractors, manufacturers, or other adverse interests.

## Construction

Construction of the Project should be carried out under one general contract. Any division of the work into separate contracts would lessen the interest of the larger and more competent firms, reduce competition, and add to administrative costs. Only pre-qualified contractors, with proven experience and adequate resources, should be allowed to bid. Contracts should be let at fixed unit prices with adequate guarantees of performance bond and insurance.

Preparation of the project lands for agricultural use should proceed concurrently with the construction of the civil works. This work can be carried out under force account by the Center of Rural Mechanization (C. M. R. ), an agency of the Service of Production of the Administrative Region of Boffa. Suitable mechanized equipment and operators are available to this agency.

Proper coordination between the land preparation and the contractor's operation will allow a partial rice crop to be harvested at the end of the first construction year.

## Administration

As soon as the Project is authorized, an organization should be established for the administration of construction and of subsequent operation. This organization should be a regional agency, with budgetory support from the national government. It should have a reasonable degree of

autonomy and be held responsible for the success of the Project. This agency should exercise fiscal and operational control of the Project, be able to employ expert assistance when needed, and have call upon the agricultural supporting facilities of other agencies.

The administrative agency should have a fiscal department to control construction funds released by the national government and the lending agencies for the Project, and later to control assessments on the farmers and payments for operation. A department closely associated to the Project is needed to insure that proper certification is made for disbursements, that assessments are made in accordance with Project obligations, and that collections due are in fact received.

An operations and maintenance department will be needed to control outlet gates, keep canals free of obstructions, and maintain the levees.

Agricultural Extension Program

It is of utmost importance for the success of the proposed project that all of the reclaimed lands be brought to cultivation as early as possible and that farming practices be improved.

We recommend that an experienced rice agronomist be employed full time in the Project area for a period of several years from the beginning of the construction phase. Because of the present shortage of trained Guinean technicians, this agronomist may have to be an expatriate. He should direct the agricultural program, and guide and advise the farmers on methods of increasing production.

The agronomist could also direct the program of land levelling and farm preparation.

Under the direction of the agronomist, pilot demonstration plots should be formed in the Project area for experimentation with rice varieties and fertilizers. The results of these research programs should be disseminated in an easily understood manner among the farmers. Practical demonstrations of improved cultural practices, particularly through mechanization, should be given to the farmers. Also, the agronomist should perform routine physical and chemical tests on the Project soils.

If the agronomist engaged for the Project is an expatriate, he should be assigned a Guinean assistant who should be a young agronomist with college training.

# PART II

## SUPPORTING INFORMATION


| | | |
|---|---|---|
| Chapter | I | Geography of the Project Area |
| | II | History of the Monchon Project |
| | III | Field Investigations |
| | IV | Project Lands |
| | V | Agriculture |
| | VI | Project Design |
| | VII | Project Construction |
| | VIII | Project Economics |
| | IX | Project Operation and Development |

Chapter I

# GEOGRAPHY OF THE PROJECT AREA

## General Description

The Republic of Guinea is located on the Atlantic coast of the "Bulge of Africa" 700 kilometers southeast of Dakar (Republic of Senegal) as shown on Exhibit 1. It extends from latitude 9° to 12.5°N and from longitude 17° to 12°W. The country is bounded by Portugese Guinea on the northwest, the Atlantic Ocean on the west, Sierra Leone on the southwest, Liberia on the south, the Republic of Ivory Coast on the southeast, and the Republics of Senegal and the Mali on the north. The country has an area of about 250,000 square kilometers.

Guinea is divided into four regions. The coastal area (Lower Guinea) forms a band along the Atlantic which averages 100 kilometers in width. This area is characterized by heavy rainfall from May to September. There is little variation in temperature throughout the year--the average maximum temperature is 85°F and the average minimum 75°F. The second region, occupying over half the total area, is the Fouta Djallon, a plateau averaging about 300 meters above sea level but rising in places to over 1000 meters. This area has less rainfall and lower temperatures than does the coastal region. Upper Guinea, the third region, is a low land to the north and east of the Fouta Djallon, where the Sahara belt is approached. The rainfall is relatively light and the temperatures are much higher than on the coast. Finally, there is the forest region, immediately north of Liberia. This is an area of typical West African tropical rain forest with high temperatures. The rainfall, while heavy, is somewhat less than on the coast.

The plains of Monchon are located in the northern part of Lower Guinea, approximately 50 kilometers northwest of the seat of the Administrative Region of Boffa. Their general location is shown on Exhibit 1. The plains occupy the southern edge of the basin of the Rio Kapatchez and the northern edge of the Koumba River basin.

Like a large part of the Guinean coastal zone, the plains of Monchon are fertile, with a great potential for rice production. Climatologic, physiographic and hydrologic factors play an important role in the successful exploitation of ricelands. This chapter presents the conditions that prevail in the Monchon area which are typical of those in Lower Guinea as well as conditions that are peculiar to the Monchon area.

## Climatology

### General

The climate of Lower Guinea is monsoonal, characterized by a dry season followed by a very wet one.

The dry season extends from December through April. It is hot, with high relative humidity, but is somewhat tempered by moist marine winds. There is generally no precipitation in the Monchon area during the December-April period. Vegetative growth may cease for several months because of the complete lack of precipitation.

The wet season extends from May through November. The monsoon is at a maximum in July and August, with a high persistence. Precipitation during the wet season is in the form of violent and continuous rains. Relative humidity is very high during the wet season. Total precipitation for the May-November period averages about 2800 millimeters in the Monchon area.

## Air Masses

The fundamental cause of the climate of Lower Guinea is the seasonal migration of two air masses, the Tropical Continental and the Tropical Maritime. Some role is also played by the Inter-tropical Front.

The Tropical Continental Air, warm and dusty, extends from the Sahara southward, reaching its maximum extend in January between about 5 and 7°N. Associated with it are dry north-easterly or easterly winds. The mass of Tropical Maritime Air, warm and humid, trends from the ocean inland in July or August to about 17°N on the coast and to about 21°N in the interior. Associated with it are wet south-westerly or westerly winds.

These two masses alternate seasonally over Lower Guinea. Owing to different densitites of the two air masses, the front slopes upward toward the south, so that the maritime air forms a wedge under the continental air. This wedge penetrates northward as the maritime mass becomes predominant in and after May, and brings the heavy monsoonal precipitations. It retreats southward in August or September.

Between these two main air masses is the Inter-tropical Front, which lies north of the Equator throughout the year. With the penetration inland of the maritime air mass, the Front pushes north-westward. It returns south-eastward upon the retreat of the maritime tropical air.

## Prevailing Winds

Line Squalls. At the change of season in May, with the north-westward advance of the Inter-tropical Front, the dominant winds may



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change suddenly. This is accompanied with thunderstorms or "line squalls," often misnamed tornadoes. These north-easterly storms are the partial cause of almost all rain received on the Guinea coast between May and July, and again from September to October.

"Line squalls" are preceded by a day or two of high temperatures and oppressively still air. Finally, the sky darkens, there is vivid lightning and the noise of rushing wind. Winds become south-westerly and temperatures drop by 10 to 20°F (5 to 10°C). Heavy rain, up to 50 millimeters in less than an hour, follows the wind and dust. This rain then gives way to a gentler rain without lightning. When the rain ceases, the clouds disappear and temperatures rise again.

South-westerlies. Associated with the moist maritime air mass are south-westerly winds. They prevail all the year south of Guinea, and penetrate up the coast in July. During the prevalence of these winds, continuous rains may occur for long periods. Skies are frequently cloudy, and early morning mist is common. Visibility is good, except during actual rainfall.

Sea Breeze. The sea breeze in Lower Guinea may reverse the normal winds. In January, for example, a westerly wind frequently replaces the North-east Trades during the afternoon. They may also reinforce the south-westerly winds during the monsoon period.

## Precipitation

In Lower Guinea substantial precipitation generally starts in the beginning or the middle of May and ends in the first half of November. The number of rainy days as well as the amount of rain varies considerably from year to year and from north to south.

The average number of rainy days in the year varies from 100 to 150, and the average annual precipitation varies from about 2850 to 4300 millimeters depending upon the location. The highest annual precipitation in Lower Guinea generally occurs around Conakry.

## Average Rainfall in the Project Area

Three rain gage stations are located in the vicinity of the project area. They are located at Boke, Victoria, and Boffa. The Boke station has been in continuous operation since 1933. The Boffa station was installed in 1954 and has been in service until September 1962. The Victoria station was installed in 1951 but its operation has been intermittent from 1958 through 1960. In addition, two stations were in service during the rainy season of 1957 at Mankountan and Yogoya. These were installed to obtain basic data in connection with the studies of the Mankountan Reclamation Project.

Average monthly precipitation for the periods of record at Boke, Boffa, and Victoria is given in Table I-1.

Long-term averages were estimated for the Boffa and Victoria stations by comparison of their periods of record with concurrent periods for Boke. These adjusted values are shown in Table I-2.

In adjusting the average precipitation for the period of record, a good correlation was found between the stations of Boke and Boffa. The correlation was weaker for Victoria, possibly because Victoria is located on the coast, whereas both Boke and Boffa are inland.

Table I-1 - Average Monthly Rainfall
(in millimeters)

| Month | Boke (1933-62) | Boffa (1954-62) | Victoria (1951-57, 1961-62) |
|---|---|---|---|
| May | 94 | 86 | 49 |
| June | 276 | 337 | 268 |
| July | 481 | 837 | 785 |
| August | 746 | 1,002 | 947 |
| September | 463 | 579 | 588 |
| October | 384 | 256 | 301 |
| November | 100 | 77 | 112 |
| Average for the wet season | 2,546 | 3,174 | 3,050 |

Table I-2 - Estimated Long-Term Average Monthly Rainfall

| Month | Boke | Boffa | Victoria |
|---|---|---|---|
| May | 94 | 75 | 50 |
| June | 276 | 341 | 270 |
| July | 481 | 814 | 790 |
| August | 746 | 1,050 | 1,100 |
| September | 463 | 564 | 590 |
| October | 384 | 256 | 300 |
| November | 100 | 60 | 90 |
| Average for the wet season | 2,546 | 3,140 | 3,150 |

The monthly precipitation recorded in 1957 at Mankountan and Yogoya is summarized in Table I-3. Also shown are the corresponding values for the other three stations.

Table I-3 - 1957 Monthly Rainfall

| Month | Mankountan | Yogoya | Boke | Boffa | Victoria |
|---|---|---|---|---|---|
| May | - | - | - | 4 | 16 |
| June | 58 | 49 | 382 | 272 | 263 |
| July | 679 | 764 | 535 | 781 | 700 |
| August | 503 | 647 | 421 | 764 | 562 |
| September | 568 | 468 | 533 | 691 | 500 |
| October | 400 | 231 | 388 | 397 | 540 |
| November | 136 | 157 | 152 | 143 | 82 |
| Total for the 1957 wet season | 2,344 | 2,316 | 2,419 | 3,052 | 2,663 |
| Long-term average | - | - | 2,546 | 3,140 | 3,150 |

Table I-3 indicates that the 1957 wet season was somewhat dryer than average at the three permanent observation stations. It also shows that, although the annual precipitation recorded at Mankountan and Yogoya was smaller than that for Boke, most of the monthly values for July through October were higher than the corresponding ones for Boke.

## Extreme Precipitation at Boke

Annual precipitation in the project area varies from year to year by not more than about 30 percent above or below the yearly average. At Boke, where the average annual precipitation is about 2550 millimeters,

the driest year was 1955, when about 2000 millimeters of rainfall were recorded. The wettest year was 1933, with a total precipitation of 3275 millimeters. The monthly precipitation for these years is shown on Exhibit 3.

Monthly precipitation is more variable, as is evidenced by the data summarized in Table I-4.

Table I-4 - Range in Monthly Precipitation at Boke

| Month | Driest on Record | Wettest on Record |
|---|---|---|
| May | 0 | 250 |
| June | 139 | 401 |
| July | 300 | 673 |
| August | 288 | 1,162 |
| September | 285 | 679 |
| October | 37 | 761 |
| November | 0 | 262 |

## Atmospheric Humidity

Atmospheric humidity in Lower Guinea does not vary much from year to year. However, its monthly variations are great, and so are its diurnal variations. On Exhibit 2 is presented a graph showing the relative humidity as recorded at Boke during the year 1962 at 6:00 a.m., 12:00 noon, and 6:00 p.m. The shapes of the curves reflect the movements of the maritime and continental air masses.

## Temperature

The daily temperatures recorded at Boke in 1962 are presented on Exhibit 2. Graphs are shown for the minimum, mean, and average temperatures as plotted for each day of 1962. These values are typical for the project area.

## Physiography

### The Coastal Belt

The coastal belt of Lower Guinea is a continental shelf that was submerged by the ocean in recent geologic times. In earlier eras it was crossed by important rivers flowing to the ocean in well-defined valleys. Structural upsets of the Fouta Djallon then displaced and faulted the old summit line. New tectonic breaks, generally oriented along two perpendicular directions, deeply modified the relief. Later, the level of the ocean rose, flooding the old alluvial valleys which became the estuaries of rivers whose watersheds were made smaller by the surface twisting of the Fouta Djallon. Thus were formed the broken coast line and numerous islands that are now present along the coast.

There is no smoothed coast, because the continental shelf is comparatively wide, the tidal range is relatively high, tidal scour is strong, and because the coast is oriented directly across the path of south-west or north-west winds that agitate the waters.

The relief of the coastal plain is cut deeply inland by the old estuaries. During the dry season, when surface runoff in the coastal belt is practically non-existent, the submerged valleys become tidal

inlets bordered by saline, muddy lands. The coast line and the coastal plain of Lower Guinea are broken at two points by rocky spurs, at Cape Verga and behind Conakry. The former consists of micaceous schists and quartzite, and the latter of granite and ultra-basic eruptive rocks, found also in the Los Islands and north-east of Conakry.

## The Tidal Estuaries

Tidal variations extend far inland into the deep estuaries, since the coastal plain is at an elevation of only a few meters above sea level. During the wet season, the estuaries provide natural drainage outlets for the large surface runoff of fresh water. The discharge capacity of the channels is substantially reduced during the high tides, and increases during low tides. During the dry season, there is practically no fresh water discharge in most of these channels,and salt water flows up and down the channels under the influence of the tide. Their downstream reaches carry water with a high salt content, somewhat reduced during the rainy season.

These tidal streams, called locally "marigots," generally present pronounced meanders which, in places, cause real archipelagos.. But nowhere deltas are found, primarily because of the turbulence that prevails at the estuaries.

Salt water vegetation in the form of mangrove is present along those reaches where the salt content remains high throughout the year. The mangrove forms a border, several hundred meters wide, along the tidal streams. It is thick, and mangrove trees may reach an impressive height in the vicinity of the ocean. They become smaller and less dense in the upper reaches, where the tidal variations are smaller and where the salinity decreases during the wet season.

Along the tidal streams and their estuaries, the coast is covered by an alluvial, muddy sediment which is very viscous, called locally "poto-poto." Its bluish-black color and its marine salt content indicate an oceanic rehandling of its continental, clayey constituents.

These soils are very soft when wet. Their moisture content can be extremely high. They constitute a good support for the mangrove-type vegetation.

## The Rio Kapatchez

The Rio Kapatchez or Kapatchez River, is the principal stream in the Monchon area. Its location is shown on Exhibit 1.

The Rio Kapatchez is a coastal water course draining an area of about 900 square kilometers. Most of its drainage area is located in the Region of Boke. The remainder is in the Region of Boffa. The Kapatchez follows a south-westerly course to the ocean. Its estuary is located about midway between Cape Verga and the Rio Nunez estuary. Its main tributaries are the Kiaye and the Songolon on the right side, the Kitali and the Diberedi[1/] on the left side. The Diberedi drains an area of about 150 square kilometers and joins the Kapatchez a short distance upstream from its estuary.

Average discharge of the Kapatchez during the wet season has been estimated to be 200 to 250 cubic meters per second. Flood flows for the 10-year storm have been estimated to be 900 cubic meters per second. During the dry season, the lack of precipitation results in practically no flow in the Kapatchez over a period of several months.

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1/ Also called Colo, or Kollo.

In its lower reaches the Kapatchez is a typical tidal stream, being within the zone of tidal influence for a distance of about 15 kilometers from the ocean.

Until recently, the Kapatchez drained large lands in its watershed in a fairly effective manner. Among these are areas that were traditionally rice production lands, such as the Kapatchez Area, the Mankountan Area, the Monchon Area. In the early 1930's, a process of aggradation of the bed of the Kapatchez began to take place. Fine clay similar to the "poto-poto," was brought up the stream by the rising tides and was deposited on the bed and banks during the receding tides.

Several theories have been advanced to explain the causes of this influx of material from the ocean, but the phenomenon is still not well understood. However, whatever the reason, a severe aggradation of the bed of the Kapatchez and its lower tributaries progressed at a rapid rate. The channel invert of the Kapatchez was thus raised by several meters along the reach between the downstream end and a point located several kilometers upstream from Bentimodia. A similar aggradation of the Diberedi occurred along its course, up to the vicinity of Kitifini.

Silting of the channels resulted in the decrease of tidal amplitudes in the Kapatchez and the Diberedi, and in the decrease of mean water depth in the dry season, thus handicapping navigation. As another result of the channel aggradation, the discharge capacity of the Kapatchez and Diberedi channels has now decreased considerably. Wet season flows can no more be accommodated by the channels and are forced onto the plains where large volumes of fresh water ponds at depths reaching three meters for periods of several weeks to months.

A tributary of the Diberedi, the Yomponi, which formerly drained an area of about 16 square kilometers, is now completely non-existent. In places, the route of the old channel cannot be identified. Surface run-off now accumulates in the plains until discharged through small water courses. Some low-lying areas have been transformed into permanent fresh water marshes, with typical fresh marshland vegetation.

## Tidal Variations

### Ocean Tides

The coast of Guinea along the Atlantic Ocean is subject to comparatively large tidal variations. Tide tables for Conakry, with corrections for the harbors of Benty and Taboria, are published yearly. 1/

Tidal variations at Conakry have an amplitude reaching a maximum of approximately four meters. From north to south of the Guinean coast the amplitude varies by less than 0.2 meters. The tides do not reach their ebb and flood levels at the same time on all points of the coast, although the difference is not very great. Maximum and minimum levels near Taboria may be reached 25 minutes after they occur at Conakry, and near Victoria about 20 minutes later.

Each tidal cycle has a period of 28 days, with two subcycles characterized by a series of high and low levels reached at full moon (spring tide), and another series of high and low levels, although not as extreme as the former, reached at new moon (neap tide). The difference between

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1/ Table des Marees des Territoires Francais d'Outre-Mer et de quelques Ports Etrangers (Tide Tables for French Overseas Territories and some Foreign Harbors), Imprimerie Nationale, Paris.

them is relatively small. The maximum flood levels of each year do not occur in a given season because the solar and lunar cycles are not in phase. Typical tide levels for 1953 are shown on Exhibit 3.

Tide Propagation in the "Marigots"

Variations of the ocean level induce corresponding water level fluctuations in the tidal streams or "marigots." These variations are propagated in an upstream direction along the streams according to well-defined patterns.

In the absence of fresh water discharge in the tidal streams, rising (or flooding) tides induce a flow of salt water from the ocean in an upstream direction. As the level of the ocean stops rising and begins falling (ebbing), the flow in the tidal streams decreases, a reversal of the current occurs and the marigot empties itself into the ocean where the water level is dropping to its ebb.

At a given point of a tidal stream, the water level undergoes fluctuations similar in character to the ocean tides that cause them. The amplitude of these tidal fluctuations decreases as the distance from the ocean to the point considered increases. The length of the period of tidal fluctuations is about the same as at the ocean, but the occurrence of the maximums and minimums is delayed by a period of time (lag) that increases as the distance from the ocean increases. These two changes in the characteristics of the tidal fluctuations in a tidal stream--decrease in amplitude and lag of peaking time--result from the frictional resistance which the stream channel opposes to the propagation of tidal currents. Smaller and longer channels cause a greater resistance and, therefore, result in a greater dampening of tidal waves.

When substantial fresh water flows are discharged in the tidal streams, the downstream current may be strong enough to prevent the upstream flow that occurs in the dry season, but during high tides the channel discharge capacity is invariably reduced by an amount that can be considerable.

Tidal Fluctuations in the Sonie Koure

The Sonie Koure[1/] is a tidal stream located along the south-west side of the Monchon Plains. It is shown on Exhibit 1. The Sonie Koure is a tributary of the Koumba River, another tidal stream, which it joins at a point located about 2.6 kilometers from the ocean. The reach of the Sonie Koure between its confluence with the Koumba and the vicinity of Dentema is about six kilometers long. Ti 'al fluctuations of the Sonie Koure were recorded in September and November, 1953, near the village of Dentema.

These observations indicate that high tides with an amplitude of 4.0 meters result in fluctuations of the Sonie Koure near Dentema with an amplitude of 2.8 meters. The maximum amplitude of spring tides is thus reduced by 1.2 meters in its propagation along the 8.5 kilometers that separate Dentema from the ocean.

Given tidal variations in the ocean do not always result in the same amplitude at Dentema. When the tidal amplitude is increasing (waxing moon), the range of fluctuations at Dentema is smaller than when the tidal amplitude is decreasing (waning moon). A graph giving the corresponding elevations for Dentema is presented on Exhibit 3. This graph

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1/ Also called Wendima River.

shows that the flood stage is the same for either moon phase, while the ebb stage is different.

The duality of ebb stage at Dentema for the same tide amplitude is the result of the channel characteristics that are peculiar to the Sonie Koure. Similar conditions have been observed at some points of other tidal streams.

High tide levels are reached near Dentema from 1/2 to 2 1/2 hours after they occur in the ocean. Small amplitudes lag by 1/2 to 1 hour and large amplitudes lag by 2 to 2 1/2 hours. For similar amplitudes, lag times to peak are generally smaller when the moon is waxing, and larger when the moon is waning.

# HISTORY OF THE MONCHON PROJECT

## Introduction

The plains located in the vicinity of Monchon are fertile lands where the cultivation of rice has been practiced to some extent for many decades by the local Baga populations. They were systematically investigated for the first time by the French colonial administration about 1935 for the purpose of increasing the production of rice in Guinea.

## Initial Studies

The initial investigations by the French revealed two major problems which would have to be solved before the cultivated area could be increased:

a. the presence of salt in the root zone of the soil; and

b. the poor natural drainage of surface waters during the wet season.

A topographic survey at a scale of 1:2000 was performed in 1937-38 by the Daude team. This survey covered most of the lands that became the Monchon Area, but did not extend far enough on the east side to determine the exact limits of the area to be developed, nor the boundaries of the watershed. However, this survey formed the basis for several reclamation projects developed subsequently. These projects consisted primarily of drainage facilities.

## 1938 Scheme

The first reclamation project was planned in 1938. It aimed at the development of 2500 to 3000 hectares for rice cultivation, of which 600 to 1000 hectares had never been cultivated. The dimensions of the project structures were based on a design rainfall of 227 millimeters in two days, which was the maximum two-day precipitation recorded at Boffa. Surface runoff was to be drained to the North into the Diberedi and the Yomponi rivers by means of large drainage canals. The main canal would have had a cross-section in excess of 100 square meters. The cost of the project had been estimated to be seven million CFA francs[1/] for an estimated increase in rice production of 1200 tons (paddy). This project was not implemented.

## 1941 Scheme

In 1941, when the wartime food situation in Guinea was critical and the construction capacity was limited, the criteria used in the 1938 project were relaxed, and a smaller project developed. This project was designed for the drainage of a daily precipitation of 30 millimeters, which is the average daily rainfall at Boke for the month of August. Although the estimated construction cost is not known, this project was designed to cost substantially less than the 1938 project. The cross-section of the main drainage canal at its end was reduced to less than 60 square meters. The project had been conceived as a closed system discharging into the Yomponi river at Bongolon and at Kamponi, but only the Kamponi structure was provided with gates. This project was constructed under the direction of the Service des Travaux Publics and

1/ Worth about 120 million CFA francs in 1951.

put in operation in the 1940's. Its cost is estimated to have been approximately five million CFA francs[1/].

It is reported that the drainage provided in the first few years of operation resulted in satisfactory conditions and permitted the growing of a few good crops. However, sediment deposits accumulated quickly in the tributaries of the Kapatchez River, the Yomponi and the Diberedi, and the cross-section of these outlets decreased considerably. An additional outlet canal was provided toward the Diberedi, with a gated structure across a dike near Tambacourou. A few auxiliary structures were also constructed at that time in an attempt to prevent this aggradation from interfering with the drainage capacity of the canals. Among them are the canal and gated structure of Tambacourou and the gated structure of Kifinda, intended to help drain the south end of the plains toward the Koumba River. These structures are now in poor condition. Some of them do not seem to have been used and gates were not installed where scheduled. In any event, the complete obstruction of the Yomponi River and the severe aggradation of the Diberedi resulted in the failure of the canal system to drain surface water during the wet season. Although the "Service des Travaux Publics" carried out the design and construction of the project, its maintenance was the responsibility of the local population. The severity of the aggradation made it impossible for the beneficiaries to take any effective action, and the canals and structures fell into a state of disrepair. Cultivation was limited to an area estimated to be 700 hectares. The remaining 3000 hectares remained flooded under up to 75 centimeters of water during the rainy season.

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1/ Estimated to be worth about 83 million CFA francs in 1953.

## 1951 Scheme

In 1951, a new plan of reclamation was studied by the newly organized "Service du Genie Rural" of Guinea. Detailed field investigations were made by Mr. de Meredieu who proposed construction of a main drainage canal to drain the plains toward the Sonie Koure. The canal was to be provided with a gated structure located near Dentema to prevent salt water from entering the canal system. The design of the 1951 project was based on a precipitation of 300 millimeters in two days. The cost of the project was estimated to be 37 million CFA francs. The increase in production expected as a result of this project was estimated to be 800 tons of rice paddy. This scheme became the basis of all later reclamation plans.

## 1953 Scheme

In 1953, the Service des Travaux Publics of Guinea developed a plan of reclamation inspired by that planned by the Service du Genie Rural in 1951. This plan consisted of:

(a) A 6700 meter long main canal to the Sonie Koure, 10 meters in bottom width, 3.0 meters deep, with slopes of 2 to 1. This canal was intended to discharge an average daily flow of about 28 cubic meters per second during the smallest diurnal tidal variations.

(b) A gated structure provided with a new type of automatic gates, located near Dentema.

(c) Two new secondary canals and a rehabilitation of the existing canals.

(d) The rehabilitation of existing dikes and closure of a number of breaches.

The cost of this project was estimated in 1953 to be 90 million CFA francs, and the area to be reclaimed expected to be 3000 hectares.

## 1954 Scheme

The 1953 scheme was reviewed in 1954 by a representative of the BCEEOM[1/], who made a detailed field inspection of the local conditions. Construction of a main canal to the Sonie Koure was endorsed with a few modifications relative to its size. The recommended width varied from 16 meters at the downstream end to 12 meters at the upstream end. The corresponding cross-sectional areas varied from 65 to 35 square meters. The 1954 report does not explicitely disapprove the gated structures, but it appears that the concept of a closed system was changed to that of an open system. No further mention was ever made of the gated structures which had been proposed earlier.

## 1957 Scheme

Following the recommendations by the BCEEOM representative, an aerial photographic coverage of the project area was made in 1957 at a scale of 1:10,000 and a topographical map at a scale of 1:5000 was started. In the meantime, a negotiated contract for dredging the Monchon Canal (and the Rio Kapatchez) was awarded in 1955 to the Societe Nationale des Travaux Publics, a private contracting company. Work at Monchon was commenced in 1957. Approximately 1900 meters of canal were

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1/ Bureau Central d'Etudes pour les Equipements d'Outre-Mer, Central Design Office for Overseas Installations.

excavated between the Sonie Koure and the Mintani dune[1/] at a cost of about 40 million CFA francs. The work was terminated in 1958 upon the departure of the French Administration from Guinea. Subsequently, the local populations attempted to extend the uncompleted canal, but were not able to accomplish much because of the magnitude of the task involved.

A small area behind the Mintani dune, near the villages of Mintani and Mombasso, benefited from the 1957 dredging operation. Drainage of surface water in the area between the Mintani and Dentema dunes, particularly in the southern half of the plains of Dentema, was improved considerably. However, the influx of salt water in this area resulted in conditions detrimental to the culture of rice. Rice yields in this area have remained relatively small.

## Recent Studies

In 1960, upon request by the Government of Guinea, two experts[2/] of the Food and Agriculture Organization of the United Nations (FAO) investigated the steps to be taken in order to increase the production of rice in Guinea. Among other recommendations, they proposed to increase the area of lands suitable for land cultivation by construction of hydraulic control structures, and to increase the yield of cultivated areas by means of an agricultural extension program.

More particularly, with regard to the Monchon project, the following was recommended:

(a) completion of the main canal over a length of 2100 meters, at an estimated cost of GF 30 million;

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1/ Also called "Mombasso dune" in some of the reports.
2/ Messrs. J. de Meredieu and H.A.A.M. Wirtz.

(b) rehabilitation of the existing system of secondary canals and construction of a few new canals at an estimated cost of GF 147 million (including GF 22 million for engineering and other studies); and

(c) construction of smaller order canals by the local beneficiaries, requiring an estimated average of 10,000 man-days of labor annually over a 10-year period.

The project, as recommended, would be an open system without control structures.

## List of Reports Relative to the Monchon Project


1. "Rapport Pedologique" (Soils Report), Secteur des Recherches Rizicoles, Service de l'Agriculture de Guinee (Department of Rice Research, Service of Agriculture of Guinea), 1950.

2. "Etude des Possibilites d'Amenagement Hydraulique du Bassin du Rio Kapatchez" (Study of Possible Hydraulic Installations in the Rio Kapatchez Basin), by J. de Meredieu, Chef de la Section Technique Locale du Genie Rural (Chief, Local Technical Section of Rural Engineering), June 9, 1951.

3. "Mission d'Etude de l'Amenagement Hydraulique de la Zone Cotiere de la Guinee Francaise" (Mission for the Study of Hydraulic Installations in the Coastal Zone of French Guinea), by Gabriel Jamme, Ingenieur en Chef des Ponts et Chaussees (Chief Engineer of Highways and Bridges), Directeur Technique du BCEEOM (Technical Director of the BCEEOM), undated. The date of publication is estimated to be August, 1952.

4. "Projet d'Execution du Plan Quadriennal 1953-57 - Production (Riz) - Rapport Complementaire" (Project of Implementation of the Four-Year Plan 1953-57 - Production (Rice) - Supplementary Report), undated. The date of publication is estimated to be May, 1953.




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5. "Etude de l'Amenagement Hydraulique des Regions du Kapatchez et de Monchon" (Study of Hydraulic Installations in the Areas of the Kapatchez and of Monchon), by Gabriel Jamme, Ingenieur en Chef des Ponts et Chaussees (Chief Engineer of Highways and Bridges), undated. The date of publication is estimated to be August, 1954.

6. "Les Plaines Rizicoles de la Basse-Cote de Guinee - La Riziculture Actuelle - Perspective de Developpement" (The Rice Producing Plains of the Coast of Lower Guinea - The Present Rice Cultivation - Outlook for Development), undated. The date of publication is estimated to be 1955.

7. "Rapport au Gouvernement de la Republique de Guinee sur les Possibilites d'Amenagement Hydro-Agricole des Terres Rizicultivables de la Basse-Guinee" (Report to the Government of the Republic of Guinea on the Feasibility of Hydro-Agricultural Installations in the Potential Ricelands of Lower Guinea), by J. de Meredieu, Food and Agriculture Organization of the United Nations, Rome, Italy, January, 1961.

8. "Augmentation de la Production de Riz en Basse-Guinee - Rapport au Gouvernement de la Guinee" (Report to the Government of Guinea for increasing the Production of Rice in Lower Guinea), by H. A. A. M. Wirtz, Food and Agriculture Organization of the United Nations, Rome, Italy, 1961.

## Chapter III

## FIELD INVESTIGATIONS

### Introduction

In compliance with the terms of their contract with the United States and its executing agency the Agency for International Development (AID), the Harza Engineering Company sent to Guinea a team of six engineers and agronomists for the purpose of making field investigations for four reclamation projects, including the Monchon Project. This team included the following personnel:

Project Manager
Hydrologist and Field Engineer
Irrigation and Drainage Engineer
Soils Agronomist
Rice Agronomist
Agricultural Economist

The activities of the Harza team were directed toward the following:

(a) Review all existing data;

(b) Conduct field reconnaissance and studies for the purpose of determining the adequacy of the existing data; and

(c) Supplement the existing data as necessary for an evaluation of the project.

The Harza team remained in Guinea from April 1963 until the start of the rainy season, in July. This allowed only sufficient time

for investigation of the Monchon Project and the Kapatchez Project. The investigations that were conducted and the results that were obtained are summarized in the remainder of this Chapter.

