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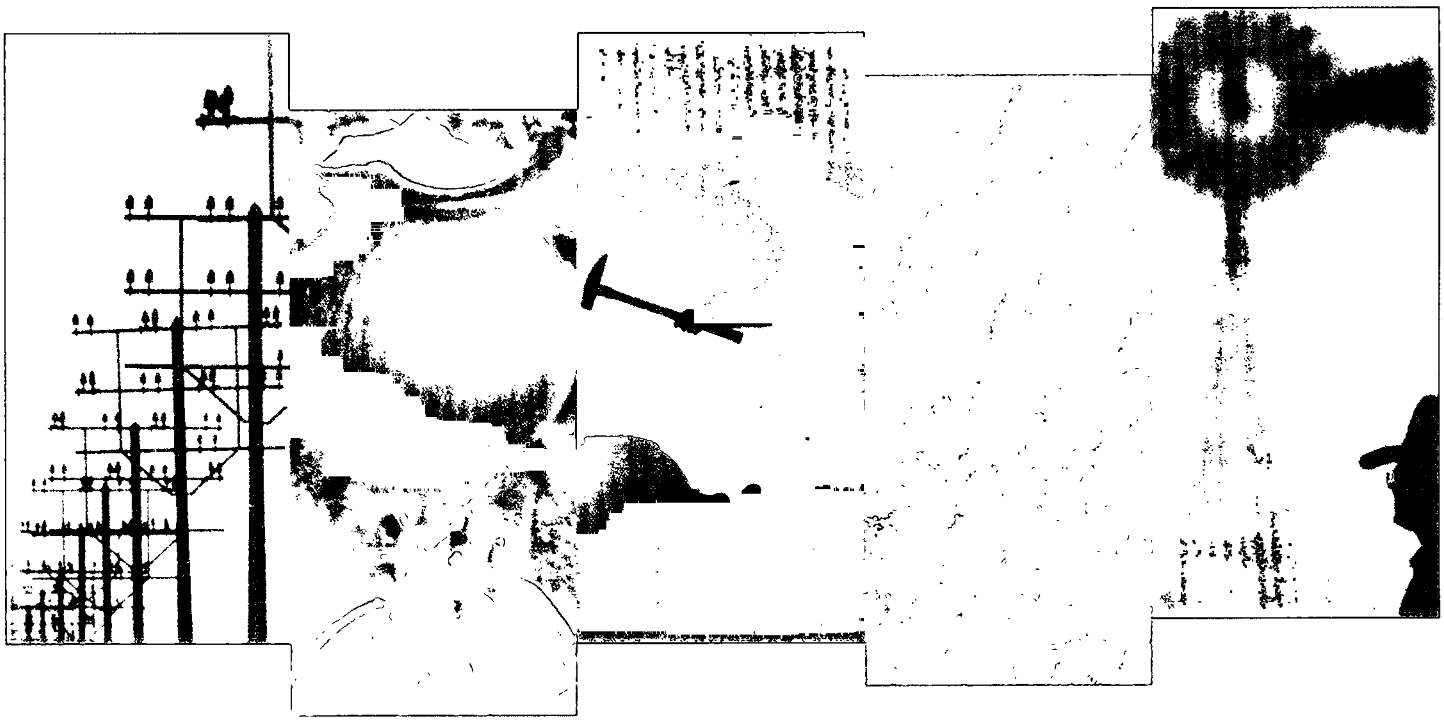
Volume 1

ESMAP TECHNICAL PAPER
024

Tanzania — Mini Hydropower Development Case Studies on The Malagarasi, Muhuwesi, and Kikuletwa Rivers: Volume I — The Malagarasi River



Energy

Sector

Management

Assistance

Programme

April 2002

ESMAP

JOINT UNDP / WORLD BANK
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

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JOINT UNDP/ESMAP

TANZANIA
KIGOMA REGION

PRE-INVESTMENT REPORT
ON
MINI HYDROPOWER DEVELOPMENT

CASE STUDY ON
THE MALAGARASI RIVER

OCTOBER 1999

PREPARED BY

SECSD (P) LTD.

First printing April 2002

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ESMAP Management"

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

LIST OF PHOTOGRAPHS

Chapter 1 Executive Summary

Section 1 Introduction

This report and accompanying studies present the findings of a small/mini hydropower study aimed at developing cost effective design of such schemes. It has been carried out for the Government of The United Republic of Tanzania. The Government of Sweden through ESMAP financed the study which forms the mini hydro component of the World Bank's assistance program to Government of Tanzania. The studies are intended for the benefit of Tanzania's state owned electric power utility TANESCO which is involved in generation, transmission and distribution and is administered under the Ministry of Energy and Minerals.

