Japan International Cooperation Agency
The Republic of Cameroon
Ministry of Mines, Water and Energy

Feasibility Study on Rural Electrification Project

in

The Republic of Cameroon

Summary Report

December 1999

Electric Power Development Co., Ltd.

Conclusions and Recommendations

The Republic of Cameroon ("Cameroon") made a drastic revision of its Electric Power Sector Law by Law No. 98/022 on December 24, 1998, and inaugurations of an Electric Power Sector Regulating Agency and a Rural Electrification Agency as of June 15 and September 8, 1999, respectively, were approved by President Paul Biya. This means that, along with introduction of privatization of the electric enterprises, on the other hand, financial and technical aid from the Cameroonian Government for promotion of rural electrification is now ensured, indicating in essence that eliminating the chronic shortage in supply of electric power to rural areas, thus improving the livelihood of the people is considered indispensable for Cameroon to become economically self-sustaining.

The Survey Team, in view of such a situation and based on a total of six field investigation trips and the results of discussions with various government agencies, conducted studies for a program of rural electrification by means of small hydroelectric power stations.

The Survey Team carried out investigations in the field regarding Ngambe-Tikar, Ndokayo, and Olamze which had been named by the Cameroonian Government as prospective sites for small hydro-electric power generation projects. Hydroelectric power development plans were formulated based on investigations of topographical and geological features of the localities, and technical and economic studies were made. The resulting conclusions and recommendations are as follows.

Conclusions

1. It is technically possible for an intake dam and power station to be constructed at each of the proposed sites, while socio-economically, electrification of neighboring rural communities through construction of a hydroelectric power station will contribute extremely to improvement of the livelihood of local people. However, as for the Ngambe-Tikar site, the civil structures are excessive due to 10 m^3/s of power station water discharge and about 1,000 m^3/s of flood discharge to be considered in design. As for the Olamze, the Woro river flows in gentle slope through the flat lands, and an upstream road-bridge site was inundated in the recent flood so that further inundation of the surrounding villages are feared by new intake-dam implementation. The Ndokayo site, particularly, is favored with optimum conditions for a power station of the scale contemplated, and is a superb site for hydro power.

2. Peak demand (kW) is forecasted in the assumption that an annual increase of population is 3 percent, and one half of house-holds receive the electricity, with 500 W each, in the environs, plus expected demand of local industries. In the meantime, the maximum scale of installed capacity is found for the 3 sites based on the usual way in the central Africa that a 180 days river discharge is set up as a standard against which the max. discharge of the power station is selected, as follows:

	Projected Installed Capacity	Forecasted Demand in 2010
Ngambe-Tikar	530 kW (2 units)	560 kW
Ndokayo	4,530 kW (3 units)	4,620 kW
Olamze	400 kW (2 units	1,145 kW

3. Ngambe-Tikar Hydro-Project

There is few suitable site for the mini-hydro project in the vicinity of Ngambe-Tikar village. The present project is found on the Kim river six kilometres south from the village. The headrace canal of 500 m long is constructed on the left bank, the generators of 530 kW of installed capacity produce 3.92 GWh of energy per year by the water head of 7 m and the max. water discharge of 10 m^3/s. It will be sent to the village of Ngambe-Tikar and its environs by the 30 kV transmission of 25 km long. The intake dam could be made inexpensive by good use of the rock outcrops in the riverbed, however, only a few head available, a large and long canal needed, and the structure shall be built to withstand about 1,000 m^3/s of flood discharge.

The project costs amount to 1,852 x 10^6 F.CFA for the civil works, 2,475 x 10^6 F.CFA for the electromechanical works, 335 x 10^6 F.CFA for the transmission lines, and 5,203 x 10^6 F.CFA in total inclusive of the engineering costs. The project cost per kWh and kW is, respectively, 138 F.CFA and 9.8 x 10^6 F.CFA, and the hydro-project could not be justified in comparison with the diesel power station if based on such ordinary or commercial method of economic evaluation as so far made. (100 F = 17.6 Japanese Yen for reference)

4. Ndokayo Hydro-Project

1) The Ndokayo Project, approximately 10 km from Betare Oya, is a hydroelectric power development scheme which would make use of the head of 91 m provided by the waterfalls of Mari. Intake of 4 m^3/s of water to be used would be done in the right bank with a wet masonry concrete dam 4.5 m in height, with this water conducted to a power station by a headrace tunnel (length 133 m) and a steel penstock (length 306 m, inside

diameter 1.4 m), with electric energy of 30.6 GWh produced annually using three Francis turbines and generators (output 4,530 kW). The electric power generated would be supplied by 30 kV transmission lines 152 km in length to the Betare Oya and Ndokayo districts, of course, and to Garoua Boulai District and the districts of Monbal, Borongo Garga, and Sarali as well.

2) Construction of the Ndokayo Project would be carried out in two phases in consideration of the power demand in the district. That is, two generators (output 3,020 kW) would be installed by 2003 with the remaining one unit installed by the end of September 2010. The construction period for the first phase would be 18 months extending over two dry seasons. Materials and equipment for civil works would be mostly procured inside Cameroon, and electrical and mechanical equipment for the power station and surroundings would be imported. However, with regard to transmission lines, the system employed in Cameroon up to the present is to be preserved in aiming for convenience of maintenance and control.

3) The construction cost of Ndokayo Hydroelectric Power Station would be as given below.

(Unit: 10^6 F.CFA)

i) Hydro Power Project	1st Phase Construction (3,020 kW)	2nd Phase Construction (1,510 kW)	Total
Civil Construction Cost	2,540	16	2,556
Electrical Construction Cost	3,360	1,185	4,545
Engineering and Administration Cost	738	150	888
Sub-total	6,638	1,351	7,989
ii) Transmission Line (152km)			
Construction Cost	1,630		1,630
Engineering and Administration Cost	432		432
Sub-total	2,062		2,062
Total	8,700	1,351	10,051

(100F = 17.6 Japanese Yen)

4) The generating cost of Ndokayo Hydroelectric Power Station, for ultimate output of 4,530 kW, is extremely cheap at 39 F.CFA/kWh. When compared with the alternative thermal (diesel plant), the economic internal rate of return, for development in two phases, is 11.5%, and with benefit/cost ratio and benefit-minus-cost 1.27 and 2.22 x 10^6 francs CFA, respectively, the economics is amply favorable.

5) Ndokayo Hydroelectric Power Station would make use of the waterfalls of Mari having a head as much as approximately 90 m. With intake of 6 m^3/s, there is slight fear that the falls may be drained up temporarily in the dry season, however, it could be prevented by the daily regulation of water in the pond. The project site including the intake pond is in the state land, not inhabited and no rare biota has been confirmed.

6) Today, in Cameroon, almost all of the meager existing facilities for rural electrification have become antiquated and, because of shortage of funds, repairs are not being made promptly. Work on new electrification projects is faced with extreme trouble in getting started due to difficulties in procurement of funds. However, with the new Electric Enterprise Law enacted, it is necessary to start new rural electrification projects using hydro power, and Ndokayo Hydroelectric Power Station would be an answer to this demand.

Income from sales of electric power in operation after completion of Ndokayo Hydroelectric Power Station will indicate a high rate of return, and with repayment of all or part of the amount to the abovementioned Rural Electrification Agency, it will be possible for funds to be furnished other rural area hydro power projects. A considerable effect is expected of the project in this way, while at the same time, since it will contribute to improvement in the livelihood of local residents, implementation of this project will have a tremendous significance.

5. Olamze Hydro-Project

As in the case of Ngambe-Tikar, there is few suitable site for the mini-hydro project on the Woro river near the village of Ata'antem. The present project is to build a compact structure of so-called dam-type power station on the rock outcrop portion of the Woro riverbed. It will produce 2.64 GWh of energy per year through the generators of installed capacity of 400 kW, by the use of 6 m of water head created and 9 m^3/s of max. water discharge. The energy will be sent on the 30 kV transmission line of 47 km long, and respond to the demand of Ambam and Olamze area in close connection with the existing diesel power stations of 900 kVA.

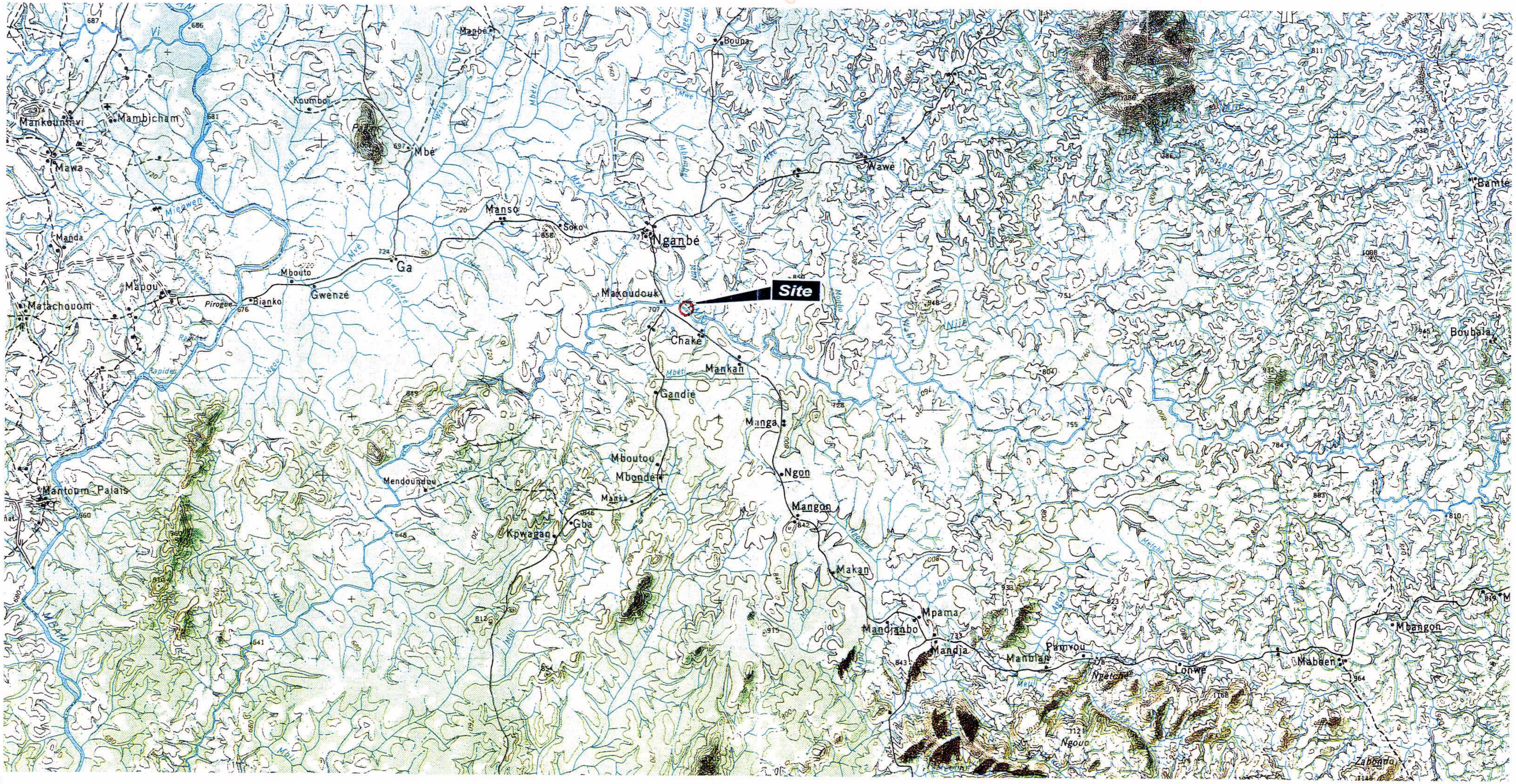
The project costs amount to 1,409 x 10^6 F.CFA for the civil works, 2,535 x 10^6 F.CFA for the electromechanical works, 615 x 10^6 F.CFA for the transmission lines, and 5,055 x 10^6 F.CFA in total inclusive of the engineering costs. The project cost per kWh and kW is 197 F.CFA and 12.6 x 10^6 F.CFA, respectively, and the hydro-project could not be justified in comparison with the diesel power station if based on such an ordinary or commercial method of economic evaluation as so far made.

Recommendations

1. Ndokayo Hydro, according to this present investigation, is judged to be a technically and economically feasible development project. It is desirable for this project to be planned for completion of its first phase (power station output 3,020 kW) by 2003 in consideration of the demand in this district. Taking into account preparations and the construction period, it is recommended that preparations for realization such as arrangements for development funds and execution of definite design work be carried out promptly.

2. With regard to the two projects of Ngambe-Tikar and Olamze, if going by conventional evaluation techniques, hydro will not be economically advantageous in comparison with alternative thermal. However, when the calls for realization of hydroelectric power stations from the local residents are considered, it is desirable for studies concerning these projects to be continued. However, with respect to the Olamze Project, it is first necessary to ascertain what effects will be brought about by backwater upstream from the pond resulting from construction of the intake dam on bridges and roads, residential areas and cultivated fields.

3. The Ndokayo hydro-project would be first rural electrification which is to be implemented under the new Electric Power Sector Law. For this reason, prior to the start of construction, the concrete set-up should have been made, by the cooperation of the ministries concerned and SONEL, not only of the frame-work but also of the definite plan, which will cover the details of management, organization and operation of the power station.



MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NGAMBÉ TIKAR

GEOGRAPHICAL LOCATION

Scale 1/200 000

Upstream view

Left bank

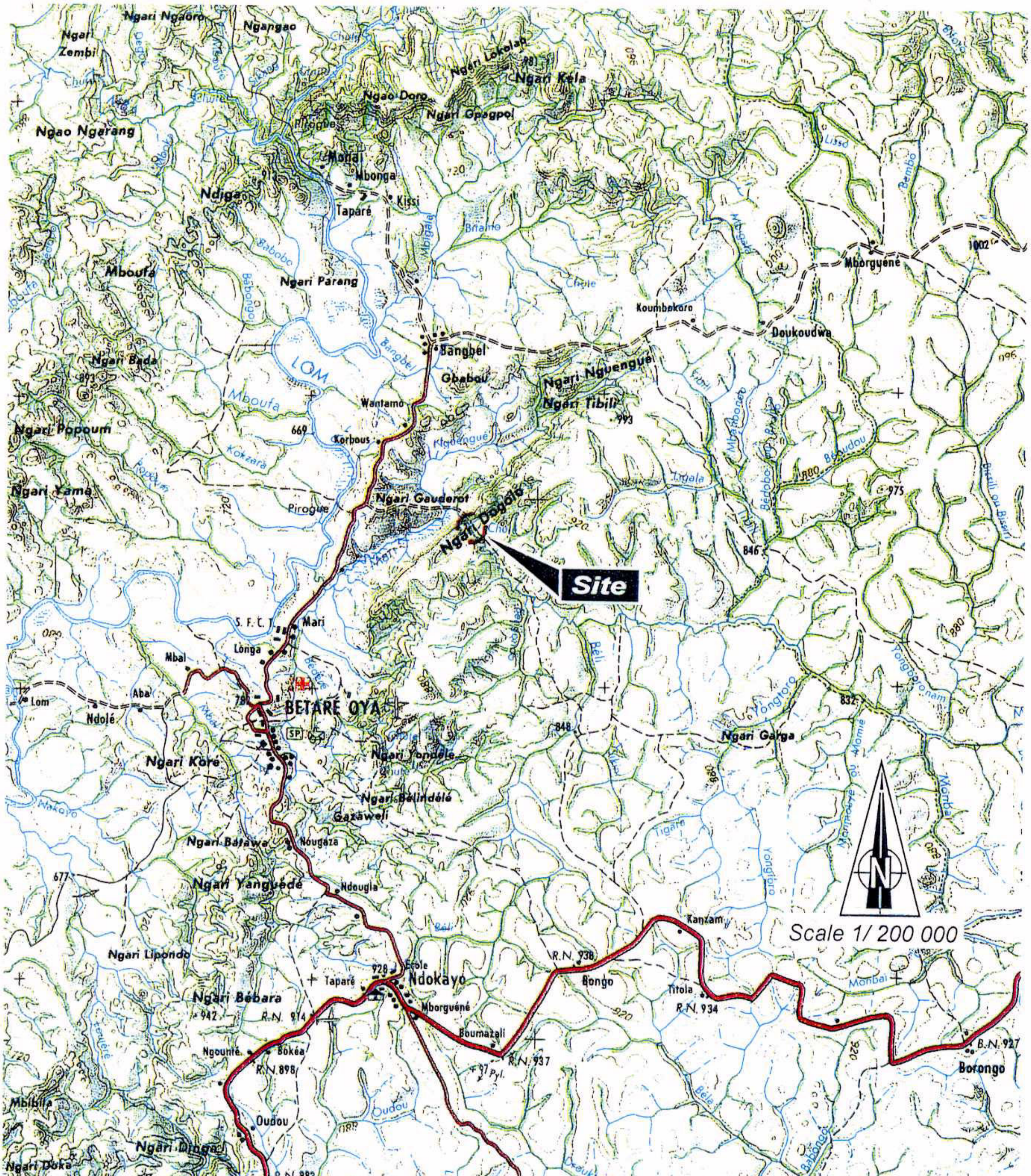
Downstream view

MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NGAMBÉ TIKAR

PHOTOGRAPHIC ILLUSTRATIONS

S-2



MINI HYDRO-ELECTRIC
POWER STATION PROJECT

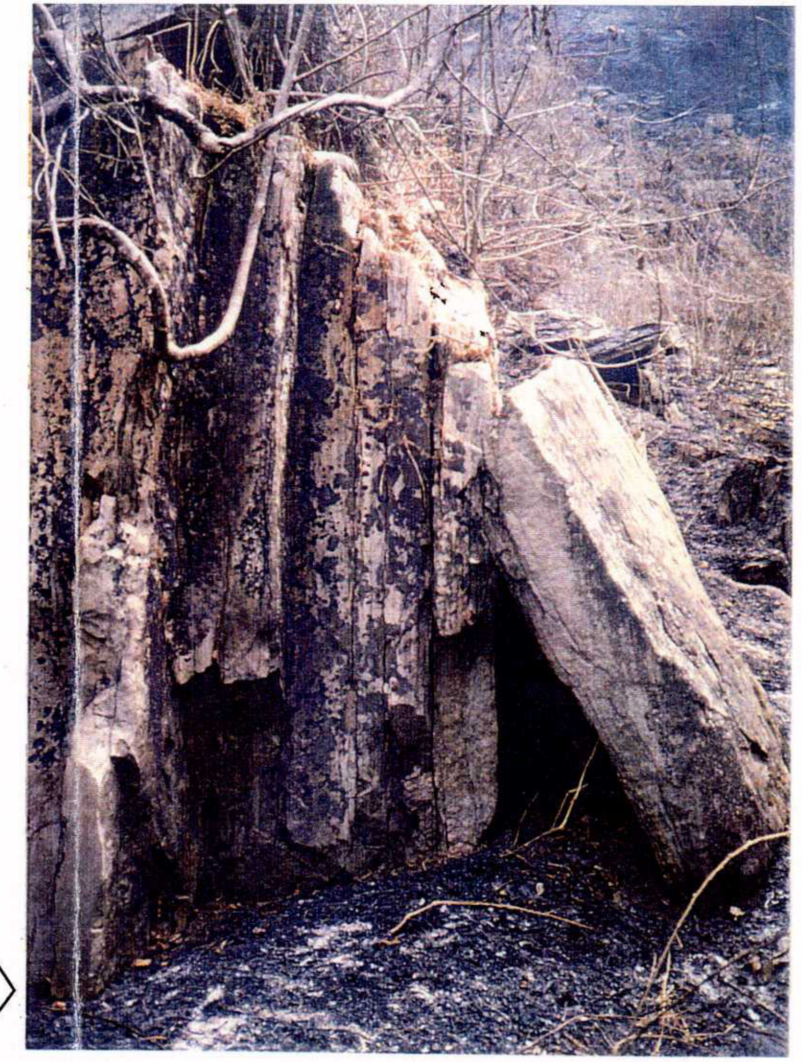
NDOKAYO SITE

GEOGRAPHICAL LOCATION

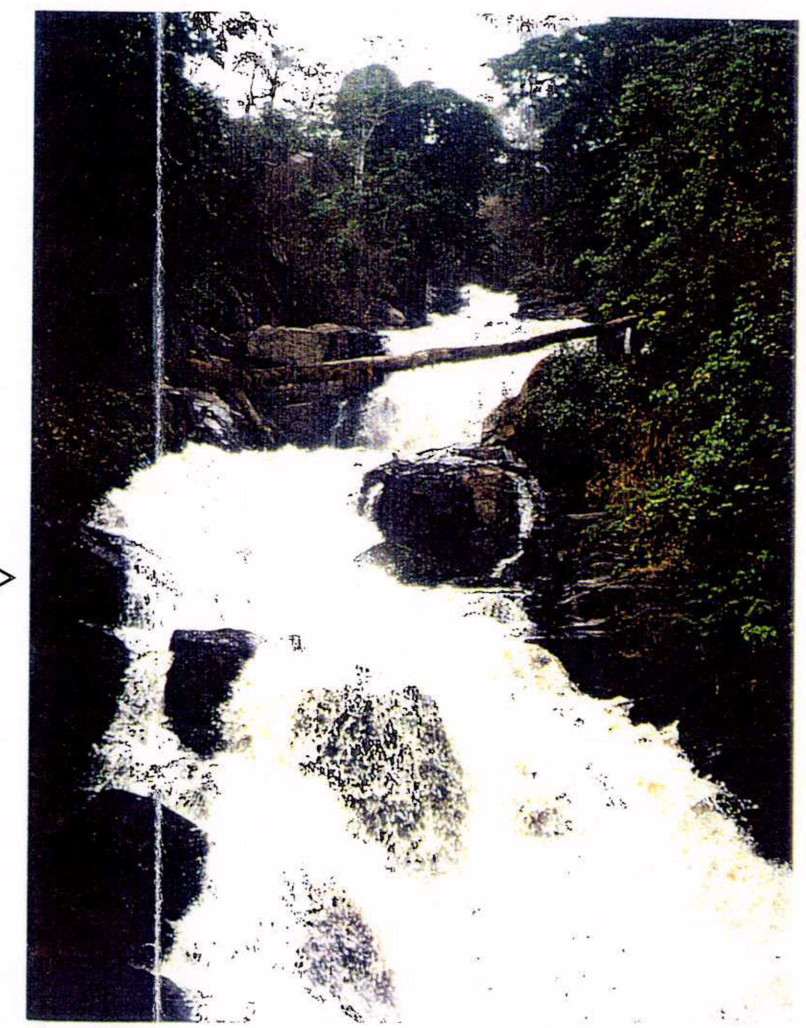
Fig. 8-7

5-3

Outcrops of quartzites
(with vertical fracturations)



Outcrops of quartzites
(Detail)



Water falls

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
NDOKAYO SITE	
PHOTOGRAPHIC ILLUSTRATIONS	
Fig. 8-10	

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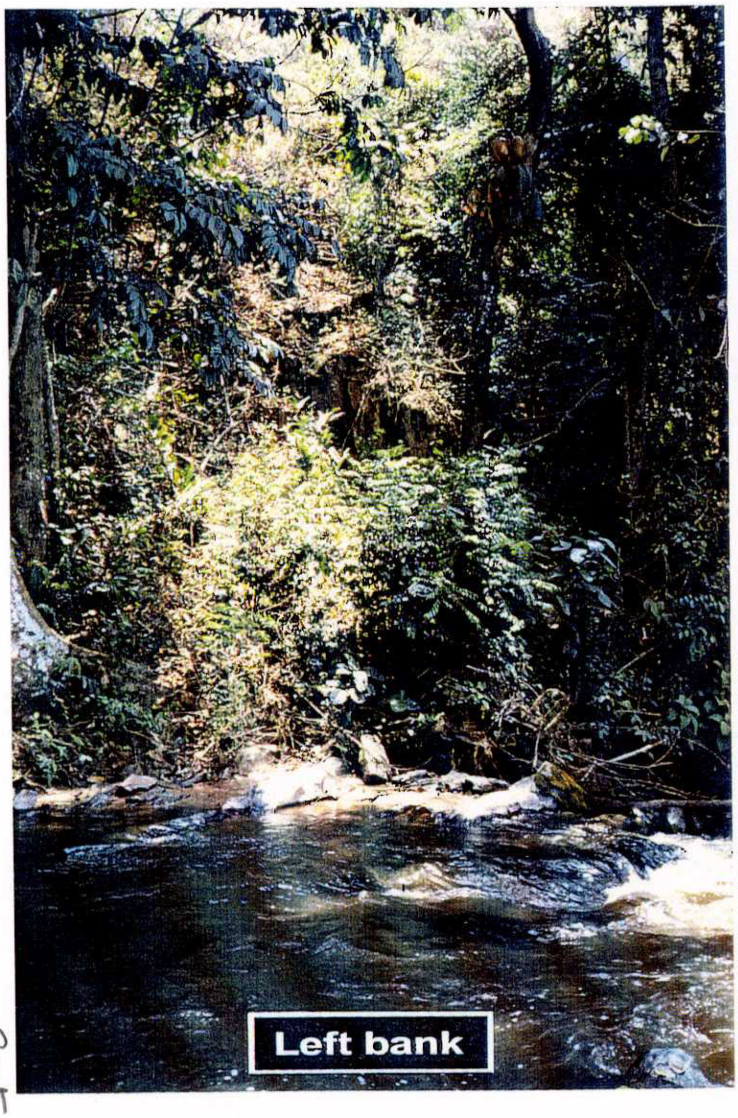
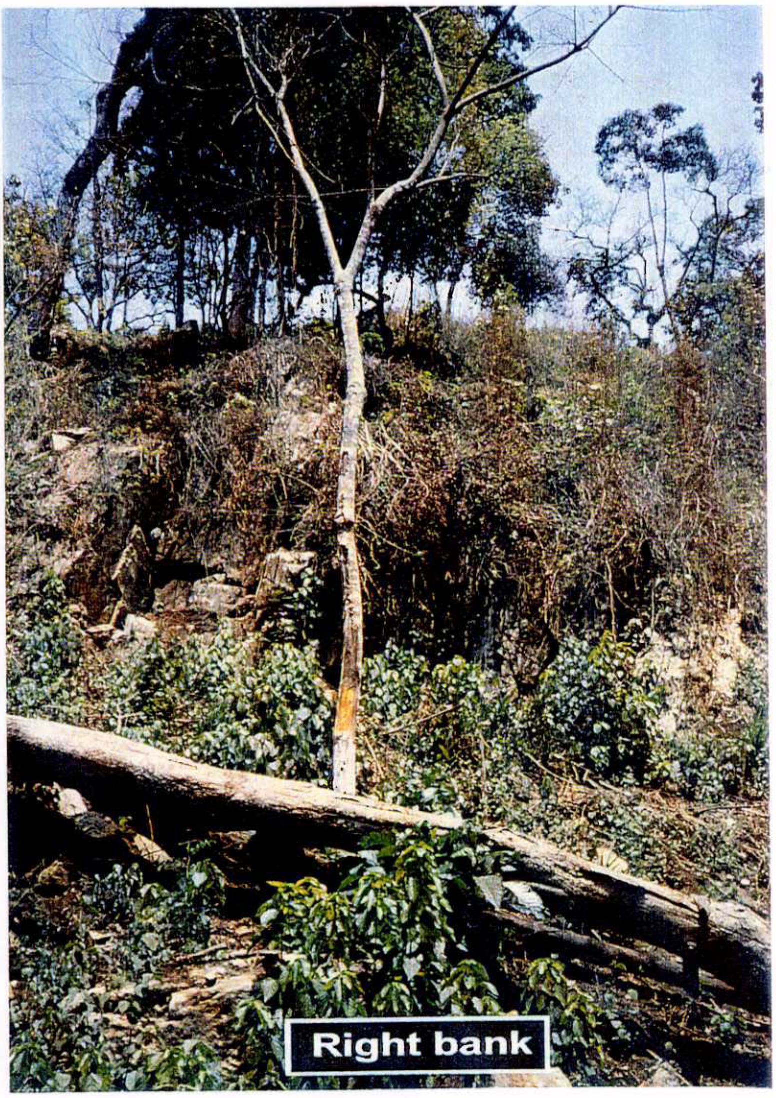