## Review of Existing Documents

A large number of reports and various documents relative to the production of rice in Lower Guinea were reviewed in Conakry. Some documentation relative to the Monchon Project was found to be available. This consisted primarily of reports presenting a plan of development or modifications of previous plans. The lack of continuity between the various reports that were found made it difficult to obtain a precise picture of the evolution of the project.

Little was found about the works actually performed, with the exception of a few transverse sections, longitudinal profiles, and specifications pertaining to the contract prosecuted in 1957. No "as-built" drawings were found in Conakry, and it is believed that none were prepared. A pedologic report relative to the soils of Guinea in general, and those of the Monchon area in particular, was found to be available. The data contained in this report were reviewed and found to be useful.

Despite the limitations in documentation the analysis of available data permitted a reasonable understanding of the basic ideas that guided previous planning of the Monchon Project.

## Field Reconnaissance

A field reconnaissance of the project area was made for the purpose of determining the present condition of existing structures, to

identify the problems involved, and to gain intimate, direct knowledge of possible solutions. This reconnaissance also served to formulate a program of more detailed field investigations.

The existing facilities were found to be out of service and in poor condition. It was apparent that the control structures, whose locations are shown on Exhibit 2, have not served the purpose for which they were intended. Control gates were apparently not installed, although the design of the structures indicates that gates were to be provided. In most places the concrete is deteriorating.

The canals are in the same state of disrepair. It was obvious that the old canal system has not drained much water in the direction toward which it slopes. Uncontrolled brush is growing on the bottom of the canals and on their slopes and many of the canals have been plugged by the local population to facilitate foot-crossings. These numerous obstructions prevent the flow of water in the canals.

The main canal, constructed in 1957-58 from the Sonie Koure to the Mintani dune, was found to be generally in good condition. Side slopes are now stable. Some sediment deposits were observed at the upper end of the canal. Upon completion of the system such deposits would normally be removed by the wet season flow; however, since the canal was not completed, its discharge has never been sufficient to prevent the accumulation of sediment. Nevertheless, much excavation work has been accomplished, and after some improvement the existing canals can be incorporated in a new drainage system.

Existing dikes were generally in good condition except for a number of locations where they were breached by the local population, presumably

to relieve flooding conditions in areas that cannot be drained by the canals toward the north side of the project area.

Local officials and populations were contacted and interviewed at length to obtain information on various specific points. Data were obtained on the extent of flooding in the plains and one the present impossibility of cultivating them economically. All persons concerned seemed to recognize the problems involved and their magnitude. All were obviously anxious to have a drainage project started so as to bring the plains to a full production status.

## Topography

The following topographic data were found in Conakry:

(a) The 1938 Daude survey, consisting of maps at a scale of 1:2000;

(b) a survey made in 1957 by COTHA for the neighboring area of Mankountan at a scale of 1:20,000, covering the northern part of the Monchon area;

(c) the 1957 Monchon survey, consisting of incomplete plane table maps at a scale of 1:5000.

The 1957 Monchon survey was potentially the most useful, therefore, its accuracy was verified in the field. Numerous bench marks were found, and the difference in elevation between bench marks was determined. Values thus found confirmed that the survey was acceptable as a basis for design. The basic data shown on the 1:5000 maps were used to complete the topographic maps presented in this report.

The various topographic surveys mentioned above used different reference datums. The 1:5000 maps were referenced to the "Ray System," hence an attempt was made to relate the other datums to the Ray datum. The following relationships were determined:

Daude elevations + 2.3 meters = Ray elevations

Cotha elevations - 42.8 meters = Ray elevations

Cross-sections and slope of existing canals were determined. This permitted determination of the capacity of the existing canals, and where additional work is proposed, to allow calculation of the amount of earthwork that has already been done.

## Hydrography

Hydrographic investigations were carried out for the following purposes:

(a) to determine the present condition of the main outlets with respect to accumulation of sediment;

(b) to collect data on the cross-section of the main canal and the tidal streams, to be used in hydraulic design; and

(c) to collect data on tidal variations for hydraulic studies.

The Diberedi and the Yomponi rivers were examined first. These channels were found to have such large accumulations of sediment that they do not provide any drainage of the plains. This condition is so critical that it makes them unsuitable as outlets for drainage canals.

A detailed reconnaissance of the Sonie Koure River and the Koumba River to its ocean estuary was made on a 12-foot boat with outboard motor. Soundings of the water depth were made from the boat at various locations. These two tidal streams were found to be wide and deep, with no evidence of aggradation. From these observations, it was concluded that these streams will provide satisfactory outlets for the water drained from the Monchon Plains.

Data on cross-sections of the Koumba and the Sonie Koure, as measured near high tide, are summarized in Table III-1.

Table III-1 - Dimensions of Tidal Streams
(measured near high tide)

| Stream | Approximate Location | Surface Width (meters) | Maximum Depth ((meters) | Water Area (square meters) |
|---|---|---|---|---|
| Koumba | 1000 m downstream from confluence with Sonie Koure | 130 | 6.5 | 520 |
| Koumba | 1200 m upstream from confluence with Sonie Koure | 140 | 4.3 | 500 |
| Sonie Koure | 700 m upstream from confluence with Koumba | 65 | 4.8 | 260 |
| Sonie Koure | 200 m downstream from Monchon Canal junction | 35 | 5.4 | 160 |
| Sonie Koure | 150 m upstream from Monchon Canal junction | 40 | 4.4 | 110 |

The canal excavated from the Sonie Koure to the Mintani dune was found to be in good condition. Side slopes appeared to have flattened since



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excavation, but they have now reached stable values. Dimensions as measured in the Sonie Koure near Dentema, with high tide at elevation 5.8, are summarized in Table III-2.

Table III-2 - Present Dimensions of Monchon Canal
(measured near high tide)

| Location | Surface Width (meters) | Maximum Depth (meters) | Average Depth (meters) | Water Area (square meters) | Side Slopes |
|---|---|---|---|---|---|
| Downstream end | 37 | 3.1 | 2.0 | 37 | 1:5 to 1:7 |
| Dentema dune | 36 | 2.2 | 1.4 | 44 | 1:5 to 1:7 |
| Upstream end | 32 | 1.5 | 1.4 | 27 | 1:5 to 1:7 |

The slope of the canal was measured and found to be approximately 0.0012.

The reduction in depth and area at the upstream end of the canal as indicated by Table III-2 is evidence that some sediment accumulation has occurred because wet season flows were not of sufficient magnitude to transport the deposited material. This material has been transported either from the ocean by the tides or from the fields by surface runoff. However, the area and depth that still remain after five years indicates that these accumulations are relatively small. This tends to give assurance that the proposed reclamation plan will not be subject to serious sediment accumulation.

Water surface elevations at high tide were measured at several locations, particularly at both ends of the Monchon canal. The elevations were within the range of observations made in 1953, as reported in Chapter I.

## Foundations

The foundations of possible sites for the control structure across the canal at the Mintani dune and at the Dentema dune were investigated. Preliminary subsurface investigations consisted of two auger holes, bored down to five meters below the ground surface. The material encountered consisted of very soft, blue-grey, organic clay. Samples were taken and brought to the United States for testing. The tests made on the foundation material at the Mintani dune yielded the following results:

| | |
|---|---|
| Natural moisture content . . . . . | 46 percent |
| Liquid limit . . . . . | 42 percent |
| Plasticity Index . . . . . | 24 |

This material was classified as a clay of medium plasticity (CL-2) in the Unified Classification System. 1/ Its behavior as a foundation is characterized by low resistance to shearing, medium to low permeability, and medium compressibility.

## Soils

A pedological report relative to the soils of potential ricelands in Guinea was prepared by the Service of Agriculture of Guinea in 1950. 2/

1/ The Unified Soil Classification System, Technical Memorandum No. 3-357, Corps of Engineers, U.S. Army, 1953.
2/ See reference 1 on Page II-8.



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This report was reviewed and found to contain a detailed description of the types of soils encountered in the Monchon Area. The survey that formed the basis of the 1950 report is considered to have been in the nature of a reconnaissance survey. The report contained a soils classification taking into account the following factors: texture and structure of the soil, salinity, movement of iron, and vegetation. The soil profiles as observed at a number of locations were described in the report. Quantitative data on the order of magnitude of salinity and nitrogen content were given in a generalized form. A small-scale map of soil classes was attached to the report.

Although the 1950 report contained useful data, these were not sufficient for the purpose of the present studies. Many of the soil profile locations were not identified on the map. Results of the detailed chemical analyses were not included in the report, nor could they be found in the records. Moreover, the chemical and physical properties of the soils might have been altered by the lack of drainage and the land uses since 1950. Consequently, a supplementary soil survey and a more extensive series of chemical analyses were necessary for a proper evaluation of the present suitability of the land for rice production and of the yields that can be expected after reclamation. These investigations were performed by the Harza team.

A total of 47 auger holes were bored and one test pit excavated within the area of the Monchon Project. The location of the holes is indicated on Exhibit 5. The profiles were examined to depths of 1.8 meters and preliminary, visual classification of the horizons encountered was made in the field. About 100 representative samples were taken, and tested in a laboratory set up in Guinea with equipment brought from the



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United States. These tests consisted of the determination of the pH (degree of acidity) and of the conductivity of saturation extracts (degree of salinity). The logs of the auger holes and the results of these tests are presented on Exhibit 6.

This series of preliminary tests led to the selection of 32 representative soil samples from six typical areas for detailed, systematic, chemical analyses. These 32 samples were tested in the United States at the soils laboratory of the Department of Agronomy, University of Arkansas. The analyses performed were for the purpose of determining pH, total salt content, anions and cations of the saturated extract, cation exchange capacity, total boron, exchangeable aluminum and sulphur, and percent water of saturation. Other determinations included organic matter, percent free iron, available phosphorus,, and particle size distribution (mechanical analysis). These analyses are considered adequate for the economic feasibility studies.

## Subsurface Drainage

For the purpose of subsurface drainage studies, the coefficient of permeability of the subsoil was determined in the field. Five typical areas were selected on the basis of the soils survey. One auger hole was bored in each of these areas, at the locations shown on Exhibit 5. A permeability test was performed at each of the auger holes.

The auger hole was bored with a standard auger, 10 centimeters in diameter, to a depth of about one to two meters below the groundwater table. Water was pumped out of the hole by means of a plunger pump. The rate of rise of the water in the hole after interruption of pumping was measured with a float and a chronometer.

The data supplied by this test allowed determination of the order of magnitude of the coefficient of permeability of the subsoil. The test is relatively easy to perform and generally provides reliable results. The results obtained for the Monchon area are summarized in Table III-3.

Table III-3 - Results of Permeability Tests

| Auger Holes | Location | Soil Classification | Coefficient of Permeability (cm/sec) |
|---|---|---|---|
| A | N.E. of Bongolon | Sandy clay loam | $1.0$ to $1.3 \times 10^{-3}$ |
| B | Komponi | Silty clay loam | $0.3$ to $0.4 \times 10^{-3}$ |
| C | N.E. of Mintani | Silty clay loam | $0.4$ to $0.6 \times 10^{-3}$ |
| D | S. of Kountountan | Sandy clay loam | $1.1$ to $1.5 \times 10^{-3}$ |
| E | W. of Madine | Silty clay loam | $0.5$ to $0.7 \times 10^{-3}$ |

The values of permeability as shown in Table III-3 indicate that:

(a) the silty clay loam horizons exhibit a coefficient of permeability between $3 \times 10^{-4}$ and $7 \times 10^{-4}$ centimeters per second; and

(b) the sandy clay loam horizons exhibit a coefficient of permeability between $1.0 \times 10^{-3}$ and $1.5 \times 10^{-4}$ centimeters per second.

Prior experience in other parts of the world indicates that the values found above are representative of soils having the textures as described. The tests are, therefore, considered to be reliable. The values they yielded reflect a relatively high degree of permeability.

## Rice Agronomy

In the course of the field reconnaissance and other field investigations made in the Monchon area, present land uses were observed and recorded. The results of these observations is shown as a land use map on Exhibit 4.

The fields presently cultivated were inspected for the purpose of determining the present cultural practices and production rates. Several of the rice fields were being seeded or plowed. Rice stubbles remaining from the last growing season were also examined. Estimates of the total area presently under cultivation and estimates of the rice yields of each field were thus made. The results of these estimates are shown in tabular from on Exhibit 4.

The rice varieties presently used in the Monchon Area were examined. All were found to be local varieties, generally dark in color, and apparently well adapted to the prevailing salt and water conditions. Among them were the Sangtom, Tangolon, and Martini Male varieties. Samples of rice seeds were obtained and brought to the United States for the purpose of identification and growth tests under controlled conditions. Unfortunately, all the samples were found to infested by insects upon arrival in the U. S. and had to be destroyed.

The agricultural mechanical equipment available in the Monchon Area was inspected. All such equipment is owned and operated by the Centre de Mechanization Rural (CMR, Center of Rural Mechanization), an agency of the Direction of Production, Administrative Region of Boffa. A few Massey-Ferguson tractors, being used in the area, were observed in operation.

An agricultural experiment station was established at Koba about 1951, but this station is presently out of service. However, valuable data relative to the experiments made between 1951 and 1958 have been kept in the records. The annual reports of the Koba station were reviewed and found to contain important information on the local and other rice varieties and on cultural practices. These data were used in the evaluation of the agricultural and economic potential of the ricelands of the Monchon area.

## Miscellaneous

Important basic data and information were obtained through direct contacts with various officials and individuals. Conferences were held with officials of several ministries in Conakry to obtain economic, agricultural and other data; with the Governor of the Region of Boffa and his staff to obtain detailed information relative to local conditions; with village officials and individual farmers to secure first hand information on the agricultural practices; with government agencies to obtain miscellaneous data on the availability and cost of various commodities; with foreign contractors presently engaged in civil engineering works to obtain information relative to construction practices, labor and materials availability, and their experience in Guinea; and with U.S. Embassy and AID officials to obtain economic and other data already compiled by them.

All individuals contacted were anxious to help, and their cooperation is appreciated. The information received through these contacts was sometimes contradictory, but this reflects the scarcity of accurate statistical data. First hand information was secured whenever possible

and all other data were examined critically, with judgement being used to interpret apparent discrepancies.

Chapter IV

# PROJECT LANDS

## Introduction

A reconnaissance survey of the arable lands located in the Monchon Area was made to determine to what extent their soils are suitable to the cultivation of rice. Approximately 2970 hectares were covered in the course of this survey. The area investigated was found to include lands with varying degrees of adaptability to rice production. A map of present land use is presented on Exhibit 4. These lands were classified with respect to their agricultural potential on the basis of topography, natural drainage, and soil properties.

The results of soil analyses and permeability tests made by the Harza team are given in Chapter III. This chapter presents details with respect to soils, land use, land evaluation, and land management problems.

## Soils Evaluation

### Soils Classification

Most of the Monchon Area consists of flat plains with heavy alluvial clayey soils, traversed longitudinally by a series of low sandy ridges rising a few meters above the level of the plains. Colluvial soils resulting from recent sheet erosion of the higher adjoining areas are also present along the eastern boundary of the project area.

The Monchon soils conform closely to the soil association described by the Food and Agricultural Organization as alluvial soils with inclusion of grumusols, hydromorphic soils and mangrove soils.[1/]

The 1950 pedology survey[2/] classified the soils of Monchon into three main groups: saline alluvial soils (poto-poto); non-saline alluvial soils; and colluvial soils.

Saline Alluvial Soils. These soils exhibit some of the characteristics of acid sulphur soils or cat clays. They are either undeveloped or developed. Undeveloped saline soils (poto-poto) are found in the areas subjected to intermittent flooding by the tides or permanently submerged, or with mangrove vegetation. Developed soils overlying poto-poto are found west of the Mintani dune, between the dunes of Nkoutounou and Kerimponi, and between the dunes of Kerimponi and Bongolon. They are generally saline and contain some organic matter. The characteristic color of these soils, ochre brown to yellow, results from the oxidation of iron. Mangrove vegetation present on these soils sometimes shows signs of dying. This is an indication of the withdrawal of ocean water.

Non-saline Alluvial Soils. These are non-saline alluvial soils with high content of organic matter. They occupy all the depressed areas in the center of the project area, between the dunes of Monchon, Kaba and Dibensi, and also along the Somaya River. Between Nkoutounou and Kaba, and in the triangle of Kaba, iron concretions appear in depth. Cemented material and gypsum are also found at varying depths near the Kaba, Dibensi and Kolafoton dunes.

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1/ FAO Africa Survey - Report on the Possibilities of African Rural Development in Relation to Economic and Social Growth - Appendix 2 - Soil Resources of Africa - pp 166-168

2/ See Reference 1, page II-8.

Colluvial Soils. These soils have no developed profile. They may or may not contain organic matter. Colluvial soils are light textured and non-saline. They contain iron concretions at depths. They are found east of Kolafoton.

## Soil Properties

Physical and chemical properties were derived from laboratory analyses performed on soil samples obtained from auger holes. The locations of the auger holes are shown on Exhibit 5.

Soil profiles were established on the basis of texture and other properties. Some of these properties are shown with the soil profiles on Exhibit 6. They include the soils texture, pH, conductivity of the saturated extract, presence of carbonates and the position of the water table at the date of sampling. The results of detailed laboratory analyses performed on selected, representative soil samples are presented in tabular form on Exhibit 7.

Composition and Physical Properties. The surface soils of the area are mainly heavy clays. A typical sample of these soils was taken from hole No. 6 at 6 to 20 centimeters depth. This sample contains 3 percent sand, 21 percent silt, and 75 percent clay. The cation exchange capacity of these soils varied from 16 to 50 milliequivalents per 100 grams. These low base exchange capacities indicate that the clays are probably illite or kaolinite, which do not have the expanding properties of the montmorillonite clays.

These clay soils have a well developed horizon differentiation with respect to color, texture, and organic matter, but are without structure or have a weak structure, depending on their stage of development.

The more developed soils are granular to nutty and very friable, or sometimes blocky to slightly prismatic.

The depth of developed soil is variable. In area VI (see Exhibit 4), it is less than 14 centimeters because of the presence of a cemented layer. In the wet areas, the developed profile is from 30 to 60 centimeters deep, and in some of the better drained areas it extends to a depth of 90 centimeters.

The subsurface soils are also generally clays (poto-poto), although many of the profiles show lenses of sand at varying depths. Open spaces left by decayed roots are also present. This combination of roots and sand in the subsoil is conducive to good subsurface drainage properties.

Chemical Properties. Many of the characteristics and properties of the soil can be ascribed to the constitution of the soil mass. Some of their properties are low to medium exchange capacity and absence of a well developed blocky or prismatic structure. The high percentage of organic matter may have been responsible for some of the higher base exchange capacities obtained.

The soil pH of the saturated paste ranges from 4.9 to 8.0 but is basically acid in reaction. The lower pH values obtained reflect the pH of a dry season. Generally with soils of this nature the pH will rise during the wet period. Extensive acidification of the soil often results in a pH lower than 4 when the amount of the bases present is small compared to the sulphate present. The ultimate pH depends on the sulphur-base ratio.

The chemical composition of the soil partly reflects the acid conditions. The soil profiles with low pH's were generally found to contain a small quantity of $CaCO_3$ in contrast to the high percentage of free iron

and aluminum. The analyses of the alluvial soils show a high sodium and magnesium content on the cation complex. Calcium and potassium are less. There is a possibility that the so-called magnesium clays could be formed if there were no accumulation of sulphides or $CaCO_3$. These magnesium clays have the same poor characteristics as the sodium clays: they have a very unstable and very unfavorable structure.

Salinity. The soils of the project area have been grouped with respect to their degree of salinity. A salinity map is presented on Exhibit 5. The delineation of areas with the same degree of salinity in the upper part of the profile, as shown on Exhibit 5, is based on measurements of the electrical conductivity of the saturation extracts.

The salt contained in the alluvial soils of the Monchon Area is generally associated with the marine origin of the sediments. It may also be caused by salt water intrusions and subsequent evaporation of water from the ground surface. These salt deposits have remained in the soil because of lack of effective drainage.

Although rice exhibits a natural tolerance to moderate contents of salt, particularly when transplanting is practiced, salinity conditions presently prevailing in about 38 percent of the project area limit the potential yields to some degree. In about 10 percent of the project area, potential yields are seriously limited by strongly saline conditions.

Fertility. The degree of fertility of the soils in the project area is indicated by the content of organic matter in the top layers, the content of available phosphorus, and the content of exchangeable potassium.

The content of organic matter in the top six to eight centimeters of the soil profiles ranges from 2.8 percent in a cultivated area to 39 percent

in a non-cultivated area. This percentage for either profile drops rapidly toward zero below eight centimeters.

The available phosphorus content of the topsoil, expressed as $P_2O_5$, varies from 2.9 to 19.1 kilograms per hectare. A favorable response to phosphate fertilizers is likely for the lands located in the vicinity of soil profiles 29, 38, and 45, and probably also for those near soil profiles 6 and 42. A response to phosphate fertilizers for lands around soil profile 16 is unlikely. Since phosphate fixation in tropical soils is large, because of the formation of insoluble compounds of iron and aluminum, the addition of phosphate fertilizers as early as practicable will be helpful if the expected yields are to be achieved.

The tests for exchangeable potassium show contents in the topsoil ranging from 0.13 to 1.19 milliequivalents per 100 grams. These amounts will be adequate to obtain the yields that are expected during the first few years of cultivation. Fertilizers may have to be added thereafter.

## Present Land Use

About one-third of the project area is presently under cultivation. Present use of these lands was investigated to gain information on the problems particular to the project lands and to determine the present agricultural production of the project area.

The project lands were classified into eight groups, designated I through VI, including two sub-groups 1A and IIIA. Each designation corresponds to a grouping of lands with similar characteristics and present production capabilities. The boundaries of each group are delineated on the map of present land use, presented on Exhibit 4.

Group I includes about 700 hectares of low-lying lands subjected to intermittent fresh water flooding. Approximately 40 percent of the area is cultivated. Rice yields are estimated to be about 0.7 tons of rice per hectare.

Group II includes about 300 hectares of land slightly higher in elevation. Approximately half of the area is cultivated. Average yields are estimated to be 0.7 tons of rice per hectare. Groups I and II include the lands that are presently the most productive of the Monchon plains.

Group III includes about 860 hectares of land located along the west and north sides of the project area. These lands are subject to salt intrusion and frequent flooding. Approximately 45 percent of these areas are cultivated. Yields are estimated to be about 0.4 tons of rice per hectare.

Groups IA and IIIA, with an aggregate area of about 660 hectares, include low-lying, marshy lands that are variations of groups I and III respectively. Flooding and salt intrusion problems are more severe, and none of these lands are cultivated at the prevent time.

Groups IV and V include lands that are subject to salt intrusion from tidal action. Group IV comprises about 210 hectares of strongly saline lands. About 35 percent of these lands are cultivated, with yields limited to about 0.4 tons of rice per hectare. Group V comprises about 190 hectares of lands covered with mangroves or mangrove stumps. Although some of these lands have been cleared for the purpose of rice cultivation, their production is very small.

Group VI designates a small area (50 hectares) with a shallow topsoil underlain by cemented material. It is under cultivation, but rice yields are limited to about 0.5 tons per hectare.

This analysis of present land use indicates that, although one-third of the project area is under cultivation, rice yields are severely limited by adverse natural conditions.

## Reclaimable Area

Inspection of the lands located in the project area enabled the identification of those parts of each area which are susceptible of economic reclamation. Table IV-1 summarizes these data. It shows that, in addition to the 32 percent of total arable lands presently under cultivation, about 53 percent can be reclaimed, thus bringing the area under cultivation to about 85 percent of the total arable land area.

Table IV-1 - Presently Cultivated and Reclaimable Areas in Each Present Land Use Class

| Present Land Use Designation | Arable Land Area (hectares) | Presently Cultivated Area | | Reclaimable Area 1/ | |
|---|---|---|---|---|---|
| | | ha | % | ha | % |
| I | 702 | 290 | 41 | 654 | 93 |
| IA | 526 | 0 | 0 | 526 | 100 |
| II | 304 | 155 | 51 | 284 | 93 |
| III | 860 | 382 | 49 | 807 | 94 |
| IIIA | 133 | 0 | 0 | 133 | 100 |
| IV | 210 | 75 | 36 | 75 | 36 |
| V | 188 | 0 | 0 | 0 | 0 |
| VI | 50 | 50 | 100 | 50 | 100 |
| Total | 2,973 ha | 952 ha | 32% | 2,529 ha | 85% |

1/ Includes presently cultivated area.

The data in Table IV-1 indicates that reclamation will result in a substantial increase of the cultivated area. However, this is not the only effect that will result from it. In addition to an increase of the useful area, the yields obtained from the lands presently under cultivation will be greatly increased as a result of drainage and land management.

## Topography

The project area is nearly flat except for the lands located along its eastern boundary. The ground slopes gently in two general directions: northward toward the Diberedi and southward toward the Koumba. Low spots or depressions are present between the dunes. These low areas are subject to ponding of water, creating a flooding problem, and possibly a salinity problem.

The flat areas will require little land preparation. Some levelling will be required to fill the existing depressions and insure drainage of surface water toward the canals. Land planning will be required over most of the project area.

## Land Evaluation

### Land Classification

The lands located in the project area were classified to estimate their potential value for rice cultivation. This classification takes into account the present land use, soils evaluation, and topography.

Six classes of land were established to represent significant degrees in the potential of lands for rice cropping. Each class corresponds

to a grouping of lands having similar present uses, physical and chemical properties, and topographic features. Each class corresponds, therefore, to a certain potential yield and to a certain cost of land preparation for satisfactory production. The classes are defined below:

Class 1. Lands with features of soils, topography and drainage which will provide for high yields at low production costs.

Class 2. Lands which are slightly less adaptable, therefore, with lower productive capacity yields and increased production cost.

Class 3. Lands with features which materially restrict their production capacity such as flooding, salinity, salt intrusion, hardpan near the soil surface, or pH. Greater expenses for drainage, leaching and land preparation will be necessary.

Class 4. Lands which are temporarily unsuited for agriculture because of flooding, tidal action, salinity, or low pH.

Class 5. Lands which are presently considered marginal, but which could prove suitable for agriculture after further engineering and agriculture studies.

Class 6. Lands which are unsuitable for any type of permanent agriculture.

Each land class was assigned a rating indicating the yields that can be expected. The rating for each land class is indicated in tabular form on Table IV-2.

It is estimated that at the present time about 400 hectares of Class 3 land yield about 0.7 tons of rice per hectare. About 1500 hectares are presently Class 4 land. Of these, about 450 hectares yield about 0.4

Table IV-2 - Rice Yields that can be Expected from Each Land Class

| Land Class | Rice Yield Range (tons/hectare) |
|---|---|
| 1 | 2.5 - 4.0 |
| 2 | 2.0 - 3.5 |
| 3 | 0.5 - 3.0 |
| 4 | 0 - 0.4 |
| 5 | 0 |
| 6 | 0 |

tons per hectare. The remainder is not in production. These data are shown in Columns (1) through (4) of Table IV-3.

It is estimated that immediately upon completion of the proposed drainage canals, the resulting surface drainage of the field will upgrade the lands that are presently Class 4 lands to a Class 3 rating. At the same time, the yields of all arable lands will be increased, as shown by Column (6) of Table IV-4. Thus, about 2530 hectares will have a Class 3 rating, with production yields ranging from 0.6 to 1.2 tons per hectare. Considering that about five percent of the area will be occupied by canals and levees, the net area of cultivable lands will then be about 2400 hectares, with an average yield slightly below one ton per hectare. These data are shown in Columns (6) through (9) of Table IV-4.

After a short period of development of five years, it is expected that the yield of these lands can be increased substantially: the best lands would yield about 2 tons of rice per hectare, the remainder about 1.5 tons per hectare. This is indicated on Table IV-4. Included in this development period are: very limited land preparation, surface leaching,

## Table IV-3 - Project Land Class Ratings through Development Period

| Present Land Use Designation (1) | Area of Reclaimable Lands (2) | Present Conditions | | After Reclamation | | After 5 Years | | After 10 Years | | After 20 Years | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Land Class Rating (3) | Rice Yield (tons/ha) (4) | Land Class Rating (5) | Rice Yield (tons/ha) (6) | Land Class Rating (7) | Rice Yield (tons/ha) (8) | Land Class Rating (9) | Rice Yield (tons/ha) (10) | Land Class Rating (11) | Rice Yield (tons/ha) (12) |
| I | 654 | 3 | 0.7 | 3 | 1.2 | 2 | 2.0 | 1 | 2.5 | 1 | 4.0 |
| IA | 526 | 4 | 0 | 3 | 1.2 | 2 | 2.0 | 1 | 2.5 | 1 | 4.0 |
| II | 284 | 3 | 0.7 | 3 | 1.2 | 2 | 2.0 | 1 | 2.5 | 1 | 4.0 |
| III | 807 | 4 | 0.4 | 3 | 0.6 | 3 | 1.5 | 2 | 2.3 | 2 | 3.5 |
| IIIA | 133 | 4 | 0 | 3 | 0.6 | 3 | 1.5 | 2 | 2.3 | 2 | 3.5 |
| IV | 75 | 4 | 0.4 | 3 | 0.6 | 3 | 1.5 | 3 | 2.3 | 3 | 3.0 |
| V | 0 | 5 | 0 | 5 | 0 | 5 | 0 | 5 | 0 | 5 | 0 |
| VI | 50 | 3 | 0.5 | 3 | 1.0 | 3 | 1.0 | 3 | 2.5 | 3 | 2.5 |
| Total | 2,529 | | | | | | | | | | |

Table IV-4 - Reclaimed Area and Yields Expected from Each Land Class

| Land Class Rating | Present Conditions | | | | After Reclamation | | | | 5 Years After Reclamation | | | | 10 Years After Reclamation | | | | 20 Years After Reclamation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | |
| | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av. |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
| 1 | | | | | | | | | | | | | 1464 | 1390 | 2.5 | 2.5 | 1464 | 1390 | 4.0 | 4.0 |
| 2 | | | | | | | | | 1464 | 1380 | 2.0 | 2.0 | 940 | 890 | 2.3 | 2.3 | 940 | 890 | 3.5 | 3.5 |
| 3 | 988 | 940 | 0.5-0.7 | 0.7 | 2529 | 2400 | 0.6-1.2 | 1.0 | 1065 | 1020 | 1.5 | 1.5 | 125 | 120 | 2.3-2.5 | 2.4 | 125 | 120 | 2.5-3.0 | 2.8 |
| 4 | 1541 | 1470 | 0 - 0.4 | 0.2 | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | |

agricultural extension, fertilizing, and other improvements of present agricultural practices. The project lands are not considered suitable for other crops at the present time, nor for the first few years of project operation.

The yields that can ultimately be expected from each area are shown in the last columns of Table IV-4.

## Land Management Problems

### General

Maximum production from the lands of the project will depend to a great extent on the way in which the soil, water, and land management problems are handled. Important management problems will be connected with land drainage and its effects on the chemical and physical properties of the soils, salinity control, and soil fertility. Immediately after completion of the proposed reclamation works, it will be advisable to begin a measurement program to establish records on the properties of the soils. Any changes in these properties during the period of development of the Project can then be noted. If necessary, any action program will follow, aimed at correcting the problems that may have arisen.

It is possible at this time to anticipate three major sources of difficulty that can be kept under control if properly diagnosed and treated. They are associated with soil toxicity, salinity, and fertility. The presence in the area of acid sulfate soils and soils with a high sodium absorption comples will probably pose the most difficult management problems.

## Toxicity

Acid sulphate soils generally contain a high content of sulphides. The lowering of the water table that results from surface drainage changes the reduction process to one of oxidation, indicated by a decrease of the measured pH. As a result of the formation of sulphuric acid, free iron and aluminum appear in the soils. These elements, when present in excessive quantity, may be toxic to the rice plants and hinder their growth. It will be important, therefore. to maintain the degree of acidity within a range that is high enough to prevent the formation of toxic elements. One way of accomplishing this consists of controlling the position of the groundwater table, thereby decreasing the rate of oxidation.

## Workability

Some of the alluvial soils in the project area contain a high percentage of sodium and a fairly low amount of calcium. Leaching of the calcium may change the absorption complex to one of sodium. This may affect the structure of the soil, causing it to be easily puddled and difficult to work. Such an objectionable soil complex can be modified by the addition of an electrolyte such as $CaCO_3$ or by the introduction of water containing calcium salts.

## Salinity

Control of the degree of salinity will be very important, particularly in the areas affected by salt intrusions. When the salt content level is high, the best time to leach them effectively will be at the beginning of the rainy season. Drainage must be effective at that time so as to remove the salts from the soil profile.



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## Fertility

The maintenance of soil fertility is also important to the success of the project. Organic matter decomposes rapidly in tropical conditions, particularly in well-drained areas. Maintenance and improvement of the content of organic matter should be accomplished for the following reasons:

(a) to preserve and improve soil physical conditions by maintaining good tilth and reducing soil erosion.

