THE REPUBLIC OF MADAGASCAR

FEASIBILITY REPORT
ON
ANDEKALEKA HYDROELECTRIC POWER DEVELOPMENT PROJECT

March 1975

JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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PREFACE

In accordance with the request made by the Government of the Republic of Madagascar for technical cooperation regarding the Andekaleka Hydro Power Project, which is being proposed in the middlestream of the Vohitra River flowing eastward through the central region of Madagascar into the Indian Ocean, the Japanese Government decided to extend its cooperation by a feasibility study of the project and entrusted its survey to the Japan International Cooperation Agency, in view of the significance that the project will contribute greatly to the economic growth of Madagascar by promoting mining and other industries, particularly the power consuming industries.

The Japan International Cooperation Agency organized a survey team consisting of 7 experts of The New Japan Engineering Consultants, Inc., headed by Mr. Naoaki Yamada as the team leader and delegated them to the project site for 46 days from August 29th to October 13th, 1974.

The survey was conducted by the team on the middlestream of the Vohirta River over the proposed site for the hydroelectric power develoment, the selected right-of-way for the transmission line route, the prospective service territory, and the planned site for the ferrochrome producing plant, and all relevant information and data were collected. The work continued, after the team's return to Japan, on the preparation of their presentation report. This report recommends that the site of Andekaleka should be developed in two stages, one, the construction of the No. 1 Power Station and two, the construction of the No. 2 Power Station. With the completion of the two stages, power will be supplied to the proposed ferrochrome plant in Moramanga and to the service territory in and around the capital city of Tananarive.

In presenting this report, we hope that this will contribute towards the promotion of the hydro power development project and its associated industrial development thus increasing the economic growth of the Republic of Madagascar. Though this, we also hope to strengthen the friendly relationship between the Republic of Madagascar and Japan.

On behalf of the Japan International Cooperation Agency, I wish to express our sincere gratitude to each member of the survey team for their meritorious service rendered to accomplish their task, to those governmental officials of Madagascar for their kind cooperation ungrudgingly extended to the survey team, and to those people concerned in the Ministry of Foreign Affairs and in the Ministry of International Trade and Industry of the Japanese Government for their kind support for the delegation of the survey team to the Republic of Madagascar.

March 30, 1975

Shinsaku HOGEN
President,
Japan International Cooperation Agency

Letter of Transmittal

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency

Dear Sir,

On behalf of The New Japan Engineering Consultants, Inc., I hereby present you with the report on the feasibility study of the subject project being proposed in the Republic of Madagascar.

The report was prepared by The New Japan Engineering Consultants, Inc., which was commissioned by the Japan International Cooperation Agency, the official agency responsible for implementation of technical cooperation programmes of the Government of Japan.

The survey team was composed of seven experts selected from The New Japan Engineering Consultants, Inc., headed by Mr. Naoaki Yamada as the leader, and was delegated to the site in Madagascar from August 29th, 1974 to October 13th of the same year.

The survey team won the hearty cooperation of various bodies concerned and accomplished its investigations over the power demand situation in and around Tananarive, the proposed site for the hydro power development project, the planned site for the ferrochrome production project and the other associated industrial areas.

After their return to Japan, by reference to the data collected at the site and to the results of surveys conducted, the team members continued their work covering the power demand forecast, the preliminary design for Andekaleka Hydro Power Project, the estimation of construction cost, the economic evaluation and financing plan and schedule, etc., and finalized them into a report.

Concerning the ferrochrome production project, it is concluded and recommended in the report that in view of commerciability of the project and availability of major raw materials, the optimum size of the project should be a plant capable of 25,000-ton annual prodution as the first step, and additionally construct the plant of the same capacity after five years when the first unit is expected to be operated under normal condition.

For hydro power development at the proposed site, the two alternative plans, either the 1-stage or the 2-stage development plan, depending upon the method to utilize the gross head available at the proposed site, were taken into consideration. After comparative studies from the viewpoints of the forecasted demend increase and of the finacial prospect, it was concluded that the 2-stage development plan should be advantageous over the 1-stage development plan.

The ultimate capacity planned for Andekaleka Hydro Power Project will reach 106.4 MW; 70.4MW for No.1 Power Station and 36.0 MW for No.2. After full review of the estimated trend of power demand increases and all other related factors, it is recommended that the overall construction schedule be devided into the three different work-terms as proposed below:

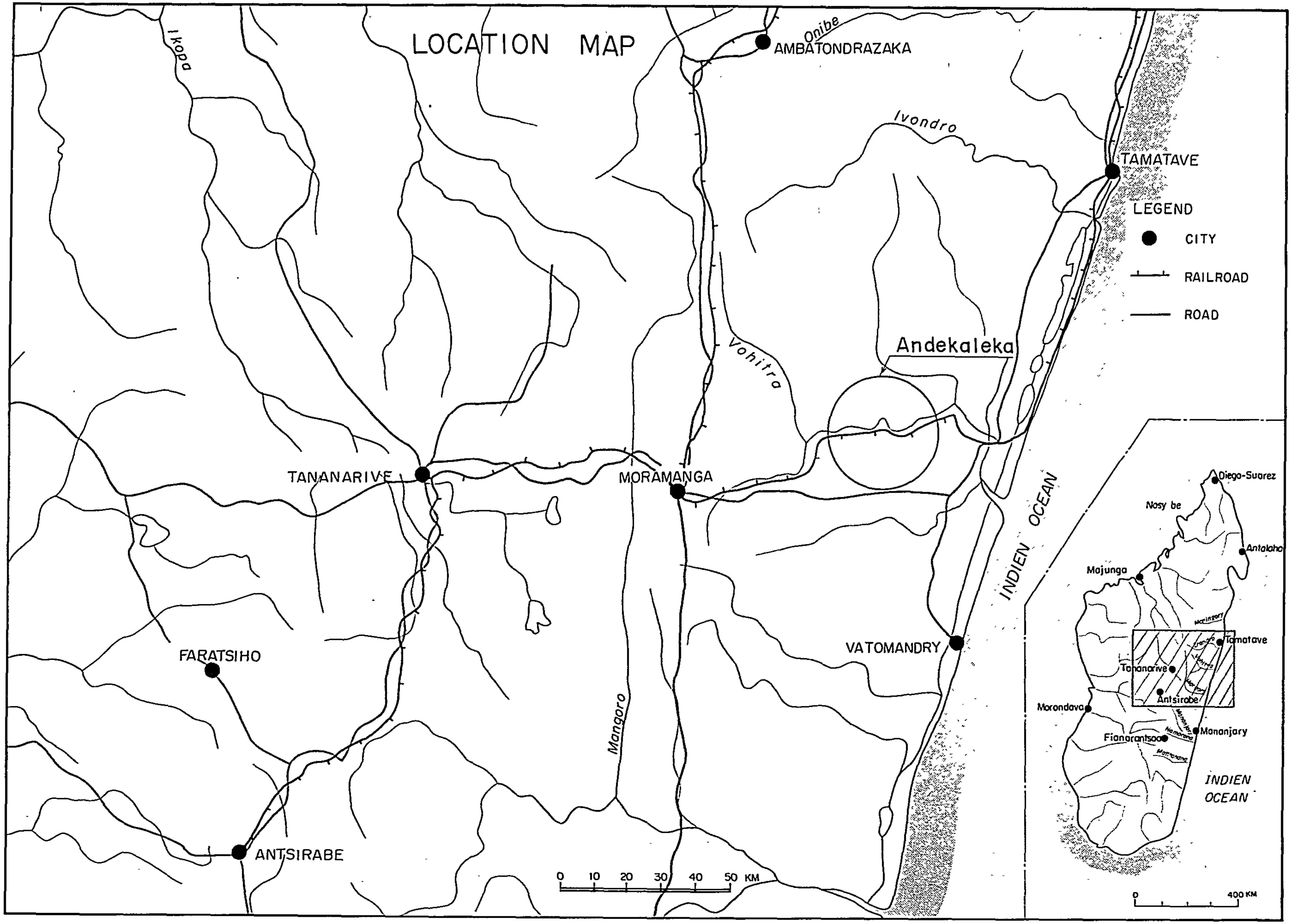
1st term: Work on the No. 1 Power Station to develop 35.2 MW output.
2nd term: Work on the No. 1 Power Station to develop the remaining capable output of 35.2 MW to bring the total output of the No. 1 Power Station to 70.4 MW.
3rd term: Work on the No. 2 Power Station to develop total capable output of 36.0 MW.

In presenting this report, I wish to extend our hearty thanks to those people of the Government of Madagascar and to the other public bodies concerned for their kind cooperation afforded our survey team. It is sincerely hoped that the earliest realization of the proposed project will promote the industrialization of Moramanga and Tananarive and contribute towards further economic growth of the Republic of Madagascar.

Sincerely yours,
The New Japan Engineering Consultants, Inc.

Eiji Matsumoto

Eiji Matsumoto
President


LOCATION MAP
Ikopa
Onibe
AMBATONDRAZAKA
Ivondro
TAMATAVE
LEGEND
CITY
RAILROAD
ROAD
Vohitra
Andekaleka
TANANARIVE
MORAMANGA
INDIEN OCEAN
VATOMANDRY
FARATSIHO
Mangoro
ANTSIRABE
0 10 20 30 40 50 KM
Diego-Suarez
Nosy be
Antalaha
Majunga
Tamatave
Tananarive
Antsirabe
Morondava
Mananjary
Fianarantsoa
INDIEN
OCEAN
0 400 KM

Andekaleka NO. 1 Power Station's Intake Dam and Intake Site

(A-zone)

NO.1 Power Station's Outlet, NO.2 Power Station's Intake and Intake Dam Site (B-zone)

NO.2 Power Station's Outlet Site

(C-zone)

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UNITS

mm	millimeter
mm^2	square millimeter
cm	centimeter
cm^2	square centimeter
m	meter
m^2	square meter
m^3	cubic meter
m/s	meter per second
m^3/s	cubic meter per second
ton	metric ton
kW	kilowatt
MW	megawatt
kWh	kilowatt-hour
MWh	megawatt-hour
GWh	gigawatt-hour (10^6 kWh)
kV	kilovolt
kVA	kilovolt-ampere
MVA	megavolt-ampere
r. p. m	revolutions per minute
Hz	Hertz
FMG	Malagasy Franc
MFMG	millions of Malagasy Franc

ABBREVIATIONS

G. D. P	Gross Domestic Product
E. E. M	Societe Electricite et Eaux de Madagascar
S. E. E	Service de l'Eau et de l'Electricite
S. E. M	Societe d'Energie de Madagascar
S. M. E. E	Societe Malagache de l'Eau et de l'Electricite
S. I. N. E. E	Societe d'Interet National de l'Eau et de l'Electricite
S. N. A	Societe Nationale Alumette
S. I. B	Societe Industrielle Bois
U. C. C	Union Carbide Co., Ltd.
E. D. F	Electricite de France
NEWJEC	The New Japan Engineering Consultants, Inc.
EL.	elevation above mean sea level
H. W. L	high water level
N. W. L	normal water level
I. W. L	intake water level
T. W. L	tailrace water level
T. S. W. L	top surging water level
A. C. S. R	alminum cable steel reinforced

Exchange Rate of Japanese Yen to Malagasy Franc

100 FMG = 125 Yen

1 US$ = 300 Yen

Chapter 1.

Introduction

Chapter 1 Introduction

1. 1 General information

1. 1. 1 Approach to Madagascar on governmental basis

Japan's governmental approach to the power development programme in Madagascar initiated in 1964 when the Government of the Republic of Madagascar made an official request, through the diplomatic channel, for a survey team from Japan.

In 1965, entrusted by the Ministry of International Trade and Industry (M. I. T. I) of the Japanese Government, the Overseas Technical Cooperation Agency of Japan (O. T. C. A) organized its survey team of 7 experts and sent it over to Madagascar as the first survey team, which was succeeded by a second team in 1970.

Within a decade the effort has borne fruit on the Namorona River, and Ambodikimba Hydro Power Project is now under way for construction of a power station to serve the area of Fianarantsoa.

1. 1. 2 Combined utilization of mineral and water resources

The Government of Madagascar was very active in pursuing surveys for exploitable hydro power potential near and around its capital city, Tananarive. Since the nation has wealth of mineral reserves in deposit, such as nickel and chrome, the Government has had an advanced idea of industrialization by the combined use of abundant mineral and water resources aiming at a higher growth of the nation's economy. After surveys and studies, the site in Andekaleka on the Vohitra River and the site in Fatita on the Mananjory River were proposed as development sites.

1. 1. 3 Past surveys on Andekaleka site

For many years the Andekaleka site has been favoured by the concerned people because of its terrain and abundant water flow. Over the past decade various investigations were made several times to determine the feasibility of such a development:

1968: Power supply to a silico-chrome plant using chrome-ore produced in Andriamena was studied under the United Nations Special Fund Programme.

1970: Site and geological surveys conducted by Electricite de France (E. D. F.).

1971: Economic analysis and evaluation of the project conducted by E. D. F.

1972 (July): The proposal of the Vohitra River Development Scheme was prepared by the E. D. F, recommending that after utilizing the total available head all at one stage of development the equipment for power generating units should be additionally installed from one stage to the next.

1972 (December): The experts of the New Japan Engineering Consultants, Inc. (NEWJEC) were delegated to the site through the Engineering Consulting Firms' Association of Japan (E.C.F.A) with the subsidy granted by the Japanese Government. They made site reconnaissance and collected as much data as were locally available. In April of the following year, a technical proposal was prepared covering construction of a waterway and adoption of 2-stage development pattern.

1973 (September): Economic evaluations were made by the Societe d'Energie de Madagascar (S. E. M) for various patterns of development on the Andekaleka site.

1. 1. 4 Final choice of development plan

After the series of studies were made and before the project could be implemented, it became necessary to select the most suitable proposal from among the various proposals including that for a 2-stage development pattern as recommended by NEWJEC. Such being the case, again through the diplomatic route, the Government of Madagascar requested for a prompt visit of the survey team from Japan.

1. 2 Object of investigation

The object of this latest investigation was to study first, the public power demand in and around Tananarive and secondly, the industrial demand for ferrochrome production, and then, to review the various development schemes, including 1-stage and 2-stage alternative plans, for the final choice of the most suitable one.

Finally, feasibility studies were made from economic, technical, and financial aspects to select the most suitable method for hydro power development on the Vohitra River.

1.3 Investigation activities on site

1.3.1 Activities by groups

The survey team members committed themselves to various investigation activities in compliance with the Investigation Time Schedule as annexed during their full 40-day period of stay starting from August 31st, 1974. Their activities are outlined as stated below.

Prior to proceeding with the scheduled activities, the team had an opportunity to fully discuss, with the representatives from the governmental authorities concerned and other related agencies, the setting up of a properly scheduled investigation plan. Preparations were also made to fix the work schedule and to arrange the availability of tools, instruments and materials for site surveys.

The group organized for site surveys was engaged in topographical and geological surveys over the proposed site, while the power survey group members investigated solely the current power situations in and around Tananarive. Thanks to the full cooperation of the governmental agencies and the utilities, S. E. M and Societe d'Interest National de l'Eau et de l'Electricite (S. M. E. E), the groups were able to collect the necessary data for their studies. The mining group investigated the exising condition of the Andriamena chrome-mine, the land transit for ore and its shipping port facilities, and investigated a site for a ferrochrome production projict.

After their return to Japan in October 1974 with all the collected data, the team members proceeded with the formulation of the plan and schedule of power demand and supply. They then prepared a feasibility report containing the proposal for a ferrochrome production project and containing the proposal for a suitable plan for hydro power development with evaluations by comparative studies based upon economic effects from investments.

1. 3. 2 Survey team members

The team was composed of 7 experts whose names and specialities are as listed below:

Leader	Naoaki Yamada	Chief Engineer
Adviser	Dr. Haruo Tanaka	Geologist
Member	Yasukichi Shyuku	Economist (Power demand forecast)
"	Tsutomu Maeba	Mining Engineer
"	Toshio Hida	Economist
"	Shiro Horikawa	Civil Engineer (Hydro power planning)
"	Akira Shimizu	Civil Engineer (Cost estimation)

1. 3. 3 Period of survey

The whole period of survey covers full 46 days from the date of departure from Japan on August 29th, 1974 to the date of return on October 13th, 1974.

1. 3. 4 Schedule

The detailed schedule is as per Table-1. 1.

1. 4 Information and data

All information and data used for studies by all the team members were furnished by courtesy of the governmental authorities concerned of the Republic of Madagascar, two utility companies, the S. E. M and the S. M. E. E, and other local bodies associated with the project.

1. 5 Acknowledgement

With renewed sense of gratitude the team members wish to express their heartfelt thanks to the governmental authorities concerned, to the local bodies involved, and to the persons in charge, for their most generous cooperation and support which enabled the team members to carry out their investigation activities to the fullest during their stay in Madagascar.

Table-1.1 Investigation Time Schedule by Andekaleka Hydro Power Project Survey Team

No. of Members: 7 persons

Period: 46 days, August 29th, 1974 to October 13th, 1974.

Date	Investigation schedule			Remarks
Aug. 29th (Thur.)	Lv. Tokyo for Nairobi (BA 911)			Stay in Nairobi
30th (Fri.)	Nairobi			Ditto
31st (Sat.)	Lv. Nairobi for Tananarive (AF 485)			Tananarive
Sept. 1st (Sun)				
2nd (Mon.)	Courtesy call to Japanese Embassy & Ministere de l'Economie et de l'Finances (Direction des Mines, Service de l'Eau et de l'Electricite (S. E. E))			
3rd (Tue.)	Courtesy call to Ministere de l'Economie et de l'Finances & S. E. M. Meeting at S. E. E.			
4th (Wed.)	Meeting at S. E. E. Data collection			Dr. Tanaka's arrival in Tananarive
5th (Thur.)	Meeting at S. E. M. Data collection			
6th (Fri.)	Preparation for site survey Review of data Investigation at Mining Company			
7th (Sat.)	Ditto			
8th (Sun.)	Site Survey Group	Power Survey Group	Mining Group	
9th (Mon.)	Site Survey Lv. Tananarive for Andekaleka	Meeting with S. M. E. E	Meeting with S. E. E	

Date	Investigation schedule			Remarks
Sept. 10th (Tue.)	Site survey	Meeting with S. M. E. E.		
11th (Wed.)	Ditto	Review of data	Survey at Moramanga & Andasibe	
12th (Thur.)	Ditto	Meeting with S. E. M.	Meeting with S. E. E.	
13th (Fri.)	Ditto	Ditto	Ditto	
14th (Sat.)	Ditto	Review of data	Ditto	Mr. Hida's arrival in Tananarive
15th (Sun.)	Ditto			
16th (Mon.)	Ditto	Lv. Tananarive for Andekaleka	Meeting with Direction des Mines	
17th (Tue.)	Ditto	Site survey	Ditto	Dr. Tanaka's departure
18th (Wed.)	Ditto	Site survey	Meeting with Forest Laboratory	
19th (Thur.)	Lv. site for Tananarive	Lv. site for Tananarive	Survey at Moramanga (Yamada & Maeba)	
20th (Fri.)	Meeting with S. E. E & S. E. M			
21st (Sat.)	Data arrangements			
22nd (Sun.)				
23rd (Mon.)	Data arrangements and review. Yamada, Shyuku, Maeba and Hida made survey at Tamatave.			
24th (Tue.)	Data arrangements and review			
25th (Wed.)	Data arrangements and review			

Date	Investigation schedule	Remarks
Sept. 26th (Thur.)	Meeting with S. E. M.	
27th (Fri.)	Data arrangements and review	
28th (Sat.)	Ditto	
29th (Sun.)		
30th (Mon.)	Preliminary general studies	
Oct. 1st (Tue.)	Ditto	
2nd (Wed.)	Ditto	Mr. Hida's departure
3rd (Thur.)	Meeting with S. E. M and S. E. E.	
4th (Fri.)	Preparation of interim report	
5th (Sat.)	Ditto	
6th (Sun.)		
7th (Mon.)	Preparation of interim report Report to Japanese Embassy Shyuku & Maeba visited Antsirabe for survey.	
8th (Tue.)	Report to S. E. M and Ministere de l'Economie et de l'Finances	
9th (Wed.)	Lv. Tananarive for Paris (AF 486)	
10th (Thur.)	Arrival in Paris	Stay in Paris
11th (Fri.)	Call to E. D. F in Paris	Stay in Paris
12th (Sat.)	Lv. Paris for Moscow	
13th (Sun.)	Lv. Moscow for Tokyo.	

Chapter 2.

Summary and Recommendation

Chapter 2 Summary and Recommendation

2.1 Summary

2.1.1 Outline of project planning

Andekaleka Hydroelectric Power Development Project envisages construction of the hydro power stations by two stages utilizing the rapid current in the middlestream of the Vohitra River which flows eastward from the central part of Madagascar.

The plan is to exploit some 110 MW output with No. 1 and No. 2 Power Stations connected one to the other, utilizing the 236 m gross head in the rapidly flowing section of the water-course which will become available with an intake dam to be provided about 2. 6 Km downstream of Andekaleka in the middlestream of the Vohitra. The site will be situated in the most suitable location for developping potential energy resources on the river, a part of which will be harnessed under the proposed project planning.

No. 1 Power Station will be capable of 70. 4 MW by the utilization of nearly two-third of the gross head available, or 150 m head, and No. 2 Power Station will be capable of 36 MW with the balance of 86 m out of the gross head. Their total annual energy production will be 787 GWh; 516 GWh from No. 1 and 271 GWh from No. 2.

2.1.2 Present power situation

Power demand in Madagascar, particularly in and around Tananarive, was rising sharply at an average increase rate of 10. 3 % each year from 1966 to 1972 and since 1973 the increase rate has dropped to 3 %. Gross energy sales as of 1972, in and around Tananarive, amounted roughly to 130 GWh, or 52% of the nation's total.

According to the records of 1972, from 1968 to 1972 the peak demand at generating end was recorded at 32 MW and the annual load factor was maintained at about 50 %. To cope with such power demand, both the Antelomita and Mandraka Power Stations have been serving as base load stations for security of constant yearly supply. A diesel generating plant of two 6 MW units built in 1972 in

Ambohimanambola is used during peak load. At present, the total installed capacity is 69,960 kVA to meet the prevailing power demand of 144 GWh.

2.1.3 Power demand forecast

With growth of the nation's economy, power demand is increasing at a rapid rate. According to the long-range forecast made herein for increases in energy consumption from the past trend, classified by service categories, energy consumption is estimated at 178 GWh for '77, 243 GWh for '82 and 343 GWh average for the '86 - '87 period. On the other hand, an attempt was made to try to approach the macroscopic forecast from the growth rate of the G. D. P of Madagascar. The obtained result from elasticity values of power demand to the G. D. P's growth rate coincides with the above forecast.

Meanwhile, the Government of Madagascar intends to strengthen the foundation for further economic growth, not only by the export of mere chrome ore product, but also by export of product of higher value added from the ferrochrome processing utilizing the abundant available hydraulic energy. For this reason, power demand for ferrochrome production is estimated to take a great portion in the total load. According to the ferrochrome production plan referred to in Chapter 4, the estimated energy requirement for the industry will be 84.8 GWh for '81, 224.8 GWh for '86 and up to 246.3 GWh by 1990.

2.1.4 Ferrochrome production plan

The Government contemplates economic growth with its plan for expansion of mining and other key industries particularly associated with power energy, by combined utilization of both mineral and hydraulic energy resources locally available. This plan is blueprinted to construct a ferrochrome production plant near Moramanga, where chrome ore, now on export sale will be used for ferrochrome production with the use of electricity available from Andekaleka.

The present ore-deposit with an estimated reserve of 7 million tons, together with other encouraging deposits now being exploited, will supply some 120,000 tons of chrome ore annually for ferrochrome production.

As for charcoal, to be substituted for coke as sub-material, arrangements for annual increase production of charcoal of 40,000 tons can be made by planned utilization of the woodland around Moramanga.

Energy requirement for production of ferrochrome per ton is estimated at 4,500 kWh, and therefore for annual 50,000 tons production it is estimated roughly at 250 GWh. To meet such industrial need, a new power generating station must be built for adequate power supply at lower costs, since at present, the power rate tends to be rather expensive and under the existing power system the balance of demand and supply seems to be extremely low. To solve this problem, a power development project is planned at the proposed site of Andekaleka nearest to Moramanga, and adequate power supply will be fully secured when the project will have been completed. In this respect, the Moramanga area is the most suitable for the siting of a ferrochrome production plant.

According to the plan and schedule for ferrochrome production, the plant will be equipped with one 20,000 kVA furnace as a first step and a second furnace of same capacity will be added in five years time when the first furnace is expected to be put into its full operation. If the plan is carried out on such step-by-step basis as scheduled, it will undoubtedly become possible to produce 50,000 tons of ferrochrome annually at the cost of 122,000 FMG per ton (3 FMG per kWh at power cost) in 1990 when both of the two furnaces will be operated to their fullest capacity. This will eventually bring a profit of 700 MFMG per year to Madagascar, if the market price abroad of ferrochrome is maintained at the currently quoted level of 136,000 FMG per ton.

2.1.5 Adaptability of Andekaleka Power Project to ferrochrome production plan

The hydroelectric power development project being proposed at Andekaleka is absolutely necessary, as aforestated, for the realization of the ferrochrome production project. Furthermore, when the production project is viewed with regards to the power generation scheme, the power demand for ferrochrome production can be said to be of a definite favourable load pattern, unlike the load in the other public sector, for a hydro power generating source. This means that the load on the furnace is readily regulatable; for instance, the load on the furnace can be lowered to 70 % of its capacity when a power station is at peak operation during drought season in the face of difficulty in keeping stability of supply, while during the off-peak time the furnace can be operated at its full load. The ferrochrome production industry is also a large consumer of surplus energy. It is still more possible to make a large load regulation by reducing it to zero in the ferrochrome plant, if the furnace is overhauled for annual inspection, taking advantage of the critical time of on-peak during the driest season of a year. For the above reasons, the power cost for ferrochrome production can be maintained at a low level.

2. 1. 6 Location of hydro power project site

On the eastern coast of Madagascar there is much potential for hydro power generation because of its climate condition with much rainfall and its topographic feature represented by steep mountains. As of this date, however, the bulk of such potential resources remains unexploited except a small portion equivalent to 51 MVA hydro power generating capacity. The rest of the total installed capacity, or 102 MVA, depends upon diesel generating plants. Especially in the face of the oil crisis on a global scale today, the production cost of electric energy tends to be escalating upwards with the increase of fuel cost. Under such circumstances, prompt action must be taken to develop as much hydro power generating source as possible. In this sense, it is our firm belief that the efforts for future development should be directed to exploitation of the abundant hydraulic energy resources in Madagascar.

The proposed site for hydro power development in Andekaleka is situated in the middlestream of the Vohitra River, about 120 Km from Tananarive and 150 Km from Tamatave Port. The ferrochrome plant will be located in the 'right-of-way' area of the transmission line from the proposed power station to Tananarive, only 70 Km from the proposed power site. With this excellent site, coupled with good climate and topographic conditions, the availability of the energy resources will certainly be more economical.

The access to the proposed power project site is easy by way of the near-by existing railroad. The investigations and studies made on this proposed site show that this site has more advantages and is more economical than any of the other proposed sites for power development. In conclusion, therefore, it can be safely said that in order to cope with the anticipated future critical power demand, including the demand for ferrochrome production, there are no possible sites other than the Andekaleka site which can fully meet the time requirement for the earliest implementation of the development project in the immediate future.

2.1.7 Comparative studies on Andekaleka Power Project site

For many years, the Andekaleka project site has been the subject for studies from various aspects. In 1972, a 1-stage development plan was recommended by the E.D.F. in their report. Later, in 1973, a 2-stage development plan was proposed by NEWJEC, but no conclusion was reached after comparative studies were made with the original proposal of E.D.F.

For this study, therefore, request is made to draw out any final conclusion for solution from comparative reviews of all those alternatives. Then, reviews have been made on several alternatives mainly as to how to utilize the 236 m gross head for hydro power development. After all, the 1-0-B draft has been selected as the representative plan for 1-stage development pattern and the two drafts, 2-1-A and 2-2-A, as the representative for 2-stage development, from which the final one is to be chosen.

Chapter 6 of this Report deals with economic evaluations on the two alternatives, in which it is revealed that at about 12 % rate of discount, the economy of both 1-stage and 2-stage development plans become almost equalized in terms of their converted present value. Although the S.E.M's data in 1973 disclose that the 2-stage plan is advantageous over its counterpart, there is very little to choose between those two alternatives, because a sharp rise in commodity price, especially that of equipment and fuel, in and after 1973, has reduced most of the expected advantage of the 2-stage plan.

Such being the case, comparative studies have been made from more realistic aspect. As a result, it appears that the 2-stage plan has the following advantages over the 1-stage plan:

1) The required amount for investments is averaged over a long-range period, which makes it easy to raise the necessary fund for development.

2) The plan has such flexibility that it can be developed to meet real needs in response to any possible change in power demand.

3) The plan involves no financial risks for the reason mentioned in Chapters 6 and 10.

For such reasons as mentioned above, we have arrived at the judgement that the 2-stage development plan is more advantageous over the other, and have reached a conclusion that the development plan combined by both 2-1-A and 2-2-A should be adopted.

2. 1. 8 Andekaleka No. 1 Power Station

The ultimate installed capacity planned for Andekaleka No. 1 Power Station will be 70. 4 MW, capable of generating 516 GWh per annum at its generating end. In the initial stage, however, it will be operated at half of its planned total capacity that is 35. 2 MW, and when the demand will have increased to 35. 2 MW, it will be complete with the remaining two units after construction of a regulating pond on the upstream side. The outline of this project is as follows:

Gross head	152. 0 m
Effective head	138. 7 m
Maximum discharge	60 m^3/s
Maximum output	70. 4 MW
Annual capable energy production	516 GWh

2. 1. 9 Andekaleka No. 2 Power Station

Construction of No. 2 Power Station will commence in succession with the completion of No. 1 Power Station. It is forecasted that by 1990 a power station of this size will be needed to meet the power demand. The outline of this project is as follows:

Gross head	84. 4 m
Effective head	70. 9 m
Maximum discharge	60 m^3/s
Maximum output	36. 0 MW
Annual capable energy production	271 GWh

2. 1. 10 Transmission and substation

Power generated at Andekaleka No. 1 Power Station will be first transmitted to the switchyard of No. 2 Power Station through the 150 kV transmission line, and finally to Tananarive via Moramanga. The ferrochrome plant will be served without stepping down of voltage, directly connected to the 5 Km branch-off feeder line outgoing from the switching station to be installed in Moramanga. In order to serve the demand in Tananarive, a new 150 kV substation will be constructed adjacent to the existing substation in Ambohimanambola, for which the transformers of 150 MVA will be provided to step down the voltage to 60 kV for supply to the existing 60 kV system.

2. 1. 11 Work schedule and construction cost

The start of the work for the construction project is scheduled for 1977 at which time the detailed design including a part of survey and basic design left unfinished at the earlier stage is completed and the tendering for award of contract and all other necessary preparations are done. The 1st-term work is scheduled to be completed in four years after start of the work, with scheduling for the commercial operation in and from April of 1981.

The total construction cost amounts to some 23,751 MFMG which does not include the interest during construction, which may be largely divided into foreign and local currency portions as broken down in the Table below:

	Foreign Currency	Local Currency	Total
1st. Term (35.2 MW)	7,088	4,710	11,798
2nd. Term (35.2 MW)	2,956	709	3,665
3rd. Term (36.0 MW)	5,848	2,440	8,288
Total	15,802	7,859	23,751

2. 1. 12 Benefit and internal rate of return

Economic evaluation for the project has been made by comparison with the estimated cost for the most economically alternative diesel plant. Analysis has been made on the basis of 50 durable years. Capital recovery factor is used as 7 %.

The alternative diesel plant used for evaluation includes the combined use of both 11 MW diesel power generating unit for firm operation and 15 MW gas-turbine unit as reserve capacity. If there is power demand for ferrochrome production as per schedule, the expected rate of return will be 13.6 %.

Even if there is no power demand for ferrochrome production, the rate will still be maintained at 11. 2 %. These calculated results assure profitability of investment for the power development project.

2. 1. 13 Power rate (for incremental load)

On the calculated basis of a 30-year repayment term including a 7-year grace period, at an annual interest rate of 7 % for the construction loan fund, it is expected that for the first five consecutive years after operation the power rate should be lowered to 7. 2 FMG per kWh for the public demand and 3. 9 FMG per kWh for ferrochrome production, and then to 6. 5 FMG per kWh for the public demand and 3. 5 FMG per kWh for ferrochrome production in and after the 6th year.

As a result, the wholesale power rate for the public demand will be fixed at about 80 % of the presently applied power rate, or 9. 1 FMG per kWh, at the initial stage of operation. Evidently, the project will serve to lower the present level of power rate, thus making the ferrochrome production economically feasible. Furthermore, redeemability of the loan fund can be assured, as mentioned in Chapter 10, without any financial difficulty on the basis of the expected revenue from such lowered power rate as mentioned.

However, it should be kept in mind that for several years at the initial stage of development there will inevitably be a continuation of a deficit account with relatively small power demand, if the initial operation of the ferrochrome plant is delayed to meet the scheduled start-up of the power station. Therefore, in order to cope with this situation any possible measure must be taken to stimulate increase of power demand in the other sectors.

2. 1. 14 Necessity of earliest start for development

The construction period for Andekaleka No. 1 Power Station is estimated at four years, in addition to the 2-year lead time for preparations. If arrangements can be proceeded with right now, the initial start-up will not be sooner than 1981. Therefore, until completion of the proposed project, two 6 MW diesel power plants will have to be added to the system in order to meet the power demand situation in Tananarive. If this is done, it is apparent that the current power rate of 9. 1 FMG/kWh in the Tananarive system should continue rising under the pressure of price rises of equipment and materials, not to mention the soaring costs of fuel.

It is therefore finally concluded and recommended that Andekaleka No. 1 Power Station should be in operation as soon as possible so as to bear a large portion of the load on the diesel power plant. This will reduce the power rate to the possible minimum and the cheap and adequate power thus available should be fully utilized for ferrochrome production to further the growth of the nation's economy.

2. 2 Recommendation

2. 2. 1 Sequential order of development

It is recommended that Andekaleka Hydro Power Development Project should be divided into three terms of construction work; from 1st to 3rd.

(a) 1st-term construction

Andekaleka No. 1 Power Station

1981 - 35. 2 MW

Whole civil engineering and construction work and installation of two turbine-generators capable of 35. 2 MW in total output.

Erection of transmission line over the whole distance of 168. 5 Km.

Ambohimanambola Substation

Two 25 MVA transformers (50 MVA).

Moramanga switching station.

(b) 2nd-term construction

Andekaleka No. 1 Power Station

1986 - 70. 4 MW

Additional installation of two turbine-generators capable of 35.2 MW in total output.

Completion of regulating pond construction.

Ambohimanambola Substation

Additional installation of two 25 MVA transformers

(25 MVA x 4 = 100 MVA)

(c) 3rd-term construction

Andekaleka No 2 Power Station

1989 - 106.4 MW

Completion of whole construction 36.0 MW.

Ambohimanambola Substation.

Additional installation of two 25 MVA transformers

(25 MVA x 6 = 150 MVA).

The relationship between power demand and development is defined in Fig 2.1 and 2.2 and the overall construction time schedule is as shown in Table-2.1.

At present, it is urgently needed to complete the 1st-term construction work for security of 35.2 MW output by the end of 1980. The time for development in the future beyond 1980 must be scheduled, with due consideration to the increasing trend of power demand.

2.2.2 Ferrochrome production plan

Mutual benefit can be expected from the combined planning for Andekaleka Hydro Power Project and Ferrochrome Production Project. In this case, the applicable power rate to ferrochrome production is estimated at 3.5 to 3.9 FMG per kWh. Although further efforts must be made for feasibility study of the ferrochrome production project, it is certain that the future of ferrochrome production and export is encouraging as long as the world market situation continues its present trend. Since Andekaleka No. 1 Power Station is scheduled to be completed by the end of 1980, there is still plenty of lead time for the project which may require 1 year for investigation and study, and 3 years for construction including necessary preparations, even assuming that the initial operation of the ferrochrome plant would be scheduled for the spring of 1981. Within this allowable period of lead time, preparations must be made to the fullest extent by extensive studies regarding charcoal production plan and industrial water supply plan in Moramanga.

2.2.3 Preparations in pre-construction period of Andekaleka No. 1 Power Station

Financing arrangements will be necessary for preparation of Andekaleka No. 1 Power Station construction. In order to make such arrangements, the most approximate estimation of the necessary construction cost must be made from the basic design. Even though investigations have been made, there still remains a certain portion of the project to be further investigated in relation to the detailed design. The detailed design work will be completed after the results of further investigations are made clear. Upon completion of the detailed design, the contract must be awarded by tender to the successful bidder by March, 1977.

In order to meet the time requirement scheduled above, it is necessary that prompt action should be taken, as recommended later in Chapter 11, to finance the cost of basic and detailed design including investigation of site details. Such financing arrangements must be made separately in advance of the loan arrangements for financing the construction of the project.

Table-2.1 Time Schedule of Andekaleka Hydro Power Project

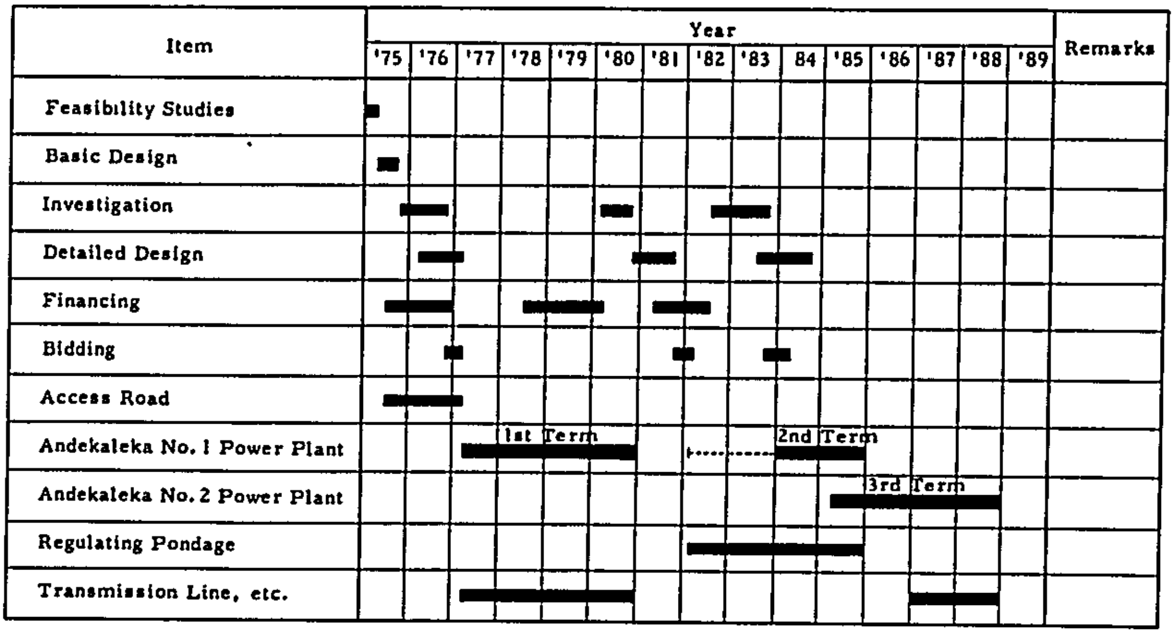


Fig-2.1 Peak Demand and Capable Output (Most Probable)

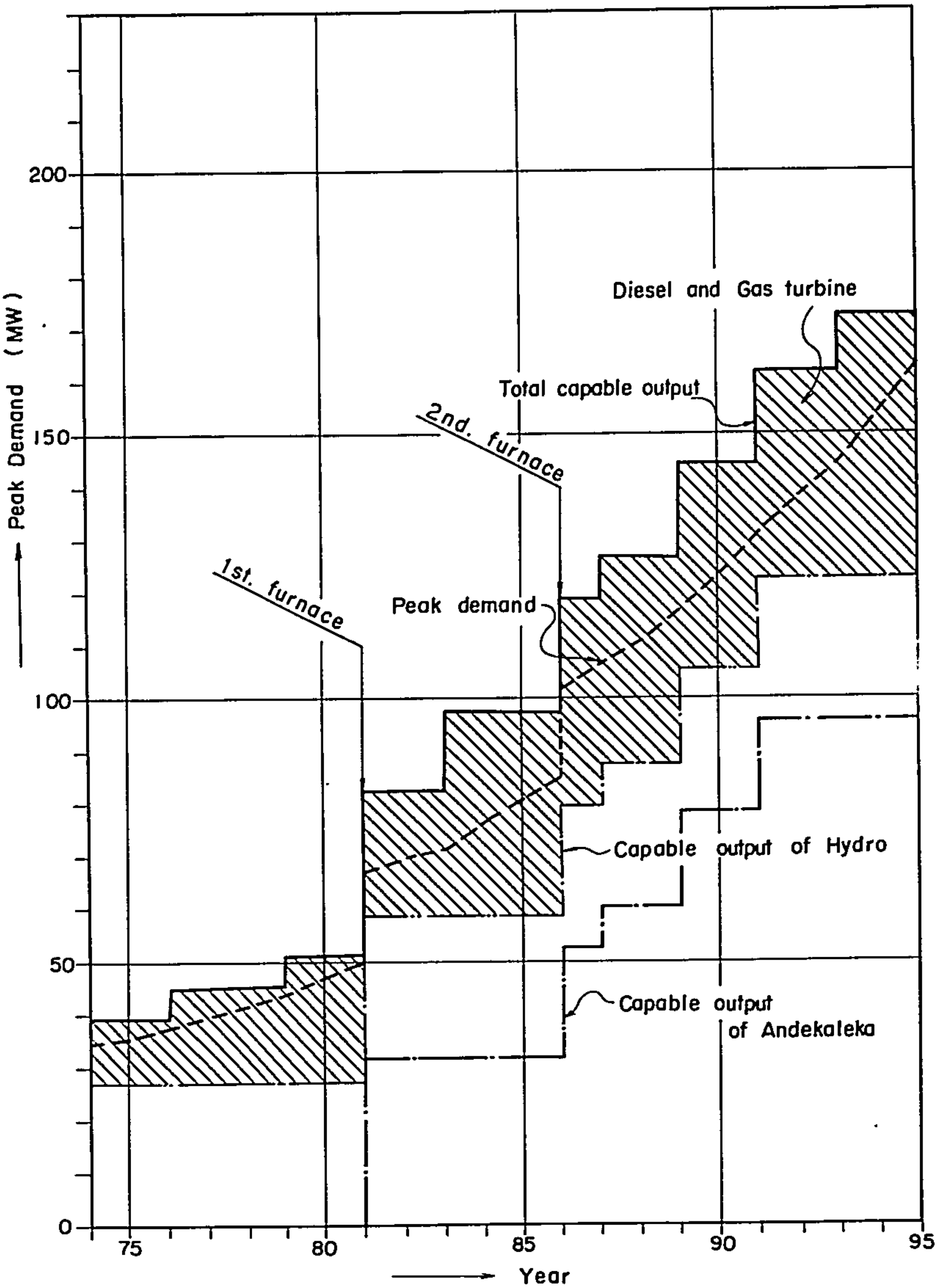
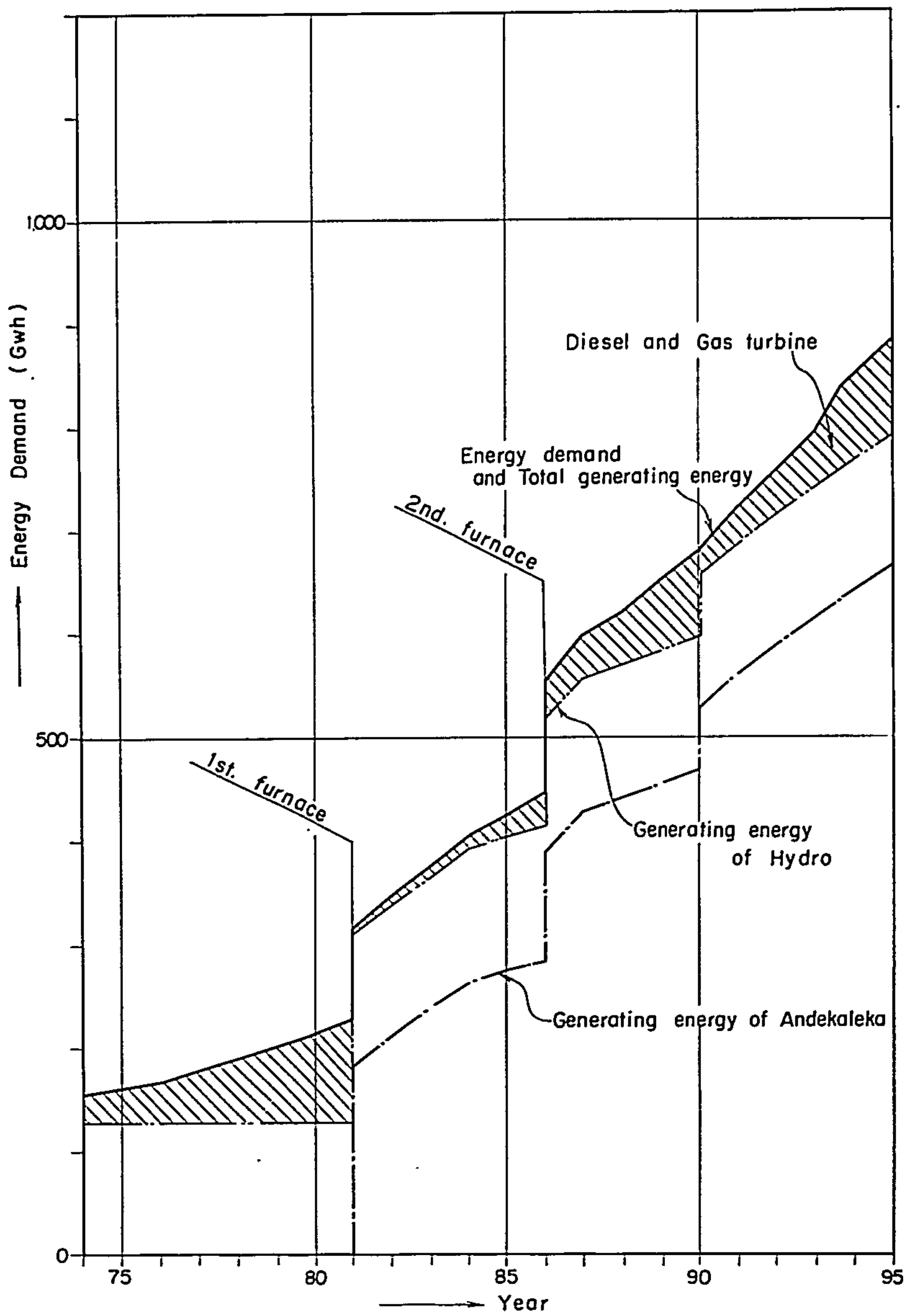


Fig-2.2 Energy Demand and Generating Energy (Most Probable)



Chapter 3.

Power Demand Forecast

Chapter 3 Power Demand Forecast

3. 1 General power situation of Madagascar

3. 1. 1 Profile of national economy

The Gross Domestic Product (G. D. P) of Madagascar representing its economic growth grew to 273 x 10^9 FMG in 1972. As shown by growing figures given in Table-3. 1 the nation's G. D. P continued to grow at an annual increase rate of 6. 5 % for the decade from 1960, the Year of Independence, to 1971. In the latter half of that decade the nation's G. D. P grew at an annual increase rate of 8. 1 %.

However, the fact that Madagascar's economy depends chiefly upon agriculture necessitates the nation to import most of the raw materials, machinery and other daily necessities from foreign countries. While efforts are being made to counter-balance the import by increasing the export sales composed mainly of the primary agricultural products, the unfavourable balance of trade still continues at the present time. (Table-3. 2 thru 3. 4)

In order to improve this situation, the government is continuing further effort toward development of the mining and manufacturing industry. Also the government is encouraging the modernization of the nation's industrial activities which have been supported principally by cottage industries, and intends to improve the nation's industrial structure for further economic development of introduction of modern and high-productivity industries into Madagascar. (Table-3. 5 and 3. 6)

The Government established in 1972 formulated its economic plan, by analysis of the economic realities, setting the target year in 1977. Presently, the economic policy is being advanced under the leadership of the governmental authorities concerned.

The economic plan envisages growth of G. D. P to 319. 4 x 10^9 FMG (1. 2 x 10^9 \$) in 1977 aiming at an annual growth rate of 3. 2 % on the average for '72 - '77 which promises industrial development on a nationwide scale. The plan is as shown in Table-3. 7 thru 3. 9.

3. 1. 2 Current power situations

Total consumption throughout the nation reached 250 GWh in 1972. Out of this total, some 194 GWh consumption, or 78 % of the total, corresponds to power supply from utilities and the remaining 56 GWh, or 22 %, covers consumption for private household services. The proportion of power sales from utility companies is showing an increasing tendency year by year as shown in Table-3. 10.

The nation's total capacity of power generation amounted to some 153 MVA as of 1972; 51 MVA for hydro power and 102 MVA for thermal power generation. Out of the total above, the utility industry owns 65 % and the private industries own the remaining 35 % for their own household services. The former owns hydro and thermal power installations at nearly fifty-fifty ratio, while the bulk of the latter's facilities are of thermal power generation as shown in Table-3. 11. Table-3. 12 shows annual power productions by hydro and thermal generating plants.

3. 1. 3 Historical background of electric utility industry

The origin of electric power service in Madagascar can be dated far back to 1899 when the Societe Civile d'Etude et de Traveaux initiated the electrification project for Tananarive with the work permit granted and then to 1905 when, as the successor to the above-cited company, the Compagnie des Eaux et Electricite de Madagascar commenced its power service.

So far, the Electricite et Eaux de Madagascar (E. E. M), owned and operated by private investors of France, has been engaged in construction, operation and maintenance of hydro power stations, diesel generating plants, substations, and transmission lines as well as supplying power to Tananarive and to other major urban areas.

In the meantime, the Societe d'Energie de Madagascar (S. E. M), a joint company, public and private, was established in 1953. This company has been supplying electricity solely to the cities not served by the E. E. M, and even supplying to the E. E. M by way of wholesale contract, by construction, operation and maintenance of its own hydro power stations, diesel generating plants and transmission lines.

The utility industry is regulated, according to the licensed agreement, with respect to its business activities concerning power source development, transmission, construction and power supply service including power rate system. The regulatory agent is Service de l'Eau et de l'Electricite of Direction des Mines et de l'Energie.

After establishment of the S. E. M, the E. E. M was not granted any new license for development of hydro power generating sources and expansion of the power supply territory. These were taken over by the S. E. M.

After the political change in 1972, under the policy to realize 'economic independence' all the capital assets of the E. E. M were nationalized by the Government in January, 1974, and at the same time the E. E. M was reorganized to be a public corporation named the Societe Malagache de l'Eau et de l'Electricite (S. M. E. E).

Furthermore, in line with the basic policy toward nationalization and unification of key industries, the present Government is taking necessary measures, setting its goal in January 1975, to merge the existing two utility companies into a single body of enterprise named the Societe d'Interet National de l'Eau et de l'Electricite (S. I. N. E. E).

3. 1 4 Current situation of power industry

Table-3. 13 summarises the outlined business activities and capabilities of both S. E. M and S. M. E. E. The total installed generating capacity in Madagascar amounted to some 153 MVA in 1972 as shown in Table-3. 14. S. E. M and S. M. E. E own a combined capacity of about 100 MVA which accounts for about 65 % of the nation's total and accounts for about 79 % in terms of energy production. The aforestated 100 MVA generating capacity owned by the two utility companies consists of hydro power and diesel-operated generating sources whose capacities can be halved at about 50 MVA respectively. The majority of the existing installed capacity, which corresponds nearly to 61 % of the total in 1973, serves the interconnected system to Tananarive and Antsirabe, while the remainder serves the small systems isolated in each local city and town. (Fig-3. 1, 3. 2, 3. 3 and Table-3. 14 and 3. 15)

3.1.5 Electric power rate

The applicable power rate varies from area to area according to, in principle, actual production costs for the area served.

Though there is a slight difference in the rate system between S. E. M and S. M. E. E, the service category can be classified into Lighting, High-voltage Power, Low-voltage Power, and Public Service.

According to the actual billing in 1973, the comparative check of the average unit prices within the service area of S. M. E. E reveals a wide range of variations from 12.70 FMG per kWh in Antsirabe to 28.09 FMG per kWh in Fianarantsoa. Although such variations may have occurred because of the difference in the composition of applicable power rates, the density of power demand in each area may also be considered as a variable factor in determining the difference in the unit price in each area. In the district where the hydro power generating-source is available for power supply, the average unit price of the power rate is relatively inexpensive except for a few certain sectors of the district.

As for the unit price of energy sales throughout the whole service territory, the wholesale price from the S. E. M is 9.04 FMG per kWh, the sales within the interconnected system is priced at an average of 14.34 FMG per kWh, and the unit sales price in all the other areas is averaged at 22.43 FMG per kWh. The average general unit price in the S. E. M's whole service territory is found to be 11.18 FMG per kWh.