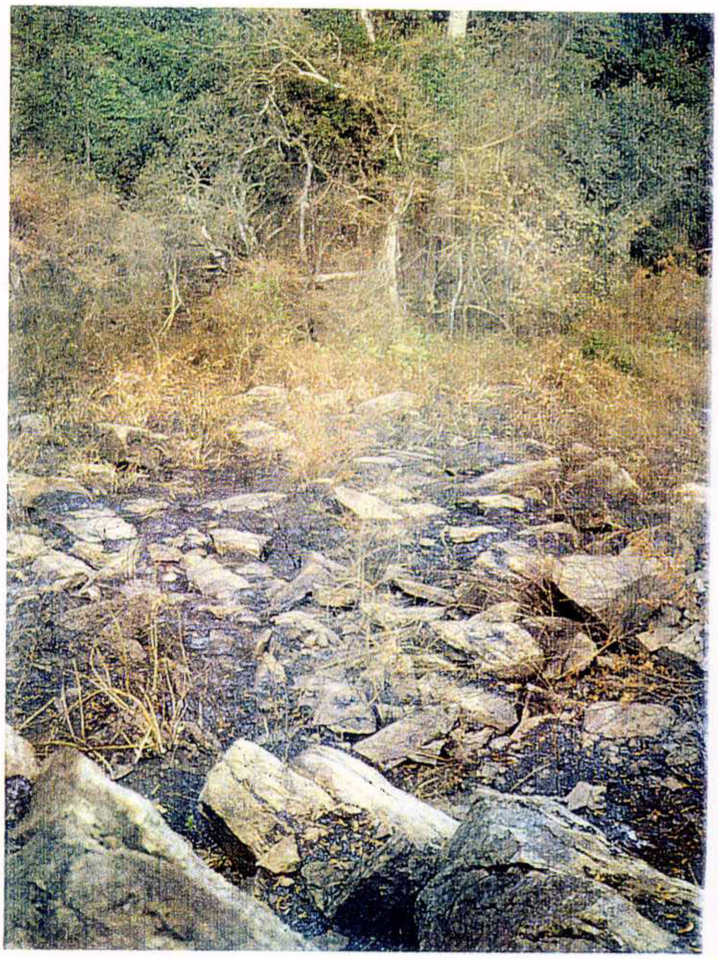
MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NDOKAYO SITE

PHOTOGRAPHIC ILLUSTRATIONS
- DAM SITE -

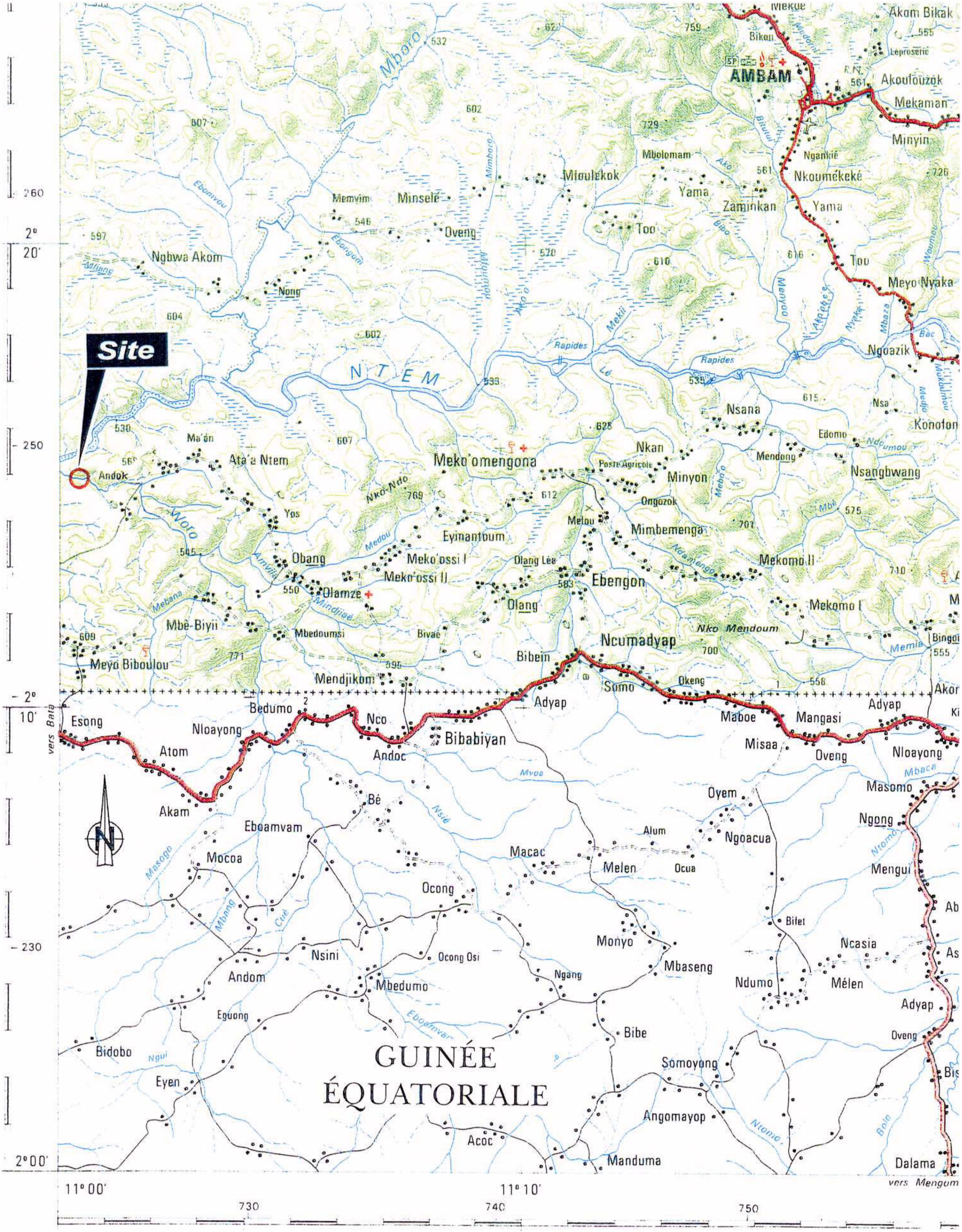
Fig. 8-12

Penstock area



Details of the slope with mass of fallen quartzites

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
NDOKAYO SITE	
PHOTOGRAPHIC ILLUSTRATIONS - PENSTOCK AREA - RIGTH BANK HILL	
Fig. 8-14	



MINI HYDRO-ELECTRIC
POWER STATION PROJECT

OLAMZÉ

GEOGRAPHICAL LOCATION

Fig. 8-15

River bed and left bank

River bed and right bank

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
OLAMZÉ	
PHOTOGRAPHIC ILLUSTRATIONS	
Fig. 8-19	

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Summary Report

Contents

Summary Report

1. Introduction

1.1 Background of Project

The Republic of Cameroon is providing approximately 98% of the electric power generated within its boundaries by means of water power. The electric energy production during one year in 1994-1995 was 2,735 GWh, while in 1995-1996 it was 2,823 GWh.

The power transmission distribution structure of the country is divided into the Southern System with its power sources Edea and Song-Loulou Hydro Stations, and the Northern System with its source Lagdo Hydro. Areas not serviced by these power transmission and distribution systems are supplied from independent diesel power plants. As of 1994, the electrification ratio of the country as a whole was an average of 24% of the total population of 12,900,000. Compared with the electrification ratio in areas centered at large cities such as Yaounde and Douala, the ratio of 46% in other areas is only 4%, so that electrification in regions other than metropolitan areas lags far behind. Independent-system diesel power plants are burdened with many problems such as rising fuel costs, difficulty in maintenance and parts replacement, antiquation of the distribution network, uncollected electricity bills, etc., and unless thoroughgoing remedial measures are set up, improvement of the present situation cannot be expected.

It was with such a background that the Government of Cameroon requested the Government of Japan to carry out a feasibility study on rural electrification through development of small hydro power stations.

1.2 Objectives and Scope of Study

This Study, the "Study on Rural Electrification Project in the Republic of Cameroon through Small Hydroelectric Development" has the objectives of formulating the optimum plan for electrification through development of small hydro power stations at three sites, namely, 1) Ngambe-Tikar, 2) Ndokayo, and 3) Olamze, sites which had been conformed in the scope of work agreed upon between the Japan International Cooperation Agency and the Government of the Republic of Cameroon on December 19, 1997, to evaluate the technical, economic, and financial feasibilities thereof.

In formulation of the plan, operation of the small hydros that would be done by local people was kept in mind and, along with carrying out studies of the two aspects of economics and finance, investigations were made under the principle of giving consideration to impact on the environment also.

Meanwhile, technology transfer to engineers of government agencies concerned and SONEL is considered as an important objective in carrying out the Study. As methods for achieving this may be cited technical discussions and examinations at work sites in Cameroon, including investigation sites, and joint operations carried out on inviting engineers to Japan and France.

1.3 Progress of Study

The investigations proceeded divided into three stages: 1) Preliminary Study, 2) Detailed Study, and 3) Feasibility Study. The Preliminary Study was carried out from February to October 1998 with the objective of obtaining adequate information for making the Detailed Study. In succession to the Preliminary Study, the Detailed Study was carried out from November 1998 to March 1999. The results of the Detailed Study were submitted by the end of March 1999 from the local firms LANA CAMEROUN and GEOFOR S.A. regarding topographic surveying and geological investigations, respectively.

Feasibility study work, the final stage of investigation, was commenced from April 1999. The ultimate objective of the feasibility study work was to make clear the appropriateness of the abovementioned three small hydro power development projects, and initial studies were completed by June 1999. The results of these initial studies were submitted in July 1999 in the form of an Interim Report. The comments ensuing from the explanations and discussions at the time of submission of the Interim Report further examined in detail have resulted in this Final Report.

This Study, as previously described, was executed in the three stages of Preliminary Study, Detailed Study, and Feasibility Study, each stage consisting of work in Japan and France, and work in Cameroon. Survey team at the various stages were made up with members of EPDC International Ltd. and those of Electricité de France.

During the study period, 3 counterpart engineers of the Ministry of Mines, Water and Energy, and Société Nationale de Electricité du Cameroun participated in the training program in Japan, they toured hydroelectric power stations including those of EPDC and public institutions in addition to taking part in discussions concerning the Project.

2. Outline of the Republic of Cameroon

2.1 Geography and Climate

The land has diverse features with tropical rain forests in the southern and western regions, savanna in the central region, and semi-arid desert in the north. The terrain is also varied with a coastal plain in the southwest, development of eroded canyons on a central plateau, a high mountainland in the west, and a plateau gently sloping down to Lake Chad in the north. As a consequence, vegetation and the living environment are extremely varied, and the diverse features of the African continent are all contained in this one country.

As the principal natural resources of the country may be cited petroleum, bauxite, iron ore, lumber, and besides, hydroelectric potential. The land is made up of 13% arable land, 2% agricultural land, 18% grassland and pasture, 54% forest, and 13% other, and there is much possibility left for development, there being only about 280 km^2 of agricultural land now under irrigation.

The climate in Cameroon, as described in detail in Chapter 5, is influenced by the country's topographical features, the generation and movement of hot, dry air from the Sahara Desert and the humid air from the Gulf of Guinea. That is, from November to March, high atmospheric pressure originating in the Sahara Desert to the north cause fronts to move south, along with which, dry, hot winds called "harmattan" blow into Cameroon to result in a dry atmosphere of high temperature. On the other hand, from April to October, when these air masses from the Sahara quiet down, Atlantic highs generated in the Gulf of Guinea become active, and pushing up the fronts north, bring in extremely humid air, and Cameroon's rainy season sets in.

The climate of Cameroon may be broadly divided according to (1), a two-season tropical climate zone north of a line connecting Bertoua and Bafia, and (2), a four-season equatorial climate zone south of the line. To describe the climate of the country in outline, the coastal area along the Gulf of Guinea in the southwest has high temperatures, much rain, and high humidity, while there is a trend for this to change to higher temperatures, less rain, and dryer air the farther inland on the continent for a great degree of diversity.

2.2 Government

A president elected by direct vote to a seven-year term appoints a prime minister. Other cabinet members are appointed upon being nominated by the prime minister. The current president is Paul Biya, who has been in office for 17 years since 1982. The legislature is bicameral with 180 members, and a plural political party system was legalized in 1990.

Cameroon has 10 provinces, and local government consists of the 10 provinces divided into 58 divisions, each of the divisions made up of subdivisions which are further subdivided into districts. Under these districts are towns and villages. The sites which are the objects of this Study, Ngambe-Tikar, Betare Oya, which is near Ndokayo, and Olamze, are all centers of subdivisions.

The Government of Cameroon has set June 30 as the end of the fiscal year. Accordingly, fiscal year is a period of one year from July 1 of a calendar year to June 30 of the following calendar year.

2.3 Economy

The economy is based on agriculture, but there are petroleum reserves along the coast, and favored with a diverse terrain and climate, the Cameroonian economy may be counted as that of one of the most favored primary resource producing countries of Subsaharan Africa. With the development of oil production, the country experienced a rapid economic growth from 1970 to 1985. However, because of falling prices of the principal export products of coffee, cocoa, and petroleum since 1986, one third of export income has been lost, and combined with problems of financial management, there has been a rapid turnaround to minus growth. In 1990, the country agreed to implementation of the reform program prescribed by the IMF and the World Bank, and embarked on a structural reorganization consisting of expedition of private investment, privatization of state-run industries, and reforms in the banking system. However, due to the political unsettlement following the general elections of 1992, the IMF-World Bank drastically cut back aid and structural reorganization practically came to a stop. On January 12, 1994, a 50% devaluation of the currency was carried out and inflation occurred temporarily, but the international balance of exchange improved. During the period from 1990 to 1996, both imports and exports indicated minus growth, and the economy has remained stagnant. A drastic structural reorganization is presently underway as required by the IMF and the World Bank.

Cameroon is a participant in Union Douanière et Economique de l'Afrique Centrale, having a central bank and currency in common. The currency, the CFA franc, had been linked to the French franc at a rate of 50 CFA to 1 since 1948, but with the devaluation in 1994, it dropped to 100 to 1, where it is to date.

The estimated national revenue in the 1992/93 fiscal year was $1.6 billion and the outgo $2.3 billion. The principal industries are petroleum extraction and refining, and aluminum refining, while hardly any food processing, light industry, textile manufacturing, or lumber milling is to be seen. Export items are crude oil and petroleum products, lumber, aluminum, cocoa beans, coffee, and cotton. Countries exported to are EU members headed by France, which take up 50%, followed by African countries. Imports consist of machinery, electrical equipment, foodstuffs, consumer goods, vehicles, and petroleum products, 38% coming from EU countries, again headed by France, followed by African countries, while imports from the United States and Japan are both 5%.

2.4 Energy Resources

Cameroon is an oil-producing country, and along with being rich in natural gas reserves, it is favored with a hydroelectric potential which is the second greatest in Africa. Consequently, the country is self-sufficient in energy.

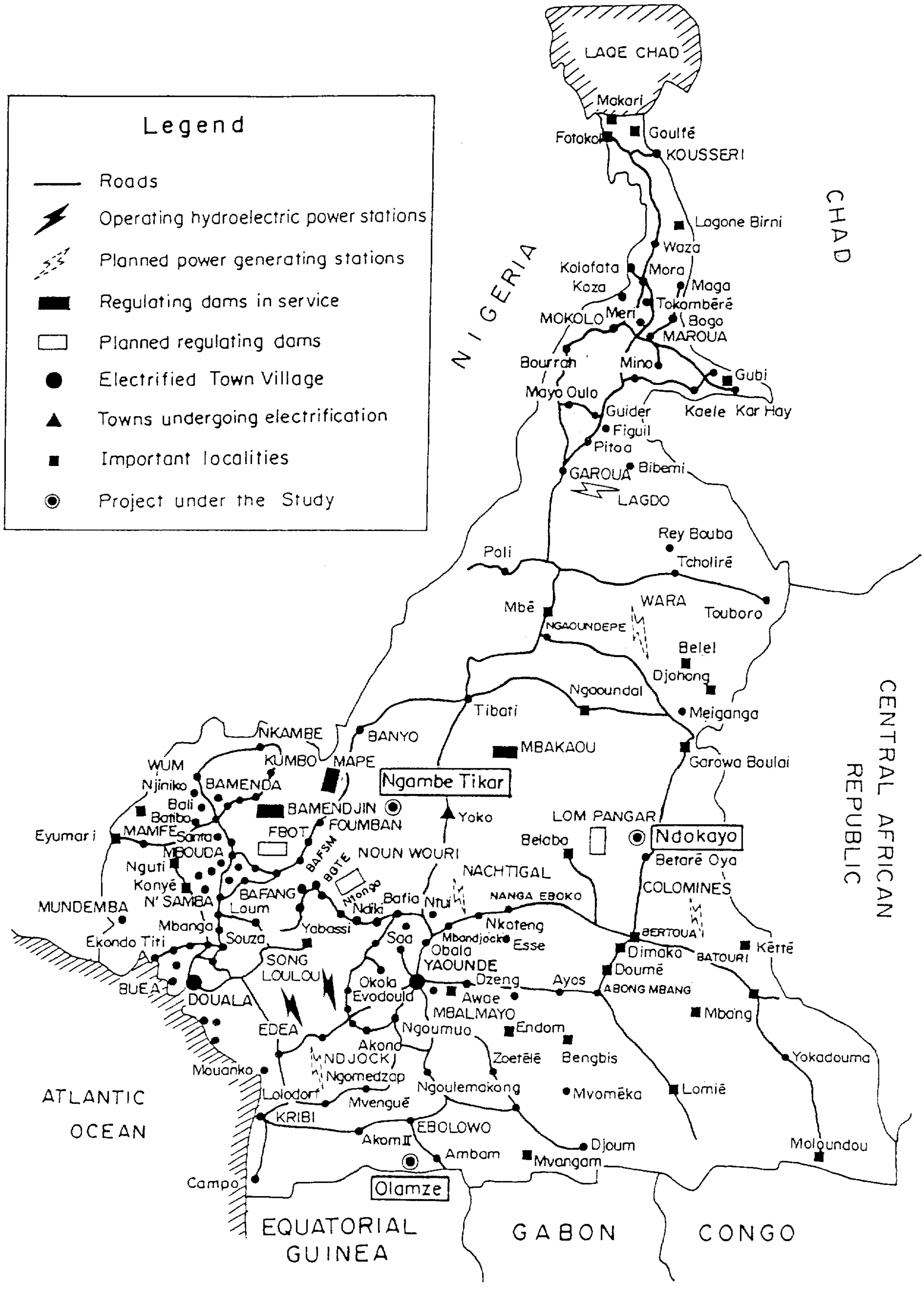
In mid-1980's, the economic situation abruptly worsened due to such circumstances and equilibrium was lost. With the economic activity of Cameroon having contracted in this way, the government has temporarily adopted a recovery program. Although the economic outlook is gray, oil has continued to play an important role in the country's economy. Of primary energy products, 95% is oil and the remainder is hydroelectric power generation. Approximately 80% of all energy consumption comprises petroleum products. The amount of this energy consumption had gradually increased since 1980, but with 1985 as the turning point, it has been declining. On the other hand, electric power consumption continued to increase up to 1989, and since then, it has been stable in the neighborhood of 2,300 GWh.

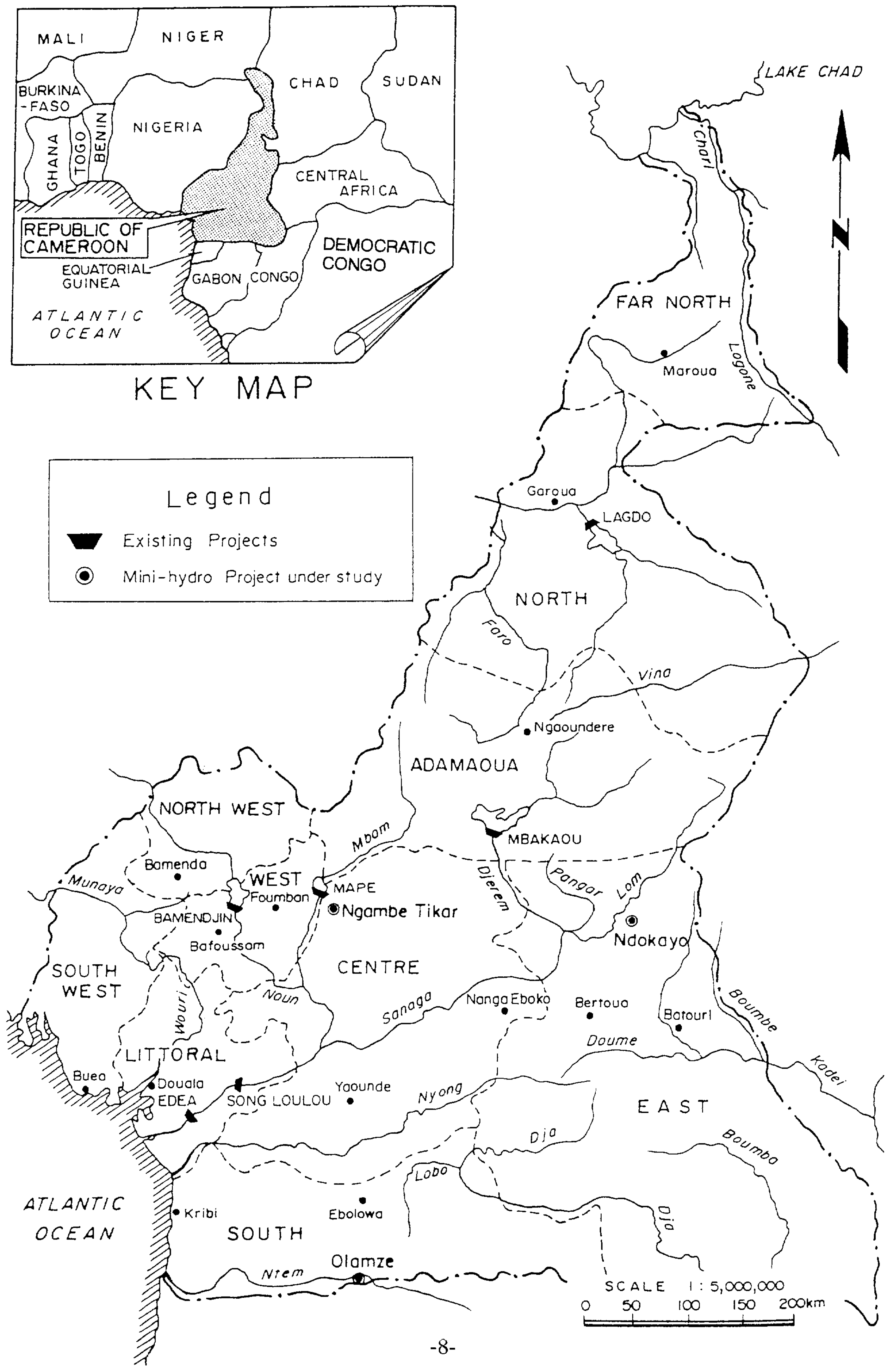
Cameroon is first in electric power production among franc-economy countries of Africa. The electric power corporation, SONEL, established in 1974 carries out power generation, transmission, and distribution of the entire country, and also is responsible for street lighting and traffic lights. SONEL is capitalized at 30 billion FCF francs, of which the Cameroonian government holds 93.1% and Agence Francaise de Developpement most of the remaining 6.9%. Approximately 95% of the country's electric power since the 1980s has been hydroelectric power, and imports of diesel thermal fuel amount to only 1% of all imports. Of new types of energy, utilization of solar energy is barely managing to pay, a total of 50 kW being used for lighting and air conditioning, and heating and cooling of water at medical clinics in remote areas.

In the electric power energy sector, SONEL has been placing emphasis on development of consumption or distribution rather than generation. At present 24% of the population enjoys the benefits of electric power, but whereas the electrification rate in urban areas is 46%, the rate in rural areas is only 4%. It was targeted for the electrification rate of the rural population to be brought up to 30% in the year 2000.

SONEL's plans, up to 2005, are not to introduce any new hydro, but to continue to extend power distribution lines. In 1983, a hydroelectric potential survey of entire Cameroon was carried out aided by Electricite de France (EDF). A middle- and long-term development program was formulated based on this, while a survey of small hydroelectric sites in Adamaoua Department was also carried out. In 1996, EDF, under the auspices of JICA, carried out a preliminary study of small and mini hydro sites for rural electrification in four West Sub-saharan countries including Cameroon.

REPUBLIC OF CAMEROON




MALI
NIGER
BURKINA -FASO
CHAD
SUDAN
GHANA
TOGO
BENIN
NIGERIA
CENTRAL AFRICA
REPUBLIC OF CAMEROON
EQUATORIAL GUINEA
GABON
CONGO
DEMOCRATIC CONGO
ATLANTIC OCEAN
KEY MAP
Legend
Existing Projects
Mini-hydro Project under study
LAKE CHAD
Chari
FAR NORTH
Maroua
Logone
Garoua
LAGDO
NORTH
Faro
Vina
Ngaoundere
ADAMAOUA
MBAKAOU
NORTH WEST
Bamenda
Munaya
WEST
Foumban
MAPE
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Bafoussam
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Kadei
Doume
LITTORAL
Buea
Douala
EDEA
SONG LOULOU
Yaounde
Nyong
EAST
Dja
Boumba
Lobo
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Kribi
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3. Present Condition of Rural Electrification

3.1 Present Condition

The objective of the electrification policy of Cameroon had been to raise living standards in rural areas, but today, using electric power for production has become an additional major objective of rural electrification. In rural areas electrified through small hydro and diesel generation, not only do people living there need to have sufficient economic strength to be able to pay electricity charges, but they also have to take part in management of the facilities through means such as by setting up people's cooperatives. In addition, from a technical point of view, it will be necessary for guidance and management to be provided by SONEL.