(b) to maintain the nutrient level of the soil and increase its base exchange capacity.

Crops residues, when ploughed back into the soil, help maintain soil fertility and act as a source of organic matter and plant nutrients. The addition of fertilizer will also cintribute to an increase of soil organic matter by increasing the amount of crop residue, including both stubbles and roots.

Chapter V

# AGRICULTURE

## National Production Requirements

### National Economy

A presentation of the Guinean economic structure is difficult because of the lack of accurate statistical data. The following data, based on estimates by Guinean and U.S. agencies, are intended to provide an economic background of the Monchon Project.

The population of Guinea is estimated to be about three million. Over 90 percent of the people receive their living directly or indirectly from agriculture, largely on a subsistence basis. Only about 120,000 persons are wage earners, most of them being employed in non-agricultural enterprises. The income per capita in rural areas is much lower than in the urban areas.

The gross national product appears to have been increasing constantly since 1959, largely as a result of gains in the mining industry. However, the per capita value of the gross national product has remained at about $100. The production per man-hour of agricultural labor is believed to have declined.

The amount of cash income received per capita is estimated to be about $40. However, for a large majority of the people, money is of little use except to buy a few products not available from the land. The usual pattern is for the family to consume most of the goods they produce and to use a small part for sale, or to barter for other products. The



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shortage of transportation facilities handicaps the movement of products beyond a relatively small radius.

## Foreign Trade

For many years Guinea has suffered from a serious trade deficit. This dificit will probably continue for some time unless energetic measures are taken toward self-dependency and economic development programs. A comparison of imports and exports is given in Table V-1.

The principal exports of Guinea are bananas, coffee, diamonds, and alumina.

Table V-1 - Guinea's Foreign Trade, 1957-62
(GF millions)

| | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 |
|---|---|---|---|---|---|---|
| Imports | 12,600 | 15,300 | 15,300 | 12,300 | 18,000 | 16,200 |
| Exports | 7,200 | 5,700 | 7,200 | 13,600* | 15,200 | 11,100 |
| Balance | -5,400 | -9,600 | -8,100 | +1,300* | -2,800 | -5,100 |

* Restudy of 1960 export figures by the U.S. Embassy indicated that errors made in that year's trade figures would actually show a barely balanced account, if not an actual deficit.

Prior to 1959 three quarters of the country's total value of exports were agricultural products and the remaining quarter were minerals. However, since that time, the composition of Guinea's exports has changed significantly. Agricultural commodities accounted for 62 and 40 percent of exports in 1959 and 1960, respectively, but only 32 and 30 percent in 1961 and 1962.

The main imports consist of machinery, cotton cloth, petroleum products, and rice. The value of agricultural imports in 1962 amounted to 18 percent of total imports, with rice being the most important, amounting to about 53 percent of total agricultural products.

The value of agricultural exports has exceeded value of imports in all recent years. However, in 1962 the difference was small because of large imports of rice and wheat flour.

Available data indicate that Guinea has become more dependent on imports to provide adequate food for her people, particularly rice and flour. Imports of rice amounted to approximately 10 percent of domestic production in 1962. Although it is believed that domestic production of food has increased slightly in recent years, population appears to have increased at a greater rate. However, official statistics on this point may be misleading because it is suspected that important quantities of agricultural commodities are smuggled out of the country.

## Agricultural Production

Although mineral production has become increasingly important in Guinea's export trade, agriculture remains the foundation of the country's economy. Guinean agriculture is segmented into an export sector and a subsistence sector. The export sector is the plantation-type farming consisting mainly of bananas, palm nuts, peanuts, coffee, pineapple, and rubber. The major staple food crops produced on subsistence farms are cassava, rice, millet, corn, and sweet potatoes. Livestock production is important economically but cattle are of poor quality and pastures are seriously over-grazed. It is estimated that there are about 1,300,000 head of cattle in Guinea, mostly undersized bush animals. It is the custom for farmers to be either a cultivator or a herdsmen but not both.

The grazing of livestock is free to cattle owners, who are usually nomad farmers.

Agricultural land in Guinea is held under three general types of ownership, each with distinct production practices and problems. Over 80 percent of agricultural land is farmed by the individual subsistence farmer. Individual holdings are generally small and crop yields are low. For the most part, these farmers have no cash surplus to spend on fertilizers or insect sprays. There is little money for even basic mechanization, although the majority of holdings are so small that mechanization would generally not be profitable. There is little understanding of crop rotation or proper land utilization. Burning of the vegetative cover to develop new fields is the usual practice. Imports of fertilizers go mostly to export crops.

The second type of ownership, that of the large commercial plantations, was introduced by the former colonial administration by issuing titles to land that was either not claimed or was tribal land not in use. These lands are used mostly for coffee and bananas.

The third general type of land ownership is a commercial kind of ownership, based on tribal affiliation. It is estimated that 10 percent of the arable land in Guinea is tribal land, existing mainly in Upper Guinea and in the coastal region of Lower Guinea. The land is owned in common by tribal groups but is divided into small plots and farmed by individual families. In practice, plots remain with the same family from generation to generation.

Much of the deficiency in agricultural production stems from the social condition of the average farmer. Lacking capital and training, he

barely succeeds in feeding himself. However, one of the most important factors holding down productivity is the high incidence of crop diseases. For this reason, serious failures have occurred in recent years for most crops, particularly bananas and rice.

Economic development programs for Guinea have recently been adopted by the Government with heavy emphasis on an increase of agricultural production. A Ministry of Rural Economy was organized in January 1961 to carry out the proposed agricultural programs. Development is to be concentrated on the reorganization of land tenure into cooperative holdings to the greatest extent possible, most of them to be owned either by the state or by commercial organizations. Production centers have been organized for the principal crops with emphasis on export crops. The Ministry of Rural Economy plans to furnish each of about 5000 villages with agricultural tools and machinery not now available.

## Rice Production

Estimates of total production of rice in Guinea are presented in Table V-2. Total production in 1962 was approximately one-third higher than in 1952-53, however, there has been practically no change since 1957-58. On the basis of a per capita index, rice production has consistently declined since 1958.

It is estimated that approximately 240,000 hectares of land are devoted to rice. The yield of rice is extremely variable but averages less than 1.5 tons of rice paddy per hectare.

Table V-2 - Production of Rice in Guinea

(rice paddy)

| Year | Total Production (metric tons) | Production Index (percent) | Per Capita Production Index (percent) |
|---|---|---|---|
| 1952-53 and 1954-55 (ave.) | 243 | 100 | 100 |
| 1957-58 | 312 | 128 | 113 |
| 1958-59 | 299 | 123 | 106 |
| 1959-60 | 319 | 131 | 109 |
| 1960-61 | 320 | 132 | 108 |
| 1961-62 | 320 | 132 | 104 |

## Food Requirements

Guinea is the third largest producer of rice in Africa, after Egypt and Madagascar, yet is unable to meet her own consumption requirements. Annual imports have increased consistently from about 7000 tons in 1959 to 30,000 tons in 1962 (polished rice). It is estimated that approximately 35,000 tons will be imported in 1963.

Much of the rice imported in recent years came from the United States. The quantity imported in 1962 under the surplus commodity program authorized by U.S. Public Law 480 amounted to almost 27,000 metric tons.

Rice is the basic staple in the average Guinean diet. It is estimated that each person consumes food equivalent to 2100 to 2400 calories per day of which almost 50 percent is supplied by rice.

Table V-3 - Guinea's Import of Rice

| Year | Metric Tons |
|---|---|
| 1959 | 7,000 |
| 1960 | 20,000 |
| 1961 | 25,000 |
| 1962 | 30,000 |
| 1963 | 35,000 1/ |

1/ Estimated on basis of present trade agreements

On the basis of production estimates plus imports, the consumption of rice per capita has increased consistently during the past 15 years. Consumption was computed at 235 grams per day in 1948 but increased to 310 grams in 1953, and 325 by 1962. It is expected that consumption per capita will continue to increase if adequate supplies are available.

As was seen in Table V-2, production per capita has consistently decreased since 1958. Unless this downward trend is reversed, the national deficit of rice will continue to rise and increasing amounts of imports will be required to meet the increasing demands of a growing population. At current consumption rates, an annual increase in supply of over 20,000 tons is necessary to meet requirements for the increase in population. This situation could easily become more critical if the rate of population growth exceeds the present rate of 3 percent per annum. This appears now highly probable.

## Present Production in Project Area

### General Country Practices

Rice production in Guinea may be separated into two general methods: (1) mountain rice and (2) plain or marsh rice. Estimates for the combined period of 1947-49 and 1952-54, presented in Table V-4, show that approximately 60 percent of the total production is mountain rice.

Mountain rice is produced by nomad farmers. The common practice is to cultivate a plot of land continuously until the natural soil fertility is depleted and then left idle for several years until regenerated by natural vegetation. The plots are very small, usually sufficient to supply only the families needs. Because of increasing demands for food, shorter periods of time are allowed for regeneration of organic matter while brush fires, repeated each year to clear the land, prevent the natural replacement by trees and other vegetation. This practice is detrimental to the land, particularly in mountainous areas, because it brings about a systematic destruction of the vegetative cover and an accelerated degradation of the topsoil through excessive erosion. The potential for increasing production of rice through improved management and cultural practices in all areas of Guinea is very great.

Data in Table V-3 show that approximately 15 percent of the total production of rice in Guinea is marsh or plain rice. It is difficult to estimate how much of this production is from the marsh areas but it is believed to be a large proportion.

Table V-4 - Estimated Production of Rice for Guinea and Lower Guinea, 1947-49 and 1952-54

(metric tons)

| Area | 1947-49 | 1952-54 |
|---|---|---|
| Guinea | | |
| Mountain rice | 100,000 | 140,000 |
| Plain or marsh rice | 75,000 | 103,000 |
| Total all Guinea | 175,000 | 243,000 |
| Lower Guinea | | |
| Mountain rice | 24,000 | 23,000 |
| Plain or marsh rice | 25,000 | 36,000 |
| Total for Lower Guinea | 49,000 | 59,000 |

Although the production from marsh lands in Lower Guinea is presently a relatively small portion of the total Guinean production, it is in this coastal zone that the potential for increasing rice yields is the greatest. Heavy precipitation during the wet season from June to November permits the culture of one annual crop of rice without irrigation. The soils, composed mainly of heavy alluvial clays, are for the most part fertile and suited for rice production.

Because of low elevation, these areas are poorly drained during the wet season and subject to the influences of salt water during high tides. The potential amount of riceland in Lower Guinea has been estimated at about 150,000 hectares of which 90,000 hectares are below sea level. Approximately 50,000 hectares are now sparsely cultivated. In recent years, 8000 hectares have been reclaimed and are being cultivated by methods generally adapted to local conditions, although this varies considerably from one area to the next.

Among the ricelands presently under cultivation in Lower Guinea, only those located in the valleys of the Konkoure or the Forecariah rivers produce relatively high yields. The large flows of these rivers prevent the intrusion of salt water on the land during the growing season, and yields of over four tons per hectare are not rare.

Most of the other ricelands in Lower Guinea suffer from excessive flooding during the wet season by fresh water due to lack of drainage or from salinity by salt water intrusion during high tide. The cultivators have attempted to reclaim some of these areas by construction of dikes and drainage channels but yields still are generally very low. Although reclamation of most of these lands is technically possible, the magnitude of the work involved is beyond the financial and physical capabilities of the cultivators.

Most of the rice is produced by antiquated hand methods, but attempts by the government are being made to mechanize and improve cultural practices. Present efforts are concentrated on reorganization of land tenure into cooperative holdings owned by the State or communal organizations (C. A. P.). To assist the cooperatives, Centers of Rural Mechanization (C. M. R.) are being established. These are, in effect, combination experiment stations, machinery pools, and land agent services. It was announced in March 1962 that 295 cooperates, and 27 C. M. R.'s had been established. Machinery and equipment are being imported, including about 400 tractors. The C. M. R.'s are operating rice enterprises by force account, mostly on new reclaimed land.

Though progress is being made, total production of rice from C. M. R., C. A. P., and private enterprises have fallen short of

established goals. Primary problems are associated with lack of trained personnel, machinery parts, fertilizers, and storage facilities, with losses from diseases and insects; and with poor cultural practices. Much of the machinery that has been imported is useless because of being unsuited to local conditions and because of lack of mechanics, trained operators, and spare parts for machinery.

Practices in the Project Area

As in most ricelands of Lower Guinea, widespread flooding by fresh water during the wet season and, to a certain extent, by salt water during high tides is the major limitation to rice production in the Monchon area. Little, if any, increase in production through improved management and cultural practices can be expected without, first, an effective control of flooding. Excessive flooding by fresh water is common to the entire plains, while flooding and intrusion of sea water is confined to specific areas, thus resulting in varying degrees of soil salinity. The lands adversely affected by salinity from tidal flooding are shown on Exhibits 4 and 5.

The cultivators have adopted rice production practices which reflect influences of the flooding, and of age-old cultural practices. Unimproved rice varieties known as Mamasu, Possa, and Singbegi are commonly grown on non-saline soils, and a salt resistant variety, Martini Male, on saline soils.

Nearly all of the rice in the project area is produced in small paddies, mostly for subsistence for the cultivator and his family. With the exception of clearing the land and preparing the seed bed, most of the work is performed by women. Clearing is accomplished by burning

and the seed bed is prepared by mere scratching of the surface with simple native grubbing hoes. The seed is planted in primary beds in July or early August, depending on flooding conditions, and after about six weeks, are transplanted in the paddy. Harvesting is done in about 145 days after planting, usually in December.

The value of weeding is recognized and weeds are apparently not a serious problem. Generally several families work together and go from one field to another, cleaning out and destroying the weeds. After the rice is in head, the fields are guarded by watchers to scare away birds and animals, but frequently large losses are sustained.

The rice is cut by hand with a sickle or knife. Usually, only the heads are cut, leaving stubbles about 8 to 10 inches long which are subsequently burned-off in preparation for the next crop. The rice is carried by women on their heads, usually to the native village, where it is dried and threshed. Threshing is done with flails and the straw separated from the rice by tossing it into the air. Hulling is accomplished by placing small amounts at a time in a crude basin hued out of a log and then pounding with a stock or pole. The rice kept for home use is stored in the family hut, with the portion kept for seed usually better protected against insects than the rice used for food.

Modern methods of controlling diseases and insects are not used. Frequently, complete crop failures are experienced and in most every year some damage and loss in production occurs. Since fertilizers are not used, yields diminish rapidly after two or three years of continuous cropping. The cultivator then moves to paddies that others have left, or to new land, allowing the old paddy to remain out of production for a year or so, and then eventually moving back or leaving it to another

family to cultivate. Although government officials indicated that there is ample land for the local population at the present time, it seems to be increasingly difficult to obtain plots that have been out of production long enough to regain the original fertility.

## Transportation and Markets

The surplus rice above the family's need for food and seed is bartered for other products among the natives, or sold to government stores, called "Comptoirs." As modern means of transportation and even animal-drawn wheeled vehicles are not available, the rice is carried on a man's head in bags weighing up to 50 kilograms to the nearest village where a truck may be available. Walking distance to a truck or a Comptoir may be as much as 15 kilometers.

The government of Guinea, through the Comptoirs, is in charge of distribution between regions. The government sets the price to be paid the cultivator for the rice, usually prior to planting time, and presumably on the basis of supply and demand conditions existing throughout the country. The Comptoir also acts as the retailer and sells rice at prices set by the Government.

## Present Production

Statistics on actual yields of rice on the project lands are lacking. Estimates by cultivators and local officials vary considerably, mainly because the exact area or the production are seldom measured. The only published yield data are estimates provided by local officials for the entire Region of Boffa. Available production data for the Administrative Region of Boffa in 1962 estimate that a total of 11,500 hectares produced 13,431 metric tons or 1167 kilograms per hectare.

Estimates of yields presently obtained in the Monchon area is shown in the table presented on Exhibit 4. Estimated production from each of the areas delineated on Exhibit 4 is given in Table V-5. The total production from the cultivated area of 952 hectares was 519 metric tons or an average of 545 kilograms per hectare.

Table V-5 - Estimated Crop Yields and Total Production of Rice on Project Lands

| Area Designation | Cultivated Riceland (hectares) | Average Yield (tons) | Total Production (tons) |
|---|---|---|---|
| I | 290 | 0.7 | 203 |
| IA | - | - | - |
| II | 155 | 0.7 | 108 |
| III | 382 | 0.4 | 153 |
| IIIA | - | - | - |
| IV | 75 | 0.4 | 30 |
| V | - | - | - |
| VI | 50 | 0.5 | 25 |
| Project Area | 952 | 0.55 | 519 |

These estimates are based on interviews with local cultivators, and government officials acquainted with the area, and on personal knowledge of the productivity of rice as evaluated by such factors as thickness of stands, extent of salinity and productive capacity of the soil, known performance of existing varieties, and estimated losses from disease and insects, etc.

The characteristics of the soil, as affected by salt water and shortage of water during the dry seasons, limit production to one crop per year. Provision of water from surface or underground storage during the dry season would enable double cropping. This possibility is beyond the scope of this investigation but does not appear to be feasible in this area.

## Anticipated Project Production

### Methods of Improving Production

Without provisions for drainage and reclamation of saline soils, production of rice on the Project lands will remain at low levels. With proper drainage and reclamation of saline soils, lands now only partially productive and most of the non-productive swampy lands will be capable of full production. Sustained production is possible providing adequate fertilizers are added and systematic rotations are introduced. Large increases in total production of rice will be possible as a result of: (1) bringing swampy and marshy lands into full production, (2) increased yields from varieties better adapted to well drained and non-saline soils, and (3) more intensive use of lands presently cultivated.

New and fertile riceland would be provided for additional cultivators, and existing plots could be enlarged to permit mechanization and more efficient operation. Additional forage for grazing of livestock will be available as a result of the enlarged and more productive cultivated area. Although rice cultivation and livestock raising are not integrated operations, the opportunity for integration will be improved as the lands will be more adaptable to systematic rotation with crops that are now restricted because of flooding and salinity conditions.

It is expected that several years will be required after the project is in operation before the full productive potential is attained. Numerous changes and improvements in cultural practices are necessary which will take considerable time even if extension and research programs, and financial assistance to the cultivators are available.

The production potentials due to drainage and reclamation, and to anticipated technological advancements for 20 years after the project is in operation have been estimated. Estimates of yields, cropping intensities, and crop rotations were analyzed for four 5-year time intervals over this period. Progressively higher crop yields corresponding to consistent improvement due to drainage and gradual reduction in salinity, increasing use of fertilizers, better seed, mechanization, plant protection, and systematic crop rotations were assumed.

Rice Submergence Criteria

The lands in the project area are flat and surface drainage toward the Sonie Koure will be in a direction opposite to the natural slope. It would not be economical to design the drainage system so as to avoid occasional submergence of the rice plants in the paddies. Consequently, it was determined to what extent rice plants could be submerged without being damaged.

Rice, when still in the vegetative stage of growth, can be completely submerged in clear water for short periods of time without being seriously affected insofar as production of seed is concerned, if the water is moving around the plants. The rice plants will withstand intermittent periods of complete submergence for about four days provided that the water level is subsequently lowered to about one-half of the

plant height for at least four days before complete submergence occurs again. An allowable cycle of submergence following these principles has been shown graphically on Exhibit 8. It was assumed that before initial submergence the rice plants would be about 30 centimeters tall, which is about the plant height when they are transplanted from the seed beds to the paddies.

If the rice is planted on butts or ridges that are 25 centimeters high, as is presently the practice in Lower Guinea, the allowable water surface elevations can be correspondingly higher.

These criteria are based on the fact that light penetrating shallow depths of clear water will enable the process of photosynthesis to continue. The criteria apply to water allowing at least 70 percent of light transmission. When sediments are in suspension, the allowable depth of submergence or the length of the period of submergence must be reduced.

The time of change from vegetative stage of growth to the reproduction cycle of the rice plant occurs from 70 to 80 days after seeding. After the rice plant has entered the reproduction phase, it rapidly becomes more susceptible to excess flood water. This is particularly true during the period starting two weeks before the panicle emerges and ending two weeks after panicle emergence.

However, taking into account the fact that this generally occurs in September, this period does not appear to be critical. The plants are then taller and precipitation is less intense. Flooding of the lands that may have occurred in August will be relieved by the drainage system shortly after its occurrence.

The implication of the above submergence criteria is that direct seeding in the fields will not be possible without risk of losing the crop. The use of seed beds and transplanting when the plants are about 30 centimeters tall will be necessary. Although this method requires additional labor, it is believed that the yields can be higher than those obtained from direct broadcasting.

Projected Crop Yields

Rice yields that can reasonably be expected over the 20 year development period have been presented in Table IV-3. For the first crop-year after the project is in operation, an average yield increase from 0.5 to 1.0 tons per hectare is expected. Most of this increase would be attributable to the improved drainage conditions, with little change from cultural practices or from reduction in soil salinity anticipated.

It is believed that five years will be required to leach the saline soils by alternate flooding and drainage from natural rainfall. At that time production levels equal to those presently obtained on non-saline soils could be realized. It is estimated that yields will be increased by 0.5 to 1.8 tons per hectare during this time, most of which would be attributable to the combined drainage and reclamation program. The average yields estimated with the project are similar to those obtained on well drained and non-saline soils using present cultural practices. With drainage and reclamation, higher yielding non-saline tolerant rice varieties will replace the low-yielding varieties. Also, increased yields will be possible because rapid drainage will permit better timing of planting and control of the fresh water supply. Improvements in cultural practices, fertilization, etc., are expected to be slow and will, therefore, not be significant factors towards increasing yields during the

initial 5-year period. Allowances for nominal applications of fertilizers, particularly phosphorus, were made in estimating probable yields and costs of production. Progressive increases due to these improvements are practical after this time up to 20 years after the project is in operation.

The potential for continued increases due to improvements in cultural practices is great. These will not occur, however, without technical assistance from agronomists working with the farmers and financial assistance to obtain fertilizers, insecticides, etc. It has been assumed that this assistance will be provided as an integral part of the reclamation program after the project is in operation.

## Anticipated Land Use and Crop Rotations

The anticipated land use, cropping intensities, and cropping rotations for each five-year period are presented in Table V-6. We have assumed a three-year rotation with rice occupying two-thirds of the cultivated land area but with increasing amounts of other crops occupying the remaining one-third of the land. The cropping intensity is expected to increase gradually from 67 to 100 percent. A cropping intensity of 100 percent will be possible sooner than 20 years if ample technical and financial assistance is available to the cultivators.



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Table V-6 - Projected Crop Land Use and Cropping Intensity

(in percent)

| Crops | Number of Years After Reclamation | | | |
|---|---|---|---|---|
| | 1 | 5 | 10 | 20 |
| Rice | 67 | 67 | 67 | 67 |
| Lespedeza* | -- | 8 | 15 | 20 |
| Maize* | -- | -- | 3 | 9 |
| Grain sorghum* | -- | -- | -- | 4 |
| Percent cultivated | 67 | 75 | 85 | 100 |

* Or equivalent legume forages and grain crops.

## Projected Agricultural Production

Total production anticipated for various time intervals after the project is in operation are summarized in Table V-7. These estimates are based on average yields for rice given in Table IV-3. The gross reclaimed area has been reduced by five percent to allow for land utilized by dikes, levees, and drainage channels from which no production will be obtained. The net reclaimed project area is 2400 hectares.

Table V-7 - Estimated Total Agricultural Production with the Project

(metric tons)

| Years | Crops | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rice | | Lespedeza | | Maize | | Grain Sorghum | | Idle | Total in Prod. |
| | Ha. | Prod. | Ha. | Prod. | Ha. | Prod. | Ha. | Prod. | Ha. | (ha) |
| 1 | 1600 | 1600 | - | -- | - | - | - | - | 800 | 2400 |
| 5 | 1600 | 2800 | 200 | 2000 1/ | - | - | - | - | 600 | 2400 |
| 10 | 1600 | 3840 | 360 | 3600 1/ | 80 | 160 | - | - | 360 | 2400 |
| 20 | 1600 | 6080 | 500 | 5000 1/ | 200 | 500 | 100 | 200 | - | 2400 |

1/ Equivalent green weight.

## Land Settlement

There is no specific national or regional policy for selection of settlers for the new project lands after reclamation. Assuming an average of four-hectare farm units, sufficient land would be available to support 600 families. This would be equivalent to an additional 245 units than are in existence at present.

Local officials anticipate no problems in getting voluntary movement of families from other areas immediately upon completion of the project. There is also the possibility that cooperatives may be developed to operate large sections of land with the help of mechanization. However, for the purpose of analysis, it is assumed that the lands would be settled for subsistence farming in units averaging four hectares each.

Chapter VI

# PROJECT DESIGN

## Introduction

A plan for the reclamation of the Monchon Area was developed in 1957, and its implementation started with the dredging of a drainage canal. This plan, developed by the Service du Genie Rural and the Service des Travaux Publics, was well defined in its general lines. However, few data were found relative to its details. It is believed that dredging of the main drainage canal was commenced in advance of detailed design or planning of the remainder of the reclamation plan.

The basic concept of the 1957 plan of reclamation, i.e., drainage of the Monchon plains toward the Sonie Koure, has been reviewed and is considered to be sound. However, certain engineering studies had to be performed within the scope of the present assignment to select the type of structures that will be needed to reclaim the plains, to determine the dimensions of these structures, and to estimate their cost.

The engineering studies consisted of hydrologic analyses, hydraulic investigations, structural and foundation designs, and a survey of quantities. These studies are described in this chapter.

## Water Supply

### Consumptive Use Requirements

An estimate of the consumptive use requirements of rice was made on the basis of evaporation recorded at Boke, and using the results of



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systematic experiments made by the Rice Pasture Experiment Stations, Beaumont and Eagle Lake, presented in a report of the Texas Board of Water Engineers. 1/

Monthly evaporation data for Boke are presented in Table VI-1. These data indicate relatively low rates of evaporation during the wet season, probably due to the high relative humidity that prevails at that time.

Table VI-1 - Measured Monthly Piche Evaporation at Boke in millimeters

| Year | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|
| 1958 | - | 56 | 43 | 29 | 45 | 55 | 59 | 106 |
| 1959 | 179 | 83 | 47 | 30 | 38 | 45 | 65 | 115 |
| 1960 | 121 | 49 | 50 | 38 | 39 | 47 | 70 | 179 |
| 1961 | 139 | 95 | 44 | 33 | 41 | 60 | 69 | 122 |
| 1962 | 151 | 75 | 53 | 39 | 85 | 53 | 65 | - |

Although Piche measured evaporation is somewhat higher than the theoretical lake surface evaporation, measured evaporation data were used without correction. The highest evaporation recorded from 1958 to 1962 for each month were multiplied by the Use Coefficients KU found by the Texas Experiment Stations for the corresponding stage of growth, except that the June coefficient was used for the month of July, for conservatism. The results are summarized in Table VI-2.

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1/ Consumptive Use of Water by Major Crops in Texas, Bulletin 6019, by Louis L. McDaniels, Texas Board of Water Engineers, November 1960.

Table IV-2 - Estimated Consumptive Use Requirements of Rice in Monchon Area

| Month | June | July | Aug. | Sept. | Oct. | Nov. | Total |
|---|---|---|---|---|---|---|---|
| Evaporation, mm | 95 | 53 | 39 | 85 | 60 | 69 | |
| Use coefficient KU | 1.8 | 1.8 | 2.0 | 1.5 | 1.0 | 1.6 | |
| Consumptive Use Requirement, mm | 171 | 95 | 78 | 128 | 60 | 110 | 642 |

## Available Moisture Supply

It is generally accepted that the moisture available from natural rainfall over the Monchon area is sufficient for the cultivation of one crop of rice. This belief is based on the heavy precipitation that occurs during the growing season that extends from July through December. Rice generally requires from 1000 to 1500 millimeters of rain from seeding time to harvesting.

Although no records are available in the immediate area of Monchon, rainfall estimates have been made on the basis of the long-term Boke records and of the precipitations recorded at Yogoya. The conditions prevailing at Yogoya are considered to be representative of those for the Monchon area, since the distance between Yogoya and Monchon is less than five kilometers. The 1957 precipitation recorded at Yogoya was about 10 percent greater than that recorded at Boke, therefore, the use of the Boke records would appear to be conservative. The annual precipitation recorded at Boke from 1933 through 1962 was used to

construct a frequency curve, presented on Exhibit 9, which was considered to be representative of the annual precipitation over the Monchon area. This curve indicates that 95 percent of the time the annual precipitation at Monchon is equal to, or greater than, 2000 millimeters. This can be expressed differently: an annual precipitation of 2000 millimeters or less would occur not oftener than once every 20 years.

It would appear, since all of the annual precipitation occurs during the wet season, that the wet season rainfall is well in excess of the requirements for rice cultivation. However, it is reported that unusually dry years result in lower rice production in some parts of Guinea. Apparently, this has not been a common occurrence in the Monchon area, because the lack of drainage causes the water to pond for extended periods of time, thus storing all the water needed for the growth of rice. As a matter of fact, decreases in production in this area were more likely to result from excessive rainfalls, such as happened during the 1962 wet season. This condition will be corrected by construction of the proposed drainage facilities. It is important, therefore, to determine whether the expected rice production will be affected by possible droughts.

Rainfall distribution recorded in 1955 was selected for this investigation. The annual precipitation in 1955 at Monchon is estimated to have been 2200 millimeters. This year is the second driest on record, and corresponds to a recurrence of about once every 10 years, as shown by the duration curve.

A mass curve of cumulative rainfall for the months of October and November was drawn, as shown on Exhibit 9. The mass curve shows that an average daily rate of eight millimeters could be sustained until the middle of November, provided that a storage of 15 centimeters

were plotted on a logarithmic-probability chart, and frequency curves drawn and their frequency determined. From the frequency curves, the precipitation for one, two, three, six, and thirty consecutive days corresponding to probabilities of 10 percent (10-year recurrence interval) was determined. These values were increased by 10 percent since the short period of available data at Yogoya indicated that precipitation in the Monchon area exceeded that at Boke by about 10 percent. The resulting chart of cumulative rainfall for consecutive days, presented on Exhibit 9, is considered representative of the Monchon area.

This chart shows that the difference between the 10-year and the 30-year cumulative rainfalls is not great. A recurrence interval of 10 years was selected for design purposes. This selection results in the acceptance of damages to agricultural crops in the event of occurrence of a more intense rainfall. However, damages would probably not be great in view of the fact that the 30-year, six-day rainfall (500 millimeters) is only 15 percent greater than the 10-year, six-day rainfall (435 millimeters).

Table VI-3 shows the cumulative and incremental rainfall for 15 days that can be expected once every 10 years. It should be noted that the incremental daily values given in the tabulation are not necessarily in chronological sequence, although the cumulative values correspond to consecutive days.

For the purpose of determining a realistic chronological sequence, the maximum 15-day precipitation period recorded in 1962 was examined. The year 1962 was considered because its annual rainfall of 3070 millimeters (3380 millimeters estimated at Monchon) has a recurrence of

Table VI-3 - Monchon 15-day Precipitation with a 10-year Recurrence Interval

| Number of Consecutive Days | Cumulative Precipitation in consecutive days (mm) | Incremental Precipitation (mm) |
|---|---|---|
| 1 | 200 | 200 |
| 2 | 255 | 55 |
| 3 | 305 | 50 |
| 4 | 350 | 45 |
| 5 | 400 | 50 |
| 6 | 435 | 35 |
| 7 | 475 | 40 |
| 8 | 515 | 40 |
| 9 | 550 | 35 |
| 10 | 585 | 35 |
| 11 | 615 | 40 |
| 12 | 650 | 35 |
| 13 | 680 | 30 |
| 14 | 710 | 30 |
| 15 | 730 | 20 |

about once in 10 years, and also because daily precipitation data were available for that year. During the 15-day period from August 21, 1962, through September 4, 1962, a total rainfall of 530 millimeters were recorded at Boke, corresponding to an estimated 585 millimeters at Monchon.

Table VI-4 shows the largest precipitation for consecutive days of the August 21, 1962, storm. Also shown in Table VI-4 are comparable values as given in Table VI-3. An examination of the last two columns of Table VI-4 reveals that the August-September 1962 storm is fairly close to the 10-year event for the first nine days. After the

ninth day, the daily rainfall increments in the 1962 storm were definitely smaller than the 10-year event.