Meanwhile, the average unit sales price in the S. M. E. E's service territory is 17.16 FMG according to their actual sales record in 1973. (Table-3.16 and 3.17)

3.2 Power demand and supply in connected service areas

3.2.1 Demand and supply situation of Tananarive - Antsirabe interconnected system territory

As of 1973, the interconnection system serving Tananarive, including its surrounding areas, and Antsirabe, is composed of about 43 MVA hydro power and 27 MVA thermal power generating capacities. The total reaches about 70 MVA accounting for about 61 % of the nation's total installed generating capacity. (Table-3.14)

The total power sales in this territory amounted roughly to 130 GWh in 1972 which corresponds to 67 % of the total sales of the whole utility industry and 52 % of the total power consumption throughout the whole of Madagascar. The maximum power demand within the territory was about 32 MVA as recorded at generating end in 1972.

Power demand for general and small cottage industries under High-voltage category accounts for 63 % of the total demand, which is the majority of the whole power demand in the territory. This tendency becomes more pronounced in Antsirabe where industrial activities are particularly encouraged.

The annual load factor at generating end was maintained almost at an equal level of 50 % or so for the '68 - '72 period.

In order to meet power demand, power supply is available mainly from the Antelomita and Mandraka Hydro Power Stations in and around the urban area of Tananarive. On the upstream of these two power stations, there are two large reservoirs, named Tsiazonpaniry and Mantasoa, which assure supply of abundant water flow at a constant rate all the year round.

In 1972, two diesel generating units of 6 MW each was installed to serve as peak load station. As a stand-by operating unit there is an outdated 5 MVA diesel generating station. (Fig-3. 3 and 3. 4)

In Antsirabe, the other consumption center, the only available generating sources before 1971 were a small hydro power station and the Antsirabe Diesel-Generating Plant, the latter being more important in the role of power supply.

In order to catch up with the increasing demand, however, the Tananarive and the Antsirabe power systems were interconnected in 1972 through the 60 kV transmission line to cover shortage in Antsirabe by power accommodation from the Tananarive system.

3. 2. 2 Power demand for ferrochrome production

The power demand for ferrochrome production, whose project is mentioned in detail in Chapter 4, can be featured as follows when viewed from the aspect of power supply to the proposed plant.

(a) Load factor will be 60 to 70 % in the initial year of plant operation and will become very high, 80 to 86 % in subsequent years of normal operation.

(b) Without any difficulty to the productive activity of the plant, regulations can be made for plant load within a range of 30 % in response to variations of power supply.

(c) A large quantity of energy production will be required at a low price.

(d) Technical problem may occur on 'flicker'.

The features mentioned in the above items (a) and (b) will satisfy such economic requirement as referred to in item (c) above. Details are mentioned on such related matters in Section 3. 2. 3 of this Chapter.

With respect to item (d) above the problem will become rather negligible when the capacity of the ferrochrome furnace is smaller than the capacity of the power receiving system. However, in the proposed project where the furnace capacity would take a greater share in the total supply system capacity, technical studies must be made from the operational aspect of the plant.

3. 2. 3 Relationship between Andekaleka Hydro Power Project and power demand for ferrochrome production

The Andekaleka site on the Vohitra River is suited for a large-scale hydro power development project. In reality, however, its potentiality can not be fully utilized if there is no other large consumer besides the public consumers. When the public demand is combined with the industrial demand for ferrochrome production, the proposed power station will then manifest its own potential in respect to both economy of scale and load factor. One more advantage can be supported by the fact that the load for ferrochrome production can be regulated either daily or seasonally, which can compensate for the defect in the nature of hydro power generation characterized by its daily or seasonal change in output.

In addition to the proposed Andekaleka Power Station, it is recommended that it should be properly combined with either a timeworn thermal power unit or a gas turbine unit of low cost construction to serve as a small reserve unit, so that cheap and stabilized supply of energy can be secured. This pattern of combination of power generating sources is most recommendable for the case of Madagascar which is endowed with hydro power potential.

3.3 Power demand forecast

3.3.1 Outline of approach to demand forecast

Demand forecast within the interconnected system is herein separated into two categories of demand for public sector and industrial use of ferrochrome production.

Forecast is first made for the most probable demand with the highest probability under the current prevailing conditions, then, for the maximum demand so as to make full review of economy as referred to in Chapter 6, finally, for the minimum demand, on the assumption that there would be no demand for ferrochrome production, in order to take care of the worst situation. These forecasts magnify the economic significance of power demand for ferrochrome production. The results are as shown in Table-3.18 and 3.19.

3.3.2 Demand forecast for public sector

(1) Energy sales forecast

Energy sales within the system was showing a large increasing tendency, for the '66 - '71 period, at an average annual increase rate of 10.3 %. As the result of changes in the nation's economic policy after the political power shift in '72, it is estimated that in the years after 1973 there should be considerable changes in the general trend of power demand.

The energy sales forecast made herein is, therefore, based upon such economic situation as mentioned above, being classified by service categories applied:

(a) Lighting demand

The lighting demand has been on the increase at an annual rate of 4.2 % since 1968. Although there was a trend towards a big recession in '72 and '73 and is still continuing, it is forecasted that the future demand will make a recovery to 4 % or so, per annum by 1981. From 1981 on, an additional increase by 1 % every 5 years is estimated.

(b) Low-voltage demand

The increase rate of low-voltage demand is relatively small and variable within a range of minus 1.3 % per annum at minimum and 5.1 % at maximum, being averaged at 1.9 %. In this forecast, therefore, the rate of increase is estimated at 2 % each year up to and including 1986, and 3 % from 1987 on.

(c) High-voltage demand

The demand of this category accounts for largely 60 to 65 % of the total demand throughout the system, whose rate of share is growing year after year. The increase rate shows a high figure of 9 % at average. However, viewed from such economic changes as aforementioned, it is anticipated that the increase rate would show a decline for several years in and after 1973 and after this slowdown period, it would gradually increase up to 6 % or so by 1981, finally attaining about 8 %, the averaged rate of increase for the past 6 years.

(d) Public demand

In the past trend the public demand has been showing its increasing tendency at an annual rate of 3.1 %. In this forecast, the same average increase rate is expected for the coming years until 1981. It is further forecasted that the increase rate for the '81 - '86 period would be 4 % per annum and that after '86 it would be 5 %. Table-3.24 is a summary of the power demand forecast for easy reference.

(2) Macroscopic forecast from G. D. P

As mentioned in the foregoing Section 3.1, the Gross Domestic Product (G. D. P) of Madagascar was growing at an annual rate of 8.1 %, while for the same period, the energy sales was increasing at 10.3 %. Therefore, the elasticity of energy increases to the growth of the G. D. P is calculated as 1.28.

According to the long-range economic plan formulated by the Government for the '72 - '77 period, the target rate of growth for the G. D. P is 3.2 %, while the increase rate of energy sales is 4.6 % with elasticity of 1.3 to the growth rate of G. D. P.

Since the annual rate of increase of energy sales for the '78 - '82 period is estimated at 6. 5 %, the elasticity value to be obtained is 1. 3 at the estimated 5 % rate of growth for the G. D. P.

For '83 - '87 period the energy sales is estimated to increase at 7 % each year, while the growth rate of G. D. P is estimated at 5. 5 % each year. Thus, the elasticity value is attained at 1. 27.

In and after 1988, the energy sales increase is estimated at 7. 7 % per annum, while the G. D. P is estimated at an annual growth rate of 6 %. Then, the elasticity of 1. 28 can be obtained.

As summarized above, the increase of energy sales as forecasted from the growth of G. D. P shows its coincidence at its elasticity value within a range of 1. 27 to 1. 30, with the growth rate of G. D. P estimated for the period under the governmental economic plan and the growth rate of 0. 5 % addition every five years for the future beyond the period of economic plan.

(3) Macroscopic forecast from per-capita energy consumption

In this forecast, the energy sales forecasted for years in the preceding item is divided by total population available from the official statistical data in the regio· The result is that the energy consumption per capita is 109 kWh, 160 kWh, 168 kWh and 184 kWh in '66, '73, '77 and '80 respectively. This forecast is considered as 'most probable' case.

(4) Maximum forecast

The foregoing forecast is made on the assumption that the increase rate after 1988 would come to the ceiling at the rate of 7. 7 %. In the case of the maximum forecast, it is made on the assumption that for the '88 - '92 period the rate of increase would be 9 % per annum and beyond that period 10 % each year.

3. 3. 3 Demand forecast for ferrochrome production

The demand forecast is made herein for the following two cases in accordance with the production plan stated in Chapter 4.

In the 'most probable' case the forecast is based upon two units of electric furnace as the ultimate capacity in due consideration of charcoal supplies and availability of industrial water. Consideration is also given to the possible plant availability factor each year which can be determined from skills in plant operation.

In the alternative 'maximum' case, the maximum possible limit is forecasted in addition to the foregoing conditions, on the assumption that the third furnace would go into operation in and from the 11th year. (Table-3. 23)

3. 4 Power demand and supply scheme

As an approach to economic analysis made in Chapter 6, power demand and supply plan is herein drafted on each of the following six cases in accordance with the flow-sheet shown in Fig.-3.6 in order to make it serve as a basic plan to determine the necessary power generating source, substation and transmission facility, and fuel consumption.

	Forecasted demand	Hydro power project
Case 1	Most Probable - 2 furnaces -	1-0-B
Case 2	ditto	2-1-A & 2-2-A
Case 3	Maximum - 3 furnaces -	1-0-B
Case 4	ditto	2-1-A & 2-2-A
Case 5	Minimum - no furnace -	1-0-B
Case 6	ditto	2-1-A & 2-2-A

Demand and supply schedule in each of the above cases is as shown in the annexed tables. (Table-A. 3. 1 thru A. 3. 15)

3. 4. 1 Demand at generating end

On the basis of the foregoing energy for public sector and for ferrochrome production, calculations are herein made for generating end power and energy demands with the following factors taken into account:

(a) The possible transmission energy loss for the demand in the public sector is estimated at 11 to 13 % as shown in Table-3. 24 and 3. 25. The recorded rate of transmission loss in the past was considered along with any possible increase of loss from the generating source up to the primary substation and any reducible loss by mitigating efforts after the primary substation.

(b) The annual maximum demand at the generating end is forecasted on the assumption that the annual load factor at the terminal would be 51 % for the first year derived from the past trend and then it would be improved by an additional 1 % every 5 years.

(c) Generating end demand for ferrochrome production has been forecasted on the assumption that for peak demand the transmission loss may be offset by diversity. Energy demand is estimated with an allowance of 2 to 4 % transmission loss.

3.4.2 Peak balance

Peak balance is planned in accordance with the following principles, so that the forecasted peak demand at generating end can be supplied both economically and constantly every year.

(a) Selection of standard month

Peak demand months in a year are May to June, inclusive, while a hydro power generating source normally suffers from shortage of water in the drought period of June thru October of the following year. Naturally, October is assumed to be the worst month with the tightest balance of power demand and supply. However, on the assumption that the annual overhauling of ferrochrome plant installation should be scheduled for October, the month of May, the second tightest next to October in the year, has been selected as a standard month.

(b) Determination of hydro power output

On the upstream of the existing main hydro power stations, Antelomita and Mandraka there are two large reservoir ponds capable of seasonal regulations, from which capable output of 27 MW is available the whole year. The estimated output available from the proposed Andekaleka Power Station has been herein determined from the rate of stream flow per diem at a lowest 5-day average in May. The details are as shown in the annexed data. (Table-3.27)

Available output every year after construction of the regulating pond has been determined from the rate of flow as cited above, the capacity of the pond and the daily load curve. (Table-3.26 and 3.28)

(c) Reserved capacity

Adequate capacity for standby will be required for security of stabilized power supply. In this project such reserved capacity is secured on the following principles:

i) Adequate reserve capacity equivalent to a single largest generating unit in the existing system is to be secured.

ii) If mechanical reserve is available, however, marginal reserve is to be secured at about 10 % of the peak load.

iii) Maintenance of a diesel generating unit is added into the plan.

iv) In the light of the economy in a special year, a part of the output available from a timeworn thermal power generating unit (9 MW) will serve as cold reserve.

v) Determination has been made from an economic viewpoint to select the most suitable one from among hydro power, diesel generating set, or, gas turbine for use as supplement to the estimated shortage in reserve capacity.

3.4.3 Energy balance

The following methods are adopted for the estimation of generating energy for such various generating sources as hydro power, diesel and gas turbine, on the assumption that these generating sources would be combined most economically for a system operation.

(1) Outlined method of computation of generating energy

Since there is a remarkable difference in the daily requirements for energy between ordinary weekdays and Sundays or other holidays, computations are made herein separately. On Sundays or holidays, load is normally small. In this case, computation is rather easy; a larger portion of load can be borne by the existing hydro power generating source, and only the remainder can then be supplied by a newly built power station. Therefore, mentioned, herein, is the outline of how to estimate for normal weekdays.

In order to insure the most economical operation, the following method is used for computation. First, the average daily load on weekdays is forecasted. Then, after necessary regulation in accordance with such forecasted load the power is supplied by the existing hydro power generating source. The balance of load is to be supplied by the proposed Andekaleka Power Station and then by a diesel generating unit as supplement. If even after this the balance is not reached, additional power is to be supplied by a gas turbine unit.

(2) Daily load forecast

From the actual trend in the past, daily load for the public sector has been forecasted as follows: Maximum load on a weekday is estimated at 84 % of the annual peak, average load on weekday at 111 % of the annual average, minimum load on a weekday at 45 % of the weekday maximum, and average load on Sunday or holiday at 75. 5 % of the annual average.

Load for ferrochrome production is estimated herein at its annual average.

(3) Available output from existing hydro power generation

Available output from the existing power stations is expected to be an average of 14. 6 MW annually and an average of 10. 8 MW annually at its regulated capacity. Priority of power generation is herein given to the existing hydro power stations and, if any surplus energy arises, it is assumed, herein, to be due to the output from the proposed Andekaleka Hydro Power Station.

(4) Available output from the proposed Andekaleka Power Station

In order to determine ordinary annual stream flow, computation has been made for 20-year series-parallel halved-average daily flow, by reference to the basic data available from the annexed gauging record of stream flow at Andekaleka, which covers the whole 20 years except 3 years in which data were missing. The daily average available output from the proposed Andekaleka Power Station is based upon the aforecited ordinary annual stream flow as shown in Table-3. 29.

In case where there is a regulating pond, the output is to undergo daily regulation, within the limit of the regulating pond capacity (approx. 900 x 10^3 m^3), in accordance with daily load curve.

(5) Computation of estimated energy

On the assumption that the existing hydro power stations would be put into operation to take their maximum share out of the estimated daily load of the system, then, the proposed Andekaleka Power Station will be operated to generate its output in a similar pattern to the obtained load curve and the diesel generating unit will be used to cover the balance, followed by the operation of the gas turbine to make up for further shortage. Computations have been made by use of a computer to attain the daily average capable output for a full 365 days for the proposed Andekaleka Power Station, and the annual total of generating energy has been obtained after the calculations were summed up and multiplied by percentages of total weekdays and total Sundays and holidays in a year.

(6) Estimated energy adjustment

Since the energy output from the existing power stations is based upon actual record of operation, there is no need for any adjustment to be supplemented. The estimated output from the other generating sources must be adjusted to be used as the projected energy output with a certain rate of adjustment for the reasons stated below:

i) The capable output estimated for the proposed Andekaleka Power Station relies solely upon the flow gauging record.

ii) Scheduled or forced outages of hydro power generation must be allowed for in a year.

iii) Change in peak load on a weekday and unforeseeable system trouble must be allowed for to some extent.

For the reason above, the estimated energy output from the proposed Andekaleka Power Station is adjusted by 3 % of its calculated result and the generated energy, estimated from the reserve, is adjusted, herein, in accordance with the available reserve output.

3.4.4 Conclusion on power demand and supply

(1) 'Most probable' case

As shown in Fig.-3.8-(1), according to the power development programme the initial start-up of the first two units of Andekaleka No. 1 Power Station is scheduled for 1981, and the remaining two units for 1986. However, since the reserve capacity, which will be required to cover the one single maximum unit capacity of the operated system, will come into shortage in the whole connected system as power demand increases in the course of the development programme, such reserved capacity will have to be secured by 1983 for the 2-stage development project and by 1984 for the 1-stage development project. For this purpose, the gas-turbine generating plant capable of 15 MW is highly recommendable from the economic aspect.

The regulating pondage will also be required for either the 1-stage or 2-stage development project by the time when the third additional unit will be installed at Andekaleka No. 1 Power Station.

For future long-range projection beyond 1984, in case of the 1-stage development project, a diesel power generating unit of 11 MW each will have to be added in 1993 and 1994 to make up for the estimated shortage of supply from the Andekaleka Hydro Power Station. In case of the 2-stage development project, Andekaleka No. 2 Power Station will have to be put into initial operation by 1989, and its connected system will have to be added with the diesel power generating units of 11 MW each in 1993 and 1995 respectively. This will be sufficient to meet the increasing demand beyond the limit of supply available from Andekaleka No. 1 and No. 2 Power Stations.

As planned for the 1-stage development and 2-stage development programmes, the total installed capacity proposed for the former, exceeds largely that for the latter. Since the unit capacity for the former is larger than that for the latter, there is the need to secure the larger reserve capacity for the former adequately enough, to cover the difference in unit capacity of the latter.

(2) 'Maximum' case

As shown in Fig.-3. 8-(2) the scheduled years for initial operation of the four units are same as.those scheduled for the 'most probable' case. The difference between the 1-stage and the 2-stage development plans lies in the fact that the latter should require initial operation of a gas-turbine power plant at latest by 1983, while the former will not require it earlier than 1990. Besides that, additional installation of a diesel power plant will be required by 1988 in the latter case.

In and after 1991 either diesel or gas-turbine generating unit will have to be added each year to cover shortage in supply from the Andekaleka Hydro Power Stations.

(3) 'Minimum' case

As shown in Fig.-3. 8-(3), in the 1-stage development plan initial operation of the four units of the Station is scheduled for '81, '86, '90 and '94 respectively, while the 2-stage plan will require initial operation of the first unit in '81, then followed by the second in '83, the third in '87 and the fourth in '91. For the Andekaleka No. 2 Power Station the initial operation is scheduled for '93 for the first unit and '95 for the second. By 1986 the gas-turbine unit will be required to serve as the reserve and after 1998 either diesel or gas-turbine unit will have to be added year after year.

Table-3.1 Gross Domestic Production

Item		1960	1966	1971	1972	Ratio % per year 1966-1971	1960-1971
Gross Domestic Product in perchasers' value	10^6FMG	134,200	181,557	268,521	273,138	8.1	6.5
	10^6 $	559.2	756.5	1,118.8	1,138.0		
Population	10^3	5,298	6,562	7,647	7,871		
GDP per Capita	FMG	25,330	27,668	35,115	34,702		
	$	105.5	115.3	146.3	144.6		

Note : 100 FMG = ¥.125
1 $ = ¥.300

Table-3.2 Trade Balance

Exportation	Weight and Price 1960	1966	1971	1972	Rate 1960-1966	1966-1971	1960-1971
Weight	235,116	378,728	700,593	714,969	8.3	13.1	10.4
Price	18,485	24,132	40,807	41,864	4.6	11.1	7.5
Importation							
Weight	426,806	602,746	1,046,527	1,053,103	6.0	11.6	8.5
Price	27,539	35,074	59,262	51,754	4.1	11.1	7.2
Balance of Trade (Im-Ex)	9,054	10,942	18,455	9,890			
Rate Ex/Im (%)	67.1%	68.8%	68.9%	80.9%			

Weight: ton
Price: 10^6 FMG

Table-3.3 Trend of Import of Major Articles

Item	Weight and Price 1960	1966	1971	1972	Percentage 1960	1966	1971	1972
Raw Materials .. (1)	155,643	305,946	792,962	845,057	36.4	50.7	76.1	80.3
(2)	5,436	7,761	16,424	15,364	19.7	22.1	27.8	29.7
Energy .... (1)	136,632	170,940	61,638	44,523	32.1	28.4	5.8	4.2
(2)	1,258	1,246	487	339	4.5	3.6	0.9	0.6
Machinery ......(1)	14,374	15,674	25,043	25,402	3.4	2.6	2.3	2.4
(2)	4,848	7,535	16,512	15,147	17.6	21.4	27.8	29.3
Food .... (1)	85,046	76,771	138,929	118,834	19.9	12.7	13.2	11.3
(2)	4,504	4,778	8,172	6,381	16.4	13.6	13.7	12.3
Daily necessities (1)	35,111	33,415	27,955	19,287	8.2	5.6	2.6	1.8
(2)	11,493	13,754	17,666	14,523	41.8	39.3	29.8	28.1
Total .... (1)	426,806	602,746	1,046,527	1,053,103	100	100	100	100
(2)	27,539	35,074	59,262	51,754	100	100	100	100

(1) Weight: ton
(2) Price: 10^6 FMG

Table-3.4 Trend of Exports Sales

Item	Weight and Price				Percentage			
	1960	1966	1971	1972	1960	1966	1971	1972
Raw Materials.. (1)	71,176	76,346	200,722	217,974	30.2	30.2	28.7	30.5
(2)	4,606	5,894	6,330	7,007	24.9	24.4	15.5	16.7
Energy .... (1)	26	22,670	262,718	279,474	0.04	5.9	37.4	39.1
(2)	-	166	1,297	1,520	-	0.7	3.1	3.6
Machinery ... (1)	1,298	442	8,405	837	0.5	0.19	1.2	0.1
(2)	225	262	1,555	175	1.2	1.0	3.8	0.4
Food .... (1)	162,310	278,677	227,967	215,903	69.1	73.5	32.6	30.2
(2)	13,537	17,502	31,044	32,576	73.2	72.6	76.1	77.9
Daily necessities (1)	306	593	781	781	0.16	0.21	0.1	0.1
(2)	117	308	581	586	0.7	1.3	1.5	1.4
Total .... (1)	235,116	378,728	700,593	714,969	100	100	100	100
(2)	18,485	24,132	40,807	41,864	100	100	100	100

(1) Weight: ton

(2) Price: 10^6 FMG

Table-3.5 Comparison of Locally-Owned Capital versus Foreign Investment

Item	Madagascar	French	Other Foreign Investors	Total	Ratio of Madagascar owned enterprises
No. of enterprises	61	229	68	358	17%
No. of enterprices Capital Less than 10^8FMG	53	180	65	298	17.8%
" Capital 10^8 - 3×10^8FMG	6	29	2	37	16.2%
" Capital More than 3×10^8 FMG	2	20	1	23	8.7%

Table-3.6 Income of Cottage Industry

Item	Income (10^6 FMG)		Inhabitants		Income/Capita		%/Year
	1962	1970	1962	1970	1962	1970	
Agriculture	63,551	88,510	4,951,533	5,984,645	12,835	14,790	1.8
Non-agriculture	39,284	65,300	835,486	1,124,539	47,019	58,068	2.7
Foreigners	26,226	41,190	75,239	63,209	348,569	651,648	8.1
Total	129,061	195,000	5,862,258	7,172,393	22,016	27,188	2.7

Table-3.7 Governmental Economic Plan - Production Schedule

Item	1972		1977	
	10^6FMG	%	10^6FMG	%
1. Agriculture,Fishing, Stock-raising	82,402	38.3	95,504	37.5
2. Food	17,512	8.1	20,787	8.2
3. Other Industries	21,686	10.1	27,950	11.0
4. Construction Works	9,427	4.4	11,190	4.4
5. Commerce and Services	84,041	39.1	98,832	38.9
Industries Sub Total	215,068	100.0	254,263	100.0

Table-3.8 Governmental Economic Plan - Distribution

Unit: 10^6FMG

Item	1972	1977
Industries Sub Total	215,068	254,263
Import Duties	13,853	18,795
Sub Total	228,921	273,058
Income from State and Companies	40,917	43,010
Domestic Service by Households	3,300	3,300
Gross Domestic Product	273,138	319,368
Rate of Growth		3.2 % per year

Table-3.9 Governmental Economic Plan - Expenditure

Item	1972		1977		Rate of Growth
	10^6FMG	%	10^6FMG	%	
Household	191,713	70.2	219,910	68.9	2.8
State & Companies	52,590	19.3	56,814	17.8	1.6
Investment	35,967	13.2	45,360	14.2	4.8
Savings	1,936	0.7	2,545	0.8	5.6
Exports of Goods and Services	46,282	16.9.	56,020	17.5	3.9
Total	328,488	120.3	380,649	119.2	3.0
Imports of Goods and Services	-55,350	-20.3	-61,281	-19.2	2.1
Gross Domestic Product	273,138	100.0	319,368	100.0	3.2

Table-3.10 Energy Sales and Consumption in Madagascar

Item / Year	Electric Utilities		Privately-owned		Total	
	GWh	%	GWh	%	GWh	%
1968	124	71	50	29	174	100
1969	133	71	54	29	187	100
1970	156	75	53	25	209	100
1971	178	76	56	24	234	100
1972	194	78	56	22	250	100

Table-3.11 Installed Generating Capacity (Electric Utilities and Privately Owned Facilities in Madagascar)

Unit: kVA

Year \ Item	Electric Utilities			Privately-owned			Total		
	Hydro	Thermal	Sub-total	Hydro	Thermal	Sub-total	Hydro	Thermal	Total
1968	42,957	29,217	72,174	1,548	43,727	45,275	44,505	72,944	117,449
1969	44,057	31,657	75,714	1,548	45,180	46,728	45,605	76,837	122,442
1970	49,757	35,565	85,322	1,548	47,984	49,532	51,305	83,549	134,854
1971	49,932	37,230	87,162	1,548	46,609	48,157	51,480	83,839	135,319
1972	49,962	49,836	99,798	1,548	51,867	53,415	51,510	101,703	153,213

Table-3.12 Total Generated Energy in Madagascar

Unit: GWh

Year \ Item	Electric Utilities			Privately-owned			Total		
	Hydro	Thermal	Sub-total	Hydro	Thermal	Sub-total	Hydro	Thermal	Total
1968	104	41	145	1.2	50	51.2	105.2	91	196.2
1969	112	44	156	1.7	55	56.7	113.7	99	212.7
1970	120	58	178	1.5	50	51.5	121.5	108	229.5
1971	131	70	201	1.5	56	57.5	132.5	126	258.5
1972	143	75	218	1.3	57	58.3	144.3	132	276.3

Table-3.13 Outline of Business Activities and Capabilities of Electric Utilities

Year : 1973

Company \ Item	Capital	Customers	Annual Energy Sales	Annual Revenues from Energy Sales	Average Revenues per kWh	Employees	Thermal Power Stations	Hydro Power Stations
	10^3 FMG	10^3	10^6 kWh	10^6 FMG	FMG/kWh		No. of PS Installed kVA	No. of PS Installed kVA
S.M.E.E	1,000 (Provisoire)	67 (Electricite)	173	2,967	17.16	2,051	13 42,762	4 19,402
S.E.M	250,000	10.6	85 (2.0)	946 (359)	11.18 (18.20)	842	22 21,810	3 30,135
Total		78	258 (193)	3,913 (3,326)	15.19 (17.26)	2,893	35 64,572	7 49,537

Note: The figures in parenthesis do not include 60 kV wholesale, which can be broken down as follows :

	60 kV Wholesales	Interconnected Zone	Other Zones	Whole S.E.M
Sales (MWh)	64,925	10,301	9,426	84,652
Revenues (10^6 FMG)	587	148	211	946
Average (FMG/kWh)	9.04	14.34	22.43	15.19

Table-3.14 Installed Generating Capacity

Unit: kVA

	S.M.E.E		S.E.M		Total		
	Hyd.	Th.	Hyd.	Th.	Hyd.	Th.	Total
Interconnecting Zone							
Am Bola				15,400			
Mandraka			30,000				
Antelomita	11,050						
Mandroseza		5,020					
Manandona	2,000						
Antsirabe		6,490					
Sub Total	13,050	11,510	30,000	15,400	43,050	26,910	69,960
Tamatave	5,700	6,190	-	-	5,700	6,190	11,890
Fianarantsoa	652	1,630	-	-	652	1,630	2,282
Others	-	23,432	135	6,410	135	29,842	29,977
Total	19,402	42,762	30,135	21,810	49,537	64,572	114,109

Note Am Bola; Ambohimanambola

Table-3.15 Transmission, Substation and Distribution Facilities

1. Substation Facilities

Item / Company	No. of Sub-Stations	Transformers													
		63/30 (kV)		63/20 (kV)		63/5.5 (kV)		63/3.2 (kV)		60/35 (kV)		35/5 (kV)		20/5 (kV)	
		Set	kVA	Set	kVA	Set	kVA	Set	kVA	Set	kVA	Set	kVA	Set	kVA
S.E.M	4	1	2,000	2	14,000	1	15,000	4	30,000	-	-	-	-	-	-
S.M.E.E	9	-	-	-	-	-	-	-	-	3	22,500	12	44,100	10	27,080

2. Transmission and Distribution Facilities

Item / Company	Length of Line (km)					No. of Transformers	Note
	63 kV	35, 30 kV	20, 15 kV	5.5, 5 kV	Low-Voltage		
S.E.M	189.3	44.2	434.1	43.3	489.4	238	
S.M.E.E	-	170.0	51.4	394.0	929.0	906	No. of Transformers: 1971

Note: S.E.M - Figures shows in 1974
S.M.E.E - Figures shows in 1973

Table-3.16 Sold Energy and Revenues in Madagascar in 1973

Item	S.M.E.E MWh	S.M.E.E 10^3 Francs	S.M.E.E Prix in Francs	Item	S.E.M MWh	S.E.M 10^3 FMG	S.E.M Prix per kWh
Tananarive	82,277	1,524,368	18.53	Interconnected Zone			
Antsirabe	36,102	458,486	12.70	Tananarive	64,925	586,833	9.04
Fianarantsoa	3,729	104,747	28.09	Sub-Total	64,925	586,833	9.04
Tamatave	11,128	198,211	17.81	Except Tananarive			
Majunga	30,215	448,836	14.85	Moramanga	2,631	41,505	15.78
Nossi-Be	2,467	47,296	19.17	Ambatorampy	220	3,347	15.185
Morondava	899	19,539	21.74	Grand-Tana	7,450	102,885	13.81
Diego-Suarez	5,495	149,333	27.17	Other zone	9,426	211,455	22.43
Mananjary	607	16,424	27.05	Sub-Total	19,727	359,192	18.20
Total	172,919	2,967,240	17.16	Grand Total	84,652	946,025	11.18

Table-3.17 Tariffs of Electricity in 1974

1. Tariffs of Energy

	Lighting			Domestic Use			
	Private	Public	Max. Price	1st Stage	2nd Stage	3rd Stage	Off Peak
Tananarive	31.367	28.013	18.700	18.700	11.977	14.965	10.483
Antsirabe	40.687	32.816	27.211	27.211	17.782		13.633

2. Tariff (Power)

Special Contract

	Low Voltage				High Voltage		5 kV		
	Customer Charge MAX.	Customer Charge MIN.	1st Stage	2nd Stage	C.C. MAX.	C.C. MIN.	1st Stage	2nd Stage	3rd Stage
Tana.	147.21	139.32	23.307	22.597	184.01	148.79	13.446	12.101	10.084
An.	1,186.36	1,122.80	30.539	30.048	1,101.62	889.77	18.808	18.053	16.921

Note: C.C: Customer Charge

3. Tariff (Power High Voltage = 5 kV)

	Customer Charge MAX.	Customer Charge MIN	Intermediate 1st Stage	Intermediate 2nd Stage	Intermediate 3rd Stage	Off Peak 1st Stage	Off Peak 2nd Stage	Peak
Tana.	368.02	297.57	13.446	10.757	9.412	8.068	6.723	13.446
An.	3,381.13		18.808	11.211		9.066	8.259	21.461

4. Tariff (Power High Voltage > 5 kV)

Tana.	368.02	297.57	12.625	10.122	8.852	8.068	6.723	12.625
An.	3,381.13		17.741	10.942		9.066	8.257	21.461

5. Supplementary Taxes

	Lighting		Domestic Use				
	1st Stage	2nd Stage	Max. Price	1st Stage	2nd Stage	Peak	Off Peak
Tana.	0.68	0.75	0.25	0.25	0.25	0.25	0.25
An.	1.32	1.55	1.01	1.01	1.01		0.50

Table-3.18 Peak Demand (Generating End)

Unit: MW

Item	1972	1981	1986	1991	1995	Note
Most Probable						
Public Sector	32.2	50.0	68.9	98.7	130.4	
Ferrochrome	-	16.5	32.5	32.5	32.5	
Total	32.2	66.5	101.4	131.2	162.9	
Rate (%)	100	207	315	407	506	
Maximum						
Public Sector	32.2	50.0	71.3	107.2	152.7	
Ferrochrome	-	16.5	32.5	48.5	48.5	
Total	32.2	66.5	103.8	155.7	201.2	
Rate (%)	100	207	322	484	625	
Minimum						
Public Sector	32.2	50.0	68.9	98.7	130.4	
Rate (%)	100	155	214	307	405	

Table-3.19 Energy Demand (Generating End)

Unit: GWh

Item	1972	1981	1986	1991	1995	Note
Most Probable						
Public Sector	144	228	320	467	628	
Ferrochrome	-	87	232	254	254	
Total	144	315	552	721	882	
Rate (%)	100	219	383	501	612	
Maximum						
Public Sector	144	228	331	507	736	
Ferrochrome	-	87	232	360	383	
Total	144	315	563	867	1,119	
Rate (%)	100	219	391	602	777	
Minimum						
Public Sector	144	228	320	467	628	
Rate (%)	100	158	222	324	436	

Table-3.20 Estimated Energy Sales in Public Sector

<table>
<tr><th rowspan="3">Year</th><th>(1)</th><th colspan="2">(2)</th><th colspan="2">(3)</th><th>(4)= (2)/(3)</th><th>(5)</th><th>(6)=(1)/(5)</th><th></th></tr>
<tr><th>Sales Energy</th><th colspan="2">Growth Rate of Energy</th><th colspan="2">Growth Rate of G.D.P</th><th>Elasticity</th><th>Population</th><th>Energy per Capita</th><th rowspan="2">Note</th></tr>
<tr><th>GWh</th><th colspan="2">%</th><th colspan="2">%</th><th></th><th>10³</th><th>kWh/capita</th></tr>
<tr><td>1966</td><td>73.2</td><td rowspan="6">10.3/year</td><td>9.2</td><td rowspan="6">8.1/year</td><td rowspan="6"></td><td rowspan="6">1.28</td><td>670.6</td><td>109</td><td rowspan="7">Actual</td></tr>
<tr><td>1967</td><td>85.3</td><td>16.6</td><td>683.4</td><td>125</td></tr>
<tr><td>1968</td><td>94.7</td><td>11.0</td><td>711.8</td><td>133</td></tr>
<tr><td>1969</td><td>99.0</td><td>4.5</td><td>721.7</td><td>137</td></tr>
<tr><td>1970</td><td>108.2</td><td>9.3</td><td>750.5</td><td>144</td></tr>
<tr><td>1971</td><td>119.5</td><td>10.5</td><td>776</td><td>153</td></tr>
<tr><td>1972</td><td>129.8</td><td></td><td>8.6</td><td></td><td></td><td></td><td>804</td><td>161</td></tr>
<tr><td>1973</td><td>133</td><td></td><td>2.6</td><td rowspan="5">3.2/year</td><td>2.0</td><td rowspan="5">1.3</td><td>829</td><td>160</td><td rowspan="10">Estimated</td></tr>
<tr><td>1974</td><td>136</td><td></td><td>2.6</td><td>2.0</td><td>855</td><td>159</td></tr>
<tr><td>1975</td><td>141</td><td></td><td>3.9</td><td>3.0</td><td>886</td><td>159</td></tr>
<tr><td>1976</td><td>148</td><td></td><td>5.2</td><td>4.0</td><td>913</td><td>162</td></tr>
<tr><td>1977</td><td>158</td><td></td><td>6.5</td><td>5.0</td><td>943</td><td>168</td></tr>
<tr><td>1978</td><td>168</td><td colspan="2" rowspan="5">6.5/year</td><td colspan="2" rowspan="5">5.0/year</td><td rowspan="5">1.3</td><td>974</td><td>172</td></tr>
<tr><td>1979</td><td>179</td><td>1008</td><td>178</td></tr>
<tr><td>1980</td><td>191</td><td>1039</td><td>184</td></tr>
<tr><td>1981</td><td>203</td><td></td><td></td></tr>
<tr><td>1982</td><td>216</td><td></td><td></td></tr>
</table>

Table-3.21 Demand Forecast by Service Categories

Year	Residential			Low Voltage			High Voltage			Public			Total		
	10^3 kWh	Ratio	Increase Rate	10^3 kWh	Ratio	Increase Rate	10^3 kWh	Ratio	Increase Rate	10^3 kWh	Ratio	Increase Rate	10^3 kWh	Ratio	Increase Rate
1968	24,941	26.3	-	4,764	5.0	-	56,742	60.0	-	8,253	8.7	-	94,700	100	-
69	26,342	26.6	5.6	5,008	5.1	5.1	58,873	59.4	3.8	8,777	8.9	6.3	99,000	100	4.5
70	28,075	25.9	(4.2) 6.6	5,051	4.7	(1.9) 0.9	65,853	60.9	(9.0) 11.9	9,221	8.5	(3.1) 5.1	108,200	100	(7.0) 9.3
71	30,506	25.5	8.7	5,121	4.3	1.4	74,172	62.1	12.6	9,701	8.1	5.2	119,500	100	10.5
72	30,627	23.6	0.4	5,305	4.1	3.5	84,386	65.0	13.8	9,482	7.3	-2.3	129,800	100	8.6
73	30,674	23.1	0.2	5,236	3.9	-1.3	87,478	65.8	3.7	9,612	7.2	1.4	133,000	100	2.6
81	41,990	21	4	6,140	3	2	142,700	70	6.3	12,170	6	3	203,000	100	5.4
86	53,580	19	5	6,780	3	2	206,840	73	7.7	14,800	5	4	282,000	100	6.8
91	71,690	17	6	7,860	2	3	307,570	76	8.3	18,880	5	5	406,000	100	7.6
95	93,990	16	7	8,840	2	3	420,230	78	8.1	22,940	4	5	546,000	100	7.7

Note: Increase Rate: 1968 - 1973 - Actual,

——a—— Geometric increase rate

Table-3.22-(1) List of Large Consumers

S.E.M- Interconnected Zone

		1968	1969	1970	1971	1972	1973
TANANARIVE							
S.M.E.E	kW	7,200	7,200	8,640	10,370	12,000	11,000
	Cons.10^3kWh	20,284	31,063	32,792	36,228	31,787	30,193
Paper Mill	kW	1,700	1,700	1,700	1,700	1,700	1,700
	Cons.10^3kWh	6,717	7,185	6,537	6,867	6,630	9,453
Total	kW	8,900	8,900	10,340	12,070	13,700	12,700
	Cons.10^3kWh	27,001	38,248	39,329	43,095	38,417	39,646
GRAND TANA (1)							
Radio Nederland	kW	-	-	-	-	2,000	2,000
	Cons.10^3kWh	-	-	-	-	2,493	5,581
SOMACOU	kW	-	-	-	-	-	230
	Cons.10^3kWh	-	-	-	-	-	672
Total	kW	-	-	-	-	2,000	2,230
	Cons.10^3kWh	-	-	-	-	2,493	6,253
MORAMANGA							
Plywood Industry	kW	-	-	-	400	400	400
	Cons.10^3kWh	-	-	-	825	864	1,112
ANTSIRABE							
S.M.E.E	kW	-	-	-	-		
	Cons.10^3kWh	-	-	-	-	5,583	25,279

Nte : Cons. : Consumption

Table-3.22-(2) List of Large Consumers

S.M.E.E- Interconnected Zone

		1968	1969	1970	1971	1972	1973
TANANARIVE							
Hilton Hotel	kW Cons. 10^3kWh	- -	- -	280 701	400 1,814	400 1,690	400 1,890
Biscuit Industry	kW Cons. 10^3kWh	- -	- -	- -	- -	300 716	300 722
Radio Station	kW Cons. 10^3kWh	520 2,142	520 2,311	520 2,013	640 2,630	640 2,917	640 2,760
Railroad	kW Cons. 10^3kWh	330 907	330 963	330 931	330 941	330 856	370 851
STIMAD	kW Cons. 10^3kWh	- -	- -	240 1,864	240 1,846	240 1,562	240 1,286
University	kW Cons. 10^3kWh	- -	- -	- -	- -	- -	280 657
Total	kW Cons. 10^3kWh	850 3,049	850 3,274	1,370 5,509	1,610 7,231	1,910 7,741	2,230 8,166
ANTSIRABE							
Textile Industry	kW Cons. 10^3kWh	3,750 17,349	3,750 16,210	4,000 19,200	4,000 21,959	5,940 26,870	5,940 28,268
Beer Company	kW Cons. 10^3kWh	275 1,552	275 1,569	475 1,835	475 1,943	560 2,190	560 2,403
Total	kW Cons. 10^3kWh	4,025 18,901	4,025 17,779	4,475 21,035	4,475 23,902	6,500 29,060	6,500 30,671

Table-3.23 Ferrochrome Production Schedule and Electric Energy Requirements

Year \ Item		Production Plan		Electric Power & Energy Requirement	
		Number of Furnaces	Production (ton)	Load (kW)	Consumption (GWh)
1	1981	1	15,000	16,500	84.8
2	1982	1	19,000	16,500	101.5
3	1983	1	22,000	16,500	112.8
4	1984	1	25,000	16,500	124.5
5	1985	1	25,000	16,500	124.5
6	1986	2	44,000	32,500	224.8
7	1987	2	50,000	32,500	245.3
8	1988	2	50,000	32,500	246.3
9	1989	2	50,000	32,500	246.3
10	1990	2	50,000	32,500	246.3
11	1991	3	69,000	48,500	345.8
12	1992	3	75,000	48,500	367.3
13	1993	3	75,000	48,500	367.3

Table-3.24 Demand Forecast in Public Sector (Most Probable)

Year	(1) Growth rate of G.D.P	(2) Increase rate of Energy	(3) Sales Energy	(4) Loss rate	(5) Generated Energy	(6) Load Factor	(7) Peak Demand
	%	%	10^6kWh	%	10^6kWh	%	MW
1974	2	2.6	136	11.0	153	51	34.3
1975	3	3.9	141	"	158	"	35.3
1976	4	5.2	148	"	166	"	37.1
1977	5	6.5	158	"	178	"	39.8
1978	5.0/year	6.5/year	168	"	189	52	41.5
1979	"	"	179	"	201	"	44.0
1980	"	"	191	"	215	"	47.1
1981	"	"	203	"	228	"	50.0
1982	"	"	216	"	243	"	53.3
1983	5.5/year	7.0/year	231	"	260	53	55.0
1984	"	"	247	"	278	"	59.8
1985	"	"	264	"	297	"	64.0
1986	"	"	282	12.0	320	"	68.9
1987	"	"	302	"	343	"	74.0
1988	6.0/year	7.7/year	325	"	369	54	78.0
1989	"	"	350	"	398	"	84.1
1990	"	"	377	"	428	"	90.6
1991	"	"	406	13.0	467	"	98.7
1992	"	"	437	"	502	"	106.1
1993	"	"	471	"	541	55	112.4
1994	"	"	507	"	583	"	121.1
1995	"	"	546	"	628	"	130.4

Table-3.25 Demand Forecast in Public Sector (Maximum)

Year	(1) Growth rate of G.D.P	(2) Increase rate of Energy	(3) Sales Energy	(4) Loss rate	(5) Generated Energy	(6) Load Factor	(7) Peak Demand
	%	%	10^6kWh	%	10^6kWh	%	MW
1973	2 (3.2/year)	2.6	133	11.0	149	51	33.3
1974	2	2.6	136	"	153	"	34.3
1975	3	3.9	141	"	158	"	35.3
1976	4	5.2	148	"	166	"	37.1
1977	5	6.5	158	"	178	"	39.8
1978	5.0/year	6.5	168	"	189	52	41.5
1979	"	"	179	"	201	"	44.0
1980	"	"	191	"	215	"	47.1
1981	"	"	203	"	228	"	50.0
1982	"	"	216	"	243	"	53.3
1983	6.0/year	7.7	233	"	262	53	56.4
1984	"	"	251	"	282	"	60.8
1985	"	"	270	"	303	"	65.3
1986	"	"	291	12.0	331	"	71.3
1987	"	"	313	"	356	"	76.6
1988	7.0/year	9.0	341	"	388	54	82.0
1989	"	"	372	"	423	"	89.4
1990	"	"	405	"	460	"	97.2
1991	"	"	441	13.0	507	"	107.2
1992	"	"	481	"	553	"	116.9
1993	8.0/year	10.0	529	"	608	55	126.2
1994	"	"	582	"	669	"	138.9
1995	"	"	640	"	736	"	152.7

Table-3.26 Capacity and Capability of Hydro Power Plants

	Name of Power Station	Installed Capacity	Capability					Note
			Anual Energy	Average Cap.		Peak Cap.		
Existing	(1) Antelomita	11,050 kVA	55 GWh	6.3 MW		8 MW		
	(2) Manandona	2,000	10	1.1		1		
	(3) Mandraka	30,000	63	7.2		18		
	Total	43,050	128	14.6		27		
Planning	1 Stage Plan (1-0-B)	kVA		*1 MW	*2 m^3/sec	*3 MW	*4 %	
	Max. Flow 30 m^3/sec	33,500 x 2		48.0	(27.1)	48.0		
	ditto 45 "	33,500 x 3		57.2	(31.8)	81.0	(70)	
	60 "	33,500 x 4		61.4	(34.1)	97.3	(67)	
	2 Stage Plan	kVA		*1	*2	*3	*4	
	(2-1-A) 30 m^3/sec	22,100 x 2		31.7	(27.1)	31.7		
	ditto 45 "	22,100 x 3		37.2	(31.8)	52.8	(70)	
	ditto 60 "	22,100 x 4		39.9	(34.1)	60.4	(70)	
	(2-2-A) 30 "	25,500 x 1		16.3	(27.1)	*78.4	(70)	* include 2-1-A
	ditto 60 "	25,500 x 2		20.5	(34.1)	*91.6	(67)	* include 2-1-A

Note *1. shows L5-day output in May. *2. shows L5-day Natural Flow in May.
*3. show the Peak Cap. on the L5 day in May. *4. shows L5-day Load Factor in May in assumed year.