Rural electrification in Cameroon proceeded with supply from two large power systems, north and south, but as a result of review of the government's national land development policy, there has been a change to a dispersed electrification strategy by which electrification of areas located geographically distant from the major power transmission networks is being done. At present, consolidating the minimum bases for electrification including power supply facilities at areas called secondary centers has become one of the basic principles of rural electrification.

By secondary centers is meant centers of provincial government such as of provinces, departments, and districts not interconnected with either the Southern or Northern System. Many such secondary centers exist in the departments of Adamoua, Est, and Sud which are blank areas of the two systems. Ordinary rural electrification projects mainly consisting of diesel generation are chronically in the red, and provision and operation of high-cost independent systems only serve to worsen SONEL's finances. SONEL considers promotion of rural electrification to be one of its principal duties, while at the same time, since it must keep in mind the aspect of income as an independent electric power corporation, new rural electrification projects make resolution of the problem even more difficult.

The master plan for rural electrification set up by SONEL had been for expansion of the distribution system from the existing interconnected system or independent systems supplied from diesels and to raise the utilization rates of generators, along with which, efficiency was to be improved in maintenance and operation of facilities.

The Ministry of Mines, Water and Energy, which is responsible for water and energy policy, had worked from an early time on realization of a management system in supply of drinking water participated in by rural residents for which the residents would be responsible. In this way, in rural areas where previously the state had borne all costs, management systems of types participated in by local residents are now functioning effectively. Both the Ministry of Mines, Water and Energy and SONEL, to introduce this trend into the electricity sector, have begun to make investigations in order to carry out studies on rural electrification cooperatives managed by beneficiary residents.

When electrified, the manner in which the electric power is to be used will be 20% to 50% for industries supplied with medium-voltage power, the remainder being for low-voltage demands. Of low-voltage demands, 80% will be for lighting and residential uses, 10% for equipment motive purposes, and 10% public purposes such as street lighting.

Rural electrification where load density is low and the area is economically poor is extremely disadvantageous costwise, and SONEL has been endeavoring to lower various costs. In this respect, single-phase, medium-voltage distribution and domestically-produced electric poles of wood have been adopted fairly conspicuously in Cameroon. Fundamentally, however, it may be said that the method of resolving the rural electrification problem most suited to the present circumstances would be for amortization costs of facilities to be made zero through grants from advanced nations with only operation and maintenance costs borne locally, SONEL providing technical guidance and control.

3.2 New Electric Power Sector Law

(1) New Electric Power Sector Law

The legal framework for electric power sector in the Republic of Cameroon has for a long time been based on Law 83/20 enacted on December 26, 1983, this law being applied to power generation, transmission, and distribution, sales, export-import, and supply of electric power carried out as public utilities. However, a drastic revision was made with Law 98/022 of December 24, 1998, and especially, with respect to furthering of rural electrification, aid from the state came to be promoted in both technological and financial aspects. With this new law, private commercial enterprise techniques were taken up and what had been recognized as a monopolistic concession to SONEL ceased to be such.

According to Article 1 of the law, all activities related to power generation, transmission, and distribution, and sales export-import, and supply beginning with hydroelectric power development, are subject to the statutory system below.

- la concession
- la license
- l'autorisation
- la declaration
- la liberte

In order to be able to carry out power generation, transmission, and distribution as a public utility, it is necessary to pay royalties. The rates, and the system for levying and collection are as prescribed in separate regulations.

This law also stipulates that an "Electric Power Sector Regulating Agency" is to be established with its principal responsibilities to regulate, supervise, and follow up regarding activities of operators and enterprisers of electric power sector. The Electric Power Sector Regulating Agency is to be concerned with promotion and development of electric energy enterprises in a competitive environment which should come into being in the future, and will be setting up the tariff system in light of the procedures prescribed by the authority with jurisdiction over the electric power industry and conforming with various statutory regulations.

The statutory regulations as prescribed by this law are as listed below.

– The "la license" regulation concerns independent power generation and sales of medium-voltage electric power.
– The "l'autorisation" regulation concerns private power generation facilities larger than 1 MW and electric power distribution and operation facilities of output less than 100 kW.
– The "la declaration" regulation concerns private power generation facilities of outputs from 100 kW to 1 MW.

and

– The “la liberte” regulation concerns hydroelectric power plants of outputs less than 100 kW and distribution lines strung out on private land.

Particularly, with regard to rural electrification work, all activities are to be subject to the “l’autorisation” regulation as prescribed in Article 62 of this law.

This law also stipulates establishment of a “Rural Electrification Agency” under the jurisdiction of the electric power administration authority. The Rural Electrification Agency expedites and secures technological and financial aid necessary for development of rural electrification. Such aid is based on subsidies from the state, various royalties, or technical cooperation and donations from friendly foreign countries.

(2) Management of Electric Power Facilities

Hereafter, management of electric power facilities is to be done independently by rural communities, public initiative organizations, and provincial autonomous bodies with technological and financial aid from the Rural Electrification Agency.

Until the time that the Rural Electrification Agency is established, technological aid concerning studies, construction, and management of small hydroelectric power stations and their electric power networks will be provided by the electric power administration authority.

A Small Hydroelectric Power Station Management Committee (CGMHE) is to be established in accordance with the new law regulating the electric power industry. This is composed of a group of economic beneficiaries within the framework of the current regulations and corresponding statutory system (GIE), common initiative group (CIG), and cooperatives.

Even in case of a facility given a concession, the ownership is retained by the state.

The abovementioned Management Committee, which is a juridical person and is financially self-sustaining, receives cooperation from provincial local councils supplied with electric power, the electric power administration authority providing technological assistance, various organizations concerned with rural areas development such as the Agricultural Engineering & Regional Development Bureau of MINAGRI (Ministry of Agriculture), FEICOM, and small-scale financial institutions.

Details of the management agreement and related conditions are to be set up with the electric power administration authority, Electric Power Enterprise Regulation Bureau, Rural Electrification Bureau, and selected enterprises as the parties concerned.

The hydroelectric projects presently being carried out as parts of technical cooperation by JICA, namely, Ngambe-Tikar, Ndokayo, and Olamze, all cover plural numbers of districts or departments, these projects are to be carried out based on the "l'autorisation" regulation in accordance with Law No. 98/022 of December 24, 1998 and its enforcement regulations which regulate electric power sector.

Regarding the respective authorizations, the Cameroonian Government, along with the administration authority, has examined the operating conditions and forms.

(3) Rural Electrification Agency

Thus, based on the new Electric Power Sector Law enacted on December 24 of last year, establishment of the Rural Electrification Agency came to be approved as of September 8, 1999 by President Paul Biya to break the various bottlenecks to rural electrification. This electrification agency was placed under the supervision of various government agencies concerned with electric power that decide national policies in the electric power sector, and together with promoting rural electrification works and providing technical assistance to electric power enterprisers and utilizers, also can provide financial aid. The principal items of the corporation's business are considered to be as follows:

- Based on approved criteria and standards, carry out investigations and studies for technological and economic measures applicable to rural areas.
- On behalf of rural communities, join with government agencies concerned and enterprisers in the electric power sector to study technical problems in procurement of funds for rural electrification work.
- Joining with the supervising government agency, negotiate with investors regarding procurement of funds required for rural electrification work.

- In the event necessary, provide aid in accordance with conditions prescribed in current laws and regulations to rural electrification enterprisers for generation, transmission, distribution, and sales of electric power, beginning with small hydroelectric power stations.
- Provide financial aid to enterprisers and rural communities in accordance with conditions set by the minister in charge of electric power and the minister in charge of finance.
- Provide guidance regarding management and maintenance to rural communities where rural electrification facilities are installed.
- Carry out all public service works entrusted the Electrification Bureau by the government concerning rural electrification undertakings.

The earliest possible establishment of the Electrification Agency is presently being called for in Cameroon, and probably, operation will be started in the year 2000, with management of existing power generating facilities assumed on being commissioned by the supervisory agency concerned with electric power. The director general of the Rural Electrification Agency would be appointed by the national President, while the board of directors would be made up of representatives of ministers such as those concerned with electric power, finance, and public investment and regional development, representatives of provincial autonomous bodies, and users of electric power. The source of funds for the Electrification Agency is public money, while it is also possible for rural electrification funds to be set up separately. The Electrification Agency, besides receiving national government subsidies and grants, can collect royalties according to laws regulating the electric power sector, and can be apportioned a share in the event the newly set up Electric Power Sector Regulating Agency should turn a profit.

The Electric Power Sector Regulating Agency, as previously described, will have the principal task of regulating and supervising activities of operators and enterprisers concerned with electric power, and will be engaged in promotion and development of the electric power industry in the competitive environment coming into existence with future privatization of the electric power industry.

4. Summary of the Area

4.1 Social Environment

(1) Demography

As mentioned before, the population in Republic of Cameroon is about 13 million in 1996 and the population growth rate is as high as 2.89%.

The Ngambe-Tikar as the first proposed site of this project is located near the village named Ngambe-Tikar in Ngambe-Tikar sub-division belonged to Mbam and Kim Division, Centre Province.

Even though detail demographic census has not been reported after 1987, total population of the Ngambe-Tikar area, which will be covered by the studied microhydro-project, is estimated about 6,000. There are 20 villages belonging to this sub-division such as Gah, Kpaga, Mbeng-Mbeng.

The Ndokayo as the second proposed site is located near the Third degree village, being about 12 km from Betare Oya city, in Betare-Oya sub-division belonged to Bertoua Division, East Province. The population, which will be covered by the studied micro-hydro-project except that of Garoua Boulai, is about 18,000 and nearly 3,400 households are in the site area with average of 5.3 people in a household.

The third proposed site is located near the village of Andok which is approximately 20km from Olamze village, the center of Olamze sub-division. Olamze village, which will be covered by the studied micro-hydro-project, has population about 5,000 and households about 1,000. About 50 villages are scattered in this sub-division.

(2) Transportation

The transportation network in Republic of Cameroon is distributed centering around Douala City at coastal area and Yaounde City at inland area.

The road between Douala City and Yaounde City, and Ngambe-Tikar point has first class highway paved with asphalt until Foumban City, and most of the part from Foumban to Ngambe-Tikar is second class all-weather road.

It takes about one hour drive from Foumban to Manki. Point kilometric 36km from Manki crossing Mbam river, and 25km more drive takes to Ngambe-Tikar point. On the other hand, the another road via Yaounde Bafoussam and Magba in Manki is used for transporting lumber, so that it seems possible to transport some degree of heavy matters. The proposed dam site is located 2km from concrete made bridge crossing the Kim river which is 4km from Ngambe-Tikar village. The proposed site has good access from existing road.

It takes about 10 hours to Ndokayo site from Yaounde City via Ayos, Abong Mbang, Bertoua and Betare Oya. The road between Yaounde City and Ayos is a first class highway paved by asphalt. The road after Ayos is all weather first class road but it has problem with traffic jam during rainy season and its road surface.

The road after Ndokaya village becomes second class, a foot path take to the dam site. Private houses are scattered at the area before the foot path, but not found at the proposed site.

For access to Olamze site, the following route has to be followed ; go to Ambam via Ayos, take a ferryboat to go across a river Ntem to Olamze City, go further 20km to Olamze site . The road until Yaounde and Ebolowa is first class highway paved by asphalt. From Ebolowa to Olamze is a second class road which has no problem for use in the dry season, but presents a problem during the rainy season. The road from Olamze village to the proposed dam site is existing on the left side of Woro river but not on the right side.

(3) Land use

According to the land use draft regulation classified by agriculture & forest, fishery and hunting rules examined with Canadian cooperation, Olamze sub-division is mainly divided as a forestry section, an individual and common forestry section, a living space and agriculture & forestry section, an opening space and agricultural section. The proposed site belongs to an opening space and agricultural section, but does not belong to the prohibited district of forest cutting down, fishery and hunting.

Areas of Ngambe-Tikar and Ndokayo have no land use regulation, but according to hearing survey with the forest bureau, it is given a priority to local intention on land use. Especially, because Ndokayo village is in Savanna zone, it is said that there will be no significant problem found on developing project. Therefor, none of the 3 proposed site is in protection district, and it is required to obtain necessary land space under deliberating with local authorities and land owner.

(4) Inland water

Fishery in Republic of Cameroon is divided into 7 categories such as large scale fishery, medium and small size fishery and traditional or domestic consumption fishery and sports fishing. Inland water fishery is belonged to type of traditional or domestic consumption fishery.

At the rivers of the three proposed sites, small scale fishery purposed to residential consumption is conducted. Aquaculture, however, is not operated.

The rivers around the proposed sites are not used for transportation purpose, because the river shape is not suitable for transportation. Drinking water is supplied by underground water at all 3 proposed site, and direct river water use for drinking purpose is not conducted.

(5) Landscape

The rainy season is from April to October, and dry season is from November to March in this country. According to the survey conducted in June, the proposed intake dam site at Ngambe-Tikar has relatively flat landscape, and bottom of river is covered by rocks. The area is surrounded by forest and has relatively mild stream. Landscape at the site is not different from that of surroundings.

The proposed intake dam site at Ndokayo has steep geographical features and a waterfall running among forest, but is hard to access from a nearest village. The intake dam site at Olamze is in the dense forest, and no significant difference in landscape is found.

There is no cultural asset found in any of 3 proposed sites.

4.2 Natural Environment

(1) Geosphere

Ngambe-Tikar site is located 6 km from Ngambe-Tikar village, and its topology is very flat. Around 300 m of shallows are formed along a river but with gentle slope to downstream. Base rocks belong to a migmatite layer, which is dominant in Cameroon. The Mari River flows perpendicular to hills at Ndokayo site, bedrock stands steep, and there are some places relatively unstable on both sides of a fall. Riverbed is made of quarzite with thin layers of quartz porphyry. No sediment can be recognized in waterfall basin. Olamze site locates in a very flat area and there is little inclination in the river.

(2) Aquasphere

The Kim River belongs to Sanaga river system. It originates in the southern slope of Adamaoua Highland which extends east and west in Cameroon at the altitude of 900 to 1,500 m, and it flows south to join the Mbam River. The proposed site is at about 710 m in altitude and its catchment area is around 5,830 km^2.

Annual average of river flows at the proposed site is 59.3 m^3/sec. Traces of floods there suggest that during floods, water goes up around 2 m above its level in dry season. Since the upstream is forests and the proposed site is far apart from human settlements, it is assumed that water quality there is in natural condition. Riverbed is made of bedrock, and no polluted mud is found at all.

Ndokayo site locates at the downstream end of the Mari River, which is a tributary of the Lom River of Sanaga river system. The Mari River originates in the southern slope of Adamaoua Highland, and it flows southwest to eventually join with the Sanaga River. Total length of the Mari River is about 59 km, and its catchment area is 640 km^2. The proposed dam site locates between 700 to 790 m in altitude. Annual average of river flows at the proposed dam site is 10 m^3/sec. According to the visual observation, water there containes inorganic mud but it appeared to be clean. The upstream to this site occupies a savanna, and no situation of organic pollution is recognized there.

Olamze site locates at the most downstream of the Woro River. The Woro River originates in Guinea and it flows about 60 km to the north to join the Ntem River. More than 90% of its basin is within Guinea. Water at the proposed site is slightly brown in color, but no pollution is recognized. Annual average of river flows at the proposed site is estimated to be 12.8 m^3/sec.

(3) Atmosphere

Climate in Ngambe-Tikar area belongs to wet tropical climate, and annual precipitation ranges from 1,600 to 1,700 mm. Average temperature is 23℃ and relatively low. Rainy season is from April to October, and dry season is from November to March. Climate in Ndokayo area is also tropical climate like in Ngambe-Tikar area, and precipitation and temperature there is similar to those in Ngambe-Tikar area. Although the climate in Olamze area is equatorial climate, it is hot and humid and it rains a lot since it is close to the Atlantic Ocean and influenced by south coast-type of equatorial climate. Annual average temperature is 24 to 25℃, and precipitation is 1,800 to 2,000 mm/year.

The three proposed sites are all far from human settlements, and they are in forests or savannas where natural environment is almost preserved. There is no problem of air pollution, odor, noise nor vibration.

(4) Biota

Vegetation in Cameroon is generally divided to savannas in the north which Ndokayo area belongs to, semi-deciduous forests in the center which covers Ngambe-Tikar area, succession forests in the south, and evergreen forests along the west coast where Olamze area locates.

In Olamze area, mixed forests of semi-deciduous trees and Atlantic coast-type evergreen trees and semi-deciduous forests are dominant. Ngambe-Tikar area is covered by semi-deciduous-type development forests, and Northern type semi-deciduous forests are also found there. Ndokayo area is in savannas with small shrubs.

According to the distribution map of trees (Arbres des forêts Denses d'afrique Central), there are 127 species in Olamze area, 107 species in

Ngambe-Tikar area, and 45 species in Ndokayo area. Number of species in Ndokayo area in savannas is small.

As for mammals, according to general information prepared by WWF, 67 species were recognized in Ntem Drainage area where Olamze site is located, and 15 of them are protected animals. In Tikar area, 58 species were recognized, and 17 of these are protected. In Betare-Oye area, 51 species were found, and 15 of them are protected.

Ngambe-Tikar site and Ndokayo site are in Sanaga basin, and Olamze site is in the southern basin. In Sanaga basin, 185 species were recognized, while additional 6 species are thought to be occurring although they were not found. This makes the total number of species to 191. On the other hand, 211 species were found in the coastal basins in the south while 17 more species are presumed to be occurring, which makes the total number to 228. During the survey by WWF at a location along the Ntem River, which is close to Olamze site, 7 species of freshwater anchovies, 6 species of characins, 6 species of cichlids, 5 species of oryziatids, 3 species of spiny eels, 2 species of gobies and 5 species of carps were recognized.

5. Hydrologic Analysis

5.1 Meteorological and Hydrological Data

Regarding the meteorology and hydrology of Cameroon, Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM) had in 1986 arranged and analyzed data obtained and accumulated up to that time, and the results were published under the title “Fleuves et Rivieres du Cameroun”.

In the hydrologic analysis to be made in the present project survey, the data arranged and analyzed in the abovementioned report and the precipitation and runoff data obtained independently in the present survey will be used.

5.2 Runoff Analyses of Ngambe-Tikar Site

Data of runoff gauging stations existing in four neighboring basins can be used in runoff analysis for this project site. Here, topographies, elevations, precipitation characteristics in the surroundings of the project site, and catchment area are to be taken into consideration, and analysis performed with data of Magba and Ngongon

Gauging Stations in the two basins adjacent at north and south of the project site's basin. The runoffs were calculated from water-level records gathered from July to October 1998 by an automatic water gauge installed at the project site in this present survey.

According to the correlations of these three groups of calculated values for the observation period during this present survey, values calculated from observations in the present survey are from 38.5% to 45.9% of values calculated from runoff data of Magba Gauging Station and are more or less constant. On the other hand, the values of Ngongon Gauging Station are scattered from 49.7% to 137% and the data of Magba Gauging Station have better correlations with values calculated from observations in the present survey. Accordingly, it is judged that the runoffs of this project site, runoffs calculated from data of Magba Gauging Station are to be adopted.

With regard to the probability flood at this project site, 898 m^3/sec is obtained converted by catchment area ratio from the 100 year return period flood of 620 m^3/sec calculated according to analysis by ORSTOM.

As for 1000 year return period flood, it is 1,050 m^3/sec. The figure for the 100 year return period flood may be judged to be reasonable from the results of investigating traces remaining from past floods at the project site.

5.3 Runoff Analyses of Ndokayo Site

Data of runoff gauging stations in three neighboring basins can be used in runoff analyses for this project site. Of these gauging stations, Betare Oya Gauging Station located at the upstreammost part of the Lom River has in its basin the Mari River on which a power station is planned, and data of this gauging station are to be used in runoff analyses for this site.

Monthly average runoffs and annual runoff characteristics covers a period from 1951 to 1981.

The values of runoff observations made during the three field surveys carried out up till the present roughly coincide with the calculated values, and thus, these calculated values will be adopted as the runoffs at this project site.

Regarding the probability flood at this project site, 45 m^3/sec is obtained through conversion by catchment area ratio from the 100 year return period flood of 760 m^3/sec at Betare Oya Gauging Station calculated in analyses by ORSTOM. As for the 1000 year return period flood, it is approximately 54 m^3/sec.

5.4 Runoff Analyses of Olamze Site

Data from runoff gauging stations in two neighboring basins are available for use in runoff analyses for this project site. On the other hand, according to the results of runoff observations made in three field surveys carried out up till the present, the monthly average runoffs of the project site calculated from data of the two gauging stations of Ngoazik and Assosseng are more or less in agreement, but there are some differences in the minor rainy season of July-August and in the low-water period. Judging from results of field surveys, it may be said that the values calculated from Ngoazik Gauging Station data in which droughty runoff comes out larger are in better agreement with the discharge duration at the site.

As a consequence of the above considerations, the values calculated from data of Ngoazik Gauging Station where droughty runoff is shown to be large are to be adopted.

Regarding the probability flood at this project site, 69 m^3/sec is obtained on conversion by catchment area ratio from the 100 year return period flood at Ngoazik Gauging Station of 1,480 m^3/sec as calculated in analyses by ORSTOM. As for 1000 year probability flood, it is approximately 80 m^3/sec.

6. Power Demand Forecast and Supply Plan

6.1 Methodology

In Cameroon, the principles of estimation of LV power demand in rural areas and peak load demand have been, for each type of use, as follows:

<u>Domestic Uses</u>

The total power demand for a given year in kW is as follows, considering that the consumption occurs mostly between 6 and 10 p.m.:

$$\text{Capacity (in kW)} = \frac{P \times D}{T} \quad x \quad \frac{Cs}{N}$$

with P = estimated population at a given date

D = distribution rate

T = number of people per household

Cs = specific consumption per household and per year in kWh (600 to 1200 kWh)

N = number of equivalent operating hours per year during the peak period (1500 to 2000 hours)

with a $\frac{Cs}{N}$ ratio comprises between 250 W and 500 W.

For the study, a population growth rate of 3% per year from 1998 to 2010, 5.3 people per household and a supply rate in rural areas of 50%, with 75% for the town of Garoua Boulai were used.

The maximum power demand was estimated on a domestic consumption basis, which peaks between 6 and 11 p.m. The daily load curve in rural areas (excluding industry) for administrative centres is given by SONEL in the table below:

Daily load curve in rural areas excluding industry for 1 kW

hours	1	2	3	4	5	6	7	8	9	10	11	12
P/Pp*	0.400	0.325	0.300	0.285	0.250	0.225	0.200	0.185	0.175	0.175	0.175	0.175
hours	13	14	15	16	17	18	19	20	21	22	23	24
P/Pp*	0.175	0.175	0.175	0.175	0.420	1.0	1.0	1.0	1.0	0.850	0.750	0.70

* : Load (P) in Peak load (Pp)

As shown in the table above, the 0.43 kW average power demand for domestic uses corresponds to a daily consumption of 10.3 kWh for a peak load of 1 kW.

The estimations for the year 2010 based on SONEL hypotheses are summarised in the table below:

Areas to be supplied by the sites of:	Population in 1998	Population in 2010	Number of households in 2010	Households electrified in 2010	Maximum power demand (in kW)
Ngambe-Tikar	8 300	11 800	2 235	1 117	560
Ndokayo	44 500	63 500	11 984	7 293	4 620
Olamze	17 000	24 200	4 574	2 287	1 145
Total	69 800	99 500	18 793	10 697	6 325

In order to meet peak demand at the 3 studied sites in 2010, it will therefore be necessary to have a total available installed capacity of approximately 6.3 MW, including the existing production means (Diesel units) and the prospected hydroelectric projects (5.5 MW).

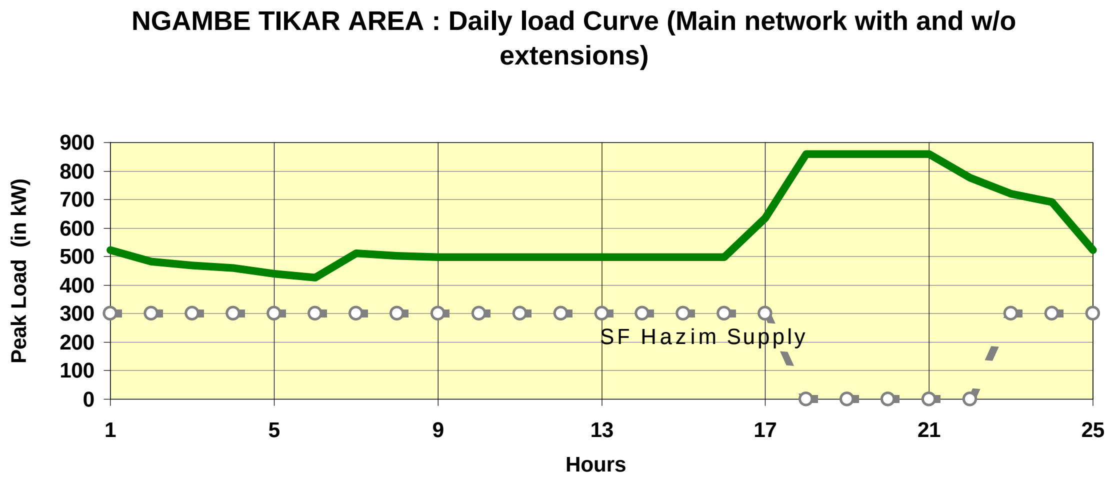
6.2 Future Load Pattern (kWh)

(1) Ngambe-Tikar Network

The estimated maximum capacity to be installed in order to meet only domestic and public lightning requirements of the main 30 kV network and the extensions of the Ngambe-Tikar area is 560 kW. The total estimated maximum capacity (not including extensions) is 350 kW.

For the main network, the estimated annual consumption for the year 2010 is approximately 1300 MWh for domestic and public uses and approximately 3000 MWh for industrial uses corresponding to a demand of approximately 300 kW over 24 hours and 100 kW between 8 a.m. and 6 p.m or 2400 MWh for industrial uses, which corresponds to a demand of approximately 300 kW over 19 hours and 100 kW between 8 a.m. and 6 p.m

The 490 kW average power demand, excluding extensions, is corresponding to a daily consumption of 12 MWh.



The gross production available at the Ngambe-Tikar power station (530 kW), which is estimated at 3.9 GWh, cannot be absorbed by the 30 kV main network (Station-Ngambe-Mbam 25 km axis) whose needs in 2010 have been estimated at 4.0 GWh, of which 2.6 GWh for the Société Forestière Hazim (SFH) and at 0.3 GWh for other industries.

The SFH possesses two 800 kVA diesel generating sets that operate alternatively at half-load at high costs (300 to 350 FCFA per gas oil litre) with a base consumption of approximately 2 to 2.5 GWh per year. The selling of power to the SFH during working hours at a lower price than diesel would enable the use of the production excesses from Ngambe-Tikar. Negotiations must be opened to supply 200 to 400 kVA during working hours from 7.30 a.m. to 6 p.m. and possibly during night peak hours from the Ngambe-Tikar power station and in return, to have available peak hour power to ensure peak hour demand between 6 and 11 p.m. in low flow periods. The SFH plans to extend its activities in the coming years.