Table IV-4 - Comparison of the August 21, 1962, Storm, Adjusted for Monchon, with 10-year Storm

| Number of Consecutive Days | Precipitation of Storm from Aug. 21 - Sept. 4, 1963 (mm): Daily Precipitation, in Chronological Order | Precipitation of Storm from Aug. 21 - Sept. 4, 1963 (mm): Max. Cumulative Precipitation for Consecutive Days | 10-year Event Cumulative Precipitation for Consecutive Days (mm) |
|---|---|---|---|
| 1 | 23 | 162 | 200 |
| 2 | 71 | 245 | 255 |
| 3 | 162 | 316 | 305 |
| 4 | 83 | 376 | 350 |
| 5 | 45 | 447 | 400 |
| 6 | 86 | 470 | 435 |
| 7 | 1 | 498 | 475 |
| 8 | 50 | 521 | 515 |
| 9 | 20 | 541 | 550 |
| 10 | 4 | 545 | 585 |
| 11 | 2 | 547 | 615 |
| 12 | 11 | 558 | 650 |
| 13 | 1 | 559 | 680 |
| 14 | 1 | 560 | 710 |
| 15 | 7 | 567 | 730 |

## Design Storm

The 15-day storm selected for the purpose of designing the drainage facilities is identical to the August 21 storm for the first nine days. Thereafter, a uniform daily rainfall of 30 millimeters was adopted, on the basis of the values shown in Table VI-3. The storm pattern thus obtained is believed to reflect realistic meteorological conditions typical

of a 15-day storm with a 10-year recurrence interval. The total cumulative rainfall would be about 730 millimeters. The distribution of this storm is shown graphically on Exhibit 9.

Excess Rainfall

Excess rainfall is defined as that portion of the rainfall that is not lost through evaporation or percolation. It corresponds to the amount of water that must be drained from the land or temporarily stored in the fields to be drained later.

An estimate of the evaporation that can be expected during the design storm was made on the basis of observations made by the National Meteorologic Service during the August 1962 storm. The average evaporation recorded at Boke in August 1962 on a Piche evaporation gage was approximately 40 millimeters per month. This amount was reduced to 30 millimeters per month to take into account the difference in elevation between Boke (80 meters above mean sea level) and the Monchon plains (6 meters above mean sea level).

On the basis of the results of permeability tests made in the Monchon area, percolation was estimated to amount to approximately 50 millimeters per month. A nominal amount of 30 millimeters per month was assigned to plant use during submergence.

On the basis of these estimates the total losses would be 120 millimeters per month. A total of 60 millimeters, uniformly distributed, were subtracted from the 15-day rainfall to obtain the excess rainfall. This is indicated graphically on Exhibit 9.



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## Main Canal Design

### Water Level in the Paddies

The Monchon plains are located at an elevation ranging between 5.5 and 7.5 meters above the Ray datum of reference. Their detailed topography is shown on Exhibit 2 by contours at vertical intervals of 20 centimeters. With the exception of low lying areas located along the upstream end of the main canal, most of the fields in the central part of the plains have a ground elevation of approximately 5.8 meters minimum.

The flooding criteria established in Chapter V, applied to fields located at an elevation of 5.8 meters, require that the water surface in these fields not exceed elevation 6.1 for more than four days, and that thereafter it be brought back to a maximum elevation of 5.95 for a period of at least 11 days. In the fields located at a higher elevation, the flooding criteria can be satisfied if the head loss in the secondary and lower order canals does not exceed the difference in elevation between the ground elevation of the fields and elevation 5.8. The small areas located below elevation 5.8 may not benefit from the drainage facilities to the same degree as the remainder of the plains in the event of occurrence of a severe and prolonged storm. These areas must be accepted as being marginal for the sake of overall economy.

The design of the main canal was conducted so as to operate with a normal water surface elevation 6.05 at its upstream end. This condition corresponds to a water surface at elevation 6.1 in the nearby paddies, allowing a minimum head loss of five centimeters between the paddies and the main canal.

## Tide Criteria

The capacity of the main drainage canal will be influenced by the elevation of the water surface in the Sonie Koure at the outlet of the main canal. Observations made in 1950 by the Genie Rural concluded that the level of the Sonie Koure is practically not affected by the discharge of fresh water from runoff, but is dependent mainly upon the amplitude of ocean tides. This is confirmed by the observations of the cross-sectional area of the Sonie Koure as reported in Chapter III.

The 1951 report by the Genie Rural mentioned the following tide observations:

| | |
|---|---|
| Amplitude at Conakry | 3.50 meters |
| Flood level at Dentema | 3.65 meters (Daude datum) |
| Ebb level at Dentema | 0.65 meters (Daude datum) |
| Amplitude at Dentema | 3.00 meters |

The report recommended for design purposes the selection of an average elevation of 2.40 meters (Daude datum), equivalent to an elevation of about 4.70 meters above the Ray datum. Subsequently, the Public Works Department accepted, as the basis of design, the water levels recorded near Dentema in September 1953. These levels are shown on Exhibit 3.

In the review report of 1954, these data were reviewed, and the recorded high tides were accepted. However, the high ebb levels recorded from September 22 through 27, corresponding to amplitudes as low as one meter, could not be explained. They were declared inaccurate and rejected. On this basis, the review report recommended the use of the following elevations for design purposes:

| | |
|---|---|
| Flood level at Dentema | 5.9 (Ray datum) |
| Ebb level at Dentema | 3.7 (Ray datum) |
| Amplitude at Dentema | 2.2 meters |

The selection of this amplitude of 2.2 meters, intended to be that for maximum tidal backwater conditions, resulted in a reduction of the cross section of the main canal of about 20 percent from that previously selected.

The basic data were reviewed by the Harza team. The September 1953 level records were accepted as plausible. The unusually high ebbs recorded at Dentema were found to be associated with the large ocean tides that occur during the full moon. The hydraulic characteristics peculiar to the Koumba and Sonie Koure are the cause of this occurrence. The same pattern was found to be typical of other Guinean tidal streams. Consequently, the tide levels as recorded in 1953 were adopted for the design of the main canal as described in the following section.

Since the chronological coincidence of the full moon high ebbs with the most intense daily precipitation of the design storm would have a small chance of occurrence, it was considered that these two severe occurrences would not occur at the same time. The method of design used is described later in this chapter.

## Gated Control Structure

As mentioned in Chapter II, a control structure provided with automatic flap gates, located across the main canal near the Mintani dune, was part of the reclamation plan until 1954. The reasons for deleting this structure from the plan are not known, but it appears that it was considered unnecessary by 1954.

This structure is considered essential for the following reasons:

(a) It prevents refilling of the main canal with water from the Sonie Koure during high tides. This results in a larger average discharge capacity of the canal, appreciable in this case because of the flat topographic slopes.

(b) It permits the control of salt water intrusion into the canal system during the dry season. As explained in Chapter V, this will result in an increased rice production, found to justify largely the cost of the control structure.

The control structure is designed to be provided with timber flap gates. Hydraulic investigations were conducted to determine the size of gates that would result in an acceptable loss of head. It was found that the proposed size would cause head losses smaller than 0.2 meters. In addition, the flap gates would be able to close almost instantaneously upon reversal of flow, thus allowing only negligible amounts of salt water to enter the canal system.

Hydraulic Design of the Main Canal

From the field investigations described in Chapter III it appeared that deposition of sediment has occurred in the main canal reach between the Mintani dune and the Sonie Koure since its construction. It was not possible to determine the dimensions of the canal as it was dredged in 1957-58, since no "as-built" drawings were available. However, it appears likely that the recommendations made in the 1954 report were implemented. The main canal, as recommended in this report,

would have had a length of about 4500 meters, a depth varying from 3 to 2 meters and a bottom width varying from 15 or 16 meters to about 12 meters at the upstream end. The side slopes would have been 2 horizontal to 1 vertical.

Hydraulic calculations were made to determine the performance, in the event of occurrence of the design storm, of a main canal having approximately the same dimensions. This canal was 4500 meters long, with a bottom width of 16 meters, side slopes of 2:1, and an invert sloping from elevation 3.8 at the upstream end to elevation 3.0 at the junction with the Sonie Koure. The hydraulic characteristics of this canal were determined taking into account an expected sloughing of the banks to a stable slope of 6:1, as shown on the cross-section of the main canal presented on Exhibit 10. Loss of head in the canal was estimated using a Manning friction coefficient of 0.030.

Backwater calculations were made to determine the discharge capacity of the canal as a function of: (a) the water surface elevation in the Sonie Koure taking into account the head loss through the gated structure, (b) the water surface elevation at the upstream end of the canal. The average canal discharge capacity was determined for two tidal cycles: the first corresponding to normal high tides; the second corresponding to full moon high tides. The results are presented graphically on Exhibit 8, where the average canal discharge for each tide condition was plotted versus various upstream water elevations.

## Water Surface Elevation in the Paddies

Using the discharge capacity curves shown on Exhibit 8, the variations of the water surface elevation in the paddies were calculated.



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The analyses were made for the critical case of the 15-day design storm occurring while water was ponded in the paddies to elevation 9.95. It was assumed that during the first few days of the storm, tides in the Sonie Koure would have normal amplitudes, so as not to compound several events, each of which have a small chance of occurrence.

The variations of the water surface in the paddies, as found from the calculations, are presented graphically on Exhibit 8. Also shown on the same graph is the submergence criterion. A comparison of the two graphs indicates that in the event of occurrence of the design storm, the water surface in the paddies will rise by less than 10 centimeters above the lowest rice plants. Submergence will last about 5 1/2 days, then the level will drop rapidly to its normal operating elevation. The duration of submergence,as found from the calculations,will be somewhat longer than that of the submergence criterion. However, since the depth of submergence reached was considerably smaller than that allowed, it is believed that no damage will be caused to the crops. Therefore, it was concluded that the proposed canal dimensions will be satisfactory for the purpose of maintaining flood levels in the paddies within safe limits during intense storms.

The maximum flow in the canal during discharge of the ponded volume was found to be about 26 cubic meters per second.

The canal dimensions thus selected are about the same as those to which the first reach was constructed. However, the present design takes into account the reduction in cross-section that will result from the flattening of the side slopes. This effect was apparently ignored in the previous designs. This led to a decrease of the canal capacity by

about 20 percent after stabilization of the banks, hence, the present need for rehabilitating the existing main canal reach.

## Design of the Secondary and Other Canals

### Layout in Plan

Secondard areas were laid out in accordance with natural boundaries as defined by the dune s, dikes, and drainage patterns of the project topography. Secondary and tertiary canals within these areas were located to take maximum advantage of both natural drainage and the existing drainage network as constructed in the 1940's. Existing 300 meter spacing of tertiaries and 100 meter spacing of quaternaries was found to be satisfactory and was used where appropriate throughout the project. The layout of existing and proposed drainage canals is shown on Exhibit 2.

### Canal Sections

The design storm was applied to the several areas served by quaternary, tertiary, and secondary canals. The maximum runoff to be discharged by the canals was found to be 700 liter per second per square kilometer and the canals were sized accordingly. Quaternaries are considered to be nominal field ditches to receive only single paddy runoff. Tertiaries extend generally at right angles with both quaternaries and secondaries and serve a number of paddies on either side. Specific runoff for tertiaries was determined as 22 liters per second for each 100 meters of length. Each secondary was designed to accept tertiary runoff yield at various points along its length. Small water surface slopes permitted use of approximate back water methods to

properly adjust water surface levels throughout the system and prevent excess heading up in the paddies during the critical design storm period. Geometric elements of the channels were selected to sustain low flow velocities above silting values for self-maintenance and provide for subsidence of excavated side slopes. Exhibit 9 shows typical elevations for both excavated and expected ultimate canal sections. Tertiary 1 1/2:1 side slopes are not expected to slough because of their relatively shallow depth and because field observations revealed approximate 1 1/2:1 side slope angle of repose in similar ditches.

## Chapter VII

# PROJECT CONSTRUCTION

### Introduction

The various features of the Morchon Project are relatively simple, and no unusual difficulties are expected during construction. However, because of the present shortage in heavy construction equipment and skilled labor in Guinea, it is believed that the services of a foreign contractor will be required.

Past experience in the Project area has shown that the local population will be capable of performing, both collectively and individually, only small scale work within the limits of their own lands. Consequently, it will be most advantageous to have the contractor perform as much of the civil works as is economically feasible. This will consist of the main, secondary and tertiary canals, the dikes, the control structure, and the bridges. Land preparation, consisting of levelling and planing operations, will be best accomplished with the mechanical equipment presently available to the Center of Rural Mechanization (C.M.R.). Installation of the new paddies and rehabilitation of existing ones will be left to the individual farmers.

Completion of the work is estimated to require about two years. A schedule of construction is presented on Exhibit 10.

### Access to the Project Site

The Project site is readily accessible to wheeled vehicles from the main north - south unpaved road between Conakry and Boke. The nearest

commercial airport is located near Boke, about 85 kilometers from the Project area on unpaved roads. The nearest port is that of Victoria. Access by small boats from Victoria to the Dentema dune is easily practicable by way of the Koumba and Sonie Koure rivers. The distance on these waterways is about 85 kilometers.

## Excavation of the Canals

The main item of work for construction of the Project consists of channel excavation. Although final selection of the construction method will be left to the contractor's option, it appears from a comparative study that a combination of floating dredge and crawling draglines will yield the most economical results. The cost estimates are based on this solution.

It is expected that shortly after award of the construction contract the contractor will move a floating dredge to the Project site. This dredge would be of the suction type, with cutterhead and about ten-inch suction and discharge pipes. The average excavating capacity of a ten-inch dredge would be about 100 cubic meters per hour. This capacity would be sufficient to perform the work within economic time limits. The dredge would be shipped to Guinea in a knocked-down condition, and partly reassembled at or near Victoria. The dredge would be moved to the outlet of the main canal by towing or by self-propulsion. Assembly would be completed at the Project site.

Excavation of the main canal by the dredge will be started at the downstream end, and the dredge will proceed upstream as the canal is excavated to the specified dimensions. About 220,000 cubic meters will be dredged from the main canal.

The draft of a ten-inch dredge is about 0.75 meters. In order for the dredge to be operated during the lowest tides, it may be necessary during the dry season to construct a low cofferdam across the canal, provided with a gated conduit. This temporary cofferdam will permit to maintain in the excavated section a sufficient depth of water.

Dredging during the wet season will be advantageous since most of the fine material put in suspension by operation of the cutterhead will be transported by the flow. The material sucked by the dredge will be pumped through the discharge pipe and deposited in settling basins along the canal, on one or both sides. These spoil areas will be located far enough from the bank's edge so as to allow for sloughing of the banks without excavated material being brought back into the canal. Maintenance roads will be located on the spoil banks.

The secondary and tertiary canals will be excavated by draglines concurrently with the main canal dredging, but only during the dry seasons. It is estimated that two draglines with 3/4 cubic yard buckets will be used by the contractor, together with one D-8 type bulldozer and one hauling truck. The total amount of material to be excavated by the draglines is estimated to be about 635,000 cubic meters. The draglines will first be used to excavate the canals located in the western part of the project area so as to put part of the reclaimable area under production after one year of construction.

## Structures

The Project includes a gated control structure across the main canal at the Dentema dune, a main bridge at the Mintani dune, and smaller structures and bridges throughout the Project area.

Construction of the gated control structure will require temporary cofferdams enclosing the work area during the first dry season. Wooden piles will be driven in the foundations and reinforced concrete placed in the dry for the slab and the piers. The deck and the gates will then be installed and the temporary cofferdams removed. The main bridge over the canal at the Mintani dune will be constructed in a similar manner.

A small, portable, concrete batching plant will be required on the project. Materials for concrete aggregates are not available in the immediate vicinity of the Project. They will have to be hauled from a quarry. Cement to be used in the concrete structures will be Type V cement, or Type II mixed with pozzolan admixtures, so as to give the concrete a better resistance to the action of salt water.

Precast concrete elements for cribs will be cast near the batching plan, to be transported and used for construction of the abutments of structures and bridges. Materials for the bridge decks, such as creosoted timber, structural steel and miscellaneous metal parts will be brought to each site, and the bridges erected.

## Land Preparation

Preparation of the lands for project operation will consist of minor levelling and smoothing over approximately one-quarter of the reclaimed project area. Paddies will be made level to permit dikes to be spaced at reasonable intervals and provide operating room for machinery. Local surface irregularities will be removed at the same time.

This work will be best performed by the C.M.R. Coordination of the land preparation with the civil works construction will be effected by the resident engineer and the project agronomist. Preparation of a portion of the project lands can thus be completed before the entire project.

Each area to be leveled will be surveyed and appropriately marked to indicate cut and fill areas. Rubber tired tractors developing about 60 horsepower, and self-loading scrapers with a capacity of about two cubic meters will be required to perform the leveling. The same equipment can also be used to construct and maintain the levees in the paddies.

## Quaternary Canals and Levees

Quaternary canals will be small ditches excavated along the paddies. It is estimated that about 100 meters of such canals will be excavated for each hectare of land. This excavation will be performed by hand be each farmer and his family. The material excavated from the ditches will be spoiled on the sides to form the levees surrounding the paddies. This work has been estimated to involve about 25,000 cubic meters of land excavation.



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Chapter VIII

# PROJECT ECONOMICS

## Scope and Procedure

This chapter presents details of the economic appraisal of the Monchon Project. The principal objectives sought were: (1) to determine if increases in production anticipated from the Project are sufficient to justify the estimated costs, and (2) to estimate the ability of the farmers to pay the costs of operation, maintenance, replacement, and amortizing the project investment.

The analyses follow general principles used by international financing institutions and most United States government agencies in determining economic and financial feasibility of resource development projects. Some modifications of standard procedures were necessary because of lack of data required to complete a rigorous analysis, and because of unique conditions of a non-private land tenure system, nomad and "shifting" cultivation, subsistence farming, and a non-market economy.

The validity of the estimates of increased income due to the drainage and reclamation programs is dependent upon a careful analysis of benefits resulting from anticipated land use under conditions with and without project development. This was accomplished by farm budgeting which provided for systematic outlining of the organization and operation of agricultural enterprises in the area, and included the anticipated income and expenditures for a normal cropping season.

## Projected Farm Income

### General Procedure

The general approach was to estimate the increase in farm income with the Project over that existing without the Project.

The basic agricultural unit in the Monchon area was considered to be a four-hectare farm. Economic budgets for this farm unit were analyzed assuming that the Project would not be constructed, and under conditions anticipated at four stages of development of the reclamation project: immediately upon completion of construction, and five, ten, and twenty years thereafter.

The first step was to obtain the gross farm income from total agricultural production under all conditions considered, by estimating the production of the four-hectare farm unit and the corresponding value of the crops.

The second step consisted of estimating the production costs. Farm investments were determined. The corresponding annual value and the current expenses of the farm yield the total annual production costs.

The third step was to determine the net crop income for each of the stages of development considered by deducting the production costs from the gross farm income. The increase in net income with the Project was then computed by deducting the net income without the Project from that with the Project.

### Projected Prices

The prices of farm products and items of farm costs should theoretically reflect long-term supply and demand relationships anticipated

over the economic life of the Project. Because prices are arbitrarily set by the Government, projected prices based on anticipated supply and demand relationships would not be realistic. Prices for major farm products at the farm and retail levels for 1961, 1962, and 1963, as shown in Table VIII-1, were used in the study.

Inspection of Table VIII-1 indicates that the relation between farm and retail prices of white rice (polished) was 90 percent of the retail price in 1963, but only 75 percent in 1961. For some products, the farm price is only 60 percent of the retail price. This variation in spread presumably reflects the costs of marketing. However, according to estimates by some government officials, this difference is unrealistic for many products.

## Farm Expenses

Investment in Land. There is little private capital, in the form of cash outlay, invested in the Project lands. An exclusive "de facto" right to use land is established by each cultivator when he settles on it, but neither the land nor improvements made during occupancy may be sold or transferred. Existing improvements including clearing, leveling, drainage and diking have been accomplished by individual cultivators almost entirely by hand without cash expenditures. Although these improvements increase the value of land for production, they do not represent an increased equity for the land users. Therefore, the present private capital investment in land has been assigned no value.

Additional land development necessary for proper cultivation and drainage of individual farm units will consist of one or more of the following operations: (1) land leveling and grading, (2) renovation of levees;(3) installation of quaternary canals connecting to the tertiary and other canals.

Table VIII-1 - Farm and Retail Prices for Farm Products in Guinea, 1961-1963

(Guinean Francs)

| Products | Unit | 1961 | | 1962 | | 1963 | |
|---|---|---|---|---|---|---|---|
| | | Farm | Retail | Farm | Retail | Farm | Retail |
| Palm nuts | kg | 15-20 | 32-40 | 25 | 37-40 | 25 | 37-40 |
| Palm oil | liter | 60 | 80 | 68 | 125 | 70 | 125 |
| White rice, polished | kg | 30-40 | 50 | 45 | 55 | 45 | 50 |
| Red rice, polished | kg | 25-30 | 40 | 40 | 50 | 40 | 45 |
| Rice paddy | kg | 17-50 | 25 | 25 | 30 | 27 | 30 |
| Peanuts, non-shelled | kg | 20 | 35-40 | 25 | 35 | 25 | 40 |
| Millet | kg | 20 | 25 | 20 | 25 | 20 | 25 |
| Coconuts | each | 5 | 10 | 7 | 15 | 7 | 15 |
| Fonio, cleaned | kg | 15 | 25 | 30 | 40 | 30 | 40 |
| Fonio, paddy | kg | 10 | 20 | 20 | 25 | 20 | 25 |
| Sweet potatoes | kg | 10 | 15 | 10 | 15 | 10 | 15 |
| Bananas | kg | 23 | 30 | 23 | 30 | 23 | 30 |
| Pineapples | kg | - | 90 | - | 90 | - | 90 |
| Meat: beef | kg | - | - | - | - | - | 180-225 |
| mutton | kg | - | - | - | - | - | 250-350 |
| pork | kg | - | - | - | - | - | 500-800 |
| Poultry | each | - | - | - | - | - | 200-500 |
| Eggs | kg | - | - | - | - | - | 15-20 |
| Fish | kg | - | - | - | - | 72-90 | 80-115 |

The cost of leveling and grading has been included in the Project investment. Quaternary canals and levees within each farm land will be constructed by hand by the farmers. The spoil material from the canals will be used for construction of the levees surrounding the paddies. It is expected that a nominal amount of cash outlay for simple tools will be required for performance of this work. The value of this work, however, has been estimated to be about GF 29,625 per farm, including grading at a unit price of GF 4625 per hectare and surface drains at a unit price of about GF 2,780 per hectare.

It is expected that some technical services will be required to supervise the installation of these facilities. Costs for these services are not included in the farm expenses, since they are included in the Project operating costs.

Investment in Buildings. The amount of investment in farm buildings is very small. Existing buildings consist primarily of a mud-thatched house for the family, and a small wooden-thatched structure to provide protection for a few sheep, goats, or chickens. Additional buildings per farm are not expected with the Project, although some improvements in the type of house will gradually be made, and new units will be established.

A typical house consists of dried mud walls on a lathing of wood branches, and roofed with grass thatching. The floors are mud and in some cases, the front step is dried mud blocks with a thin covering of cement plaster. The house can be built in approximately three months by two men and three women. The men do most of the actual construction, with the women helping by transporting materials. Most of the materials are gathered by the family. Total cost of the house and other structures is estimated to be GF 100,000 including all materials and the value of labor. The breakdown of this estimate is shown in Table VIII-2.

Table VIII-2 - Estimated Cost of Typical Farm Family Dwelling

| Item | Unit Costs (GF) | Total Costs (GF) |
|---|---|---|
| Thatch grass | 2,000 | 2,000 |
| Wall lathing | 1,500 | 1,500 |
| Roof timber | 1,500 | 1,500 |
| Mason | 12 days at 1000 | 12,000 |
| Family labor | 15 man-months at GF 5,333 | 80,000 |
| Nails, wire, etc. | | 3,000 |
| | Total | 100,000 |



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A few houses are now being constructed with galvanized iron roofs, walls of cement blocks covered with a thin layer of cement plaster, and floors covered with sand-cement mortar. It has been assumed that with improved economic condition as a result of the Project this type of house will be the most prominant after a few years of operation. The cost including labor for a cement-iron roof house was estimated to be GF 175,000 on the basis of unit costs of basic material shown in Table VIII-3.

Table VIII-3 - Costs of Various Items Used in Construction of Farm Dwelling and Buildings

| Item | Unit | Unit Cost (GF) |
|---|---|---|
| Lumber for doors and window flups | per meter | 100 |
| Galvanized - iron roofing | 2-meter lengths | 600 |
| Cement | 45 kg bag | 575 |
| Sand - transported by pirrogue from mouth of Koumba River | 1/2 $m^3$ | 1000 |
| Carpenter - labor | per man-day | 3500 |
| Family labor | per man-day | 225 |

It is estimated that other farm buildings, including a shelter for a few head of livestock plus storage space for tools and rice, would cost about GF 25,000 per family unit. This includes an equivalent value for family labor and materials expended for construction which, for the most part, does not represent cash expenditures. The size and total cost for farm buildings will increase proportionately with increases in crop and livestock production.

For analytical purposes, one-half of the investment cost for the family dwelling and all of the other farm buildings are charged as a farm investment. Annual costs for depreciation are based on a five percent sinking fund extended over the estimated useful life of the house at 100 percent of the original cost. This assumes an accumulation of funds to replace the buildings at the end of their useful life. Cost of repairs are calculated at three percent of the original cost.

Other Improvements. There are few other farm improvements present or considered necessary. Farm fences are non-existent. Domestic water is carried, usually by the women on their heads, from nearby stream or shallow village wells. Public utilities such as telephones and electricity are not available. Machine sheds and repair shops are not needed because there is little, if any, machinery except as owned and operated by the CMR. Minor repairs on equipment is done mostly by the cultivator, but in some instances, facilities for building and repairing crude tools are available in the nearby village centers. For the most part, significant changes in these types of improvements are not anticipated within the foreseeable future.

Machinery and Equipment. At the present time, most rice is produced by hand methods. The average inventory and estimated cost of equipment used by the typical farm family are presented in Table VIII-4.

For the minor equipment listed in Table VIII-4, annual repair costs, excluding labor, are computed as two percent of the initial cost. Depreciation is based on a five percent sinking fund over the useful life, and calculated on 90 percent of first cost, with ten percent allowed for salvage value.

Table VIII-4 - Estimated Amount, Original Cost, and Annual Costs of Equipment Per Subsistence Farm

| Item | Number | Original Cost (GF) | Estimated Life (years) | Annual Depreciation (GF) | Cost Repairs (GF) |
|---|---|---|---|---|---|
| Grubbing hoes | 3 | 650 | 10 | 52 | 13 |
| Axes | 2 | 600 | 10 | 48 | 12 |
| Machette - Sickles | 4 | 1,000 | 10 | 80 | 20 |
| Flails | 3 | 600 | 2 | 293 | 12 |
| Shovels | 2 | 800 | 5 | 145 | 16 |
| Rice sacks | 10/ton | 1,000 | 3 | 317 | 20 |
| Storage container | 1 | 1,250 | 10 | 100 | 25 |
| Screens for cleaning | - | 600 | 5 | 108 | 12 |
| Wheel barrel 1/ | 1 | 7,150 | 10 | 560 | 153 |
| Polishing container | 1 | 500 | 5 | 90 | 10 |
| Miscellaneous | | 1,450 | - | 115 | 29 |
| Total | | 15,600 | | 1,908 | 322 |

1/ Assumed owned only at later stages of development.

Mechanization of rice production is expected to develop very slowly. Government officials stated that the services of the CMR will eventually be extended to private cultivators, although cooperatives and force account enterprises have first choice on existing machinery at the present time. Some small plows, suited to pulling by animals, have been imported but none were being used at present.

It was assumed that little change from present hand cultivation methods will occur during an initial five-year development period. For subsequent periods, it is assumed that machinery and equipment for plowing and for harvesting will be available on a rental basis. Estimated

rental charges for machinery to perform various operations are presented in Table VIII-5. For machinery assumed to be rented, annual costs are included in the rental charge.

Table VIII-5 - Rental Charges for Farming Operations

| Item | Unit | Total Costs (GF) |
|---|---|---|
| Plowing | hectare | 3000 1/ |
| Discing, harrowing, etc. | hectare | 2000 1/ |
| Combining | hectare | 3500 1/ |
| Drying rice | 100 kg. | 150 |
| Cleaning or hulling rice | 100 kg. | 125 |

1/ Includes cost of fuel at GF 500 per hectare.

Fuel and oil for operation of a tractor was based on local costs. The price for gasoline varies from GF 41 to GF 45 per liter. Diesel fuel is sold at GF 28 per liter, and oil from GF 250 to GF 300 per liter.

Inventory Value of Livestock. The inventory value of livestock is presented in Table VIII-6. These data were used in the analysis to represent future conditions that may be expected with integrated crop and livestock enterprises, 10 to 20 years after the project is in operation.

Table VIII-6 - Inventory Value of Livestock

| Item | Value (GF) |
|---|---|
| Milk cow | 20-25,000 |
| Beef steer | 15-25,000 |
| Sheep | 4- 5,000 |
| Goat | 2,000 |
| Pig | 20-30,000 |
| Chicken | 200 |
| Eggs (dozen) | 60 |

Taxes. All agricultural enterprises are exempt from taxation. There is at present a head tax of GF 500 which must be paid on all persons of working age, except indigents. There is no real estate taxes on agricultural land.

Improvements in education, medical and transportation fa ilities, contemplated for the future will require additional taxes. Although it is not known how taxes for improvements will be assessed it was assumed that taxes will be increased to GF 1000 per person by the fifth year of operation of the project, seven persons being taxable on a farm.

Interest. There has been little need for credit facilities for agricultural purposes by subsistence farmers. Provisions are being made by the government to establish credit for plantation and cooperative-type farming for export crops. Current interest rates for these enterprises and for non-agricultural businesses are adopted for this analysis, and amount to the following:

| Length of Loan | | Interest Rates |
|---|---|---|
| Short-term | - up to 9 months | 4% |
| Medium-term | - up to 5 years | 5% |
| Long-term | - 5 years and up | 6% |

Other Crop and Livestock Expenses. The annual requirements and estimated costs for commercial fertilizer, seed, plant protection, and miscellaneous livestock expenses are presented in Tables VIII-7 through 10. These data were obtained mostly from local sources but with some adjustments to assure adequate requirements for the levels of production assumed for the study.

It is assumed that seed for planting would be home-grown, exceptions being for pasture crops and speciality crops, such as grain sorghum.

Table VIII-7 - Fertilizer Requirements and Annual Cost per Hectare[1/]

| Crop | Portion of Area Fertilized Each Year (%) | Amount of Fertilizer Hectare (kg) | Annual Costs Per Hectare (GF) |
|---|---|---|---|
| Rice and Grain Sorghum[4/] | 80 | 134[2/] | 8300[3/] |
| Legume grass | 40 | 56 | 2740[3/] |

1/ Recommended rates for full production potential.

2/ Based on 78 kgs. of nitrogen and 56 kgs. of phosphates per hectare.

3/ Based on cost of nitrogen at GF 71 per kilogram and phosphate at GF 49 per kilogram. Phosphate applied to legume grass (Lespedeza) only.

4/ Portion of area fertilized upon completion (one-year) estimated at 25%.

Table VIII-8 - Seeding Rates and Annual Costs per Hectare

| Crop | Seed Required (kg) | Cost per Kilogram (GF) | Seeding Interval (years) | Annual Costs (GF |
|---|---|---|---|---|
| Rice | 57.27 | 32 | Annual | Farm |
| Legume clover | 15 | 400 | 3 | 2000 |
| Maize | 33 | 35 | Annual | 1155 |
| Sorghum | 10 | 300 | Annual | 3000 |

Table VIII-9 - Cost of Seed Treatment, Pest and Weed Control[1/] Per Hectare

| Crops | Costs Per Measure (GF) | | | | |
|---|---|---|---|---|---|
| | Pests | Diseases | Weed Control[1/] | Seed Treatment | Total Costs |
| Rice | 500 | 445 | - | 275 | 1220 |
| Legume clover (Lespedeza) | 500 | - | - | 250 | 750 |
| Grain sorghum | 500 | 250 | - | - | 750 |
| Maize | 500 | 250 | - | - | 750 |

1/ Rates of application and costs for full protection program.

Table VIII-10 - Miscellaneous Costs for Livestock Expenses Per Head

| | GF |
|---|---|
| Beef and dairy cattle: | |
| Vaccinations | 125 |
| Minerals, salt, etc. (2 kg. at GF 75) | 150 |
| Miscellaneous equipment and supplies | 125 |
| Total per Head | 400 |
| Sheep: | |
| Dippings, parasite control, etc. | 60 |
| Miscellaneous equipment and supplies | 75 |
| Total per Head | 135 |

Miscellaneous Farm Expenses. Miscellaneous expenses, estimated at five percent of total itemized farm expenses, are included in the budgets



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to cover unforeseen contingencies and minor expenses normally incurred but not specifically identified with a specific crop enterprise.

Labor Requirements and Wage Rates. Few statistical data are available on the amount of labor expended in producing rice or other crops on subsistence farms. Estimates obtained from cultivators and government officials varied considerably. It was generally agreed that a typical family of one man with two wives plus their children, could cultivate about three hectares of rice plus sufficient other land to provide their own food requirements, and have a small portion of the production for sale. In most instances some additional labor, usually exchange labor with neighbors, is required during the peak work load seasons.