Table-3.27 Capacity and Capability of Thermal Power Plants

Item	Installed capacity (kVA)	Capability (kW)	Note
Existing Plants			
Mandroseza Power Station	5,020	3,500	
Antsirabe Power Station	6,490	5,500	Cold Reserve capability
Sub-total		9,000	
Ambohimanambola Power Station	7,700 x 2	12,000	
Proposed Plants			
Diesel Plant	7,700	6,000	Unit Capacity
	13,750	11,000	"
Gas Turbine Plant	18,750	15,000	"

Table-3.28 Characteristic Data on Monthly Discharge at Andekaleka (20-year Average)

Unit: m^3/sec

Item	Monthly Average of Flow	N	D	J	F	M	A	M	J	J	A	S	O
Data of Series	Average	43.0	68.5	97.8	113.9	135.7	76.9	54.7	54.6	60.6	61.7	48.8	37.8
	Aver. (60 m^3/sec)	39.6	50.1	54.7	56.9	56.7	52.7	46.9	47.5	51.9	51.8	46.3	37.0
	" (45 ")	36.0	41.2	43.8	44.1	44.0	42.4	40.2	40.5	42.9	43.5	41.6	35.8
	" (30 ")	28.5	29.4	30.0	29.9	29.9	29.7	29.3	29.1	29.6	30.0	29.9	29.1
	L5 (60 m^3/sec)	23.2	26.5	37.4	43.0	40.1	29.5	25.5	24.6	32.2	37.0	32.6	25.2
	" (45 ")	23.2	26.5	37.3	40.2	38.5	29.5	25.5	24.6	32.2	37.0	32.6	25.2
	" (30 ")	23.2	26.0	29.8	29.3	29.3	28.2	25.5	24.4	27.4	29.9	29.6	25.2
Data of Parallel	Average	43.0	68.5	97.8	113.9	135.7	76.9	54.7	54.6	60.6	61.7	48.8	37.8
	Aver. (60 m^3/sec)	39.6	50.1	54.7	56.9	56.7	52.7	46.9	47.5	51.9	51.8	46.3	37.0
	" (45 ")	36.0	41.2	43.8	44.1	44.0	42.4	40.2	40.5	42.9	43.5	41.6	35.8
	" (30 ")	28.5	29.4	30.0	29.9	29.9	29.7	29.3	29.1	29.6	30.0	29.9	29.1
	L5 (60 m^3/sec)	30.7	37.3	45.6	52.1	52.6	48.5	42.7	41.6	43.3	44.3	39.9	31.0
	" (45 ")	30.3	35.6	40.6	43.1	42.3	41.2	38.1	37.8	40.0	41.1	38.4	31.0
	" (30 ")	27.0	28.5	29.8	29.7	29.6	29.5	28.7	28.6	29.0	29.9	29.7	28.0
Data of the Lowest 5 Day.													
1/2(Parallel. L5. $60m^3/s$+Series. L5. $60m^3/s$)		27.0	31.9	41.5	47.6	46.4	39.0	34.1	33.1	37.8	40.7	36.3	28.1
$\frac{1/2(\text{Parallel. L5. } 60m^3/s + \text{Series. L5. } 60m^3/s)}{\text{Aver. } 60m^3/s} \times 100\%$		68.2	63.7	75.9	83.7	81.8	74.0	72.7	69.7	72.8	78.6	78.4	75.9
1/2(Parallel. L5. $45m^3/s$+Series. L5. $45m^3/s$)		26.8	31.1	39.0	41.7	40.4	35.4	31.8	31.2	36.1	39.1	35.5	28.1
$\frac{1/2(\text{Parallel. L5. } 45m^3/s + \text{Series. L5. } 45m^3/s)}{\text{Aver. } 45m^3/s} \times 100\%$		74.4	75.5	89.0	94.6	91.8	83.5	79.1	77.0	84.1	89.9	85.3	78.5
1/2(Parallel. L5. $30m^3/s$+Series. L5. $30m^3/s$)		25.1	27.3	29.8	29.5	29.5	28.9	27.1	26.5	28.2	29.9	29.7	26.6
$\frac{1/2(\text{Parallel. L5. } 30m^3/s + \text{Series. L5. } 30m^3/s)}{\text{Aver. } 30m^3/s} \times 100\%$		88.1	92.9	99.3	98.7	98.7	97.3	92.5	91.1	95.3	99.7	99.3	91.4

Table-3.29 Combined Series-Parralel Discharge Duration

695.8	462.9	438.3	348.3	289.3	257.4	249.3	242.6	233.6	199.4
197.6	186.4	178.9	173.5	168.0	163.1	161.1	156.1	152.2	150.2
145.0	142.3	140.3	137.3	135.6	132.6	131.2	129.1	128.9	125.0
124.4	121.1	119.9	117.9	117.0	114.4	113.1	112.6	110.8	109.9
109.2	107.9	107.4	104.7	104.2	103.4	102.7	101.9	101.2	100.8
99.6	99.2	97.7	96.6	96.2	94.8	94.4	93.5	93.4	93.0
91.0	90.6	90.2	89.8	89.6	89.0	87.8	87.5	87.3	86.4
86.0	85.3	85.1	84.8	84.3	84.2	83.8	83.6	82.7	82.5
81.9	81.3	81.1	80.9	79.9	79.1	78.8	78.8	78.4	77.9
77.3	77.1	76.9	76.4	76.3	75.9	75.6	75.4	75.0	74.8
74.6	74.4	74.1	73.4	73.1	72.7	72.2	71.9	71.7	71.6
71.5	71.5	70.9	70.4	70.1	69.7	69.7	69.5	69.2	69.0
68.8	68.4	68.2	67.8	67.4	67.3	66.9	66.5	66.5	66.3
65.9	65.8	65.7	65.5	65.4	65.2	64.9	64.5	64.2	64.1
63.9	63.8	63.6	63.5	63.3	63.0	62.9	62.8	62.6	62.3
62.1	62.1	61.8	61.3	61.3	61.1	60.8	60.7	60.4	60.3
59.9	59.4	59.3	59.3	59.3	59.1	58.6	58.4	58.4	58.2
58.1	58.1	58.0	57.6	57.2	57.2	56.9	56.7	56.4	56.2
56.1	56.1	55.9	55.8	55.7	55.6	55.5	55.4	55.3	54.9
54.8	54.5	54.3	54.2	54.1	54.1	53.9	53.5	53.3	53.2
53.1	53.0	52.8	52.7	52.4	52.3	52.2	51.8	51.7	51.4
51.2	51.1	51.1	51.0	50.8	50.7	50.6	50.6	50.3	50.2
49.9	49.9	49.8	49.6	49.4	49.3	49.3	49.0	49.0	48.7
48.7	48.6	48.6	48.3	48.1	48.0	47.7	47.6	47.5	47.4
47.4	47.3	47.1	47.0	46.8	46.7	46.5	46.4	46.3	46.2
46.0	45.9	45.7	45.6	45.6	45.4	45.2	45.0	44.9	44.8
44.7	44.6	44.6	44.3	44.3	44.2	44.0	43.7	43.5	43.5
43.5	43.4	43.3	43.2	43.1	43.0	42.9	42.7	42.4	42.2
42.2	41.9	41.8	41.7	41.6	41.6	41.5	41.3	41.2	41.0
40.9	40.7	40.6	40.2	40.0	39.7	39.7	39.4	39.4	39.3
39.1	39.0	38.9	38.8	38.6	38.4	38.3	38.2	38.2	37.9
37.5	37.4	37.3	37.0	36.9	36.5	36.3	35.9	35.7	35.6
35.4	35.3	35.0	34.8	34.5	34.2	34.1	33.8	33.8	33.1
33.0	32.8	32.5	32.3	32.1	32.1	31.9	31.7	31.5	31.1
31.0	30.8	30.6	30.4	30.4	30.2	30.0	29.9	29.5	29.3
29.1	28.6	28.6	28.3	27.8	27.7	27.5	27.3	27.2	26.5
26.0	25.6	25.3	24.3	23.9					

Table-3.30 Annual Discharge Duration (from Nov.1960 to Oct.1961)

147.0	144.0	141.0	131.0	131.0	131.0	130.0	130.0	122.0	120.0
120.0	108.0	107.0	106.0	102.0	96.0	95.0	94.0	89.0	87.0
87.0	86.0	86.0	85.0	84.0	82.0	81.0	81.0	81.0	78.0
76.0	76.0	75.0	68.0	67.0	66.0	65.0	64.0	64.0	63.0
63.0	63.0	62.0	60.0	58.0	58.0	57.0	57.0	57.0	57.0
57.0	57.0	56.0	56.0	55.0	54.0	54.0	53.0	53.0	53.0
53.0	52.0	52.0	52.0	52.0	51.0	50.0	50.0	49.2	49.2
49.2	49.2	49.2	49.2	49.2	48.4	48.4	47.7	47.7	47.7
46.9	46.9	46.9	46.1	46.1	46.1	46.1	45.4	45.4	45.4
45.4	45.4	45.4	45.4	45.4	44.6	44.6	44.6	43.8	43.0
43.0	43.0	43.0	42.3	42.3	42.3	42.3	42.3	42.3	42.3
42.3	42.3	42.3	41.5	41.5	41.5	41.5	40.9	40.9	40.9
40.9	40.9	40.9	40.9	40.9	40.2	40.2	40.2	39.6	39.6
39.6	39.6	39.6	38.9	38.9	38.9	38.9	38.3	38.3	38.3
37.7	37.7	37.7	37.7	37.7	37.7	37.7	37.0	37.0	37.0
37.0	37.0	36.4	36.4	35.7	35.7	35.7	35.7	35.7	35.7
35.1	34.5	34.5	34.5	34.5	34.5	34.5	33.9	33.9	33.9
33.9	33.3	33.3	33.3	32.7	32.2	32.2	32.2	32.2	32.2
32.2	32.2	32.2	32.2	31.6	31.6	31.0	31.0	31.0	30.4
30.4	29.8	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2
29.2	29.2	29.2	29.2	28.7	28.7	28.7	28.7	28.7	28.7
28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2
28.2	27.8	27.8	27.8	27.3	27.3	27.3	27.3	27.3	26.8
26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8	26.8
26.4	26.4	26.4	26.4	26.4	26.0	26.0	26.0	26.0	26.0
25.6	25.6	25.6	25.6	25.6	25.6	25.6	25.2	25.2	25.2
25.2	25.2	25.2	25.2	25.2	25.2	24.8	24.8	24.8	24.8
24.8	24.8	24.7	24.7	24.7	24.7	24.7	24.6	24.5	24.5
24.5	24.5	24.5	24.5	24.4	24.3	24.3	24.3	24.3	24.3
24.1	24.1	24.1	24.1	24.1	23.9	23.9	23.9	23.9	23.9
23.7	23.7	23.7	23.7	23.7	23.5	23.5	23.5	23.5	23.3
23.3	23.3	23.3	23.2	23.1	23.1	23.1	23.0	23.0	23.0
23.0	22.9	22.9	22.9	22.9	22.7	22.7	22.7	22.7	22.5
22.5	22.5	22.3	22.3	22.1	22.1	22.0	22.0	21.8	21.8
21.6	21.6	21.4	21.4	21.3	21.3	21.2	21.2	21.0	21.0
20.8	20.8	20.7	20.7	20.5	20.5	20.3	20.2	20.0	19.8
19.7	19.5	19.4	19.3	19.1					

Fig-3.1 Supply Area of S.E.M

Fig-3.2 Supply Area of S.M.E.E

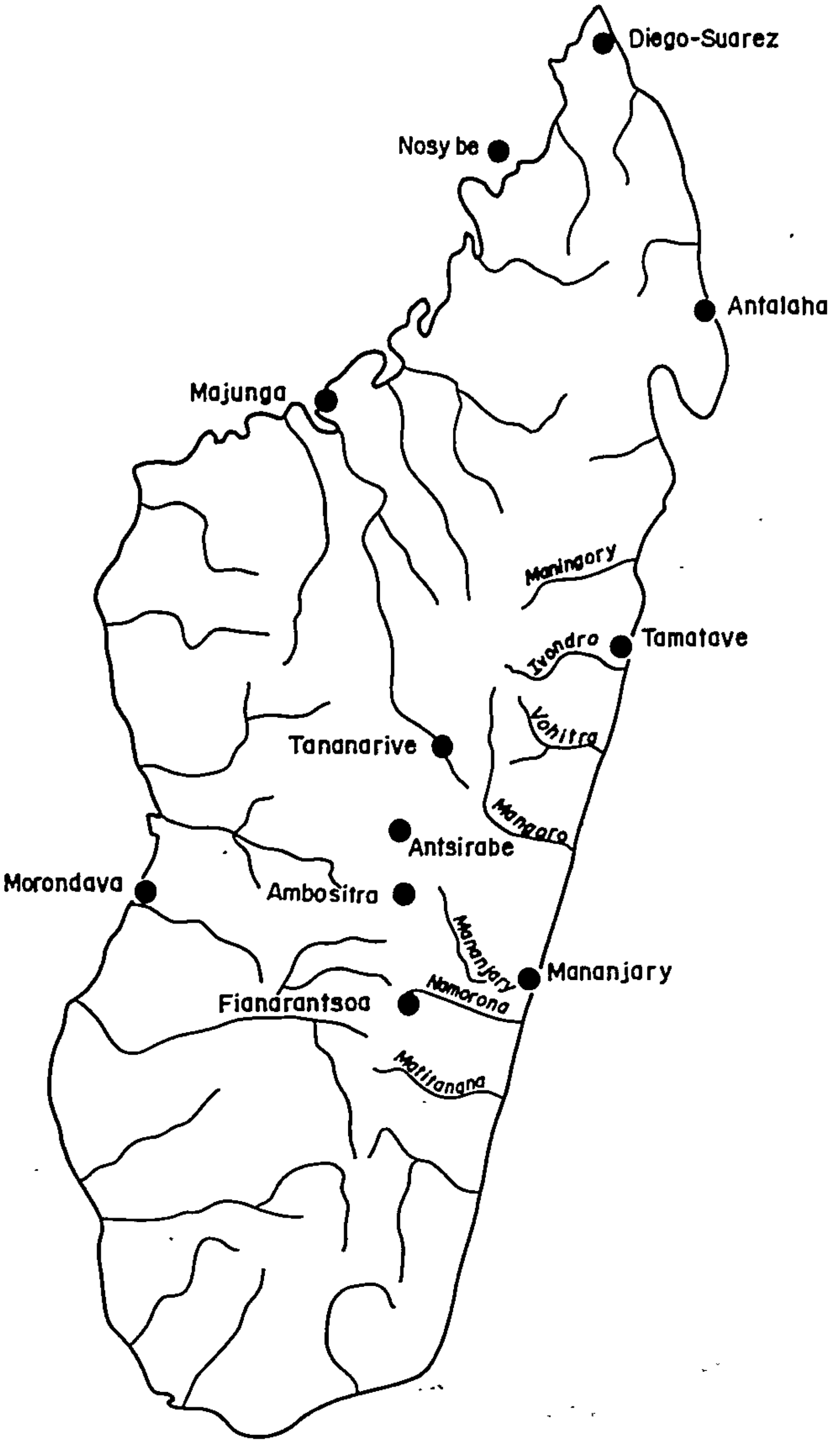


Fig-3.3 S.E.M Interconnection of Transmission System (October, 1974)

Fig-3.4 Diagram of Interconnecting System

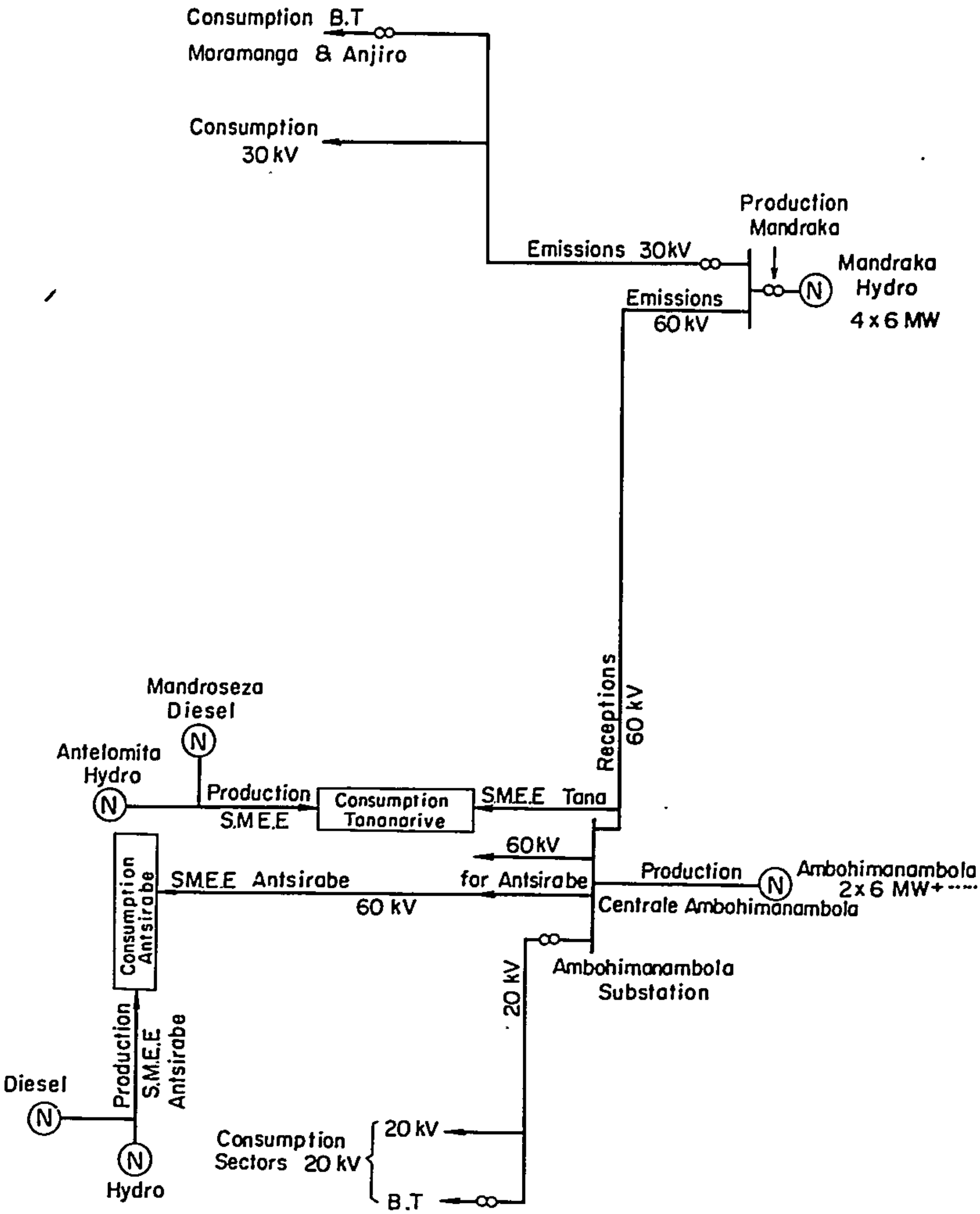


Fig-3.5 Daily Load Curve of S.M.E.E (3rd Wednesday in 1973)

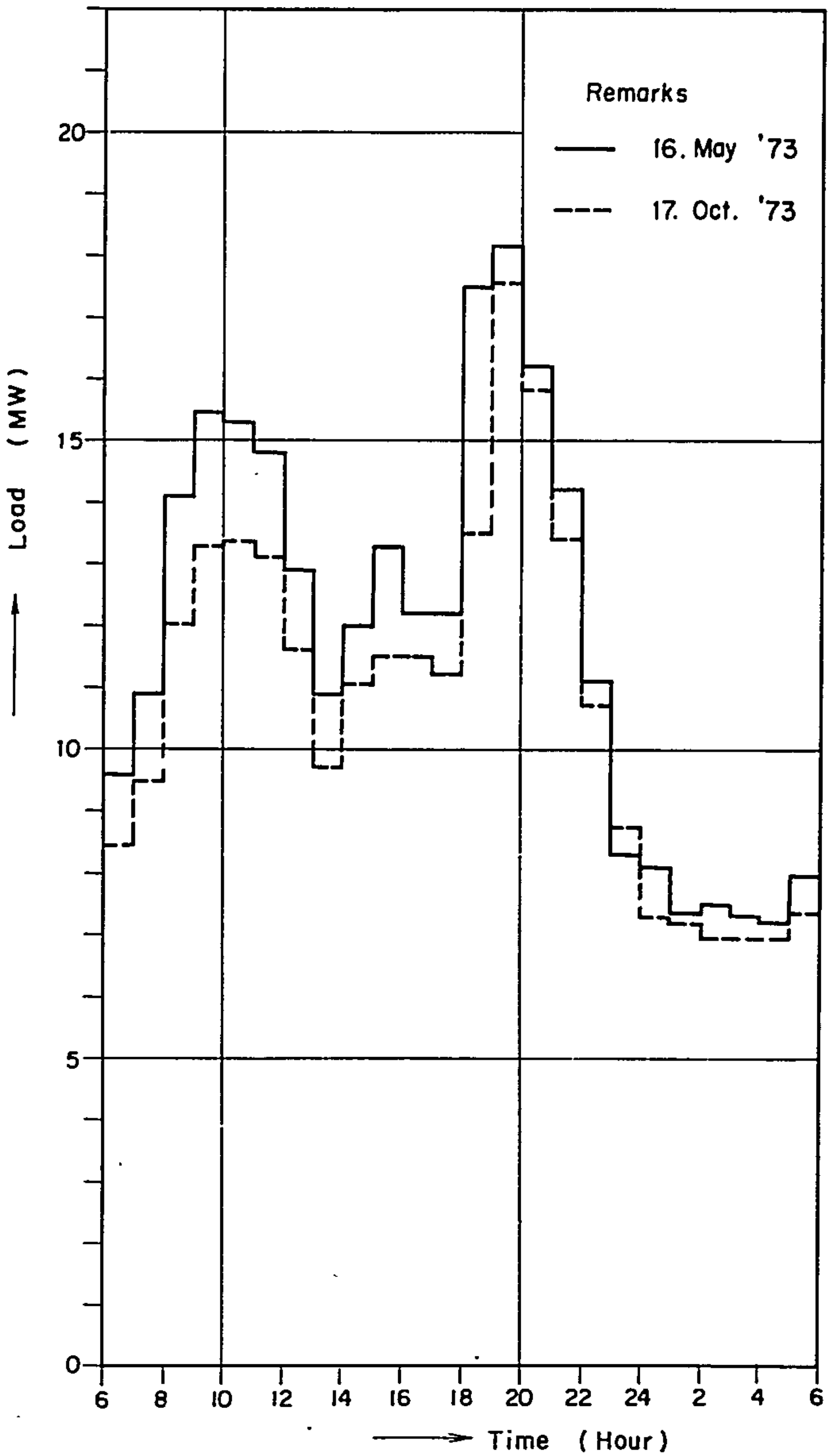


Fig-3.6 Flow Chart of Demand Forecast, Balance of Peak Demand and Energy

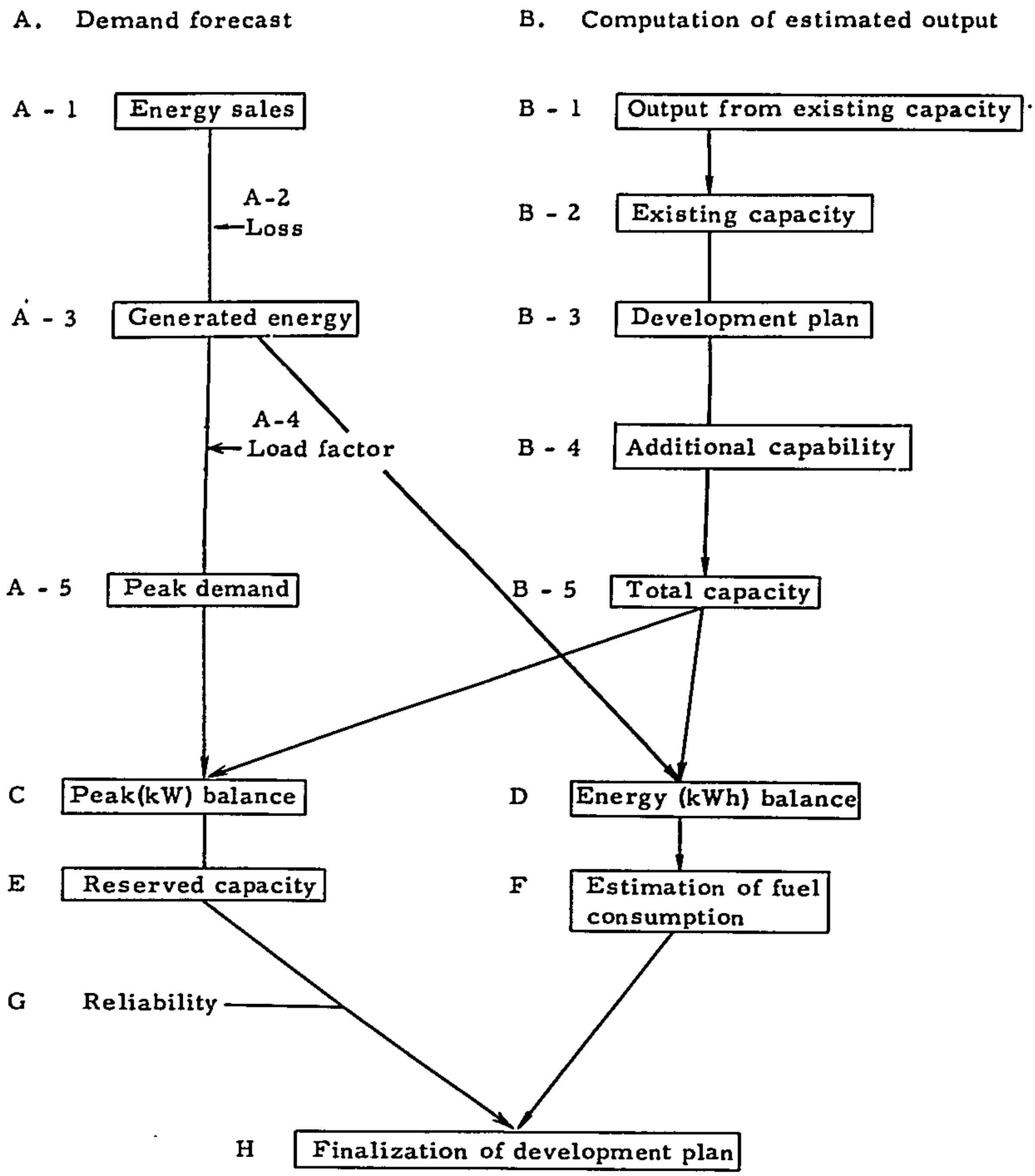


Fig-3.7 Monthly Maximum Load Curve in 1973

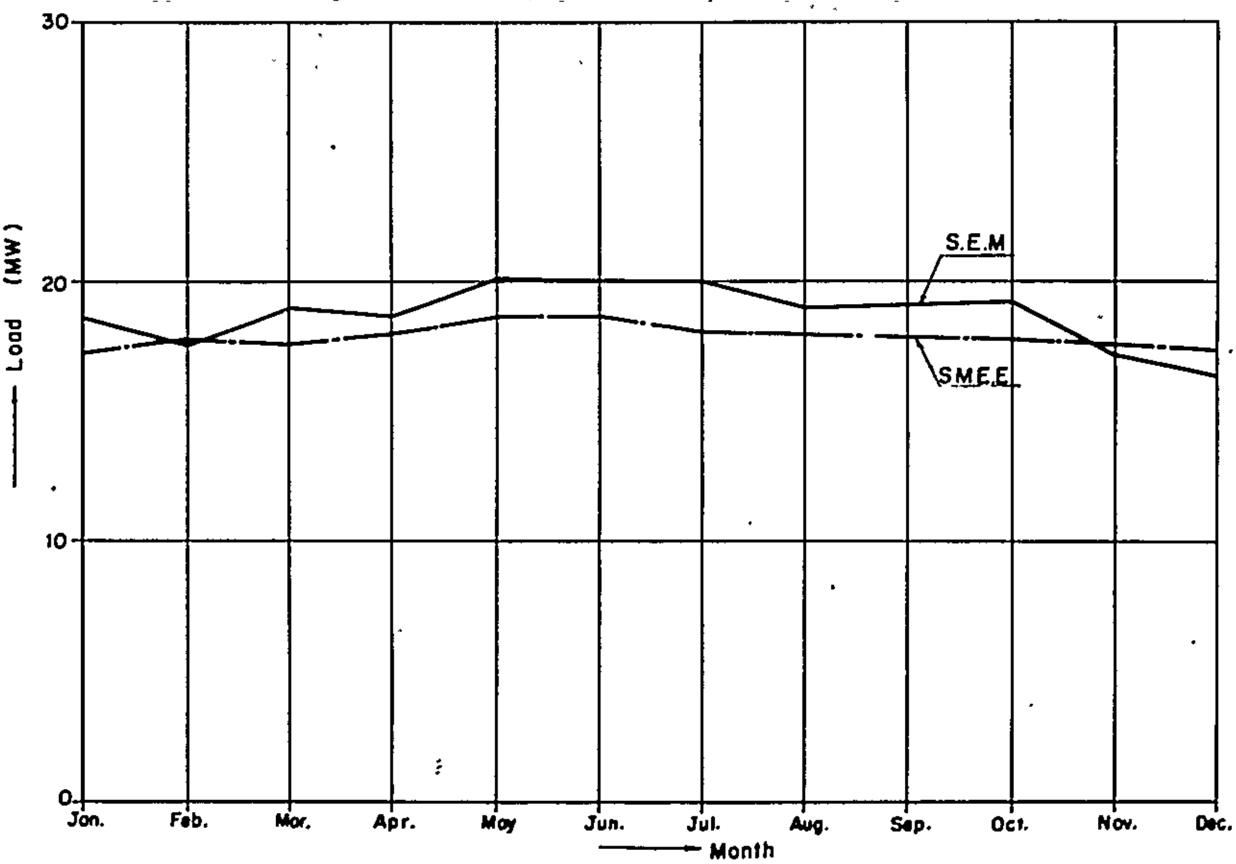


Fig-3.8-(1) Development Schedule for Most Probable Demand

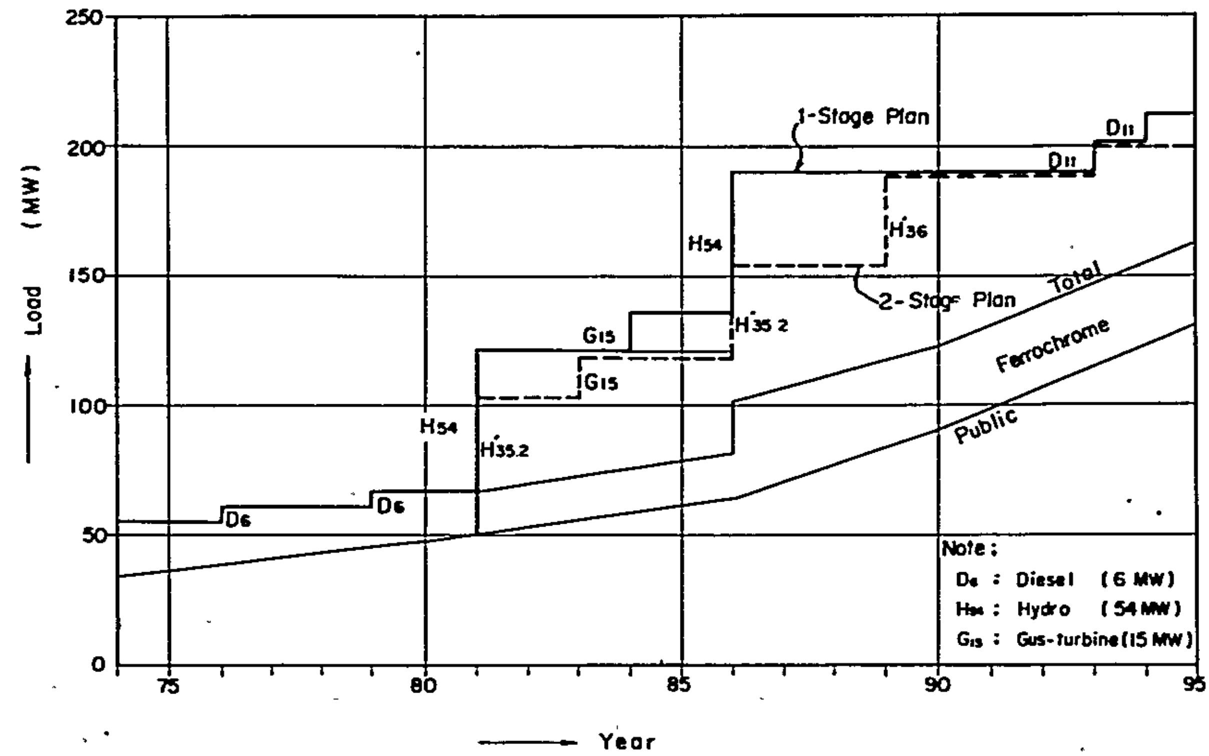


Fig-3.8-(2) Development Schedule for Maximum Demand

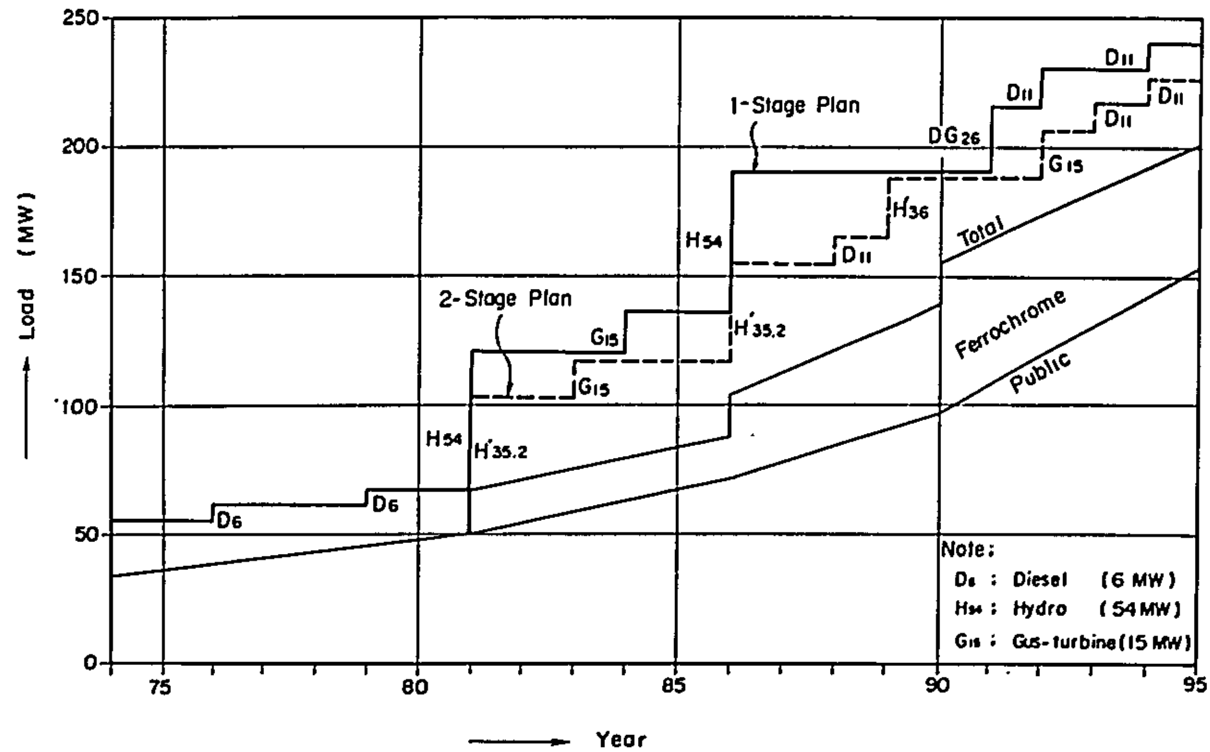
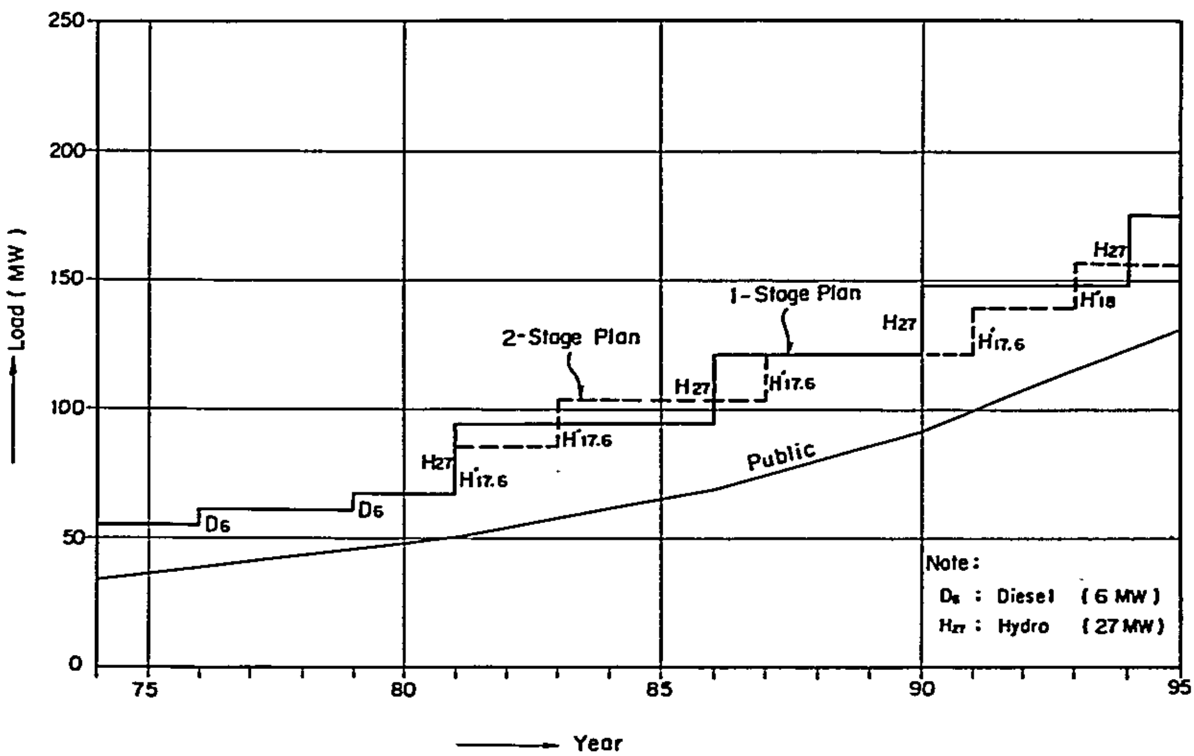


Fig-3.8-(3) Development Schedule for Minimum Demand



Chapter 4.

Studies on Development Plan for Ferrochrome Refinery Plant

Chapter 4 Studies on Development Plan for Ferrochrome Refinery Plant

4. 1 Brief summary of ferrochrome production project

Today it is earnestly hoped that the Republic of Madagascar, a country rich in chrome-ore and with a great potential for electric power, should start on its path towards becoming a more industrialized nation. She has to outgrow its state as a primary product exporting nation and start producing and exporting ferrochrome thus promoting further growth to the national economy.

Meanwhile, in view of the fact that refinery for ferrochrome consumes a great deal of electric power, the ferrochrome production plant will be the largest consumer which is a prerequisite to the proposed Andekaleka Hydroelectric Power Development Project. If Andekaleka Hydroelectric Power Project can be carried out for the sake of ferrochrome production, it will invite establishment of many other factories into the same area. This will undoubtedly serve as the driving force to encourage further growth of the national economy and, at the same time, attain a higher standard of living for the people. From such a point of view, great expectations are held for the realization of the ferrochrome production project.

In this Chapter, the result of the feasibility studies made on the ferrochrome production project is reported and the suitable plan is proposed for ferrochrome production in Madagascar with complementary advices, if and when necessary, on the requirements for the implementation of the project.

4. 2 Studies on ferrochrome production plant

4. 2. 1 Outline of ferrochrome plant development plan

The plan envisages construction of a ferrochrome production plant in Moramanga Town about 70 Km east of Tananarive City, the capital of the Republic of Madagascar. Chrome-ore produced in the mining zone of Andriamena about 160 Km north of Tananarive City will be used as the main material, combined with such sub-materials as wood-charcoal, quartzite and lime stone produced in Moramanga and its adjacent area. Electric power will be served by the proposed Andekaleka Hydro Power Station. The product, ferrochrome, will be shipped out via Tamatave Port for export sales.

As the First Step of the project a 20,000 kVA electric furnace will be built for annual production of 25,000 tons ferrochrome. Fig.-4.1 is a geographical sketch showing locations of Moramanga Town, Andriamena Mine, Tananarive City, Andekaleka Hydro Power Station (proposed) and Tamatave Port.

4.2.2 Studies on ferrochrome plant siting

As the result of reconnaissances conducted far and wide over such prospective areas (See Fig.-4.2) as Andriamena, Tananarive City, Tamatave and Moramanga, conclusion has been reached that the Moramanga area is the most suitable place for plant siting for the following reasons:

(a) It is situated nearest to the proposed Andekaleka Power Station.

(b) The place is within convenient reach for ore transportation from Andriamena and for product shipments out of Tamatave Port.

(c) Wood-charcoal is produced in the place and collection of charcoal cargo is readily available.

(d) Labour is easily available.

(e) The place is easily accessible from Tananarive.

In the surrounding area of Moramanga, there are several exploitable sites for plant construction (Fig.-4.2) in Mangoro, Ambolomborona, and Andasibe, northern and western suburbs of Moramanga. Particularly, the northern suburb of Moramanga seems to be better suited for plant siting (Table-4.1). This proposed place is in the suburb about 5 Km apart from the center of Moramanga, on the north side of the airport and on the flat ground west of the national railroad and highway running from Moramanga to Ambatondrazaka. The site condition is suitable for the installation of power transmission lines and railroad spur track.

In the suburban area of Moramanga there are several factories now in operation; such as Societe Nationale Allumette, Societe Industrielle Bois, and PANOMAD In addition to such existing industrial facilities, the new establishment of the Andekaleka Power Station will undoubtedly lure some other industrial plants into the same area after construction of the ferrochrome plant. Therefore, the said area is expected to develop as Moramanga Industrial Zone. Fig.-4.3 shows the possible site for ferrochrome plant construction.

4. 2. 3 Production plan

Electric furnaces to be used for ferrochrome production are of various capacities ranging largely from the smallest 5,000 kVA up to the largest 40,000 kVA. For the proposed project 20,000 kVA furnace at a current standard will be installed. The plan for 25,000 tons ferrochrome production per annum under normal operating condition is considered most recommendable. Table-4. 2 indicates various factors for this furnace.

The initial start-up operation of the first furnace may be scheduled for 1981. By 1984 the furnace will promise gains in profit from its steady operation under such normal condition as aforementioned. This will then allow the second furnace construction work to start with the target of initial operation in 1986. Table-4. 3 shows future production plan by years.

In this plan both first and second furnaces will be of 20,000 kVA standard capacity. This is an expected advantage because by the use of identical design and construction of both furnaces, all components, spare parts, and operating techniques, can be commonly used for either one of them. For the third furnace and further additions it would be possible to adopt 40,000 kVA or larger capacity, if the circumstance may permit, which is now considered most advantageous in terms of 'economy of scale'. Such future provisions are worthy of further consideration.

Ferrochrome product will be graded as 'charge chrome', high carbon ferrochrome of 60 % Cr content, which can be produced by a relatively simple process, and it is in high demand in the world market. Furthermore, the plant is designed for possible modifications to permit production of high-carbon ferrochrome, if and when necessary, depending upon actual demand situations. When more than two furnaces will be put into operation, ferrochrome of two or more different grades can be produced at the same time.

4. 2. 4 Required site area and appurtenance

The plant will be built on the flat ground on the west side of the national railroad and highway running from Moramanga to Ambatondrazaka, to the north of Moramanga Air Port, in the suburb about 5 Km north of the center of Moramanga Town.

The required expansion for siting area will be 100,000 m^2 for the first single unit of furnace and 170,000 m^2 for the twin. It is recommended that at the First Step of construction project the necessary land for extension should be secured in advance for readiness of the subsequent Second Step construction. As the appurtenant utility to the plant, spur track must be laid for loading and unloading of ferrochrome, chrome-ore and other materials. General arrangement of the plant is as shown in Fig.-4. 4.

4. 2. 5 Furnace construction and manufacturing process

The furnace will be composed of the furnace body, equipped with electrode, transformer, charging bin, rotation and tapping equipment and belt conveyer, etc., whose sectional views are as shown in Fig.-4. 5 and Table-4. 4.

Chrome ore and other materials will be put into the furnace through the charging bin after being weighed and mixed. Electric power will be transmitted through the electrode for continuous smelting of materials. Melted ferrochrome will be tapped out of the furnace at an interval of several hours. Then, ferrochrome will be cooled down, crushed and even-grained for shipments. The flowcharts showing this process are given in Fig. -4. 6 and Fig. -4. 7.

4. 3 Necessary materials for ferrochrome production

The ferrochrome product will have its chemical composition of 60 % Cr, 7. 5 % C and 4 % Si at average. Table-4. 5 shows, herein for reference only, chemical compositions of ferrochrome produced in different areas of the world. Necessary materials for production of ferrochrome are as stated below.

(1) Chrome ore

Chrome ore will be carried by truck from Comina Mine to Morarano Station over a distance of about 90 Km, and then by train to the suburb of Moramanga over 155 Km distance and finally carried into the ore yard in the premises of the plant through the spur track.

The unit consumption of chrome ore will be 2. 4 tons at a standard level. Therefore, the annual consumption of chrome ore will be 60,000 tons for the First Step furnace and 120,000 tons for the Second Step furnace. Chemical compositions are as shown in Fig. -4. 6.

(2) Charcoal

Charcoal is produced in the suburban areas of Moramanga, Tananarive, Antsirabe, Ambatolampy and Manzakandriana, where it is produced at an annual rate of 100,000 to 150,000 tons. Trucks will be used for the transportation to the plant.

At present, by research efforts of the Ministry of Rural Development - Logging & Industry Department, extensive studies are being progressed at the Forest Laboratory with a test plant in operation capable of 5 tons/month for charcoal production. It is recommended that this type of plant should be built in several places around Moramanga so as to secure the supply system of charcoal. In this area there are many forests of eucalyptus and mimosas whose qualities are good for use as raw materials for charcoal production. The required quality for charcoal should be hard and the optimum size should be 50 to 100 mm in diameter.

(3) Quartzite and lime stone

Quartzite and lime stone are necessary materials to be used as flux for the promotion of slag formation. It is therefore recommended that a feasibility study should be made beforehand to make sure of their availability on an industrial scale somewhere near Moramanga.

(4) Industrial water

Industrial water will be used for cooling and other auxiliary purposes of the furnace, transformer and products. Particularly, for cooling of the furnace and transformer, fresh water — not sea water — will be required. Withdrawal of underground water near the plant site will be good for this purpose.

(5) Electric power

Power will be supplied from the proposed Andekaleka Power Station to the receiving transformer to be installed at the ferrochrome production plant and then to the furnace after step-down of voltage through the furnace transformer. Table-4. 7 shows estimated power consumptions.

(6) Electrode

Electrode has its own role of vital importance to transmit electric power to the furnace. Electrode paste to be used for this purpose should be of specific quality and should therefore be an imported article.

Unit and annual consumptions of all the aforementioned materials are as shown in Tables-4. 8 and 4. 9.

4. 4 Economic analysis of development project for ferrochrome production.

The profit and loss of this undertaking will depend largely upon increases or decreases of production costs. Care must be taken to minimize production costs in all instances.

In order to make an economical review and analysis of the project, in this Section, production costs are calculated as follows on the basis of the plant project referred to in the foregoing Section 4. 2 in addition to the investigated results of the availabilities of the various materials.

Production costs herein can be divided largely into direct and fixed costs.

4. 4. 1 Direct costs

Direct costs are such expenses as may be directly required for the production of ferrochrome, which consist of material cost, maintenance cost, operating cost and labour cost.

(1) Maintenance cost:

Maintenance cost is the expense incurred with regards to repair and maintenance. From the past experience it is allowed for about 1 % per annum of the capital investment.

(2) Figures shown as operating cost are also based upon past experience.

(3) Labour cost:

Labour cost includes salaries and wages for plant workers plus social welfare benefit expenses for such workers to be estimated at 20 % of wages.

(4) Expenses for technical assistant personnel:

A certain number of personnel will be required for technical assistance from the initial year of operation to the 4th year. Such expenses are included in direct cost in terms of special expenses. Table-4. 10 shows required personnel for technical assistance.

4. 4. 2 Fixed costs

Fixed costs are such costs as may be incurred irrelevant to production activities of the plant and include depreciation, general plant overhead and insurance premium.

(1) Depreciation:

Depreciation of assets will be made on the basis of 10 % residual value.

(2) Special depreciation:

This undertaking will require special expenses for commissioning prior to start-up operation of the plant as well as for feasibility study and job training for workers. Such expenses will be depreciated in terms of Special Depreciation in three years starting from the 2nd year of plant operation thru the 4th year. The list of trainees under the job training programme is as shown in Table-4. 11.

(3) General plant overhead and insurance premium:

General plant overhead includes fringe benefits for workers, social dues, environmental preservation cost, office and travelling expenses, analysis cost and chemical material cost and any other miscellaneous expenses, and its total per annum may be estimated to be nearly equal to the labour cost.

Insurance premium. is estimated on the basis of 240 FMG/ton of the product.

4. 4. 3 Production cost

Table-4. 12 shows an example of the normal operating condition of one single furnace producing 25, 000 tons annually in the 5th year. As shown in the right column of the Table power costs will account for about 21 % of total production cost. Although the calculated result obtained herein for production cost has been calculated to be 72, 000 FMG, the rough estimation may range from 68, 000 to 76, 000 FMG when such variable factors as unit consumption, unit cost and operating condition, etc. are taken into account.

4.4.4 Profit and loss account

Profit and loss account should include, in addition to production cost, accrued interest on invested and working capitals, administration expenses, sales costs and freight and warehouse charges, etc.

(1) Accrued interest on capital investment:

Interest is calculated at the rate of 8 % per annum.

(2) Accrued interest on working capital:

Working capital sums up 25 % of the annual total of material cost plus 25 % of the annual total value of production but excludes electric and industrial water charges. Interest rate is 8 %.

(3) Expenses for administration and sales:

Ferrochrome production will require a certain rate of fee for technical assistance and sales which will also incur some expenses in terms of commission fee.

(4) Freight and warehouse charges, etc.:

For export sales of porducts, both land and marine freight charges must be estimated from plant to railroad station and to port of shipment and from port to port of delivery. Marine freight is variable with unknown factors. Warehouse charge must also be taken into account at the port. The total of the expenses covering the foregoing items (3) and (4) is estimated herein at 43,000 FMG/ton of product, though the various expenses may be variable to some extent.

(5) Profit:

Profit to be gained will be the balance obtained after deduction from the total sales, the total costs covering the expenses as classified in the foregoing items (1) thru (4) in addition to production costs. Production costs are estimated at 72,000 FMG under the normal operating condition, but, as aforementioned, the estimation ranges from 68,000 to 76,000 FMG allowing for some possible variations in value of 4,000 FMG/ton of product. They are as shown in Tables-4.13 and 4.14.

In any circumstances it is certain that the undertaking will change from a loss to a profit in a few years after the initial operation of the plant.

4. 5 Economic effect of ferrochrome production and its world market

4. 5. 1 Effect from industrial development

Ferrochrome product is estimated, in terms of export value, to account for about 10 % of the future total export value of Madagascar, and is expected to play a major role in the obtainment of foreign currency.

As for job opportunities in the local community, the estimated total employees to be engaged directly in the production plan and indirectly in such associated businesses as production or transportation of charcoal and other materials, will be some 1,000 persons. Thus, the effect of this undertaking, upon the local community inhabitants, in increasing their level of income will be really remarkable.

In addition, as the largest consumer for the proposed Andekaleka Hydro Power Station, the ferrochrome plant will secure the establishment of the economical bulk power supply system when the power station will have been put into operation. This in turn will lure many other industrial plants and factories into the territory. Thus the ferrochrome plant, coupled with the proposed hydro power station, will substantially contribute much toward the industrialization of Madagascar.

Secondary industries will utilize the bulky raw materials and the power available thus aiding the economy. These industries will be able to produce new secondary products from the charcoal, quartzite and lime stone since cheap power will now be available.

Chrome ore is processed into ferrochrome and ferrochrome is used as an additive agent to steel. Large quantity of energy consumption is required for the processing of ferrochrome and is dependent on oil as fuel in many of the industrialized countries. In the light of the oil crisis experienced so far, the general tendency all over the world is to make efforts to conserve the limited oil resources and to save oil consumption as much as possible. In this sense, the proposed ferrochrome production project making full use of the abundant hydraulic energy resources available in Madagascar will result in much savings of energy costs.

4. 5. 2 World market for ferrochrome of Madagascar

Currently, it is difficult to make an accurate estimate of international market price for ferrochrome, since the price is on a floating trend. Table-4. 15 shows, as an example, the market prices quoted by the Union Carbide Co. of U. S. A. in the past few years, which are varied with many fluctuations.

As stated in the foregoing Section 4. 4. 3, the production cost is herein estimated at 72, 000 FMG, of which, power cost accounts for 21 %, or 3 FMG/kWh. Fig. -4. 8 shows a comparison between the real trend of world market prices and the estimated trend of ferrochrome production costs with variations of plus or minus 0. 8 FMG/kWh in power cost, equivalent to 4, 000 FMG/ton (plus or minus) of conversion. According to an estimate made as at the end of '74, the unit cost at a port of delivery of a consuming country is expected to come down gradually, starting from 169, 000 FMG in the first year, down to 132, 000 FMG in the fourth year, lower than the 136, 000 FMG quoted by Union Carbide in the middle of '74. This will fully assure commerciability of the undertaking. In the seventh year, when production is at its peak, the cost will further come down to 122, 000 FMG, thus making a profit of 10 % or more.

4. 6 Future problems for ferrochrome production

As stated in the foregoing Section, the project is highly evaluated and has a good chance of realization. However, in order to insure the success of the project, preparations must first be made to such an extent as stated below, and secondly, a closer relationship with any foreign countries able to extend their technical assistance must be built up. Listed below are further explanations:

(a) Since the project appears to be very prospective, a thorough feasibility study must be made prior to the implementation of the project.

(b) Supply system of charcoal to be used as the carbonaceous reducing agent, must be firmly established.

(c) Prior to the operation of the plant, part of the labour force must undergo a job training programme and technical assistance must be extended until the plant has attained the level of normal operating condition.

(d) As a part of the integrated development scheme for Moramanga Industrial Area, infrastructural improvements must be made with respect to the following items:

(i) Joint withdrawal and drainage system of industrial water.

(ii) Installation of a spur-track and paved service roads.

(iii) Installation of transmission line.

(e) Consideration must be given to promotion of the associated maintenance industries which can deal with mechanical, electrical and vehicle repair works.

Table-4.1 Comparative List of Proposed Sites for Ferrochrome Plant

Site / Item	A	B	C	D	E	F	Summary
Provision for Side-track	◎	○	○	△	◎	◎	B, C, and D require long distance portation. D needs railroad bridge construction to cross over Highway.
Access road	◎	◎	◎	△	◎	△	No problems for A, B, C, and E located alongside main road. D and F need much construction costs for access road.
Labour potential	◎	◎	◎	○	○	○	High density of population in A, B, and C.
Power trans-mission	○	○	○	◎	◎	○	Cost comparison for feeder line construction for power supply: A>F>B, C, D, E Transmission loss: compared as D>A, B>E>F
Industrial water	△	△	△	◎	△	◎	Adequate water supply available at D and F. Other sites far from water source, therefore costly.
Topography	◎	○	○	○	○	○	A, on flat ground, needs least land readjusting cost. B, C, D, and E on ground with rise and fall. F on flat ground with woods.
Geology	○	○	○	○	○	○	All sites have good geology for land reajustment with good foundation rock for plant building.
Construction cost	○	○	○	△	○	△	
General review & evaluation	◎	○	○	△	○	○	No difference between sites in construction cost. A, B, and C near Moramanga excel in living condition, but B and C near existing industrial zone are susceptible to pollution. A is free from pollution on wide-open plain, best in all respects.