The primary objective of the study is to look for economical and reliable alternatives for meeting the growing electric power demand in the Kilimanjaro, Kigoma, Rukwa and Ruvuma regions of Tanzania. These regions with the exception of Kilimanjaro are very remote and are not yet electrified by the national grid. The existing local grid supply in last three of these regions is from diesel engine driven generators owned and operated by TANESCO. The present supply situation is however not reliable and the diesel units are expensive to operate and maintain. These diesel sets were initially installed to provide for rapid electrification of the regional capitals and important towns. However, there was continuous rise in power demand due to realization of the benefits of electrical energy in these towns and regions as well as rise in population. TANESCO is facing difficulty in meeting the demand for electric power adequately and reliably due to constraints on the installed capacity of diesel sets, fuel availability, long distance fuel transportation, adverse operating conditions and frequent outages of the diesel generating sets, some of which have reached the end of their economic life. These factors have also hindered the expansion of the regional grids with the result that most areas in these regions, with the exception of the respective regional capitals and surrounding areas are not electrified or are without electricity due to considerable load shedding which is practiced. Although in some regions demand side management studies can be done, the capacity released is unlikely to be significant in the short term due to the fact that electricity in these areas is mostly used for lighting and other domestic needs.

All regions considered in this study are endowed with perennial streams and rivers with many potential sites suitable for economically developing hydropower projects upto small scale (10 MW). To meet the load demand in the short term from these sources would necessarily require that effort and time spent on the stages in a conventional approach to hydropower such as planning, investigations, design and tendering is kept to a minimum so that implementation can commence quickly, and the design be simplified such that the construction period is limited to one or two years.

The schemes referred to SECSD come under two categories shown in figure 1-1. Under the first category are the potential schemes which have already been investigated to feasibility stage by TANESCO and other agencies, but were not implemented. The studies need updating by improving the planning, layout and design approach so as to minimize the implementation cost and construction period. Some factors which suggested this approach are the very high level of investment cost per kW and longer construction period. Hence they provided marginal economic and financial benefits. Most of the estimated costs of such candidate projects in these regions ranged from about US$3000 to 8000 per kW rendering the sites rather uneconomical for development as originally planned.

Some of the key factors contributing to such high level of implementation costs directly or indirectly in the category one schemes are

- Increase in quantum of civil works due to inappropriate planning principles and certain features incorporated in the designs such as for e.g long waterways for getting additional marginal increase in head.

- High unit costs in civil works estimate, even for indigenously available construction materials and equipment.

- High Electro mechanical equipment costs.

- Alternative layouts for the schemes as formulated or studied before selecting the final alternative on techno-economic grounds needed a closer look and review.

- Planning development of a river in its lower reaches with very large catchment (where the river is wide, shallow with considerable flood magnitude) for a power station with very small installed capacity as the load demand is very small.