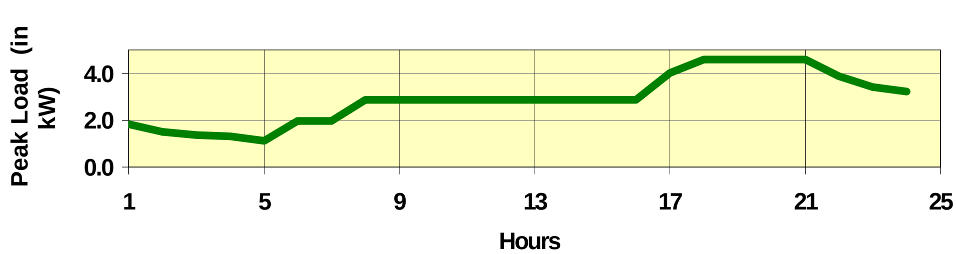
The industrial, agricultural and forestry development on the Ngambe-Tikar plain could also enable to absorb part of the production surplus (100 kWA). The extension of the 30 kV main network (80 km) should be rapidly undertaken, despite low profitability, in order to use the power surplus provided by the Ngambe-Tikar power station.

(2) Ndokayo Network

The estimated maximum capacity to be installed in order to supply the main 30 kV network and the extensions of the Ndokayo – Garoua Boulai area is 4600 kW.

The estimated annual consumption for the year 2010 is approximately 17 400 MWh for domestic and public uses and approximately 8 100 MWh for the industrial and craft sectors, corresponding to an approximate demand of 2100 kW between 8 a.m. and 6 p.m. The 2900 kW average power demand corresponds to a of 70 MWh daily consumption.

Ndokayo Area : Typical daily load curve



The 30 GWh gross production available at the Ndokayo power station (4.5 MW) cannot be totally absorbed by the main 30 kV network (Site-Ndokayo & Garoua Boulai 150 km axis) whose estimated needs for 2010 will be approximately 20 GWh, for a peak load of 4.6 MW.

In the short term, it would therefore be possible to limit the construction of the Ndokayo power station to 2 units for an installed capacity of 3.5 MVA. The existing diesel generating sets at Garoua Boulai (400 kVA) and at Betare Oya (156 kVA) will complete the production.

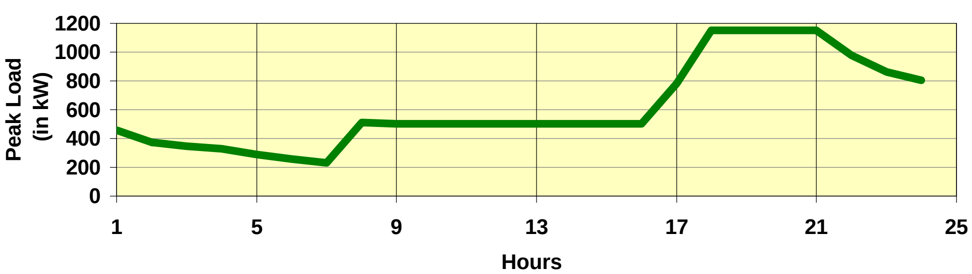
In 2010, the Ndokayo hydropower station, which could be equipped with three 1.5 MW units, could supply 85 to 90% of the consumption, i.e. 30 GWh. The peak complement must be ensured by the diesel generating sets.
The extension of the 30 kV main network by 45 km could therefore be undertaken quite rapidly to use the additional production of the third unit.

(3) Olamze Network

The maximum capacity to be installed by the year 2010 in order to supply the main 30 kV network and the Olamze site extensions is estimated at 1150 kW.

At that point in time, annual consumption is estimated at 4300 MWh for domestic and public uses and approximately 1100 MWh for industrial uses, which corresponds to a demand of about 300 kW between $7^{1/2}$ a.m. and 6 p.m. The 620 kW average power demand corresponds to a daily consumption of 15 MWh.

Olamze Area : Typical daily load curve



Almost all the gross production (2.6 GWh) from the Olamze power station (400 kW) may be absorbed by the main 30 kV MV network (45 to 50 km long Olamze-Ambam axis) whose estimated needs for 2010 are approximately 4 GWh.

The existing capacity of the diesel generating sets being 855 kVA will facilitate the meeting of demand in 2010, this especially after the 3 Ambam's units rehabilitation.

Prior to undertaking the extension of the 30 kV main network by approximately 60 km, it will of course be necessary to consider new production means.

6.3 Power Supply Plan

Potential production has been calculated from the most unfavourable classified discharge curves "Q3" (see Chapter 5 Hydrologic Analysis) for the 3 hydropower plants, each one with a capacity sufficient to allow daily +or weekly modulations during dry periods. Each power station’s output is that of Chapter 8. Power Generation Project.
The storage capacities of the 3 reservoirs have been dimensioned so as to provide a 95% guarantee of maximum capacity over the 5 daily peak hours from 6 to 11 p.m. However, the power stations guarantee about 70 to 80% of the production over the 19 off-peak and working hours.

The table below gives the corresponding potential production (excluding unavailability) with the distribution over peak hours from 6 to 11 p.m.:

Generation per Power Station	Average potential production in GWh and Load factor	Potential production: 19 off-peak and working hours	Potential production: 5 Peak hours
Ngambe-Tikar (530 kW)	3.92 (85%)	3.04 (80%)	0.88 (90%)
Ndokayo (4.5 MW)	30.6 (78%)	22.4 (70%)	8.2 (95%)
Olamze (400 kW)	2.64 (77%)	1.91 (70%)	0.73 (95%)
Total (5.4 MW)	37.2	27.3	9.8

7. Geology

7.1 Ngambe-Tikar Site

The region of Ngambe Tikar belongs to the migmatite set that covers almost two-thirds of Cameroon. This group of migmatite (commonly called granito-gneiss by Anglo-Saxon authors) is very heterogeneous. It is a complex hybrid formation wherein all the lithological terms may be represented. It is a highly varied set from the standpoints of texture, chemical composition and mineralogical make-up, composed of diadysites, embrechites, anatexites and anatexic granites. The site studied at Ngambe Tikar is marked by outcrops of embrechites and amphibolitic gneiss.

The almost entire riverbed for a distance of 300 m is formed of outcropping rock, very high quality amphibolitic gneiss, sound and with no weathering, forming small jumps. In places it has been severely eroded by the running water. All of the rock is covered over with dried algae that in places hides its geology. The rock seems to be foliated parallel to the river (N100 ° E). A few seams of quartz (strike N100°E and with a vertical dip) affect the rock.

The rock is marked by:

- 2 main groups of fracturing, with a perpendicular strike:
  - group A: strike: N110°E – 130°E, dip: 70°SW to the vertical, i.e. parallel to the river: the fracture planes show openings of several centimetres in places;
  - group B: strike N60° - N80°E, dip: 60° to 85° towards the South-East, i.e. perpendicular to the river and towards the left bank.

- A secondary group of fracturing:
  - group C: strike N170° to N20°E, dip: 60° to 80° towards the East.

No major fault is visible on the site. The riverbed is marked by the presence of many alluvial deposits, consisting of fine sand that in places forms small islands (in dry season), boulders of varying sizes, and a sort of agglomeration of small boulders cemented together by a hardened agglomerate binder that locally "fills in" hollows in the rock.

Both river banks are covered by a primary gallery-forest. The riverbanks consist of loose formations resulting from laterite weathering, which is a classic formation in equatorial Africa. A ridge 2 to 3 m high separates the river's flood plain from the feet of the river banks. No rock outcrop or boulder were observed on the banks during the site tour.

7.2 Ndokayo Site

The region of Ndokayo belongs to a volcano-sedimentary formation called the LOM formation, after the river crossing it. It covers a surface area of approximately 2,500 km^2. That formation has undergone regional metamorphism; it is probably structurally discordant on a granito-gneiss base that was rejuvenated in the pan-African period. It is a set composed of schist, greywacke and quartzite.

The site studied at Ndokayo features the presence of quartzite outcrops in the form of compact beds that are resistant to erosion and weathering, forming crests above the surrounding schists.

In comparison to the Ngambe Tikar site, the Ndokayo site is essentially marked by the hills that the Mari river must cross perpendicularly to the strike of the main crest, via major falls the height of which ranges over 100 m. The river's longitudinal profile at the falls is very steep. The river banks also have steep slopes (45° to 50°) and vertical cliffs in some places. These banks have reached their angle of natural equilibrium.

The entire riverbed is very hard rock that has created a natural obstacle to the course of the river: it is quartzite with seams of quartz. The quartzite is strongly micaceous (muscovite) in places; the rock is white and powdery when weathered, but at clean breaks it is dark blue with fine grains.

The quartzite zone forms the backbone of the hills overlooking the falls; the river has formed a path through this barrier by hollowing out a miniature canyon in it.

The main strike of the fracturing in the quartzite is N30°E. That strike corresponds to that of the crest line of the two hills overlooking the falls. It is perpendicular to the river at the falls. This main fracturing has a subvertical dip. The "benches" of quartz and quartzite are 20 to 50 cm thick. Spaces between "benches" are wide open in places (20 cm or even more).

The N30°E strike is the main strike of the weakness in the rock. Two groups of fracturing are associated with it:

- one group with strike parallel to the river in the area of the falls: strike N140°E and dip 70° towards the West,
- a subhorizontal group.

The three fracture planes that affect the rock have perpendicular strikes and dips; the combination of these planes has the effect of cutting the rock into large parallelepipedal blocks.

No alluvial deposit is visible at the falls. On the other hand, downstream from them the riverbed is cluttered with many boulders of varying sizes and with finer deposits. The gold-mining activity is in these zones. In the downstream part, a ridge several metres high separates the river's flood plane from its banks.

The river banks above the falls are very steep and very rocky. the rocky skeleton is formed by the lateral extension of the quartzite zone on either side of the falls.

The top of both banks shows many outcrops of severely (vertically) fractured quartzite "benches" that form cliffs in places. On the other hand, the middle and lower part of both banks are covered with quartzite and quartz debris mixed with topsoil. In fact a certain number of quartzite and quartz "benches" at the top of the hills have tipped over towards the foot of the slope under the effect of gravity and imbalance (toppling), creating significant zones with a chaos of parallelipipedal blocks. Those boulders are very large (often more than 1 m^3). The thickness of this talus seems variable; a rough estimation before investigations could be 4 to 8 m. The thickness should be greater at the feet of the banks.

The top of the hill on the right bank, overlooking the falls, has a double crest; the hollow between the two crests – which is continued in the subjacent cliff over the falls – could correspond to a fault or more extensive fracture zone, with a N30° to 40°E strike or a level more erodible. Regarding that hill, a certain lack of symmetry between the banks is noticeable; the southern bank, the one that is visible as the visitor arrives at the site, has no plant cover and most notably has been covered by rock falls, as noted above; the northern bank, on the other hand, has very thick plant cover (forest) and the debris or boulders of quartz and quartzite are relatively rare.

Another phenomenon – that is relatively rare in equatorial Africa – is the presence on the southern slope of the hill on the right bank of a spring of clear water (with low flow); that spring is located halfway up the slope, approximately 300 m from the river's centreline. The existence of a spring that does not dry up in low flow periods proves that water flows within the rock via the fracture planes and also that this source may be fed from the river.

7.3 Olamze Site

The Craton zone or NTEM group is caracterised by the different lithological formations:

- intrusive rocks (granite, diorite, syenite, charnockite, gabbro),
- ribbon series (gneiss, migmatite, amphibolite),
- ribbon series (gneiss, migmatite, amphibolite),
- iron formations locally.

The region of Olamze belongs to the ribbon series of the Ntem' unit, and the site studied is marked by outcrops of ampnhibolitic gneiss.

At the sill location, the riverbed is rocky. The rock outcrops at the bottom of the banks, in the middle of the river, and in the small branch located on the right bank. It is an amphibolitic gneiss, slightly quartzitic, sound, with locally a soft weathering.

The strike of the rock foliation is N90°E, approximately perpendicular to the flow of the river and the dip is subvertical. The planes are locally open, mm to cm. This rock is marked by a main group of fractures: strike: N170°E, parallel to the river, dip: 70°E, towards the right bank. No major fault is visible on the site.

Banks are covered by forest. The riverbanks consist of clayey formations resulting from laterite weathering. The thickness of this formation is probably relatively important, on the top of the bank. No rock outcrop or boulder were observed during the site tour.

8. Power Generation Project

8.1 Ngambe-Tikar Project

(1) Project Outline

Ngambe-Tikar hydro-electric project, located in left abutment of the Kim river, extends 500m long to create a head of 7m. As the dam cannot be very high since the slope of the river is relatively low, the head can hardly be higher than 7 m. The only parameter that can be modified is the design flow. It must be chosen according to the (minimum available inflow) and the future peak demand. The choice of 10 m^3/s discharge is the most relevant one because it enables the network to be supplied during peak hours, without requiring a prohibitive amount of investment.

The profitability of the scheme depends on the possibility of supplying the energy generated during off-peak hours. The Hazim sawmill represents an interesting opportunity. It is equipped with several diesel generating sets that it uses for its own needs and whose cost price is high. Negotiating an agreement with them would ensure the profitability of the power station and allow the sawmill to economise on diesel oil.

The project includes: a dam, a water intake, a headrace canal, a power house, and a channel. The 6.9 m net head, 7 m minus 0.10 m of head loss, and the 10 m^3/s flow rate generate a capacity of 530 kW. In order to optimise the project and in consideration of the low head, all the works have been dimensioned in order to reduce the head loss and the costs to the maximum. For example, masonry being the least expensive way of building dams, it is used whenever possible.

The dam is a masonry structure on a rocky weir creating a head.
As the net head is low, the scheme is designed so as to minimise head losses as much as possible. To do this, we tried to reduce the length of the plant's water supply system by building an open-air canal terminating at a starting chamber and a discharge channel into the river.

Principal structures which constitute the project are:
- trapezoidal-shaped overflow dam, 517 m long and 2 m of max. height, having 3 bottom outlets.
- an intake of 4 spans to flow 10 m^3/s of nominal discharge
- an open canal of 17.4 m^2 of section, 515 m long, leading to a water chamber of 540 m^3
- a powerhouse having 2 unit of Kaplan turbine of S-curve in upstream, 295 kW each
- a restitution canal of 41 m long to protect sedimentation of sand by the use of wall deflector of 200 m long
- 30 kV main transmission line of 25 km

(2) Main Features

1)	Location	6 km from Ngambe-Tikar village, 2 km upstream of bridge on Kim river

2)	Hydrology	
	Catchment Area	5,820 km^2
	Average Discharge	59.3 m^3/s
	Specific Average Discharge	10.2 $l/s/km^2$
	Low Discharge	1.6 m^3/s
	Flood Discharge (100 years)	898 m^3/s
	Flood Discharge (1000 years)	1,050 m^3/s
3)	Pond	
	Surface Area	9 ha
	Effective Volume	45,000 m^3
	Normal Water Level	EL. 712.00
	Low Water Level	EL.711.50
4)	Dam	
	Type	Trapezoidal-shape Spillway
	Weir Crest	EL. 712.00
	Dam Crest	EL. 712.85
	Dam Length	517.5 m
	Dam Height from Riverbed	2 m
5)	Intake	
	Intake Area	4 spans of 4 m^2 : 16 m^2
	Floor Level	EL. 710.00
	Intake Ceiling	EL. 712.00
6)	Headrace Canal	
	Length	515 m
	Section	17.4 m^2
7)	Head Tank	
	Dimension	20 x 8.7 m : 174 m^2
	Volume	540 m^3
	Floor Level	EL. 709.72
8)	Powerhouse	
	Number of Unit	2
	Net Head	6.9 m
	Installed Capacity	530 kW - 625 kVA
	Production (effective)	3.92 GWh/year
	Floor Level	EL. 702.00
	Dimension	13 m x 6.70 m
9)	Turbine	
	Type	Kaplan S-curved upstream
	Normal Discharge	5 m^3/s
	Diameter	0.85 m
	Unit Capacity	295 kW
	Rotation Speed	600 r/mn
10)	Generator	
	Type	3-phase alternative, synchronous
	Number	2
	Rotation Speed	1,000 r/mn, multiplicater
	Nominal Capacity	267 kW - 315 kVA

Frequency	50 Hz
Voltage	400 V
Power Factor	0.85

11) Transformer

Type	Indoor, 3-phase, oiled, air-cooled
Quantity	1
Nominal Capacity	630 kVA
Voltage	400 V / 30 kV

12) Transmission Line

Voltage	30 kV 3-phase
Length	25 km

13) Construction Cost (Engineering fee & Contingency included)

Civil Works	1,852 MF CFA
Equipment	2,475 MF CFA
Transmission Line	335 MF CFA
Engineering	541 MF CFA
Total	5,203 MF CFA

14) Economic Cost-price

Discount Rate	8%
Cost per kWh	138 F CFA/kWh
Cost per kW	9.8 MF CFA/kW

8.2 Ndokayo Project

(1) Project Outline

Ndokayo hydroelectric power station utilizes 91m of natural head on Mari water fall, by which it produces an annual energy of 30.6 GWh with an installed capacity of 4,530 kW. Such a dimensioning can meet power demand 93% of the time (during peak hours) as of 2010, and will make the best use of the hydrological capacities of the site, considering the dry period. Given the site layout, the 91.20 m net head is the best that can be obtained.

A 34 m wide weir, a 15 m water intake upstream of the weir, a 133 m long tunnel, a 306 m penstock and a power station comprising 3 turbines are required to operate the site.

Francis turbines, using hydraulic power, will have a maximum capacity of 4,530 kW for a production capacity of 30 GWh.

Principal structures which compose it are:

- trapezoidal-shaped masonry dam, maximum height of 4.5 m, and a total length of 36 m, of which 21 m is overflowed

- an intake of two spans in right abutment for a discharge of 6 m3/s
- a pressure tunnel of 8 m2 section in rock, 133 m long, 0.05% in slope, concreted, inner dia. of 2.20m
- a steel penstock with expansion joints, 307 m long and 1.4 m in diameter
- a powerhouse having 3 units of Francis turbines, horizontal axis, 1,600 kW each, resulting in a total powerhouse capacity of 4,530 kWe
- a short restitution canal with downstream weir of EL 697 crest which guarantees non-cavitation
- 30 kV main transmission line of 152 km long

(2) Main Features

1)	Location	On cascade of 10 km from Betare Oya on Mari river, which is affluent of Lom river
2)	Hydrology	
	Catchment Area	640 km^2
	Average Discharge	10.1 m^3/s
	Specific Average Discharge	15.8 l/s/km^2
	Low Discharge	1 m^3/s
	Flood Discharge (100 years)	45 m^3/s
	Flood Discharge (1000 years)	54 m^3/s
3)	Pond	
	Surface Area	7.5 ha
	Effective Volume	90,000 m^3
	Normal Water Level	EL. 790.80
	Low Water Level	EL. 789.60
4)	Dam	
	Type	Trapezoidal-shape Spillway
	Weir Crest	EL. 790.80
	Dam Crest	EL. 792.10
	Weir Length	21 m
	Dam Height from Riverbed	4.50 m
5)	Intake	
	Intake Area	9.12 m^2
	Floor Level	EL. 787.20
6)	Headrace Tunnel	
	Length	133 m
	Section	Concrete lined, Horse-shoe type, 3 x 3 m exterior D = 2.2 m interior
7)	Penstock	

	Unit	1
	Length	306 m
	Diameter	1.40 m
	Thickness	11 mm
8)	Powerhouse	
	Number of Unit	3
	Net Head	91 m
	Installed Capacity	4,530 kW - 5,330 kVA
	Production (effective)	26.3 GWh/year
	Floor Level	EL. 697.00
	Dimension	22.80 m x 5.00 m
9)	Turbine	
	Type	Francis, axis horizontal
	Normal Discharge	2 m^3/s
	Diameter	0.58 m
	Unit Capacity	1,600 kW
	Rotation Speed	1,000 r/mn
10)	Generator	
	Type	3-phase alternative, synchronous
	Number	3
	Rotation Speed	1,000 r/mn
	Nominal Capacity	1,535 kW - 1,805 kVA
	Frequency	50 Hz
	Voltage	5,500 V
	Power Factor	0.85
11)	Transformer	
	Type	Indoor, 3-phase, oiled, air-cooled
	Quantity	3
	Nominal Power	1,800 kVA
	Voltage	5.5 kV / 30 kV
12)	Transmission Line	
	Voltage	30 kV 3-phase
	Length	152 km
13)	Construction Cost (Engineering fee & Contingency included)	
	Civil Works	2,556 MF CFA
	Equipment	4,545 MF CFA
	Transmission Line	2,062 MF CFA
	Engineering	888 MF CFA
	Total	10,051 MF CFA
14)	Economic Cost-price	
	Discount Rate	8%

Cost per kWh	39 F CFA/kWh
Cost per kW	2.2 MF CFA/kW

8.3 Olamze Project

(1) Project Outline

Olamze project closes the Woro river, creating the head of 6m. The project was designed to make the best use of the site capacities, at the lowest cost.
The choice of the design flow takes into account the existence of two diesel power stations on the network. The flow cannot exceed 8.8 m^3/s, which is the minimum value obtained for 45% of the year. The thermal power stations, which must be renovated, make it possible to take such a strong flow since they can supply the missing energy during the periods of low flow. Larger equipment would lead to higher costs and would rarely be in operation, which would reduce the profitability of the project.

The 6 m net head is created solely by the weir and the cost of energy is therefore directly linked to its height. Given the shape of the valley, a higher dam would lead to an increased cost of energy and could cause problems at the end of the reservoir.
This head creates a capacity of 400 kW for an annual power generation of 2.64 GWh that may be entirely consumed by the population and the industries.

Principal structures are:
- a dam of 138 m long, 8.95 m max. high, having spillway of 46 m long and 6.3 m high in central portion
- in right abutment, next to spillway, a powerhouse of 12 m long houses 2 units of Kaplan turbine, horizontal axis, of a discharge of 4.5 m3/s
- 30 kV main transmission line of 47 km

(2) Main Features

1)	Location	3 km upstream of Ata'antem on Woro river
2)	Hydrology	
	Catchment Area	840 km^2
	Average Discharge	12.8 m^3/s
	Specific Average Discharge	15.2 $l/s/km^2$
	Low Discharge	0.7 m^3/s

	Flood Discharge (100 years)	69 m^3/s
	Flood Discharge (1000 years)	80 m^3/s
3)	Pond	
	Surface Area	18.3 ha
	Effective Volume	110,000 m^3
	Normal Water Level	EL. 553.90
	Minimum Water Level	EL. 555.35
4)	Dam	
	Type	Fill-Type in wing portion with spillway in Center
	Weir Elevation	EL. 553.90
	Crest Elevation	EL. 555.35
	Total Length / Spillway	138.10 m / 46.10 m
	Dam Height from Riverbed, Crest / Weir	8.75 m / 6.30 m
5)	Intake	
	Intake Area	29.12 m^2
	Floor Level	EL. 546.00
	Intake Ceiling	EL. 547.40
6)	Powerhouse	
	Number of Unit	2
	Net Head	6 m
	Installed Capacity	400 kW
	Production (effective)	2.4 GWh
	Floor Level	EL. 545.50
	Dimension	22.80 x 5.00 m
7)	Turbine	
	Type	Kaplan horizontal with angle gear
	Normal Discharge	4.5 m^3/s
	Diameter	0.9 m
	Unit Capacity	225 kW
	Rotation Speed	400 r/mn
8)	Generator	3- phase synchronous
	Number	2
	Rotation Speed	750 r/mn, multiplicator
	Nominal Capacity	204 kW - 240 kVA
	Frequency	50 Hz
	Voltage	400 V
	Power Factor	0.85
9)	Transformer	
	Type	Indoor, 3-phase, oiled, air-cooled
	Quantity	1

	Nominal Capacity	500 kVA
	Voltage	400 V / 30 kV
10)	Transmission Line	
	Voltage	30 kV 3-phase
	Length	47 km
11)	Construction Cost (Engineering fee & Contingency included)	
	Civil Works	1,409 MF CFA
	Equipment	2,538 MF CFA
	Transmission Line	615 MF CFA
	Engineering	493 MF CFA
	Total	5,055 MF CFA
12)	Economic Cost-price	
	Discount Rate	8%
	Cost per kWh	197 F CFA/kWh
	Cost per kW	12.6 MF CFA/kW

30 kV Network in Cameroon for power stations of Ngambe-Tikar, Ndokayo and Olamze

Axes et Centres	Distance to the site in km	Proposed main network in km
1. Ngambe-Tikar site (Kim river)		
Ngambe Tikar - Mbam axis		
Ngambe-Tikar	7	7
Mansouh	15	8
Ga	20	5
Gwenze	25	5
Ngambe-Tikar Network		**25**
2. Ndokayo site (Mari river)		
Bétaré Oya - Garous Boulai axis		
Mari Village	8	8
Lom	22	
Bétaré Oya	16	8
Ndokayo	22	6
Bongo	31	9
Borongo	46	15
Mombal	61	
Nadongwé	69	8
Botila	76	7
Badzéré	80	4
Badang	88	
Yoko Sire	98	
Ganko	101	
Garaoua Boulai	106	60
Ndokayo - Tongo axis		
Oudou	29	7
Kongolo	42	13
Garga Sarali	49	7
Ngaoundéré	60	
Tongo	66	
Ndokayo Network		**152**
3. Olamze site		
Olamze - Ngoasik - Ambam axis		
Olamze	15	15
Meko'Ossi	16	1
Eyinantoum	17	1
Meko'Omengona	19	2
Ebengon	24	
Nsana	25	6
Ngoasik	35	10
Nkoumeké	44	9
Ambam	47	3
Olamze Network		**47**