Legend: A: site on north side of Moramanga Airport
B: site west of Moramanga industrial zone
C: site in middle point between Moramanga and Mangoro
D: Mangoro
E: middle point between Moramanga and Andasibe
F: Andasibe

Marks: Best ◎ Good ○ Fair △

Table-4.2 Ferrochrome Scale and Facilities Capacity

Capacity of Furnace Transformer		20,000 kVA
Power Factor x Load Factor		0.75
Load Capacity of the Furnace (20,000 kVA x 0.75)		15,000 kW
Furnace Operation Hours per year		7,500 h
Repair of Furnace		1,000 h
Electricity Consumption (15,000 kW x 7,500 h)		112.5 GWh
Unit Power Consumption		*4,500 kWh/T
Production	per Year (112.5 GWh ÷4,500 kWh/T)	25,000 T
	per Day (1 Day = 24 Hours)	80 T
	per Hours (1 Year = 7,500 Hours)	3.35 T

* Other Electricity Consumption 450 kWh/T

Table-4.3 Ferrochrome Production and Electricity Consumption

Year \ Item		Production		Electricity Consumption	
		Number of Furnace	Production (Ton)	Load (kW)	Consumption (GWh)
1	1981	1	15,000	16,500	84.8
2	1982	1	19,000	16,500	101.5
3	1983	1	22,000	16,500	112.8
4	1984	1	25,000	16,500	124.5
5	1985	1	25,000	16,500	124.5
6	1986	2	44,000	32,500	224.8
7	1987	2	50,000	32,500	246.3
8	1988	2	50,000	32,500	246.3
9	1989	2	50,000	32,500	246.3
10	1990	2	50,000	32,500	246.3

Table-4.4 Estimated Total Construction Cost

(Unit: 10^6 FMG)

Item	1st. Step	2nd. Step
Electric Furnace Furnace proper (lining inclusive) Power supply system Electrode system Cooling system Wastegas exhaust system Tapping system (drill mud gun) Raw Material charging system Electrical instrumentation Spare parts (holders etc.) Tapping and Casting area Ladles etc.	1,040	1,200
Raw Material handling Belt conveyer Hopper scale Crusher Instrumentation etc.	400	400
Product processing Cooling area Crusher Polishing equipment Conveyer etc.	240	240
Electric system Extra high tension system Furnace transformer Power & lighting equipment Other electric equipment etc.	480	400

Water service system Water tank Cooling tower and pond Pump and piping Air compresser and piping Heavy oil service system etc.	160	-
Machine & electrical work shop Vertical boring machine Arc welder, Gas welder and Spot welder Bending roller Shearing Forging equipment Hoist crane (2 ton) Vehicle workshop Machine tool for above etc.	160	-
Laboratory Analysis equipment (Carbon quantitative device, platinum crucible, Balance, Colorimeter, muffle furnace, PH meter etc.) Sampling equipment	80	-
Office etc. Office and clinic Senior staff housing o Change house Dining hall and restroom Guest house and store Bachelor's quarter etc.	80	-
Building above all plant fence and gate	560	440
Vehicles, truck scale etc. In-plant road	160	20
Dust collector etc. Park and green belt Plantation	80	50
Spare	560	250
Total	4,000	3,000

Table-4.5 Chemical Composition of Ferrochrome

JAPAN

Name	Grade	Chemical composition (%)				
		Cr	C	Si	P	S
High Carbon Ferrochrome	FCrH1	65 - 70	< 6.0	< 1.5	< 0.04	< 0.08
	FCrH2	60 - 65	< 6.0	< 2.0	< 0.04	< 0.08
	FCrH3	60 - 65	< 8.0	< 2.0	< 0.04	< 0.06
	FCrH5	55 - 60	< 8.0	< 8.0	< 0.04	< 0.05

U.S.A (Union Carbide Corporation)

Grade	Chemical composition (%)			
	Cr	C	Si	S
High carbon Ferrochrome	63 - 67	5 - 6.5	< 3	< 0.04
Charge chrome	65 - 70	5 - 6.5	1 - 2	

U.S.S.R

Group	Grade	Chemical composition (%)						
		Cr	C	Si			P	S
				L	M	H		
Carbon	Khr 4	65	4.1 - 6.5	2.0	3.0	5.0	0.07	0.04
	Khr 6		6.6 - 8.0					

Table-4.6 Chemical Composition and Content Ratio of Chrome Ore

Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO
45.48	16.50	4.43	14.02	10.26

Cr	Fe	Cr/Fe
31.12	12.83	2.43

Reference

(1) Size (fine)

(%)

Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	Cr/Fe
49.66	17.76	3.82	12.93	10.50	2.46
50.20	17.88	3.92	13.06	10.77	2.47
50.0	18.4	3.8	13.1	10.3	2.39

Mean values

Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	Cr/Fe
49.95	18.01	3.85	13.03	10.52	2.44

Source: NIPPON DENKO

(2) Size (lumpy)

(%)

Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	Cr/Fe
4.1	15	5	15	10	2.40

By sampling from "COMINA" ANKAZOTAOLANA ORE BODY

(3) Mean values of above (1)+(2)

(%)

Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	Cr/Fe
45.48	16.50	4.43	14.02	10.26	2.43

Table-4.7 Energy Consumption Schedule

Item	1 1981	2 1982	3 1983	4 1984	5 1985	6 1986	7 1987	8 1988	9 1989	10 1990
1st Furnace										
Average Load (kW)	12,500	14,000	14,500	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Operation Hour (h)	6,000	6,500	7,000	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Consumption (GWh)	75	91	101.5	112.5	112.5	112.5	112.5	112.5	112.5	112.5
Production (t)	15,000	19,000	22,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
2nd Furnace										
Consumption (GWh)	-	-	-	-	-	91	112.5	112.5	112.5	112.5
Production (t)	-	-	-	-	-	19,000	25,000	25,000	25,000	25,000
Other										
Load (kW)	1,500	1,500	1,500	1,500	1,500	2,500	2,500	2,500	2,500	2,500
Hour (h)	6,500	7,000	7,500	8,000	8,000	8,500	8,500	8,500	8,500	8,500
Consumption (GWh)	9.8	10.5	11.3	12	12	21.3	21.3	21.3	21.3	21.3
Total Consumption (GWh)	84.8	101.5	112.8	124.5	124.5	224.8	246.3	246.3	246.3	246.3
%	68	82	91	100	100	180	198	198	198	198
Total Production (t)	15,000	19,000	22,000	25,000	25,000	44,000	50,000	50,000	50,000	50,000

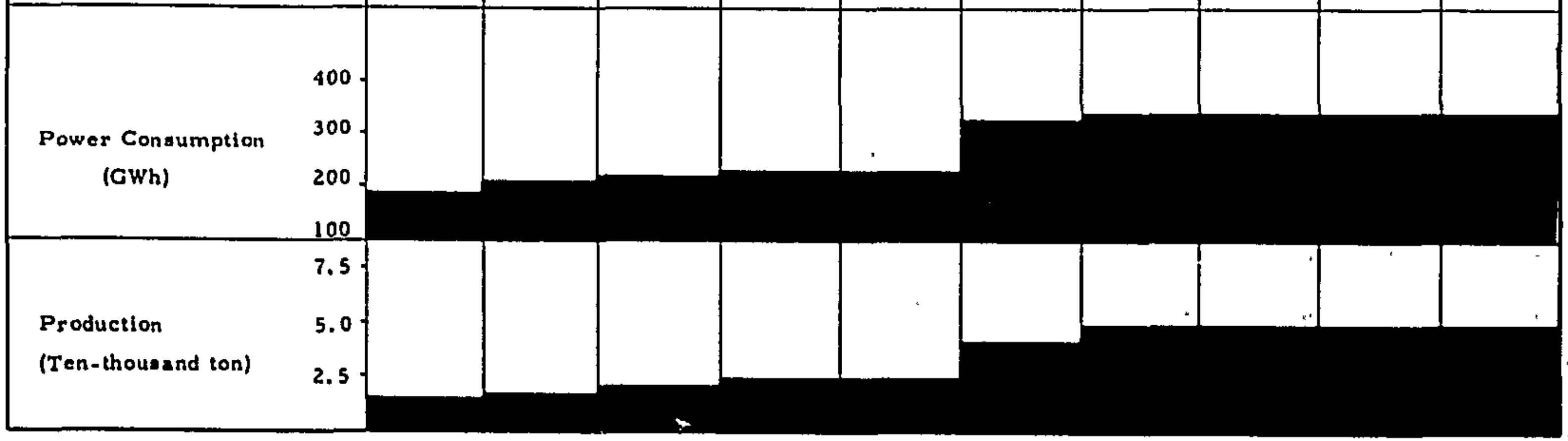


Table-4.8 Unit Consumption Schedule of Materials

Item	1981	1982	1983	1984	1985
	1st	2nd	3nd	4th	5th
(1) Chrome Ore	kg 2,500	kg 2,450	kg 2,420	kg 2,400	kg 2,400
(2) Wood Charcoal	850	800	770	750	750
(3) Quartzite	120	110	105	100	100
(4) Lime Stone	120	110	105	100	100
(5) Electrode Paste	50	45	42	40	40
(6) Electric Power	kWh 5,670	kWh 5,370	kWh 5,140	kWh 4,950	kWh 4,950
(7) Industrial Water	100^t	85^t	80^t	75^t	75^t

Item	1986	1987	1988	1989	1990
	6th	7th	8th	9th	10th
(1) Chrome Ore	kg 2,420	kg 2,400	kg 2,400	kg 2,400	kg 2,400
(2) Wood Charcoal	770	750	750	750	750
(3) Quartzite	105	100	100	100	100
(4) Lime Stone	105	100	100	100	100
(5) Electrode Paste	42	40	40	40	40
(6) Electric Power	kWh 5,140	kWh 4,950	kWh 4,950	kWh 4,950	kWh 4,950
(7) Industrial Water	79^t	70^t	70^t	70^t	70^t

Table-4.9 Annual Consumption Schedule of Materials

Item	1981 1st	1982 2nd	1983 3rd	1984 4th	1985 5th
Annual Production	15,000	19,000	22,000	25,000	25,000
(1) Chrome Ore	37,500	46,550	53,240	60,000	60,000
(2) Wood Charcoal	12,750	15,200	16,940	18,750	18,750
(3) Quartzite	1,800	2,090	2,310	2,500	2,500
(4) Lime Stone	1,800	2,090	2,310	2,500	2,500
(5) Electrode Paste	750	855	924	1,000	1,000
(6) Electric Power	GWh 85	GWh 102	GWh 113	GWh 123.8	GWh 123.8
(7) Industrial Water	Mt 1,500	Mt 1,615	Mt 1,760	Mt 1,875	Mt 1,875

Item	1986 6th	1987 7th	1988 8th	1989 9th	1990 10th
Annual Production	44,000	50,000	50,000	50,000	50,000
(1) Chrome Ore	106,550	120,000	120,000	120,000	120,000
(2) Wood Charcoal	33,950	37,500	37,500	37,500	37,500
(3) Quartzite	4,590	5,000	5,000	5,000	5,000
(4) Lime Stone	4,590	5,000	5,000	5,000	5,000
(5) Electrode Paste	1,855	2,000	2,000	2,000	2,000
(6) Electric Power	GWh 226	GWh 247.5	GWh 247.5	GWh 247.5	GWh 247.5
(7) Industrial Water	Mt 3,495	Mt 3,500	Mt 3,500	Mt 3,500	Mt 3,500

Table-4.10 List of Personnel for Technical Assistance

Job classification	1st Year	2nd Year	3rd Year	4th Year
	1981	1982	1983	1984
Manager	2	2	1	1
Engineer	2	2	1	1
Clerk	0	0	0	0
Skilled electrician	3	3	3	1
Skilled worker	9	6	3	3
Operator	0	0	0	0
Analyst	1	1	1	0
Maintenance man	2	1	1	0
Total	19	15	10	6

Table-4.11 Trainees for Job Training

Job	Number	Job	Number
Manager	1	General skilled Labour	3
Engineer	2	Operator	6
Skilled electrician	3	Total	15

Table-4.12 Production Cost of Ferrochrome

Item			Unite Consumption (Ton)	Unite Price (FMG)	Cost Per Ton of. Products (FMG)	Ratio %
Direct Cost	Mate-rials cost	Chrome Ore	2.4	8,000	19,200	27
		Wood Charcoal	0.75	8,000	6,000	8
		Quartzite and Lime Stone	0.2	3,200	640	0.8
		Electrode Paste	0.04	120,000	4,800	7
		Electric Power	kWh 4,950	3.0	14,850	21
		Industrial Water	75	2.0	150	0.2
		Sub Total			(45,640)	64
	Maintenance Cost and Operating supplies Cost				4,800	7
	Labor Cost				3,500	4
	Sub Total				(53,940)	(75)
Fixed Cost	Depreciation				14,200	20
	General Plant Overhead and Insurarce Premium				3,800	5
	Sub Total				(18,000)	(25)
Production Cost					71,940	100

Table-4.13 Profit and Loss Account

Unit: FMG

Item			
Sales Price (per Ton of products)		136,000	
Total Cost Per Ton of products	Production Cost	72,000	
	Interest on invested capital and working capital	14,870	
	General Administrative Expenses, Selling Administrative Expenses and Freight Warehouse charge etc.	43,000	
	Total	129,870	
Total Cost ± 4,000 (FMG)		125,870	133,870
Profit (befor Tax, per Ton of products)		10,130	2,130
Annual Profit (25,000 Ton)		253,250,000	53,250,000

Table-4.14 Profit and loss Account of Each Year

Year	Volume of Production sold (Ton)	Total Cost (FMG)	A		B	
			Profit (10^3 FMG)	Total (10^3 FMG)	Profit (10^3 FMG)	Total (10^3 FMG)
1981	15,000	169,218	▲438,280	▲438,280	▲558,280	▲ 558,180
1982	19,000	151,437	▲217,266	▲655,546	▲369,266	▲ 927,546
1983	22,000	140,688	▲ 15,109	▲670,655	▲191,109	▲1,118,655
1984	25,000	132,803	180,200	▲490,455	▲ 19,800	▲1,138,455
1985	25,000	129,870	253,250	▲237,205	53,250	▲1,085,205
1986	44,000	128,058	526,443	289,238	174,443	▲ 910,762
1987	50,000	122,438	859,577	1,148,815	429,577	▲ 481,185
1988	50,000	122,438	879,909	2,028,724	478,909	▲ 2,276
1989	50,000	122,438	879,909	2,908,633	478,909	476,633
1990	50,000	122,438	879,909	3,788,542	478,909	955,542

Note: A = Total Cost - 4000FMG
B = Total Cost + 4000FMG
▲ : Deficit

Table-4.15 Market Price of U.C.C

Year	U.C.C Market Price	Notes
1970	¢ 23.6	Cr/lb
1971	23	
1972	20	
1973	20	
1974	42	

Fig-4.1 Ferrochrome Plant

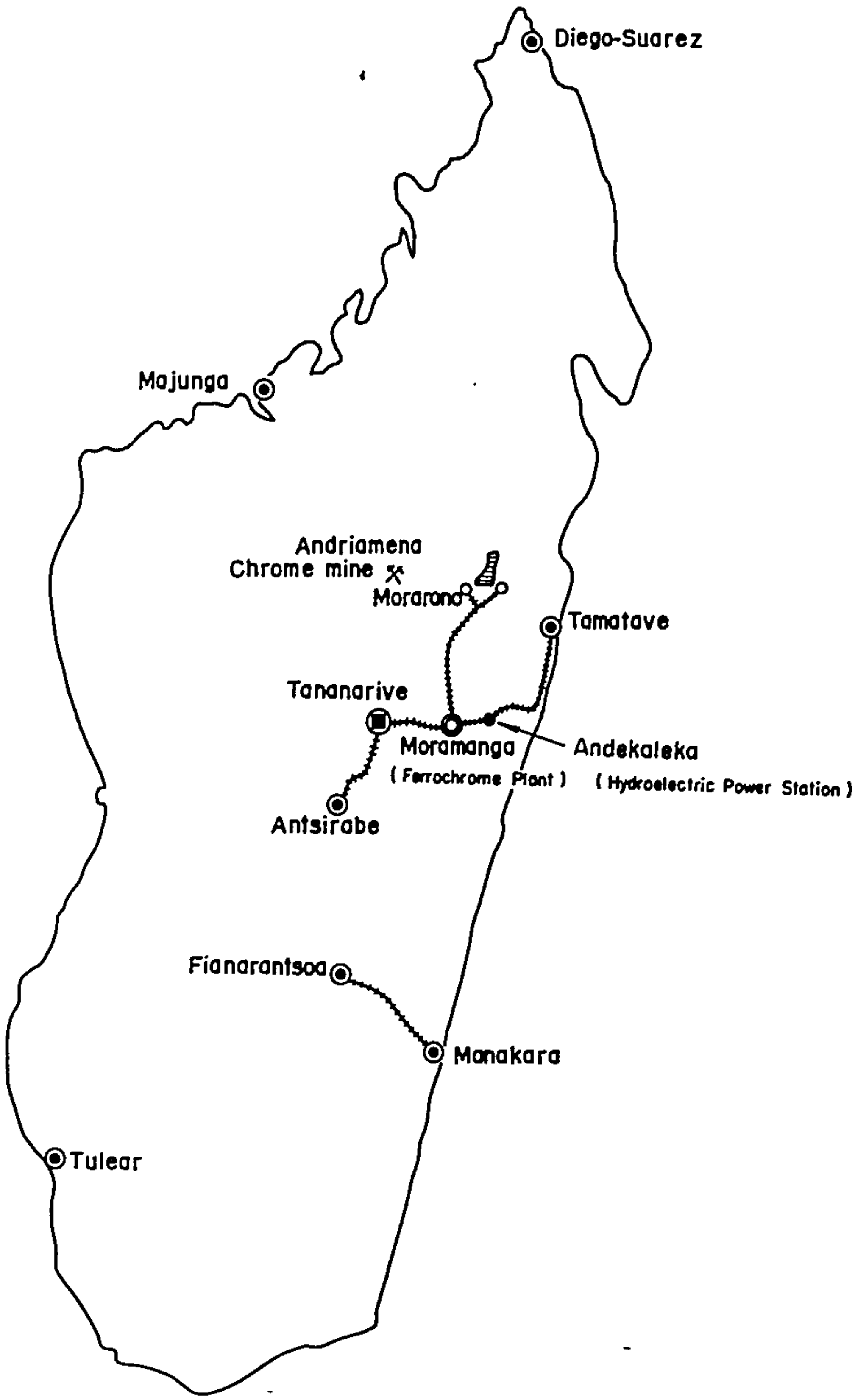
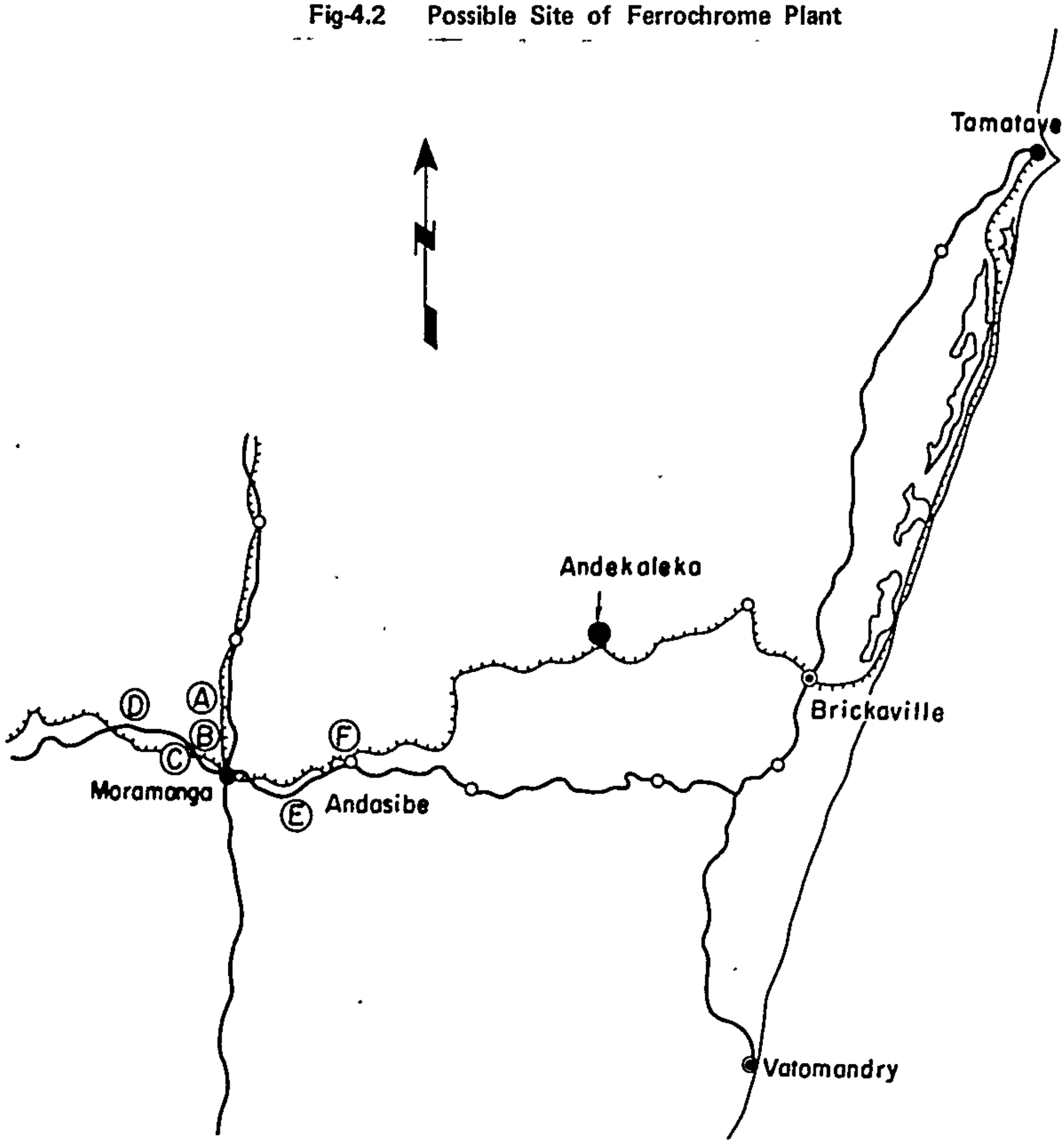


Fig-4.2 Possible Site of Ferrochrome Plant



Ⓐ North Side of Moramanga Airport

Ⓑ West Side of Moramanga Industrial Area

Ⓒ Site between Moramanga and Mangoro

Ⓓ Mangoro

Ⓔ Site between Moramanga Andasibe

Ⓕ Andasibe

Fig-4.3 Ferrochrome Plant Site

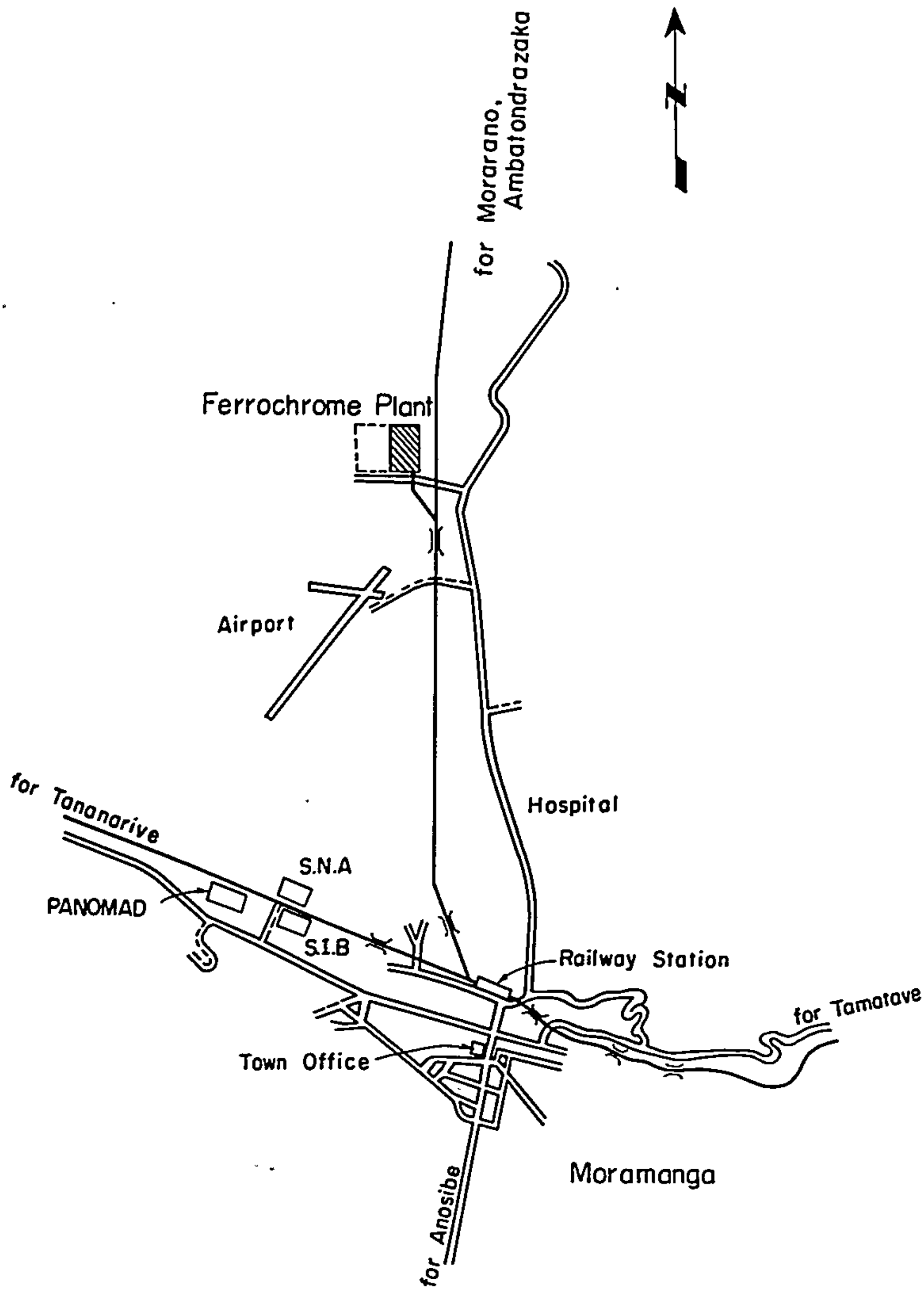


Fig-4.4 Arrangement of Ferrochrome Plant

Area 170,000 m^2 (500x340m)

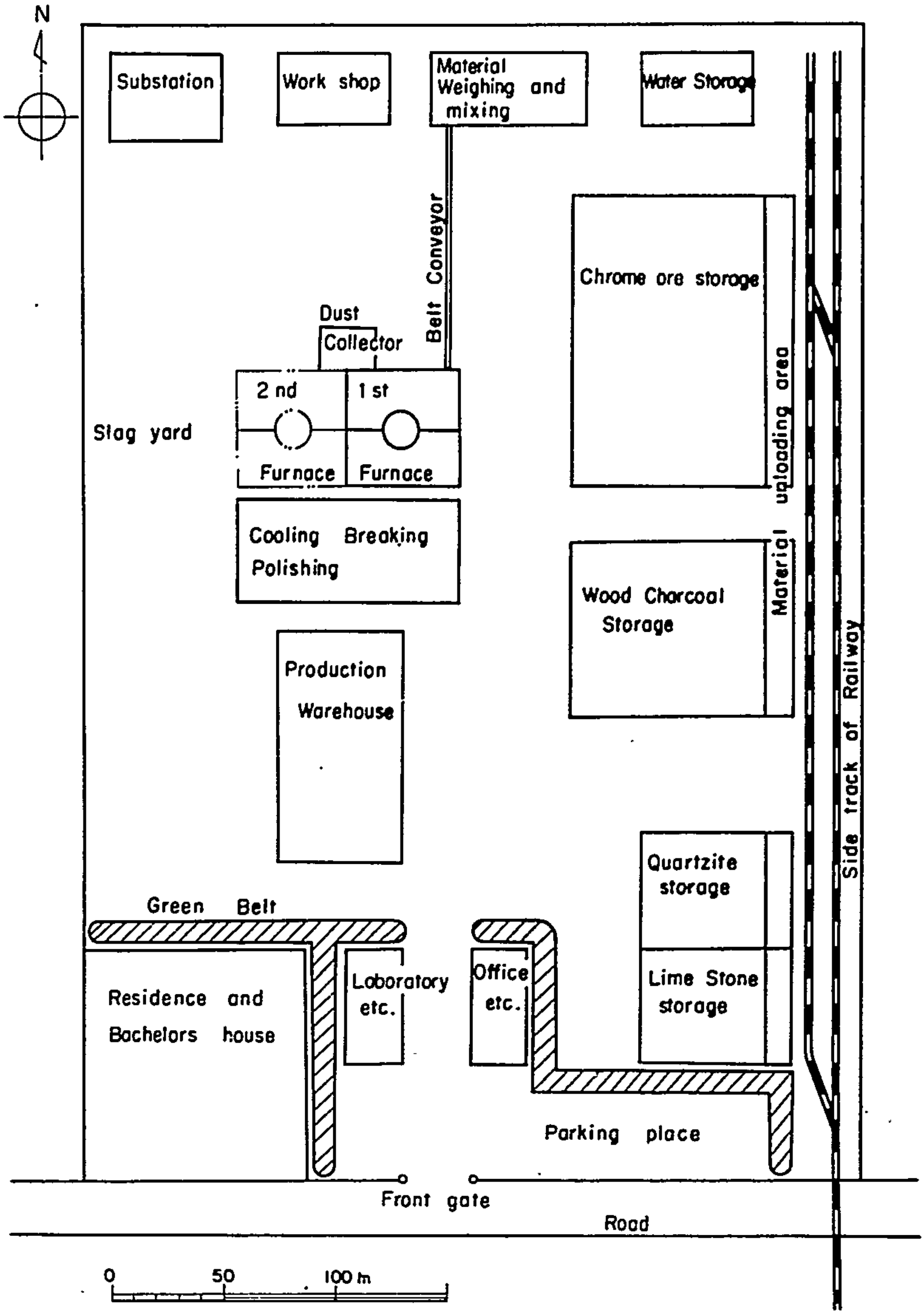


Fig-4.5 Section View of Electric Furnace

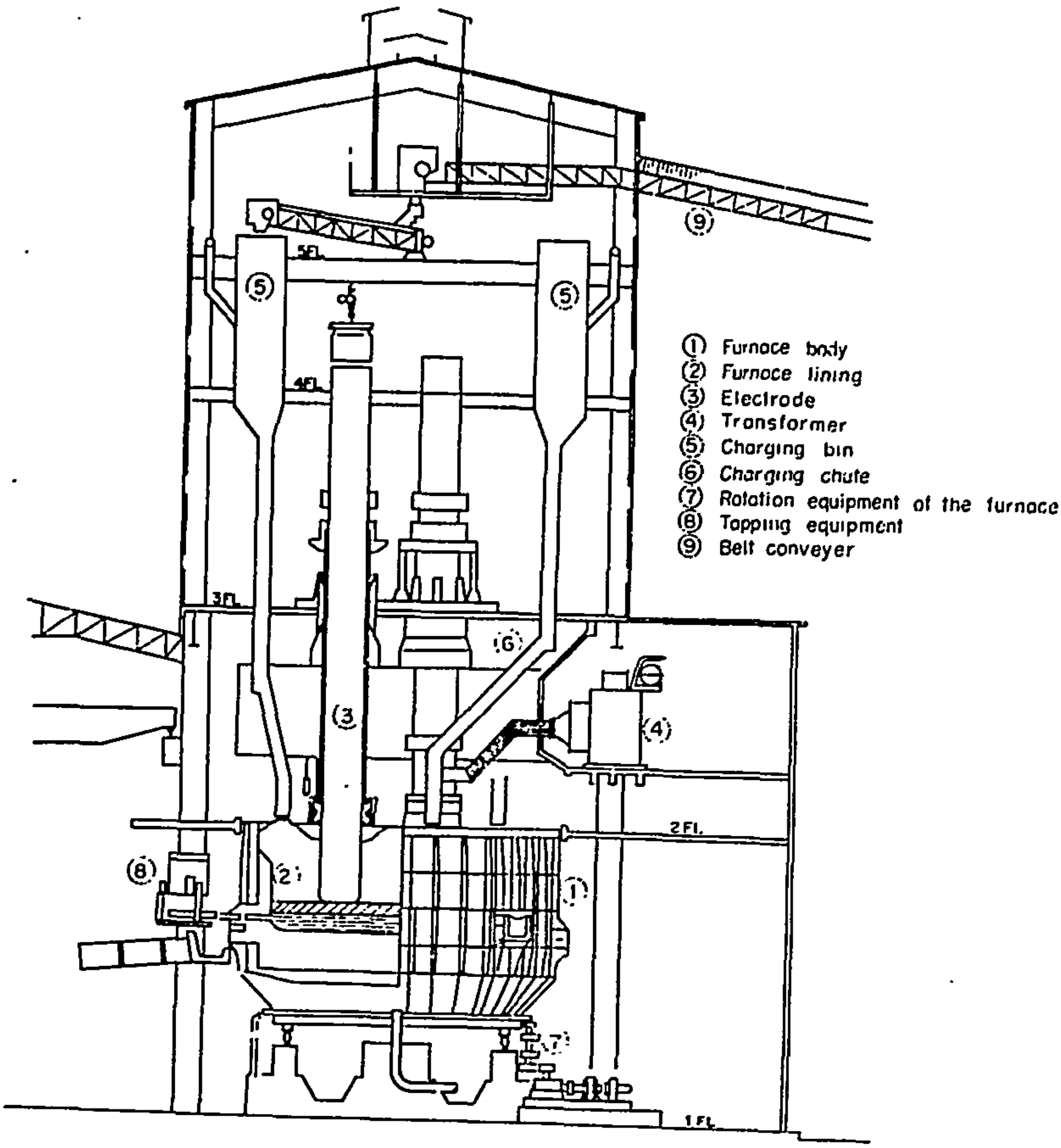


Fig-4.6 Flow Chart of Ferrochrome Processing

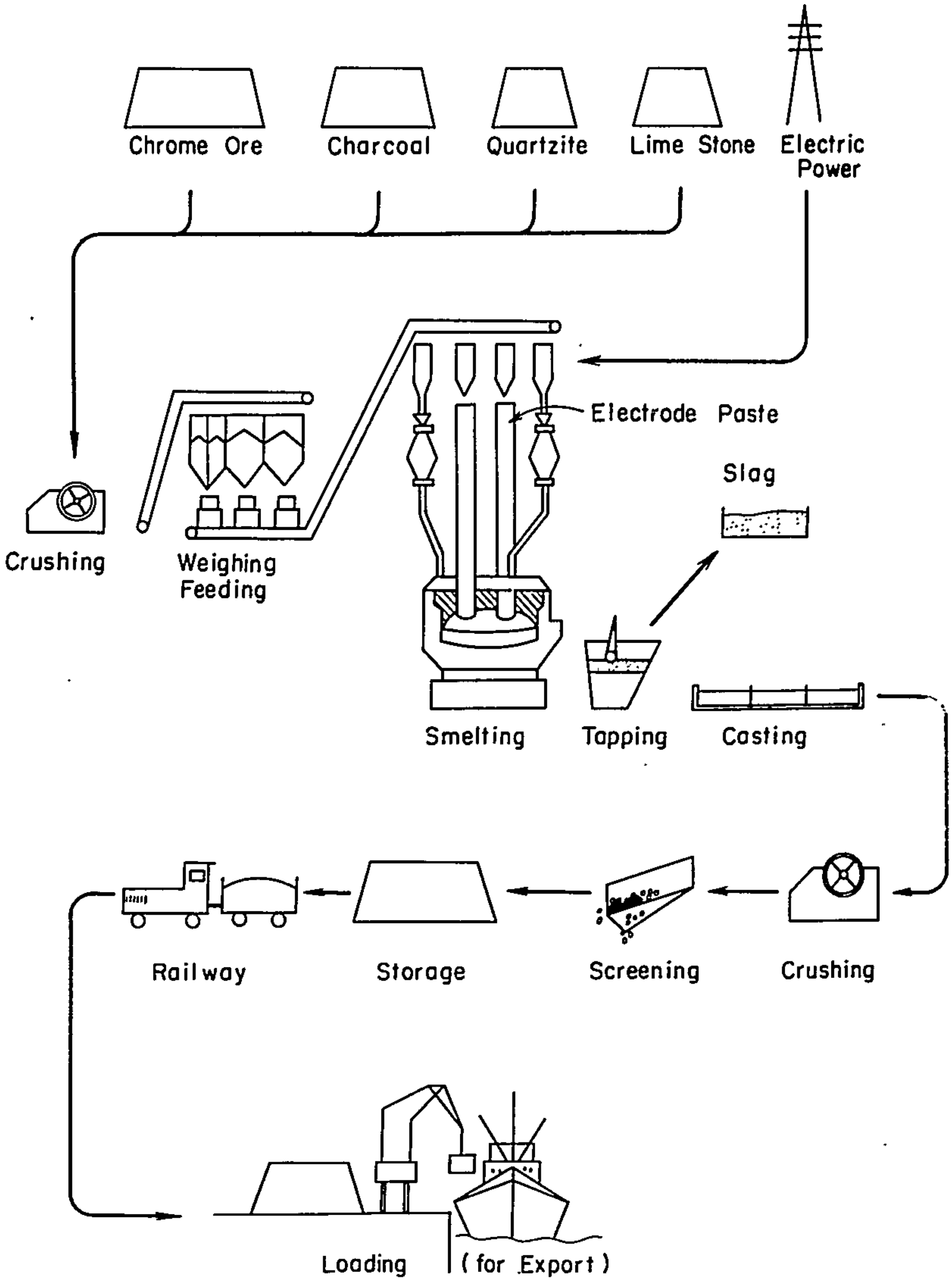


Fig-4.7 Ferrochrome Production Plant Flow Chart

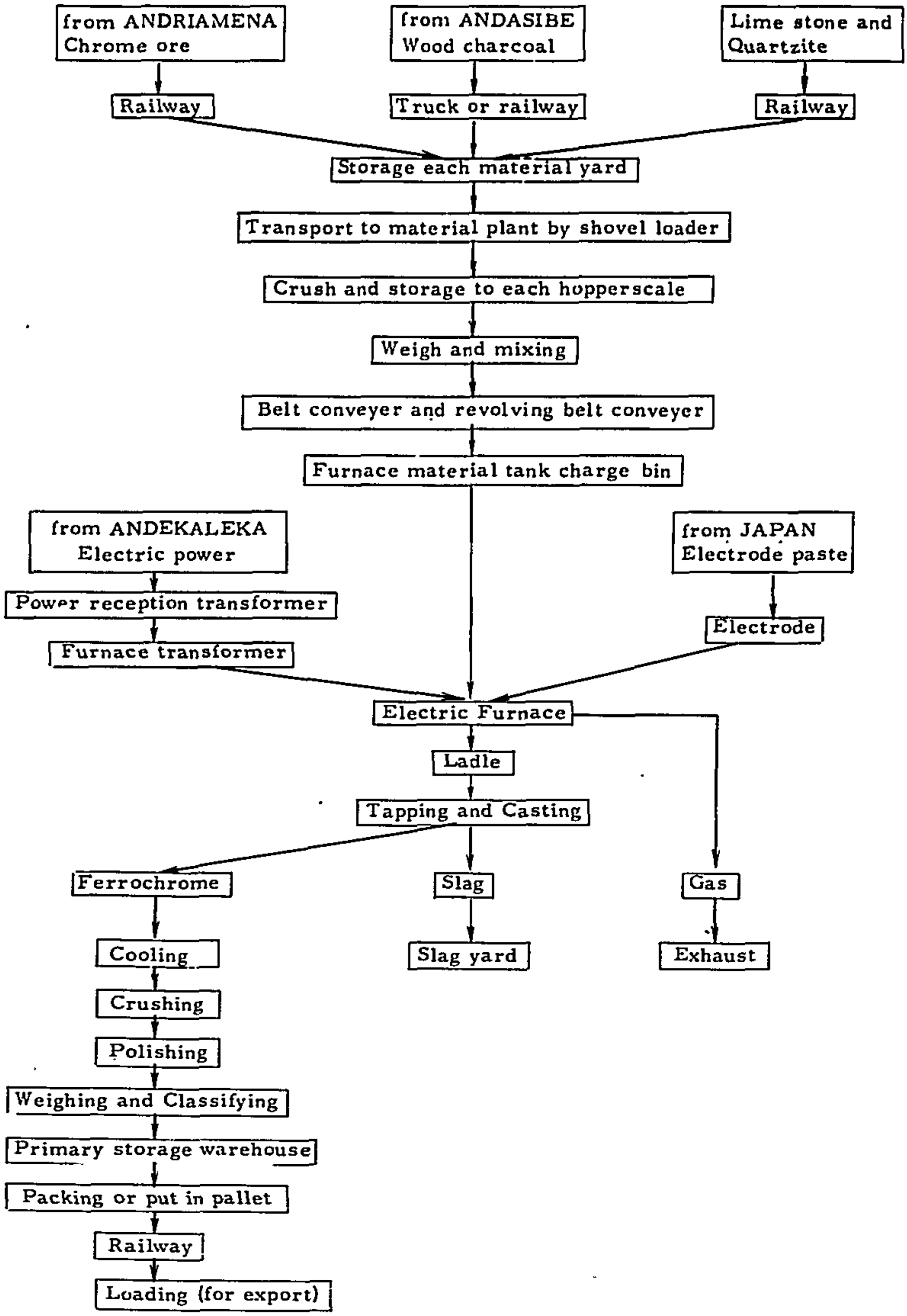
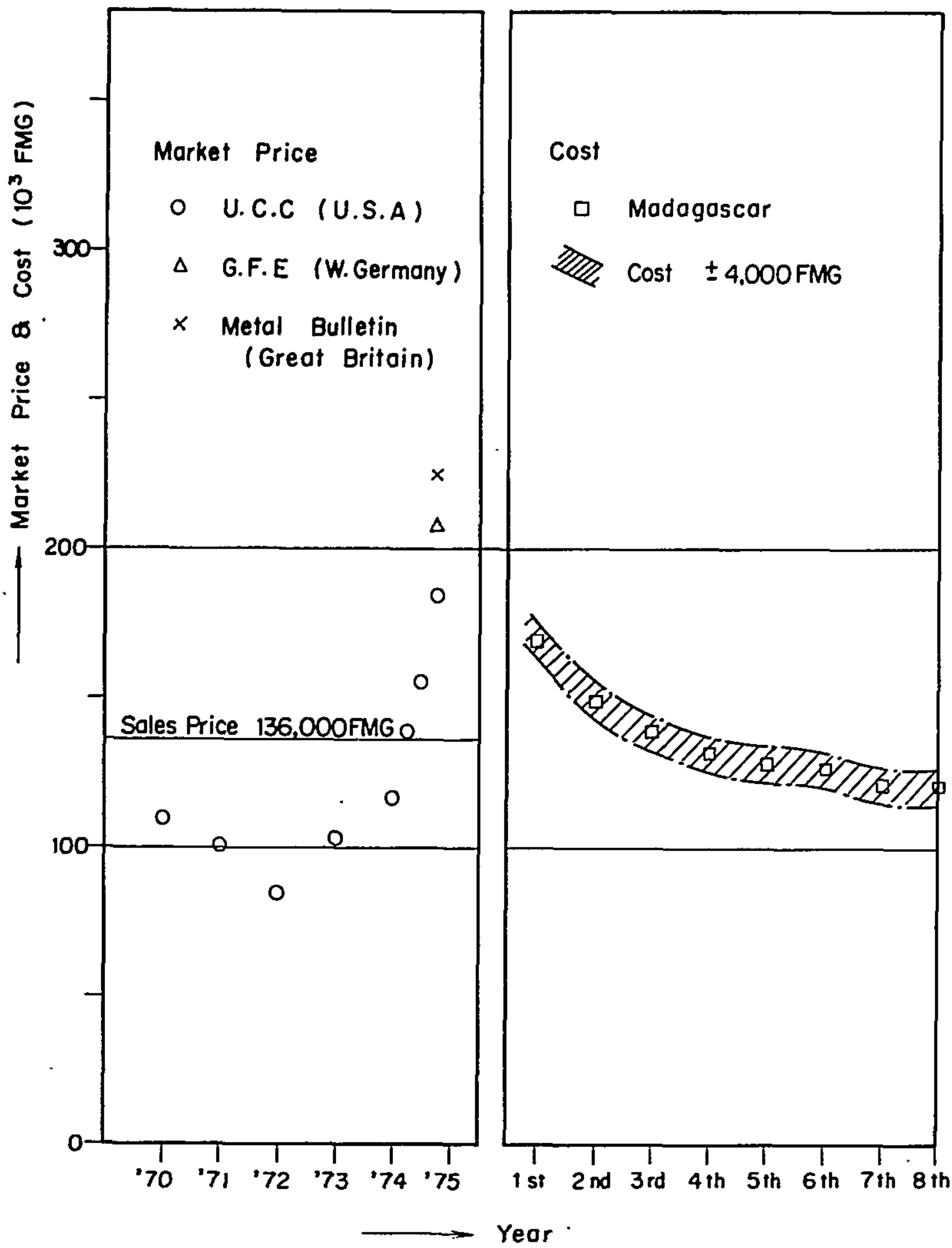


Fig-4.8 Market Price and Cost (High-carbon Ferrochrome)



Chapter 5.
Basic Guideline for Andekaleka Hydro Power Project

Chapter 5 Basic Guideline for Andekaleka Hydro Power Project

5. 1 General site information

5. 1. 1 Profile of Vohitra River

From its source in the highlands of Ankay at 1, 200 m altitude level, the Vohitra River flows southward through the marsh land of Ankazahoto, a drop of 300 m. In turns eastward after joining the Sahatandra River at about 3. 5 Km upstream of Andekaleka, flows into the Rianila River at Anivorano about 70 Km downstream and at Brickaville it flows into the Indian Ocean.

Collecting precipitation of 1, 000 mm in the upstream and 3, 000 mm in the middle-stream on an annual average over the 2,630 Km^2 catchment area, the Vohitra has tremendous potential for hydro power. With an affluent flow over a gross head of 1, 200 m and a stream course length of about 140 Km, the river has many exploitable sites for power generation.

On studying a topographic map the river appears to have the following topographic features:

On the upstream in the Ankay highlands, the precipitation over the area of its origin is utilized for watering the farm lands and is stored in a reservoir at Ankorohotra. Here at Ankorohotra the stream flow could be adjusted annually or seasonally when utilized for energy production in the future. On the middlestream near Mozoina and Andekaleka, there are potential sites for large-scale hydroelectric power development projects utilizing the high head available. On the downstream, at or near the 80 m altitude level, it is possible to develop a power generating source with low head and large discharge, combining this with irrigation usage for the rich and vast coastal plain along the Indian Ocean. The river has many exploitable potentials differently featured by each of its upstream, middlestream and downstream. (Fig. -5. 1)

5. 1. 2 Outline of Andekaleka site

The idea of harnessing the river flow of the Vohitra for hydro power generation is not new, and investigations have progressed so far with much interest. Particularly, the site at Andekaleka provides the most suitable conditions for hydroelectric power development with a high head available in a relatively short length of waterway and its situation on the rapid and meandering stream of the Vohitra River.

In addition to the above, there is another advantage in that the site is conveniently located near the railroad, while the other proposed hydro power sites are located in remote mountainous areas. For this reason, it has long been drawing people's attention as the most suitable site for hydro power development, and extensive studies and investigations have been in steady progress for years. In 1972 a summary of the schematic plan on the project was made by E. D. F as follows:

Major Factors Proposed by E. D. F

	1-stage development plan
Catchment area at intake	1,884 Km^2
Annual available gross discharge	1,295 x 10^6 m^3
Gross head	236.4 m
Effective head at maximum discharge	211.6 m
Maximum discharge	45 m^3/s
Maximum output	80.5 MW
Annual average capable energy production (on-site)	649 GWh

Fig. -5. 2 shows the general outline of the aforestated scheme.

In 1973, as the alternative to the E. D. F's proposal planned for the 1-stage development, the NEWJEC newly proposed its own drafts of an aqueduct-crossing over the Sahantsiva River and the 2-stage development plan, as outlined in Figs. -5. 3 and 5. 4. In 1968, several years before the study made by the NEWJEC, the Motor-Columbus, on behalf of the United Nations Special Fund was in charge of a study mainly in regard to the supply of electric energy to a silico-chrome processing plant.

5. 2 Hydrology and geology

5. 2. 1 Profile of catchment area

The total area of the catchment at intake covers 1,884 Km^2, being comprised of swampy land and flood plain in the central highlands and the thick forest zone in the middlestream basin. In the catchment area, the annual average rainfall is no more than 1, 200 mm in the west, while it reaches as much as 3, 000 mm at an intake located in the east. Rainfall is greatest in the months from November to April and the months from May to October is the dry season. The area is under the influence of cyclonic belt of the Indian Ocean, and in March of 1959 the whole area was "attacked" by a cyclone bringing with it heavy rainfall. There are 16 rainfall observatory stations, as indicated in Fig. -5. 5, serving the whole catchment area. The oldest rainfall observation station is the Moramanga Station whose monitoring activity was initiated in 1931. Others are as shown in the annexed Table-A.5.1.

A rainfall observatory station is also located in Andekaleka 2. 6 Km upstream of the proposed intake site with a catchment area of 1, 873 Km^2. Monitoring activity and recording have been carried out since 1948, except for the periods of '49 - '52 and '67 - '68. Data on monthly rainfall and on daily and monthly flow, are shown in the annexed Table-A. 5. 2. thru A. 5. 4.

5. 2. 2 Characteristic of catchment area

Shown below are the characteristics of the catchment area as given by the flow-recording data available after 1948, and Figs. -5. 6 and 5. 7 show hydrograph of monthly average flow and discharge duration curve.

Average discharge for '48 - '72 period	71. 3 m^3/s
Specific discharge	38 $l/s/Km^2$
Lowest droughty water discharge	15. 7 m^3/s
355-day discharge	27. 4 m^3/s
275-day discharge	41.4 m^3/s
Annual average gross discharge	2, 249 x 10^6 m^3

5. 2. 3 Estimated high-water discharge

According to the record available from the flow observatory at Andekaleka, monitoring since 1948, the highest flood discharge occurred on March 27th, 1959 with the average discharge of 2, 020 m^3/s and the peak discharge of 3, 950 m^3/s. The estimated high-water flow for the veturn period attained from probability calculations is as shown in Table-5.1. The figures indicated in the Table are based upon additional use of the data recorded in 1972, after review of its applicability to the results that the E. D. F obtained by Pearson III Method from the '48 - '71 recorded data.

Table-5.1 Return Period and Flood Discharge

Return Period (year)	Average high-water discharge (m^3/s)	Peak high-water discharge (m^3/s)
2	470	900
10	1, 365	2, 600
100	2, 670	5, 100
1, 000	3, 980	7, 500
10, 000	5, 290	10, 000

Peak high-water discharge is calculated herein from the obtained ratio (1:1.9) of average versus peak flow rate in the flood recorded on March 27th, 1959.

Since the value of peak discharge naturally becomes an important factor to the estimated high-water discharge, the figure of 7, 500 m^3/s at its peak on a 1,000-year return period is used, for which the specific discharge is 4. 0 $m^3/s/Km^2$.

5. 2. 4 Estimated high-water level

The relationship between water level and discharge at the proposed sites for construction of an intake, a power station and an outlet on the Vohitra River is herein defined from the relevant data* available from S. E. M, in which an estimate is based upon the correlation of the water level measured at such sites versus that monitored at the Andekaleka observatory.

On the other hand, the water level of the flood experienced in the past is estimated from the traceable marks remaining at the site. Fig. -5. 8 shows such relations between water level and discharge at each proposed site. Table-5. 2 shows high-water levels after construction of facilities. Along the valleys of the Sahantsiva River and the Sahalimoina River, the tributaries of the Vohitra River, there are some proposed sites for a semi-underground power station and an outdoor switchyard. Also proposed are access roads and a stockyard for construction materials.

* Science de la Terre: La Vohitra a Andekaleka (Rogez) Campagne 1970 - 1971, Decembre, 1971.

Therefore, in order to protect such permanent or temporary facilities from flood damage, necessary arrangements for flow marking and rainfall gauging must be made quickly so that necessary information for water level and discharge may be obtained.

Table-5.2 High-water Level by Zones

Zone	Water Level
Zone A	EL.364.2
Zone B	EL.213.5
Zone C	EL.131.4

5.2.5 Engineering geological survey on proposed Andekaleka site for Hydro Power Station

(1) General geology

The rocks being distributed over the Andekaleka site are quartz gneiss, amphibole gneiss, igneous dyke rocks, laterite, and quaternary deposits.

The quartzose gneiss and amplibole gneiss form the foundation rocks of this area, and the igneous dyke rocks exist sporadically as dyke among the foundation rocks. These rocks are exposed along the banks of large and small rivers and at railroad cuttings. The laterite, product of weathering of gneiss rocks, is found extensively on the hill slopes. The quaternary deposits, consisting of river terraces, talus deposits, and surface soil, are found distributed over the hill slopes covering the laterite and the foundation rocks. The river bed is sporadically covered by quaternary sand and gravel.

The quartz gneiss being composed of quartz, mica, and feldspar, is comparatively hard and compact, of lithic character, and rich in cleavage along schistosity plane. The amphibole gneiss being composed of amphibole, feldspar, and mica, is compact but not so rigid as the quartz gneiss.

The difference in the physical properties of both rocks is evident from the study of the borings executed in this area. There is a lower percentage of core recovery in amphibole gneiss in comparison with that of quartz gneiss. Further difference is evident from the data obtained from the uniaxil compressive strength tests with core samples of both rocks as shown in Table-5. 3.

Table-5.3 Comparison of Strength between Quartz gneriss

Kind of rock sample \ Dip angles of sample (α)	Strength of rock samples in miscellaneous dip		
	$\alpha = 90$ Bar	$\alpha = 60$ Bar	$\alpha = 0$ Bar
Quartz gneiss	1,250	800	1,450
Amphibolgneis	1,000	500	1,250

Note: (α) is dip angle of schistosity plane of core samples.
The test stress was applied vertically.
(Source: E.D.F Report, 1972)

The laterite is divided into reddish brown and pale yellowish brown laterites. The reddish-brown clayey laterite is derived from the weathering of the pale yellowish-brown sandy laterite. As a result there remains little texture of gneiss. On the other hand, the pale yellowish-brown sandy laterite is a result of heavy weathering of gneiss, therefore, it is somewhat sandy, leaving a little texture of gneiss and containing some large rounded boulders or cobbles resulting from exfoliation in the process of weathering of gneiss. The sandy laterite may be stronger in its bearing capacity and more permeable than the clayey laterite.

The river terraces consist of sand, gravel, and silty materials. The terraces are found here and there, covering the top surface of flat ground on both banks of the Vohitra River and its tributaries. On these flat grounds, the relics of river terraces are used for banana and coffee plantations and for settlement.

The talus deposits being distributed sporadically at the base of the hill slopes are mainly composed of reddish-brown clayey materials and debris of gneiss rocks.

Sand and gravel over the river bed are generally of a thin layer except several places in a river bottom where large accumulations are found. In the youthful tributaries, characterized by their narrow width, a large portion of the river bed is often filled up with debris or large blocks of rock which is the result of mechanical weathering of the gneiss rock on the slopes.

In order to grasp the complete geological structure of this area, strikes and dips of schistosity and joint planes of outcrops of railroad cuttings and in zones A, B, C, D, were studied statistically with the use of a schmidt net. The results are illustrated in Fig. -5. 9 and Fig. -5. 10 respectively. According to the Figures, dominant strike and dip of schistosity and joint planes are as follows:

Schistosity plane :	N6° W/85° SW
Joint plane :	N69° E/80° SE*
	N76° W/85° SW***
	N6° W/80° NW*
	N61° W/20° NE**
	N39° E/25° NW***

The river courses of the Vohitra and its tributaries or the direction of fault are partially subjected to the strike of schistosity or joint planes, but the aero-photographic observation reveals that they appear slightly oblique somewhere.

There are small-scale localized foldings in the gneiss rock, but they have no significant effect upon the geological structures of the foundation rocks. Faults which may be deemed to be largely related to the geological structures have not been found during the reconnaissance survey of railroad cuttings and Zones A, B, C, D. However, the fault along the Sahantsiva River was recognized by the inclined boring (B4) executed by E. D. F in 1970, and in Zone C the other NEE trending fault along the Sahamamy River is assumed to be morphological.

According to the map annexed to the E. D. F report, there are a few morphological lineaments trending NWW, NE, EW. Some of them will coincide with the direction of actual faults or of assumed faults.