The man labor requirements for rice was estimated at 800 man-hours per hectare, or 100 eight-hour days, excluding time spent in hulling and preparation for cooking. An increase of approximately 10 percent for each additional increase in yield of 1.0 ton per hectare was used in projecting future requirements without mechanization, most of which is assumed to be hired or exchange labor. Use of tractors and powered machinery for plowing, harvesting, and threshing would reduce labor requirements by more than one-half. Estimates for labor requirements and equivalent costs in producing rice are presented in Table VIII-11.

Wage rates, set by the government, are GF 28 per hour for farm labor and GF 32 for non-farm labor, primarily in Conakry. This amounts to about GF 225 or about $0.90 per day. Work contributed by women in producing crops is considered equally productive as for men.

Although wage rates may appear low, there is evidence that they are high relative to the marginal value productivity of labor. Because labor comprises the major portion of total costs an inbalance in its pricing tends

to affect adversely the economic feasibility of the project. On most subsistence farms much of the available labor is under-employed and alternative employment opportunities offering greater economic returns are practically nil. Assuming this represents future conditions throughout the period of analysis the cost of family labor could justifiably be excluded as a production cost in computing project benefits. Because of the uncertainty of this situation and because present cultivators do sustain themselves economically, the imputed value of family labor has been considered as an economic cost and it has been included in computing net returns to the drainage and reclamation program.

Table VIII-11 - Estimated Man Labor Requirements, and Equivalent Costs for Rice Production Under Present Cultural Methods

| Operation | Unit | Annual Man-hour Requirement per Hectare 1/ | Equivalent Labor Costs per Hectare (GF) |
|---|---|---|---|
| Preparing seed bed | Plot | 20 | 450 |
| Seeding primary bed | Plot | 10 | 225 |
| Preparing land in paddy | Hectare | 100 | 2,250 |
| Transplanting rice 2/ | Hectare | 60 | 1,350 |
| Weed control | Hectare | 200 | 4,500 |
| Harvesting | Hectare | 200 | 4,500 |
| Threshing and cleaning | Hectare | 200 | 4,500 |
| Total | | 790 | 17,775 |

1/ Does not include time of one man hour per four kilograms of rice estimated for hulling and preparation for cooking and cleaning for sale.

2/ Assumed to continue to be done manually in the future.

## Farm Budgets

The five farm budgets established for conditions without the project and for conditions anticipated upon completion of the construction and after five, ten, and 20 years of operation are presented in summary form on Tables VIII-12 through 16. The net income found in each of the five farm budgets were used to determine the increase in net income as shown in Table VIII-17 for each farm unit.

Results of the analysis show that net income, after a five-year development period, will increase from GF 6,738,000 to GF 55,033,000 or by an average of over GF 20,100 per hectare for the net reclaimed area of 2400 hectares. Most of this increase is attributable to production from about 650 hectares of new land which is now essentially non-productive because of poor drainage and saline conditions. The total increase includes the value of farm privileges, composed of non-cash allowances for the equivalent rental value of the farm dwelling, and the market value of the rice and other products consumed by the farm family.

The results for conditions anticipated after 10 and 20 years of operation show that large increases in production and income are possible with moderate applications of fertilizers, insecticides, improved plant varieties, and better cultural practices. It is estimated that net income after 10 and 20 years of operation could be increased by about 40 and 180 percent, respectively, above that estimated after five years without these improvements.

Table VIII-12 Farm Budget No. 1 - Estimated Income and Expenses From Subsistence Rice Farm Without Reclamation Project

(In Guinean Francs)

| Crop | Production and Value: Hectares | Unit | Yield | Total | Price | Value | Disposition of Production: Seed | Consumed | Sales |
|---|---|---|---|---|---|---|---|---|---|
| Rice | 2.7 | Kg | 545 | 1,472 | GF 32 | 47,100 | 3,840 | 38,400 | 4,770 |
| Idle | 1.3 | | - | - | | - | - | - | - |
| Total | 4.0 | | | | | 47,100 | 3,840 | 38,400 | 4,700 |

**Farm Investment**

| Item | Value |
|---|---|
| Land Development | GF - |
| Dwelling (Farm Share) | 50,000 |
| Other Improvements | 15,000 |
| Equipment and Supplies | 15,600 |
| Miscellaneous | 4,030 |
| Total | GF 84,630 |

**Farm Expenses**

| Item | Value |
|---|---|
| Interest on Investment | GF 5,080 |
| Taxes | 3,500 |
| Depreciation and Repairs: | |
| a. Buildings and Improv. | 7,120 |
| b. Equipment | 2,230 |
| Cleaning at GF 3/kg. | 4,056 |
| Hired Labor 1/ | 6,000 |
| Marketing at GF 2.5/kg. | 265 |
| Miscellaneous (5%) | 1,413 |
| Total | GF 29,664 |

**Financial Summary**

| Item | Value |
|---|---|
| Cash Sales | GF 4,770 |
| Farm Privileges: | |
| a. Consumed by Family | 38,400 |
| b. Rental Value of Dwelling | 5,475 |
| Total Income | 48,645 |
| Total Expenses | 29,664 |
| Net Income | GF 18,981 |
| Family Labor Income 2/ | (18,981) |

1/ Equivalent value of hired or exchange labor.

2/ Total equivalent value of labor estimated at GF 60,750 of which GF 6,000 is exchange or hired labor.

## Table VIII-13 Budget No. 2 - Estimated Income and Expenses From Subsistence Rice Farm Upon Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value: Hectares | Unit | Yield | Total | Price | Value | Disposition of Production: Seed | Consumed | Sales 1/ |
|---|---|---|---|---|---|---|---|---|---|
| Rice | 2.7 | Kg | 1,000 | 2,700 | GF 32 | 86,400 | 4,928 | 48,000 | 32,950 |
| Idle | 1.3 | | | | | | | - | - |
| Total | | | | 2,700 | | 86,400 | 4,928 | 48,000 | 32,950 |

### Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 29,625 |
| Dwelling (Farm share) | 50,000 |
| Other Improvements | 20,000 |
| Equipment and Supplies | 15,600 |
| Other | 5,760 |
| Total | GF 120,985 |

### Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 7,259 |
| Taxes | 3,500 |
| Depreciation and Repairs: | |
| a. Buildings and Improve. | 7,665 |
| b. Equipment | 2,230 |
| Cleaning at GF 3/kg | 7,638 |
| Hired Labor 2/ | 7,500 |
| Marketing at GF 2.5/kg | 1,830 |
| Fertilizer | 3,350 |
| Miscellaneous | 2,049 |
| Total | GF 43,021 |

### Financial Summary

| Item | Value |
|---|---|
| Cash Sales | GF 32,950 |
| Farm Privileges: | |
| a. Consumed by family | 48,000 |
| b. Rental value of dwelling | 5,475 |
| Total Income | 86,425 |
| Total Expenses | 43,021 |
| Net Income | GF 43,404 |
| Family Labor Income 3/ | (43,404) |

1/ 1,046 kg paddy or 732 kg polished at GF 45.

2/ Equivalent value of hired or exchange labor.

3/ Based on labor requirements of equivalent to GF 61,875 of which GF 7,500 is hired or exchange labor.

Table VIII-14 Budget No. 3 - Estimated Income and Expenses From Subsistence Rice Farm Five Years After the Reclamation Project

(In Guinean Francs)

| Crops | Production and Value: Hectares | Unit | Yield | Total | Price | Value | Disposition of Production: Seed | Consumed | Sales 1/ | Feed |
|---|---|---|---|---|---|---|---|---|---|---|
| Rice | 2.70 | kg | 1,800 | 4,860 | GF 32 | 155,520 | 4,928 | 48,000 | 100,440 | |
| Lepedeza | .33 | kg | 10,000 | 3,300 | 3.7 | 12,210 | | | | 12,210 |
| Idle | .7 | | | | | | | | | |
| Total | 4.0 | | | | | 167,730 | 4,928 | 48,000 | 100,440 | 12,210 |

Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 29,265 |
| Dwelling (Farm Share) | 87,500 |
| Other Improvements | 25,000 |
| Equipment and Supplies | 19,700 |
| Miscellaneous | 8,590 |
| Total | GF 170,055 |

Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 10,225 |
| Taxes | 7,000 |
| Depreciation and Repairs: | |
| a. Buildings and Improv. | 12,320 |
| b. Equipment | 3,630 |
| Cleaning rice at GF 3/kg | 14,067 |
| Hired Labor 2/ | 9,000 |
| Marketing at GF 2.5/kg | 5,580 |
| Fertilizer | 6,700 |
| Seed (Lepedeza) | 667 |
| Miscellaneous | 3,459 |
| Total | GF 72,648 |

Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 100,440 |
| b. Fodder (Equiv. products) | 3,300 |
| Farm Privileges: | |
| a. Rice consumed | 48,000 |
| b. Other products | 3,295 |
| c. Rental value of dwelling | 9,375 |
| Total Farm Income | 164,370 |
| Farm Expenses | 72,648 |
| Net Income | GF 91,722 |
| Family Labor 3/ and Management | 54,750 |
| Residual Income Available for Profit and Repayment | 36,972 |

1/ 3189 kg. paddy or 2232 kg. polished rice at GF 45.

2/ Assumed hired labor or equivalent value of exchange labor.

3/ Labor requirements of equivalent value at GF 63,750 of which GF 9,000 is exchange labor.

Table VIII-15 Budget No. 4 - Estimated Income and Expenses From Subsistence Rice Farm Ten Years After the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value: Hectares | Unit | Yield | Total | Price | Value | Disposition of Production: Seed | Consumed | Sales | Feed |
|---|---|---|---|---|---|---|---|---|---|---|
| Rice | 2.7 | kg | 2,400 | 6,480 | GF 32 | 207.360 | 4,928 | 48,000 | 152,010 1/ | - |
| Maize | .1 | kg | 2,000 | 200 | 35 | 7,000 | 115 | 1,925 | 4,960 | - |
| Lespedeza | .6 | kg | 10,000 | 6,000 | 3.7 | 22,200 | - | - | - | 22,200 2/ |
| Total | 4.0 | | | | | 236,560 | 5,045 | 49,925 | 156,970 | 22,200 |

Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 29,625 |
| Dwelling | 87,500 |
| Other Buildings | 30,250 |
| Equipment and Supplies | 25,265 |
| Livestock | 22,500 |
| Miscellaneous | 9,760 |
| Total | GF 204,900 |

Farm Expenses

| Item | Value |
|---|---|
| Interest on Investments | GF 12,295 |
| Taxes | 7,000 |
| Depreciation & Repairs: | |
| a. Buildings & Improv. | 12,895 |
| b. Equipment | 4,185 |
| Equipment Rental | 10,200 |
| Marketing | 8,415 |
| Crop Seed | 1,000 |
| Cleaning Rice | 18,980 |
| Fertilizer | 8,770 |
| Plant Protection 3/ | 1,550 |
| Hired Labor | 10,000 |
| Livestock Expenses | 400 |
| Miscellaneous | 4,790 |
| Total | GF 100,580 |

Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 152,010 |
| b. Other Crops | 11,065 |
| Farm Privileges: | |
| a. Rice Consumed | 48,000 |
| b. Other Products | 8,030 |
| c. Rental value dwelling | 9,375 |
| Total Farm Income | 228,480 |
| Total Expenses | 100,580 |
| Net Income | 127,900 |
| Family Labor & Management | 57,970 |
| Residual Income Available for Profit and Repayment | 69,930 |

1/ 4826 kg of paddy or 3378 polished at GF 45/kg.

2/ Equivalent value of livestock products at GF 12,210 assumed sold or eaten in home.

3/ Assumes 40% coverage of cultivated area.

Table VIII-16 Budget No. 5 - Estimated Income and Expenses From Subsistence Rice Farm 20 Years After Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value | | | | | | Disposition of Production | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hectares | Unit | Yield | Total | Price | Value | Seed | Consumed | Sales 1/ | Feed |
| Rice | 2.7 | kg | 3,800 | 10,260 | GF 32 | 328,320 | 4,928 | 48,000 | 270,540 | - |
| Maize | .3 | kg | 2,500 | 750 | 35 | 26,250 | 350 | 1,925 2/ | 23,975 2/ | - |
| Lepedeza | .8 | kg | 12,000 | 9,600 | 37 | (35,520) | - | (9,770) | (9,770) | (35,520) |
| Grain Sorghum | .2 | kg | 2,000 | 400 | 40 | 16,000 | - | - | 16,000 | - |
| Idle | - | - | - | | | | | | | |
| Total | 4.0 | | | | | 370,570 | 5,278 | 49,925 | 310,515 | (35,520) |

Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 29,265 |
| Dwelling (Farm Share) | 87,500 |
| Other Improvements | 35,500 |
| Equipment and Supplies | 32,000 |
| Livestock | 45,000 |
| Miscellaneous | 11,460 |
| Total | GF 240,725 |

Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 14.445 |
| Taxes | 7,000 |
| Depreciation and Repairs: | |
| a. Buildings & Improv. | 13,500 |
| b. Equipment | 4,740 |
| Equipment Rental | 12,000 |
| Marketing | 15,030 |
| Crop Seed | 2,545 |
| Cleaning Rice | 30,320 |
| Fertilizer | 12,655 |
| Plant Protection | 4,265 |
| Hired Labor | 15,000 |
| Livestock Expenses | 1,000 |
| Miscellaneous | 6,625 |
| Total | GF 139,125 |

Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 270,540 |
| b. Other Crops | 49,745 |
| Farm Privileges: | |
| a. Rice Consumed | 48,000 |
| b. Other Products | 11,695 |
| c. Rental value of home | 9,375 |
| Total Farm Income | 389,355 |
| Total Expenses | 139,125 |
| Net Income | GF 250,230 |
| Family Labor and Management | 74,215 |
| Residual Income Available for Profit and Repayment | 176,015 |

1/ Rice sold 8589 kg. at GF 45.

2/ Equivalent value of sales or amounts consumed on farm.

Table VIII-17 - Summary of Increased Net Crop Income With Drainage and Reclamation, Monchon Project, Guinea

| Item | Unit | Without Project | With Project: Upon Completion | With Project: Five Years After Completion | With Project: Ten Years After Completion | With Project: Twenty Years After Completion |
|---|---|---|---|---|---|---|
| Rice | Hectare | 950 | 1,600 | 1,600 | 1,600 | 1,600 |
| Other Crops | Hectare | - | - | 200 | 440 | 800 |
| Idle | Hectare | 1,450 | 800 | 600 | 360 | - |
| Total | | 2,400 | 2,400 | 2,400 | 2,400 | 2,400 |
| Gross Income | GF 1000 | 17,269 | 51,855 | 98,622 | 137,088 | 233,613 |
| Farm Expenses | GF 1000 | 10,531 | 25,813 | 43,589 | 60,348 | 83,475 |
| Net Income | GF 1000 | 6,738 | 26,042 | 55,033 | 76,740 | 150,138 |
| Per Hectare | | | 10,850 | 22,930 | 31,975 | 62,560 |
| Net Increased Income | GF 1000 | - | 19,304 | 48,295 | 70,002 | 143,400 |
| Per Hectare | | - | 8,043 | 20,123 | 29,168 | 59,750 |

## Economic Analysis

### General Procedure

The economic value of the Monchon Project has been analyzed on the basis of the relative measure of benefits and costs. Project benefits are defined as those benefits resulting from the increases in services and production of goods attributable to construction of the project. They have been classed as direct, indirect, and public benefits, and their annual values have been estimated separately for several stages of project development. In addition to benefits susceptible to monetary measurement, the project will result in significant benefits which are intangible and to which no monetary value can be assigned. Although these were not included in the analyses, their importance should not be discounted.

Project costs have been estimated on an average annual basis, using a rate of return of six percent per annum, which is what could be expected from equivalent investments in alternative enterprises in Guinea.

### Annual Equivalent Costs of the Project

The total annual equivalent costs are the amortized net project investment (construction cost plus interest during construction) plus the average annual operation, maintenance, and replacement costs. The economic life of the project, taken as 50 years, was used as the length of the period of analysis.

A rate of interest of six percent per annum was selected as applicable to the project investment, as indicated on page VIII-10.

The construction cost of the project has been estimated to be $1,300,000 and GF 220 million, or a total equivalent to GF 545 million.

The detailed estimate of the project construction cost is presented on Exhibit 11. At an interest rate of six percent, the interest during construction amounts to about GF 35 million. The project investment is GF 580 million. Amortized over a period of 50 years at six percent per annum, the project investment is equivalent to GF 37 million. Annual charges for operation, maintenance and replacements, estimated to be GF 6 million, were added to obtain the annual equivalent cost of the project, GF 43 million.

## Direct Benefits

Direct benefits are the increases in net income anticipated for the entire project area after completion of the reclamation project. The net project income for conditions without the project and for each stage of development was derived from the net farm income and the corresponding number of farm units. The increases in total net income for each level of development from the net income accruing to the Monchon area were thus calculated. These values were discounted to account for the fact that the projected levels of production will be obtained after a number of years. The resulting values are the direct benefits corresponding to each stage of development.

Discount factors, as used in Table VIII-18 are functions of the rate of interest and the length of the evaluation period. The magnitude of these elements is critical to the amounts of annual equivalent benefits. A 50-year period of analysis and an interest rate of six percent were used.



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Table VIII-18 - Determination of Direct Project Benefits
(Amounts in GF 1000)

| | Without Reclamation Project | Upon Completion of Project | After 5 Years of operation | After 10 Years of operation | After 20 Years of operation |
|---|---|---|---|---|---|
| Net farm income | 18,981 | 43,404 | 91,722 | 127,900 | 250,230 |
| Number of farms | 355 | 600 | 600 | 600 | 600 |
| Net project income | 6,738 | 26,042 | 55,033 | 76,740 | 150,138 |
| Increase in net income | - | 19,304 | 48,295 | 70,002 | 143,400 |
| Discount factor | - | 1.00 | 0.89 | 0.78 | 0.65 |
| Total direct benefits | - | 19,304 | 42,983 | 54,602 | 93,210 |
| Use GF 1000 | | 19,500 | 43,000 | 55,000 | 93,000 |

## Indirect Benefits

Indirect benefits are increases in net income to persons other than the cultivators as a result of the increased flow of rice and other crops from the project lands. These benefits are normally estimated by the use of factors representing the ratio of a share of profits in processing and retailing to the increased value of the crop sales. As such factors are not available for Guinea, estimates have been made on the basis of differences between farm and retail prices of the products sold.

In 1963, the farm price of rice paddy was GF 27 per kilogram, and the retail price of polished red rice was GF 45 per kilogram, or GF 65 per kilogram of equivalent paddy. As farm and retail prices are established by the government, the difference between farm and retail prices of rice does not necessarily correspond to the actual added value due to processing. For the purpose of determining indirect benefits, the added value for increase sale per kilogram of rice paddy polished and processed by the farmers for their consumption and for marketing was taken conservatively as GF 4.5 per kilogram. The determination of indirect benefits, discounted as in the case of direct benefits, is summarized in Table VIII-19.

Table VIII-19 - Determination of Project Indirect Benefits

| | Upon Completion of Project | After 5 years of operation | After 10 years of operation | After 20 years of operation |
|---|---|---|---|---|
| Increase in rice production (not including seed), tons paddy | 385 | 1,859 | 2,842 | 5,099 |
| Added value, GF 1000 | 1,734 | 8,368 | 12,788 | 22,948 |
| Discounting factors | 1.00 | 0.89 | 0.78 | 0.65 |
| Indirect benefits, GF 1000 | 1,734 | 7,448 | 9,975 | 14,916 |
| Use GF 1000 | 1,500 | 7,500 | 10,000 | 15,000 |

## Public Benefits

Public benefits are defined as the value of achieving national objectives other than those included in direct and indirect benefits. Their

evaluation represents a judgement estimate, more than a rigorous determination. The following benefits have been estimated.

(1) Employment Opportunities. This consists of benefits resulting from the contribution of the project to stabilization of income, employment, and investment opportunities outside of the project area. Although there is no accurate criteria for estimating these benefits, experience in the United States show such benefits to be at least five percent of discounted direct project benefits. It is believed that these benefits would not be less for Guinea.

In addition, employment will be afforded during the construction and development period. It is estimated that no less than GF 100,000,000 of the construction costs will be spent in purchase of local goods and services. Depending on actual contracting arrangements, at least 70 percent of this, or about GF 70,000,000 would be paid to local laborers. This would result in employment and training for many local workers, and in stimulating the national economy. At six percent annual interest, this benefit would amount to an equivalent of GF 4,200,000 annually.

The combined public benefits from increased employment and economic stimulation of the region are shown in Table VIII-20. They are the only public benefits for which we have made a monetary evaluation.

Table VIII-20 - Determination of Public Benefits
(GF 1000)

| | Upon Completion of Project | After 5 years of operation | After 10 years of operation | After 20 years of operation |
|---|---|---|---|---|
| Employment outside of project | 965 | 2,149 | 2,730 | 4,660 |
| Employment during construction | 4,200 | 4,200 | 4,200 | 4,200 |
| Total Public Benefits | 5,165 | 6,349 | 6,930 | 8,860 |
| Use GF 1000 | 5,000 | 6,500 | 7,000 | 9,000 |



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(2) Settlement Opportunities. Reclamation of the project lands will provide opportunities for the establishment of additional subsistence farms, or enlargement of existence farms and creation of cooperative enterprises. At four hectares per subsistence farm, about 245 new subsistence units could be established. Public benefits from providing settlement opportunities would result, equivalent to at least the alternative earnings of the new cultivators. Although these benefits have not been evaluated in monetary terms, they would be very significant to the economy of the region and to Guinea. The magnitude of these benefits will increase as the population continues unless equal alternative economic opportunities are provided.

(3) Reduction in Foreign Currency Expenditures. The additional production anticipated from the project will contribute to a reduction of import requirements and, in turn, a reduction in expenditures of Guinea's scarce foreign currency. The value of additional production to the Nation would, therefore, be equal to the cost of imported rice. The value of rice imported from the United States in 1962 was about $140 per metric ton, including shipping costs. Increased production of rice to offset this expenditure for import rice would be extremely important in bolstering the economy of Guinea. Although this has not been included in the evaluation of public benefits, the importance of this factor can be easily illustrated. The foreign currency component of the project investment is $1,380,000, which corresponds to the cost of about 10,000 tons of rice. These foreign currency expenditures can be recovered by the project through reductions in imports in the first eight years of operation, on the basis of present worth at an annual rate of six percent.

## Benefit-Cost Ratios

The ratios of total benefits to costs were determined for each stage of development of the project. A summary of these calculations is presented on Table VIII-21.



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Table VIII-21 - Project Benefit-Cost Ratios

(All amounts in GF 1000)

| Annual Benefits | Upon Completion of Project | After 5 years of operation | After 10 years of operation | After 20 years of operation |
|---|---|---|---|---|
| Direct Benefits | 19,500 | 43,000 | 55,000 | 93,000 |
| Indirect Benefits | 1,500 | 7,500 | 10,000 | 15,000 |
| Public Benefits | 5,000 | 6,500 | 7,000 | 9,000 |
| Total Annual Benefits | 26,000 | 57,000 | 72,000 | 117,000 |
| **Annual Costs** | | | | |
| Capital Costs | 37,000 | 37,000 | 37,000 | 37,000 |
| Operating Costs | 5,000 | 6,000 | 6,000 | 6,000 |
| Total Annual Costs | 42,000 | 43,000 | 43,000 | 43,000 |
| **Benefit-Cost Ratios** | | | | |
| With direct benefits only | 0.5 to 1.0 | 1.0 to 1.0 | 1.3 to 1.0 | 2.2 to 1.0 |
| With total benefits | 0.6 to 1.0 | 1.3 to 1.0 | 1.7 to 1.0 | 2.7 to 1.0 |

## Financial Analysis

### Financing Terms

Construction of the Monchon Project will require funds in the amount of $1,300,000 and GF 220 million, to be expended over a period of about two years. These amounts will probably be secured through an international lending institution. Since the terms of such financing are not known, it has been assumed that the entire project investment would be financed, to be repaid over a period of 40 years with an interest rate of 0.75 percent per annum. The first payment would be deferred to the eleventh year after beginning of operation. These terms are those currently offered by international lending institutions such as the International



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Development Association (IDA), an affiliate of the International Bank for Reconstruction and Development (IBRD, World Bank), and by the Agency for International Development (AID), an agency of the United States, Department of State.

## Annual Costs

Such financing terms would require repayments at an annual rate of $16,000 for the first ten years, and $63,000 for the following 40 years, equivalent to GF 4 million and GF 16 million, respectively.

The annual costs of operating the project, including operation, maintenance, replacements, and the support of an agricultural extension program have been estimated to be GF 9 million for the first three years of operation, and GF 6 million thereafter.

## Repayment Ability

The repayment ability of the farmers has been evaluated by determining the amounts available annually to them after all farm expenses are met. The net farm incomes calculated in the farm budgets were reduced by amounts corresponding to the values of the family labor utilized in operating the farm unit. These amounts, shown on Tables VIII-12 through 16, were estimated on the basis of current wages for farm labor. The remaining amounts, multiplied by the number of farms to be operated in the project area, are the residual amounts available for profit of the farm enterprises and for repayment of the project. They are indicated on Table VIII-22. Also shown in the table are the project annual costs.



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Table VIII-22 - Financial Analysis

(Amounts in GF Million)

| Years after Completion | Residual Income for Profit and Repayment | Annual Costs | | | |
|---|---|---|---|---|---|
| | | Interest and Amortization | Operating Costs | Extension Services | Total |
| 0 | 0 | 4 | 5 | 4 | 13 |
| 1 | 4 | 4 | 5 | 4 | 13 |
| 2 | 8 | 4 | 5 | 4 | 13 |
| 3 | 12 | 4 | 5 | 1 | 10 |
| 4 | 17 | 4 | 5 | 1 | 10 |
| 5 | 21 | 4 | 5 | 1 | 10 |
| 6 | 25 | 4 | 5 | 1 | 10 |
| 7 | 29 | 4 | 5 | 1 | 10 |
| 8 | 34 | 4 | 5 | 1 | 10 |
| 9 | 38 | 4 | 5 | 1 | 10 |
| 10 | 43 | 16 | 5 | 1 | 22 |
| 15 | 71 | 16 | 5 | 1 | 22 |
| 20 | 104 | 16 | 5 | 1 | 22 |

Inspection of Table VIII-22 indicates that only during the first three years of project operation will residual income of the farmers be less than the total annual costs of the project. From then afterward, income becomes substantially greater than project costs.

## Chapter IX

# PROJECT OPERATION AND DEVELOPMENT

### Introduction

Ultimate success of the proposed project is contingent upon the following essentials: (1) bringing the reclaimed land into production as early as possible; (2) increasing yields through improvements of production techniques; (3) effective operation and maintenance of the project facilities. These elements are interrelated and must be attacked simultaneously which will require joint and well-coordinated efforts between the farmers and a designated administrative authority from the very beginning of construction.

### Administrative Authority

The responsibility for project operation and development must be firmly established at the start of construction. It is not known at present what type of organization will be implemented to carry out the project.

It is recommended that responsibility be vested in an administrative and supervisory authority at the project level. This responsibility should include overall coordinating functions covering all technical, educational, and operational matters pertinent to the success of the new venture.

It is recommended that an experienced rice agronomist be employed full time to direct this agency for several years beginning at the time of construction. Because of the present shortage of experienced Guinean technicians, this agronomist may have to be an expatriate. Guinean assistants should be assigned to work with him with the objective of ultimately assuming full responsibility after sufficient experience is gained.

The agronomist would also be assigned the technical direction of the CMR or such organization created specifically for the purpose of controlling the available mechanized equipment, acquiring and distributing farm supplies, and maintenance operation. He would be responsible also for conducting research and experiments on test plots, and extension activities to extend results to the farmers.

The Monchon Project could serve as a pilot project for demonstration purposes and for training personnel for projects contemplated in other areas of Lower Guinea. Several trainees could be assigned to the project, under the technical direction of the agronomist, for subsequent assignment to other projects.

## Land and Soil Preparation

Proper coordination between the land preparation and the contractors' operations is an absolute essential for integration of the drainage and reclamation scheme. Considerable reorganization and consolidation of presently cultivated lands will be necessary. Farm units of proper size and shape, and surface drains to be installed by the farmers must be laid out in proper patterns at the time the primary drainage channels are constructed. The spoils from these channels may be used for dikes and farm borders. Also the construction and land preparation must proceed systematically to permit as much land being brought into production as rapidly as possible. This will enable partial production during the construction period without serious disruption of current farming operations.

The technical services of the agronomist, and other specialists as required, must be available during construction to assist farmers with proper land preparation, and operation of the drainage facilities.

## Agricultural Development Programs

The primary goal of the administering authority will be to assist the farmers in achieving and sustaining substantial increases in rice production. Substantial improvements are possible from a technological standpoint but realistic objectives must fit within the present patterns of land holdings and cultural methods. There are severe limitations to the range of improved practices that can be introduced. A rapid enlistment of peasant and nomad farmers in a change from traditional practices to intensive and modern practices is not expected. Short and long range programs should be initiated simultanteously with emphasis on those factors which will bring immediate results with least cost and management.

Short Range Programs. The immediate steps must deal with proper drainage and control of the fresh water supply, reduction of salinity in the surface soils, seed bed preparation, and adoption of varieties most suitable to the changed soil conditions. These improvements can be accomplished with practically no cash expenditures or changes in use of available hand implements.

The use of fertilizers, particularly phosphorus, and plant protection measures should be introduced at the start of the project. Initially this may require government assistance under communal rather than individual programs. It is expected that several years will be required to inform the farmers of the factors of utility, availability, use, supply, and planning necessary to secure substantial universal application of inorganic fertilizers. However, adaption will have to be more rapid in certain fields. For instance, water levels within the paddies will be altered with drainage from those to which the farmers are accustomed. Proper timing in seed

bed preparation, transplanting, spacing of plants, etc. are expected to be changed. Rapid adjustment to these new conditions is necessary to obtain the production levels anticipated.

Long-Range Programs. It is essential to introduce programs concerned with the primary factors of production at the beginning, even though the results may not be realized for several years. These include research for improvement of seed, introduction of complementary crops to be used in rotation with rice, test plots for fertilization trials with various combinations of plant food elements, soil testing and drainage studies, and a training program.

It is likely that at least five years will be needed before the first seeds from the research programs may be available for widespread distribution. However, the potential for increased yields from this source justifies this endeavor. Extensive plant protection measures are required for effective disease and pest control. These activities fall logically under the purview of the project area and can best be employed where substantial contiguous areas are planted to the same crop.

The long-range program should include integrated studies and analysis of the soils and corrective measures necessary to improve their fertility. This will involve fertilization trials, crop rotations with green manure and other crops, and chemical analysis. This program would be integrated also with drainage studies for reduction and control of salinity, and control of water tables.

With the exception of plowing and threshing, mechanization is not expected to be a significant goal in improving rice production. These operations could be handled through machinery pools or the operating agency. Much improvement in production techniques, however, is

possible with adoption and use of improved simple tools and equipment. For instance, hand plows pulled by animals would do much to lighten the burden of the farmer.

The success of the project will stand or fall with the success of contact with the farmers. Technical information must be transferred to the farmers which requires communication skills and methods. Also, the farmers must be motivated to change traditional methods and to intensify production.

We recommend that extension services be established through locally trained field agents in getting the farmers to accept and adopt new practices and materials. As the Monchon Project is small only one or two agents may be required. The beginning technical tasks should be relatively simple, but growing more complex as the project develops. The agents can be trained through short courses, field demonstration, and working with the technical director.

## Maintenance and Operation

The maintenance and operation program will be one of the most important responsibilities of the technical director. The drainage channels, the tide control gates, and the other structures must be kept in a good state of repair. This will include constant cleaning to keep them free of debris, dredging to maintain grades, and other miscellaneous operations.

The responsibility for these operations must be with the technical director to enforce strict discipline throughout the project. Close cooperation and understanding from the farmers must be obtained for continued success. It is recommended that a farmers' committee be appointed to work with the director on these and other functions of the project. This

arrangement frequently creates interest in the farmers for maintaining the project because of understanding the problems and recognizing the benefits to them.