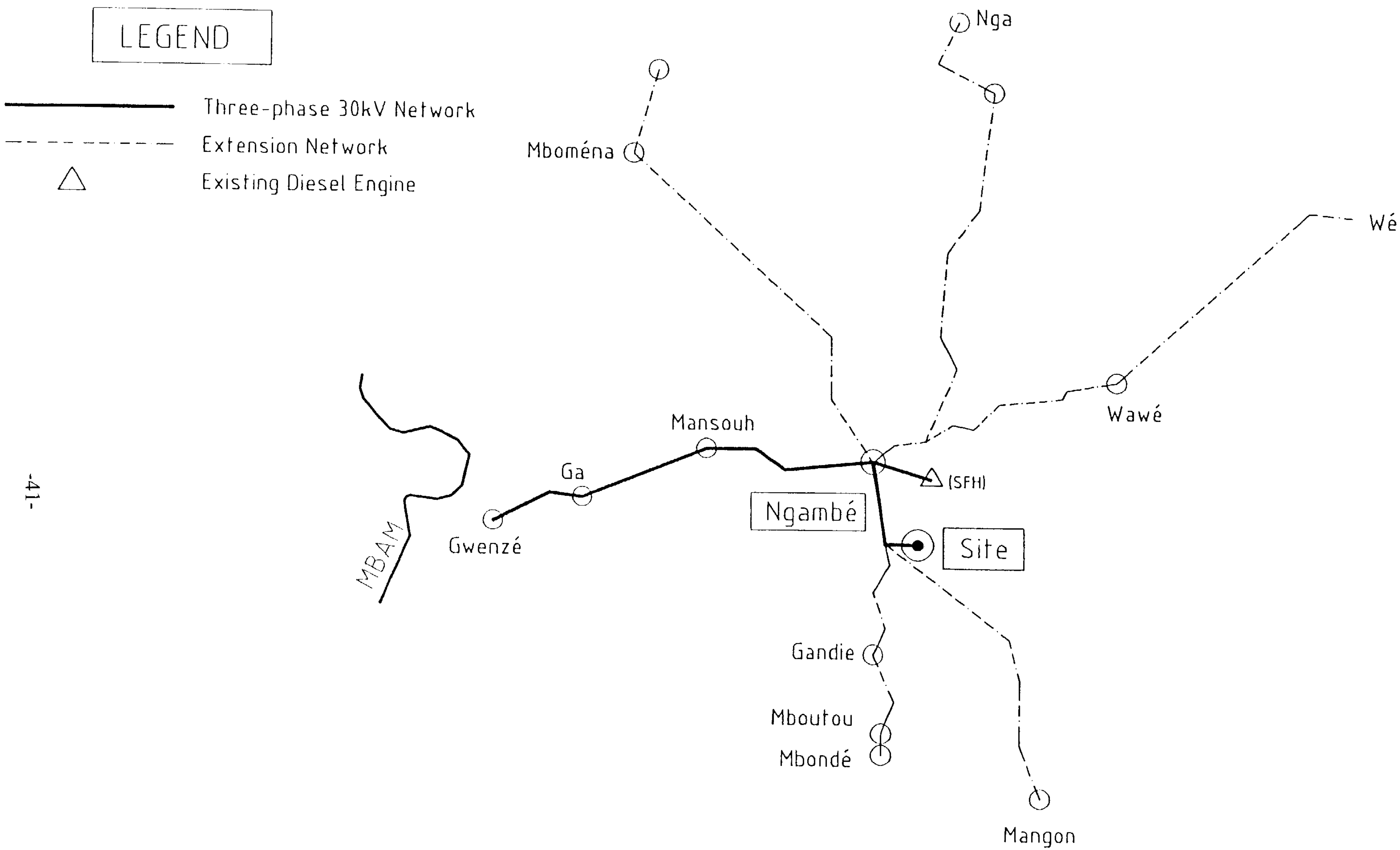


Fig. 9-1 Ngambe-Tikar Network

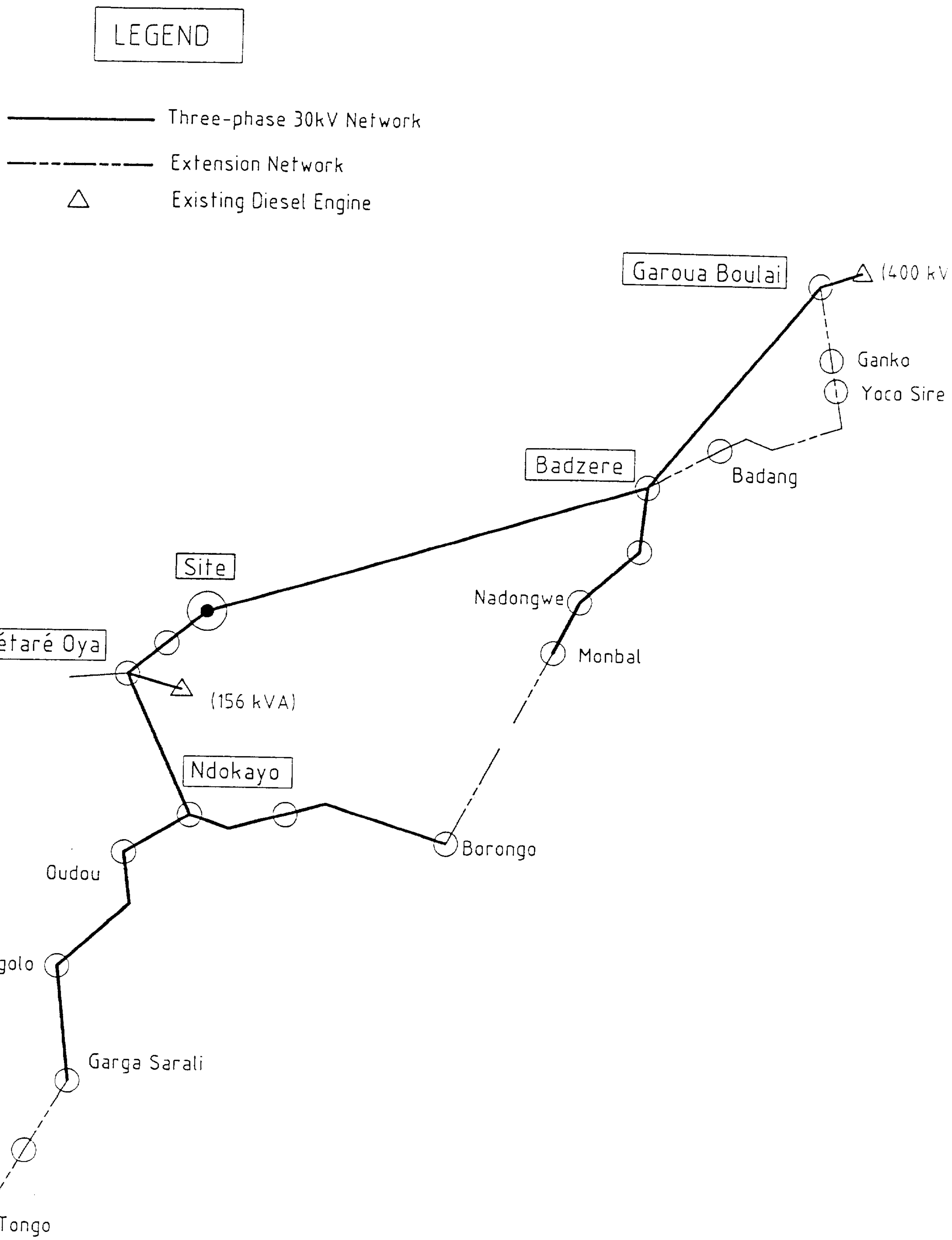


Fig. 9-2 Ndokayo Network

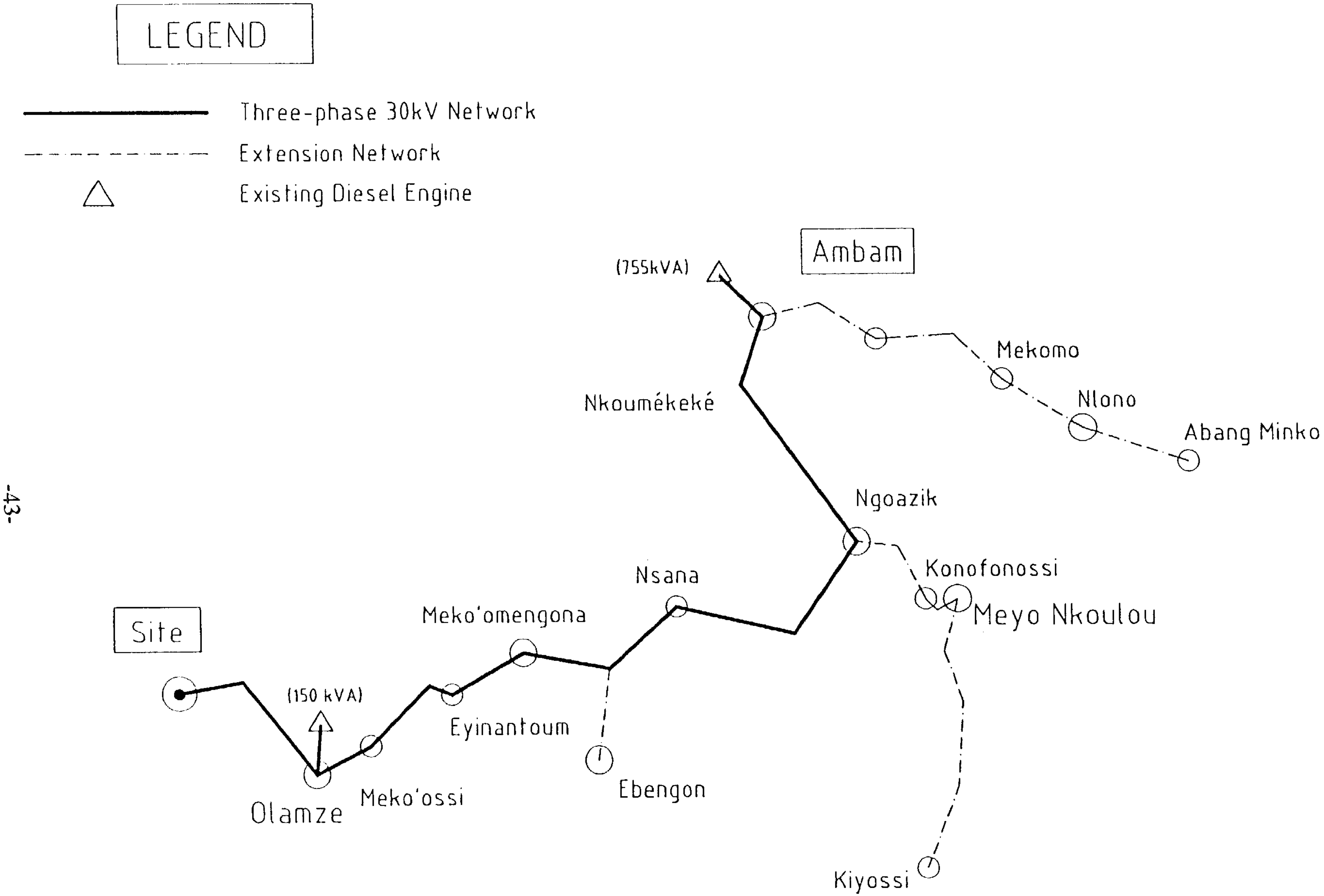


Fig. 9-3 Olamze Network

9. Environmental Protection Measures

9.1 Environmental Preservation Measures

(1) During Operation

The three hydroelectric power stations of this Project are all to start power generation by 2010, with power transmitted to villages neighboring the respective power stations by 30 kV medium voltage transmission lines. As socio-economic effects, although of small number, local residents will be employed as unskilled technicians or laborers for rises in incomes, while also, opportunities to experience elementary-level power generation and transmission technologies will be increased. Further, the installation of hydroelectric power stations will be useful for improvement of local electrification rates, improvement in livelihood of residents, and promotion of livelihood activities. Still further, since roads from the principal villages to the dams and power stations will be maintained in good condition, the situation will be far better than at present, and the benefit to the regional society and economy will be great. Communications and medical services will also be improved.

The three hydroelectric power stations of this Project are all small hydros and there will be no fear of large amounts of discharge to threaten the safety of residents, and neither will there be risk of slopes collapsing and sedimentation occurring. During flood, however, there will be risk that the surroundings will be inundated by backwater of Olamze Intake Pond, and it is necessary for a separate investigation to be made in this regard for some measure to be taken including changing of plans. Effects on public sanitation and changing of stream water quality will be little since all of the power stations will be small.

When the power stations are operated, stream water will be impounded by the dams and, especially at the Ndokayo site, Mari Waterfalls located between the intake dam and the power station will dry up temporarily. However, this site is at a remote location and is not a place where tourists would come, while local residents will not be affected at all.

Regarding impact on the ecosystem, at Ngambe-Tikar and Olamze, flow of river water will be cut off temporarily due to construction of intake dams and there will be a risk of obstructing migration of fish. However, the existence of fishes with such a habit, especially in this season, has not been confirmed, and it is believed there will be no harmful effect. Concerning land animals also, the dams, power stations, and transmission lines will all have vast wild plains around them and it is thought the animals will not be affected in particular.

At all of the hydro sites, there may be benefits for the residents of the surrounding areas, but it is not conceivable that there will be negative effects with respect to safety and public sanitation. As for negative influences on the ecosystem, there should be none when the existence of the surrounding wilderness is considered. However, if there is to be any exception, it would be the inundation of the surroundings by the backwater of Olamze Intake Pond, and it is thought this is a matter which should be cleared up through flood area surveys in an additional field investigation.

(2) During Construction

Each of the projects will require a period of approximately 2 years for construction, and laborers will be hired from within and without the project area to carry out works such as clearing, temporary facilities, permanent facilities, access roads, etc. It is thought approximately 30% of these laborers will be mobilized from outside, while the remainder is estimated will be hired from within the project area and immediate surroundings, that is, they will comprise the majority of unskilled workers.

It is estimated that the number of local residents who will be hired during the construction period will be approximately 200 for the respective projects. Thus, the execution of construction will provide employment opportunities for many people living in the project area and surroundings, and bring about increases in income.

As for the case of a laborer who is a carrier of a contagious disease being mobilized from outside the project area, there would be the fear that the disease would be spread among residents of the area, but a contagious disease of a type communicated from person to person is not highly infectious, and it is considered there will be no problem if sanitation of the laborers' quarters were to be maintained.

Regarding effects of transporting materials and equipment during the construction period, carbon monoxide, nitrogen oxide, and particularly, dust in the dry season, may temporarily increase when a vehicle passes by, but it is thought normally regulated values, for example, dust approximately 250 mg/m^3, carbon monoxide approximately 20 ppm, and nitrogen oxide approximately 0.05 ppm will not be exceeded. However, regarding volume of dust, people living along roads will be troubled so that in areas where housing densities are high, measures such as sprinkling of water are to be carried out as suited.

During construction, there is a possibility for traffic accidents to occur in areas where there are many local residents. Measures such as traffic regulation and speed regulation should be taken as necessary, and trouble with local residents must be avoided. In the event trouble does occur, quick medical service and compensation must be provided. Traffic noise will affect wild animals living in forest areas along roads and transmission line rights of way, but this will be in a narrow range, while not very many animals inhabit these parts. Results of investigations indicate that protected animal species do not exist in the project area. A vast wilderness makes up the surroundings and it may said there will be hardly any impact felt.

9.2 Monitoring Program

The environmental monitoring program to be followed during construction and when the power stations are in operation is as shown in the tables below.

(1) When Operating

Major Impact	Cause	Monitor Item	Monitoring Purpose	Data Collection Method	Data Analysis Method	Object Area	Period & Frequency	Organization Concerned
1) Income increase	· Employment · Electricity tariff · Industry, others	· Labor pool & wages · Industry	Monitoring item at left	Government & local agency data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	Government & local agency
2) Public sanitation	Electric power distribution	Sicknesses	Monitoring sicknesses	Government & local agency data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	Government & local agency
3) Impact of inundation (Olamze only)	Intake pond backwater	· Complaints, disputes · Compensation	· Inundation scale investigation · Monitoring complaints & compensation situation · Improvement works execution	Field investigation, interview	· Data tabulation, illustration · Analysis	Intake pond surroundings	Flood duration	Government & local agency

(2) During Construction

Major Impact	Cause	Monitor Item	Monitoring Purpose	Data Collection Method	Data Analysis Method	Object Area	Period & Frequency	Organization Concerned
1) Income increase	Employment	Locally hired laborers number, wage level	Monitoring item at left	Contractor's data	Data tabulation & trend analysis	Project area (incl. transmission line route)	Bimonthly	· Government & local agency · Contractor
2) Traffic obstruction & traffic accident	· Equipment & materials delivery · Road repair & access road construction	· Complaints · Disputes · Accidents	· Monitoring traffic accidents, number & frequency of interference to transportation traffic · Monitoring complaints, disputes of residents	· Data from contractor and police · Field investigations	· Data tabulation · Trend analysis	· Project site (incl. transmission line route) · Roadside area	Monthly	· Government & local agency · Contractor
3) Noise, air pollution, public sanitation	· Equipment & materials delivery · Road construction, materials collection works · Laborers' quarters	· Complaints · Disputes · Sicknesses · Dust quantity · Noise level	· Monitoring dust quantity, noise level · Monitoring complaints, disputes of residents · Monitoring sicknesses	· Field investigations	· Data tabulation · Trend analysis	· Project site (incl. transmission line route) · Roadside area	Monthly	· Government & local agency · Contractor
4) Impact of inundation (Olamze only)	Inundation	· Compensation · Complaints, disputes	· Inundation scale investigation · Monitoring complaints and disputes situations · Improvement works execution	· Field investigations · Interviews of farmers, land owners	· Data tabulation, illustration, analysis	Intake pond surroundings	Flood period	Government & local agency

9.3 Evaluation

The project sites of the three hydros are all only several kilometers away from their respective neighboring villages and, since the power generation schemes are all of extremely small scale, there will be hardly any effects on the present natural and social environment. If there are any points in particular requiring attention to be paid, they are (1) the negative effects from backwater of the intake pond at Olamze must be eliminated at the time final plans are made, (2) the waterfalls of Mari at the Ndokayo site may dry up temporarily during the dry season, if left as it is, but it could be prevented by the daily regulation of water in the pond, (3) the works are of small scale, but with regard to increased traffic volume during construction and the resulting dust and noise, it will be necessary for the constructor to give appropriate consideration in village areas with high concentrations of housing. The table below is a summary of the overall assessment on the environmental impacts of the Project.

Environment Affected	Content	Impact	Analysis and Degree of Impact	
1. Industry in power system area	Power generation	Electric energy supply	Society, economy	A+
2. River water use				
When operating	Maintenance and control of dam and power station	Downstream flow reduction when operating	Society, economy	C
During construction	Construction of structures	Water pollution from muddy water	Society, ecosystem	B-
3. Land transportation				
When operating	Access road	Improvement of traffic	Society, economy	B+
During construction	Traffic of vehicles concerned	Traffic safety and dust	Society	B-
4. Esthetics				
When opeating	(Ngambe Tikar, Olamze)	Loss of tourism resources	Society, economy	C
When operating	(Ndokayo)	Loss of tourism resources	Society, economy	B-
5. Public sanitation				
When operating	Pollution of water used	Contamination of drinking water	Hygiene	B-
During construction	Pollution of water used	Contamination of drinking water	Hygiene	B-
	Inflow of laborers, wastes	Outbreak of sickness	Hygiene	B-
6. Land animals				
When operating		Influence of structures, intake ponds	Ecosystem	C
During construction	Clearing and construction	Impacts of noise, air pollution	Ecosystem	C
7. Aquatic animals				
When operating		Change in downstream water flow	Ecosystem	B-
During construction	Construction	Impact of contaminated water	Ecosystem	B-
8. Ecosystem				
During construction	Construction work	Impact due to changes in habitat and restriction of movement	Ecosystem	C
9. Atmosphere				
When operating			Society, economy, ecosystem	C
During construction	Construction work	Pollution due to traffic volume and construction	Society, economy, ecosystem	B-
10. Employment				
When operating	Operation and maintenance	Employment in items at left	Society, Economy	A+
During construction	Construction work	Employment in item at left	Society, economy	A+

A: influential + : plus

B: slightly influential - : minus

C: non influential

10. Construction Program, Construction Schedule, and Construction Cost

10.1 Construction Program and Construction Schedule

The schedules of major civil works in the individual projects are as shown in Figs. 10-1, -2, and -3, respectively, and since each requires a construction period straddling two dry seasons, power generation would be started after approximately 18 months from start of construction.

(1) Ngambe-Tikar Project

In construction, various preparatory works including access roads and temporary works, and waterway work at the right bank are to be carried out as much as possible before the rainy season arrives, while in the dry season following the rainy season, main civil works and electrical works are to be about completed, power generation to be started with the onset of the next rainy season.

(2) Ndokayo Site

In construction, various preparatory works including access roads and temporary facilities are to be completed before the rainy season of the first year sets in, and part of the penstock route is also to be excavated. Even during the rainy season, work on the headrace tunnel is to be continued and is to be brought roughly to completion. Main works such as the dam, penstock, and power generation facilities are to be started as soon as the rainy season of the first year ends, and work in the open is to be finished by the onset of the next rainy season. A part of equipment installation works will extend into the rainy season, but similarly to Ngambe-Tikar, it will be possible for power generation to be started within 18 months.

(3) Olamze Site

At this site, construction of access roads and temporary facilities would be completed before onset of the rains from May to July. In December, when the rainy season is over, works involving the river bed such as the dam and power station are to be started, and the greater part of open work at the river bed is to be completed before the onset of the rainy season in May. Indoor works such as equipment installation would be done during the next rainy season.

10.2 Construction Materials

The principal civil works materials required in construction of this project, namely, concrete aggregates, cement, reinforcing bars and steel can be procured in Cameroon except for a very small part. Especially, wet masonry concrete structures are specified for facilities such as intake dams, and this, as can be seen in riparian civil structures like Edea Hydroelectric Power Station (installed capacity 263.2 MW) on the downstream part of the Sanaga River, is a technique which has been nurtured by workers of Cameroon over a long period of time, with materials procured locally and, moreover, being cheap.

Power station electro-mechanical equipment such as turbines and generators, and gate equipment such as penstock gates, would be imported from overseas countries, including Japan.

However, with regard to transmission lines, concerning both equipment and installation, planning and estimating were done based on records of actual work recently done by SONEL. Regarding main contractors to perform construction of dams and power stations would be by foreign contractors, Japanese ones included, but for transmission lines, it was considered that local contractors would do the work supervised by SONEL. This is based on the thinking that it would be more convenient to use locally marketable items as facilities required for transmission lines after entering the maintenance stage.

10.3 Construction Cost

(1) Hydroelectric Power Stations

The construction costs of the hydroelectric power stations of Ngambe-Tikar, Ndokayo, and Olamze, not including customs and VAT, in effect, the amounts to be invested, are as given in detail in Tables 10-1 to -3.

Table 10-1 3 Hydro Construction Cost

M.CFA Franc (1999)

	Ngambe-Tikar	Ndokayo	Olamze	Total
Installed Capacity	530 kW (2 units)	4,530 kW (3 units)	400 kW (2 units)	5,460 kW
Civil Works	1,852	2,556	1,409	5,817
Electromechanical Equipment	2,475	4,545	2,538	9,558
Engineering & Administrative	541	888	493	1,922
Total	4,868	7,989	4,440	17,297

Table 10-2 30 kV Line Construction Cost

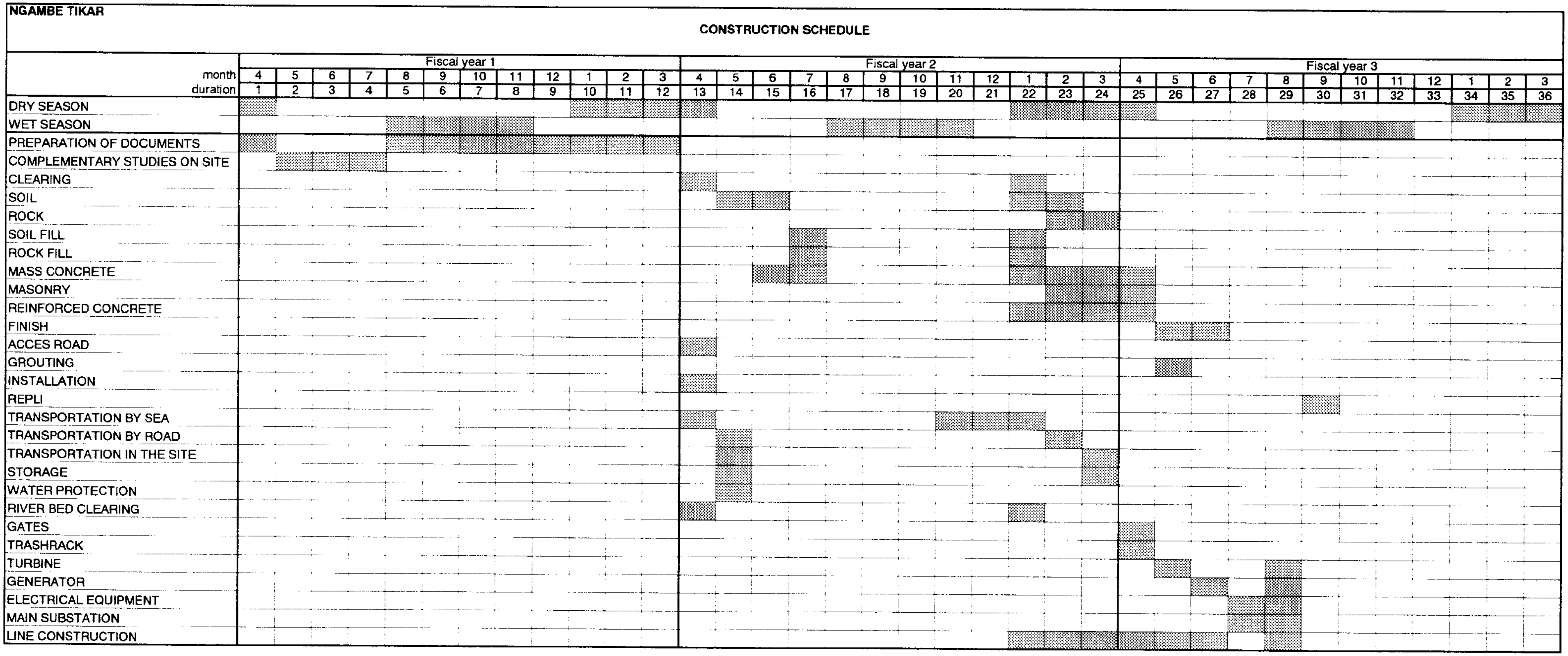
M.CFA Franc (1999)