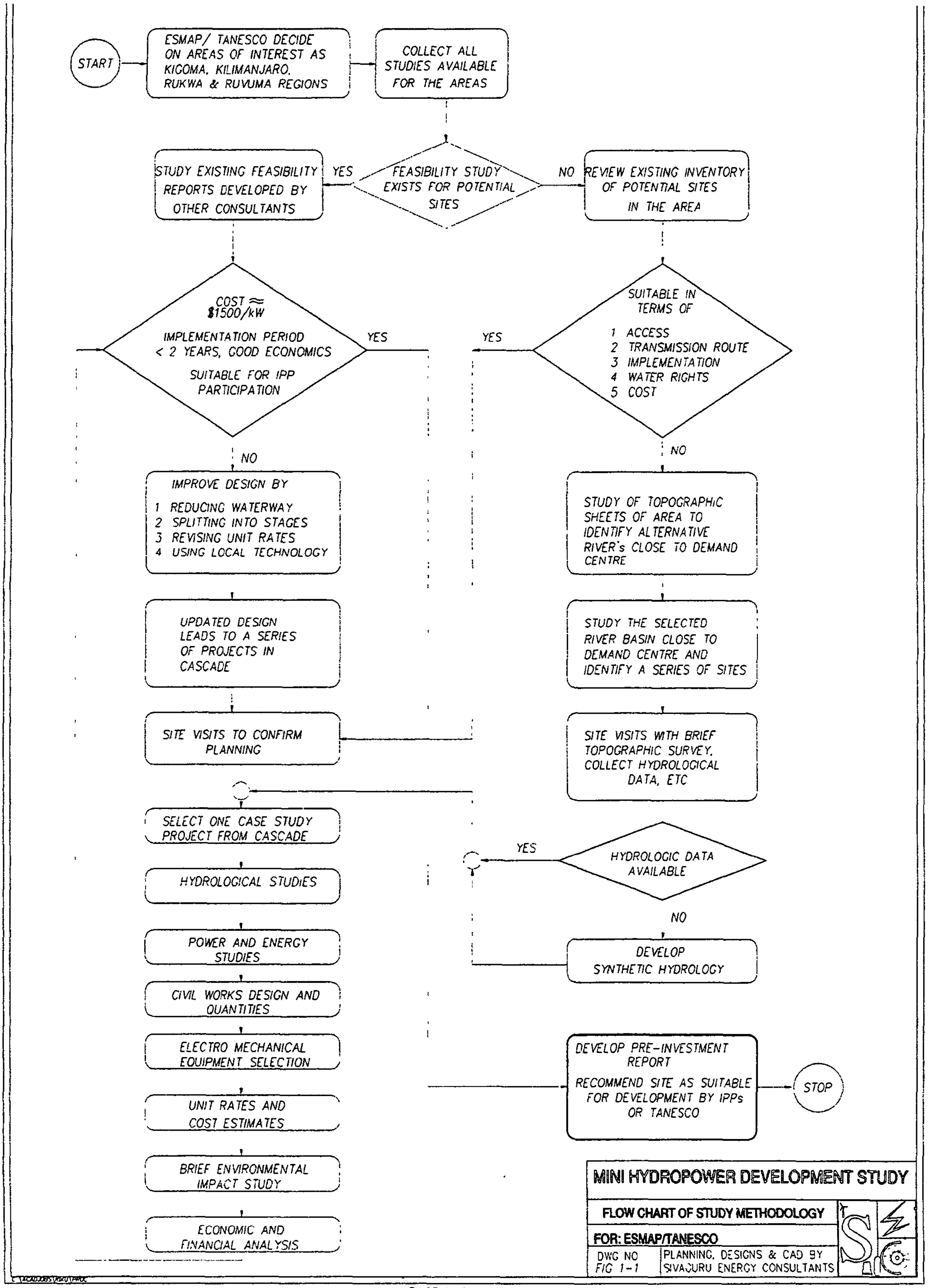
- Planning of power stations on a stream on isolated basis without doing planning of the entire stream or river basin.

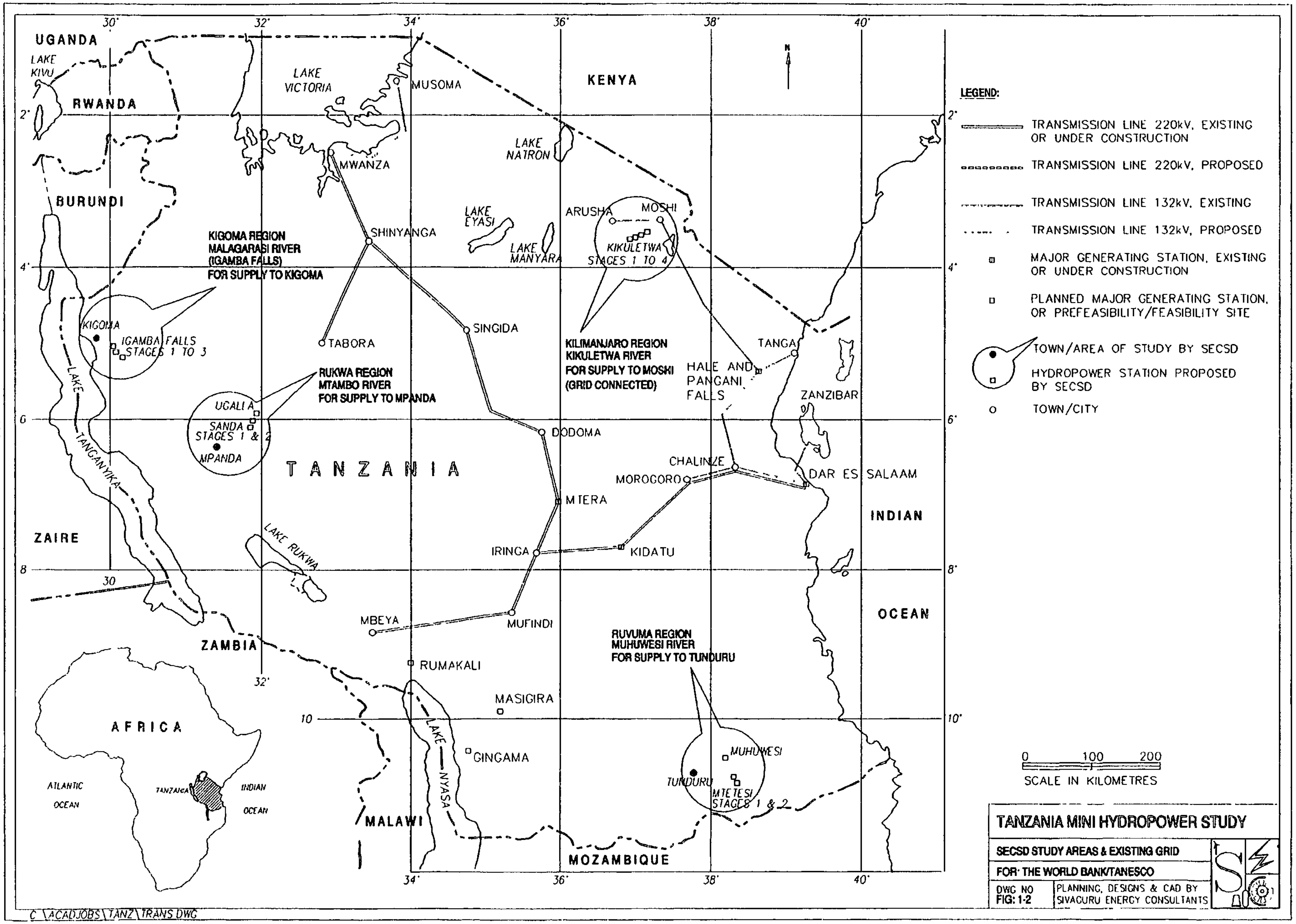
- Inadequate reconnaissance and investigation of alternative sites in the vicinity of a demand center.