*** first class
** second class
* third class

(2) Engineering geological conditions of Zone A

Zone A includes the sites for a low intake dam on the Vohitra and an intake or intake shaft which will be provided for in either the 1-stage or 2-stage development project.*

The rocks which will compose the proposed dam and intake sites are quartz gneiss and amphibole gneiss These rocks alternate each other with different thickness in the strata. These gneiss rocks run from N20°E, and inclinate 75° - 85° toward southeast. There are ditches, 2.0 - 5.0 m in width, developed here and there in the river bottom with similar strike of gneiss rocks.

These ditches seem to be developed by differential erosion of running water in parts of amphibole gneiss layer, because amphibole gneiss is softer and weaker than quartz gneiss in its physical properties. These phenomenon were clarified by boring A6 excuted by E. D. F. Owing to the development of such a group of ditches the river course of the Vohitra is fully concordant with the strike of schistosity plane of gneiss.

(a) Dam site

The proposed height of the concrete dam is about 5 - 8 m from its foundation rock, whereby the stress from the dam structure to the foundation rocks is estimated at about 2 kg/cm^2. The foundation rocks are strong enough to sustain the load of the dam as realized from the values obtained by uniaxial tests of boring cores described earlier.

On the other hand, leakage along schistosity plane must be taken into consideration, because the direction of schistosity is perpendicular to the axis of the dam. However, this problem can be settled easily by the use of curtain grouts to the depth of 5 - 7 m placed in interlocking pattern in the foundation rocks.

---

* 1-stage development: Dam to be sited at Zone A, and power station at Zone C, or at Zone A.

  2-stage development: Dam to be sited at Zone A, No. 1 Power Station at Zone B, and No. 2 Power Station at Zone C, No. 2 Power Station is supplied with discharge water from No. 1 Power Station and the river water to be withdrawn by a low dam constructed on the Vohitra River.

The most important thing to know before the dam is to be constructed is to know exactly the situation and depth of the ditches in the river course. Such ditches had already been pointed out by the E. D. F in 1972. However, at the construction stage of the dam more precise exploration by boring over the whole dam foundation area is most desirable, because these ditches must be replaced by concrete.

In excavating the dam foundation, care must be taken to make smooth the excavated surface for the purpose of preventing possible concentration of stress to the sharp edge of excavated gneiss. Because the gneiss rocks are easily broken along the schistosity plane but not easily broken perpendicular to the schistosity planes, sharp ridges are formed on the rock surface as a natural course of event.

To make smooth the excavated surface, the method of blasting must be restricted to some extent. This restriction will facilitate the smoothing out of the excavated rock surface and also prevent segregation of rock masses along schistosity planes. The prevention against segregation of foundation rocks will contribute toward diminution of consolidation grouting.

On the right bank of the Vohitra, there are a series of exposed gneiss rocks. Because of their lithic characteristics these rocks are hard, therefore, no problem will arise from abutting a dam on these rocks.

On the left bank, the height of exposure of the foundation rocks above the water level is less than one meter, and these exposures do not extend for a long distance in horizontal direction. Above these exposures, there are thick deposits of large blocks of gneiss and surface soil. The thickness of these deposits is estimated to be 5 m or more in vertical direction.

The existence of deposits of this kind was already recognized by the E. D. F exploration in 1972. Therefore, the abutment of the dam should be settled deep within the valley wall. For deep excavation in the valley wall, care must be taken for a possible slide of thick, unconsolidated overburden from the hill slope. Precise explorations of the depth of the overburden are desirable.

(b) Intake, intake shaft, and underground power station site

No problems are anticipated in the construction of the intake as planned for in the 2-stage development project. The reason is that a series of outcrop of foundation rocks are observed in the neighbourhood of the site and its quality is good. There is no risk of sliding of the overburden, although there is a little fear for sliding of rock masses separated by the joint forming a sliding plane. Since excavation is not on a large scale, such sliding of rock mass may easily be protected by rock bolts, even if it should occur during excavation.

For construction of the intake inclined-shaft, the geological condition will not differ so much from that of the intake.

(c) Underground power station site

The geological condition of the proposed underground power station site was examined from the data of boring AP executed by E. D. F in 1970. The data reveal that there is only one clayey portion in the depth between 160. 65 and 162. 53 m, and neither fractured nor sheared layers are found in the other layers.

Judging from above data, it seems highly possible to construct a large underground power station. Nevertheless, in past experience of constructing large underground power stations it was found that various geological problems were common occurances. Therefore, it is advisable to drill more exploration boring at the proposed site in advance of the implementation of the project, so that any problem that might arise from geological defects may be of a minor nature or avoided altogether.

(3) Engineering geological conditions of Zone B

Zone B includes the proposed sites for the No. 1 Power Station and the intake dam on the Vohitra under the 1-stage development plan and also the site for the aqueduct, or conduit tunnel below the Sahantsiva River,under the 2-stage development plan.

The Vohitra River changes its direction of flow from NS to NE at the junction with the Sahantsiva. This abrupt change of the river course is due to the restriction caused by schistosity and joint planes of gneiss; that is to say, from the junction upstream, the course must have been restricted by the direction of schistosity plane and from the junction downstream, the course must have been restricted by the direction of joint plane. The general direction of the Sahantsiva is N20° E and the lineament of this river seems to extend to the Vohitra on the downstream side of the point of junction. According to the data and observation core samples available from inclined boring B4 on the left bank of the Sahantsiva, there are remarkably cracky or fractured layers between the depth of 48. 15 m and 61. 45 m. Therefore, the above-mentioned lineament may correspond with a fault line as already pointed out by the E. D. F report.

(a) Surface power station

The power station is proposed on the tableland to the west of the junction of the Vohitra and the Sahantsiva Rivers. This tableland is a river terrace composed of sand and gravel.

The foundation rocks are gneiss. The strike and dip of schistosity plane are N10° E/80° SE. The thickness of terrace gravel is estimated at about 5 - 8 m. As the thickness of the river terrace becomes thin at the foot of the hill slope in the hinterland of the power station site, sandy clay, derived from weathering of laterite, and very cracky amphibole gneiss cover the foundation rocks.

According to the data and observation of B3 boring cores, the total thickness of these layers is about 11.20 m.

In order to construct a surface power station at the proposed site, the above mentioned layers must be excavated out so that the power station may be settled on the good foundation rock. In excavating such thick deposits, the hill slope on the back side of the power station will have to be excavated to a considerable depth.

Since the hill slope is densely covered by laterite, there is a fear of causing slides of the unconsolidated layers. Traces of sliding of these layers is observed here and there along railroad cuttings, and the most conspicuous one is located between P.K.203. 360 and P. K. 203. 287 Km. Such landslides seem to have taken place within recent years, judging from the conditions that the railroad embankment leaves a new mark of recovery. The slided cliff is about 50 m in height, 73 m in width and 10 m in depth; the total volume of the slided mass can then be estimated at about 18,000 m^3 above the railroad and the slide extends below the railroad.

When such extent of slides is added, the whole volume of slided mass will be twice as much as the estimated volume of the above.

In order to eliminate the danger of sliding which might arise from deep cutting of the hinterland hill slope of the proposed power station site, the power station must be situated further east closer to the present course of the Sahantsiva River. If this is done, however, there would be very little space left for the construction of a power station.

Another problem involved is the existence of a fault on the foundation rocks as aforementioned. As observed from B4 boring core, the fault is composed mainly of very cracky or fractured rocks and there is very little clayey or clay material. Therefore, it would not be so difficult to improve the zone by consolidation grouting. However, it is not advisable to locate the presently proposed power station on the faulted rocks, even though there are many instances in which a power station is situated on faulted foundation rocks. At the present time an alternative plan is already proposed for the selection of the power station siting.

A further problem for the construction of a surface power station here is that the maximum flood level of the Vohitra and the Sahantsiva is too high, since this site area is on the junction of these two rivers.

According to our visual survey conducted on the Vohitra River, the maximum flood level recorded on September 10th, 1974 reached 10 m higher than the normal water level and as officially recorded in 1970 it reached 8.00 m higher. In order to avoid such high rise at maximum flood, the power station must be protected with a semi-gravity type retaining wall or any other suitable substitute, or, the power station must be situated higher than the maximum flood level. To arrange to take either step will be very complex and costly.

(b) Underground power station

For the purpose of preventing such geological and hydrological problems as mentioned in (a), it is recommended that the power station should be placed in the depth of the hill slope.

The geological conditions and the lithic characteristics of the site and its adjacent area of the proposed underground power station are fairly good as observed from the core of boring B7. At this site, it was observed that there is laterite or laterite like loose layers up to the depth of 20.6 m from the ground surface, but beyond that depth are foundation rocks of gneiss and amphibole gneiss with neither faults nor fractures. The lithic character in this deeper zone is not so rigid but somewhat cracky, though the recovery of cores reached nearly 100 %. For the construction of an underground power station, the rigidness of the rock is not always required, but rather a tight cohesion of mutual rock masses without faults or fractured zones are required.

Although the gneiss rocks appear to be often separated along schistosity planes and cracks, such phenomena seems to be attributable to the boring technique and would not reflect on the characteristics of rock masses themselves.

The strikes of schistosity planes of gneiss at this site is almost NNW with a high dip angle.

Accordingly, the power station must be built so that its longitudinal axis is perpendicular to the strike of schistosity in order to ensure safety during excavation. In spite of this measure, certain separations of rock masses from schistosity and joint planes may take place on every face of the wall, being affected by the release of stresses during excavation.

Such separations can be sustained by rock-bolts. Judging from all the geological conditions mentioned above, there will not be any big problem involved in the construction of the underground power station at the proposed site. However, stresses, Young's modulus, velocity of logitudinal and lateral seismic waves of the rock masses, and, precise geological structures must be measured in situs in the exploration adit to be provided prior to construction.

(c) Aqueduct and pressure conduit tunnel on the Sahantsiva

For the 1-stage development project there are two alternatives as to the route of the water conduit to pass the Sahantsiva River; one is to pass over the river by use of an aqueduct (1-0-B), the other is to install a pressure conduit tunnel in the rock beneath the river bottom (1-0-A).

In 1-0-B Plan, the geological factors are confined only to the foundations of the piers of the aqueduct. It will be very easy to deviate from the existing fault zone by the rearrangement of the pier intervals. According to the data of boring B9, B10 and B11, which were made on the alluvial island in the river, the thickness of sand and gravel on the river bed are 8.0 m, 14.0 m and 13.05 m respectively, and below these deposits, the foundation rock of amphibole gneiss.

Some parts of the foundation rocks are decomposed by weathering as observed from B9. The thickness of the decomposed parts is less than 2.0 m, and beneath these layers are cracky foundation rocks.

The thickness of the overburden to be excavated out is about 15.0 m in maximum depth.

Since the load estimated to work upon the foundation rocks is not so much, the site may pose no problem for the installation of the aqueduct. The cracky foundation rocks may present slight problems.

In the 1-0-A Plan, the geological problems are limited only to the existing fault zone as aforementioned.

As previously explained in the section on the surface power station, this fault has very little clayey material. Therefore, it will be easy to consolidate this fault by lower pressure grouting and reduce to minimum the deformation of faulted rocks by high pressure grouting.

The thickness of rock from the bottom of the Sahantsiva River to the pressure conduit tunnel is about 17 m. This obtained value is too small for the value of the working water pressure (about 144 m) at this site, therefore, it is advisable to strengthen the concrete lining of the pressure tunnel by steel lining as already designed by E. D. F.

(d) Upstream dam site

The proposed site is situated on the upperstream edge of rapids portion of the Vohitra River. The site is on the opposite side of the junction point where the base rock is gneiss. The strike and dip of schistosity and joint planes of gneiss are NS/78°E and N74°E/72°NW respectively. At the site the river course shows a complete coincidence with schistosity planes. The lithic characteristics of the foundation rocks are compact and sound enough for a construction of a low intake dam, but as observed in the foundation rocks of the main dam in Zone A there is likely to exist ditches in the river bottom. Therefore, it is recommended that probable ditches be explored by inclined interlocking pattern boring from both banks.

The lineament extending from the Sahantsiva River is observed by aerophotography, on the left bank of the dam site. It is not exactly sure whether this lineament should correspond to a fault or not. This must be examined by a precise reconnaissance and by inclined boring toward the valley wall from the left abutment of the proposed dam site. Other geological problems involved in the dam construction are almost as same as those involved in the foundation rocks of the main dam in Zone A. For details refer to the preceding section dealing with the main dam.

(e) Downstream dam site

The downstream dam site is proposed herein as an alternative plan to the upstream dam site. This site is situated downstream from the junction. The general engineering geological problems and the methods of explorations do not greatly differ from those of the preceding Section (d), even though the river course is oblique to the direction of schistosity plane at this site. The biggest problem in the dam site lies in the feared existence of the fault which may extend from the Sahantsiva River to the middle of the Vohitra River.

However, supposing such a fault should really existed, it would not be so difficult to consolidate and make impermeable the fault by remedial treatments including grouting, since it may not be composed of any clay or clayey material.

(4) Engineering geological conditions of Zone C

Zone C includes the proposed sites for the power station, the surge tank, and the tailrace as planned by both the 1-stage and 2-stage development projects.

In Zone C, there are gneiss as foundation rock, laterite as overburden, sand and gravel as river bottom deposits, and talus or debris as cover layers of all the other layers.

The strike and dip at schistosity and joint planes of gneiss are as follows:

schistosity plane:	NS/70°NW
joint planes:	NS/70°SE, EW/10°SW

There is a conspicuous NEE trending lineament running along the Sahamamy River and extending toward the Vohitra River. The mode of occurrence of this lineament has a strong resemblance to that of the Sahantsiva River in Zone B.

Moreover, according to the observation results from the core of boring C3, there are fractured layers and very soft amphibole gneiss between the 15. 24 m and 17. 93 m depths and some portion of the rocks in these layers are easily mashed by fingers. Therefore, this weak rock zone may be regarded as being correspondent to the fault zone as expressed by the above-mentioned lineament. The stream containing the railroad culvert runs in the NS direction and extends to the Vohitra River forming a NS trending lineament, where faults or fractured layers or zones do not exist.

It would be reasonable to assume that the lineament might have been developed in accordance with the direction of schistosity planes. There is thick layer of laterite above the foundation rocks on the upper parts of the hill slope, and a portion of them has slid down slightly and has left small reddish-brown bald patches over the hill slope. The most conspicuous one is found on the hill slope of the proposed surge-tank site. The site was explored by C5, C6 and C7 boring and reconnaisanced by E. D. F in 1972. The data of these borings show that the thickness of the laterite or heavily weathered rock, which may slide down, is 10. 0 - 13. 0 m.

(a) Surface power station site

The surface power station is proposed as an alternative to the underground power station included in the 2-stage development project. The site for the surface power station is proposed on the left bank of the Sahalimoina River about 100 m downstream from the railroad culvert. At this site there exists a lot of large gneiss blocks which must have fallen down from both banks of the valley wall, and the voids of these blocks are filled up with sand and gravel recently carried by the river current. Beneath those large block deposits, there may exist terrace deposits composed of sand and gravel. The total thickness of the overburden is estimated to be 10 m. Beneath this there are foundation rocks of gneiss. In the hinterland of the site at the foot of hill slope, there are a series of exposed gneiss. The lithic characteristics of these outcrops of gneiss are hard and compact, but considerably blocky owing to the existence of openings along joint and schistosity planes.

The strike and dip of schistosity and conspicuous joint planes are as follows;

schistosity planes: N 5°E/80°NW

N 15°E/85°NW

joint planes: EW/80°NE
N 65°W/72°SW
N 60°E/55°SE
N 70°W/60°SW
N 60°W/15°NE } (Sliding plane)
N 80°W/20°NE }

Among these planes, N60°W/15°NE and N80°W/20°NE planes form a kind of sliding plane, and there remain certain evidences that the rock masses surrounded by such separation planes have slipped out more or less along sliding planes. Owing to such slight movements, other planes come to open and are separated from each other forming rock blocks of approximately 2 m x 2 m.

At the proposed site the space for the surface power station construction is not large enough to meet the requirements. Therefore, in order to secure enough space suitable for the construction of the surface power station, the hinterland hill slope at the proposed site must be excavated on a large scale.

As the result of such large cutting, there may arise some rock slidings along low dip joint planes and the sliding of overburdens, composed of laterite and decomposed gneiss, because the thickness of overburden in this area is about 6.0 - 8.0 m as noted from the data of boring C1, C2 and C3.

For protection of possible rock sliding, the rock bolting method may be useful. Another problem is the high maximum flood water level, the same as in the case of the power station site in Zone B mentioned earlier. Judging from the aforementioned geological and hydrological conditions, the construction of an underground power station is more advisable.

(b) Underground power station site

The geological and lithic conditions deeper within the hill slope in this area, will be deduced from the observations of cores of boring C1, C2, C3 and C4. The observations of the cores reveal that the foundation rocks are not very hard but rather cracky having small foldings.

Moreover, the slickensides along schistosity planes are observed between the 70.74 m and 71.30 m depths according to the cores of boring C4.

These slickensides are made by a little movement along schistosity planes. The above data indicate that the geological and lithic conditions here are slightly inferior to those of the underground power station site in Zone B. A more careful treatment of rocks and more precise measurements of their physical properties are necessary here than at the site of Zone B for the projection of an underground power station. The recommendation does not mean that an underground power station could not be constructed here in future years. The core recoveries of the borings are very good and there exist no minor foldings which may change the rocks into either inbricated fragments or powder.

(c) Tailrace site

The tailrace will be situated almost at the same level as the water level of the Vohitra River in the case of both the 1-stage and 2-stage development projects. On the shore of the Vohitra River, there are pronounced exposures of sound gneiss rocks, but these exposures will pose no problem for the construction of the tailrace.

(d) Surge-tank site

The rocks forming the surge tank site are gneiss, laterite, and surface soil.

According to the data and observed results of cores of boring C5, C6, and C7 in the neighbourhood of the site, the overburden consists of laterite and heavily weathered gneiss whose thickness ranges from 10. 0 to 13. 0 m.

Beneath the overburden there exists foundation rocks of gneiss. The lithic characteristic of gneiss here is cracky, and due to the existence of cracks, the boring cores are separated into pieces of 6 - 7 cm long.

Foundation gneiss is pretty soft, but the recovery rate of cores is about 100 %. Therefore, the construction of a surge-tank in the proposed depth of the hill slope will be possible if it is treated with sufficient grouting even though the water pressure is very high. On the other hand, however, since the shallow portion below the surface is composed of unconsolidated overburden and cracky rocks, full care must be taken, in anticipation that those foundation rocks should be separated off and fall down during excavation. For the security of the surge-tank from the high water pressure, a temporary concrete lining outside and a steel lining inside the permanent concrete lining will have to be provided for.

(e) Engineering geological conditions in the route of pressure conduit tunnels

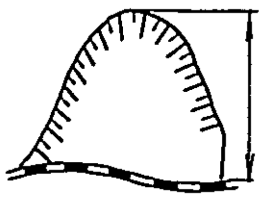
The geological conditions and lithic characteristics of the pressure conduit tunnels were examined by the reconnaissance alongside the railroad cutting. The locations of outcrops, together with geological and lithic conditions are as shown in Table-5. 4.

According to the data obtained from the reconnaissance, the most important fact is that landslides in laterite rocks have occurred frequently. The laterite always covers the foundation gneiss and thickness of this rock is estimated at 30 m maximum. It is believed that the landslides in laterite rocks should exert very little influence upon the geological conditions of pressure conduit tunnels. The evidences of frequent occurrances of landslides in laterite rocks served as a very useful reference for the selection of the surface power station site.

Gneiss rocks beneath the laterite rocks looked generally good in respect to lithic characteristic, and no faults could be found on the outcrop of these rocks, though there existed a few small and slight fractured layers.

It seems to us that the differential erosion on faulted rocks may be too strong to leave the traces of large faults on the outcrops of the foundation rock. Thus, such faulted zone might have been eroded into the river or weathered into laterite rocks. Joints appear abundantly on the outcrops of the foundation rocks. The conditions of joint planes (including schistosity planes) were studied. The results are illustrated in Fig. -5. 9 and Fig. -5. 10. In order to observe the influence of these planes to be exerted upon the pressure conduit tunnels, the directions of principal joint planes and schistosity planes in relation to the route of the conduit tunnel are illustrated schematically on the general plan. (Fig. -5. 11)
As illustrated in Fig. -5. 11, all the routes of the pressure tunnels interesect with the schistosity plane in a vertical or high angle. The direction of intersection is very favourable for the excavation of the tunnel in the light of safety and a good effect of blasting. However, the tunnels intersect with the dominant joint plane N76°W/85° SW in parallel or in a low angle, which poses an unfavourable situation. However, the frequency of this joint is about 1/2 in comparison with that of the schistosity plane as can be noted from Figs.-5. 9, 5. 10. Moreover, the dip angle of this joint

Table-5.4 Geological and Lithic Conditions of Outcrops along Railroad

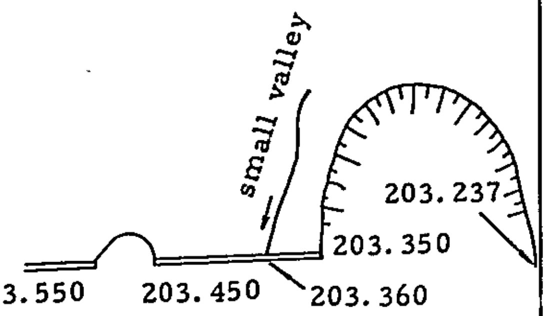
Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
194.150		N80°E/85°S N15°W/80°W	rocks are more or less weathered
.180			Composed of quartz gneiss; it is exposed only on the valley floor.
.200			Composed of disintegrated but very compact quartz gneiss 
195.444 .450	N25°E/75°ES	N70°W/90°	Rocks are weathered, blocky and loose. Sliding plane: N30°W/20°N
.600 .695	N5°E/60°E	N50°E/90° N35°E/75°W, N85°W/45°N, N40°E/30°N	Composed of amphibole-quartz gneiss, which is much folded
.800	N10°E/85E	N70°W/90°	Rocks are blocky and weathered Sliding plane: N70°W/90°
.890	N5°E/90°	N80°W/75°S	Rocks are blocky, The out-crop is 5 m in width
196.033 .115	N22°E/70°ES	EW/45°N, N45°W/68°N N80°W/90° N70°W/90°	

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
196.220			Rocks are blocky and decayed
.350			This place seems to be one of landslide areas. The scale is assumed to be 100 m in width and 100 m in height.
.450			Near the inlet to a water-fall, there is a landslide, 50 m wide and 70 m high
.720			There is a continuous exposure of decayed rocks between points 196.72 and 196.40.
197.000		N80°E/80°N	There is no exposure of rocks in the ravine. Sliding plane: N50°E/30°W
.061 .144	N15°E/70°E N25°E/75°E	N80°W/70°S N40°W/45°NE N60°W/82°WS	Here is a valley, the floor of which is covered by debris
.350 .380			This place consists of laterite layers and is likely to cause a landslide. Generally, a place where a thick laterite layer is developed is regarded as a landslide area. Thick layers of laterite suggest landslide areas.
.600			Rocks crop out on the ravine floor. The weathered rock zone is assumed to be 15 - 20 m in thickness.
198.216 .250	N25°W/90°	N75°E/80°N N40°W/32°SW N65°W/28°SW N15°E/75°ES	Rocks are blocky

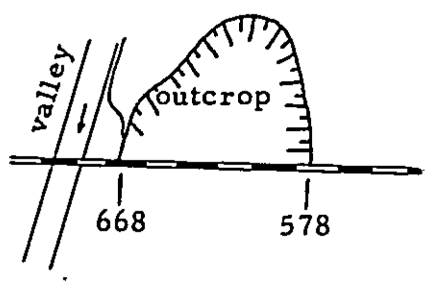
Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
198.250 .373	N5°W/85°E	N85°E/85°S N50°W/70°NE N70°W/80°S N15°W/78°E N15°W/60°NE N80°W/20°S	
.510	N5°E/80°E		Rocks are blocky along schistosity planes. Joint planes are not so developed.
.535	N10°E/90°	N65°W/90°	Here is a small exposure of rocks (3 m in width), which are blocky.
.846			There is a valley and some outcrops of rocks near a railroad bridge
199.232			There is a symptom of landslide (30 m high and 30 m wide)
.290	N20°E/70°ES		There is only a small exposure of rocks, more or less decayed.
.300			There is some exposure of rocks in the valley.
.500			There is an outcrop of rocks in the valley at the same altitude as that of the railroad, but under the bridge there is no exposure of rocks. Overburden seems to be 20 m thick.
.910	N10°E/85°N	N60°W/80°WS	Some exposure of rocks are in the valley. Joints are well developed.
.930	N20°E/88°W	N70°W/90°	There is a blocky outcrop of rocks. A mass of block is about 1.5 m in diameter.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
200.300 .385	N15°E/80°E N15°E/70°E	N85°W/90° N70°E/60°ES N40°E/20°NW	From topographical point of view, there must be a fault or a weak zone here, but its existence is not clear.
.490	N10°E/90°	N70°W/90°	A river terrace is developed on both sides of the railroad. The altitude of the terrace is equal to that of the railroad.
			Here is a small landslide, 7 m wide and 10 m high, composed of weathered rocks.
.135 .145	N5°E/90°	N80°W/78°N	Sliding plane: N50°E/20°N
.412 .455	N5°W/90°	N70°E/90°	Composed of good rocks.
201.612	NS/90°	N80°E/75°N	Joints are not well developed. Rock conditions are good.
.657	N10°E/90°		Joint planes are obscure.
.734	N30°E/80°ES	N85°W/48°S	Joints are not well developed. There is an outcrop of rock between points 201.657 and 201.734.
.795	N20°W/50°WS	N30°E/85°NW N10°E/60°NW N75°E/85°ES	Rock conditions are good. Direction of schistosity is changes here.
.840	N50°E/90°	N80°W/80°N N15°E/50°E	There is an outcrop of rocks between points 201.795 and 201.840.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
202.240 .255	N5°E/78°E	N85°W/90° N60°E/85°NW	Rocks are somewhat weathered.
.400			Here is a landslide layer 30 m wide and 30 m high, which is composed wholly of laterite. The landslide has a spoon shape, reaching to the base of railroad and is still moving.
.600			Here is a valley.
.910 .917	N15°W/80°E	N80°E/52°N (N60°E/62°ES)	Rocks are somewhat weathered.
.917 .932			A sliding plane of N5°W/10°WS is very important.
203.000 .050			Rocks are somewhat weathered and blocky.
.027	N5°W/70°E	N50°E/70°ES N30°W/90° N50°W/90° N80°E/85°N N70°E/70°ES NS/80°W N70°W/90°	Sliding plane: NS/62°W
.100			There is a house on left hand.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
203.287 .550			The area of landslide which is still moving is from point 203.287 to a stone wall. The scale is 63 m wide, 50 m high and 60 m deep. The stone wall is from point 203.35 to point 203.450. The landslide is composed of laterite and white soil exist under the laterite layer. The landslide caused damage to the railroad and scarping cliffs still remain clear. 
203.630	not obscure.	N25°W/70°EN N80°W/70°S N60°W/90°	Rocks are decayed like sand.
.630 .730			There is a continuous exposure of disintegrated rocks.
.800	N5°W/90°	N75°E/90° (N70°E/90°)	From this point forward, there are rock exposures. In the valley at around point 203.800 there are many blocky rocks.
.810	N5°W/70°E		Rocks are a little blocky.
.873	N20°E/85°W	N80°W/90° (N60°W/60°WS)	Composed of good rocks.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
203.900		N60°W/36°NE	A distinct fractured and also sliding plane of N60°W/30°E can be seen between points 203.900 and 203.936.
.965	N10°E/90°	(N70°W/68°NE)	
.970			Sliding plane, N50°W/20°NE
204.000 .055	N50°E/80°NW	(N50°W/74°NE)	There is an outcrop of good rocks
.055 .100			A symptom of landslide is detectable on the mountain slope between tow valleys.
.100	not obscure.	N5°E/80°W N60°W/90° N40°W/90°	At the upstream of valley, there is a small collapse of mountain surface.
.240	N5°E/ ?	N80°E/80°N	Here is a small valley.
.269	N10°W/88°W		Here is an exposure of rocks, 5 m wide.
.470 .480	N5°W/85°W	NS/90°	Sliding plane (not so dominant); N25°W/20°NE.
205.070			There is a valley and rocks crop out there.
.110 .135			Sliding plane; N5°W/30°E
.180 .195	NS/85°W	N60°W/90°	
.390 .470			Composed of weathered rocks.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
205.400 .410			Rocks are blocky.
.415	N5°E/85°E		The area of outcrops is from points 205.410 to 205.460.
.460	N5°E/75°W N10°W/80°W	N30°W/60°NE (N85°W/90°)	Sliding plane (weak); N80°W/10°WS
205.578 .668	N10°W/78°W	N73°W/80°WS N65°W/52°WS	Good rocks are exposed between these two points. This place is a site of power station proposed by NEWJEC.
.658	N10°E/80°W	N85°E/80°N N80°E/60°N	Site proposed by NEWJEC. 
.725 .745	N10°W/78°W	N10°E/90° N80°E/78°S	Fractured zone is from points 205.725 to 205.735. The plane; N20°W/70°WS
.745 .746		N70°W/48°NE N60°E/70°ES N45°W/50°NE	
.750			Here is a fractured zone (N5°W/80°W). Rocks crop out between point 205.725 and 205.755.
.750 .810			There is a spoon shaped topographical feature. This seems to indicate the existence of old landslide. There is no outcrop of rocks.

Station (Distance of railroad from TANANARIVE)	Schistosity plane	Joint plane	Remarks
205.900 .950	N30°W/78°WS	N30°W/78°WS N80°W/72°N (dominant) N30°E/55°ES	There are continuous good rocks.
206.270 .300	N15°W/80°WS (?)	N88°E/50°E N25°W/90° N15°W/80°WS N65°W/15°NE	

is 85°. From those results, it is sure that the existence of this joint would not cause any big problem during excavation. The joint for tunneling, for which utmost care will be needed, is that in N61° W/20°NE. This joint in question may often become the sliding plane in the tunnel at any possible stress release.

General evaluation for geology of the pressure tunnels can be made, same as once evaluated by the E. D. F.

Normal	:	80 %
Interior	:	15 %
Bad	:	5 %

(6) Engineering geological conditions of Zone D

Zone D is situated about 1.7 Km upstream from Zone A and a dam of 14 m in height is proposed for the regulating pondage in the Vohitra River.

The rocks forming this dam site are composed of gneiss rocks. These rocks run N9°E in strike and inclinate 75°to NE. This direction of strike is perpendicular to the river course, which is favourable for prevention of the feared leakage of inponded water.

There are no outcrops of gneiss on the bottom of the Vohitra River except a few small rocky islands. The proposed center line of the dam is to be aligned almost along the group of islands. On the right abutment of the dam, there are extensive exposures of sandy gneiss, the weathering product of gneiss, alongside the railroad cutting.

The upper part of this sandy gneiss is changed into laterite. On the left abutment, there are no such exposures of foundation rocks, and the surface is densely covered with boulders of gneiss. On the hinterland of the left abutment, there exists a spoon-shaped depression on the hill slope, and the configulation in the neighbourhood of the left abutment looks like a fan. It seems that the boulder layer as cited above may be the deposits of landslide.

According to the data and observation of boring D5 on the left bank, the thickness of the boulder layers is 7.88 m, and beneath such block layers there exist sand and gravel which look like river deposits. Under the river deposits there are cracky foundation rocks. The lithic characteristics of the foundation rocks are not so good due to the cracky nature.

The data of boring D3 show existence of shallow alluvium and cracky gneiss rocks, and the data of D2 show the existence of decomposed parts of gneiss below 19. 30 m depth, inclined as the boring is, and the data of D1 show the existence of sound but cracky gneiss in the depth of 14. 48 m, and the data of D6 show that foundation gneiss is cracky, including decomposed parts here and there.

On the left abutment of the dam, there are thick deposits of overburden and the elevation of the foundation rock in the inner part of the hill slope remains unknown. Therefore, this point must be drilled by borings. If the ascendance of the foundation rock in the hill slope is not steep, a deep core wall must be inserted up to the point where the elevation of the foundation surface becomes higher than the maximum water level of poundage. In the same way, the elevation of the sound foundation rock surface must be explorated by borings on the right bank, because there are very cracky or weathered gneiss or decomposed sandy gneiss on that bank side. Judging from all the aforementioned conditions, the geological conditions and lithic characters of the proposed dam site are not necessarily favourable for a 14 m high dam construction, for the site requires lots of treatment for improvement of the foundation.

However, by full assurance of the foundation treatments including grouting, the foundation could be improved to become like a rock which could be bearable for the proposed dam construction.

5. 3 Studies on exploitable size for power development

When viewed from the future power demand, the required optimum size for a power station should cover the forecasted demand increase, mainly in and around Tananarive, and the sizable demand for ferrochrome production.

After deliberations entered into jointly by the Government of Madagascar and E. D. F, the basic policy has been devised in such a way that the project should be planned for an annual capable energy production of 550 to 600 GWh at 100 MW output with its maximum discharge of 60 m^3/s. An attempt is herein made to renew the same study, from comparison between both gross and unit costs of construction, which may be varied depending upon the projected capable energy productions. The result reveals that, as shown in Table-5. 5, the maximum discharge becomes the most economically advantageous at 60 m^3/s.

Although the aforestated comparative study has been made only for the 1-stage development plan proposed by E. D. F, a similar trend is estimated for the 2-stage development plan as well. Therefore, the basis of 60 m^3/s will be used as the realistic figure for the maximum discharge when both of the development plans are further reviewed.

Table-5.5 Construction Cost

unit: 10^6FMG

	45 m^3/s	60 m^3/s	75m^3/s
Access road	350	350	350
Regulating pondage	1,047	1,047	1,047
Civil works	4,037	4,551	5,383
Mechanical works	1,823	2,431	3,039
Installation of transmission and substation	1,348	1,348	1,348
Gross construction cost	8,605	9,727	11,167
Annual capable energy production (GWh)	643	786	881
Unit cost (FMG/kWh)	13.4	12.4	12.5

Note: Unit prices of construction cost were adopted from the E.D.F Report of 1972.

5.4 Comparative studies on alternative development plans

5.4.1 Proposed plans for development

With respect to the applicable pattern of development project for the Andekaleka site, there are two alternative plans to be considered depending upon two different ways of utilizing a 236 m head available in the section between Zone A and Zone C as shown in Fig. -5. 11.

(1) 1-stage development plan

The 1-stage development plan envisages power generation at a capable output of some 110 MW by utilizing a 236 m head available from the construction of a waterway about 4. 5 Km to be interconnected in the section between the intake in Zone A and the outlet in Zone C.

The plan has its two alternatives. The one is proposed by the E. D. F whose plan and profile drawings are as shown in the last of this Chapter (1-0-A). The other one is the NEWJEC's proposal featured by the use of an aqueduct to cross over the Sahantsiva River (1-0-B). Both plan and profile drawings showing the outline of the scheme designed from this proposal are as shown in the last of this Chapter.

Various design factors for those two alternatives are as indicated in Table-5. 6.

(2) 2-stage development plan

The 2-stage development plan encourages a more realistic pattern of development on an one-step-to-next basis, at a relatively small but steady pace as compared with the 1-stage development, by divinding the use of the same 236 m head available into Zones A and C. The plan is devised from such economic advantages that development could be progressed at well-balanced paces with the increasing power demand, and then the initial capital investment could be reduced to minimum to avoid excessive advanced investment.

The divisional point between the two stages will be located near the confluence (Zone B) of both the Vohitra River and the Sahantsiva River, as so determined from the topographical aspect. The upstream from that point is proposed for the No. 1 Power Station and the downstream for the No. 2 Power Station. The 236 m gross head will also be divided at a ratio of nearly 2 to 1 to be utilized by both Power Stations; 150 m head for the No. 1 Power Station and 86 m head for the No. 2.

The pattern of development is divided further into the two alternatives, 2-1-A and 2-1-B, for the No. 1 Power Station, as shown by Table-5. 6, by deisgned types of power station either underground or semi-underground and the three alternatives, 2-2-A, 2-2-B and 2-2-C, for the No. 2 Power Station by designed types of intake in addition to such types of power station as is the case for the No. 1. Plan and profile drawings covering all such alternative plans are as shown in the last of this report.

5. 4. 2 Comparisons or development plans by design features

(1) 1-stage development plan

As aforementioned, the plan includes two alternatives.

The following are major differences in design feature between Plan 1-0-A (E. D. F) and Plan 1-0-B (NEWJEC).

(a) River crossing

Plan 1-0-A is devised to use a 300 m long pipe of steel lining for crossing over the Sahantsiva River at EL 220.00 m approx., about 20 m above the river bed, while Plan 1-0-B is to use a 210 m span aqueduct for river crossing at about EL 270. 00 m.

In case of the former plan, excavation of adits will be required to facilitate its erection work, while such excavation may be dispensable to the latter, although the latter will require foundation and piers to support the aqueduct.

(b) Penstock

Plan 1-0-B contemplates mitigation of head loss as well as shortening of the total penstock length by laying the penstock in vertical shaft and thus by moving the location of a power station inwards. In addition, this would facilitate installation work of the penstock.

(c) Outdoor switchyard

Plan 1-0-B includes relocation of the switchyard which would serve to shorten the length of the tunnel to be excavated for construction purpose.

(d) Headrace

The length of a headrace included in Plan 1-0-A is longer by some 100 m than the same in Plan 1-0-B. In the latter Plan, it is planned to run about 50 m higher, EL 270. 00 m approx., than that in Plan 1-0-A.

(2) 2-stage development plan

According to the Plan, the water intake and dam for No. 1 Power Station will be constructed in Zone A, same as in the case of the 1-stage development plan. Through the pressure tunnel of about 1. 9 Km in length water will be supplied to No. 1 Station in Zone B and then discharged into the Vohitra River through the tail-race tunnel. Gross head available will be about 150 m enough to insure the capable output of roughly 70 MW.

Meanwhile,. the proposed plan in the downstream of the river is to provide the water intake and dam in Zone B, leading water to No. 2 Station in Zone C through a pressure tunnel about 2 Km long and finally discharging into the river. Gross head avaialble will be about 86 m and the capable output will then be roughly 40 MW.

(a) Comparative design features for No. 1 Power Station

i) Power station

Since adequate covering is to be secured for a power station of underground type, the tunnel to be provided for construction has a length of about 330 m.

The site for construction of a semi-underground power station is selected at a height on the right bank of the Vohitra River at the confluence of the Vohitra and the Sahantsiva. However, the height is situated on the fault zone when viewed geologically. This would require full stabilization of the rock-bed for the construction of the power station, and at the same time some structure must be built up to prevent possible sliding of the sloped face which may arise from chipping-out of the thick inclined face of laterite layer. Besides, protection work of the Vohitra and improvement of the Sahantsiva will be required for the semi-underground type construction, so that the power station can be protected from floods to come from those two rivers. Therefore, the semi-underground type would require considerable expense for flood protection, while the underground type would eliminate this kind of problem and would result in no extra spending. The specifications for both types of power station are as shown in Table-5. 6.

ii) Penstock

The underground power station construction plan has its advantage, as aforestated, to reduce the total length of the penstock by moving the power station inwards to such an extent that adequate covering can be secured for the building and, besides, by laying the penstock in vertical shaft. In case of the semi-underground type, however, the length of the penstock will have to be extended three times longer than the case of the underground type, judging from the proposed location of the power station and the topographical conditions.

iii) Outdoor switchyard

There is no difference as to the location of the switchyard between the two alternatives; it will be installed on the plain ground on the left bank of the Sahantsiva River.

(b) Comparative design features for No. 2 Power Station

In addition to the two alternative plans for the type of a power station, whether underground or semi-underground, similar to the case of No. 1 Power Station, there are also two alternatives to be considered by types of the intake:

i) Water intake alternatives

The first plan is to connect the intake of No. 2 Power Station directly with the tailrace of No. 1 Power Station. In this case, both water intake and its dam will be provided on the upstream of the outlet of No. 1 Power Station on the Vohitra River, so that No. 2 Power Station can continue its operation even when No. 1 Power Station may go into outage. The waterway will be provided for the connection between No. 1 Power Station's afterbay and No. 2 Power Station's intake.

The alternative to the first plan is featured by a discontinuity with No. 1 Power Station's tailrace and outlet. Water to come from No. 1 Power Station will be discharged into the river directly. The water intake and dam for No. 2 will be provided on the downstream of No. 1 Power Station's outlet for direct withdrawal of water from the river.

The design features of both alternatives are compared as follows:

Both of the alternatives will require construction of the intake dam similarly in the river, but the former will require a longer waterway by about 140 m than the latter. Furthermore, in the case where No. 2 Power Station's intake may be directly connected with No 1 Power Station's afterbay, the operational methods of both Power Stations will be subject to various restrictions, while the latter will pose no such problem. It should be noted, however, that in the latter case some extra expenses will be required for the protection of No. 1 Power Station, if it is of semi-underground type, from possible flood damage to arise from the high water level raised up at the confluence of both the Vohitra and the Sahantsiva Rivers.

ii) Settling basin

In the former case of the intake connection, no sand-settling basin except the scouring device will be provided because withdrawal of water from the river will be limited only at the time where No. 1 Power Station is shut down in outage. The latter one will require a settling basin because of its constant withdrawal of river water.

iii) Power station

The location for the underground type power station is set as far inward as possible to such a point that adequate covering can be secured. This will require a construction tunnel some 500 m long. The semi-underground type power station will be located at the selected site on the heights between the right bank of the Vohitra River and the Saharimoina River. Similar to the case of the same type power station for the No. 1 Power Station, the site poses geological and flood protection problems.

iv) Outdoor switchyard

The site for the switchyard will be located at the point of P. K. 205.750 Km for the semi-underground power station, on the reclaimed land on the mountain side from the railroad. At the same time, measures must be taken to improve the marsh stream coming down from the reclaimed site. In case of the underground power station, the site for the switchyard will be at the point of P. K. 206. 200 Km, the same place as selected by the E. D. F, on the mountain side of Salimoana Village. Since the site forms a sunken ground, it must be reclaimed and levelled off for construction.

In case of the semi-underground power station, it will be distanced about 150 m from the switchyard.

5. 5 Selection of alternative plan for development

As aforementioned, there are two alternatives by their development patterns, 1-stage and 2-stage development plans, proposed for the hydro power project at Andekaleka. For easy comparisons, each representative draft is herein selected from both of those two alternatives.

5. 5. 1 1-stage development plan

As compared with the draft 1-0-A, the draft 1-0-B will reduce the construction cost by 2 % or so as shown in Table-5. 7, by use of an aqueduct to cross over the Sahantsiva River and a penstock in vertical shaft. Therefore, the draft 1-0-B is herein selected as the representative plan for the 1-stage development pattern and is used for economic evaluation by comparison with its counterpart representing the 2-stage development pattern.

5. 5. 2 2-stage development plan

In case where the semi-underground type power station will be provided for each of No. 1 and No. 2 Power Stations, extra costs will be required for stabilization of the fault zone on which the power station is to be built, protection against flood due to its limited space for siting on the bank of the Vohitra River, installation for protection against sliding due to chipping-off of the laterite zone. On the other hand, no such problems may arise when the underground type power station is built. The result is as shown in Table-5. 7, and the construction cost of the semi-underground power station becomes, contrary to the normally practiced conception, nearly equal to that of the underground type power station.

From this result, therefore, the plan for construction of the underground type power station, i. e. the drafts 2-1-A and 2-2-A, which will involve very few problems related to geology or flood protection and far less a risk in the construction cost, is herein selected for No. 1 and No. 2 Power Stations respectively and is to be used for comparative studies with its counterpart for 1-stage development.

Table-5.6 Specification for Each Plan

Item	Unit	1-Stage Dev. Plan		2-Stage Development Plan				
		1-0-A	1-0-B	2-1-A	2-1-B	2-2-A	2-2-B	2-2-C
Type of Power Station		Under-ground	Under-ground	Under-ground	Semi-outdoor	Under-ground	Semi-outdoor	Semi-outdoor
Water Level at Intake	E.L	357.00	357.00	357.00	357.00	206.00	206.00	210.00
Water Level at Outlet	"	120.60	120.60	206.00	210.00	120.60	120.60	120.60
Gross Head	m	236.40	236.40	151.00	147.00	85.40	85.40	89.40
Loss of Head	"	28.90	27.70	13.30	17.30	14.50	14.40	12.80
Effective Head	"	207.50	208.70	137.70	129.70	70.90	71.00	76.60
Maximum Discharge	m^3/s	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Generator	unit	4	4	4	4	2	2	2
Out Put per Unit	kW	26,500	27,700	18,100	16,500	18,600	18,800	21,000
Total Output	GWh	784	787	516	489	271	271	291
Length of Headrace	m	3,807	3,710	1,935	1,920	2,051	2,086	2,225
Length of Penstock	"	303	247	198	527	103	218	218
Aqueduct	"	-	210	-	-	-	-	-
Height of Headrace Surge-tank	"	150.0	101.4	55.2	45.2	45.2	45.2	45.2
Height of Tailrace Surge-tank	"	16.0	25.0	24.0	-	25.8	25.8	25.8
Length of Tailrace	"	608	859	273	20	250	146	146
Length of Power Station	"	69.0	68.0	67.0	67.0	61.5	36.0	36.0
Width of Power Station	"	16.5 - 19.0	18.0	17.0	17.0	13.0 - 16.5	16.5	16.5
Height of Power Station	"	26.5	24.0	28.8	31.0	34.3	33.0	33.0
Access Tunnel	"	713	600	330	-	480	-	-

Table-5.7 Construction Cost for Each Plan

unit: 10^6FMG

Item	1-0-A	1-0-B	2-1-A	2-1-B	2-2-A	2-2-B	2-2-C
Civil Works	4,281	4,131	2,792	2,806	2,723	3,121	2,830
Meterials	313	324	105	277	63	95	95
Subtotal	4,594	4,455	2,897	3,083	2,787	3,216	2,925
Electrical Equipment	2,210	2,210	1,721	1,598	1,147	1,300	1,247
Subtotal	6,804	6,665	4,618	4,681	3,934	4,416	4,172
Regulating Pondage,	952	952	952	952			
Subtotal	7,743	7,617	5,570	5,633	3,934	4,416	4,172
General Expenses	774	762	557	563	393	442	417
Total	8,517	8,379	6,127	6,196	4,324	4,858	4,689
Transmission Line	1,348	1,348	1,370	1,370			
Grand Total	9,865	9,727	7,497	7,566	4,324	4,858	4,689

Note; Cost as of 1972

Combination Cost MFMG
2-1-A and 2-2-A : 11,821
2-1-A and 2-2-B : 12,355
2-1-B and 2-2-A : 11,890
2-1-B and 2-2-B : 12,424
2-1-B and 2-2-C : 12,264

Fig-5.1 Profile of Vohitra River

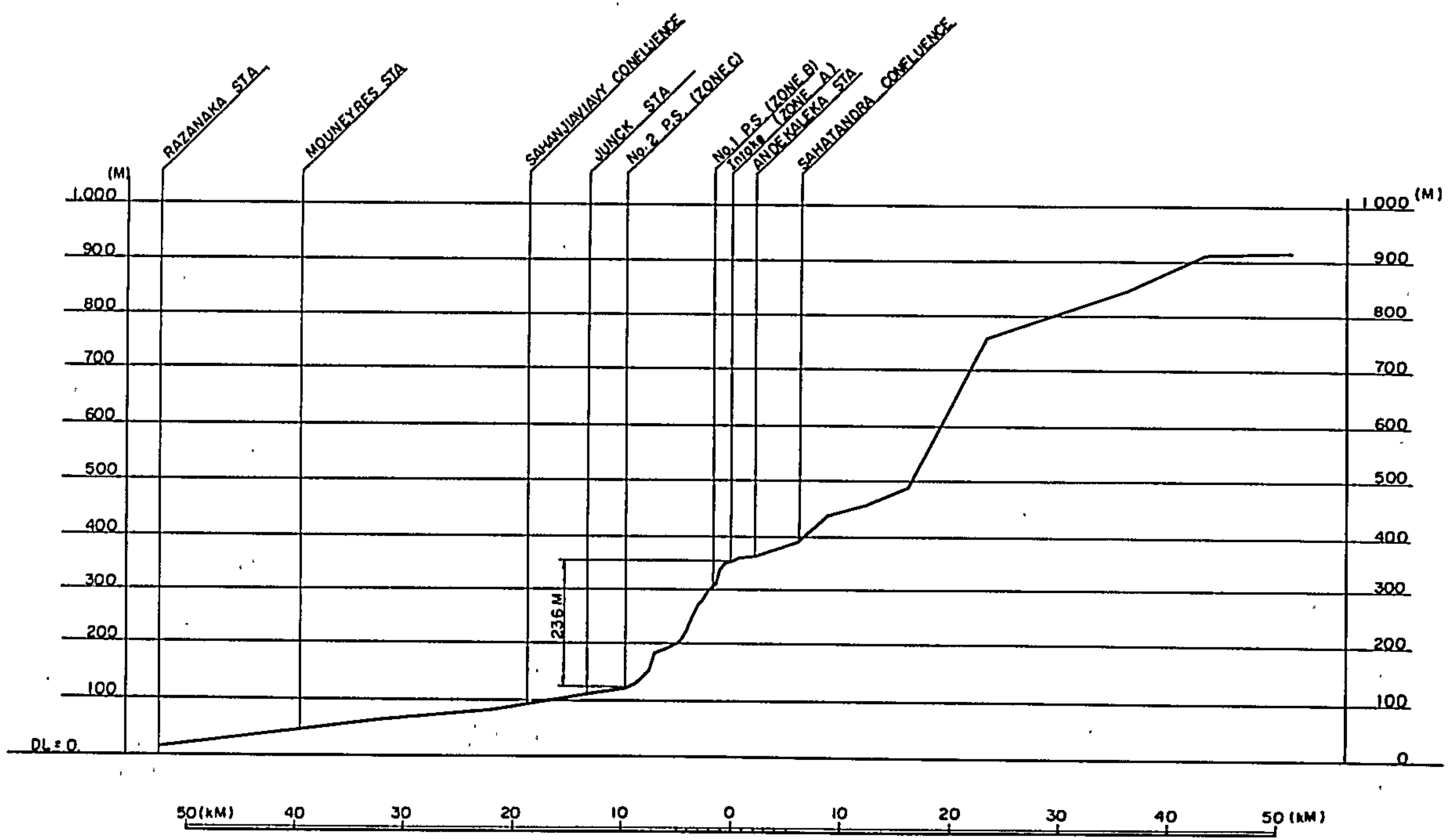
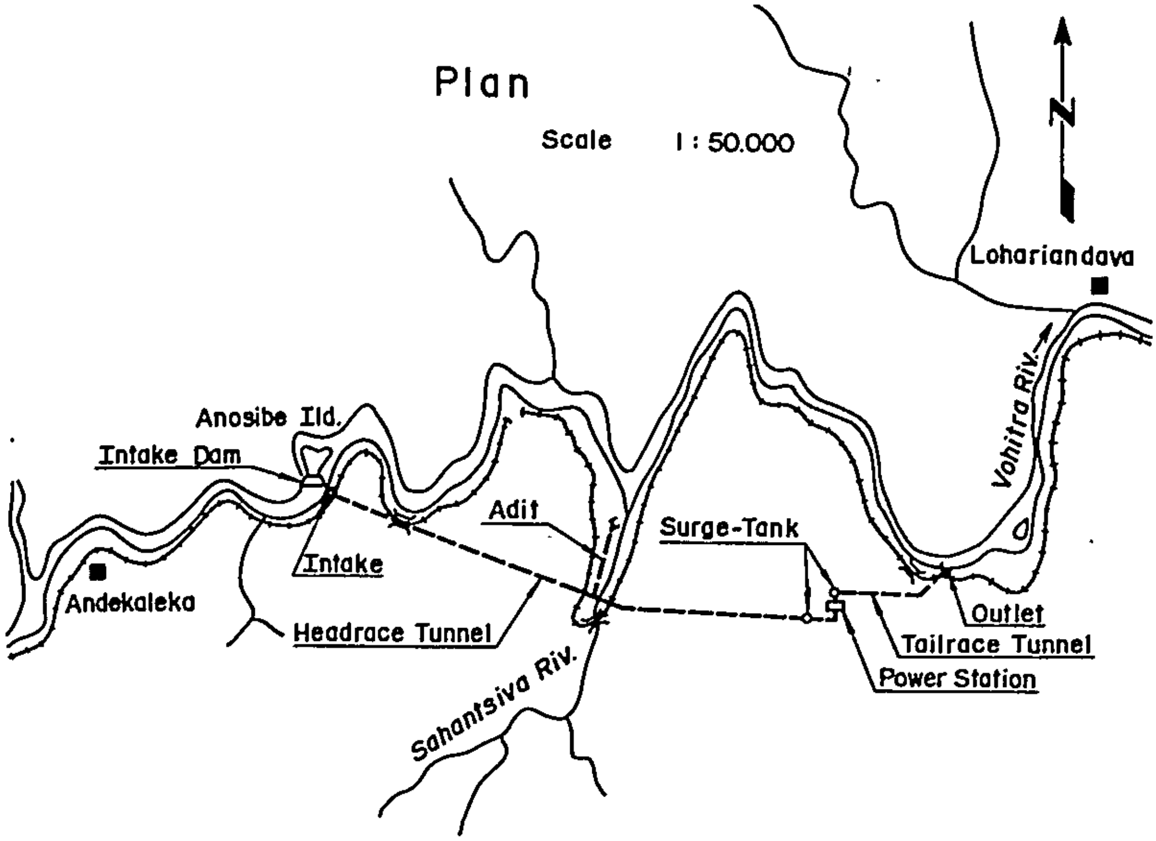