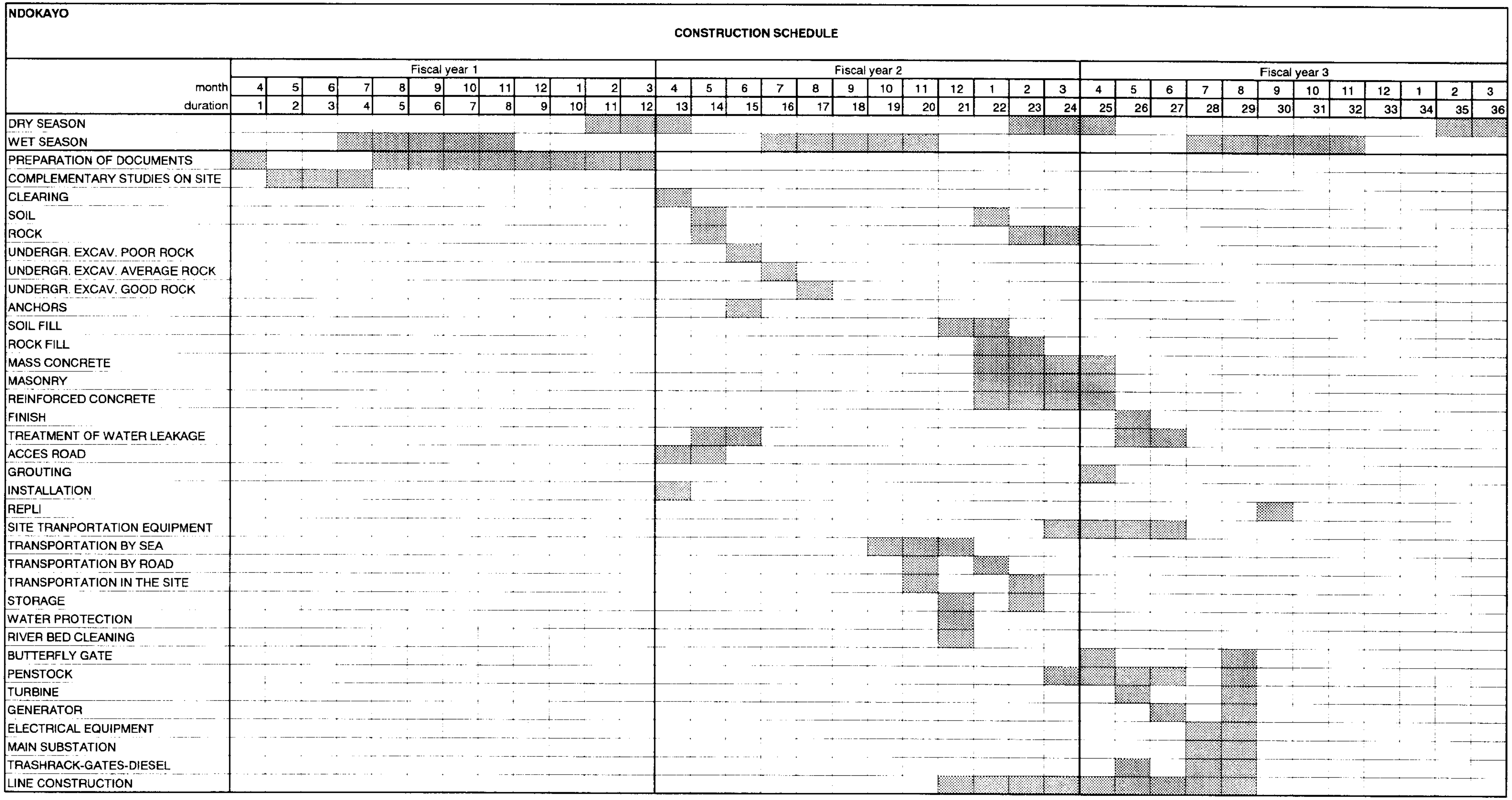
	Ngambe-Tikar	Ndokayo	Olamze	Total
Total Length	25 km	152 km	47 km	224 km
Construction Cost	265	1,630	486	2,381
Engineering & Administrative	70	432	129	631
Total	335	2,062	615	3,012

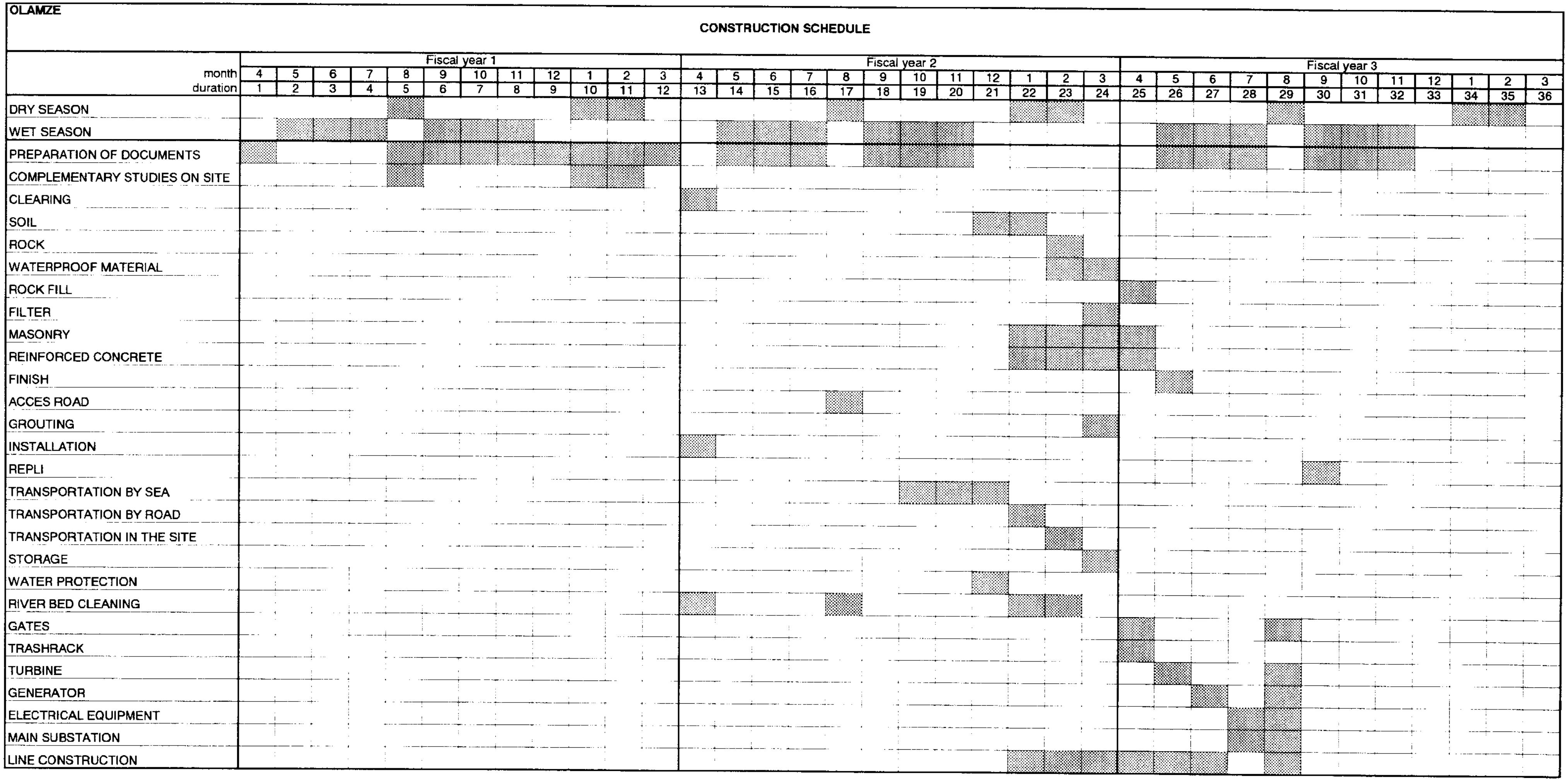
Table 10-3 3 Hydro Construction Cost

M.CFA Franc (1999)

	Ngambe-Tikar	Ndokayo	Olamze	Total
Hydro power Station	4,868	7,989	4,440	17,297
30 kV Transmission Line	335	2,062	615	3,012
Total	5,203	10,051	5,055	20,309
Installed Capacity	530 kW	4,530 kW	400 kW	5,460 kW
Construction Cost per kWh	9.8	2.2	12.6	3.7


NGAMBE TIKAR
CONSTRUCTION SCHEDULE
Fiscal year 1
Fiscal year 2
Fiscal year 3
month
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
duration
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
DRY SEASON
WET SEASON
PREPARATION OF DOCUMENTS
COMPLEMENTARY STUDIES ON SITE
CLEARING
SOIL
ROCK
SOIL FILL
ROCK FILL
MASS CONCRETE
MASONRY
REINFORCED CONCRETE
FINISH
ACCES ROAD
GROUTING
INSTALLATION
REPLI
TRANSPORTATION BY SEA
TRANSPORTATION BY ROAD
TRANSPORTATION IN THE SITE
STORAGE
WATER PROTECTION
RIVER BED CLEARING
GATES
TRASHRACK
TURBINE
GENERATOR
ELECTRICAL EQUIPMENT
MAIN SUBSTATION
LINE CONSTRUCTION


NDOKAYO
CONSTRUCTION SCHEDULE
Fiscal year 1
Fiscal year 2
Fiscal year 3
month
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
duration
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
DRY SEASON
WET SEASON
PREPARATION OF DOCUMENTS
COMPLEMENTARY STUDIES ON SITE
CLEARING
SOIL
ROCK
UNDERGR. EXCAV. POOR ROCK
UNDERGR. EXCAV. AVERAGE ROCK
UNDERGR. EXCAV. GOOD ROCK
ANCHORS
SOIL FILL
ROCK FILL
MASS CONCRETE
MASONRY
REINFORCED CONCRETE
FINISH
TREATMENT OF WATER LEAKAGE
ACCES ROAD
GROUTING
INSTALLATION
REPLI
SITE TRANPORTATION EQUIPMENT
TRANSPORTATION BY SEA
TRANSPORTATION BY ROAD
TRANSPORTATION IN THE SITE
STORAGE
WATER PROTECTION
RIVER BED CLEANING
BUTTERFLY GATE
PENSTOCK
TURBINE
GENERATOR
ELECTRICAL EQUIPMENT
MAIN SUBSTATION
TRASHRACK-GATES-DIESEL
LINE CONSTRUCTION



OLAMZE
CONSTRUCTION SCHEDULE
Fiscal year 1
Fiscal year 2
Fiscal year 3
month
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
duration
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
DRY SEASON
WET SEASON
PREPARATION OF DOCUMENTS
COMPLEMENTARY STUDIES ON SITE
CLEARING
SOIL
ROCK
WATERPROOF MATERIAL
ROCK FILL
FILTER
MASONRY
REINFORCED CONCRETE
FINISH
ACCES ROAD
GROUTING
INSTALLATION
REPLI
TRANSPORTATION BY SEA
TRANSPORTATION BY ROAD
TRANSPORTATION IN THE SITE
STORAGE
WATER PROTECTION
RIVER BED CLEANING
GATES
TRASHRACK
TURBINE
GENERATOR
ELECTRICAL EQUIPMENT
MAIN SUBSTATION
LINE CONSTRUCTION

11. Economic Evaluation and Financial Analysis

11.1 Generation Cost per kWh

For calculation of cost per kWh, the method based on effective energy was used. Effective energy was determined based on annual duration curves Q_3 of dry year for the various sites.

The unit costs per kWh (excluding customs and VAT) of the power stations of Ngambe-Tikar, Ndokayo, and Olamze are given in the table below.

Generation Cost per kWh

	Ngambe-Tikar	Ndokayo	Olamze	M.CFA 1999 Total
Net Output	530 kW	4,530 kW	400 kW	5,460 kW
Annual Generation	3.92 GWh	30.6 GWh	2.64 GWh	37.2 GWh
Transmission Line Losses	5%	7.5%	5%	
Net Annual Generation	3.72 GWh	28.3 GWh	2.51 GWh	34.5 GWh
Net annual generation with outage	3.5 GWh	26.3 GWh	2.4 GWh	32.2 GWh
HPP Investment Costs	4,869	7,989	4,400	17,298
Transmission Line Costs	335	2,062	615	3,012
Total Project Costs	5,204	10,051	5,055	20,310
Life Duration	50 years	50 years	50 years	
Annuity Costs at @8% (a)	425	822	413	1,660
Annual HPP O&M Costs	31.8	135.9	24	191.7
Annual T. Lines O&M Costs	6.8	41.0	12.7	60.5
Annual Renewable Provisions	25.1	39.4	18.8	83.4
Total Annual O&M Costs (b)	63.7	216.4	55.5	252.2
Total Annual Costs (a)+(b)	489	1,038	469	1,912
Generation Cost in FCFA per kWh (1)+(2)	138	39	197	59.3
with a breakdown in:				
Capital cost per kWh (1)	120	31	173	51.5
O&M cost per kWh (2)	18	8	23	7.8

The main hypotheses used for the calculation of the cost above are:

- Discount rate: 8%
- Generation losses on the main network: between 5 and 7.5%
- Outages: between 3 and 5%
- Economic life: 50 years for the civil structures and 25 years for the equipment and the transmission lines
- HPP O&M costs: from 1.55 to 1.65% of the construction cost

- Transmission Line O&M costs: 2% of the construction cost (260-270 CFA･kF per year)

11.2 Economic Evaluation

A rural electrification project in a remote area, along with being a public undertaking, is for the purpose of contributing to improvement in the people's livelihood, and requires special attention to be paid in comparison with an ordinary project. That is, it must be kept in mind that supplying electric power itself improves rural life and energizes activities in various ways. Accordingly, it is extremely difficult to quantitatively grasp the actual benefit brought about by an electrification project.

The price of a commercial item in a free market is decided by the balance of supply and demand for that item, but especially, in rural electrification, it is quite unlikely that the price can be set simply from the relation with supply and demand. That is, setting of electric power prices will generally be something outside the bounds of free market rules, and prices are normally decided by a government agency. In many cases, prices are held down for political or socie-economic reasons.

In Cameroon, too, there exists latent demand for electric power which would be awakened in response to reduction in the price of electric power, and it is not appropriate to attribute the benefit of a power development project only to power sales.

Accordingly, it is necessary for special consideration to be given in calculation of benefit and evaluation of the economics of a power development project. For hydroelectric power projects, a technique widely employed is the alternative facility method, and the results of study by that method are described below.

In case of making an economic comparison between the project concerned and the alternative project, the capacity and energy production of the alternative project versus the capacity and energy production of the project concerned are adjusted so as to satisfy the condition of "furnishing equal service". Power transmission losses are respectively taken to be zero.

Start of power generation is to be by the year 2003 for all the three hydros, but in case of Ndokayo hydro, recommended plan is made in consideration of regional demand, in which 2 units, 3,020 kW, would be started up by 2003, with the remaining unit started up in 2010. According to the power demand forecast for a period from 1998 to 2015, the peak of Ndokayo networks will be 3,560 kW in the year 2002, and Ngambe-Tikar and Olamze will be respectively 680 kW and 910 kW in the same year’s peak demand.

Service lives were taken to be 50 years for civil facilities and 25 years for electrical and mechanical equipment and transmission lines. Construction periods are all 2 years, but since there would be matters such as engineering required before start of construction, it was considered that expenditures for hydro would be over a period of 3 years.

(1) Ngambe-Tikar Hydropower Project

Alternative power plant: Diesel Power Plant: 602 kW
Installed capacity of Ngambe-Tikar Hydropower Plant: 530 kW (265 kW x 2 units)

EIRR Calculation, Installed Capacity (530 kW)

(10^3F.CFA)

Discount Rate	Ngambe-Tikar Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	4,354,564	585,613	4,940,177	639,533	761,235	1,400,768	-3,539,409
11%	4,288,202	638,490	4,926,692	650,375	829,971	1,480,345	-3,446,347
10%	4,204,749	698,227	4,902,976	661,514	907,623	1,569,137	-3,333,839
9%	4,101,563	765,954	4,867,517	672,961	995,660	1,668,621	-3,198,896
8%	3,975,974	843,019	4,818,993	684,729	1,095,837	1,780,566	-3,038,427
7%	3,825,509	931,040	4,756,549	696,829	1,210,255	1,907,083	-2,849,466
6%	3,648,211	1,031,961	4,680,172	709,274	1,341,441	2,050,714	-2,629,458
5%	3,443,048	1,148,125	4,591,173	722,078	1,492,442	2,214,520	-2,376,653
4%	3,210,392	1,282,371	4,492,763	735,254	1,666,949	2,402,203	-2,090,560
3%	2,952,468	1,438,147	4,390,615	748,819	1,869,441	2,618,260	-1,772,355
2%	2,673,671	1,619,656	4,293,327	762,787	2,105,383	2,868,169	-1,425,158
1%	2,380,584	1,832,036	4,212,620	777,175	2,381,455	3,158,630	-1,053,990

In the case of Ngambe-Tikar hydro-project, investment cost of the alternative thermal is about ten percent of the hydro, and, to make matters worse, annual cost is lower in the alternative thermal than in the hydro, so that the hydro-project would not be justified in consideration of the economy only.

(2) Ndokayo Hydropower Project (Stage-1)

Alternative power plant: Diesel Power Plant: 3,248 kW
Installed capacity of Ndokayo Hydropower Plant: 3,020 kW (1,510 kW x 2 units)

EIRR Calculation, Installed Capacity (3,020 kW)

(10^3F.CFA)

Discount Rate	Ndokayo Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	6,477,795	979,022	7,456,817	2,730,203	3,752,886	6,483,088	-973,729
11%	6,437,386	1,067,422	7,504,808	2,776,482	4,091,752	6,868,234	-636,574
10%	6,370,489	1,167,290	7,537,779	2,824,030	4,474,575	7,298,605	-239,174
9%	6,272,313	1,280,514	7,552,827	2,872,894	4,908,598	7,781,492	228,665
8%	6,137,843	1,409,352	7,547,195	2,923,123	5,402,469	8,325,592	778,397
7%	5,962,174	1,556,505	7,518,679	2,974,770	5,966,549	8,941,320	1,422,641
6%	5,741,014	1,725,222	7,466,236	3,027,891	6,613,295	9,641,186	2,174,950
5%	5,471,373	1,919,425	7,390,798	3,082,543	7,357,732	10,440,275	3,049,477

As shown in the table above,

a) In the case Ndokayo hydro project is developed in two stages, the EIRR of 1st stage of 2 units of 1,510 kW each is 9.5%, which means that the 1st stage project could be justified in the social discount rate of 8% in Cameroon.

b) The values of Benefit Cost ratio and Benefit minus Cost of the Ndokayo are 1.10 and 778.4 MF.CFA respectively, which duly supports the project economically, as well.

(3) Ndokayo Hydropower Project (Stage-I + Stage-II)

Alternative power plant: Diesel Power Plant: 3,428 kW + 1,714 kW
Installed capacity of Ndokayo Hydropower Plant: 4,530 kW (1,510 kW x 3 units)

Combined EIRR Calculation, Installed Capacity 4,530 kW

(10^3F.CFA)

Discount Rate	Ndokayo Hydro Power Project			Alternative Thermal			Difference
	1st Stage	2nd Stage	Total	1st Stage	2nd Stage	Total	
12%	7,457	516	7,973	6,483	1,263	7,746	-227
11%	7,505	554	8,059	6,868	1,429	8,298	239
10%	7,538	593	8,131	7,299	1,624	8,923	792
9%	7,553	635	8,188	7,781	1,853	9,634	1,446
8%	7,547	678	8,225	8,326	2,123	10,448	2,223
7%	7,519	721	8,240	8,941	2,442	11,384	3,144
6%	7,466	766	8,232	9,641	2,823	12,465	4,233
5%	7,391	811	8,202	10,440	3,280	13,720	5,518

As shown in the table above, in the case Ndokayo hydro project is developed in two stages, the EIRR of the total project is 11.5, and the value of Benefit cost ratio and Benefit minus Cost, in the case of 8% of the social discount rate, are respectively, 1.27 and 2.223 MF.CFA, which duly supports the project economically, as well.

(4) Olamze Hydropower Project

Alternative power plant: Diesel Power Plant: 454 kW
Installed capacity of Olamze Hydropower Plant: 400 kW (200 kW x 2 units)

EIRR Calculation, Installed Capacity (400 kW)

(10^3F.CFA)

Discount Rate	Olamze Hydro Power Project			Alternative Thermal			Difference
	Investment Cost	O/M Cost	Total	Investment Cost	O/M Cost	Total	
12%	4,277,930	568,846	4,796,776	775,213	632,695	1,407,907	-3,388,869
11%	4,163,644	620,210	4,783,854	788,353	689,824	1,478,177	-3,305,677
10%	4,082,761	678,236	4,760,997	801,854	754,363	1,556,218	-3,204,779
9%	3,982,713	744,023	4,726,736	815,728	827,535	1,643,263	-3,083,473
8%	3,860,906	818,882	4,679,788	829,991	910,796	1,740,787	-2,939,001
7%	3,714,935	904,382	4,619,317	844,655	1,005,894	1,850,549	-2,768,768
6%	3,542,897	1,002,414	4,545,311	859,738	1,114,928	1,974,666	-2,570,645
5%	3,343,786	1,115,252	4,459,038	875,256	1,240,432	2,115,688	-2,343,350
4%	3,117,960	1,245,654	4,363,614	891,226	1,385,471	2,276,697	-2,086,917
3%	2,867,577	1,396,970	4,264,547	907,666	1,553,771	2,461,437	-1,803,110
2%	2,596,902	1,573,282	4,170,184	924,595	1,749,872	2,674,467	-1,495,717
1%	2,312,327	1,779,582	4,091,909	942,032	1,979,328	2,921,360	-1,170,549

In the case of Olamze hydro-project, investment cost of the alternative thermal is about ten percent of the hydro, and, to make matters worse, annual cost is lower in the alternative thermal than in the hydro, so that the hydro-project would not be justified in consideration of the economy only.

11.3 Financial Analysis

Based on the discussion made in Yaounde between the JICA study team and the Cameroonian counterparts taking into consideration the recent revision of the electric enterprise law, the financial analysis is made to define generally the appropriate financial and legal package within the framework of the Grant which the government of Cameroon intends to request to the government concerned, for the development of the 3 hydropower projects, and within the framework of the creation of the future “Rural Electrification Agency” responsible for the totality of the decentralised networks.

The objective here was to determine the percentage of capital to be repaid by the Operator to the Agency in order to reach a relatively attractive profitability in the order of 25% to 30% on the capital stock provided by the future concession holder. Total or partial repayment of the capital to the Agency will make it possible to re-finance other projects in rural areas of Cameroon.

The main parameters taken into account and the results of the simulations are summarised in the table below.

Results of the Financial Simulation

in MF.CFA 1999

HPP Projects	Ngambe-Tikar	Ndokayo	Olamze	G. Total
Net output	530 kW	4,530 kW	400 kW	5,460 kW
Network Length	25 km	152 km	47 km	224 km
Net annual generation with outage	3.5 GWh	26.3 GWh	2.4 GWh	32.2 GWh
Total Project Costs	5,203	10,051	5,055	20,309
Annual HPP O&M costs (a)	31.8	135.9	24.0	191.7
Annual TL O&M costs (b)	6.8	41.0	12.7	60.5
Annual renewable provisions (c)	25.1	39.4	18.8	83.4
Total Annual Operation Costs (a + b + c)	63.7	216.4	55.5	335.8
in kF CFA/kW/yr.	120	47.7	138.7	61.5
"Concession" common basis	Price: 40 FCFA/kWh plus connection fees "Concession" Period: 20 years Discount rate: 8% interest rate: 0%			
Part of Equity	5%	10%	5%	
Repayment Capital	20%	90 - 80%	10%	-
Results:				
IRR on Equity	25%	25 - 35%	30%	-

According to the hypotheses defined above, and to reach a rate of financial profitability on capital stock in the order of 25% to 30% for a duration of concession limited to 20 years, and for user acceptable prices, repayment of the capital loaned by the concession holder to the Agency would be approximately.

- 20% for the Ngambe-Tikar HPP project with a 5% capital stock contribution by the operator,
- 90% for the Ndokayo HPP project with a 10% capital stock contribution by the operator,

- 10% for the Olamze HPP project with a 5% capital stock contribution by the operator.

The amount unpaid is equivalent to a subsidy covering the deficits of the project. On the other hand, the amount refunded will allow the Agency to constitute a reserve to finance other development projects.

Financial internal rate of return in Ndokayo power station is calculated to be 6.5%, with 40 F CFA/kWh and on the same assumption as in the economic internal rate of return, of which the evaluation table is shown below.