## Financial Arrangements

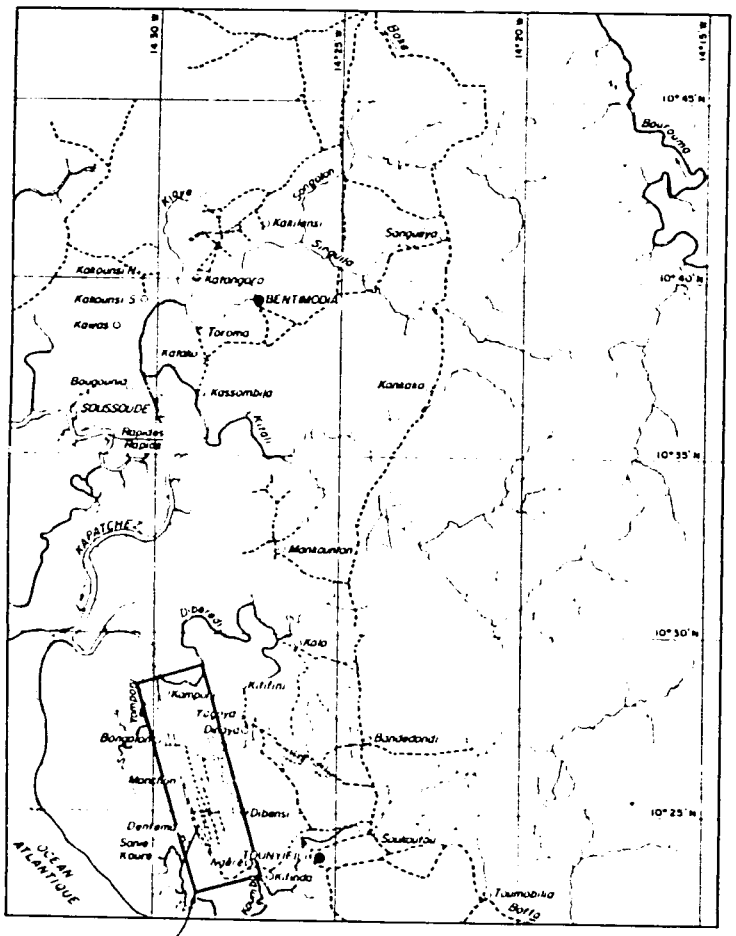
To carry out the duties and services recommended for the project the agency responsible will need a budget sufficient to enable an effective operation. This budget should be earmarked for this specific purpose by the government of Guinea and allocated to the administrative agency directly or through the Boffa regional executive government.

It is expected that costs for services involving training of field agents to be used elsewhere would not be charged to the Monchon Project. It is recommended that the regional budget be allocated additional funds for these services, if provided. Financing arrangements and sources of revenue for costs of services for the Monchon Project were discussed in Part One. A well-managed Monchon Project will ultimately yield sufficient returns to the Republic of Guinea to justify the programs necessary for assuring its success.

## THE EXHIBITS


Exhibit 1. General Maps
2. Project Plan (on 5 sheets)
3. Climatological and Hydraulic Data
4. Land Use Map
5. Salinity Map
6. Logs of Auger Holes
7. Results of Laboratory Tests
8. Results of Hydraulic Analyses
9. Details of Structures
10. Construction Schedule
11. Estimate of Project Construction Cost

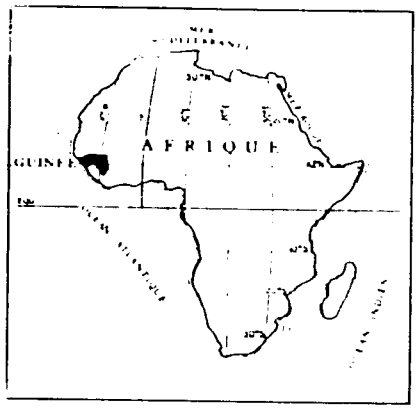
PLANCHE
EXHIBIT I




PROJET DE MONCHON
MONCHON PROJECT

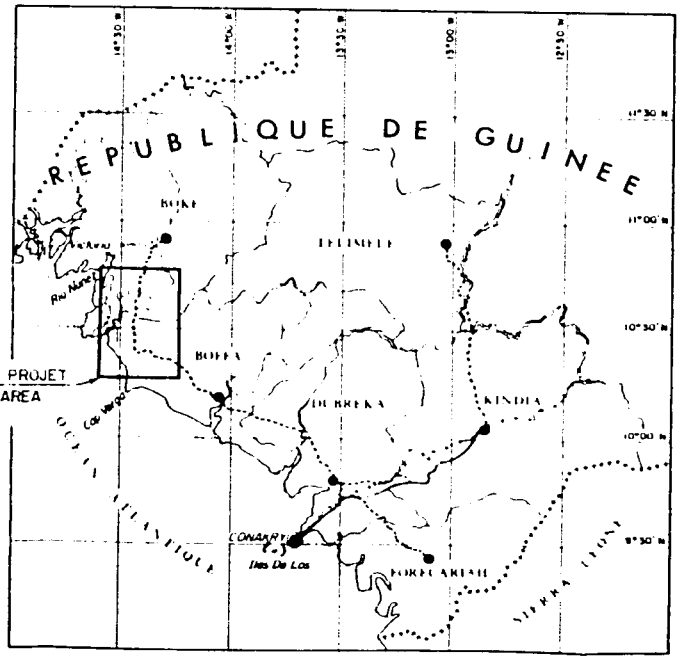
CARTE REGIONALE
PROJECT AREA

Echelle / Scale 0 1 2 3 4 5 Kilomètres / Kilometers




SITUATION
KEY MAP

Echelle / Scale 0 1000 2000 3000 Kilomètres / Kilometers




REGION DU PROJET
PROJECT AREA

BASSE GUINEE
LOWER GUINEA

Echelle / Scale 0 10 20 30 40 50 Kilomètres / Kilometers

LEGENDE
LEGEND

- Route / Paved road
- Piste / Unpaved road
- Chemin de fer / Railroad
- Villes et villages / Main cities and villages
- Frontière / Nation boundary
- Limite de région administrative / Regional boundary
- Réseau de canaux de drainage / Drainage canal system
- Cours d'eau / Streams

CARTES D'ENSEMBLE
GENERAL MAPS

Post Available Document



LEGENDE
LEGEND

- Canal principal / Main canal
- Canal secondaire / Secondary canal
- Canal tertiaire / Tertiary canal
- Canal quaternaire / Quaternary canal
- Pont d'entretien et exploitation / Operation and maintenance bridge
- Ponceau / Foot bridge
- Digue / Dike
- Piste et sentier / Road and track
- Piste d'entretien et exploitation / Operation and maintenance road
- Cours d'eau / Stream
- Marécage / Marsh
- Canal à abandonner / Canal to be abandoned
- Dune
- Village

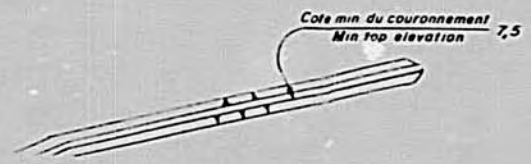
NOTES

1. Les lignes blanches représentent les détails topographiques et les ouvrages existants. Les lignes noires représentent les ouvrages proposés.
2. Cette carte a été assemblée et dessinée à partir de levés topographiques effectués en 1957-58 par le Service des Travaux Publics de Guinée, en archives au Ministère de l'Economie Rurale.
3. Les cotes indiquées sont rattachées au Nivellement Général Ray qui est basé sur une cote arbitraire de 13,427 pour la borne repère de Tougnifili.
4. Toutes les dimensions et cotes sont indiquées en mètres.
5. La largeur des canaux et les dimensions des autres ouvrages ne sont pas dessinées à l'échelle.

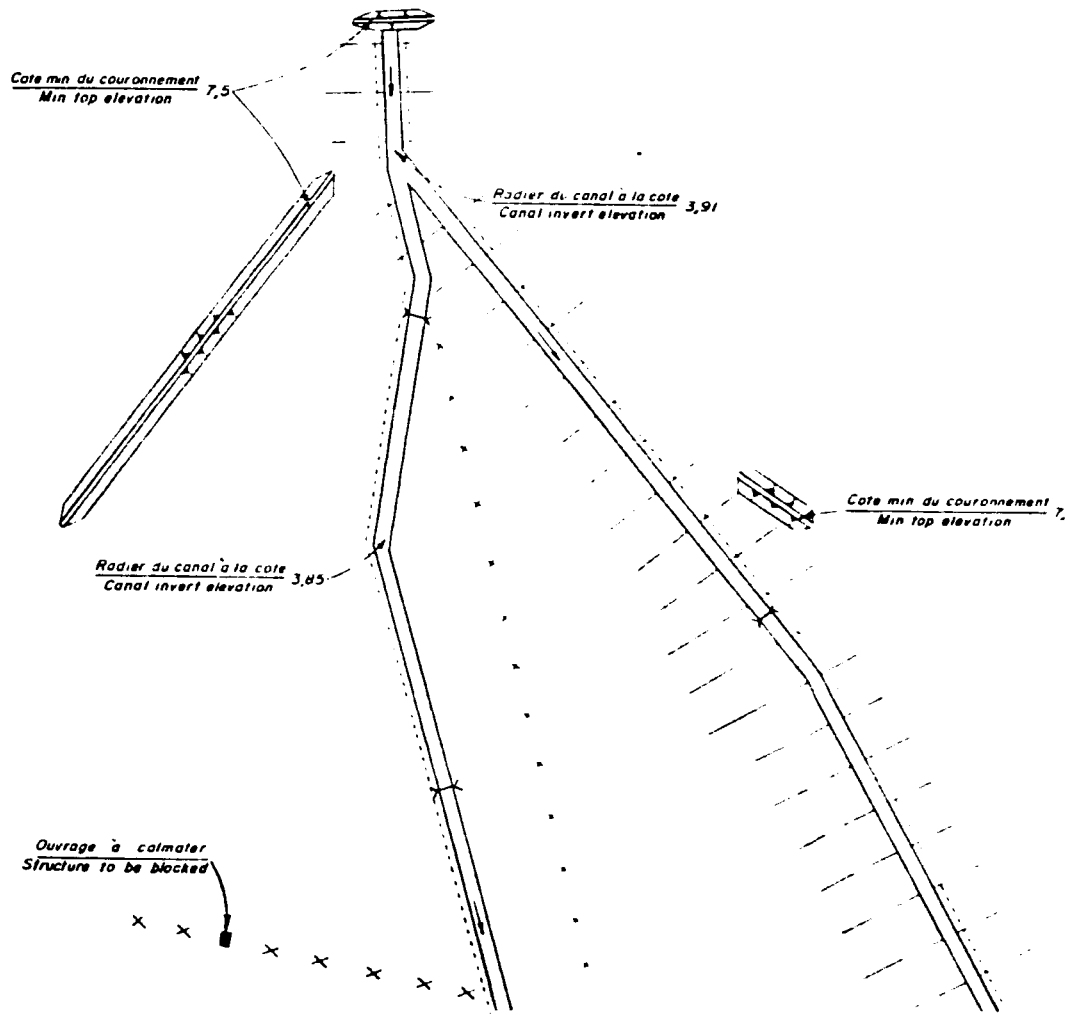
NOTES

1. White outlines represent existing works and topographic features. Black outlines represent proposed works.
2. Map compiled and drawn from plane table survey data made in 1957-58 by the Bureau of Public Works of Guinea, on file with the Ministry of Rural Economy.
3. Elevations shown are in the "Ray" system of reference which uses an arbitrary elevation of 13,427 for the Tougnifili bench mark.
4. All dimensions and elevations are in meters.
5. Canal widths and dimensions of other structures not shown to scale.

Echelle / Scale 0 — 500 Mètres / Meters




PLAN DE L'AMENAGEMENT
PROJECT LAYOUT


Cote min du couronnement
Min top elevation
7,5
Radier du canal à la cote
Canal invert elevation
3,91
Cote min du couronnement
Min top elevation
Radier du canal à la cote
Canal invert elevation
3,85
Ouvrage à colmater
Structure to be blocked

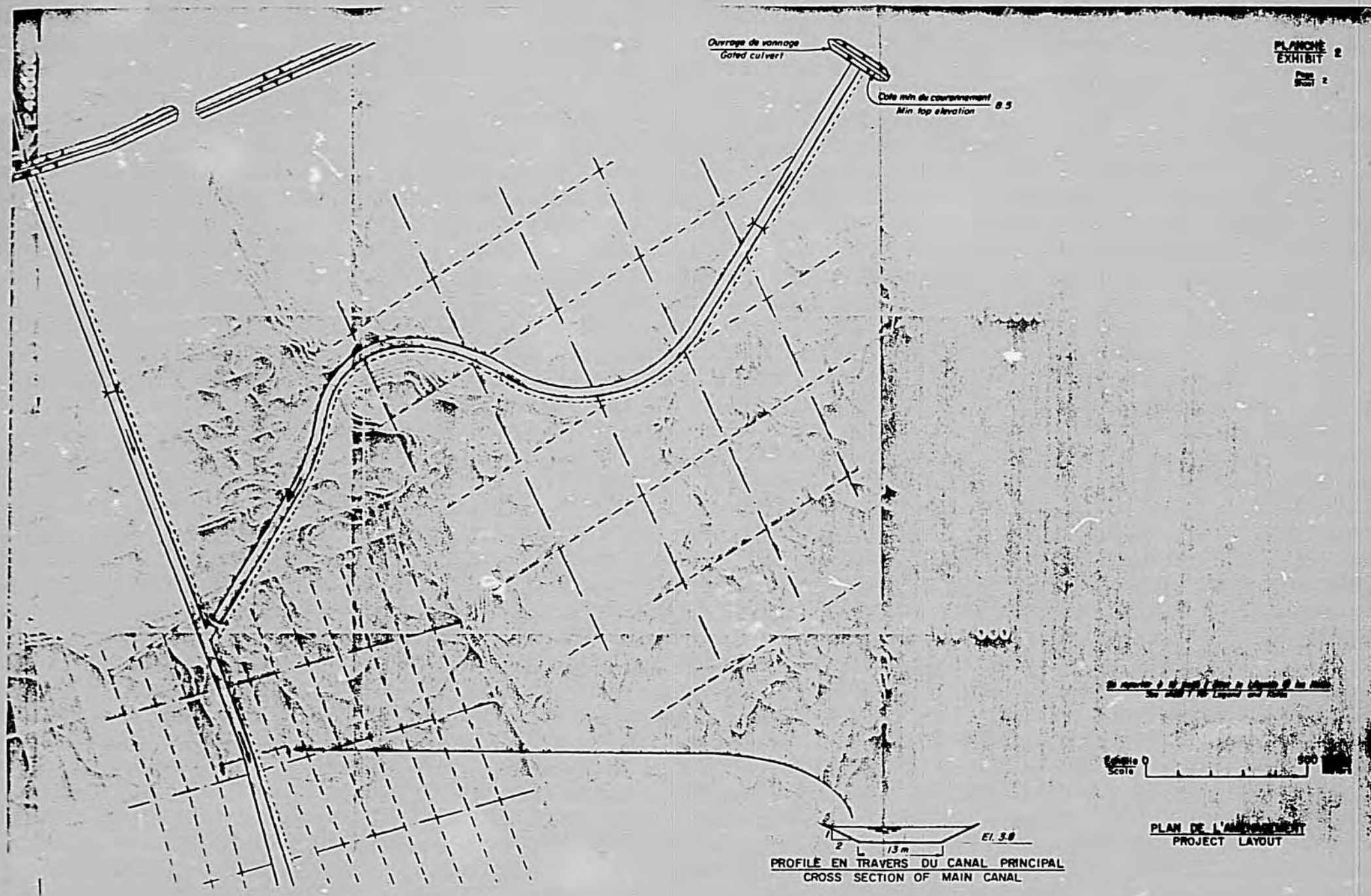
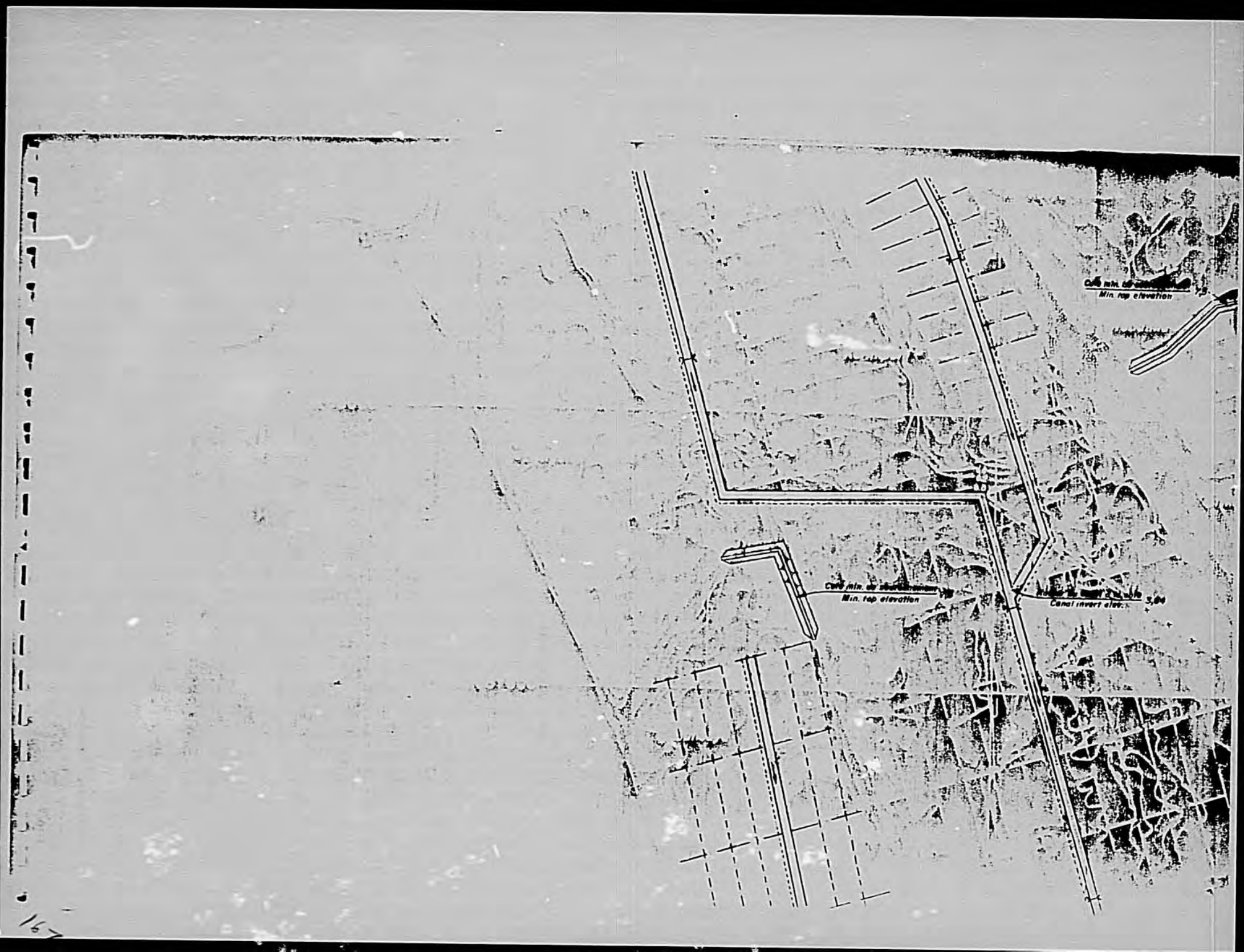
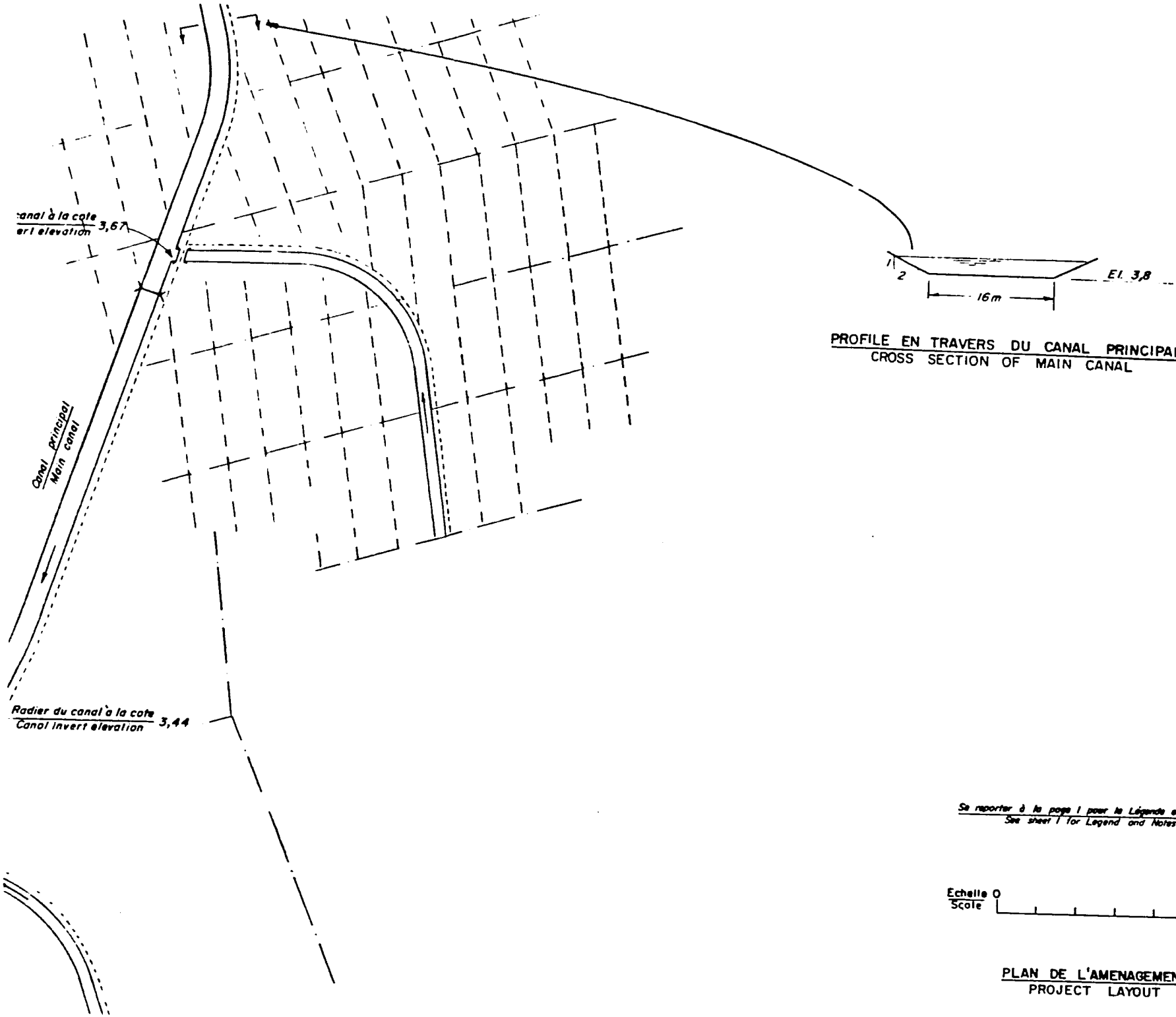


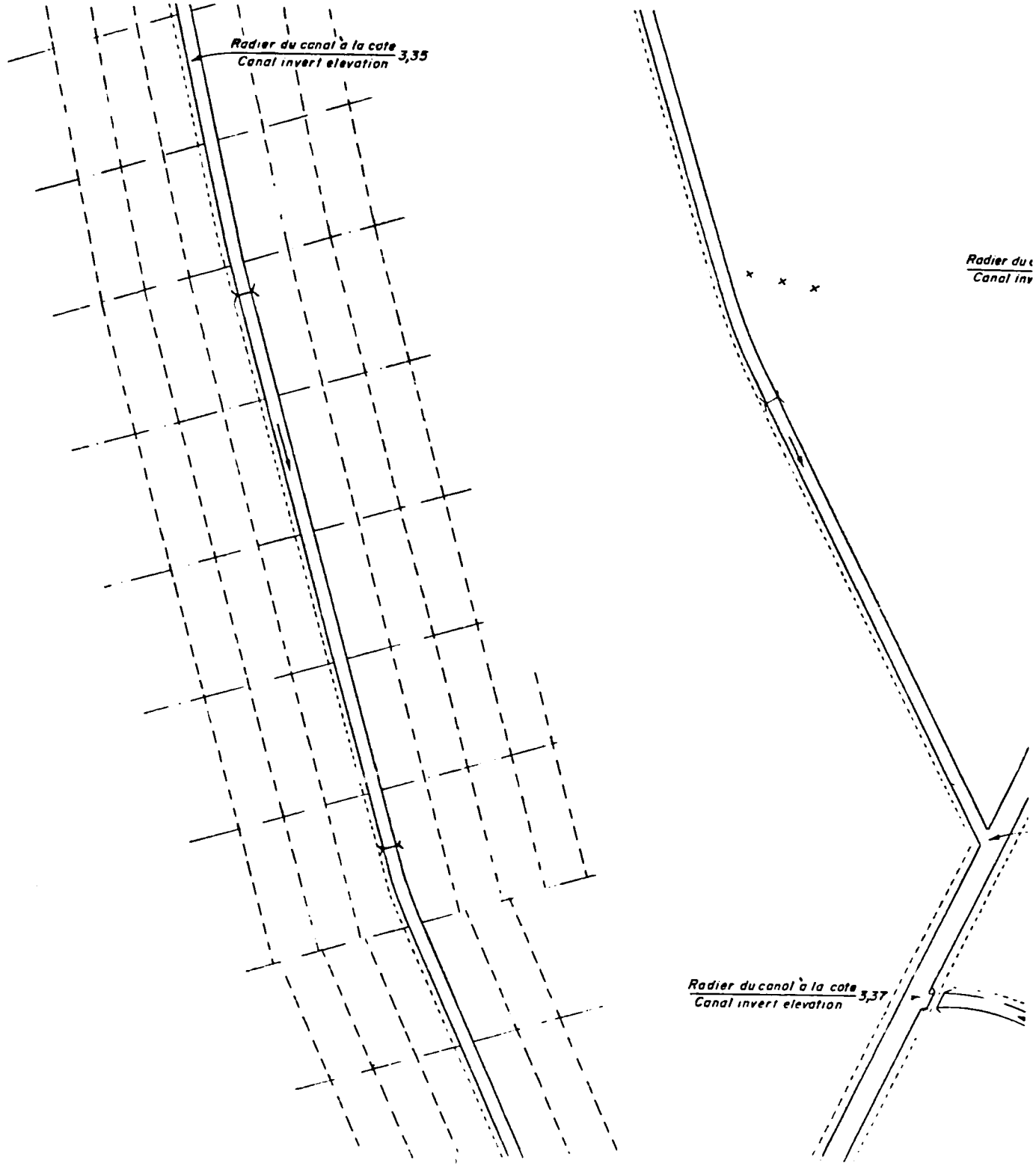
PLANCHE
EXHIBIT 2
Ouvrage de vannage
Gated culvert
Cote min du couronnement
Min top elevation
8.5
El. 3.8
13 m
PROFILE EN TRAVERS DU CANAL PRINCIPAL
CROSS SECTION OF MAIN CANAL
Echelle
Scale
0
500
PLAN DE L'AMÉNAGEMENT
PROJECT LAYOUT

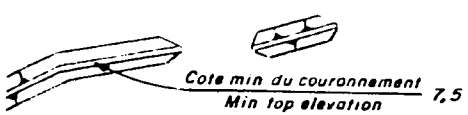

Min. top elevation
Min. top elevation
Canal invert elev.
3,04




PROFILE EN TRAVERS DU CANAL PRINCIPAL
CROSS SECTION OF MAIN CANAL

PLAN DE L'AMENAGEMENT
PROJECT LAYOUT

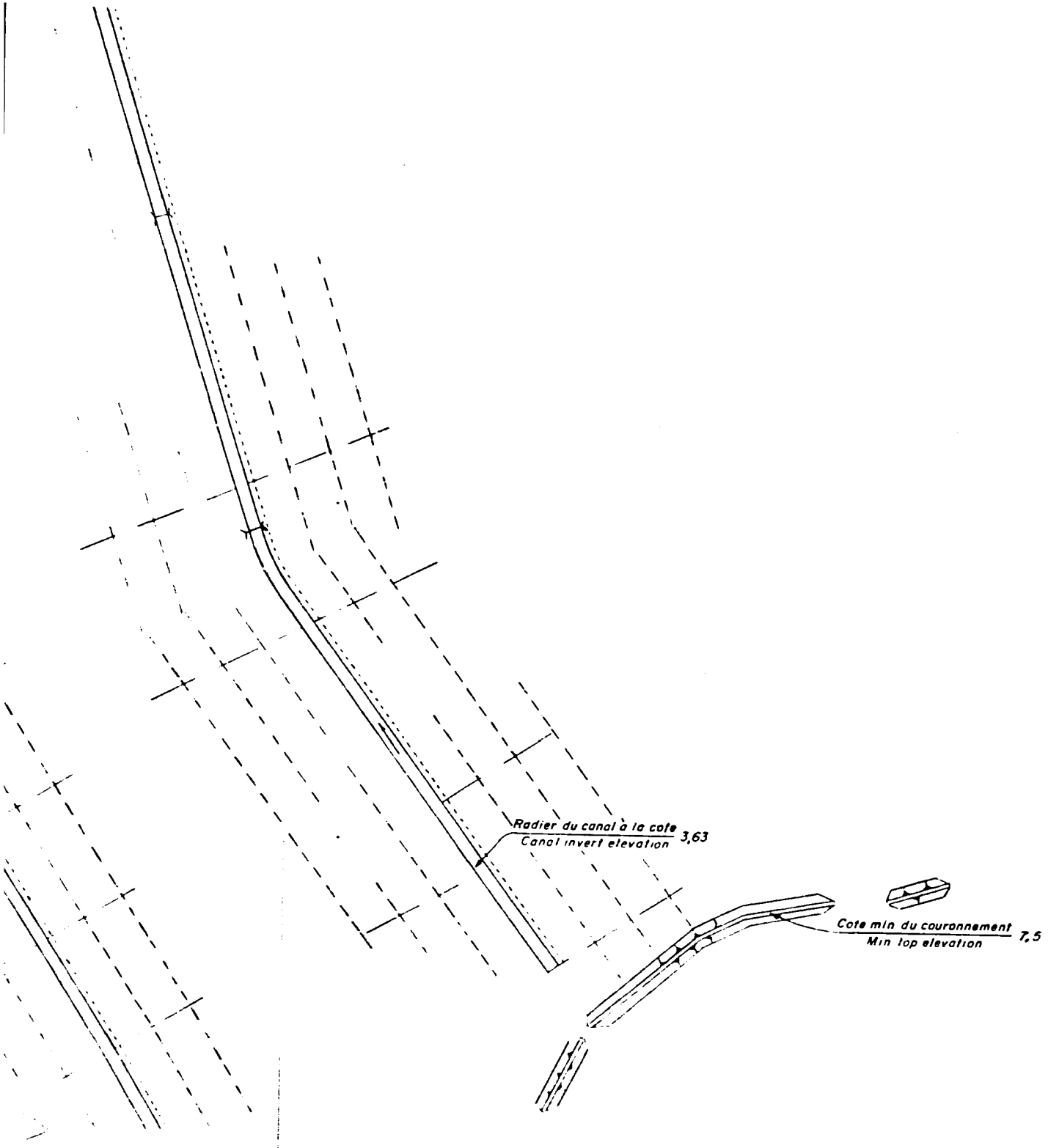

Radier du canal à la cote
Canal invert elevation
3,35
Radier du c
Canal inv
Radier du canal à la cote
Canal invert elevation
3,37

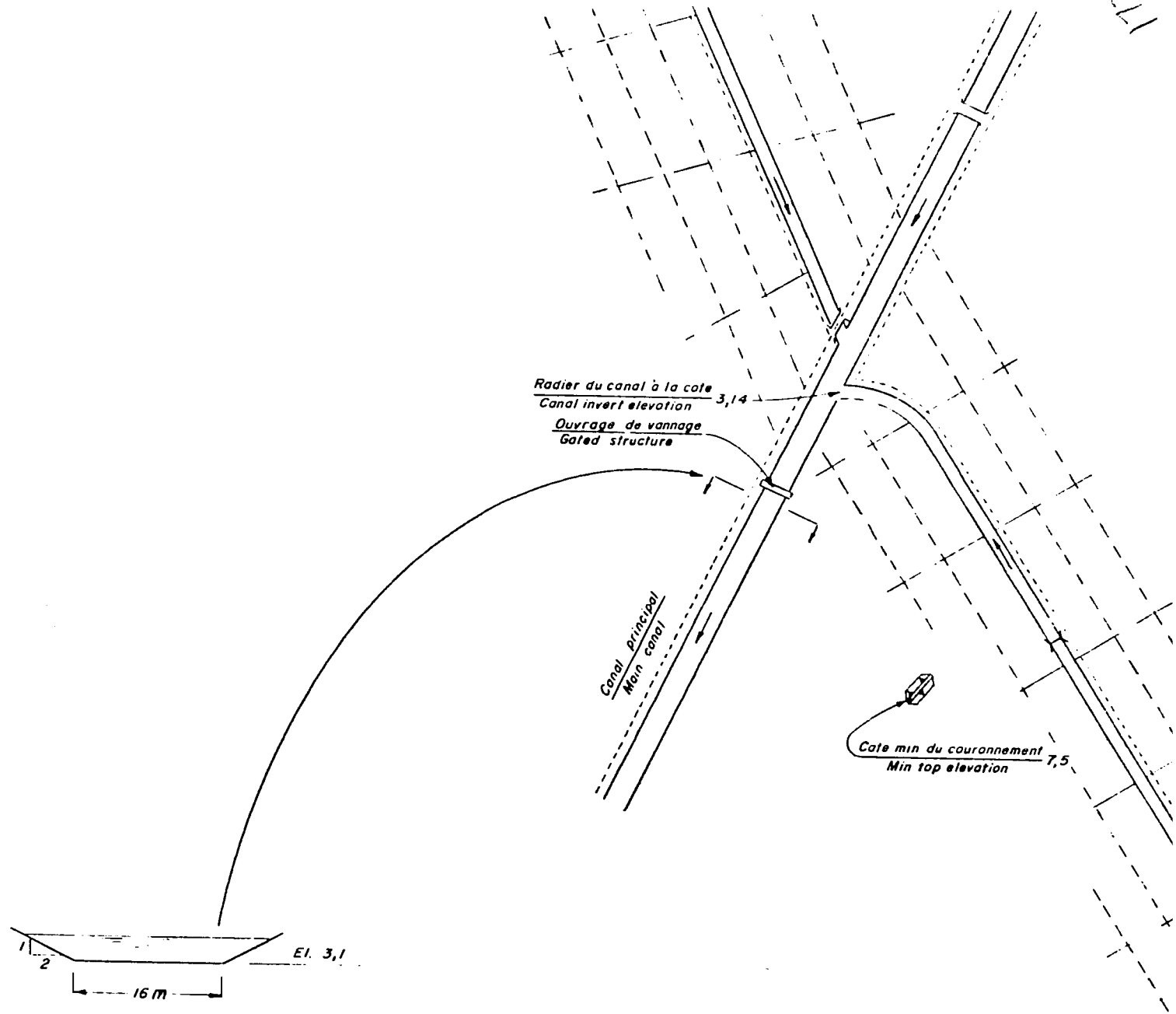



Se reporter à la page 1 pour la Legende et les Notes
See sheet 1 for Legend and Notes