Fig-5.2 Original Proposal by E.D.F



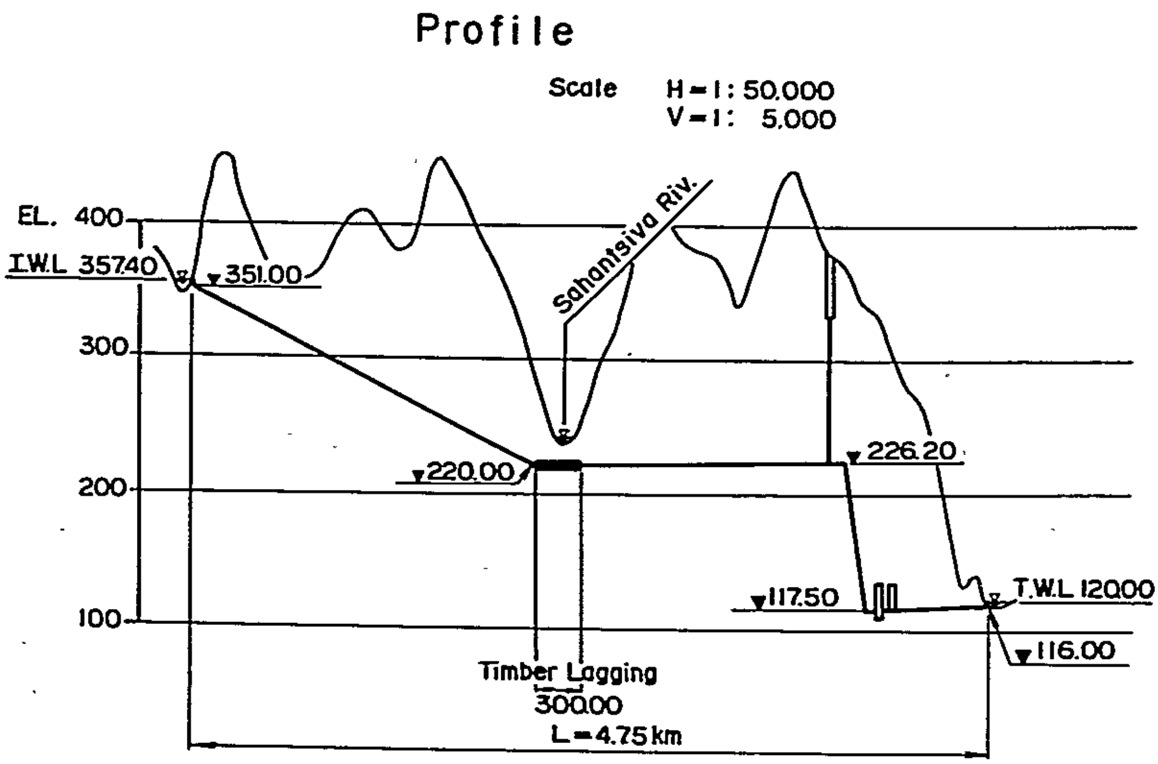
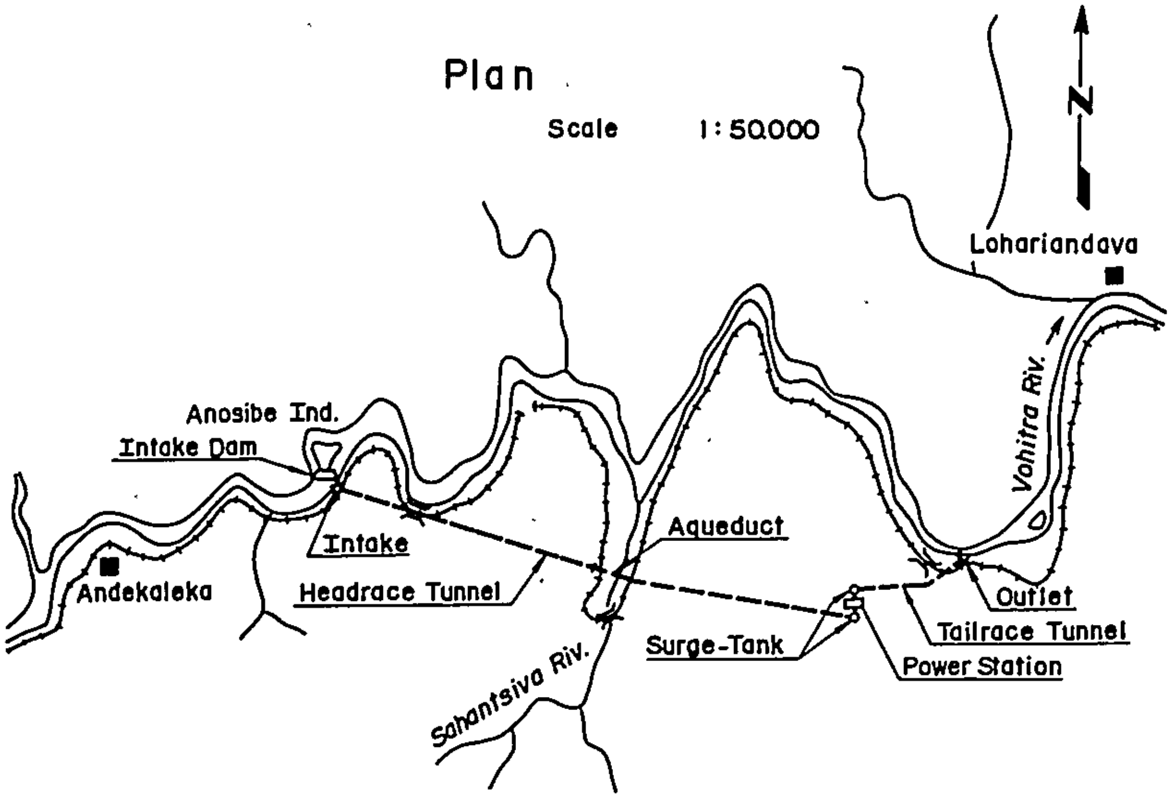


Fig-5.3 Original Proposal by NEWJEC (1-Stage Plan)



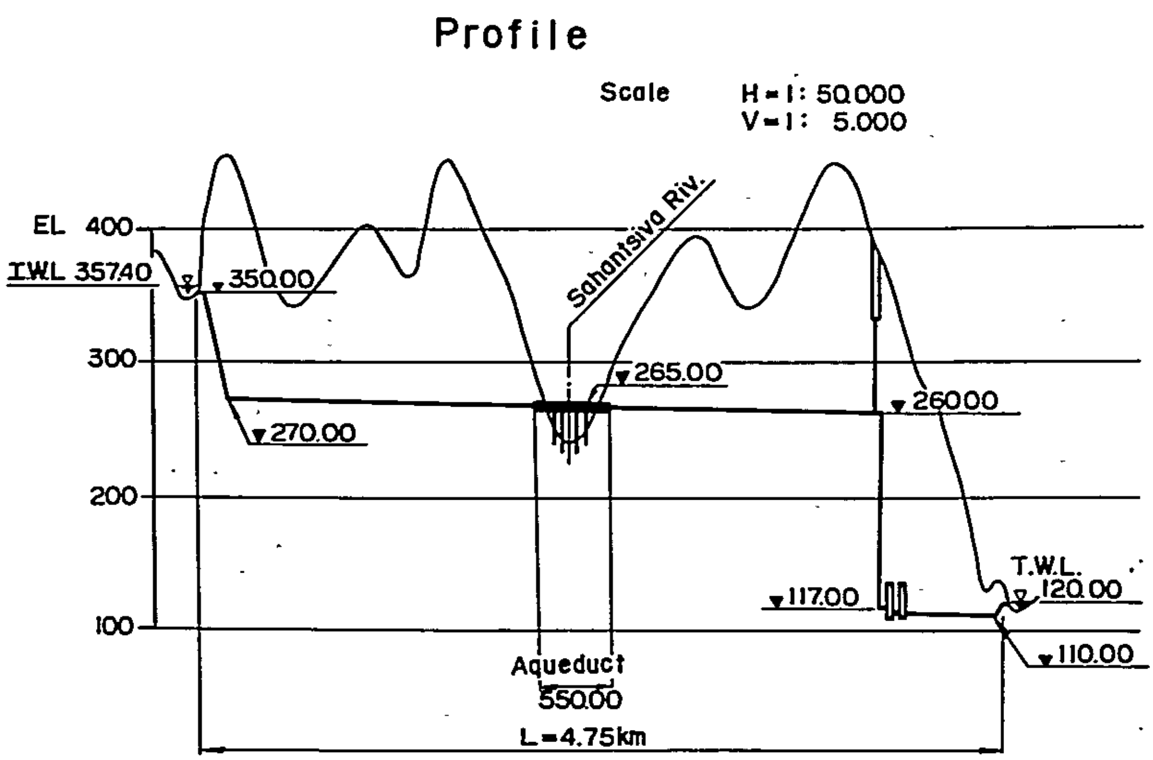


Fig-5.4 Original Proposal by NEWJEC (2-Stage Plan)

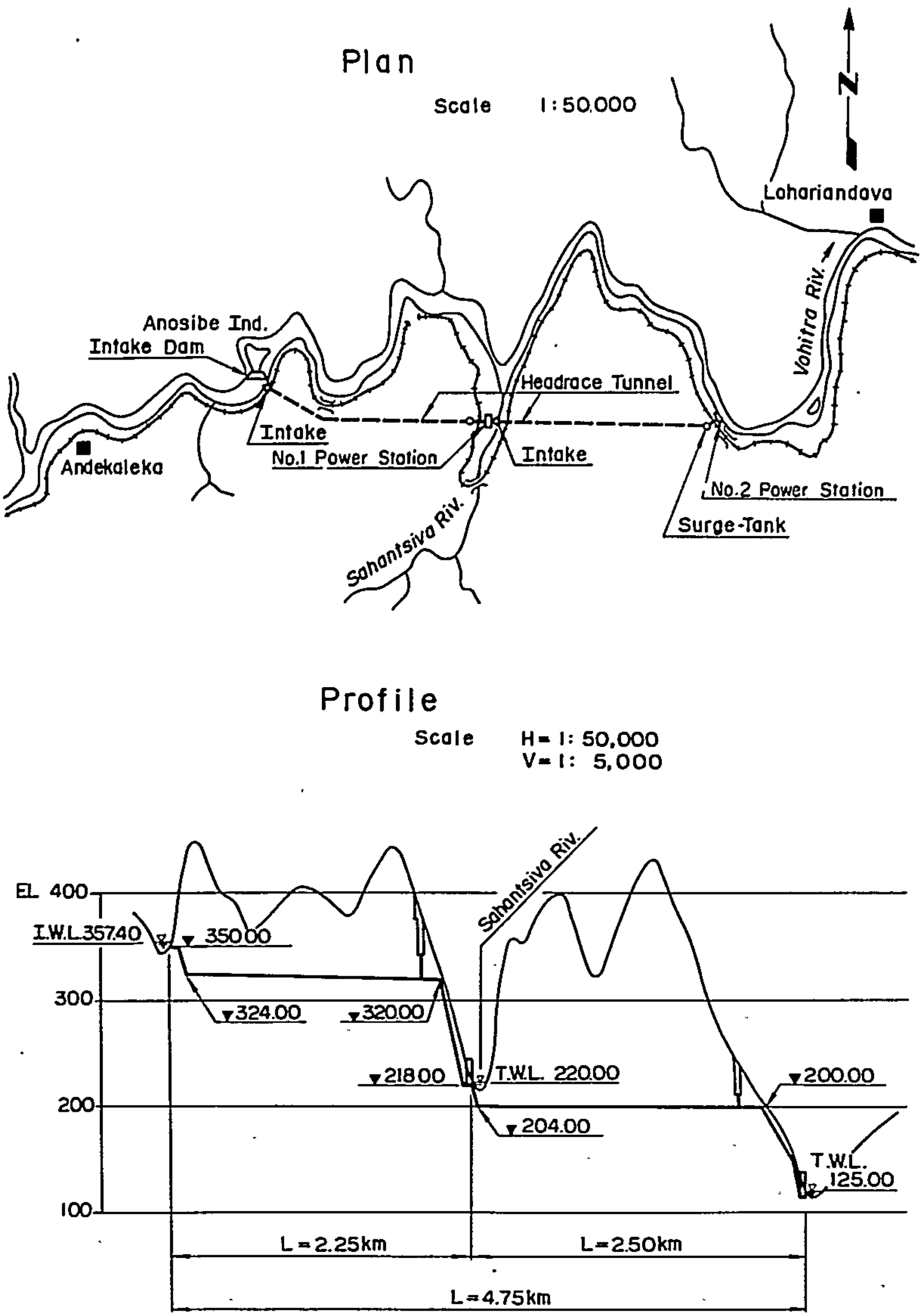


Fig-5.5 Rainfall Observatory Stations and Stream Gauging Station

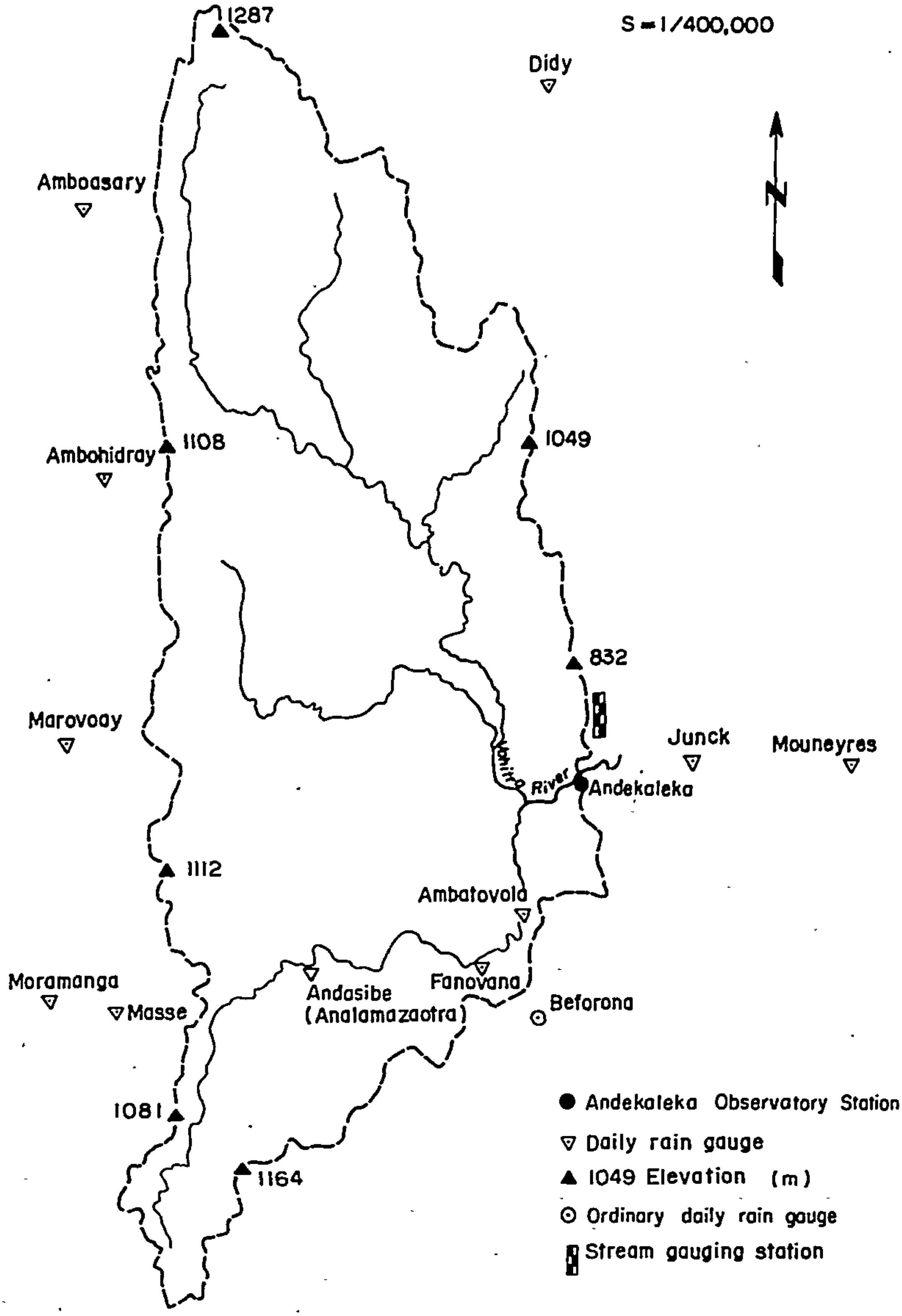
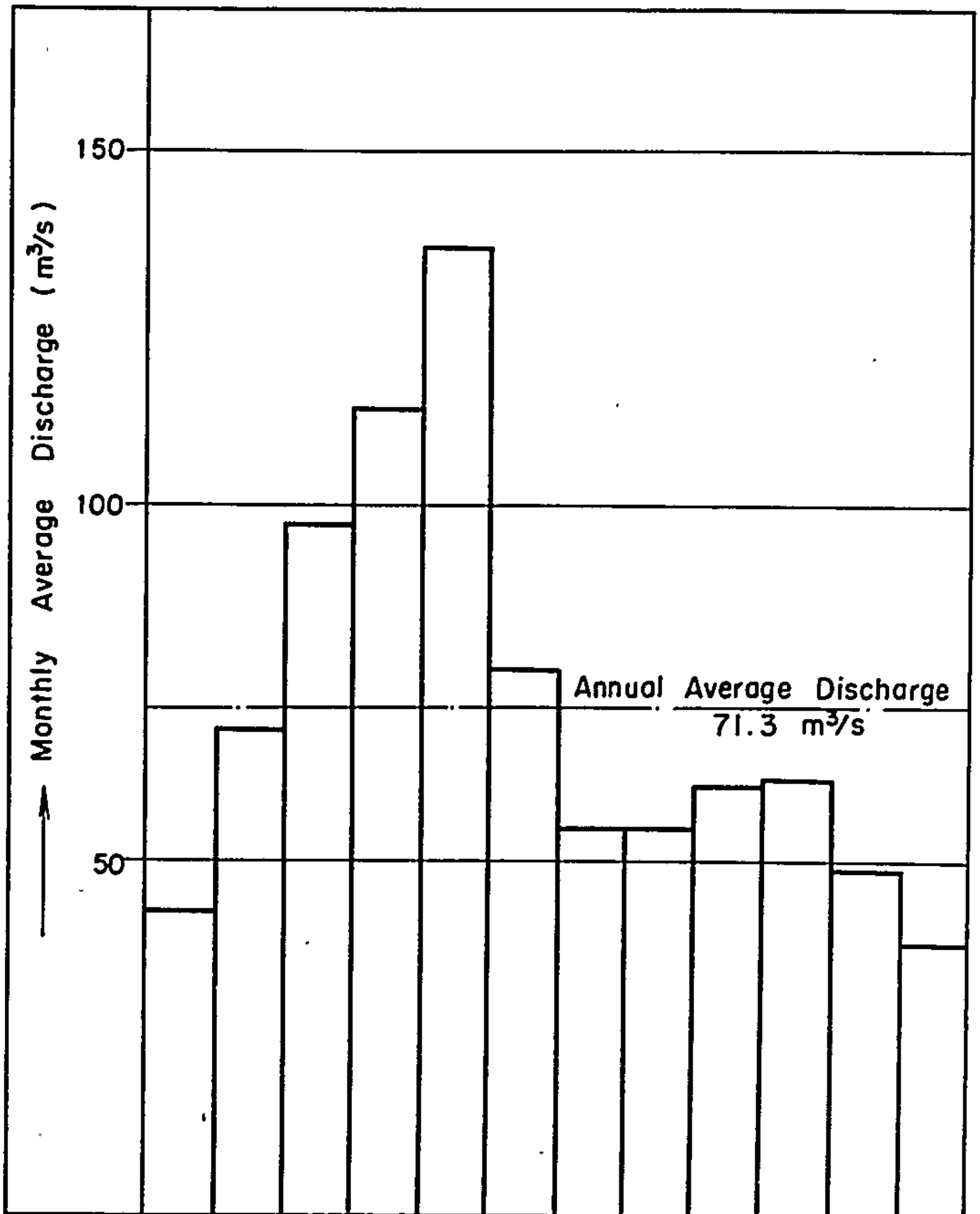


Fig-5.6 Monthly Average Discharge



Month	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Average	43.0	68.5	97.7	113.5	136.7	76.9	54.7	54.7	60.6	61.7	48.8	38.6

Fig-5.7 Discharge Duration Curve

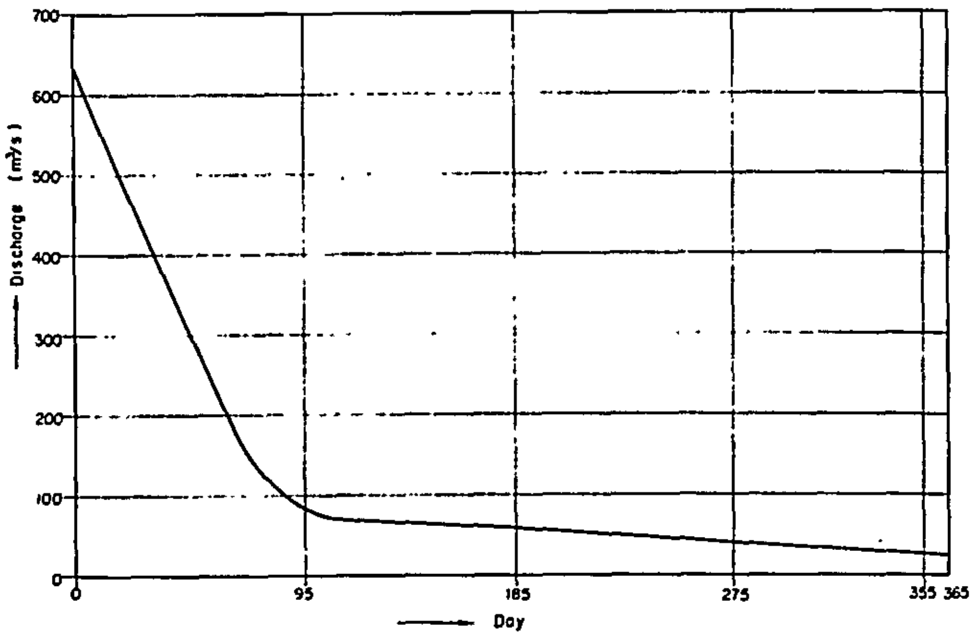


Fig-5.8 Water Depth Discharge Curve

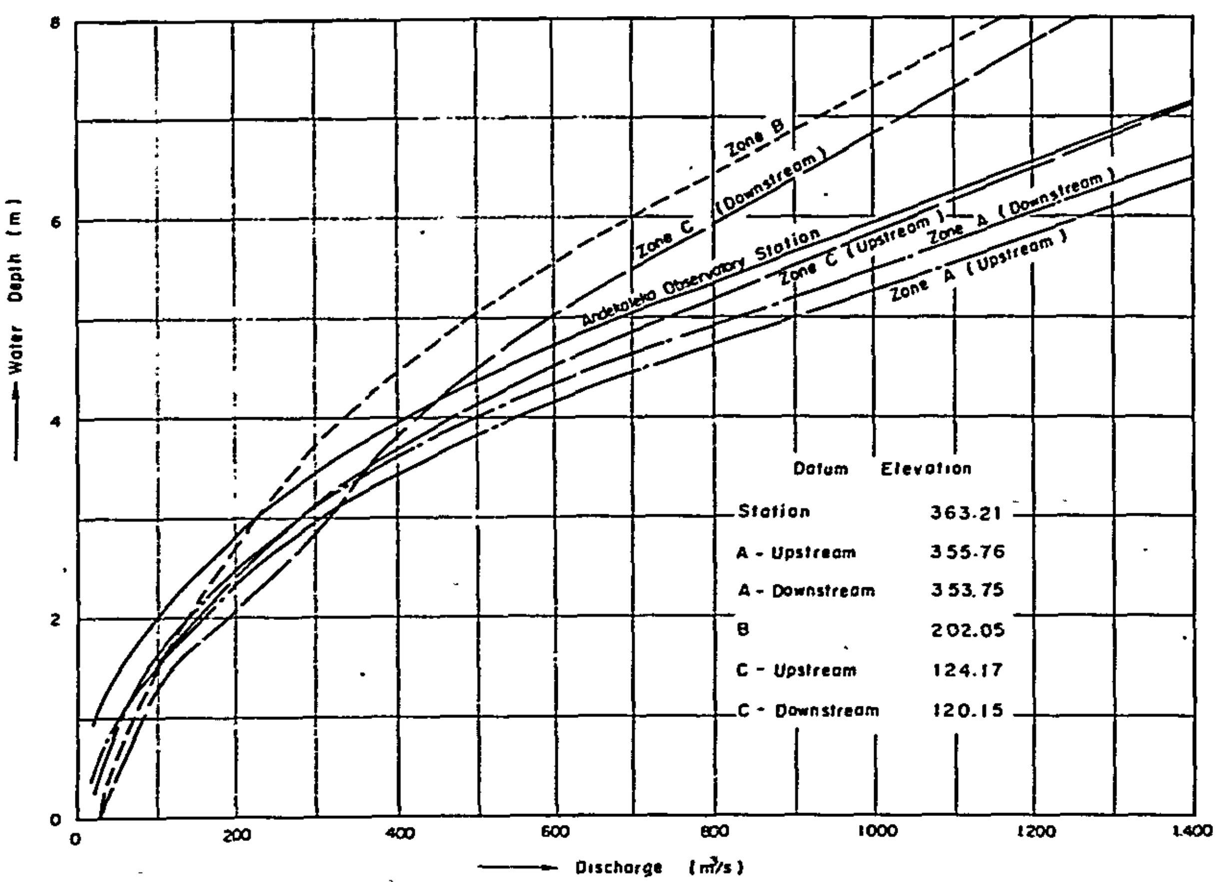


Fig-5.9 Pole of Schistosity Planes of Foundation Rocks

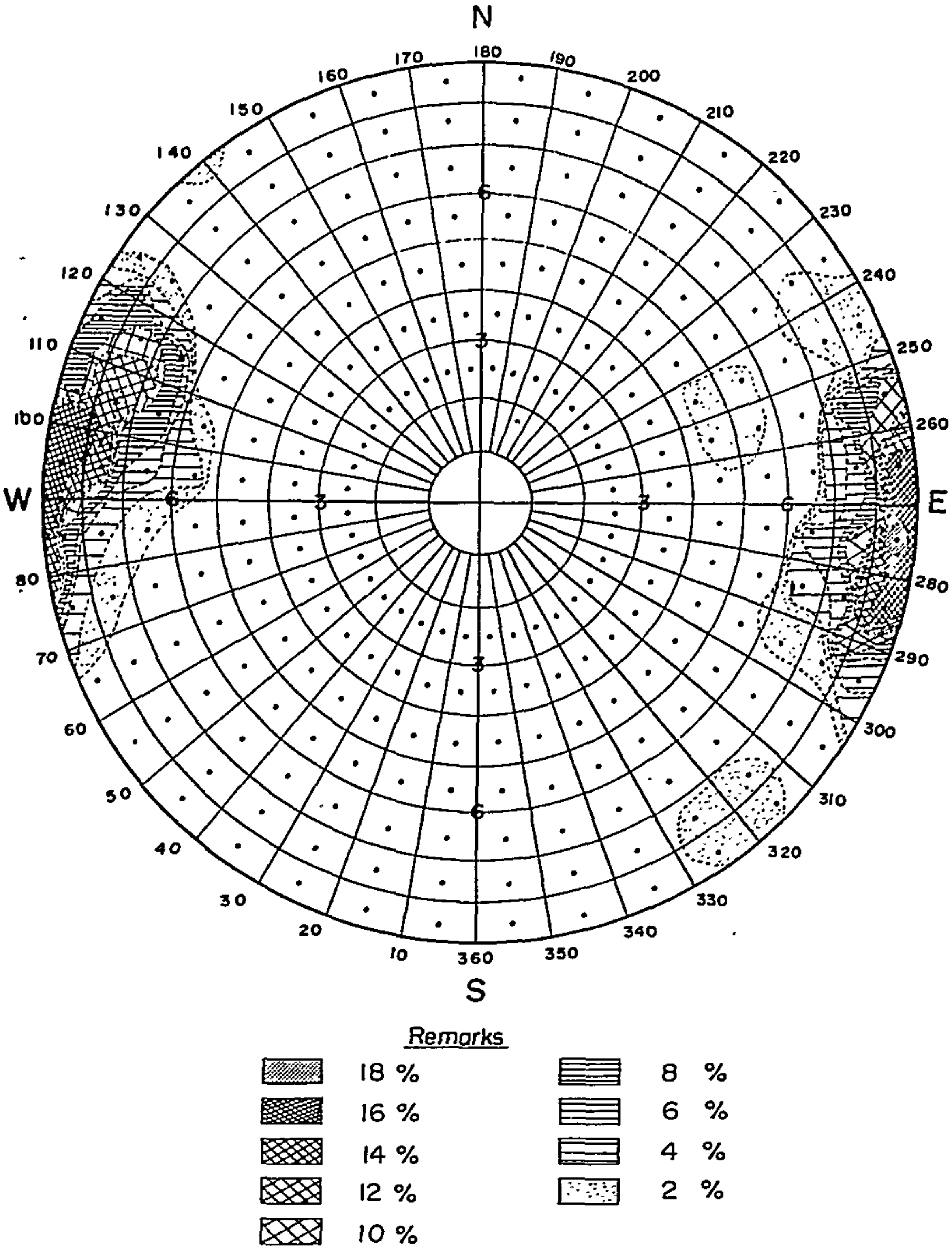
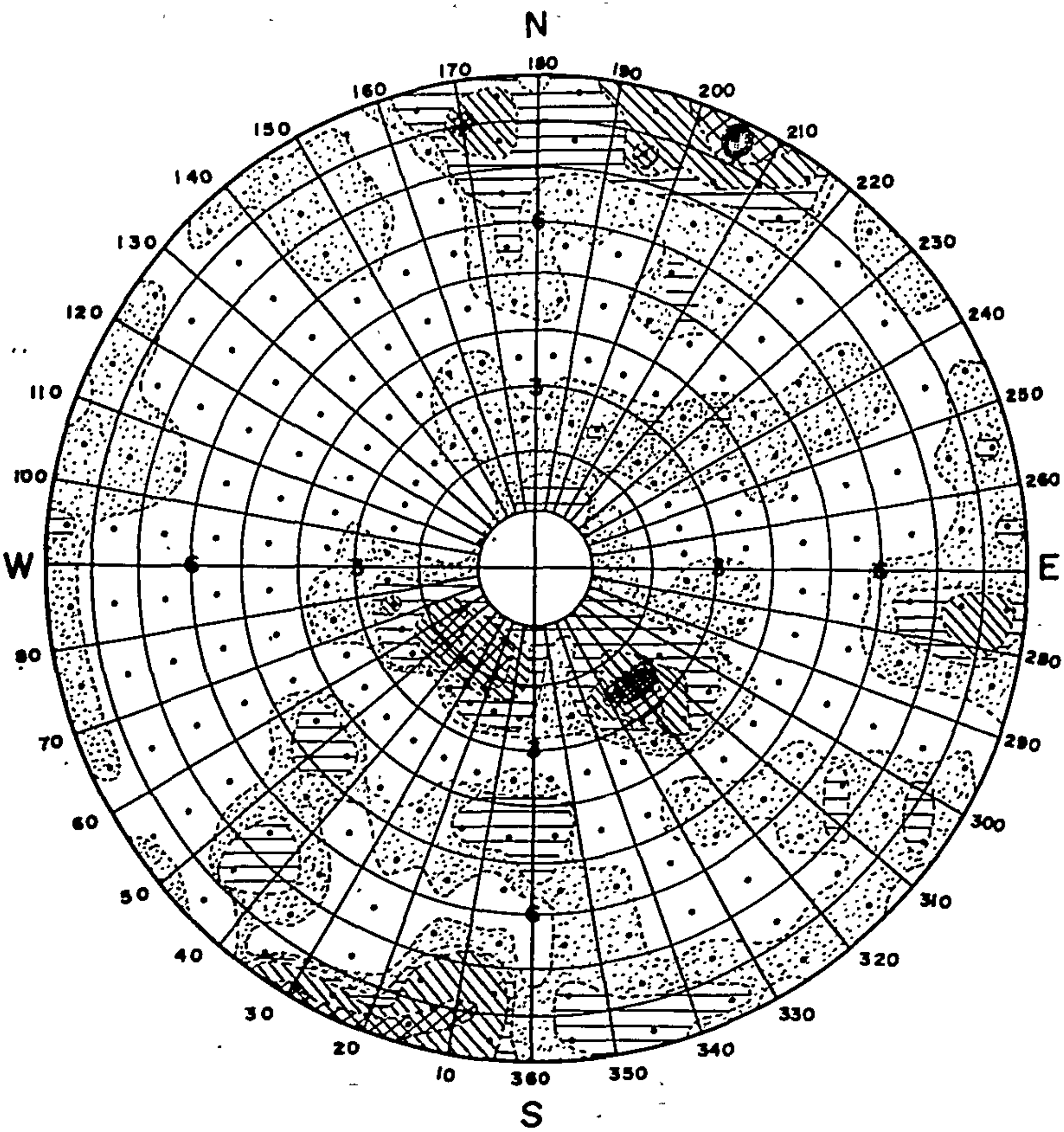


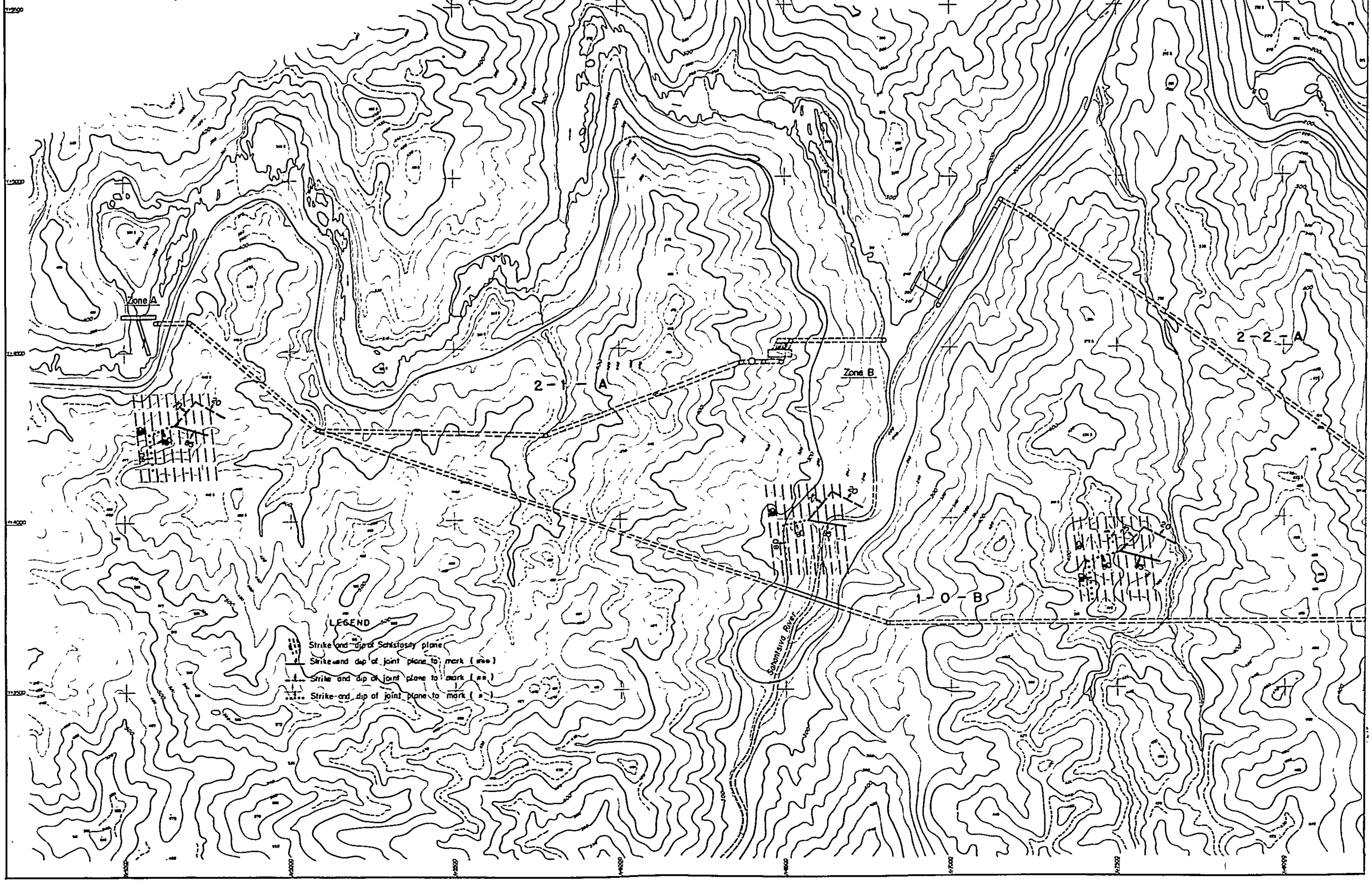
Fig-5.10 Pole of Joint Planes of Foundation Rocks



Remarks

1 ~ 2 %	6 ~ 7 %
3 ~ 4 %	8 %
5 %	9 %

Fig-5.11 Plan of Conduit Tunnel and Principal Direction of Schistosity and Joint Planes of Foundation Rocks



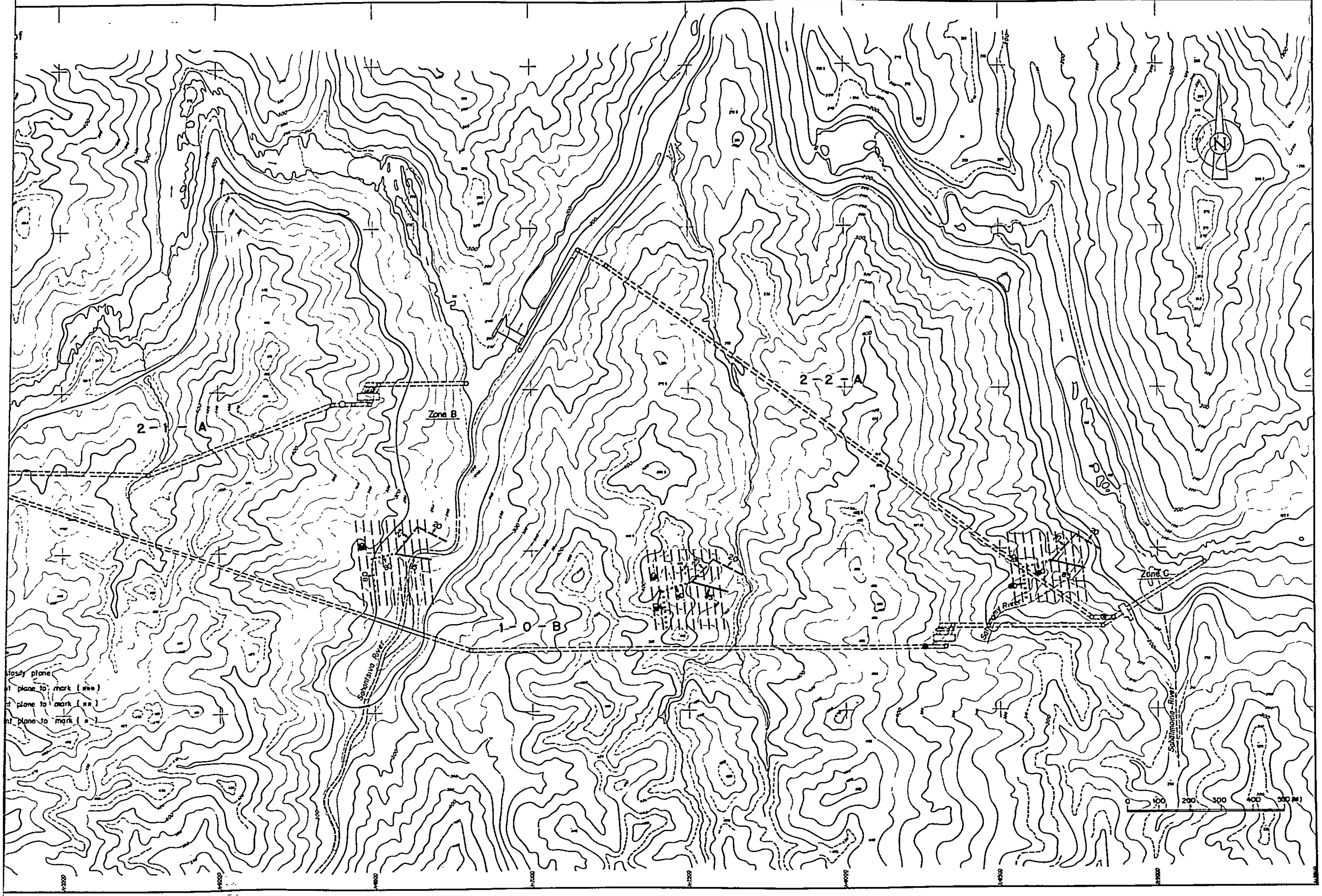
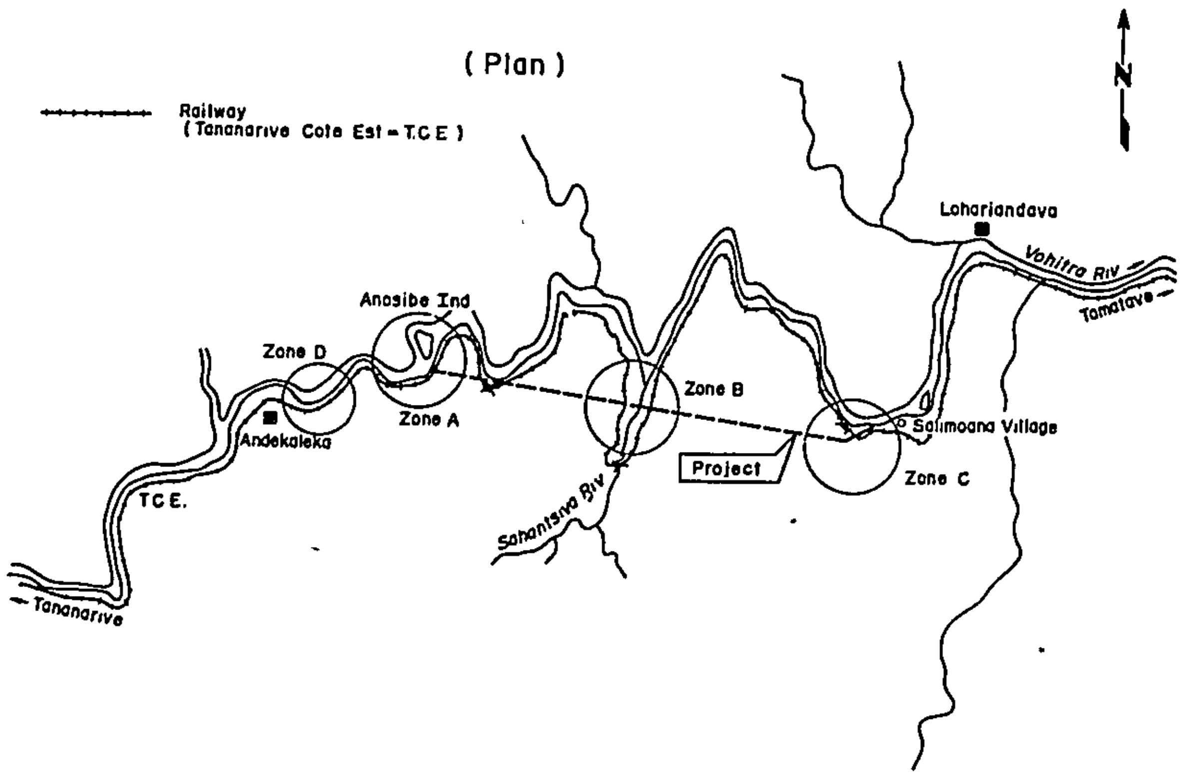

2-1-A
2-2-A
1-0-B
Zone B
Zone C
Sahamisiva River
Sahamony River
Sahamoana River
0 100 200 300 400 500 (M)

Fig-5.12 Project Area



Chapter 6.

Economic Evaluation of Development Project

Chapter 6 Economic Evaluation of Development Project

6.1 Approach to economic evaluations

In order to determine the most economic and realistic pattern of development, comparative studies are made by the following sequences:

First of all, both the 1-stage development pattern as represented by 1-0-B Plan and the 2-stage represented by 2-1-A and 2-2-A are compared after conversion into the present value of capital investment, fuel cost, and operating and maintenance expenses to be required to satisfy maximum power and energy demands for the '76 - '95 period.

Secondly, comparisons are made of benefit on the basis of the internal rate of return calculated from each alternative.

Then, the financial problems are studied by forecasting the status of cash flow in the future ahead when necessary expenses and loan funds will have been paid off by the revenues earned from energy wholesales at a properly fixed unit price.

Finally, general reviews are made for conclusion to determine the most suitable pattern of development.

6.2 Comparison in present value

1-stage and 2-stage development patterns are compared by three different demand patters; 'most probable', 'maximum' and 'minimum' as defined in the preceding Chapter 3. The results are as shown in Fig. -6. 1 thru 6. 3. See Table-A. 6. 1 thru A. 6. 6 for further details on calculated values.

As inferred from those Figures, it is apparent that both of the development patterns are nearly equalized in present value at about 12 % rate of discount if there is power demand for ferrochrome production, and, if not, equalized at about 9 % rate of discount.

6.3 Benefit and internal rate of return

The term 'benefit' herein refers to the annual expenses for the alternative diesel power generating unit having equal reliability and function to the hydro power unit proposed in each alternative plan.

The difference between the above benefit and the annual operating and maintenance costs estimated for each hydro power plan is herein referred to as the net benefit. Table-6. 1 indicates the internal rate of return, at which the above benefit can be yielded from necessary investments for 50-year durable lifetime of the proposed Andekaleka Hydro Power Station.

As shown in that Table, the economic priority of profitability can be placed upon Case 4, then followed by Case 3, 2, 1, 6, and 5. The rate of return will be as high as 15 % in the case where there is power demand for 2 furnaces of ferro-chrome production. Even if there is no power demand, the rate can still be maintained at 12 % or so. These calculated results fully assure profitability of the project.

In the case where there is power demand for ferrochrome production the rate of return will be higher by about 20 % in profitability than in the case where there is no such demand. See Table-A. 6. 1 thru A. 6. 6 for details.

6.4 Financial reviews

Comparisons of the required fund for investments by years are as shown in Table-6. 2. As noted from the Table, the 2-stage plan is superior to the other, for spending of the fund is well-balanced in nearly equal amounts by years and such fund can be raised without difficulty if and when necessary.

Table-6. 3 shows the status of cash flow after complete repayment of the total loan fund under the following terms and conditions:

Interest rate	:	7 % per annum
Term of repayment	:	30 years including 7-year grace period
Method of repayment	:	Equal instalment of total amount added with interest.

See Table-A. 6. 1 thru A. 6. 6 for details.

As shown in the above Table, the 2-stage plan poses no financial problems with the earnings from energy wholesales to the public sector and sales to the ferrochrome plant at unit price of properly fixed power rate. (See Section 3. 2 of

Chapter 10 for details.) On the other hand, the 1-stage plan includes some financial problems to be anticipated with deficit finance in years.

6.5 Conclusion from economic evaluations

Conclusions reached from evaluations are as summarized in each item below:

(a) When reviewed from the purely economic aspect, there is little to choose between the 1-stage and the 2-stage development patterns.

(b) To raise fund from time to time is easier in case of the 2-stage than its counterpart.

(c) The 2-stage plan can assure financial stability from its expected earnings.

(d) Even in the case of the 2-stage development, the deficit account will continue for some years at the early stage of development with a relatively low level of power demand in the public sector if there would be no power demand for ferrochrome production. Therefore, any possible measures must be taken to stimulate power demand increase, so that the deficit can be reduced.

(e) The profitability can be expected from the case of the 2-stage development and. also from the case where power demand arises from ferrochrome production.