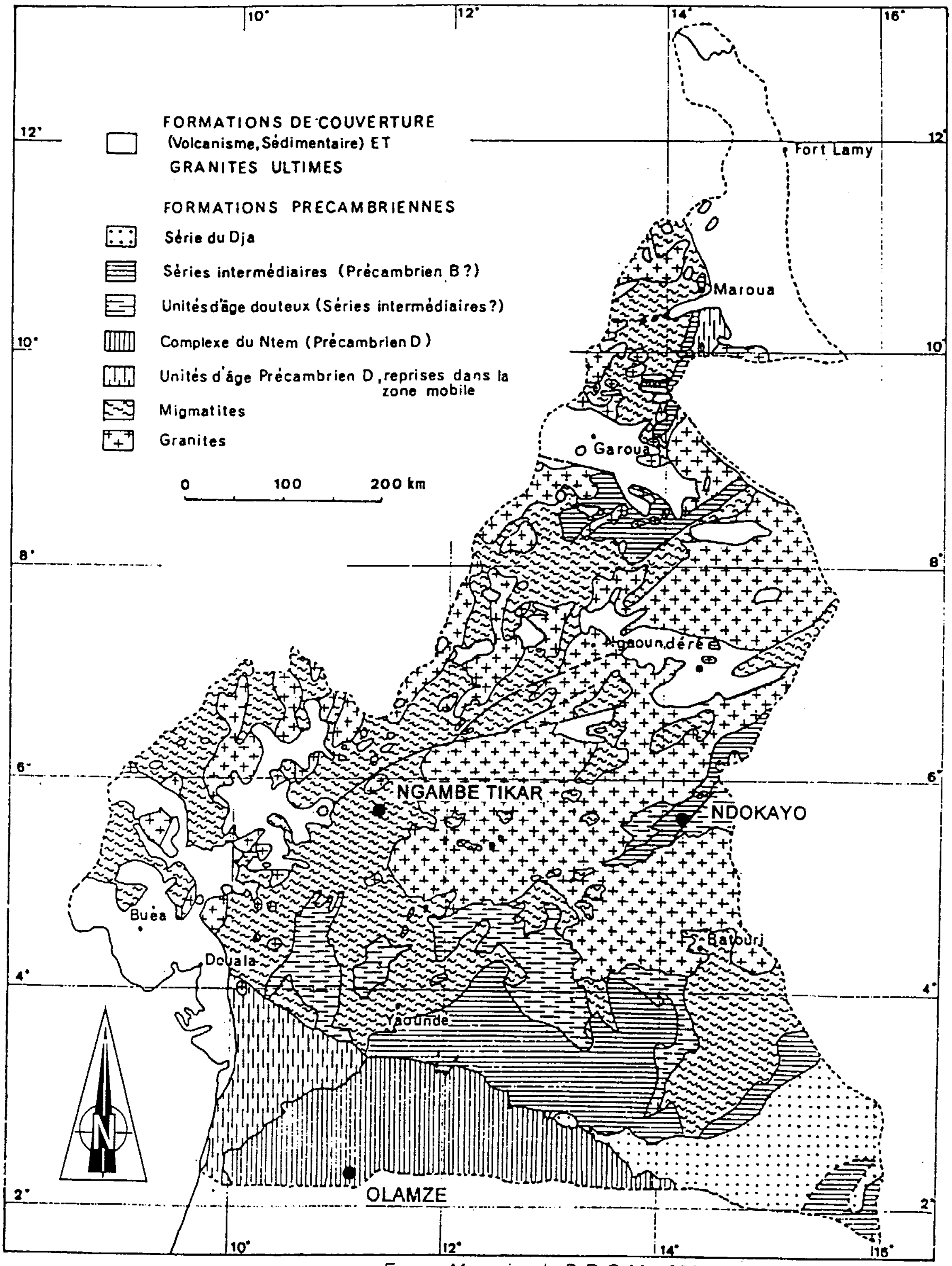
FINANCIAL EVALUATION

(Unit: Thousand F CFA)

No.		Ndokayo Hydro Project			Benefit		(B)-(C)
		Construc-tion Cost	O & M Cost	(C) Total Cost	Annual Available Energy	(B) Power Sales Revenue	
					(kWh)		
1		1,116,000		1,116,000			-1,116,000
2		4,808,000		4,808,000			-4,808,000
3		2,776,000		2,776,000			-2,776,000
4	1		174,000	174,000	17,530,000	701,200	527,200
5	2		174,000	174,000	17,530,000	701,200	527,200
6	3		174,000	174,000	17,530,000	701,200	527,200
7	4		174,000	174,000	17,530,000	701,200	527,200
8	5	0	174,000	174,000	17,530,000	701,200	527,200
9	6	904,000	174,000	1,078,000	17,530,000	701,200	-376,800
10	7	447,000	174,000	621,000	17,530,000	701,200	80,200
11	8		201,020	201,020	26,300,000	1,052,000	850,980
12	9		201,020	201,020	26,300,000	1,052,000	850,980
13	10		201,020	201,020	26,300,000	1,052,000	850,980
14	11		201,020	201,020	26,300,000	1,052,000	850,980
15	12		201,020	201,020	26,300,000	1,052,000	850,980
16	13		201,020	201,020	26,300,000	1,052,000	850,980
17	14		201,020	201,020	26,300,000	1,052,000	850,980
18	15		201,020	201,020	26,300,000	1,052,000	850,980
19	16		201,020	201,020	26,300,000	1,052,000	850,980
20	17		201,020	201,020	26,300,000	1,052,000	850,980
21	18		201,020	201,020	26,300,000	1,052,000	850,980
22	19		201,020	201,020	26,300,000	1,052,000	850,980
23	20		201,020	201,020	26,300,000	1,052,000	850,980
24	21		201,020	201,020	26,300,000	1,052,000	850,980
25	22		201,020	201,020	26,300,000	1,052,000	850,980
26	23		201,020	201,020	26,300,000	1,052,000	850,980
27	24	1,808,000	201,020	2,009,020	26,300,000	1,052,000	-957,020
28	25	894,000	201,020	1,095,020	26,300,000	1,052,000	-43,020
29	26		201,020	201,020	26,300,000	1,052,000	850,980
30	27		201,020	201,020	26,300,000	1,052,000	850,980
31	28		201,020	201,020	26,300,000	1,052,000	850,980

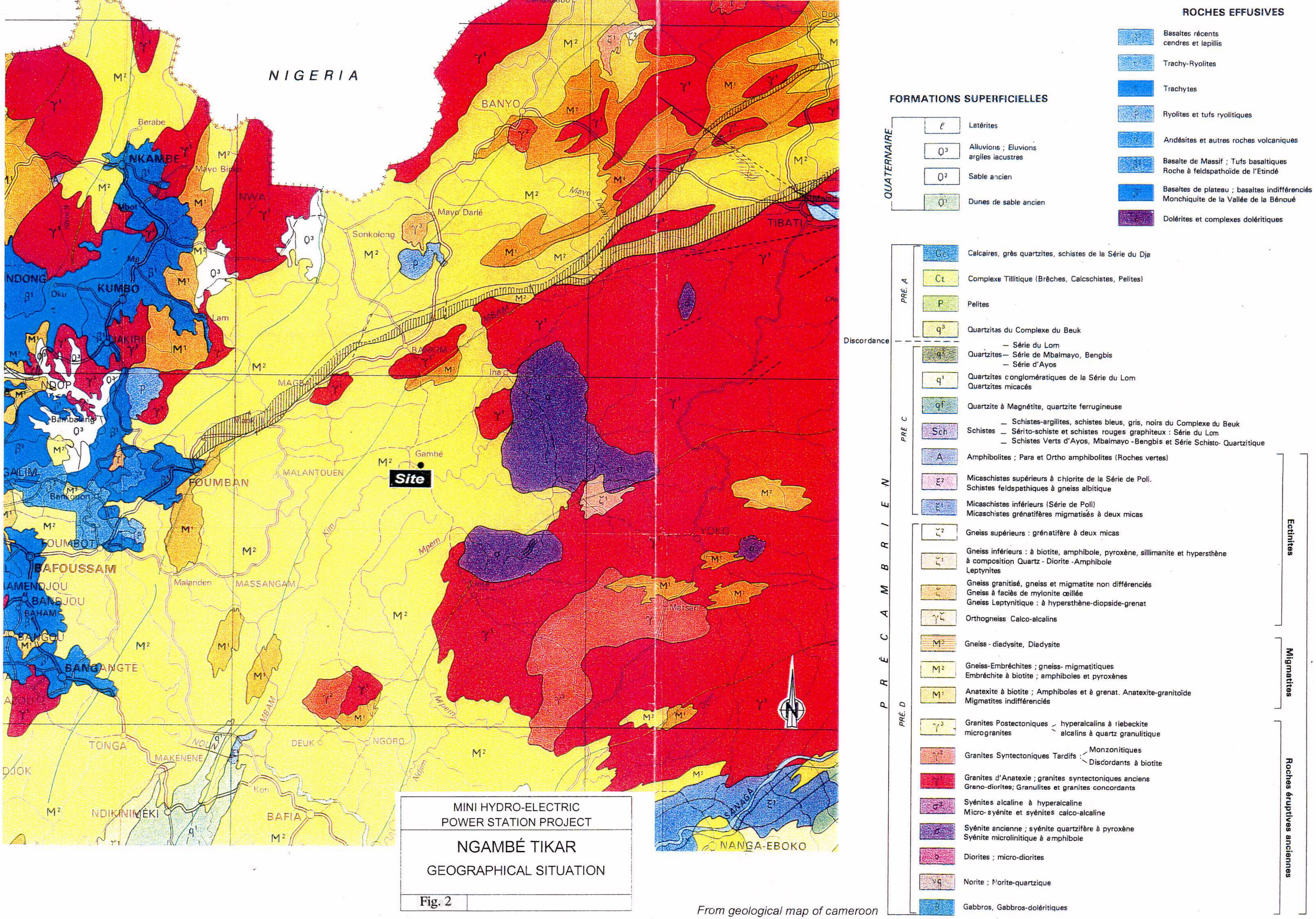
No.		Ndokayo Hydro Project			Benefit		(B)-(C)
		Construc-tion Cost	O & M Cost	(C) Total Cost	Annual Available Energy	(B) Power Sales Revenue	
32	29		201,020	201,020	26,300,000	1,052,000	850,980
33	30		201,020	201,020	26,300,000	1,052,000	850,980
34	31		201,020	201,020	26,300,000	1,052,000	850,980
35	32		201,020	201,020	26,300,000	1,052,000	850,980
36	33		201,020	201,020	26,300,000	1,052,000	850,980
37	34	904,000	201,020	1,105,020	26,300,000	1,052,000	-53,020
38	35	447,000	201,020	648,020	26,300,000	1,052,000	403,980
39	36		201,020	201,020	26,300,000	1,052,000	850,980
40	37		201,020	201,020	26,300,000	1,052,000	850,980
41	38		201,020	201,020	26,300,000	1,052,000	850,980
42	39		201,020	201,020	26,300,000	1,052,000	850,980
43	40		201,020	201,020	26,300,000	1,052,000	850,980
44	41		201,020	201,020	26,300,000	1,052,000	850,980
45	42		201,020	201,020	26,300,000	1,052,000	850,980
46	43		201,020	201,020	26,300,000	1,052,000	850,980
47	44		201,020	201,020	26,300,000	1,052,000	850,980
48	45		201,020	201,020	26,300,000	1,052,000	850,980
49	46		201,020	201,020	26,300,000	1,052,000	850,980
50	47	-540,400	201,020	201,020	26,300,000	1,052,000	850,980
51	48		201,020	201,020	26,300,000	1,052,000	850,980
52	49		201,020	201,020	26,300,000	1,052,000	850,980
53	50		201,020	-339,380	26,300,000	1,052,000	1,391,380
Total		13,563,600	9,861,860	23,425,460	1,253,610,000		1,230,184,540
						F.I.R..R.	6.5%

Attached Drawing List



From : Memoire du B.R.G.M. n°92 (R. Bessoles et al. 1977)

MINI HYDRO-ELECTRIC POWER STATION PROJECT	
GEOLOGICAL MAP OF CAMEROON WITH THE LOCATION OF THE SITES UNDER STUDY	
Fig.1	



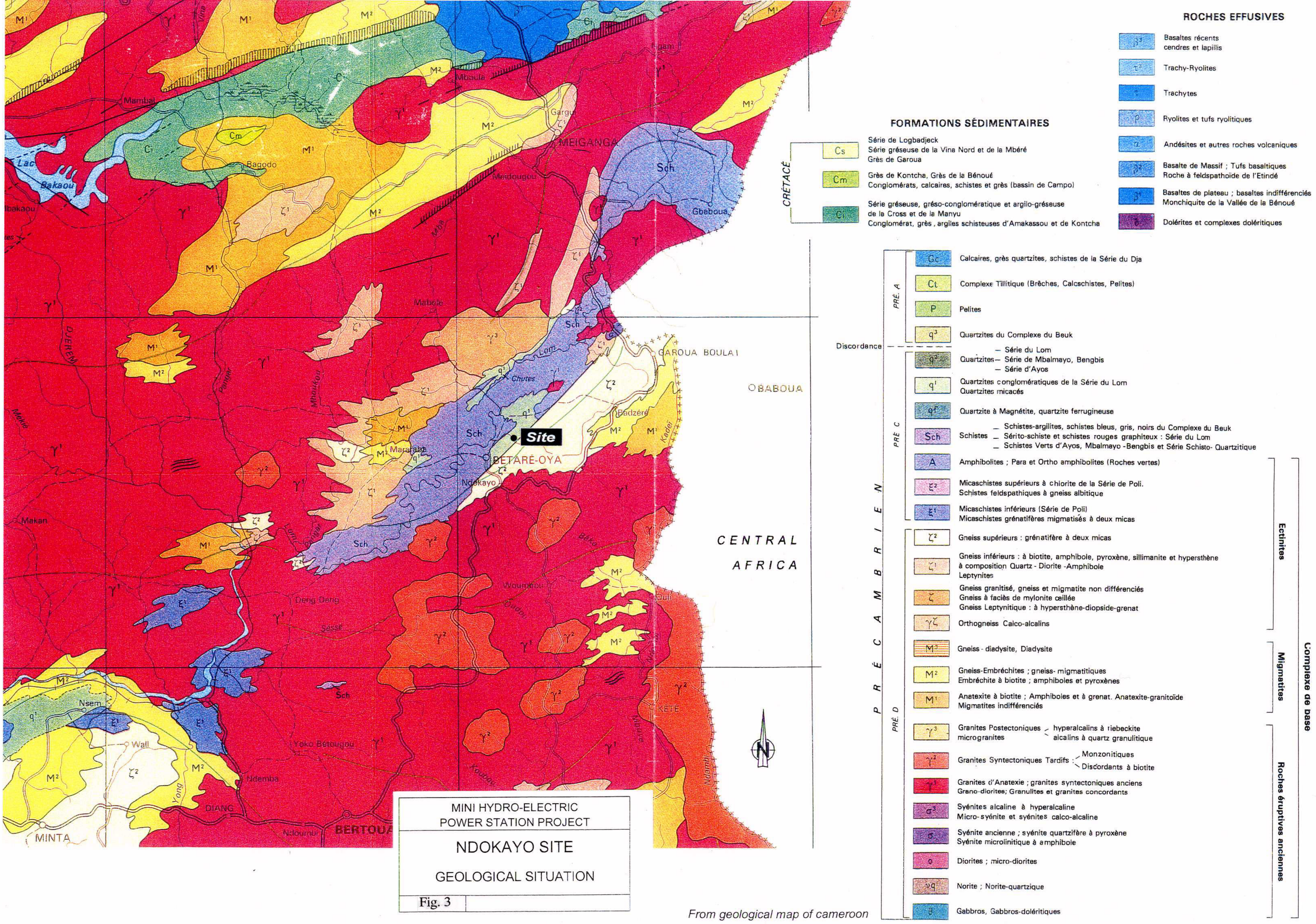
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBÉ TIKAR

GEOGRAPHICAL SITUATION

Fig. 2

From geological map of cameroon



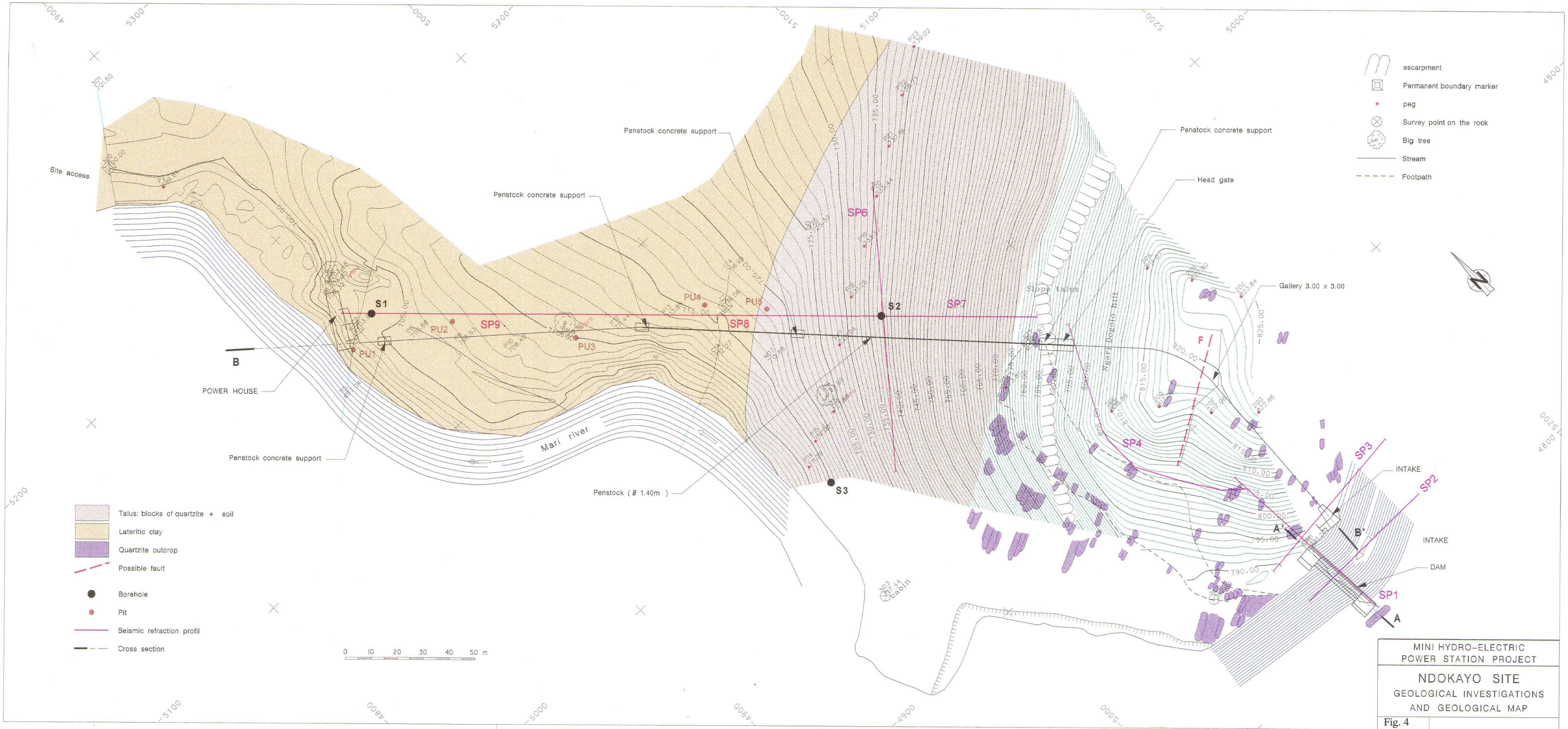
MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

GEOLOGICAL SITUATION

Fig. 3

From geological map of cameroon



MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

GEOLOGICAL INVESTIGATIONS AND GEOLOGICAL MAP

Fig. 4

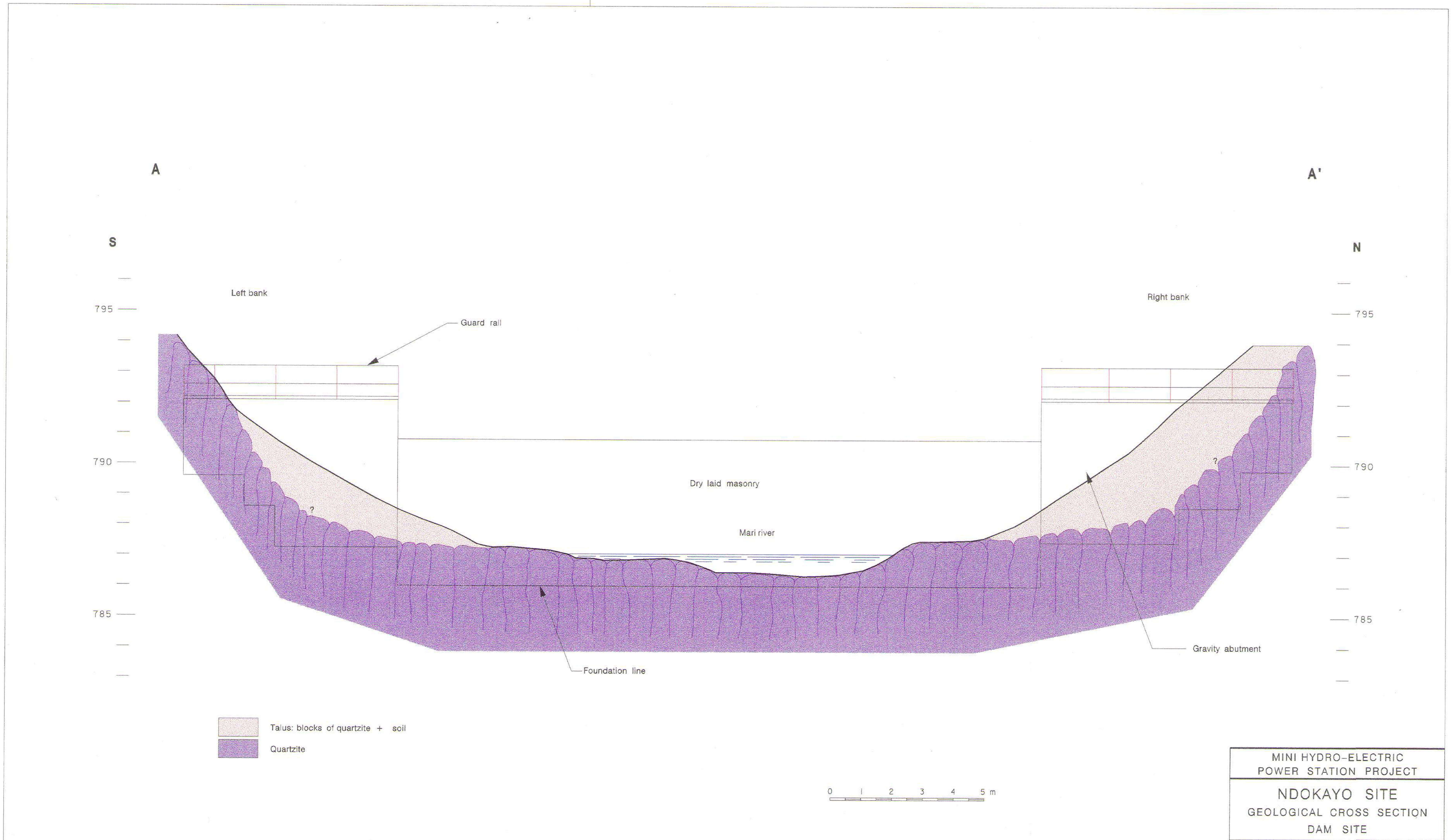
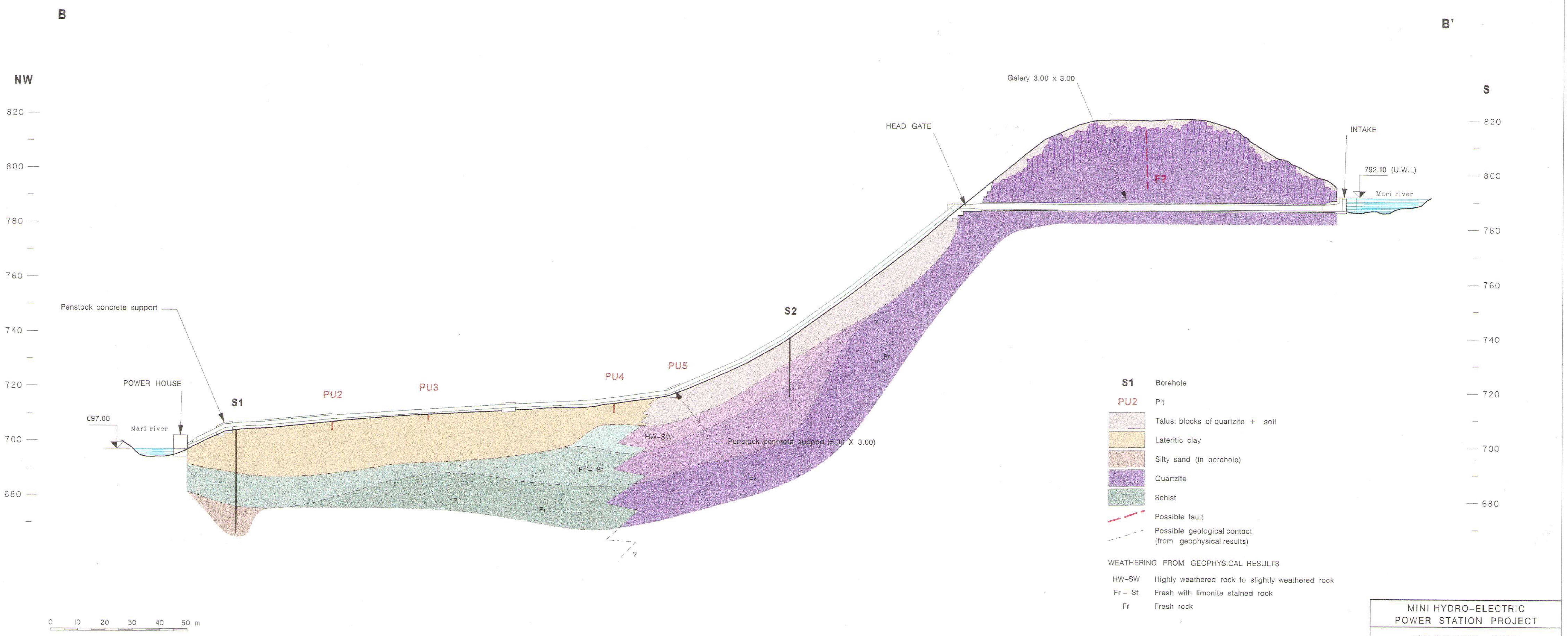

A
A'
S
N
Left bank
Right bank
795
790
785
Guard rail
Dry laid masonry
Mari river
?
Foundation line
Gravity abutment
Talus: blocks of quartzite + soil
Quartzite
0 1 2 3 4 5 m
MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NDOKAYO SITE
GEOLOGICAL CROSS SECTION
DAM SITE

Fig. 5

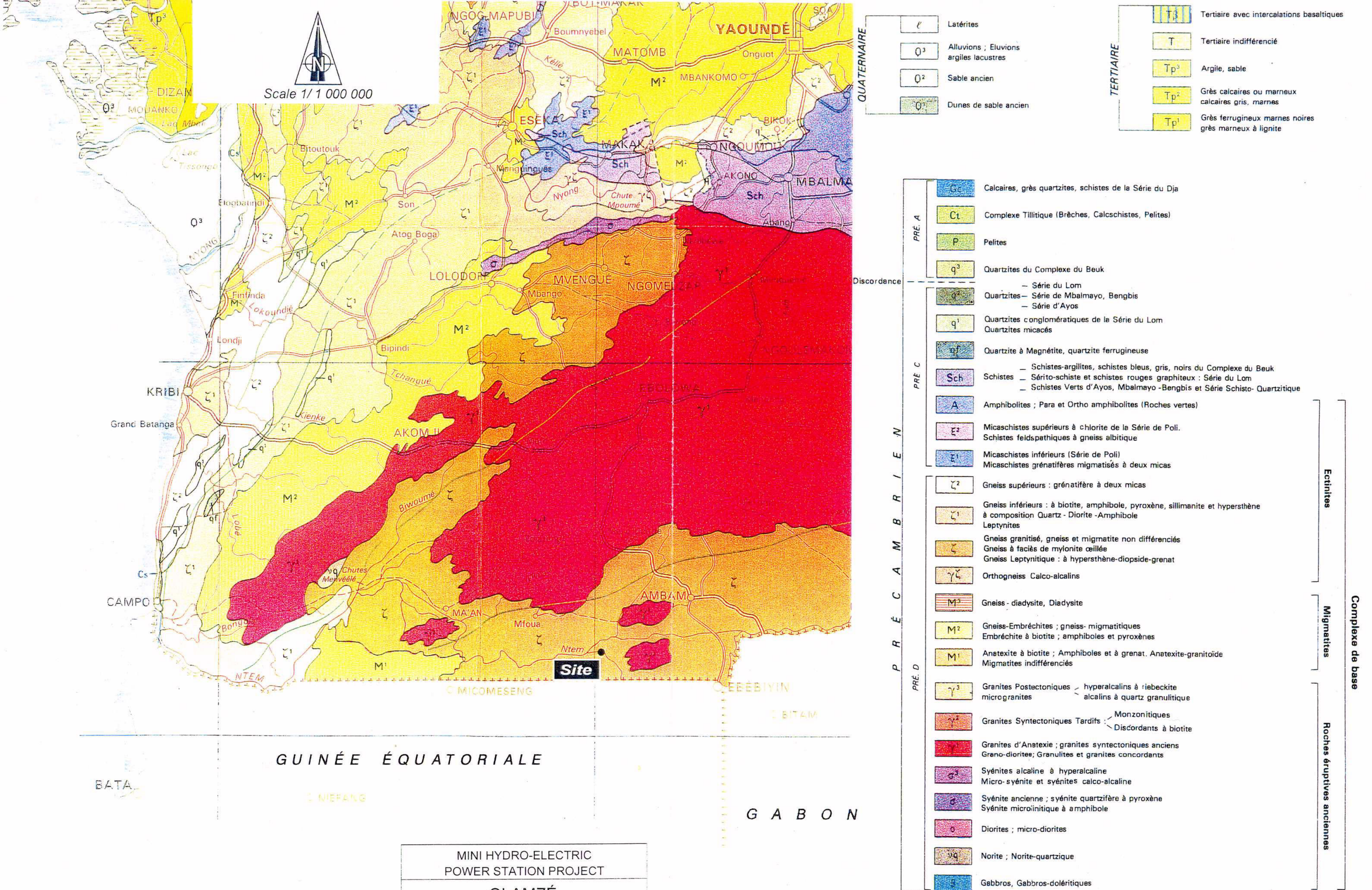


MINI HYDRO-ELECTRIC POWER STATION PROJECT

NDOKAYO SITE

GEOLOGICAL CROSS SECTION PENSTOCK AND POWER STATION

Fig. 6



FROM GEOLOGICAL MAP OF CAMEROON

MINI HYDRO-ELECTRIC POWER STATION PROJECT
OLAMZÉ
GEOLOGICAL SITUATION
Fig. 7

MINI HYDRO-ELECTRIC POWER STATION PROJECT

NGAMBE TIKAR SITE

GENERAL LAYOUT

Plan view (sheet 1)