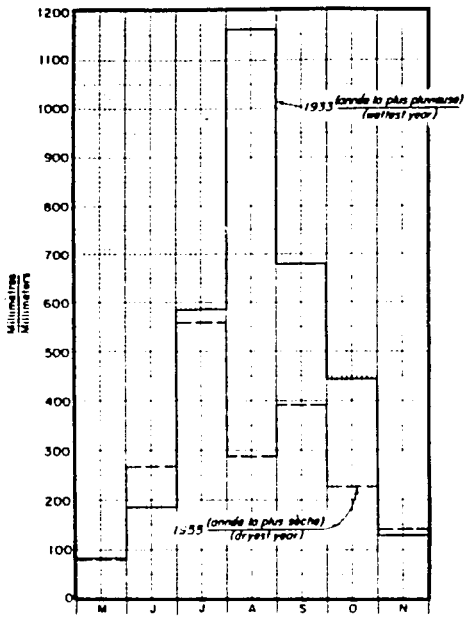
Echelle / Scale 0 500 Mètres / Meters

PLAN DE L'AMENAGEMENT
PROJECT LAYOUT

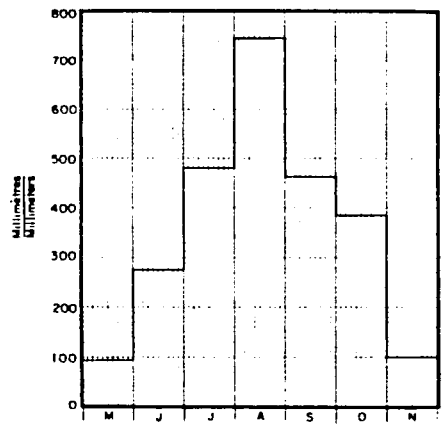

Radier du canal à la cote
Canal invert elevation
3,63
Cote min du couronnement
Min top elevation
7,5




PROFILE EN TRAVERS DU CANAL PRINCIPAL
CROSS SECTION OF MAIN CANAL

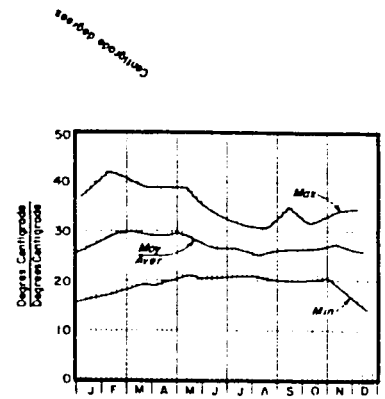



ANNEES EXTREMES
EXTREME YEARS

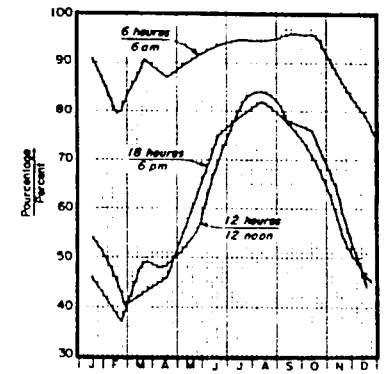



ANNEE MOYENNE (1933-62)
AVERAGE YEAR

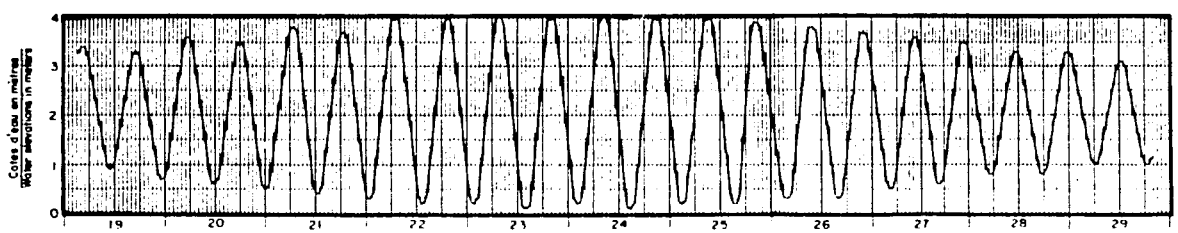
PLUVIOMETRIE MENSUELLE A BOKE
MONTHLY RAINFALL AT BOKE



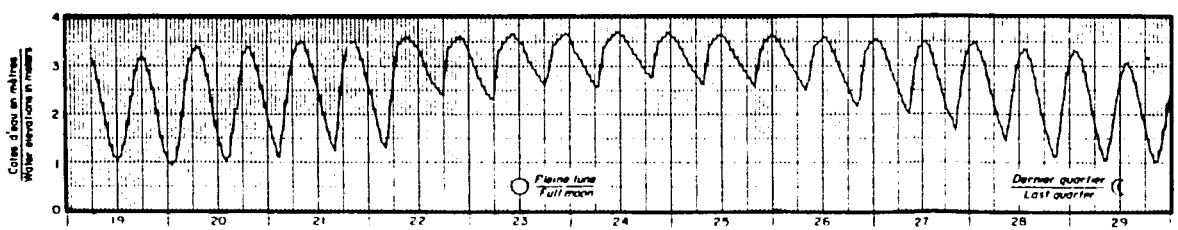

TEMPERATURES A BOKE
TEMPERATURES FOR BOKE
(1962)



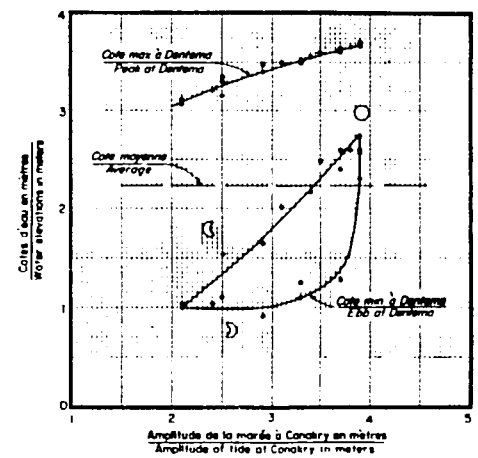

HUMIDITE A BOKE
HUMIDITY FOR BOKE
(1962)




VARIATIONS DE LA MAREE A CONAKRY EN SEPTEMBRE, 1953
TIDAL VARIATIONS AT CONAKRY FOR SEPTEMBER, 1953




VARIATIONS DU PLAN D'EAU SUR LE SONIE KOURE PRES DE DENTEMA EN SEPTEMBRE, 1953
TIDAL VARIATIONS OF THE SONIE KOURE NEAR DENTEMA FOR SEPTEMBER, 1953




RELATION ENTRE L'AMPLITUDE DE LA MAREE A CONAKRY ET LES NIVEAUX MAXIMA ET MINIMA DU SONIE KOURE PRES DE DENTEMA
RELATIONSHIP BETWEEN AMPLITUDE OF TIDES AT CONAKRY AND FLOOD & EBB LEVELS NEAR DENTEMA

NOTES

1. Données sur la pluviométrie, la température, et l'humidité à Boke proviennent des archives du Service Météorologique National.

2. Variations de la marée à Conakry extraites des Tables des Marées pour 1953. Ces tables n'indiquent que les niveaux maxima et minima. Niveaux interpolés ici, obtenus par interpolation. Les cotes données se rapportent à un zéro arbitraire, non relatif aux cotes indiquées pour Dentema.

3. Niveaux d'eau sur le Sonié Kouré près de Dentema ont été enregistrés en 1953 par le Service des Travaux Publics. Les cotes indiquées sont rapportées à un zéro arbitraire. Pour obtenir les cotes correspondantes dans le système de nivellement Rey, ajouter 2.8 mètres aux cotes indiquées.

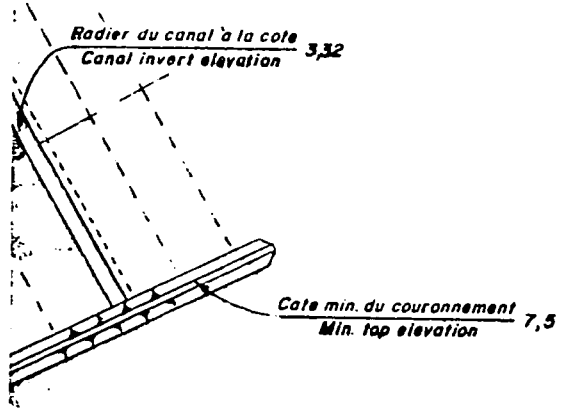
NOTES

1. Precipitations, temperatures and humidity at Boké were obtained from the files of the National Meteorological Service.

2. Tidal variations at Conakry are from the 1953 Tide Tables showing only maximum and minimum levels. Interpolated levels were interpolated. Elevations are referred to an arbitrary datum, not related to other datums used on this Exhibit.

3. Water level elevations of the Sonié Kouré near Dentema were recorded in 1953 by the Public Works Department. Elevations shown refer to an arbitrary datum. To obtain corresponding elevations referred to the Rey datum, add approximately 2.8 meters to the elevations shown.

DONNEES CLIMATOLOGIQUES
ET HYDRAULIQUES
CLIMATOLOGICAL AND
HYDRAULIC DATA

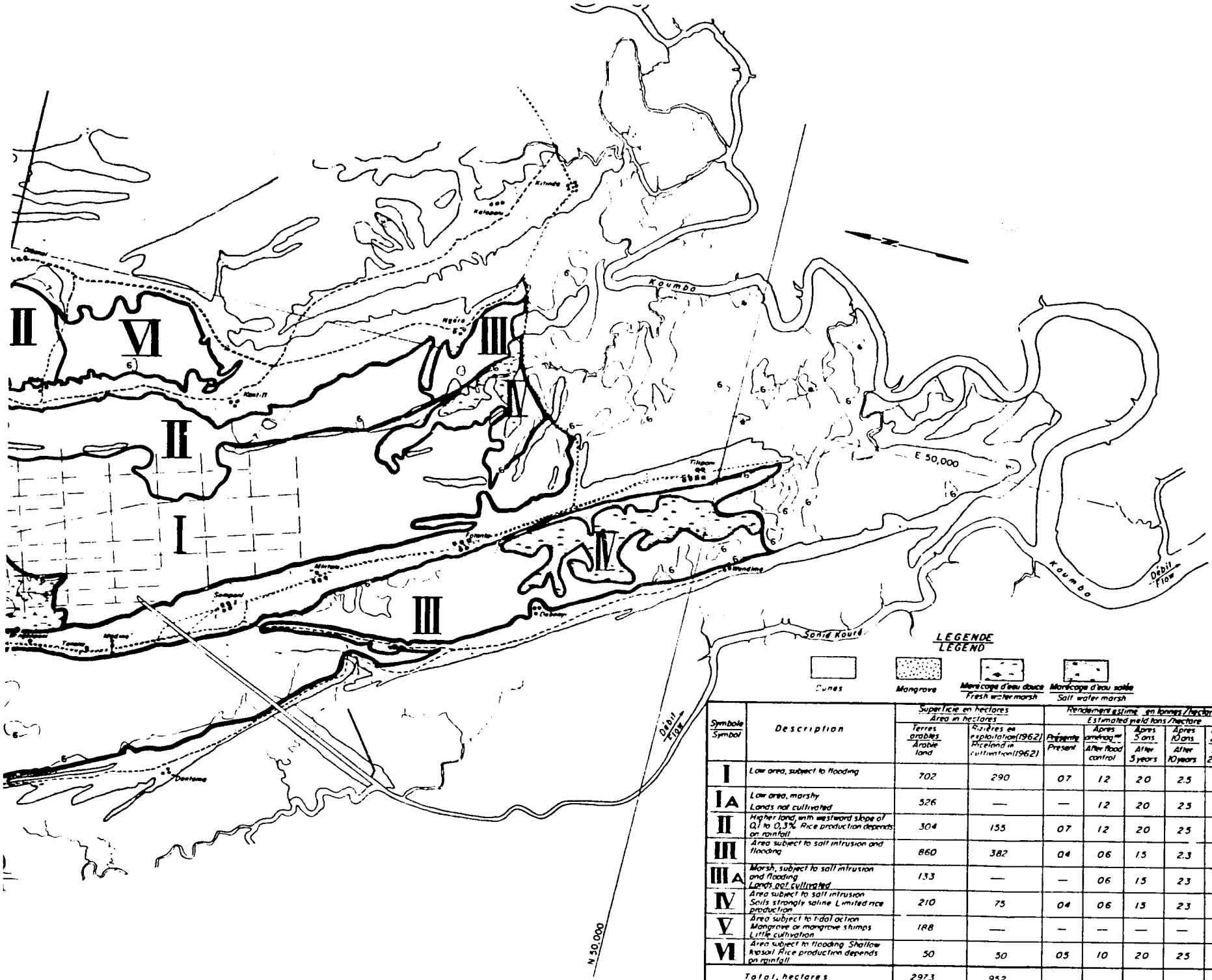



Se reporter à la page 1 pour la Légende et les Notes
See sheet 1 for Legend and Notes

Echelle / Scale 0 — 500 Mètres / Meters

PLAN DE L'AMENAGEMENT
PROJECT LAYOUT

PLANCHE
EXHIBIT



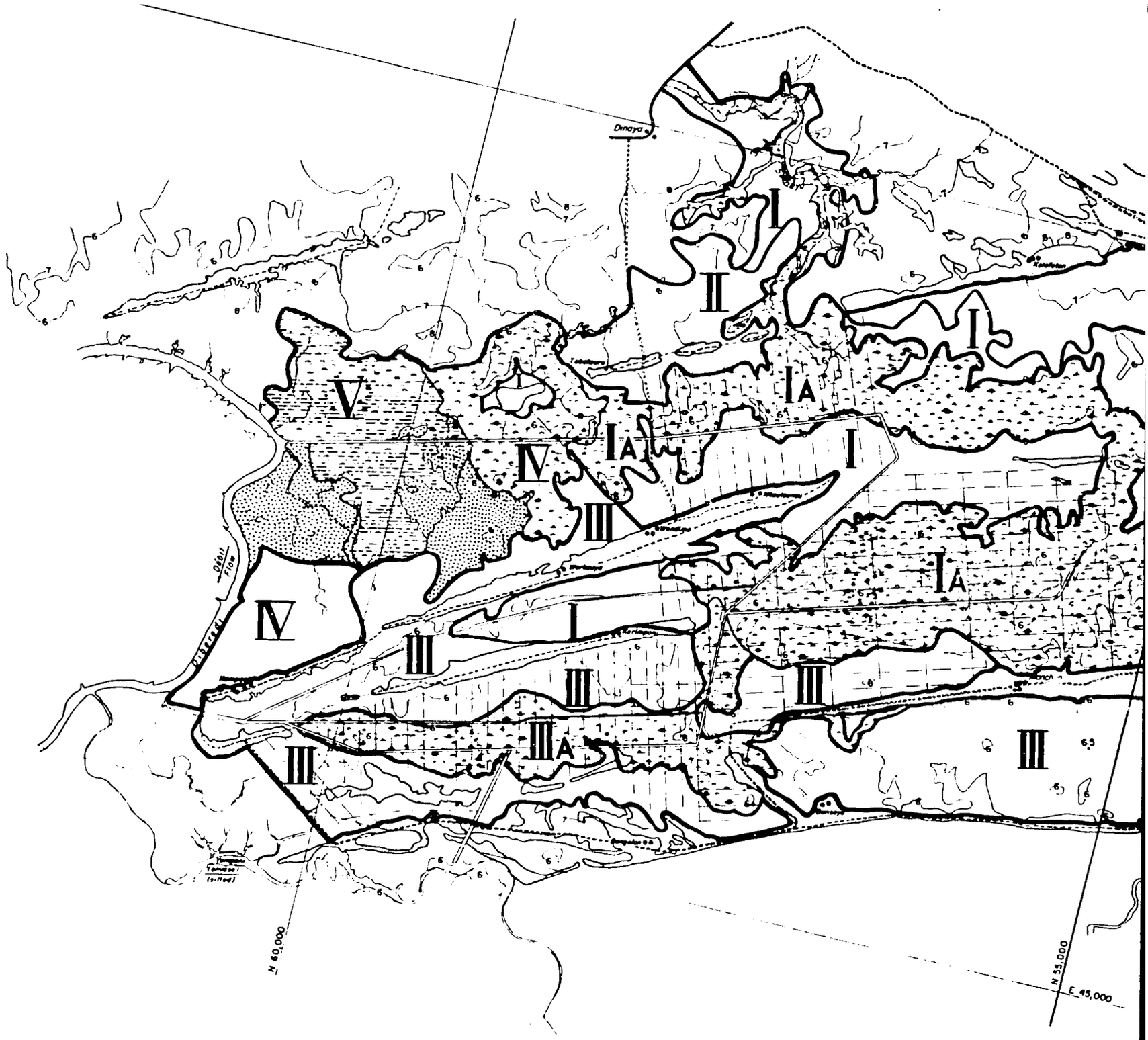

## LEGENDE
## LEGEND

Dunes — Mangrove — Marécage d'eau douce / Fresh water marsh — Marécage d'eau salée / Salt water marsh

| Symbole / Symbol | Description | Superficie en hectares / Area in hectares: Terres arables / Arable land | Superficie en hectares / Area in hectares: Rizières en exploitation (1962) / Riceland in cultivation (1962) | Rendement estimé en tonnes/hectare / Estimated yield tons/hectare: Présently / Present | Après aménagement / After flood control | Après 5 ans / After 5 years | Après 10 ans / After 10 years | Après 20 ans / After 20 years |
|---|---|---|---|---|---|---|---|---|
| I | Low area, subject to flooding | 702 | 290 | 07 | 12 | 20 | 2.5 | 40 |
| IA | Low area, marshy Lands not cultivated | 526 | — | — | 12 | 20 | 25 | 40 |
| II | Higher land, with westward slope of 0,1 to 0,3% Rice production depends on rainfall | 304 | 155 | 07 | 12 | 20 | 25 | 40 |
| III | Area subject to salt intrusion and flooding | 860 | 382 | 04 | 06 | 15 | 2.3 | 35 |
| IIIA | Marsh, subject to salt intrusion and flooding Lands not cultivated | 133 | — | — | 06 | 15 | 23 | 3.5 |
| IV | Area subject to salt intrusion Soils strongly saline Limited rice production | 210 | 75 | 04 | 06 | 15 | 23 | 30 |
| V | Area subject to tidal action Mangrove or mangrove shimps Little cultivation | 188 | — | — | — | — | — | — |
| VI | Area subject to flooding Shallow Hydrosol Rice production depends on rainfall | 50 | 50 | 05 | 10 | 20 | 25 | 25 |
| Total, hectares | | 2973 | 952 | — | — | — | — | — |

Echelle / Scale 0

CARTE DES CULTI
LAND USE M


Dinaya
I
II
I
IA
I
IA
V
IV
III
IA
IV
I
III
III
III
IIIA
III
N 60,000
N 55,000
E 45,000

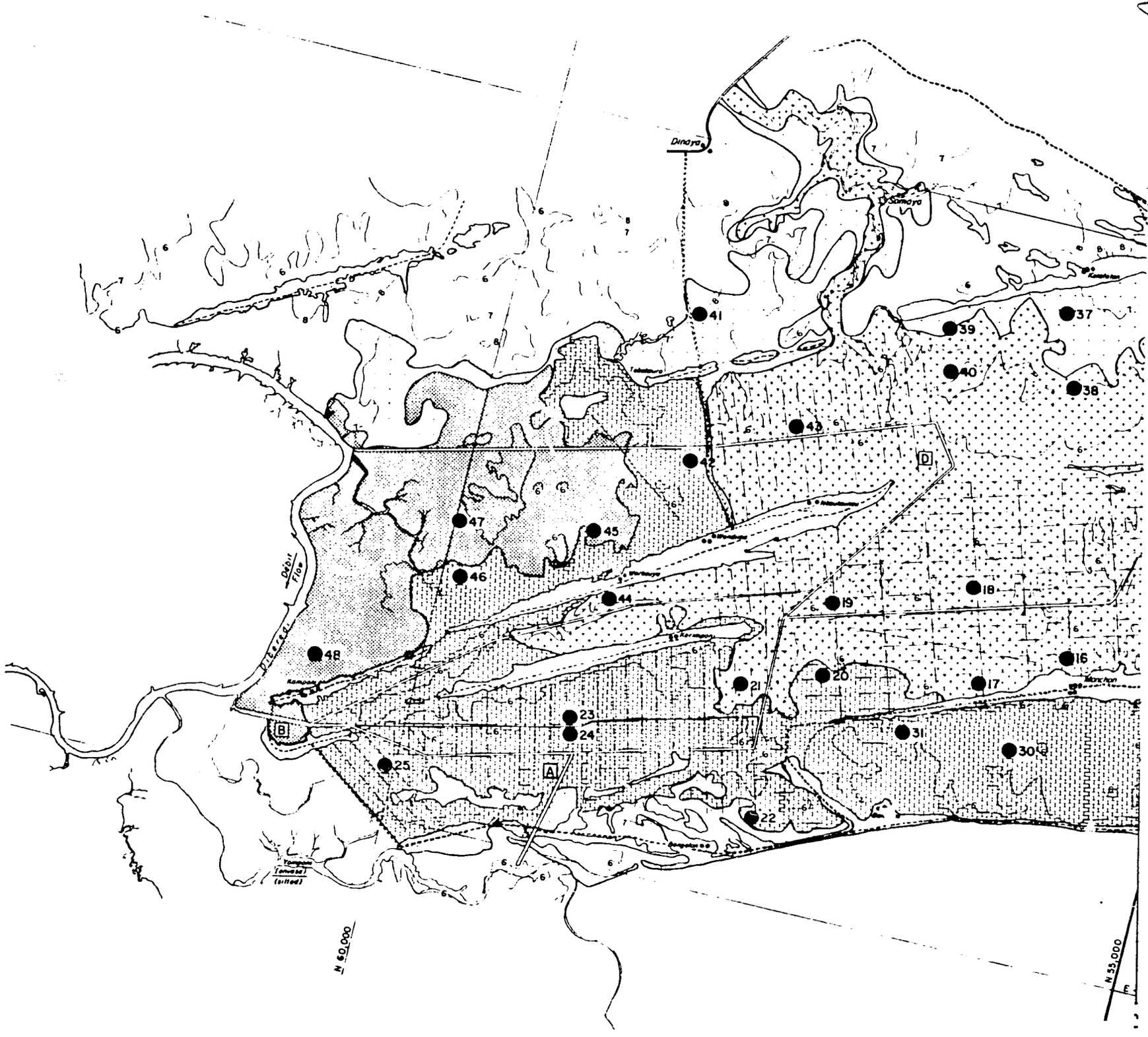
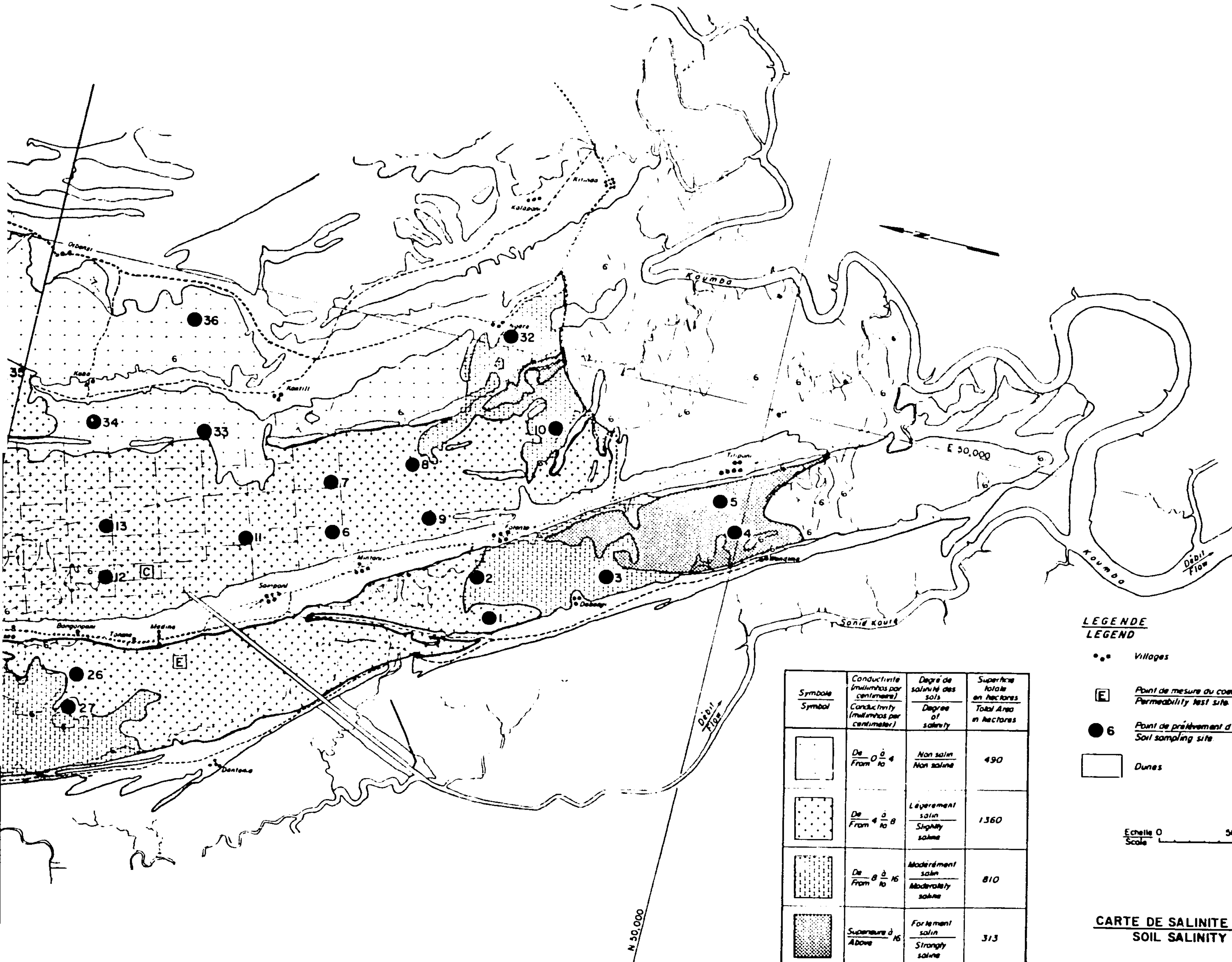

Dinaya
Samaya
Debit Flow
Drained
Kamaya
Kamaya (swamp) (silted)
Morchon
A
B
D
N 60,000
N 55,000
41
39
37
40
38
43
42
47
45
46
44
18
19
48
16
20
21
17
23
24
31
30
25
22

**PLANCHE / EXHIBIT 5**



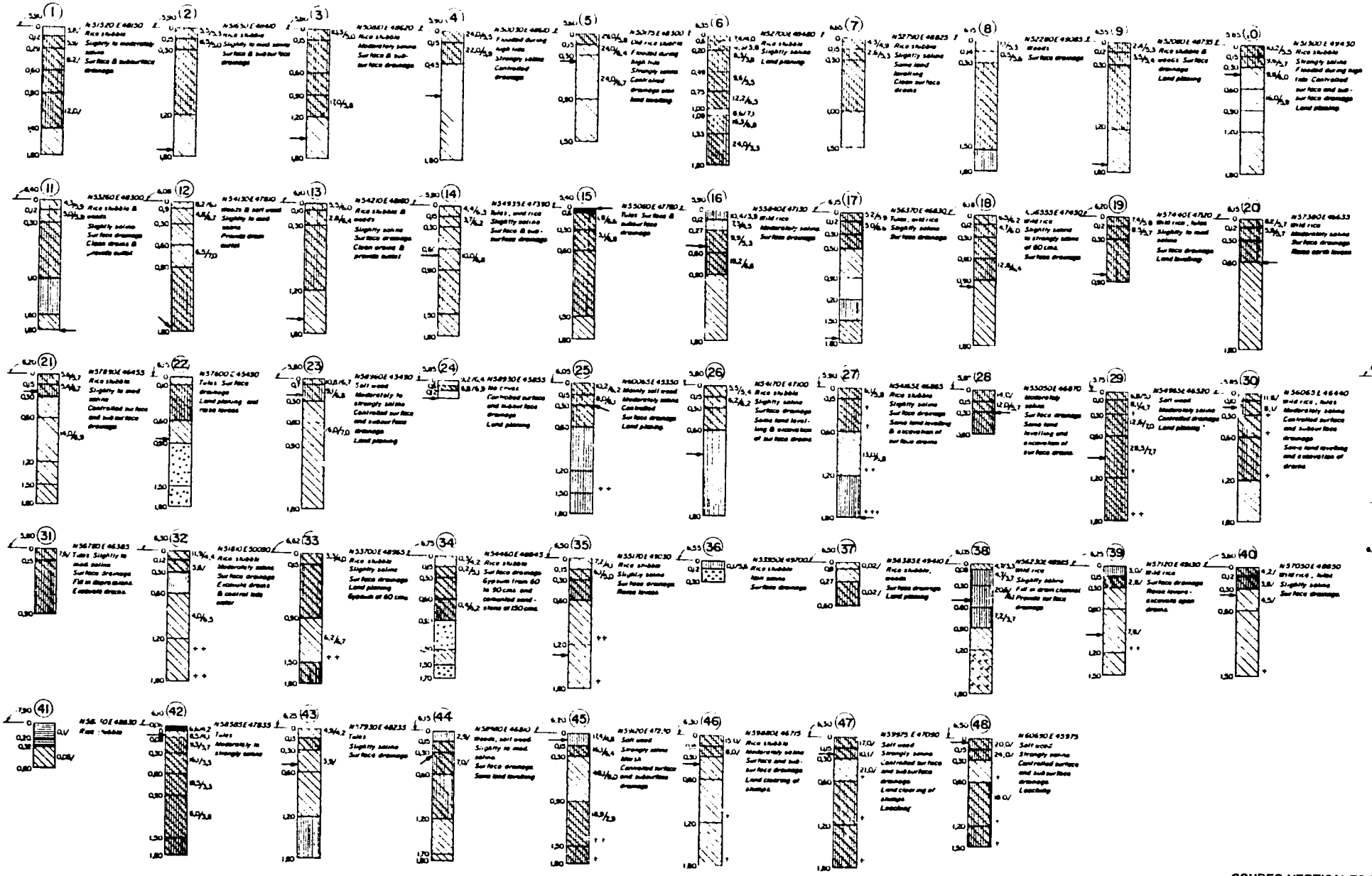

| Symbole / Symbol | Conductivité (millimhos par centimètre) / Conductivity (millimhos per centimeter) | Degré de salinité des sols / Degree of salinity | Superficie totale en hectares / Total Area in hectares |
|---|---|---|---|
| | De / From 0 à / to 4 | Non salin / Non saline | 490 |
| | De / From 4 à / to 8 | Légèrement salin / Slightly saline | 1360 |
| | De / From 8 à / to 16 | Modérément salin / Moderately saline | 810 |
| | Supérieure à / Above 16 | Fortement salin / Strongly saline | 313 |
| Total, hectares | | | 2973 |