Table-6.1 Internal Rate of Return

Case	Demand	No of Furnace	Development Plan	I. R. R. (%)
Case 1	Most Probale	2 Furnaces	1 Stage Plan	13.44
" 2	"	2 "	2 "	13.56
" 3	Maximum	3 "	1 "	14.45
" 4	"	3 "	2 "	14.65
" 5	Minimum	0 "	1 "	10.92
" 6	"	0 "	2 "	11.23

Table-6.2 Annual Investment

Unit: 10^6 FMG

Year	Most Probable		Maximum		Minimum	
	1-Stage Plan	2-Stage Plan	1-Stage Plan	2-Stage Plan	1-Stage Plan	2-Stage Plan
1976	1,454	1,454	1,454	1,454	1,454	1,454
1977	2,912	2,294	2,912	2,294	2,912	2,294
8	3,560	2,873	3,500	2,873	3,560	2,873
9	4,062	2,972	4,062	2,972	4,062	2,972
1980	3,121	2,205	3,121	2,205	3,121	2,205
1	-	-	-	-	-	-
2	672	524	672	524	-	-
3	1,111	1,828	1,111	1,828	-	524
4	2,051	1,088	2,051	1,088	-	988
5	1,162	2,906	1,162	2,906	-	1,088
6	-	1,955	-	1,955	672	1,065
7	180	2,517	180	2,517	1,111	-
8	30	1,975	30	2,767	1,211	-
9	-	-	-	-	1,162	1,841
1990	-	-	-	-	-	1,955
1	-	-	1,632	-	180	2,517
2	-	-	792	840	30	1,975
3	792	792	-	792	-	-
4	792	-	792	792	-	-
5		792	840	792	-	-

Table-6.3 Cash Flow

Unit: Px in FMG/kWh
Cash Flow in 10^6FMG

Year	2 Furnaces				No Furnace		
	Unit Px		Cash Flow		Unit Px	Cash Flow	
	Pub.	Fe-Cr	1-Stage Plan	2-Stage Plan	Pub.	1-Stage Plan	2-Stage Plan
1981	7.20	3.90	-411	-121	7.20	-725	-442
2	"	"	-236	47	"	-623	-340
3	"	"	-311	-140	"	-837	-483
4	"	"	-180	3	"	-713	-360
5	"	"	-162	67	"	-576	-224
6	6.50	3.50	46	72	6.50	-484	-131
7	"	"	195	254	"	-334	-302
8	"	"	253	319	"	-172	-141
9	"	"	409	-43	"	9	42
1990	"	"	458	76	"	-166	146
1	6.20	3.20	598	164	6.20	4	291
2	"	"	710	125	"	215	470
3	"	"	789	208	"	332	25
4	"	"	919	371	"	548	267
5	"	"	920	428	"	827	514

Fig-6.1 Comparison of Present Value (Minimum)

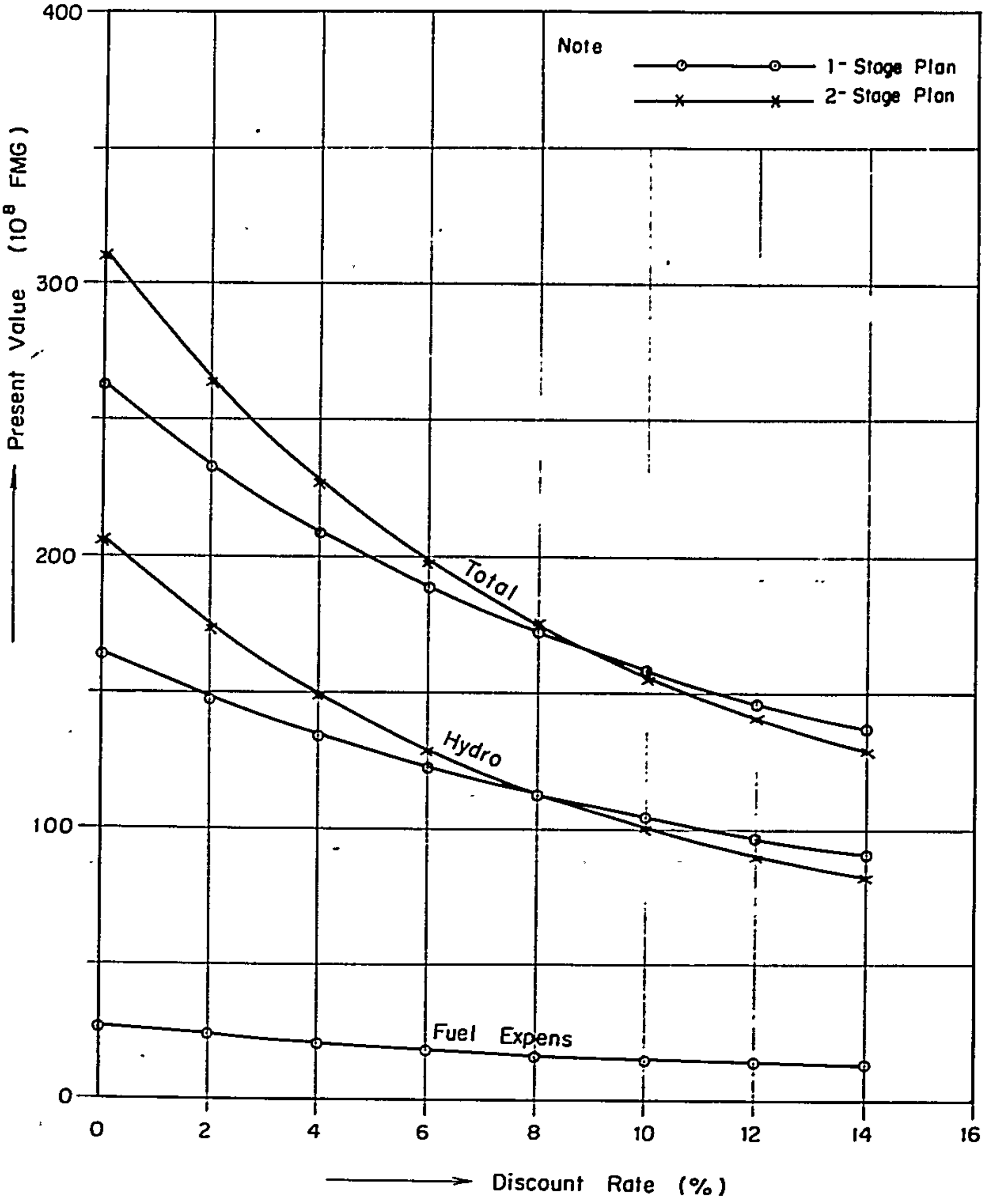


Fig-6.2 Comparison of Present Value (Maximum)

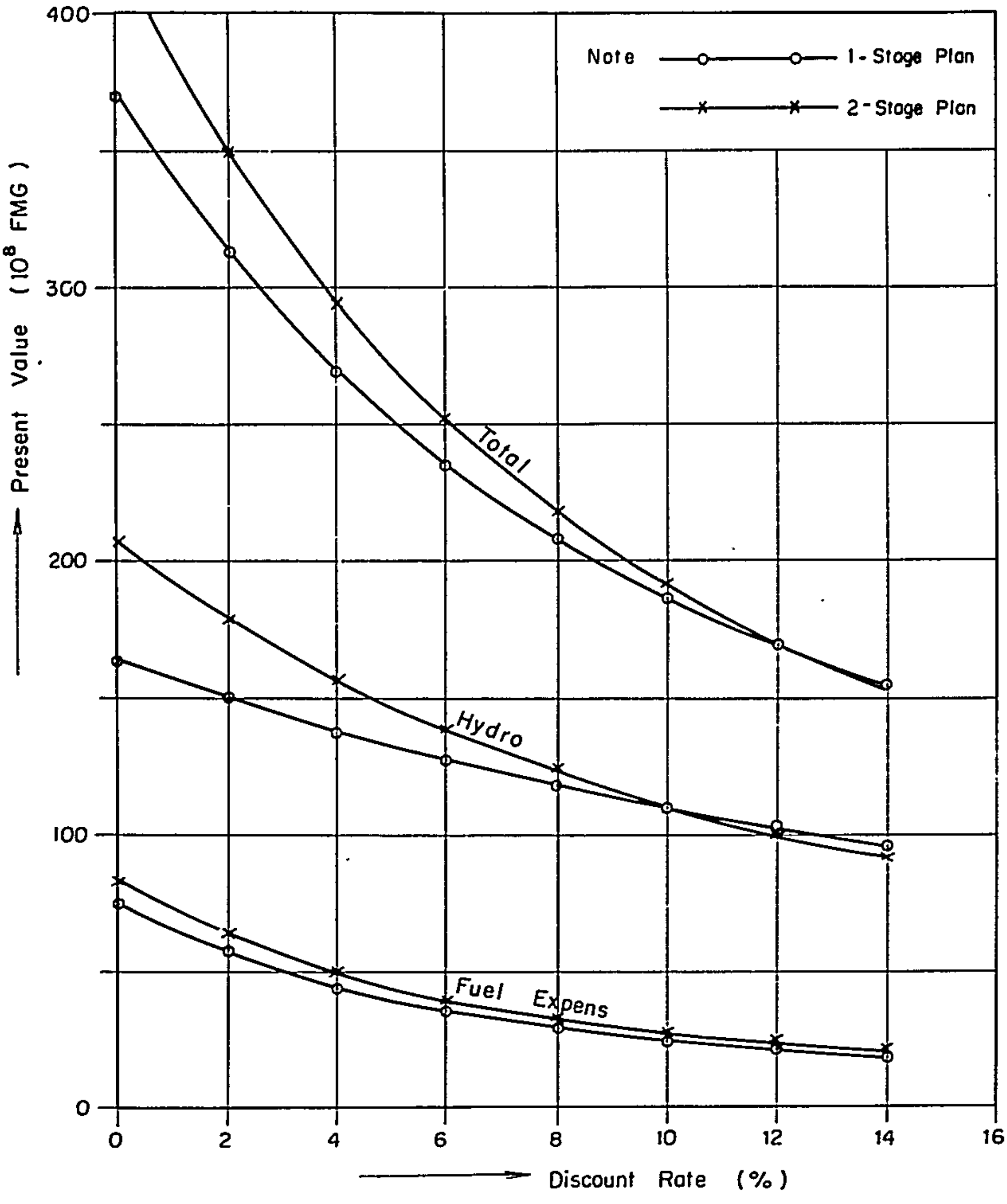
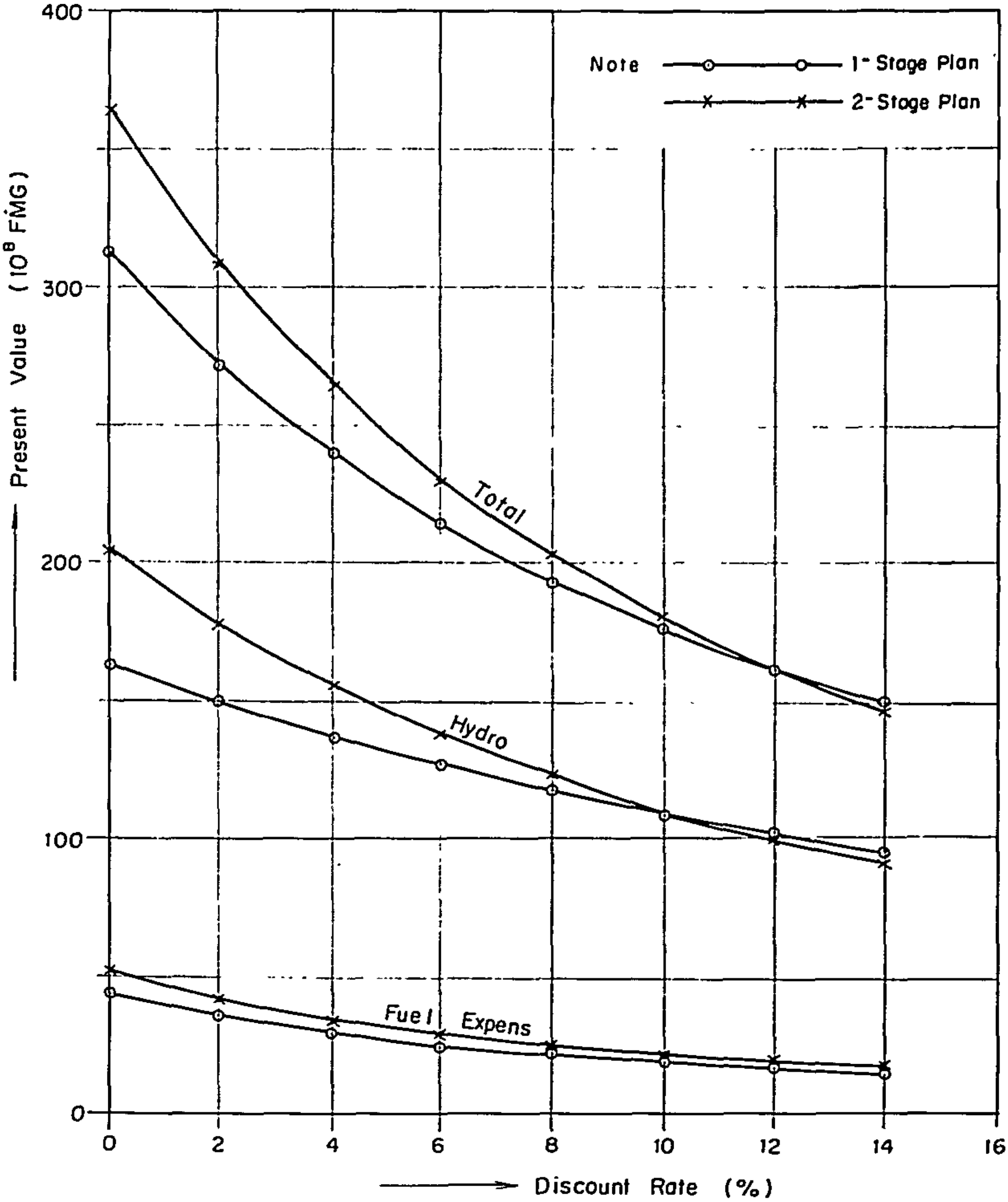


Fig-6.3 Comparison of Present Value (Most Probable)



Chapter 7.

Development Scheme at Andekaleka Site

Chapter 7 Development Scheme at Andekaleka Site

7. 1 Summary of scheme

In the preceding Chapter economic evaluations were made on each representative plan for 1-stage and 2-stage development patters which have been selected after technical reviews as referred to in Chapter 5. After such comparative studies, decision has finally been made by judgement that the 2-stage development pattern is advantageous over the 1-stage development in view of fund-raising for investments and flexibility to future increases of power demand, and the plan to combine 2-1-A with 2-2-A has finally been adopted for implementation of the project. Hereinafter, the 2-1-A plan is named as 'Andekaleka No. 1 Power Station Project' and the 2-2-A plan as 'Andekaleka No. 2 Power Station Project'.

7. 1. 1 Design factors

Design factors for both Andekaleka No. 1 and No. 2 Power Station Projects are tabulated in Table-7. 1 and 7. 2. Plans and profiles of both Power Stations are as shown in Dwgs. -2-1-A and 2-2-A.

Specification

	No. 1 Power Station	No. 2 Power Station
I. W. L	357. 0	205. 0
T. W. L	205. 0	120. 6
Gross Head	152. 0	84. 4
Effective Head	138. 7	70. 9
Maximum Discharge	60 m/s	60 m/s
Maximum Output	70, 400 kW	36, 000 kW
No. of Units	4	2
Annual Capable Energy Production	516 GWh	271 GWh

7. 1. 2 Development priority

As shown in Table-7. 1 and 7. 2, the installed capacity for No. 1 Power Station consists of four generating units of 17,600 kW each and for No. 2 Power Station, two generating units of 18,000 kW each. The development priority of the one to the other of the two Stations must be determined from the following factors to be considered:

(a) Accessibility to construction sites

(b) Comparison of construction costs

(c) Power demand increases

Firstly, as for the accessibility, there is little to choose between both construction sites, because both of them are situated near the railroad. Although the No. 2 Power Station site appears to be a little more advantageous in view of the fact that the feeder road from National Highway Route 2 leads to Salimoana Village where the switchyard for the No. 2 Power Station is to be built, it is not considered as a priority factor, because both of the power stations are distanced only 10 Km or so.

Secondly, when the construction costs are compared, the unit cost for No. 1 project will be 20. 5 FMG/kWh, while that for No. 2 will be 33. 0 FMG/kWh. Evidently, the former is advantageous over the latter with its lower unit cost.

Finally, in view of the additional installation plan for increasing power demands, No. 1 Power Station will be provided with two 17,600 kW generating units (one as standby),. as the 1st-term construction, for security of 35,200 kW maximum output for the estimated prevailing demand. Then, at the time of further increase in power demand, the 2nd-term construction work will start with additional installation of two 17,600 kW units to finally complete the No. 1 Power Station. At the same time a regulating pond will have to be constructed on the upstream of the intake in Zone A.

On the other hand, No. 2 Power Station will be completed with two 18,000 kW generating units (one as standby) all at one time. Before No. 2 Power Station will go into its full operation, a regulating pond will be constructed at the same point as provided for the No. 1 Power Station. In this case, however, the pond will be located about 6 Km apart from the intake, which will add some difficulty to its regulating function.

After full review of additional installation plans for each Power Station in relation to increasing demands, a conclusion has been reached that No. 1 Power Station has its advantage over No. 2, in that it can be developed in such a pattern as may be able to meet the gradual increase of power demand.

In view of all aforementioned, the priority of development is given to the construction of the No. 1 Power Station, for which two generating units will be installed as the 1st-term work, and as the 2nd-term work, the other two units will be additionally installed together with the construction of a regulating pond. Then, completion of the No. 2 Power Station will come next as the 3rd-term construction. Such priority of development from No. 1 to No. 2 is recommendable as the most economic and efficient way of development. Fig. -7. 1 shows additions of generating capacity in relation to increases of power demand.

7. 2 Andekaleka No. 1 Power Station

7. 2. 1 Civil engineering works

(1) Intake dam

The intake dam will be located in the stream on the upstream end of Anosibe Island, P. K. 197. 500 Km. The site is situated between both banks with exposed bed-rock. Topographically viewed, the Vohitra River will be halved with bed-rock laying bare in parallel with the line of the river stream. The main stream will flow down on the left-bank side, and on the right bank side, a stream with flow at the rate of some 50 m^3/s. Since the railroad is at the 366 m altitude, the dam site and its crown height have been determined with precaution not to cause the railroad submergence due to the high water level raised by the dam at 3, 500 m^3/s discharge during operation. The dam will be an overflow type, gravity concrete dam.

(2) Intake

The intake with a screen in its front will be located, closer to the dam, at a right angle to the axial line of the dam. The regulating gate will be provided on the upstream of the inlet to the pressure tunnel.

(3) Settling basins

The river-flows on both bank sides will be halved with a weir to be constructed by utilizing the bed-rock laying bare as aforementioned in the item of intake dam (1). Then, there will be the settling basins to be utilized; Main-basin on the left-bank side and Sub-basin on the right-bank side. The crown height of the weir is lowered by 1 m as compared with that of the intake dam, so that the discharge of 60 m^3/s or less may be flown into the basin on the right-bank side. There will be two radial gates, one in the center of the left-bank side river flow, and the other near the intake on the right bank side. They can be used as drain gates during construction.

(4) Head race

The total extension of the head race will be 1,937 m. With due consideration to topographic and geological conditions involved, it is designed in such a way that the portion equivalent to 80 %, or 1,550 m, of the total length will be of no-concrete-lining, and the remainder, or 387 m, will be lined with concrete. It will be a standard horse-shoe shape with diameter of 5. 2 m as determined from the economic viewpoint. The route for centering of the alignment has been selected with full consideration to adequacy of the covering in the marsh zone, under which the route is to pass through. Further consideration is given to reducing the effect of hydraulic pressure to act upon the waterway by raising the elevation of the route.

(5) Surge tank

The surge tank will be of restricted orifice type for prompt stabilization of surging.

(6) Penstock

The penstock will be laid in a vertical shaft with respect to the power station siting, in an attempt to try to reduce the total length to the possible minimum. The penstock will start in a single line at its upper portion and will be diversified into four lines at the lower portion.

(7) Power Station

The power station will be of a complete underground type, located at the site with adequate covering on the mountain side at the point of P. K. 199. 300 Km.

The access road for transit of equipment to the power station will be tunnelled after the outdoor switchyard and will terminate at the generator room of the power station. The power station will accommodate various operating rooms, such as control room, telecommunication room, etc. and will be equipped with an overhead crane capable of 50 tons load at maximum.

(8) Tailrace surge tank

The chamber-type surge tank will be provided for the tailrace with total extension of 273 m, equipped with a draft gate.

(9) Tailrace

The total extension of the tailrace will be 273 m. It will be of a standard horse-shoe shape, similar to the case of the head race. The portion equivalent to 80 %, or 218 m, of the total length will be of no-concrete-lining and all the remainder, or 55 m, will be lined with concrete.

(10) Outlet

The outlet will be located on the right bank of the Vohitra River, about 60 m upstream from the confluence with the Sabantsiva River. Since its location coincides with the point where the Vohitra River changes its course nearly at right angl. and the rapids on the upstream side of the outlet form a head of about 10 m, the siting condition for the outlet appears to be rather complex when viewed from the hydrological aspect. Therefore, in determining the exact location for the outlet and the type or size of the outlet, full reviews must be made by means of a model test or the like.

7.3 Andekaleka No. 2 Power Station

7.3.1 Civil engineering works

(1) Intake dam

The dam will be constructed in the stream of the Vohitra River, about 200 m downstream from the confluence with the Sahantsiva River. The dam site is featured by the bed-rock laying bare on both sides of river banks. In selecting the dam site, consideration is given to restraining possible.increase of overflow depth at flood, thus reducing its effect upon the upstream flow, by making the crest length of the dam longer. Also, the provision for settling basins alongside the river has been taken into consideration. The dam will be of an overflow type, gravity concrete dam.

(2) Intake

The intake will be provided in a right angle to the intake dam on its right-bank side. Since the flow after the intake turns to an angle of 90 degrees, a forebay will be provided before the regulating gate with a wider inlet to reduce the flow velocity. A screen will be provided in front of the intake.

(3) Settling basin

The settling basin connected with the regulating gate of the intake is, for the sake of construction cost saving, designed for open-surface type on the ground on the right-bank side of the dam alongside the Vohitra River, though the tunnel type basin may be desirable if the alignment of the waterway alone is considered from the hydraulic standpoint. A spillway will be provided to facilitate withdrawal of water in a fixed quantity. At the terminating point of the basin, the scouring sluice gate will be installed to halve the basin for easy removal of sand.

(4) Head race

The total extension of the head race will be 2,051 m. With due consideration to both topographic and geological conditions involved, it is designed in such a way that the portion equivalent to 80 % of the total length, or 1,641 m, will be of no concrete lining, and the remainder, or 410 m, will be lined with concrete. It will be of a standard horse-shoe shape with same diameter as applied to that for the No. 1 Power Station. The route for centering the alignment has been selected, as is the case of No. 1 Power Station, with full consideration to the condition of the marsh zone under which the route is to pass through. The elevation of the route is raised so as to mitigate the effect of hydraulic pressure acting upon the waterway.

(5) Surge tank

The surge tank will be of a restricted orifice type, similar to that for the No. 1 Power Station.

(6) Penstock

The penstock will be laid in a vertical shaft for the same reason as mentioned in the case of No. 1. The penstock will start in a single line, and branch off into two lines at its lower portion.

(7) Power station

The power station will be of complete underground type, located at the selected site for adequate covering on the mountain side at the point of P. K. 205 Km. The access road for equipment transit to the power station will be tunnelled after the outdoor switchyard to be located on the mountain side of Salimoana Village, and will terminate at the generator room of the power station. The power station will accommodate various operating rooms, such as control room, telecommunication room, etc.

The overhead crane to be installed will be capable of 80 tons load at maximum. Main transformers will be arranged alongside the access road to the entrance of the power station.

(8) Tailrace surge tank

The chamber-type surge tank will be provided for the tailrace having a total extension of 283 m. The tank will be equipped with a draft gate.

(9) Tailrace

The total extension of the tailrace will be 283 m. It will be of a standard horse-shoe shape, similar to the case of the head race. The portion equivalent to 80 %, or 226 m, of the total length will be of no-concrete-lining and all the remainder, or 57 m, will be lined with concrete.

(10) Outlet

The outlet will be located at P. K. 205. 900 Km on the right bank of the Vohitra River,which has been selected as the most suitable location from topographic and geological conditions.

7.4 Electrical installation

7.4.1 Turbine

(1) Selected type of turbine

From effective head and specific speed designed for the project, Francis turbines are selected as the most suitable type for both the No. 1 and No. 2 Power Stations. Although the use of Deriaz type turbines may be considered desirable, in the case of No. 2 Power Station, so as to meet the rise or fall of the intake water level or requirement for partial load operation, the vertical-shaft Francis turbine of relatively low price has been finally selected, since a number of generators are to be installed and the effective head will remain almost unchanged.

(2) Turbine specifications

Specifications for the turbine to be used for both Power Stations are as shown in the Table below:

	Type	Output (kW)	Effec. Head (m)	Disch. (m^3/s)	Revol. Speed (r.p.m)	Specific Speed	No. of Units
No. 1 Power Station	Francis Turbine	18,100	138.7	15	500	142	4
No. 2 Power Station	"	18,600	70.9	30	333	220	2

(3) Height for setting of turbine center

In order to prevent cavitations, the center of the turbine casing must be set at a lower level than the elevation specified below:

	Height of casing center	
No. 1 Power Station	Water level in tailrace at 1-turbine operation	- (2.4-0.354)
No. 2 Power Station	"	- (2.3-0.717)

(4) Inlet valve

A butterfly valve will be used as an inlet valve for the turbine.

7.4.2 Generator

(1) Specifications

As shown in the Table below.

	Type	Output (kVA)	Voltage (kV)	Current (A)	Power Factor (%)	Revol. Speed (r.p.m)	Frequency (Hz)	No. of Units
No. 1 Power Station	Vertical Shaft Three Phase	22,100	11.0	1,210	80	500	50	4
No. 2 Power Station	"	22,500	11.0	1,239	80	333	50	2

(2) Cooling system

Cooling system for the generator will be of a totoally-enclosed circulation type equipped with several air-coolers (water-cooled).

(3) The generator will be of a separate excitation system with a DC-generator on its main shaft to serve as an excitor.

7.4.3 Main transformer

(1) Specifications

Main transformer will be installed in a complete unit system with a turbine and a generator. In the interest of cost saving, however, it is necessary to study about the application of the system of one single transformer per two generators.

	Type	Output (kVA)	Prim. Voltage (kV)	Second. Voltage (kV)	Frequency (Hz)	No. of Units
No. 1 Power Station	Three-Phase	22,100	11.0	150	50	4
No. 2 Power Station	"	22,500	11.0	150	50	2

(2) Cooling system

Forced oil, water-cooled system will be adopted for main transformers of the underground power station. O. F. cable connections will be of elephant type.

7.4.4 Outdoor switchyard

The outdoor switchyard will be of a single bus type. The bus bar will be supported at a proper height with the outdoor structure.

The station has several divisions for the operation of transmission and the secondary side of transformer, etc. each being equipped with disconnecting switches, circuit breakers, porcelain-clad type balancers, current transformers and arresters, etc., as shown in the one-line wiring diagram in Fig. -7. 5.

Since only one circuit will be provided for the 150 kV transmission line, the bypass circuit will be provided for the breakers on both incoming and outgoing sides to prepare for any possible trouble or for the convenience of line inspection.

7.4.5 Control system

The station will be of a one-man control system. The control center will be located near the switchyard from which remote control will be provided.

7.4.6 Other installations

(1) Water supply and drainage system

For cooling water supply to the bearings of turbine and generator and to the air-cooler of the generator and the oil-cooler of the main transformer, a water tank will be provided at a suitable place in the ventilation adit of the power station to supply each equipment with water in a natural flow-down after withdrawal of water from the tailrace by use of a feedwater pump. Water will be drained out into the tailrace.

Ground water seepage and drain not collected into the tailrace will be brought into a drain pit and forced out into the tailrace by use of a drain pump.

Feedwater and drain pumps will be automatically operated, each having a spare pump as standby. Especially, the drain pump must be devised to be driven by the diesel generating set in case of emergency.

(2) Ventilation and air-conditioning

For ventilating purpose the access road tunnel and other tunnels will be used as the inlets of induced air and exhaust outlets will be separately provided. If necessary, fans will be provided at both the inlet and the outlet.

Air-conditioning system will be provided for the relay room, telephone switchboard room, and any other spaces deemed necessary.

7.5 Transmission and telecommunication

7.5.1 150 kV transmission line

The applicable line voltage to the transmission line extending over 163.5 Km from Andekaleka No. 1 and No. 2 Power Stations to Tananarive via Moramanga will be 150 kV as the optimum voltage rating for the system power capacity and the distance of transmission. The rating of 60 kV as applied to the existing transmission line is not economical for use because of its great loss rate and large conductor size in use.

The branch-off feeder line connecting both the switching station in Moramanga and the ferrochrome plant of 5 Km distance will be of 150 kV rating similar to its trunk line.

The transmission line will be of one circuit, and for the distance of 77 Km from the power station to the switching station in Moramanga the ACSR 200 mm^2 conductor will be used for the line because of the greater load estimated for that section. The same ACSR 200 mm^2 will apply to the section between Moramanga and Tananarive because the total output of power generation may often be transmitted to Tananarive while the ferrochrome plant is shut down. For the branch-off section from Moramanga to the ferrochrome plant the ACSR conductor of 160 mm^2 will be used.

The transmission system will be of direct ground connection. The overhead ground wire will be installed as a safety measure against frequent occurrences of thunder. Power stations and substations will be protected with arresters.

Towers will be of single circuit, as shown in Fig. -7.3, which will be economically suitable for both the conductor size and the wind load condition. The span between the two towers will be about 250 m. As shown in Fig. -7.4, the transmission route is selected for the sake of convenience in its erection work and maintenance; namely, along the National Highway Route 2 for the section from Andekaleka to Moramanga, in parallel with the existing 30 kV transmission line from Moramanga to Mandraka, and along the existing 60 kV line from Mandraka to Tananarive. Out of the 163.5 Km total distance, the 'right of way' line to cross over flat land and hilly zones totals 55.5 Km and the line over the mountainous area reaches 108 Km.

7. 5. 2 Substation and switching station

(1) Ambohimanambola substation

The new substation for the 150 kV system will be installed at the site provided for future extension adjacent to the existing Ambohimanambola substation.

The ultimately required site area for construction of a substation is estimated at about 15, 000 m^2. Two transformers of 25 MVA each will be installed initially, and additional installation is planned as load may increase. The ultimate installed capacity of transformers will be 150 MVA in total, 6 units of 25 MVA each. After voltage drop from 150 kV down to 60 kV by way of those transformers, the line will be connected with the existing 60 kV substation.

(2) Moramanga switching station

In order to supply power to the ferrochrome plant, the feeder line of 150 kV, 160 mm^2 and 5 Km distance will be branched off from the 150 kV trunk line. For this purpose a switching station will be installed near the place where the 150 kV transmission line is to cross over the National Highway Route 44 in the suburb of Moramanga.

The ferrochrome plant will be served at the rating of 150 kV direct from the feeder line, and will receive power for production after drop of voltage down to 20 kV through one 25 MVA transformer to be provided at the house service substation of the plant.

The above system is recommendable from an economical point of view as compared with its alternative of either 60 kV or 20 kV transmission system with a substation to be installed in Moramanga.

7. 5. 3 Telecommunication system

The telecommunication system will be required for both operational and maintenance purposes between Andekaleka, Moramanga, and Ambohimanambola. The power line carrier system is recommendable for use as the cheapest and surest method to satisfy the present level of communication demand. Either microwave or telecommunication line carrier system is too costly at this stage.

Table-7.1 Specification for Andekaleka No.1 Power Plant

Structure	Item	Specification	Stage
Intake Dam	Type	Gravity Spillway Dam	1st
	Crown Elevation	EL 357 m EL 358 m	
	Length	50 m 50 m	
	Height	8 m 11 m	
	Volume	4,550 m^3	
	Scouring Gate	Radial Gate	
		Width; 5.0m, Height; 2.0 m 1 lot	
		Width; 5.0m, Height; 3.0 m 1 lot	
	Design-flood Discharge	3,500 m^3/sec.	
Intake	Width	Width; 4.5 m 3 lot	1st
	Design Water Depth	8 m	
	Screen	Width; 16.5 m, Height; 15.5 m 1 lot	
	Gate	Sluice Gate	
		Width; 5.4 m, Height; 5.1 m 1 lot	
Headrace	Type	Tunnel, Horseshoe-shaped Section	1st
	Diameter	4.8 m and 5.2 m	
	Thickness of Tunnel Concrete Lining	0.3 m	
	Bed Slope	1:20 and 1:400	
	Length	1,935 m	
	Maximum Discharge	60 m^3/sec.	
Headrace Surge-tank	Diameter	12 m - 4.8 m	1st
	Height	55.2 m	
Penstock	Type	Welded Steel Pipe	1st
	Length	198 m	
	Diameter	3.2 m	
	Thickness of Pipe	7 - 32 mm sa = 1,300 kg/cm^2	
	Line	1 Line	

Structure	Item	Specification	Stage
Tailrace	Type	Tunnel, Horseshose-shaped Section	1st
	Diameter	4.8 m and 5.2 m	
	Length	273 m	
Power Station			
Building	Type	Underground Power Station	1st
Water turbine	Type	Francis Turbine (Vertical Shaft), 4 units	1st, 2units 2nd, 2units
	Output	70,400 kW	
	Maximum Effective Head	138.7 m	
	Maximum Discharge	60 m^3/sec	
	Number of Revolution	500 r.p.m	
Generator	Type	3 phases A.C. Generator 4 units	1st, 2units 2nd, 2units
	Capacity	22,100 kVA	
	Voltage	11 kV	
	Frequency	50 Hz	

Table-7.2 Specification for Andekaleka No.2 Power Plant

Structure	Item	Specification	Stage
Intake Dam	Type	Gravity Spillway Dam	3rd
	Crown Elevation	206 m	
	Length	75 m	
	Height	7.5 m	
	Volume	6,760 m^3	
	Scouring Gate	Fixed Roller Gate, Width; 5.6 m Height; 6.5 m 2 lots	
	Design-flood Discharge	3,500 m^3/s	
Intake	Width	6.0 m, 4 lots	3rd
	Design Water Depth	4.35 m	
	Scrren	Width; 27.0 m Height; 5.0 m 1 lot	
	Gate	Sluice Gate, Width; 4.6 m Height; 5.5 m, 2 lots	
Settling Basin	Width	4.8 m - 31.0 m	3rd
	Length	152.5 m	
	Design Water Depth	5.05 m - 3.05 m	
	Length of Over Flow Section	50.0 m	
	Regulating Gate	Sluice Gate, Width; 4.0 m Height; 4.5 m, 2 lots Width; 4.0 m Height; 3.0 m, 2 lots	
	Scouring Gate	Sluice Gate Width; 2.0 m Height; 1.7 m, 2 lots	
Headrace	Type	Tunnel, Horseshoe-shaped Section	3rd
	Diameter	4.8 m and 5.2 m	
	Thickness of Tunnel Concrete Lining	0.3 m	
	Bed Slope	1:20, 1:40	
	Length	2050 m	
	Maximum Discharge	60 m^3/s	

Structure	Item	Specification	Stage
Headrace Surge-tank	Diameter Height	20 m - 4.8 m 45.2 m	3rd
Penstock	Type Length Diameter Thickness of Pipe Line	Welded Steel Pipe 103 m 3.2 m 5 - 19 mm sa=1,300 kg/cm^2 1 line	3rd
Tailrace	Type Diameter Length	Tunnel, Horsechoe-shaped Section 4.8 m 250 m	3rd
Power Station			3rd
Building	Type	Underground Power Station	
Water Turbine	Type	Francis Turbine (Vertical Shaft), 2 units	
	Output	36,000 kW	
	Maximum Effective Head	70.9 m	
	Maximum Discharge	60 m^3/s	
	Number of Revolution	333 r.p.m.	
Generator	Type	3 phases A.C. Generator, 2 units	
	Capacity	22,500 kVA	
	Voltage	11 kV	
	Frequency	50 Hz	

Fig-7.1 Peak Demand and Capable Output (Maximum)

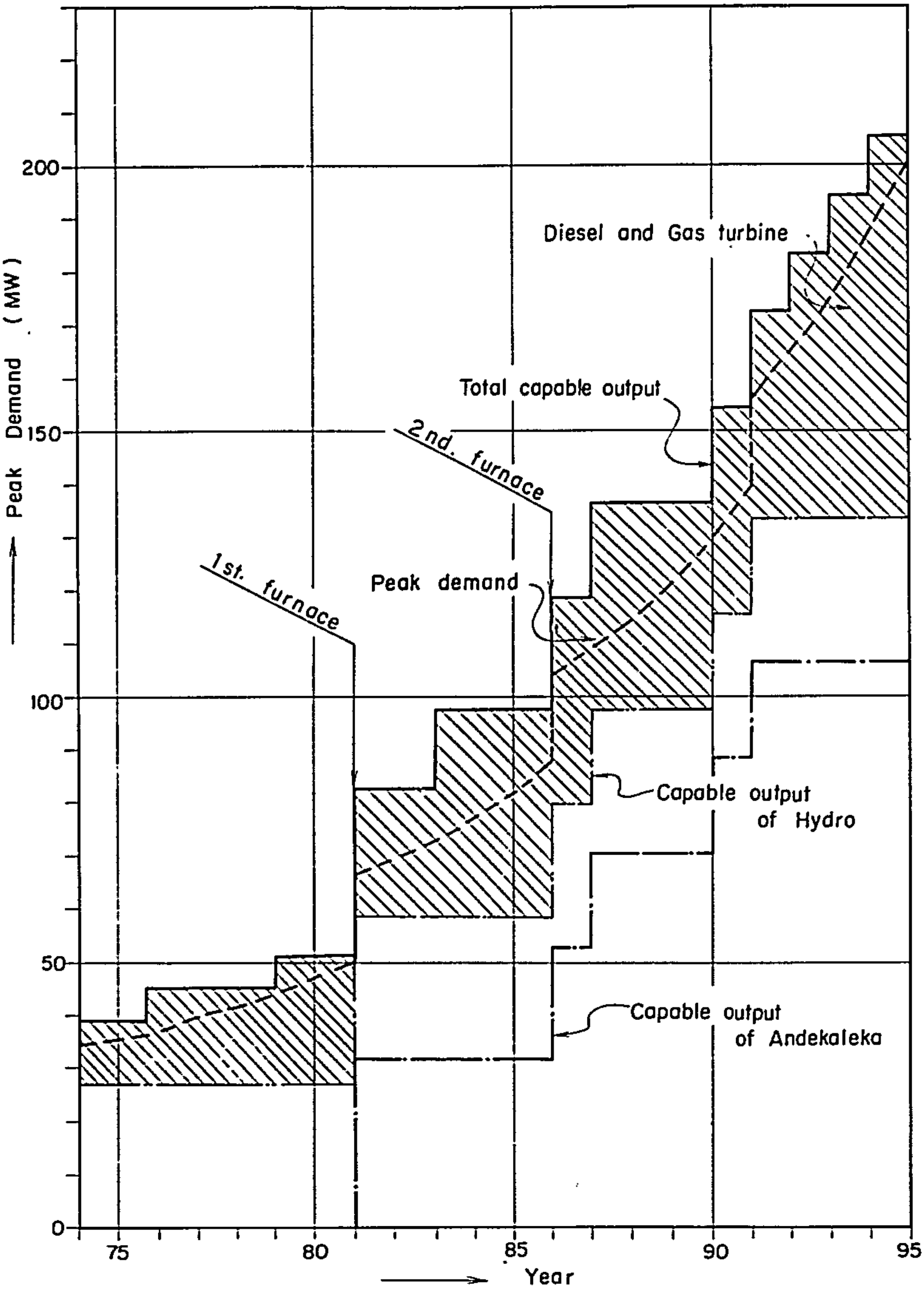


Fig-7.2 Energy Demand and Generating Energy (Maximum)

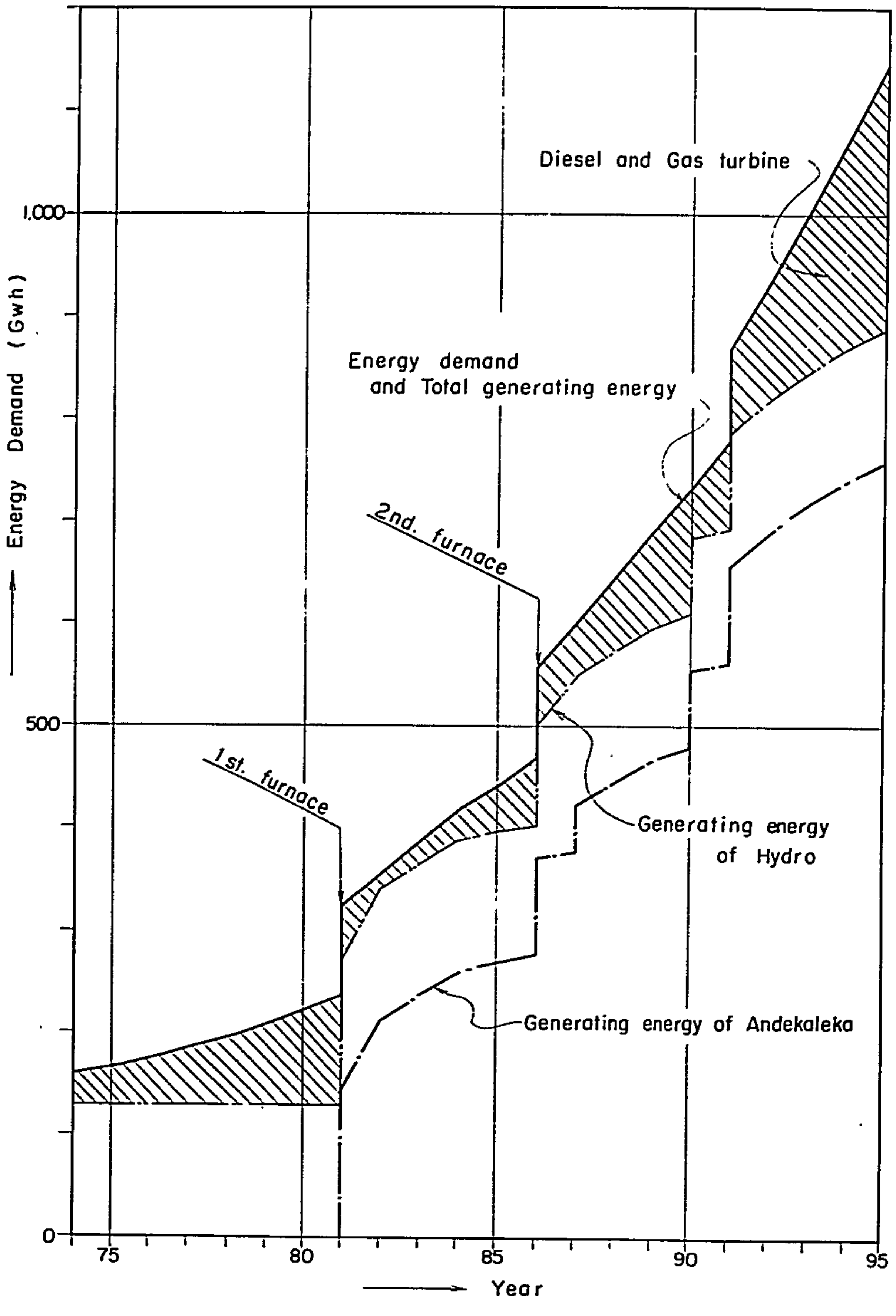
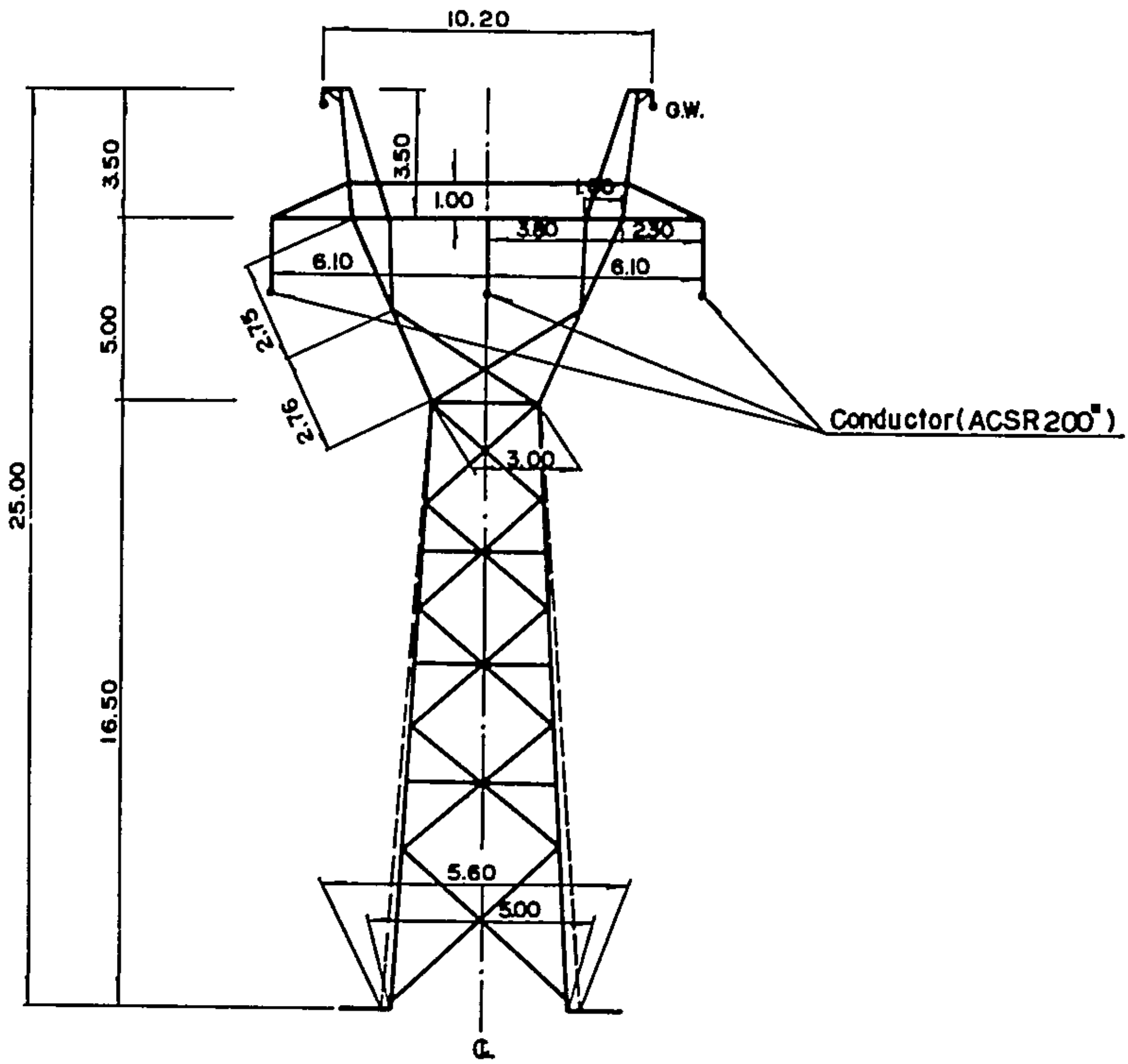


Fig-7.3 Steel Tower

S = 1/200



(A Type Arm)

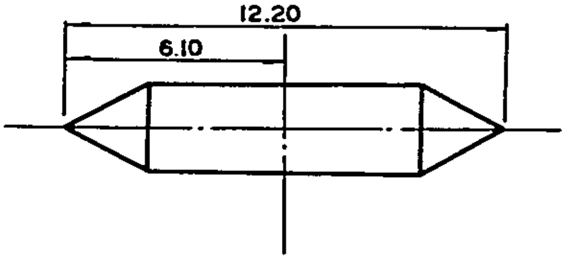


Fig-7.4 Transmission Line Route

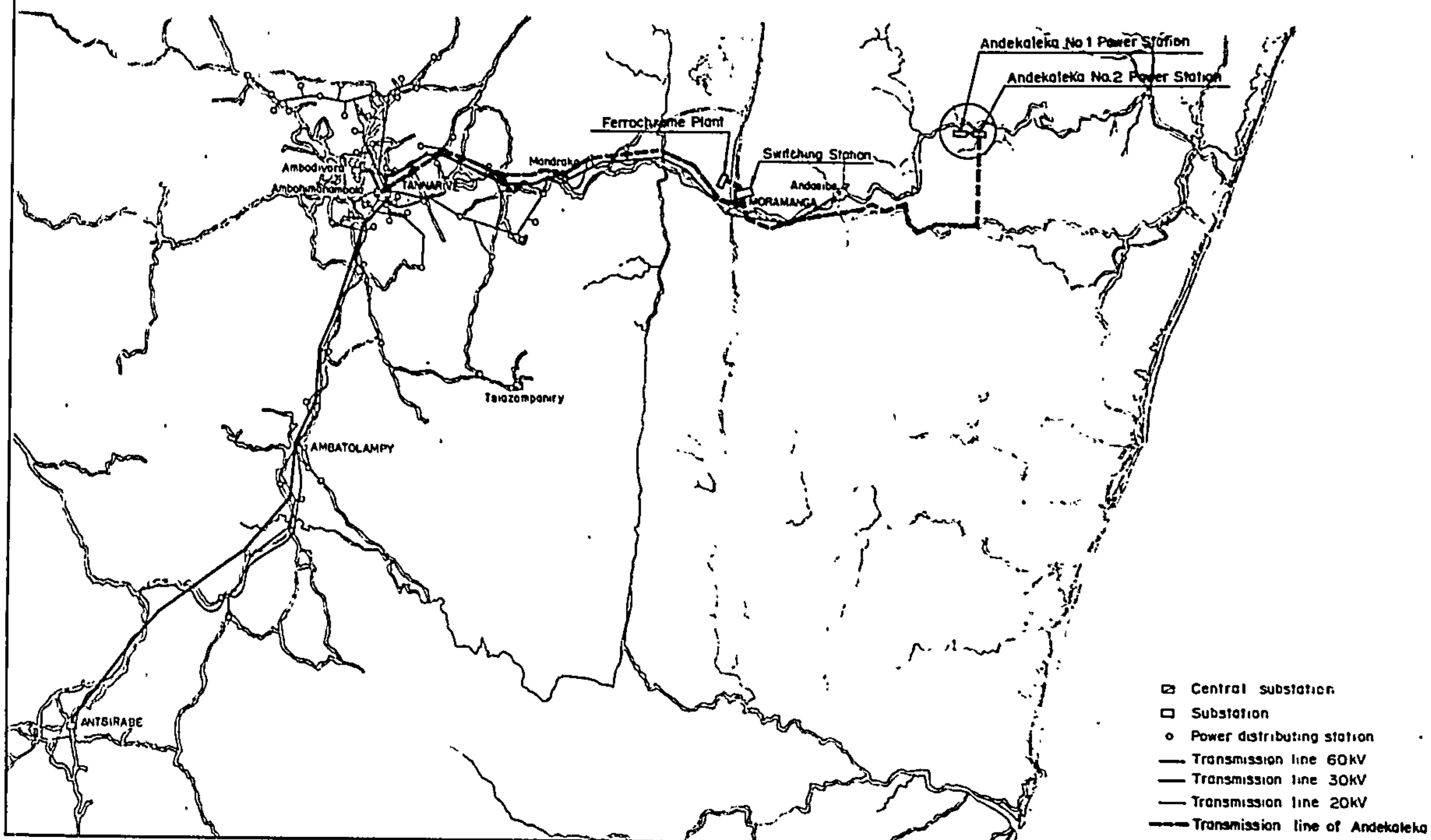
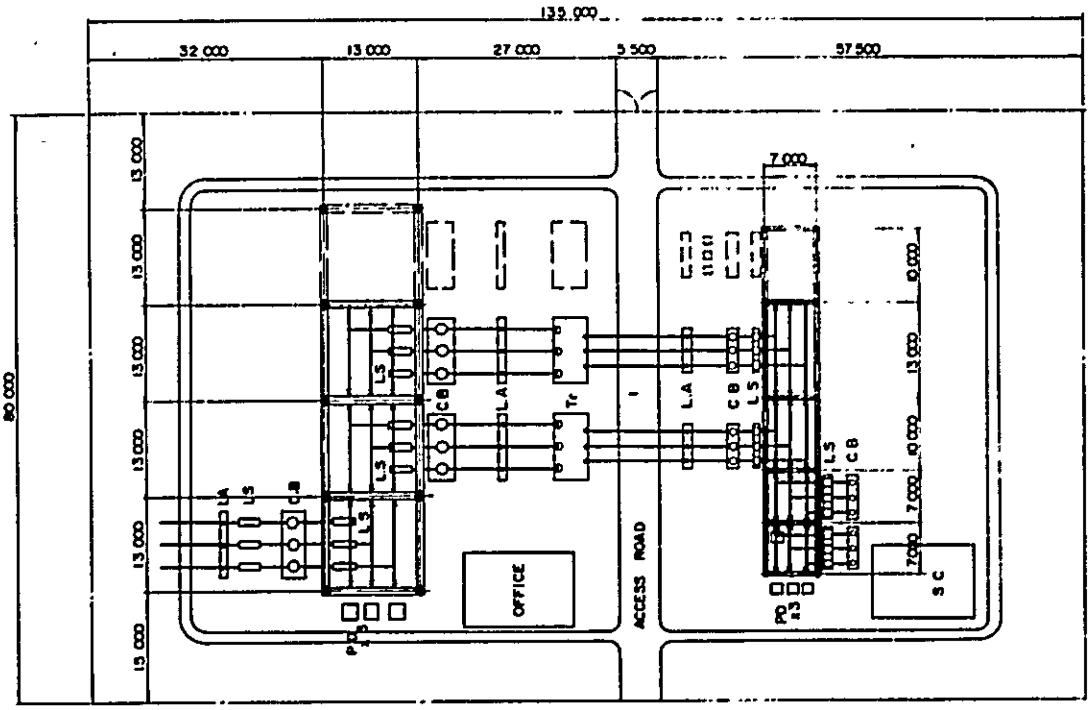


Fig-7.5 Substation and Switching Station Layout

Ambohimanambola Substation



Moramanga Switching Station

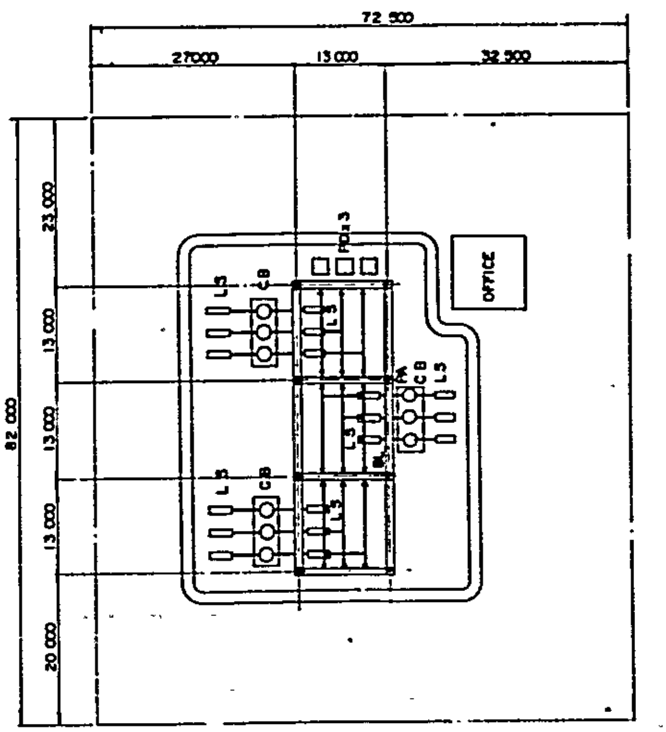
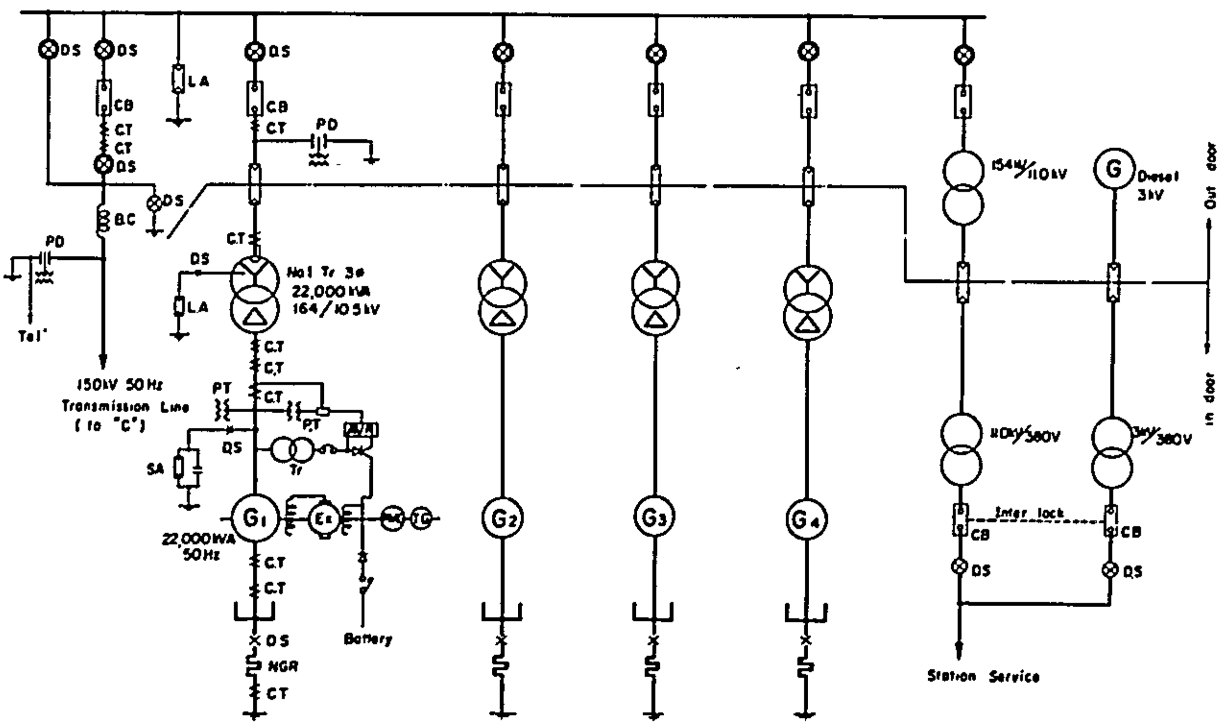
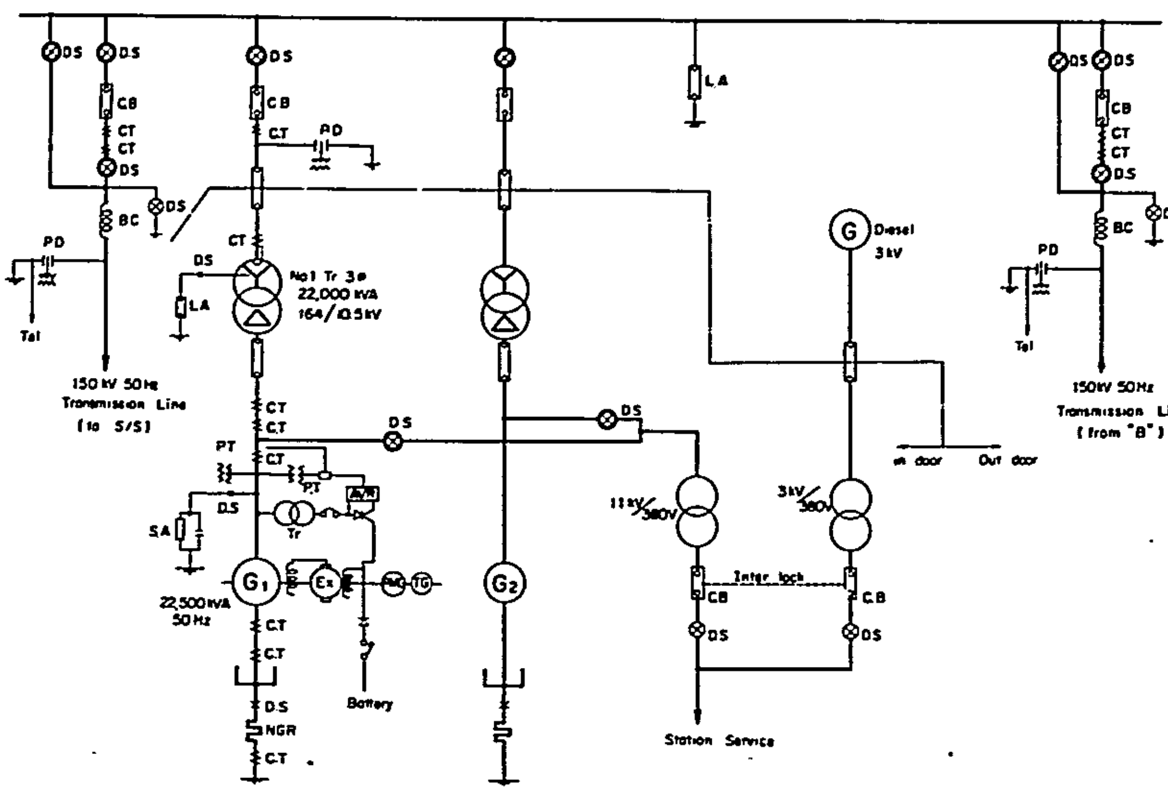


Fig-7.6 One-Line Diagram

Andekaleka No.1 Power Station



Andekaleka No.2 Power Station



Chapter 8.