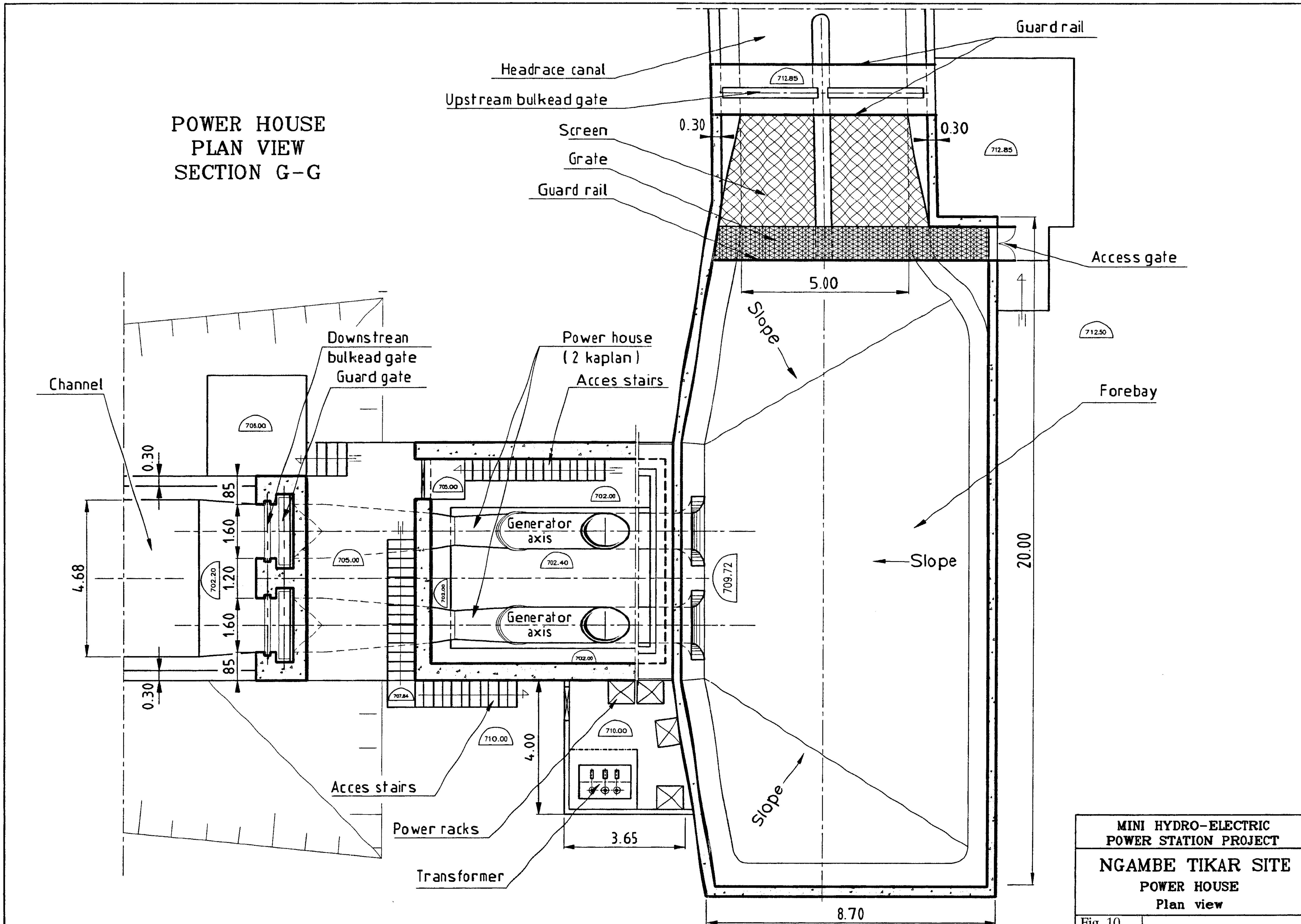
Fig. 8

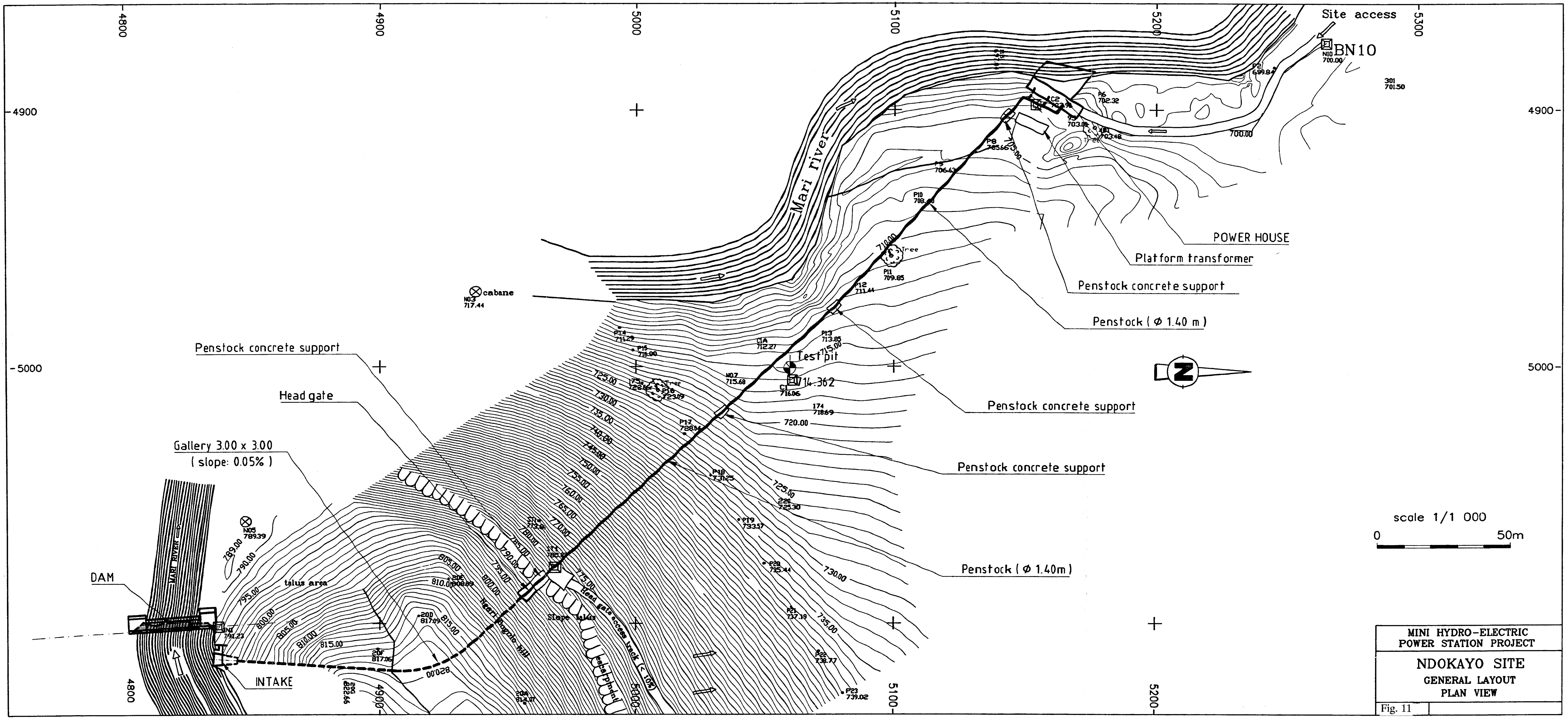
MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NGAMBE TIKAR SITE

Power House
Longitudinal section

Fig. 9


POWER HOUSE
PLAN VIEW
SECTION G-G
Headrace canal
Upstream bulkead gate
Screen
Grate
Guard rail
Guard rail
0.30
0.30
712.85
712.85
Access gate
5.00
Slope
712.50
Forebay
Slope
Slope
20.00
Downstrean
bulkead gate
Guard gate
Power house
(2 kaplan)
Acces stairs
Channel
705.00
705.00
702.00
Generator
axis
705.00
702.40
702.20
709.72
Generator
axis
702.00
702.00
0.30
85
1.60
1.20
1.60
85
0.30
4.68
707.84
710.00
710.00
4.00
Acces stairs
Power racks
3.65
Transformer
8.70
MINI HYDRO-ELECTRIC
POWER STATION PROJECT
NGAMBE TIKAR SITE
POWER HOUSE
Plan view
Fig. 10



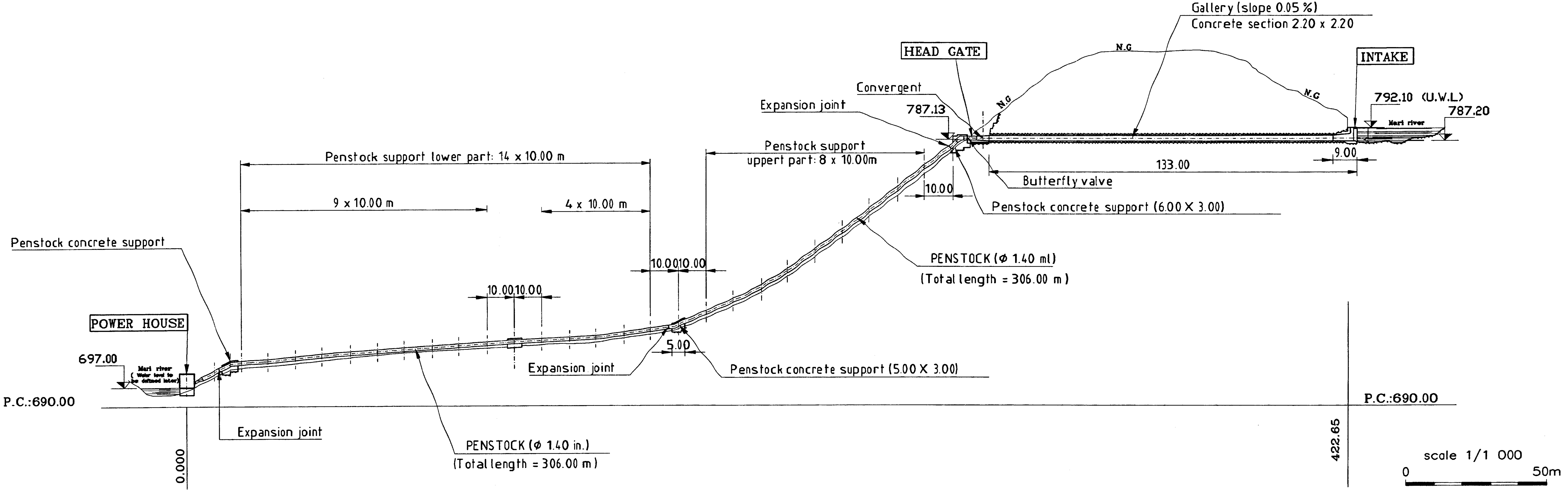
MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NDOKAYO SITE
GENERAL LAYOUT
PLAN VIEW

Fig. 11

PROFILE SECTION

(scale 1/ 1 000)

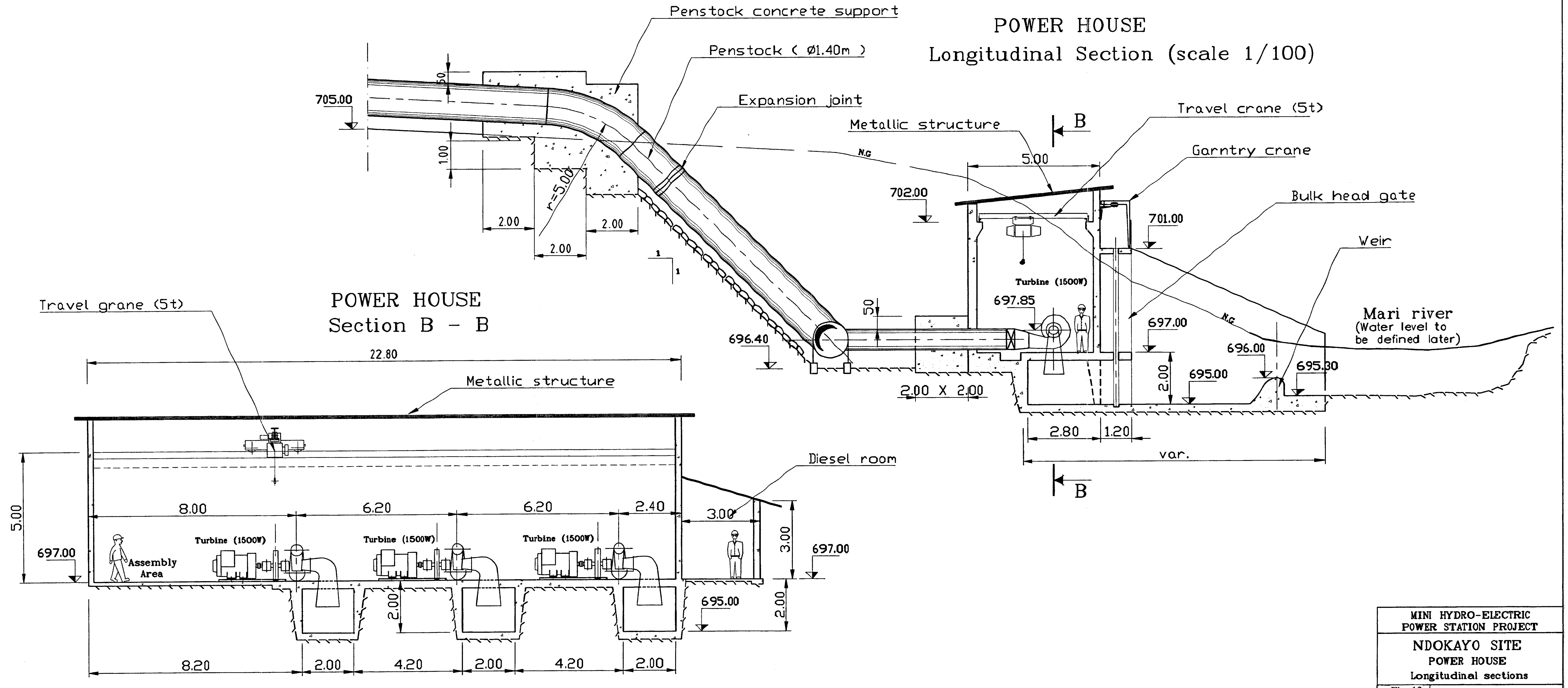


MINI HYDRO-ELECTRIC
POWER STATION PROJECT

NDOKAYO SITE

GENERAL LAYOUT
PROFIL SECTION

Fig. 12



MINI HYDRO-ELECTRIC POWER STATION PROJECT

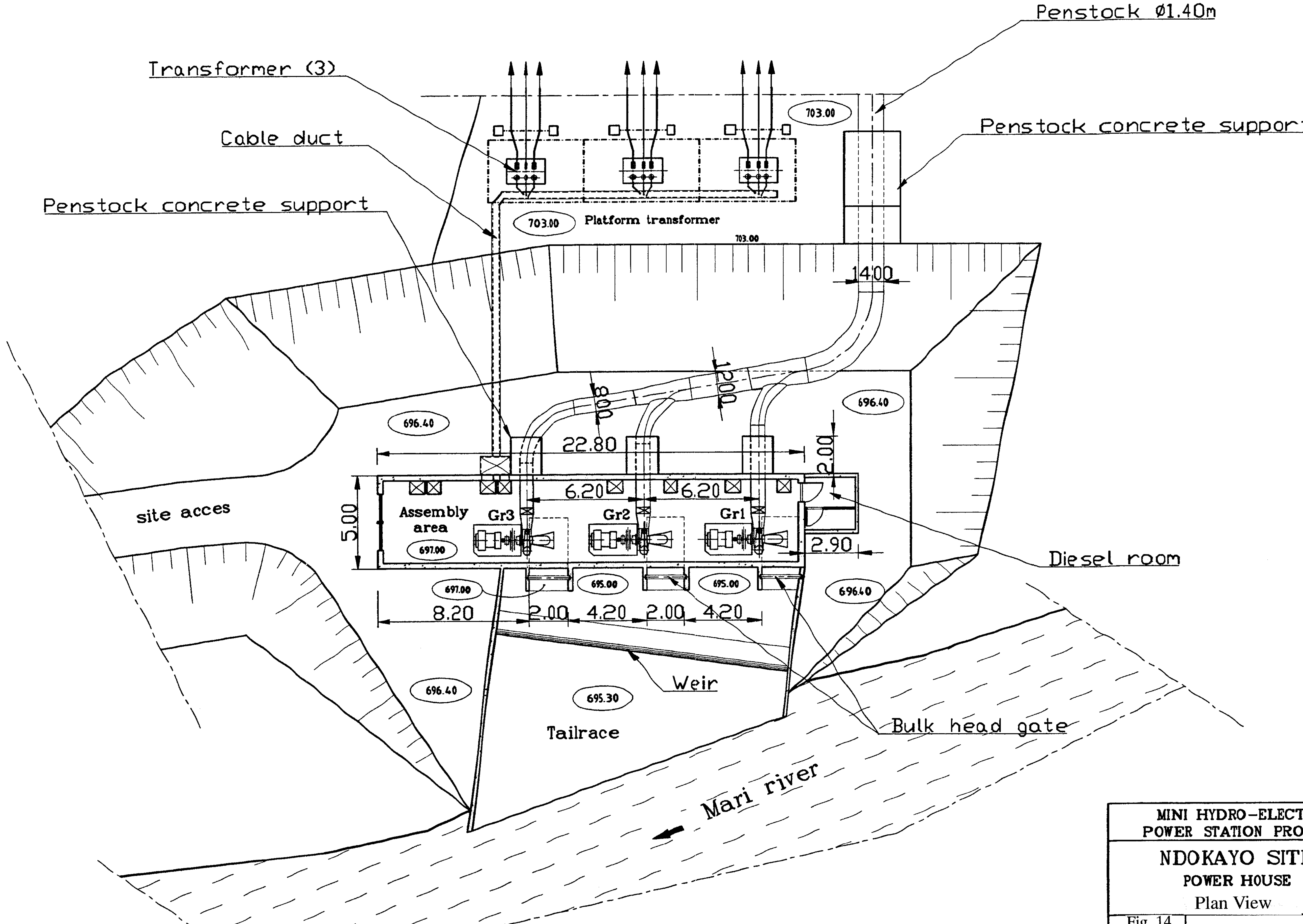
NDOKAYO SITE

POWER HOUSE

Longitudinal sections

Fig. 13

POWER HOUSE
Plan view (scale 1/ 200)



MINI HYDRO-ELECTRIC POWER STATION PROJECT

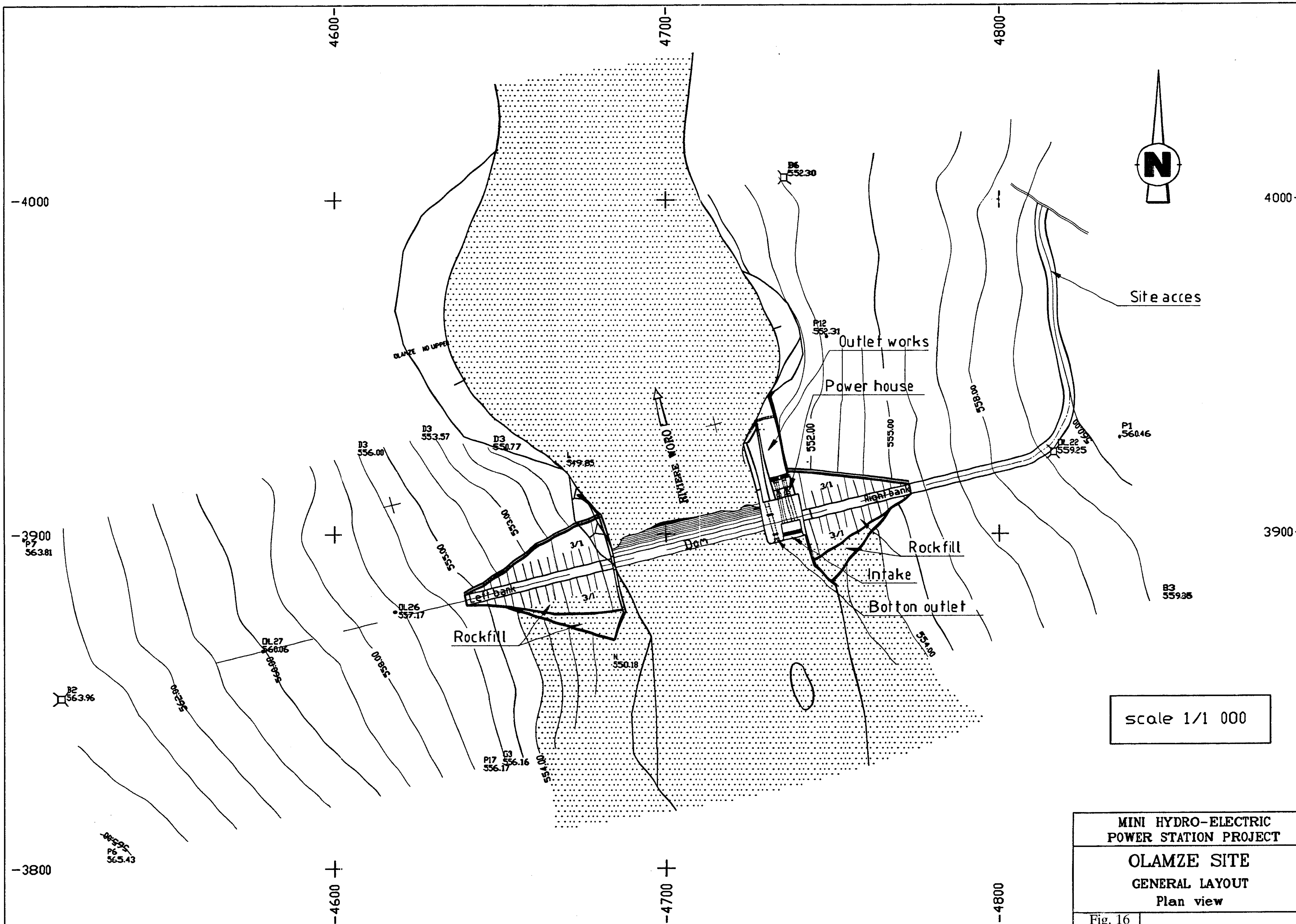
NDOKAYO SITE

POWER HOUSE

Plan View

Fig. 14


DAM AXIS CROSS SECTION
(scale 1/100)
796
792
786
7.00
21.00
8.20
Left bank
Right bank
Guard rail
792.10
790.80
Weir
masonry
1.30
4.40
4.80
0.20
1.20
0.50
1.00
bedrock level
Fondation level
Gravity abutment
Bottom outlet 1.20 x 1.20
A
B
C
D
Right bank
Section C.C
2.00
U.W.L 792.10
2.30
max. 4.50
To be defined according to bedrock level
Fondation pressure grouting
3.20
Left bank
Section A-A
L.W.L 789.60
787.60
max. 4.50
3.70
Right bank
Section D.D
786.50
786.00
bottom gate
5.30
Weir typical profile
Section B.B
U.W.L 792.10
790.80
L.W.L 789.60
786.00
max. 4.80
MINI HYDRO-ELECTRIC POWER STATION PROJECT
NDOKAYO SITE
DAM AXIS CROSS SECTION
typical sections: A-B-C-D
Fig. 15



MINI HYDRO-ELECTRIC
POWER STATION PROJECT

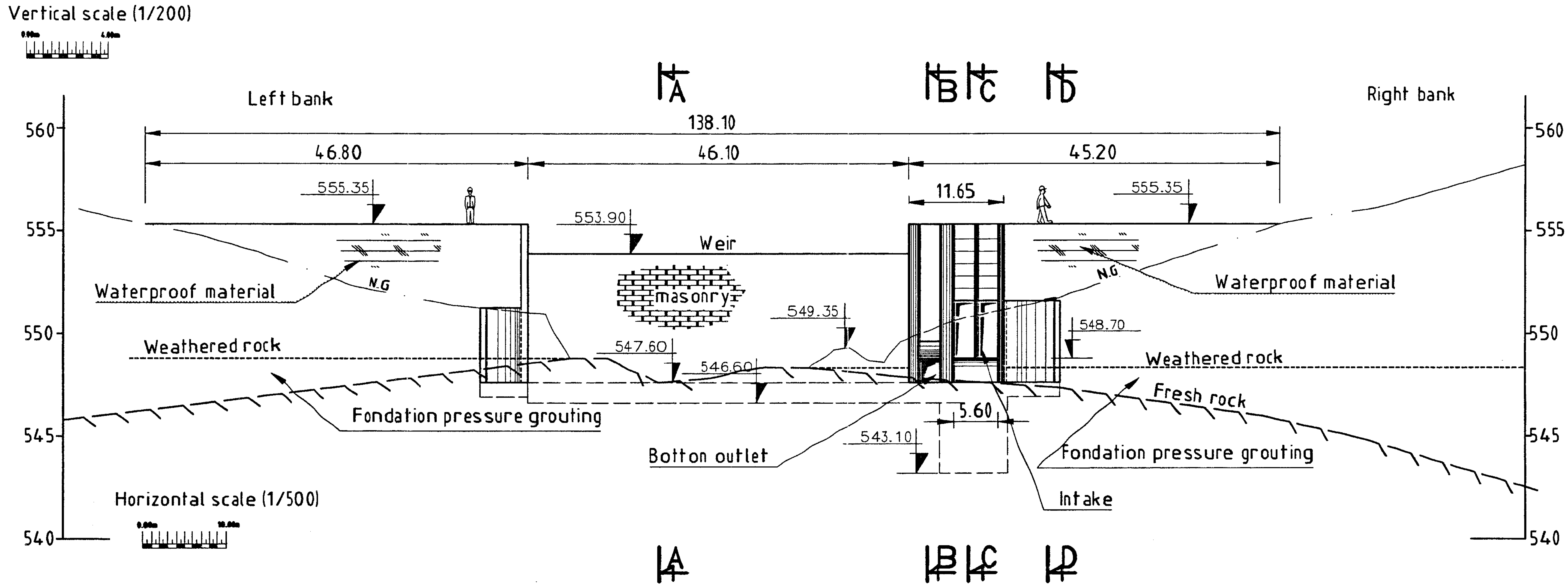
OLAMZE SITE

GENERAL LAYOUT

Plan view

Fig. 16

UPSTREAM DAM ELEVATION



MINI HYDRO-ELECTRIC POWER STATION PROJECT

OLAMZE SITE

DAM AXIS CROSS SECTION

Fig. 17