**LEGENDE / LEGEND**

- Villages
- E — Point de mesure du coefficient de perméabilité / Permeability test site
- ● 6 — Point de prélèvement d'échantillons de sol / Soil sampling site
- Dunes

Echelle / Scale 0 — 500 Mètres / Meters

**CARTE DE SALINITE DES SOLS**
**SOIL SALINITY MAP**

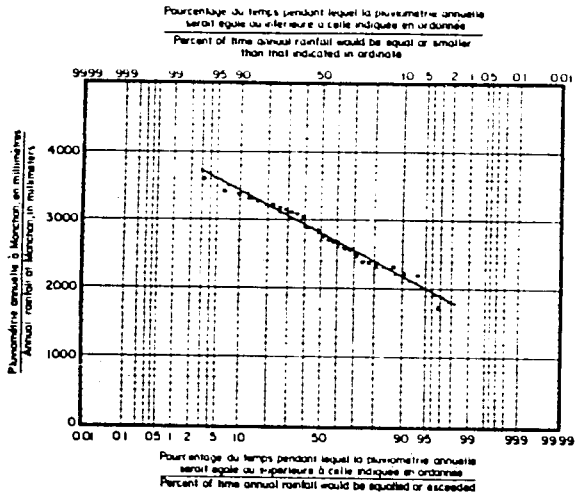



COUPES VERTICALES DES TERRAINS
SOIL PROFILES

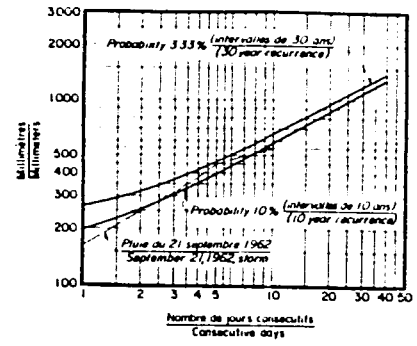
# CHEMICAL & PHYSICAL ANALYSES OF SOIL SAMPLES
## MONCHON - 1963

| LOCATION | HOLE NO. | DEPTH | SOIL DETERMINATIONS: WATER AT SATURATION | pH SATURATED PASTE | pH SATURATED EXTRACT | CATION EXCHANGE CAPACITY (NAOAC) | EXTRACTABLE CATIONS me/100 grams: K | Ca | Mg | Na | H** | TOTAL | ORGANIC MATTER | AVAILABLE P | AVAILABLE $P_2O_5$ | MECHANICAL ANALYSIS: SAND | SILT | CLAY | SOIL TEXTURE | FREE IRON | EXTRACTABLE ALUMINUM | SATURATION EXTRACT DETERMINATIONS: ELECTRICAL CONDUCTIVITY | CATIONS* me/liter: Ca | Mg | Na | K | TOTAL | ANIONS me/liter: $CO_3$ | $HCO_3$ | $SO_4$ | CL | TOTAL | SODIUM ADSORPTION RATIO (SAR) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cms | % | | | me/100 g | | | | | | | % | kg/ha | kg/ha | % | % | % | | % | me/100 g | mmhos/cm | | | | | | | | | | | |
| #52700-E48480 | 6 | 0-6 | 75 | 4.0 | 5.5 | 45.8 | 0.42 | 1.25 | 5.21 | 3.41 | 21.5 | 31.8 | 2.8 | 3.6 | 8.4 | 4.1 | 31.2 | 64.7 | C | 1.9 | | 7.4 | 12.1 | 12.8 | 41.6 | 0.7 | 67.2 | NIL | 2.5 | 26.3 | 49.5 | 78.3 | 12 |
| | | 6-20 | 96 | 3.8 | 5.8 | 30.3 | 0.68 | 1.56 | 7.29 | 3.58 | 20.3 | 33.4 | 0.8 | 3.5 | 7.8 | 3.2 | 21.4 | 75.4 | C | 9.5 | | 4.3 | 1.6 | 6.9 | 26.8 | 0.6 | 35.9 | NIL | 1.0 | 18.5 | 23.0 | 42.5 | 16 |
| | | 20-49 | 105 | 3.8 | 5.7 | 36.8 | 0.87 | 2.35 | 10.42 | 6.52 | 11.7 | 32.0 | 0.5 | 2.0 | 4.5 | 0.9 | 15.9 | 83.2 | C | 1.6 | | 6.3 | 8.8 | 10.1 | 47.8 | 0.9 | 67.6 | NIL | 3.7 | 38.9 | 25.0 | 67.6 | 16 |
| | | 49-75 | 128 | 5.5 | 4.7 | 36.3 | 1.12 | 4.00 | 8.34 | 7.83 | 5.3 | 26.6 | 0.3 | 2.0 | 4.5 | 1.5 | 17.4 | 81.1 | C | 0.7 | 0.37 | 9.6 | 20.4 | 15.6 | 72.7 | 1.0 | 109.7 | NIL | 1.0 | 63.0 | 92.5 | 156.5 | 17 |
| | | 75-100 | 125 | 6.5 | 5.3 | 32.3 | 1.03 | 4.00 | 9.38 | 14.57 | 4.4 | 33.4 | 0.2 | 5.6 | 12.9 | 2.1 | 18.7 | 79.2 | C | 1.3 | | 12.2 | 26.4 | 21.1 | 83.3 | 1.3 | 142.1 | NIL | 2.0 | 60.0 | 76.5 | 138.5 | |
| | | 100-109 | 24 | 7.1 | 6.8 | | 1.17 | 1.63 | 4.17 | 5.33 | 1.4 | 13.7 | 0.0 | 4.9 | 11.3 | 94.5 | 0.4 | 5.1 | FS | 0.3 | | 8.6 | 13.2 | 12.8 | 71.8 | 1.1 | 98.9 | NIL | 0.0 | 52.7 | 45.9 | 98.6 | |
| | | 109-133 | 119 | 6.8 | 4.5 | 25.8 | 1.22 | 5.25 | 5.38 | 17.17 | 3.2 | 36.2 | 0.4 | 7.3 | 16.7 | 7.6 | 23.7 | 68.7 | C | 2.1 | | 16.3 | 52.5 | 31.2 | 107.0 | 1.6 | 192.3 | NIL | 3.7 | 103.0 | 107.5 | 214.2 | |
| | | 133-180 | 88 | | | 40.4 | 0.40 | 3.13 | 5.21 | 15.43 | 19.1 | 43.3 | 0.7 | 4.2 | 9.8 | 11.3 | 20.2 | 68.5 | C | 6.6 | | 24.0 | 53.9 | 47.9 | 169.6* | 1.3 | 272.7* | NIL | 0.0 | 52.7 | 220.0 | 272.7 | |
| | | 180-270 | 52 | 7.8 | 6.9 | 19.5 | 1.12 | 13.75 | 5.21 | 0.76 | 0.1 | 20.9 | 1.8 | 9.8 | 22.4 | 45.8 | 20.4 | 33.8 | SCL | 0.8 | | 26.4 | 78.6 | 45.2 | 200.1 | 6.3 | 330.2 | NIL | 2.5 | 120.3 | 187.5 | 320.3 | 25 |
| #55840-E47130 | 16 | 0-12 | 74 | 3.9 | 5.7 | 63.7 | 1.07 | 2.63 | 5.21 | 6.85 | 37.8 | 53.6 | 18.4 | 8.4 | 19.1 | 2.9 | 30.8 | 66.3 | C | 0.3 | | 10.4 | 15.4 | 20.8 | 84.2 | 0.9 | 130.3 | NIL | 0.0 | 55.0 | 70.0 | 125.0 | 20 |
| | | 12-27 | 93 | 4.5 | 6.8 | 43.7 | 0.99 | 2.50 | 6.25 | 6.63 | 10.5 | 26.9 | 1.1 | 7.6 | 17.6 | 12.0 | 25.8 | 62.2 | C | 0.0 | | 7.3 | 14.3 | 12.2 | 57.9 | 1.3 | 85.7 | NIL | 5.0 | 26.3 | 47.5 | 78.8 | |
| | | 27-60 | 120 | 5.3 | 7.1 | 48.5 | 1.06 | 4.29 | 7.25 | 12.83 | 7.8 | 33.3 | 0.2 | 5.5 | 12.4 | 11.6 | 19.1 | 69.3 | C | 1.8 | | 9.9 | 15.8 | 16.2 | 84.2 | 1.1 | 121.4 | NIL | 2.5 | 36.7 | 70.0 | 109.2 | |
| | | 60-90 | 124 | 6.6 | 6.2 | 48.4 | 1.63 | 7.83 | 8.33 | 20.65 | 4.0 | 42.5 | 0.3 | 6.0 | 14.0 | 0.1 | 33.1 | 66.8 | C | 1.4 | <0.20 | 19.2 | 55.0 | 34.4 | 142.0 | 2.4 | 233.8 | NIL | 1.0 | 47.0 | 169.0 | 217.0 | |
| #54965-E46520 | 29 | 0-10 | 131 | 5.1 | 6.8 | 61.0 | 1.22 | 2.81 | 10.42 | 8.58 | 11.3 | 34.3 | 3.5 | 2.0 | 4.5 | 1.4 | 21.8 | 76.8 | C | 2.3 | | 6.8 | 18.0* | 16.3 | 52.6 | 2.0 | 88.9* | NIL | 0.0 | 22.8 | 42.5 | 65.4 | 7 |
| | | 10-30 | 109 | 4.7 | 5.8 | 45.4 | 1.28 | 2.37 | 12.50 | 7.50 | 12.8 | 36.4 | 1.5 | 2.2 | 4.9 | 2.3 | 21.0 | 76.7 | C | 2.4 | 1.40 | 3.1 | 17.0 | 16.3 | 83.1 | 1.1 | 97.5 | NIL | 2.0 | 25.2 | 57.5 | 84.7 | 15 |
| | | 30-60 | 118 | 6.9 | 6.9 | 28.7 | 1.28 | 4.25 | 8.33 | 16.30 | 3.7 | 33.9 | 0.4 | 13.2 | 30.2 | 1.0 | 17.0 | 82.0 | C | 1.6 | | 12.5 | 26.9 | 22.6 | 105.2 | 1.1 | 155.8 | NIL | 0.0 | 42.4 | 92.5 | 134.9 | |
| | | 60-120 | 122 | 7.7 | 7.1 | 39.2 | 1.63 | 19.25 | 8.33 | 29.56 | 0.9 | 59.7 | 0.5 | 15.6 | 36.1 | 1.1 | 18.9 | 80.0 | C | 4.6 | | 28.6 | 11.5 | 54.3 | 215.7 | 2.8 | 284.3 | NIL | 7.5 | 103.1 | 173.7* | 284.3* | |
| #56230-E48925 | 38 | 3-0 | 218 | 3.2 | 4.1 | | 0.33 | 0.38 | 1.04 | 1.37 | 55.1 | 58.2 | 35.0 | 1.6 | 3.8 | | | | | | | 3.9 | 1.5 | 3.8 | 23.9 | 1.7 | 30.9 | NIL | 0.5 | 14.4 | 21.0 | 35.9 | 15 |
| | | 0-8 | 43 | 3.3 | 4.9 | 21.3 | 0.77 | 0.50 | 3.13 | 2.93 | 8.4 | 15.2 | 1.3 | 2.7 | 6.4 | 50.5 | 26.6 | 22.9 | SCL | 0.8 | 11.11 | 4.7 | 2.0 | 6.8 | 35.4 | 1.0 | 45.2 | NIL | 3.7 | 18.5 | 40.3 | 63.5 | 16 |
| | | 8-30 | 68 | 3.7 | 7.2 | 16.8 | 0.44 | 0.73 | 4.69 | 2.98 | 8.7 | 17.5 | 0.4 | 0.4 | 0.9 | 36.6 | 32.9 | 30.5 | CL | 4.0 | 5.12 | 4.7 | 1.8 | 5.5 | 21.5 | 0.8 | 29.6 | NIL | 0.5 | 12.6 | 31.5 | 44.6 | 11 |
| | | 30-60 | 71 | 6.1 | 6.8 | 20.5 | 1.07 | 3.25 | 4.25 | 10.87 | 2.1 | 23.5 | 0.2 | 3.3 | 7.5 | 47.4 | 17.1 | 35.5 | SC | 1.4 | 0.55 | 20.6 | 53.9 | 37.8 | 184.1 | 2.1 | 278.0 | NIL | 2.5 | 120.3 | 137.5 | 260.3 | |
| | | 60-90 | 54 | 3.7 | 6.6 | 29.3 | 0.53 | 0.81 | 2.54 | 4.39 | 7.5 | 17.7 | 0.1 | 0.5 | 1.3 | 56.6 | 10.9 | 32.5 | SCL | 2.2 | 4.42 | 7.2 | 8.8 | 13.6 | 57.9 | 1.1 | 81.4 | NIL | 0.0 | 22.9 | 47.5 | 70.4 | |
| #58585-E47835 | 42 | 6-0 | 235 | 4.2 | 4.9 | | 0.21 | 0.45 | 1.04 | 3.15 | 51.5 | 56.4 | 36.6 | 4.2 | 9.8 | | | | | | | 6.6 | 7.1 | 16.3 | 45.9 | 1.1 | 70.4 | NIL | 0.0 | 22.6 | 42.5 | 65.1 | 13 |
| | | 0-8 | 130 | 4.1 | 4.7 | 50.5 | 0.13 | 0.44 | 1.46 | 5.11 | 49.9 | 57.0 | 28.1 | 5.3 | 12.0 | | | | | 1.9 | | 8.5 | 11.5 | 13.8 | 61.2 | 0.4 | 86.9 | NIL | 0.0 | 19.5 | 67.5 | 87.0 | 17 |
| | | 8-30 | 96 | 3.7 | 4.9 | 46.7 | 0.32 | 1.25 | 4.79 | 7.72 | 21.9 | 36.0 | 1.2 | 8.0 | 18.2 | 1.1 | 19.4 | 79.5 | C | 0.4 | | 9.3 | 17.0 | 14.5 | 73.6 | 0.4 | 105.5 | NIL | 7.5 | 19.5 | 67.5 | 94.5 | 18 |
| | | 30-60 | 87 | 3.3 | 4.2 | 39.2 | 0.28 | 1.62 | 4.16 | 10.76 | 16.9 | 33.7 | 0.4 | 1.4 | 3.3 | 9.1 | 21.5 | 69.4 | C | 4.1 | 38.90 | 16.1 | 24.7 | 31.6 | 121.0 | 0.6 | 177.9 | NIL | 7.5 | 36.7 | 135.0 | 179.2 | |
| | | 60-90 | 89 | 3.3 | 4.0 | 37.1 | 0.38 | 1.75 | 4.68 | 14.13 | 16.6 | 37.5 | 0.4 | 3.8 | 8.7 | 6.3 | 21.5 | 72.2 | C | 5.4 | 32.20 | 19.5 | 30.8 | 37.1 | 152.5 | 1.1 | 221.5 | NIL | 0.0 | 38.9 | 127.5 | 166.4 | |
| | | 90-150 | 53 | 3.8 | 6.1 | 19.1 | 0.53 | 0.75 | 2.60 | 3.80 | 5.4 | 13.1 | 0.2 | 4.2 | 9.8 | 46.7 | 22.6 | 30.7 | SCL | 3.0 | | 6.0 | 6.6 | 8.8 | 47.3 | 1.1 | 64.9 | NIL | 0.0 | 19.5 | 35.0 | 54.5 | |
| #59120-E47220 | 45 | 0-15 | 99 | 4.8 | 4.7 | 40.9 | 1.19 | 1.75 | 5.21 | 10.22 | 8.2 | 26.6 | 4.4 | 1.3 | 2.9 | 33.0 | 20.5 | 46.5 | C | 0.9 | 0.47 | 17.4 | 34.1 | 33.4 | 136.8 | 1.4 | 205.7 | NIL | 0.0 | 60.7 | 137.5 | 198.2 | 23 |
| | | 15-30 | 110 | 6.4 | 7.4 | 39.2 | 1.22 | 2.37 | 8.33 | 13.91 | 3.6 | 29.4 | 0.5 | 2.7 | 6.5 | 27.1 | 21.6 | 51.3 | C | 2.2 | 0.23 | 16.1 | 36.8 | 31.6 | 131.5 | 2.9 | 202.8 | NIL | 0.0 | 47.0 | 127.5 | 174.5 | |
| | | 30-90 | 84 | 8.0 | 7.1 | 19.7 | 1.63 | 18.00 | 6.25 | 27.65 | 0.2 | 53.6 | 0.9 | 6.7 | 15.6 | 48.2 | 19.0 | 32.8 | SCL | 1.0 | <0.20 | 48.1 | 67.7 | 113.0 | 462.9 | 1.8 | 645.4 | NIL | 5.0 | 126.0 | 495.0 | 626.0 | |
| | | 90-150 | 83 | 2.9 | 3.8 | 40.9 | 0.47 | 2.00 | 12.50 | 10.11 | 30.8 | 55.9 | 2.4 | 4.9 | 11.3 | 4.1 | 17.9 | 78.0 | C | 0.3 | >28.0 | 18.9 | 25.0 | 33.5 | 105.2 | 0.7 | 164.4 | NIL | 5.0 | 76.8* | 82.5 | 164.4* | |

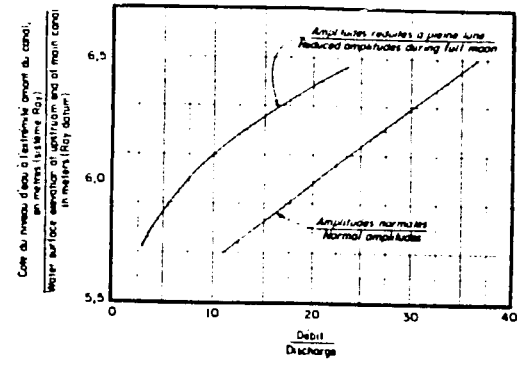
* Estimated
** Exchange Acidity



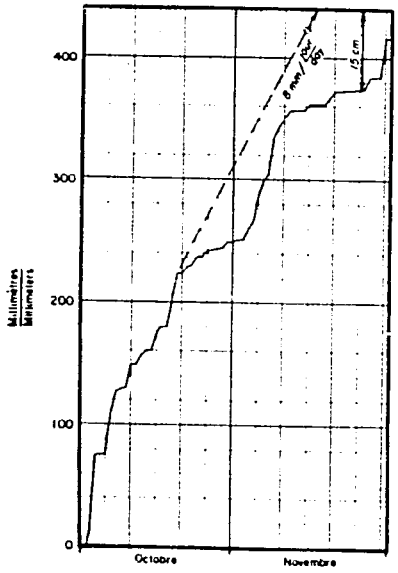

PROBABILITE ESTIMEE DE LA PLUVIOMETRIE ANNUELLE A MONCHON
ESTIMATED PROBABILITY OF ANNUAL PRECIPITATION AT MONCHON



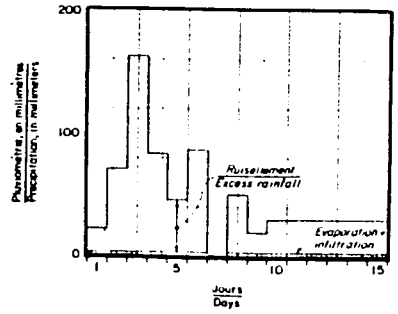

PLUVIOMETRIE CUMULEE A MONCHON PENDANT LE NOMBRE DE JOURS CONSECUTIFS INDIQUEE EN ORDONNES
CUMULATIVE RAINFALL AT MONCHON FOR CONSECUTIVE DAYS



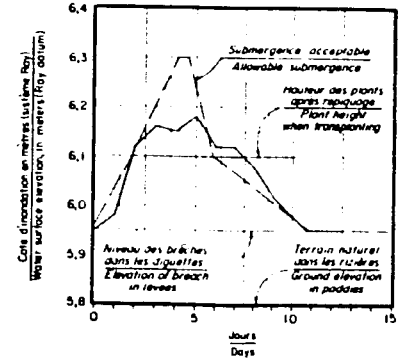

DEBIT MOYEN DU CANAL PRINCIPAL PENDANT UN CYCLE DE MAREE
MAIN CANAL AVERAGE DISCHARGE FOR ONE TIDE CYCLE




PLUVIOMETRIE CUMULEE DU
1er OCTOBRE AU 15 NOVEMBRE 1955 A MONCHON
CUMULATIVE RAINFALL AT MONCHON
FROM OCTOBER 1st TO NOVEMBER 15, 1955

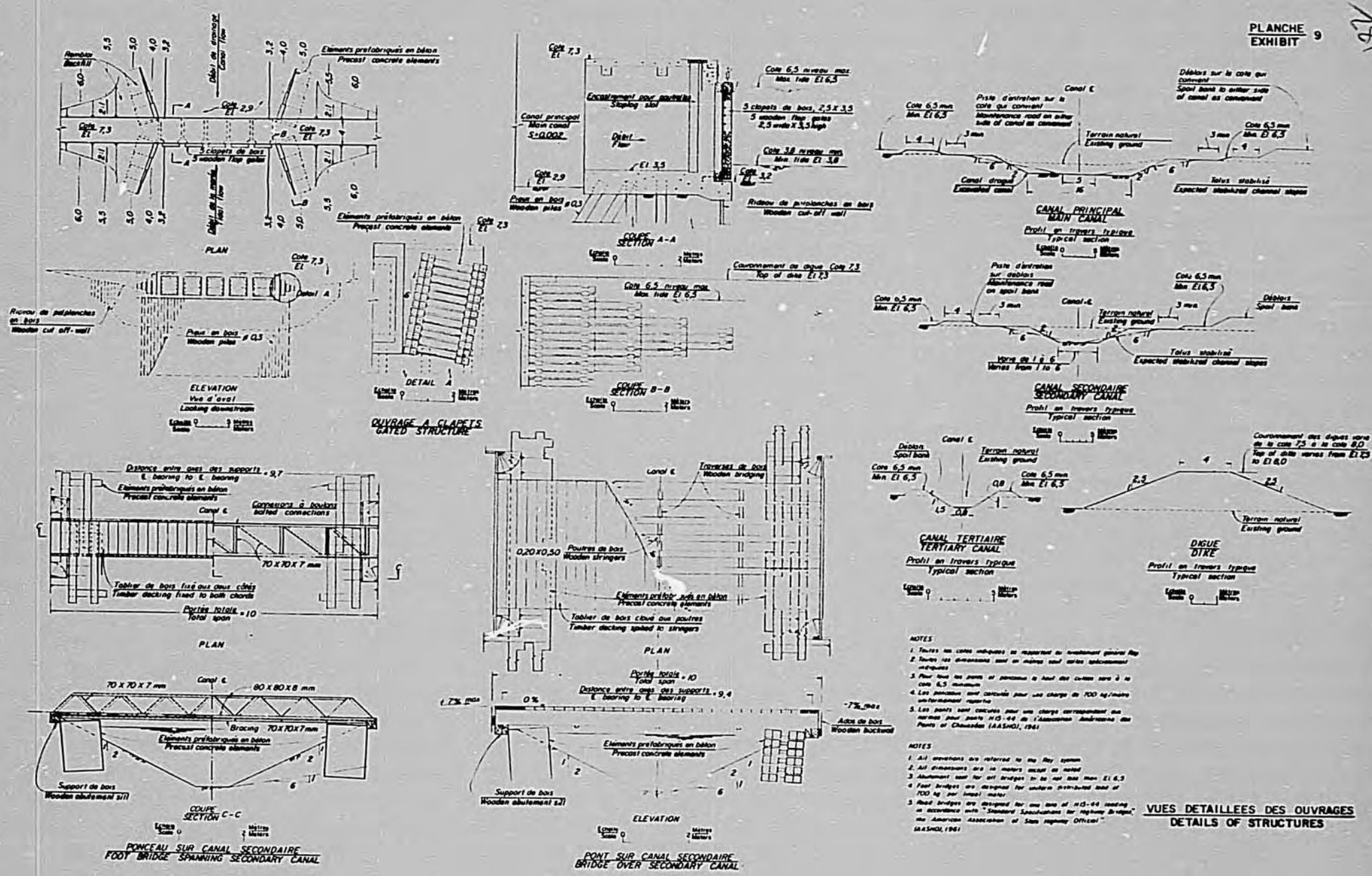



PLUVIOMETRIE EXTREME PENDANT UNE PERIODE DE 15 JOURS
15-DAY DESIGN STORM

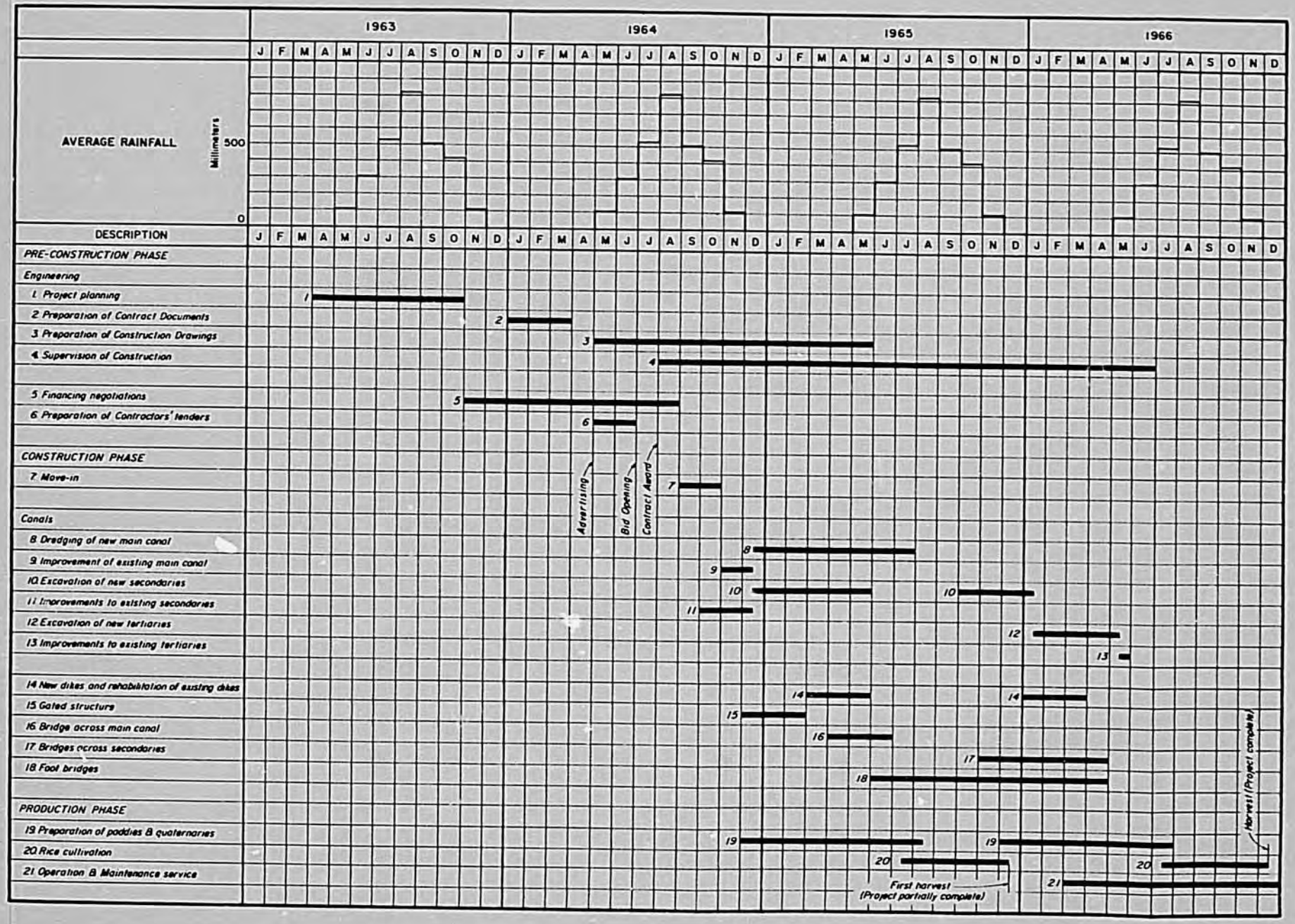



NIVEAU D'EAU DANS LES RIZIERES PENDANT
LA PERIODE PLUVIEUSE DE BASE DE 15 JOURS
WATER SURFACE IN PADDIES DURING
DESIGN 15-DAY STORM

RESULTATS DES ETUDES HYDRAULIQUES
RESULTS OF HYDRAULIC ANALYSES




VUES DETAILLEES DES OUVRAGES
DETAILS OF STRUCTURES




CONSTRUCTION

Exhibit 11

**ESTIMATE** **HARZA ENGINEERING COMPANY INTERNATIONAL**

Project Number 309

Project MONCHON Date 10.3.63 Page ____ of ____ Pages

Structure Project Construction Cost Estimated by JAT Checked by MB

| Item No. | ITEM | Quantity | Unit Price | | Amount | |
|---|---|---|---|---|---|---|
| | | | GF (Local) | U.S. Dollars | GF (Local) | U.S. Dollars |
| 1 | Canals - Excavation | | | | | |
| | Main, improvement | 41,500 $m^3$ | 187 | 0.80 | 7,760,500 | 33,200 |
| | Main, new | 177,000 $m^3$ | 187 | 0.80 | 33,099,000 | 141,600 |
| | Secondary, improve. | 153,000 $m^3$ | 110 | 1.10 | 16,830,000 | 168,300 |
| | Secondary, new | 300,000 $m^3$ | 110 | 1.10 | 33,000,000 | 330,000 |
| | Tertiary, improve. | 26,100 $m^3$ | 110 | 1.10 | 2,871,000 | 28,710 |
| | Tertiary, new | 154,000 $m^3$ | 110 | 1.10 | 16,940,000 | 169,400 |
| | Subtotal, canal excavation | | | | 110,500,500 | 871,210 |
| | | | | | | |
| 2 | Dikes | | | | | |
| | New | 10,000 $m^3$ | 143 | 1.40 | 1,430,000 | 14,000 |
| | Improvement | 33,000 $m^3$ | 110 | 1.00 | 3,630,000 | 33,000 |
| | Subtotal, dikes | | | | 5,060,000 | 47,000 |
| | | | | | | |
| 3 | Control Structure | | | | | |
| | Structural excavation | 600 $m^3$ | 165 | 1.80 | 99,000 | 1,080 |
| | Cut-off wall, timber | 20 $m^3$ | 7,590 | 7.70 | 151,800 | 154 |
| | Pile foundation, timber | 1,900 lm | 3,300 | 2.66 | 6,270,000 | 5,054 |
| | Concrete, structural | 170 $m^3$ | 17,600 | - | 2,992,000 | - |
| | Concrete in cribs (precast) | 55 $m^3$ | 35,200 | - | 1,936,000 | - |
| | Reinforcing steel | 1,500 m.t | 198 | - | 297,000 | - |
| | Flap gates | 5 each | 825,000 | 1000.00 | 4,125,000 | 5,000 |
| | Crib fill | 150 $m^3$ | 693 | 4.60 | 103,950 | 690 |
| | Backfill | 500 $m^3$ | 125 | 1.35 | 62,500 | 675 |
| | Formwork | 550 $m^2$ | 2,530 | 3.20 | 1,391,500 | 1,760 |
| | Subtotal, control structure | | | | 17,428,750 | 14,413 |
| | | | | | | |
| 4 | Main canal bridge | job | Lump Sum | | 3,300,000 | 4,000 |
| 5 | Gates at Dinaya | 2 each | 55,000 | 1000.00 | 110,000 | 2,000 |
| 6 | O. & M. bridges | 4 each | 1,650,000 | 1300.00 | 6,600,000 | 5,200 |
| 7 | Foot bridges | 17 each | 220,000 | 220.00 | 3,740,000 | 3,740 |
| | Subtotal, Direct Cost | | | | 146,739,250 | 947,553 |
| | | | | | | |

Exhibit 11

**ESTIMATE** **HARZA ENGINEERING COMPANY INTERNATIONAL**

Project Number 309

Project MONCHON Date 10.3.63 Page 2 of 2 Pages

Structure Project Construction Cost Estimated by JAT Checked by MB

| Item No. | ITEM | Quantity | Unit Price (Local) | Unit Price U.S. Dollars | Amount GF (Local) | Amount U.S. Dollars |
|---|---|---|---|---|---|---|
| | Subtotal, Direct Cost (brought forward) | | | | 146,739,250 | 947,553 |
| | Contingencies (15% ±) | | | | 22,260,750 | 152,447 |
| | Total Direct Cost | | | | 169,000,000 | 1,100,000 |
| | Engineering & Supervision of Construction (15% ±) | | | | 16,000,000 | 200,000 |
| | Construction Cost of Civil Works | | | | 185,000,000 | 1,300,000 |
| | Cost of Land Preparation | | | | 35,000,000 | - |
| | Total Project Construction Cost | | | GF | 220,000,000 | $1,300,000 |
| | Total Equivalent to | | | | US $ 2,190,000 | |
| | or | | | | GF 325,000,000 | |