Construction Work Plan and Schedule

Chapter 8 Construction Work Plan and Schedule

8. 1 Construction work plan

8. 1. 1 Outlined method of work

As mentioned in the preceding Chapter, the Andekaleka hydro power development project will be performed in three stages of construction; the 1st-term construction period covers civil engineering work for the No. 1 Power Station construction and the installation of two units of turbine generator out of the total four units; the 2nd-term period includes additional installation of the remaining two units of turbine-generator for No. 1 Power Station and the construction of a regulating pond; and the 3rd-term period covers the construction of the whole No. 2 Power Station.

Concerning the transportation of equipment and materials for construction, there are two alternative methods; one is to utilize the railroad between Tananarive and Port of Tamatave, and the other is to make use of the National Highway Route 2 connecting the same city and port.

Since the railroad is running all the way alongside the Vohitra River, passing near the proposed project site, it will serve as the key method of transport during the construction. Though, at present, the National Highway Route 2 runs about 20 Km apart southward from the project site, the Government plans to construct a new feeder road as a branch-off line from the National Highway Route 2, for the section between Ampasimbe and Salimoana (Zone C). By the time the construction work begins, the new feeder route from the National Highway will be extended to reach the Zone C of the project site, therefore, the road will also serve as an important means of transport during the construction period.

Construction materials, such as cement and steel bars, and equipment of heavy weight, such as penstocks, turbines and generators, will be carried to the site by railroad, by mass transit, while construction equipment and materials of relatively light weight, will be transported by trailers. The accommodation bases for material stockyard, machine shop, processing plant of steel bars, repair shop of heavy equipment, fuel tanks, workers' quarters and field office, etc. will be provided near the Andekaleka Railroad Station and at the proposed site for the switchyard near Salimoana Village. Besides these two large bases, sufficient space for stock materials will be provided at the port of Tamatave where lots of off-shore purchased equipment and materials will be unloaded, so that smooth supplies to those bases may become possible during construction. Also in addition to these large bases, the field bases will be established at the job site for each work section of dam site, intake, headrace, and power station, with such temporary facilities as an aggregate plant, a concrete-mixing plant, and tunnel excavation facility, etc.

To meet power requirement for construction work the diesel engine will be made available as much as possible. However, for the aggregate plant, concrete-mixing plant and tunnel excavating machines, for which electric power is absolutely required, power supply will be available from the diesel generating set at each field base.

8. 1. 2 Method of construction for No. 1 Power Station

(1) Intake dam and intake

A new road will be constructed for the distance of 2. 5 Km between the base near the Andekaleka Railroad Station and the intake, so that the road can be utilized for the smooth flow of supplies of equipment and materials.

Since the river flow increases remarkably in the rainy season, the workable period for intake dam construction will naturally be confined only to the dry season in a year. In the first dry period, the river flow will be drawn to the side of the right bank by the half-river coffering method to finish dam construction on the left bank. Then, in the second dry period, the river flow will be drawn to the opposite side in the similar way to finish dam construction on the right-bank side and the intake. Although the final finish with the installation of a gate will be left over to the third dry period, major portions of the work will be completed within a couple of years.

(2) Head-race tunnel

The tunnel of 1, 937 m in total length will be excavated from the downstream side toward the upstream by the utilization of the adit provided for the surge tank. A drill jambo will be used for all-sectional excavation of the tunnel. The period to be required for completion of the excavation work is estimated roughly at 14 months, on the assumption that daily and monthly average length of excavation would be 6 m per day and 150 m per month. The required period for concrete lining would be 5 months on the assumption that monthly average length of finished lining would be 90 m per month for the estimated total of 400 m length. The tunnel boring machine may also be used for excavation.

(3) Surge tank

The erection work for the installation of the surge tank will be divided into upper and lower parts; the former to be done above the ground and the latter under the ground. For easy access to the upper portion, a temporary road must be constructed to connect with the construction road established to connect both A and C Zones, i. e. between Andekaleka and Salimoana. The lower portion of the tank will be accessible through the head-race tunnel. The required period for completion of a surge tank will be 6 months for the expansion of the riser tunnel and 3 months for concrete placing.

(4) Penstock

The work adit for excavations of the penstock route and the tailrace tunnel will start from the connecting point between the transit road tunnel and the power station, and after descending at a trafficable gradient for dump trucks through the power station building, it will be connected with the penstock route and the tailrace tunnel.

Excavation of the penstock route will start from its bottom by use of the work adit. Since the adit for dumping out muck will pass through the power station building, as aforementioned, the penstock excavation will have to be finished before excavation can start for the power station building.

For the sake of saving in transportation cost, the penstock will be unloaded in halved pieces at the port of Tamatave and will be carried to the temporary field shop at the base by railroad. The half piece of the pipe will be welded to the other half into a complete piece of pipe at the field shop and will be carried to the job site for erection through the adit of the upper head-race tunnel. Concrete will then be placed in the sequential order of penstock erection. Time requirement for completion of penstock work is estimated at about 20 months including excavation, penstock erection, and placing of concrete.

(5) Power Station

Construction of the power station will start with excavation of the access road tunnel to serve as the work adit during construction. Excavation for the power station building will begin after the completion of the concrete lining over the ceiling arch. Concrete placing for side walls and crane columns will be done after completion of the whole power station excavation. After the completed crane columns are equipped with an overhead crane, the erection works of turbines and generators can start.

Turbines and generators will be carried to the power station through the access road tunnel after being transferred from train to trailer by an unloader to be provided near P. K. 200 Km of the railroad mark.

The total construction period starting from the onset date of the access road tunnel excavation to the terminating date of the commissioning is estimated at 40 months. In fact, the progress of the overall construction work will depend largely upon how soon the power station construction will be completed.

(6) Tailrace

The excavation work for the tailrace tunnel will be performed by the utilization of the work adit, as is the case of penstock excavation. The method of excavation and concrete placing will be similar to the case of the head-race tunnel excavation. The time requirement for the work is estimated at 15 months.

8. 1. 3 Method of construction for No. 2 Power Station

Since the size of the development project for Andekaleka No. 2 Power Station is almost similar to that for the No. 1 Power Station, the construction method for the No. 1 Project may correspondingly be applicable to the No. 2 Power Station Project.

8. 2 Construction work schedule

The entire project construction schedule and the separate work schedule for each Power Station construction in the Andekaleka Develoment Programme are shown in Table-8.1 and Table-8.2 respectively.

As far as the whole schedule goes, it covers a long-range plan over 15 years ahead in the future. However, since the construction projects scheduled after completion of the 1st-term construction project are based upon a very long forecast of power demand and supply, such schedule will necessarily be modified to meet more realistic needs, if the power demand forecast is modified as time goes on.

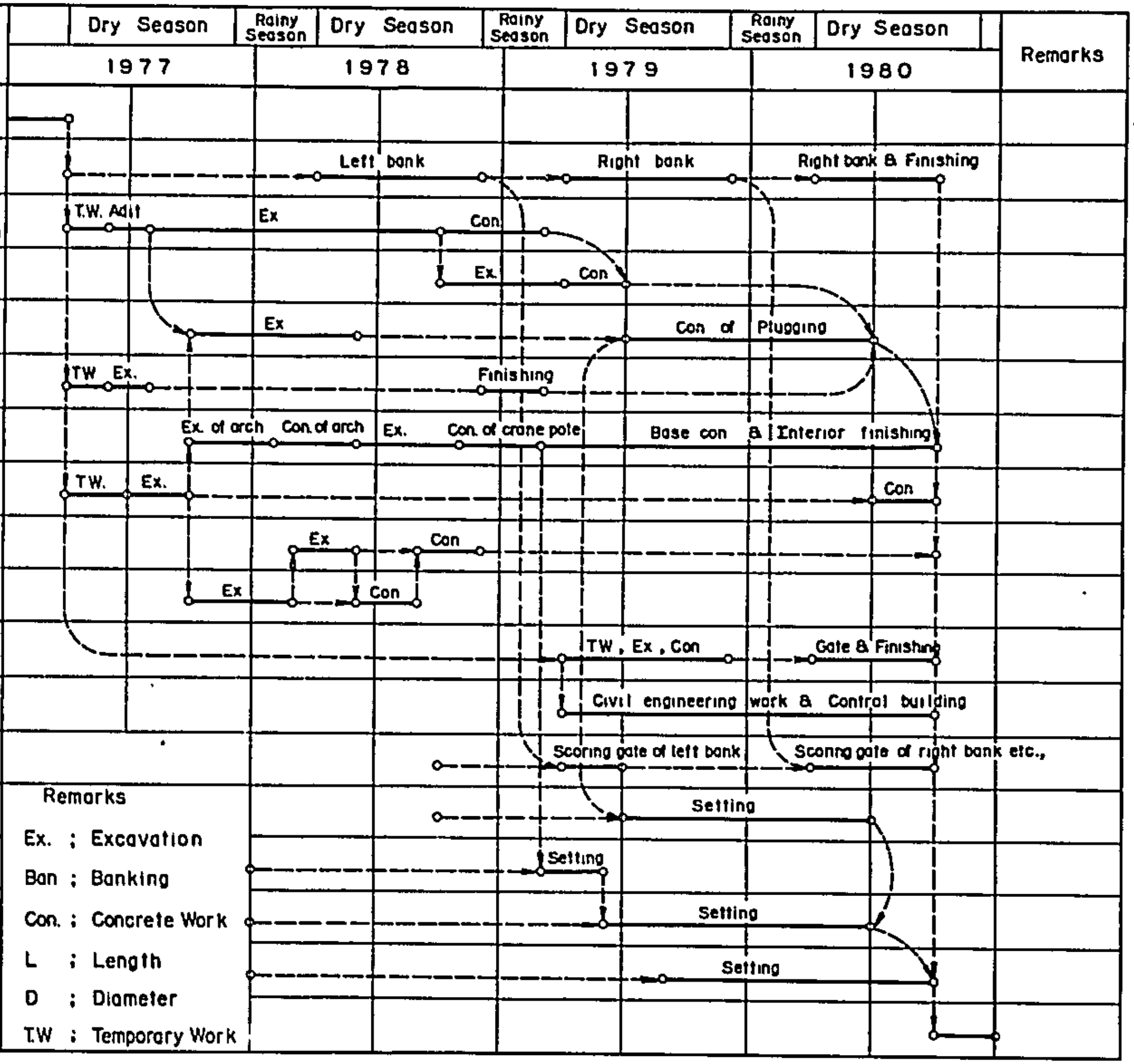
According to the schedule for the 1st-term construction work, the work will require 48 months from the onset date of construction scheduled for '77 to the start-up operation of the two generating units scheduled for the early part of '88. In view of the forecasted tight balance between power demand and supply, it is urgently required that the units should enter into their initial start-up operation as soon as possible in 1981. It is firmly believed, however, that the time requirement for the earliest completion by the target date can be fully met by reducing the time element for each phase of survey, design, tender, and preparations for temporary housing at the site.

In preparing the work schedule, the normal standard work volume to be performed for each major item of job is as estimated below:

Excavation of dam	8,000 m^3/month
Concrete placing of dam	1,200 m^3/month
Tunnel excavation	150 m /month
Concrete lining for tunnel	90 m /month

Table-8.1 Time Schedule of Andekaleka No.1 Power Plant

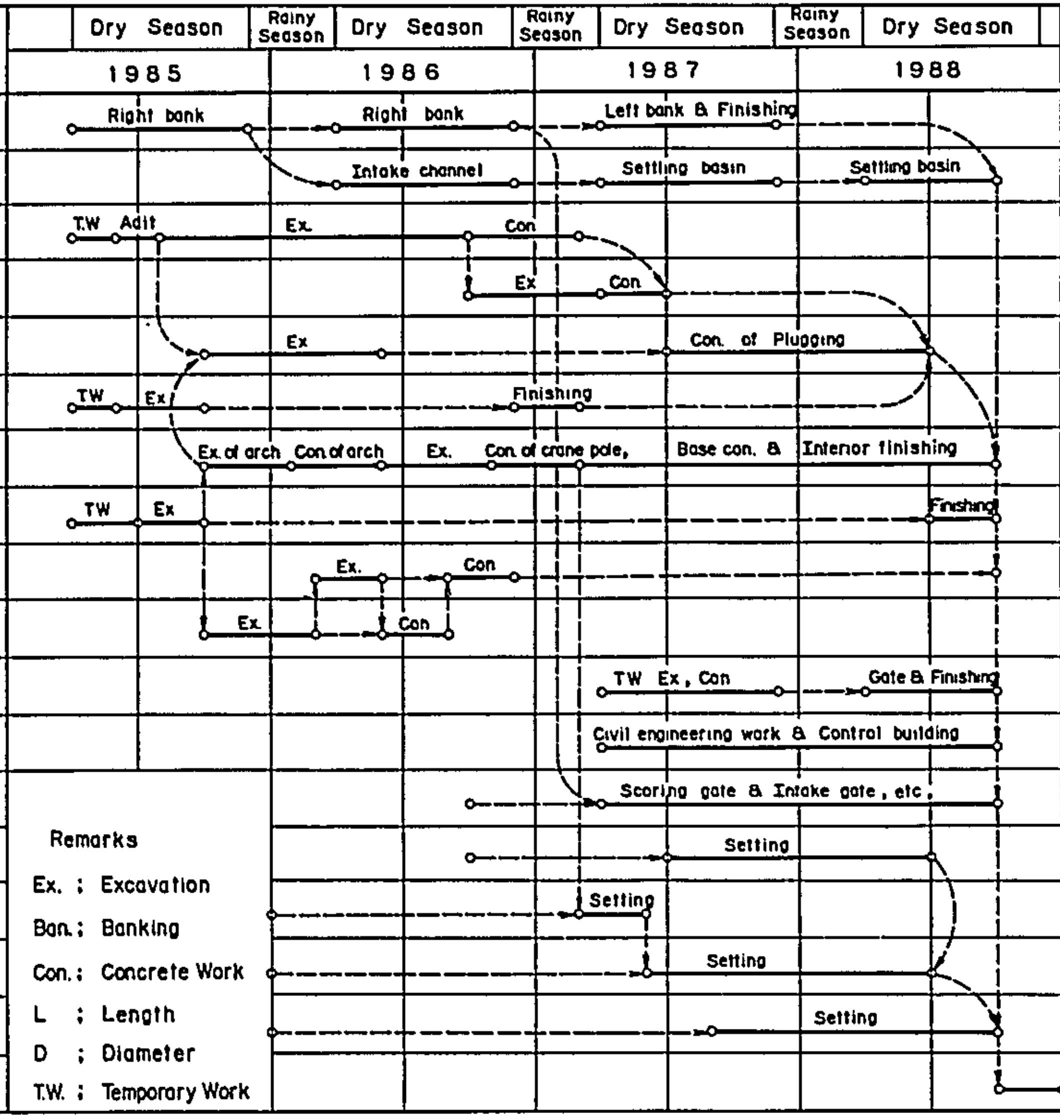
Item	Quantity
1. Access Road to Site	L = 23 km
2. Intake Dam & Intake	Ex. = 35,430 m^3 Con = 9,150 m^3
3. Headrace Tunnel	L = 1,935 m D = 5.20~4.80m
4. Headrace Surge-tank	Ex = 8,400 m^3 Con = 1,260 m^3
5. Penstock	L = 198 m D = 3.20 m
6 Ventilation Tunnel	L = 245 m D = 3.00 m
7. Power Station	Ex. = 33,380 m^3 Con. = 11,050 m^3
8 Access Road Tunnel	L = 330 m D = 5.00 m
9. Tailrace Surge-tank	Ex. = 4,890 m^3 Con. = 1,200 m^3
10. Tailrace Tunnel	L = 273 m D = 5.20~4.80m
11. Outlet	Ex. = 2,210 m^3 Con. = 790 m^3
12. Switchyard	Ex. = 14,600 m^3 Ban. = 21,540 m^3
13. Gate & Screen	
14. Pressure Steel Pipe	
15. Crane	
16. Generator & Turbine	
17. Main Transformer, etc.,	
18. Test Working	



Remarks
Ex. ; Excavation
Ban ; Banking
Con. ; Concrete Work
L ; Length
D ; Diameter
T.W ; Temporary Work

Table-8.2 Time Schedule of Andekaleka No.2 Power Plant

Item	Quantity	Remarks
1. Intake dam & Intake	Ex.= 38,050 m³ Con = 8,750 m³	
2. Intake channel & Settling basin	Ex.= 77,380 m³ Con.= 10,700 m³	
3. Headrace Tunnel	L = 2,086 m D = 5.20~4.80 m	
4. Headrace Surge-tank	Ex.= 27,510 m³ Con.= 1,610 m³	
5. Penstock	L = 218 m D = 3.20 m	
6. Ventilation Tunnel	L = 150 m D = 3.00 m	
7. Power Station	Ex.= 25,260 m³ Con.= 12,200 m³	
8. Access Road Tunnel	L = 480 m D = 500 m	
9. Tailrace Surge-tank	Ex.= 3,900 m³ Con.= 830 m³	
10. Tailrace Tunnel	L = 250 m D = 5.20~4.80 m	
11. Outlet	Ex.= 9,320 m³ Con.= 610 m³	
12. Switchyard	Ex.= 13,440 m³ Ban.= 15,220 m³	
13. Gate & Screen		
14. Pressure Steel Pipe		
15. Crane		
16. Generator & Turbine		
17. Main Transformer, etc.,		
18. Test Working		



Remarks
Ex. ; Excavation
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Con. ; Concrete Work
L ; Length
D ; Diameter
T.W. ; Temporary Work

Chapter 9.

Construction Costs and Power Generating Costs

Chapter 9 Construction Costs and Power Generating Costs

9.1 Construction costs

The total construction costs for Andekaleka Hydro Power Project amount to some 27,483 MFMG covering No. 1 and No. 2 Power Stations, regulating pond, transmission facilities, and substations. The following table shows breakdown of the construction costs classified by installations and currencies:

Unit: MFMG

	Foreign currency	Local currency	Total
No. 1 Power Station	8,316	4,580	12,896
No. 2 Power Station	6,503	2,749	9,252
Regulating pond	1,144	601	1,745
Transmission & substations	2,343	1,247	3,590
Total	18,306	9,177	27,483

The estimate for the construction costs is made on the following basis:

(a) Prices are the prevailing standard market prices as of December, 1974. Any possible price changes in the future are not allowed for in the estimate.

(b) The estimate does not include any duties to be levied upon items of off-shore purchase such as turbines, generators and the like.

(c) Quantities of the work is estimated from the preliminary design drawings annexed.

(d) It is anticipated that the construction costs estimated herein should further increase as the investigation goes into further details. To cope with such increases, contingencies are allowed for at a certain rate; 15 % for civil works and 5 % for erection of gate, penstock and electrical equipment.

(e) Overhead expenses include survey, design, engineering, supervision and administration costs, and interest during construction. The rate of interest during construction is 7 % per annum and the rest totalled is estimated at

10 % of the total construction costs.

(f) The cost for the regulating pond construction is estimated from design drawings prepared by the E. D. F in June, 1972.

(g) The construction costs include the cost of the feeder road construction to be branched off from Ampasimbe on National Highway Route 2 to the construction site.

(h) The construction costs are divided into local and foreign currency portions. The former will be appropriated for wages payable to local workers, purchases of locally available materials, such as cement, timber, etc. and inland transports. The remainder will be covered by the foreign currency portion.

Breakdown of the construction costs is outlined in Table-9. 1 thru 9. 4. Unit cost and price by principal items of work and material upon which the above breakdown is based are as per Tables-9. 5 and 9. 6. The required construction fund by fiscal years as incorporated in the financing plan and schedule, is estimated, as shown in Table-9. 7, from the work schedule shown in Tables-2. 1, 8. 1 and 8. 2.

9. 2 Power generating costs

The production cost of energy on sales, as scheduled by power demand and supply plan is mentioned later. Herein, the construction cost per kWh of the capable generated energy at average per annum is first mentioned. The construction cost per kWh can be a guide-index to make judgement of the development value for economic utilization of electric power generation, since such unit cost multiplied by the annual expense rate will easily set up the proximate standard for the power generating cost.

The construction cost per kWh at generating end for Andekaleka No. 1, No. 2, and both of No. 1 and No. 2 combined, is attained, as shown in the Table below, after the construction cost, as estimated in the preceding Section, has been divided by each capable generated energy:

Item	No. 1	No. 2	Total
Max. output (kW)	70,400	36,000	106,400
Annual capable generated energy (GWh)	516	271	787
Construction cost (MFMG)	10,555	8,940	19,495
Construction cost per kW (MFMG)	0.150	0.248	0.183
Construction cost (FMG/kWh)	20.5	33.0	24.8

As shown in the Table, the construction cost per kWh is estimated at 20.5 FMG for No.1, 33.0 FMG for No.2 and 24.8 FMG for both combined. Even when the total construction cost includes the costs, as additions, of regulating pond, transmission and substations totalled 5,155 MFMG, the unit cost can still be maintained at 31.3 FMG/kWh. This figure can be converted into 3.13 FMG/kWh in terms of the generating cost for the capable generated energy at an assumed 10 % rate of annual operating expense. This generating cost is much lower as compared with the estimated fuel cost of 5.58 FMG/kWh for a diesel generating plant which has been and will be affected by the soaring crude oil price.

Table-9.1 Estimated Costs-Andekaleka No.1 Power Plant

unit: 10^3FMG.

Item	Foreign Currency	Local Currency	Total
A. Access Road & Buildings			
Access Road (to site)	230,000	919,000	1,149,000
Access Road (in site)	150,000	150,000	300,000
Buildings	8,000	154,000	162,000
Reserve Fund	58,000	184,000	242,000
Sub Total	446,000	1,407,000	1,853,000
B. Civil Engineering Works			
Intake Dam	187,000	183,000	370,000
Intake	132,000	103,000	235,000
Headrace Tunnel	539,000	425,000	964,000
Headrace Surge-tank	79,000	61,000	140,000
Penstock	34,000	31,000	65,000
Power Station	729,000	548,000	1,277,000
Tailrace Tunnel	177,000	139,000	316,000
Switchyard	86,000	71,000	157,000
Reserve Fund	295,000	234,000	529,000
Sub Total	2,258,000	1,795,000	4,053,000
C. Metal Works			
Gate & Screen	65,000	11,000	76,000
Pressure Steel Pipe	121,000	33,000	154,000
Reserve Fund	10,000	2,000	12,000
Sub Total	196,000	46,000	242,000
D. Electro-Mechanical Works			
Water Turbine	1,090,000	50,000	1,140,000
Generator	1,147,000	53,000	1,200,000
Main Transformer	306,000	14,000	320,000
Switch Gear & Distribution Equipment	516,000	24,000	540,000
Exterior Steel Structured	48,000	2,000	50,000
Vorious Mechanical Devis	334,000	16,000	350,000
Reserve Fund	172,000	8,000	180,000
Sub Total	3,613,000	167,000	3,780,000
Total	6,513,000	3,415,000	9,928,000
General Expenses	651,000	342,000	993,000
Interest under Construction	1,152,000	823,000	1,975,000
Grand Total	8,316,000	4,580,000	12,896,000

Table-9.2 Estimated Costs-Andekaleka No.2 Power Plant

unit: 10^3FMG

Item	Foreign Currency	Local Currency	Total
A. Access Road & Buildings			
Access Road			
Buildings			
Reserve Fund			
Sub Total	-	-	-
B. Civil Engineering Works			
Intake Dam	182,000	178,000	360,000
Intake & Settling Basin	399,000	325,000	724,000
Headrace Tunnel	581,000	457,000	1,038,000
Headrace Surge-tank	148,000	120,000	268,000
Penstock	20,000	19,000	39,000
Power Station	653,000	495,000	1,148,000
Tailrace Tunnel	160,700	127,300	288,000
Switchyard	69,000	56,000	125,000
Reserve Fund	332,000	266,000	598,000
Sub Total	2,544,700	2,043,000	4,588,000
C. Metal Works			
Gate & Screen	137,300	21,900	159,200
Pressure Steel Pipe	51,700	14,100	65,800
Reserve Fund	9,300	1,700	11,000
Sub Total	198,300	37,700	236,000
D. Erectro-Mechanical Works			
Water Turbine	717,000	33,000	750,000
Generator	746,000	34,000	780,000
Main Transformer	201,000	9,000	210,000
Switch Gear & Distribution Equipment	363,000	17,000	380,000
Extrior Steel Structured	38,000	2,000	40,000
Vorious Mechanical Device	230,000	10,000	240,000
Reserve Fund	115,000	5,000	120,000
Sub Total	2,410,000	110,000	2,520,000
Total	5,153,000	2,191,000	7,344,000
General Expenses	515,000	219,000	734,000
Interest under Construction	835,000	339,000	1,174,000
Grand Total	6,503,000	2,749,000	9,252,000

Table-9.3 Estimated Costs-Andekaleka Regulating Pondage

unit: 10^3FMG

Item	Foreign Currency	Local Currency	Total
A. Access Road	13,000	12,000	25,000
B. Civil Engineering Works	510,000	368,000	878,400
C. Gate	267,300	52,700	320,000
D. Reserve Power, etc.,	54,000	1,000	55,000
E. Reserve Fund	92,600	59,000	151,600
Total	937,300	492,700	1,430,000
General Expenses	93,700	49,300	143,000
Interest under Construction	113,000	59,000	172,000
Grand Total	1,144,000	601,000	1,745,000

Table-9.4 Estimated Costs-Transmission Line and Substation

unit; 10^3FMG

Item	Foreign Currency	Local Currency	Total
A. Transmission Line (Main)	973,000	746,000	1,719,000
B. " (Branch)	23,000	19,000	42,000
C. Ambohimanambola Substation	593,000	130,000	723,000
D. Moramanga Switchyard	88,000	55,000	143,000
E. Reserve Fund	168,000	95,000	263,000
Total	1,845,000	1,045,000	2,890,000
General Expenses	184,000	105,000	289,000
Interest under Construction	314,000	97,000	411,000
Grand Total	2,343,000	1,247,000	3,590,000

Table-9.5 Unit Price of Construction

unit: FMG

Item	Particulars	Unit	Price	Remarks
Excavation	Rock, Outdoor	m^3	4,000	
"	Common, Outdoor	"	1,900	
"	Rock, Timbering, Tunnel	"	15,000	
"	Rock, Tunnel	"	11,000	
"	Rock, Timbering, Penstock	"	19,000	
"	Rock, Penstock	"	13,000	
Backfill	Common, Outdoor	"	650	
Banking	"	"	1,400	
Reinforcement Concrete	Outdoor	"	27,000	
"	Tunnel	"	29,000	
Chages of Concrete Form	Outdoor	m^2	3,100	
"	Tunnel	"	3,100	
"	Arch of Power Station	"	4,100	
Reinforcement Work	Outdoor	ton	154,000	
"	Tunnel	"	154,000	

Table-9.6 Unit Price of Materials

unit: FMG

Item	Unit	Price	Remarks
Cement	ton	27,000	
Reinforcement	"	95,000	
Steel Materials	"	93,000	
Timbering	"	130,000	
Steel Structured	"	300,000	
Sounding Pole	kg	1,040	
Bit	lot	3,100	
Lumber Sawing	m^3	29,000	
Unsawn Timber	"	22,000	
Dynamite	kg	650	
Detonator	log	120	
Gasoline	ℓ	100	
Light Oil	"	70	
Mobil Oil	"	300	
Various Oil	"	390	
Gravel	m^3	1,500	
Sand	"	3,500	

Table-9.7 Yearly Constru

Stage	Year	Andekaleka No. 1 Power Plant															Andekaleka No. 2 E						
		Temporay Work			Civil Works			Metal Works			Elec. Mecha Works			Total			Civil Works			Metal Works			El
		F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.
1st	1976	291	1,163											291	1,163	1,454							
	1977	199	385	584	482	383	865				692	32	724	1,373	800	2,173							
	1978				602	479	1,081				576	27	603	1,178	506	1,684							
	1979				722	575	1,297	108	25	133	576	27	603	1,406	627	2,033							
	1980				602	478	1,080	108	25	133	461	21	482	1,171	524	1,695							
	Total	(647)	(2,066)	(2,713)	(2,747)	(2,185)	(4,932)	(231)	(54)	(285)	(2,675)	(124)	(2,799)	(6,300)	(4,429)	(10,729)							
		490	1,548	2,038	2,408	1,915	4,323	216	50	266	2,305	107	2,412	5,419	3,620	9,039							
2nd	1982										501	23	524	501	23	524							
	1983										418	19	437	418	19	437							
	1984										418	19	437	418	19	487							
	1985				76	60	136				332	16	348	408	76	484							
	Total				(79)	(62)	(141)				(1,937)	(89)	(2,026)	(2,016)	(151)	(2,167)							
					76	60	136				1,669	77	1,746	1,745	137	1,882							
3rd	1985																560	449	1,009				7
	1986																700	562	1,262				6
	1987																840	674	1,514	110	20	130	6
	1988																699	562	1,261	109	21	130	5
	Total																(3,193)	(2,563)	(5,756)	(235)	(44)	(279)	(3,0
																	2,799	2,247	5,046	219	41	260	2,6
Grand Total		(647)	(2,066)	(2,713)	(2,826)	(2,274)	(5,073)	(231)	(54)	(285)	(4,612)	(213)	(4,825)	(8,316)	(4,580)	(12,896)	(3,193)	(2,563)	(5,756)	(235)	(44)	(279)	(3,0
		490	1,548	2,038	2,484	1,975	4,459	216	50	266	3,974	184	4,158	7,164	3,757	10,921	2,799	2,247	5,046	219	41	260	2,6

Table-9.7 Yearly Construction Expenses

Andekaleka No. 2 Power Plant											Andekaleka Regulating Pondage			Transmission Line & Substation			Grand Total		
Works		Metal Works			Elec. Mecha Works			Total											
. C.	Total	F. C.	L. C.	Total	F. C.	L. C.	Total	F. C.	L. C.	Total	F. C.	L. C.	Total	F. C.	L. C.	Total	F. C.	L. C.	Total
																	291	1,163	1,454
														119	2	121	1,492	802	2,294
														1,037	152	1,189	2,215	658	2,873
														475	464	939	1,881	1,091	2,972
														38	472	510	1,209	996	2,205
														(1,945)	(1,185)	(3,130)	(8,245)	(5,614)	(13,859)
														1,669	1,090	2,759	7,088	4,710	11,798
																	501	23	524
											361	190	551				779	209	988
											309	162	471	180		180	907	181	1,088
											361	190	551		30	30	769	296	1,065
											(1,144)	(601)	(1,745)	(199)	(31)	(230)	(3,359)	(783)	(4,142)
											1,031	542	1,573	180	30	210	2,956	709	3,665
449	1,009				795	37	832	1,355	486	1,841							1,355	486	1,841
562	1,262				663	30	693	1,363	592	1,955							1,363	592	1,955
674	1,514	110	20	130	663	30	693	1,613	724	2,337				180		180	1,793	724	2,517
562	1,261	109	21	130	529	25	554	1,337	608	1,945					30	30	1,337	638	1,975
,563)	(5,756)	(235)	(44)	(279)	(3,075)	(142)	(3,217)	(6,503)	(2,749)	(9,252)				(199)	(31)	(230)	(6,702)	(2,780)	(9,482)
,247	5,046	219	41	260	2,650	122	2,772	5,668	2,410	8,078				180	30	210	5,848	2,440	8,288
,563)	(5,756)	(235)	(44)	(279)	(3,075)	(142)	(3,217)	(6,503)	(2,749)	(9,252)	(1,144)	(601)	(1,745)	(2,343)	(1,247)	(3,590)	(18,306)	(9,177)	(27,483)
,247	5,046	219	41	260	2,650	122	2,772	5,668	2,410	8,078	1,031	542	1,573	2,029	1,150	3,179	15,892	7,859	23,751

(Note)

1. Price in parethesis includes interest during contruction.

(Remarks)

Civil Works: Civil engineering works

Elec. Mecha. Works: Electro-mechanical works

F. C.: Foreign currency

L. C.: Local currency

Chapter 10.

Project Financing Plan and Scheclule

Chapter 10 Project Financing Plan and Schedule

10. 1 Required fund for construction

10. 1. 1 Basic conditions for cost estimation

The construction cost for the project, as estimated in the preceding Chapter, is based upon the basic conditions stated below.

(a) The scope of the estimated construction costs shall include the costs for construction of both Andekaleka No. 1 and No. 2 Hydro Power Stations, regulating pond and dam at Andekaleka, 150 kV transmission line from Andekaleka Power Station to Ambohimanambola Substation, 150 kV transmission line between Moramanga switching station and ferrochrome plant, and substation at Ambohimanambola, and shall also include survey, design, and engineering costs necessary for and related to the construction project.

(b) The construction costs shall be the estimated costs as of 1974 by reference to the previaling domestic unit cost of construction work in Madagascar, on the basis of the preliminary design drawings available. See Table-9. 1 and 9. 2.

(c) The construction costs shall be divided into two portions of currency; foreign and local currency portions. The local currency portion covers wages for local workers, domestic purchases of such materials locally available as cement, timber, etc. and the cost for inland transport. The remainder is to be covered by the foreign currency portion.

(d) Estimate shall be made on such conditions that the construction work will be undertaken by contractors, while design, engineering, and supervision will be performed by a consulting engineering firm.

(e) Major equipment, such as gate, penstock, turbine, generator, transformer and electrical conductor, shall be estimated by two categories of costs; erection and transportation costs in one category, and material and manufacturing costs in the other.

(f) The expenses for buildings, fixtures and furniture, vehicles and the like shall be estimated into supervisory and overhead costs.

(g) Contingency shall be allowed for civil works at a rate of 15 % and for gate, steel structure and main equipment at 5 %.

(h) The rate of interest during construction shall be 7 % per annum for both local and foreign currency portions.

(i) The costs for the off-shore purchased equipment shall be estimated on a duty free basis.

10. 1. 2 Total required fund

The total sum of the required fund for the project amounts to 27,483 MFMG, as summarised in Table-9. 7.

10. 2 Financing of fund

The total construction cost referred to in the preceding Section 10. 1 may be broken down by terms of the construction work as follows:

Unit : MFMG

Construction Term		Construction Cost		
		Local Currency	Foreign Currency	Total
1st-Term	No. 1 Power Station: 35.2 MW (1977 ~ 1980)	5,614	8,245	13,859
2nd-Term	No. 1 Power Station: 35.2 MW Regulating Pond (1982 ~ 1985)	783	3,359	4,142
3rd-Term	No. 2 Power Station: 36.0 MW (1985 ~ 1988)	2,780	6,702	9,482
Total		9,177	18,306	27,483

The total of the required fund is assumed to be financed by loans. (the foreign currency portion : 18,306MFMG, the local currency portion :9,177MFMG)

Both of these two portions are assumed to be financed on equal terms and conditions as follows:

Interest rate	:	7 % per annum.
Method of repayment	:	Equal instalment of total amount added with interest.
Term of repayment	:	30 years including 7 years grace period.

10.3 Redeemability of loan fund

10.3.1 Power generating cost

Power generating cost tends normally to decrease with the progress of depreciation of the plant and with increases in generated energy. Table-10.1 thru 10.3 show costs in the initial year, average annual costs for durable lifetime years, and average annual costs for the first 5 years.

10.3.2 Power rate

It is important to find the optimum power rate acceptable to the ferrochrome industry and the electric utility industry likewise as suitable wholesale price to maintain its management.

In principle, the original power cost upon which the power rate is based should be the cost for the applicable year. The power cost estimate herein is made from the average costs for the first five years, and the calculation is made for the cost for power rate at generating end on the four different cases as shown in Table-10.4, in order to select the optimum cost allocation of the Andekaleka hydro power project for the aforementioned purpose. Among all of the four cases, Case 4.1 is found most suitable, in which the average cost for Andekaleka hydro power is estimated at 5.6 FMG per kWh; 3.9 FMG per kWh for ferrochrome production, and 7.2 FMG at wholesale for public demand.

As for the power cost in and from the 6th year, the calculated result reveals that the cost can be reduced to 3.5 FMG per kWh for ferrochrome production and 6.5 FMG per kWh at wholesale for the public demand.

In determining the optimum power rate in regard to the Andekaleka hydro power project, there are several important factors to be considered, as follows:

1) Since the aforecited cost is calculated as the primary cost at generating end, sales expenses and transmission losses must be considered.

2) The power rate applicable to the ferrochrome production will be based on the generating cost of power from the Andekaleka hydro power project. On the other hand, the power rate for the incremental public demand after 1980 will be determined on the basis of the generating cost of diesel and gas-turbine plants to be installed after 1980 plus the cost of supply from the Andekaleka power project.

3) For the cost allocation applied to the ferrochrome production industry in Case 4.1, it is assumed that ferrochrome production will be subject to a load adjustment up to 30 % of its maximum demand when the capable output from the Andekaleka power station decreases due to flow conditions or other reasons.

10.3.3 Redeemability of fund

After review of redeemability of fund from Table-A.6.1 thru A.6.6 the following are made clear:

1) Generally speaking, the stabilized financial status will be maintained except for certain years as stated below. The wholesale price for the public demand can be kept at 7.2 FMG per kWh continuous for 5 years in and from 1981 and 6.5 FMG per kWh in and after 1986, and the unit price for ferrochrome production can be at 3.9 FMG per kWh for the '81 - '85 period and 3.5 FMG per kWh in and after 1986.

2) Critical years for repayment

In 1981 when Andekaleka No. 1 Power Station will be put into initial operation, the incremental revenue from energy sales is expected to be 910 MFMG, while the expenditures for the corresponding period will be 970 MFMG for interest payments, in addition to an increase of 60 MFMG for annual operating expenses. The balance deficit will then be 120 MFMG.

In 1983 when the initial repayment of the loan fund for the 1st-term construction in the amount of 260 MFMG becomes due, the incremental revenue for the same year will be 770 MFMG from sales plus fuel cost saving of 460 MFMG equivalent, while the expenditures will be 140 MFMG for incremental operating and other expenses plus 970 MFMG for interest payments, in addition to 260 MFMG for repayments. of the loan fund. The balance deficit will then be 140 MFMG.

With the initial operation of Andekaleka No. 2 Power Station in 1989, the revenue will increase to some extent but will not yet meet the total expenditure in the same year with the deficit balance of some 40 MFMG, for the repayment of the loan fund for the 2nd-term construction of 80 MFMG will begin, in addition to the interest payment of 660 MFMG for the 3rd-term construction loan fund.

In the event that there will be no power demand for ferrochrome production, the deficit account will continue for eight years after completion of Andekaleka Power Station. This is due to the estimated low level of the incremental energy consumption in the public sector. It is therefore necessary to take any possible measures to increase the revenue as much as possible either by promoting demand for ferrochrome production or by stimulating demand in the public sector or other sectors of industry.

The initial repayment for the 2nd-term construction fund scheduled for 1989 will be overlapped with repayment for the 1st-term fund. However, the amount of repayment for the 2nd-term fund will be relatively small. With increase of energy sales expected in that year, the balance will turn to a profit account.

The reason for being able to maintain profit each year except for some years cited above, is because of the saving of fuel expense for the diesel power plants.

In view of the above, full repayment of the whole loan fund financed for construction works of 1st-term thru 3rd-term can be made without any financial difficulty, on condition that the power rate for the public demand be maintained at a rate of 20 % lower than the present rate of 9. 1 FMG per kWh and the power rate for ferrochrome production at 3. 5 to 3. 9 MFG per kWh.

In the worst case of a drought, as experienced in 1960 and 1961, the influence will be minimized before 1986 and any deficit arising from the drought will be covered by the profit in the preceding year. After 1987, if a drought should come, the annual energy production will be reduced by 100 to 150 GWh and this may result in an increase of fuel expense of 600 to 900 MFMG for diesel power generation. It is therefore recommended that a certain amount of reserve be maintained for possible drought. (See Table-10.8)

Table-10.1 Initial Cost (Case 2)

Unit: 10^6 FMG

Item	Const. cost	Fixed Expenses			Operation & Maintenance Ex.			Other Ex.	Total Ex.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Interest	Depreciation	Sub-total	Repair Ex.	S. & W.	Sub-total		Grand Total
1st Term									
Civil	10,729	751	193	944	26	14	64	3	1,011
El & Me					24				
T & S	3,130	219	80	299	41	-	41	-	340
Total	13,859	970	273	1,243	91	14	105	3	1,351
2nd Term									
Civil	3,912	274	70	344	9	-	27	-	371
El & Me					18				
T & S	230	16	6	22	3	-	3	-	25
Total	4,142	290	76	366	30	-	30	-	396
3rd Term									
Civil	9,252	648	167	815	27	14	68	3	886
El & Me					27				
T & S	230	16	6	22	3	-	3	-	25
Total	9,482	664	173	837	57	14	71	3	911

Note: Rate of Interest = 7%
El & Me: Electric and Mechanical works
T & S : Transmission line and Substation works
S & W : Salary and wages

Table-10.2 Average Cost during Durable Years

Item	(1) Fixed Ex.	(2) O,M & Other	(3) Total	(4) Out Put	(5) Fx/KW	(6) Gen. Energy	(7)	(8) Note
	10^6 FMG	10^6 FMG	10^6 FMG	MW	10^3FMG/kW	10^6 kWh	FMG/kWh	
1st Term								Year 1981-85
Hydro	777	67						
T & S	242	41						
Sub Total	1,019	108	1,127	35.2	32.0	234	4.82	
2nd Term								
Hydro	283	27						
T & S	18	4						
Sub Total	301	31	332	35.2		186		
Amount	1,320	139	1,459	70.4	20.7	420	3.47	Year 1986-88
3rd Term								
Hydro	670	68						
T & S	18	3						
Sub Total	688	71	759	36.0				
Amount	2,008	210	2,218	106.4	20.8	579	3.83	Year 1989-95

Note: Fixed Ex. (1) Hydro Construction Cost x 0.07246
T & S " x 0.07723
Energy Average during the years noted in Note (8)

Table-10.3 Average Cost during First Five Years

Item	(1) Fixed Ex. 10^6 FMG	(2) O & M Ex. 10^6 FMG	(3) Total 10^6 FMG	(4) Out Put MW	(5) Unit Px/kW 10^3 FMG/kW	(6) Gen. Energy GWh	(7) Unit Px/kWh FMG/kWh	Note
Hydro	917	67	984					
T & S	288	41	329					
Total	1,205	108	1,313	35.2	37.3	234	5.61	

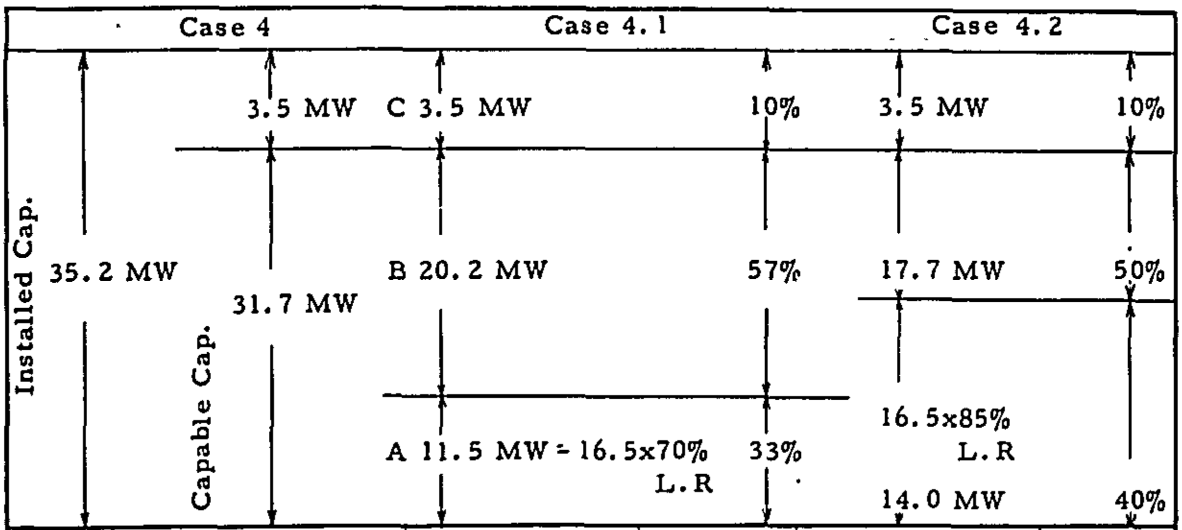
Note: T & S : Transmission line and Substation
O & M : Operation & Maintenance Expenses

Table-10.4 Cost Allocation (Average of Five Years)

Case		Total	Fe-Cr	Pub.	Note
Case-1 Total kW Alloc. (MW)		35.2	16.5	18.7	
Rate of Alloc. (%)		100	46.9	53.1	
Hydro Cost	(10^6FMG)	984	461	523	
T & S Cost	(10^6FMG)	329	66	263	See Table-10.6
Total	(10^6FMG)	1,303	527	786	
Unit Px/kWh	(FMG/kWh)	5.57	4.71	6.44	
Case-2 Total kWh Alloc. (GWh)		234	112	122	
Rate of Alloc. (%)		100	47.9	52.1	
Hydro Cost	(10^6FMG)	984	471	513	
T & S Cost	(10^6FMG)	329	66	263	
Total	(10^6FMG)	1,303	537	776	
Unit Px/kWh	(FMG/kWh)	5.57	4.79	6.36	
Case-3 (kW : kWh = 3 : 1)					
Rate of Alloc. (%)					
kW Alloc.		75	35.2	39.8	
kWh Alloc.		25	12.0	13.0	
Gross Alloc.		100	47.2	52.8	
Hydro Cost	(10^6FMG)	984	464	520	
T & S Cost	(10^6FMG)	329	66	263	
Total	(10^6FMG)	1,303	530	783	
Unit Px/kWh	(FMG/kWh)	5.57	4.73	6.42	
Case-4-1					
Total of Cost	(10^6FMG)	1,303	438	875	See Table-10.5
Unit Px/kWh	(FMG/kWh)	5.57	3.91	7.17	
Case-4-2					
Total of Cost	(10^6FMG)	1,303	507	806	"
Unit Px/kWh	(FMG/kWh)	5.57	4.53	6.61	

Note: T & S : Transmission line and Substation

Table-10.5 Cost Allocation in Case 4



	Case 4.1 Rate of Alloc.	Case 4.1 Cost	Case 4.2 Rate of Alloc.	Case 4.2 Cost
A Alloc. of Fe-Cr kW	33%	325	40%	394
B Alloc. of Pub. kW	57	561	50	492
C Alloc. of kWh	10	98	10	98
Total	100	984	100	984

Item	Case 4-1			Case 4-2		
	Fe-Cr	Pub.	Total	Fe-Cr	Pub.	Total
A	325		325	394		394
Hydro B		561	561		492	492
C	47	51	98	47	51	88
T & S	66	263	329	66	263	329
Total	438	875	1,313	507	806	1,303
GWh	112	122	234	112	122	234
FMG/kWh	3.91	7.17	5.61	4.53	6.61	5.57

Note: L. R : Load Regulation
T & S : Transmission line and Substation

Table-10.6 Allocation of Transmission and Substation Cost

Unit: 10^6 FMG

Item	Total	Fe-Cr	Pub.
Transmission Line			
Amb. - Mo. 86.5 km	1,081		1,081
Mo. - No. 2 - No. 1 77 km	999	333	666
163.5 km	2,080		
Mo. -Fe-Cr 5 km	51	51	
Sub-total	2,131	384	1,747
Switching Station and Substation			
Moramanga Switching Station	174	174	
Ambohimanambola Substation	455		455
Sub Total	629	174	455
Grand Total	2,760	558	2,202
Rate of Allocation (%)	100	20	80
Construction Cost	3,130	626	2,504
Average Cost of five years			
Fixed Expens	288	58	230
O & M Expenses	41	8	33
Total	329	66	263

Note : Amb : Ambohimanambola Substation
Mo : Moramanga Switching Station
No. 2 : Andekaleka No. 2 Power Station
No. 1 : Andekaleka No. 1 Power Station
O & M : Operation & Maintenance Expenses

Table-10.7 Cash Flow

Year	2 Furnaces			No Furnace		Note
	Unit Price		Net Cash Provided	Unit Px	Net Cash Provided	
	Public	Fe-Cr		Public		
	FMG/kWh	FMG/kWh	10^6FMG	FMG/kWh	10^6FNM	
1981	7.20	3.90	-121	7.20	-442	
82	"	"	47	"	-340	
83	"	"	-140	"	-483 (*)	
84	"	"	3	"	-360	
85	"	"	67	"	-224	
86	6.50	3.50	72	6.50	-131	
87	"	"	254	"	-302	
88	"	"	319	"	-141	
89	"	"	-43	"	42	
90	"	"	76	"	146	
91	6.20	3.20	164	6.20	291	
92	"	"	125	"	470	
93	"	"	208	"	25	
94	"	"	371	"	267	
95	"	"	428	"	514	

Note: (*) Start of Stage Repayment

Table-10.8 Generating Energy in Normal and Driest Years

Unit: GWh

Year	Normal Years	Driest Years	Dry/Normal
1981	181	181	100
82	212	210	99.1
83	238	232	97.5
84	263	250	95.1
85	276	259	93.8
86	391	319	81.6
87	427	333	78.0
88	442	338	76.5
89	504	440	87.4
90	527	454	86.1
91	559	469	83.9
92	587	481	81.9
93	615	492	80.0
94	642	502	78.2
95	666	510	76.6