- Non availability of adequate observed river flow records with the result that potentially good streams have not been selected for development. In such cases synthetic hydrology has to be developed using elaborate models.

- Vast distances between towns in a region with the result that expenditure on transmission lines becomes abnormal if a single power station is selected to supply all towns. In such a situation development of local grids has to be done using mini hydro on nearby streams.

In the second category are sites which have been identified on the basis of concentrated drops or steep gradients in the river bed. During reconnaissance of these potential sites, it was found that these sites however are not close to the existing rural demand centers. The sites occur either mainly in the upper reaches of streams where the drainage area is insignificant, the discharge low and erratic, with the result that power generation may not be reliable and has a large variance from year to year or the sites are situated in reaches where access is difficult. Because of these factors, these sites call for substantial expenditure on access roads and transmission. In these cases, the alternative approach adapted was to undertake a study of other streams and rivers in the vicinity of the demand center to identify promising sites in terms of access, hydrology and other factors but not necessarily planned for development on the basis of a naturally occurring head. A series of such viable potential sites have been identified to meet the demand at an early date. They have been studied on toposheets exhaustively and reconnoitered well. Simultaneously, a total river basin development for hydropower using a cascade approach is formulated such that additional standardized projects in the


START
ESMAP/ TANESCO DECIDE ON AREAS OF INTEREST AS KIGOMA, KILIMANJARO, RUKWA & RUVUMA REGIONS
COLLECT ALL STUDIES AVAILABLE FOR THE AREAS
FEASIBILITY STUDY EXISTS FOR POTENTIAL SITES
YES
NO
STUDY EXISTING FEASIBILITY REPORTS DEVELOPED BY OTHER CONSULTANTS
REVIEW EXISTING INVENTORY OF POTENTIAL SITES IN THE AREA
COST ≈ $1500/kW
IMPLEMENTATION PERIOD < 2 YEARS, GOOD ECONOMICS
SUITABLE FOR IPP PARTICIPATION
YES
NO
SUITABLE IN TERMS OF
1 ACCESS
2 TRANSMISSION ROUTE
3 IMPLEMENTATION
4 WATER RIGHTS
5 COST
YES
NO
IMPROVE DESIGN BY
1 REDUCING WATERWAY
2 SPLITTING INTO STAGES
3 REVISING UNIT RATES
4 USING LOCAL TECHNOLOGY
STUDY OF TOPOGRAPHIC SHEETS OF AREA TO IDENTIFY ALTERNATIVE RIVER's CLOSE TO DEMAND CENTRE
UPDATED DESIGN LEADS TO A SERIES OF PROJECTS IN CASCADE
STUDY THE SELECTED RIVER BASIN CLOSE TO DEMAND CENTRE AND IDENTIFY A SERIES OF SITES
SITE VISITS TO CONFIRM PLANNING
SITE VISITS WITH BRIEF TOPOGRAPHIC SURVEY, COLLECT HYDROLOGICAL DATA, ETC
SELECT ONE CASE STUDY PROJECT FROM CASCADE
HYDROLOGIC DATA AVAILABLE
YES
NO
HYDROLOGICAL STUDIES
POWER AND ENERGY STUDIES
DEVELOP SYNTHETIC HYDROLOGY
CIVIL WORKS DESIGN AND QUANTITIES
ELECTRO MECHANICAL EQUIPMENT SELECTION
DEVELOP PRE-INVESTMENT REPORT
RECOMMEND SITE AS SUITABLE FOR DEVELOPMENT BY IPPs OR TANESCO
STOP
UNIT RATES AND COST ESTIMATES
BRIEF ENVIRONMENTAL IMPACT STUDY
ECONOMIC AND FINANCIAL ANALYSIS
MINI HYDROPOWER DEVELOPMENT STUDY
FLOW CHART OF STUDY METHODOLOGY
FOR: ESMAP/TANESCO
DWG NO FIG 1-1
PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS



UGANDA
LAKE KIVU
RWANDA
BURUNDI
ZAIRE
ZAMBIA
MALAWI
MOZAMBIQUE
KENYA
TANZANIA
INDIAN OCEAN
LAKE VICTORIA
LAKE NATRON
LAKE EYASI
LAKE MANYARA
LAKE TANGANYIKA
LAKE RUKWA
LAKE NYASA
MUSOMA
MWANZA
SHINYANGA
TABORA
SINGIDA
DODOMA
MTERA
IRINGA
KIDATU
MUFINDI
MBEYA
RUMAKALI
MASIGIRA
GINGAMA
MOROGORO
CHALINZE
DAR ES SALAAM
ZANZIBAR
TANGA
HALE AND PANGANI FALLS
ARUSHA
MOSHI
KIKULETWA STAGES 1 TO 4
KIGOMA
IGAMBA FALLS STAGES 1 TO 3
UGALLA
SANDA STAGES 1 & 2
MPANDA
TUNDURU
MUHUWESI
MTETESI STAGES 1 & 2
KIGOMA REGION MALAGARASI RIVER (IGAMBA FALLS) FOR SUPPLY TO KIGOMA
RUKWA REGION MTAMBO RIVER FOR SUPPLY TO MPANDA
KILIMANJARO REGION KIKULETWA RIVER FOR SUPPLY TO MOSHI (GRID CONNECTED)
RUVUMA REGION MUHUWESI RIVER FOR SUPPLY TO TUNDURU
AFRICA
ATLANTIC OCEAN
INDIAN OCEAN
TANZANIA
N
LEGEND:
TRANSMISSION LINE 220kV, EXISTING OR UNDER CONSTRUCTION
TRANSMISSION LINE 220kV, PROPOSED
TRANSMISSION LINE 132kV, EXISTING
TRANSMISSION LINE 132kV, PROPOSED
MAJOR GENERATING STATION, EXISTING OR UNDER CONSTRUCTION
PLANNED MAJOR GENERATING STATION, OR PREFEASIBILITY/FEASIBILITY SITE
TOWN/AREA OF STUDY BY SECSD
HYDROPOWER STATION PROPOSED BY SECSD
TOWN/CITY
0 100 200
SCALE IN KILOMETRES
TANZANIA MINI HYDROPOWER STUDY
SECSD STUDY AREAS & EXISTING GRID
FOR: THE WORLD BANK/TANESCO
DWG NO FIG: 1-2
PLANNING, DESIGNS & CAD BY SIVACURU ENERGY CONSULTANTS
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cascade on the same river can be implemented in stages as the load demand grows. A flowchart giving the study methodology of the two alternatives is illustrated in figure 1-1.

The approach under category one by modifying the site locations, layout, planning and designs has been used for Kikuletwa No.2 project on the river Kikuletwa in Kilimanjaro region and Igamba falls on Malagarasi river in Kigoma region respectively. These two case studies demonstrate how the implementation cost has been cut significantly and construction period reduced so that mini hydro's can be rendered economical by adapting a cost effective approach in planning.

The approach under category two by exploring and selecting alternative sites has been adopted in the case studies for Mtambo river for supplying Mpanda town in Rukwa Region and Muhuwesi river for supplying Tunduru town in Ruvuma Region. A map of Tanzania showing geographical locations of the areas of concentrated study with proposed mini and small hydro projects by SECSD is given in figure 1-2. The figure also shows the existing national grid.

Both the approaches above result in a series of projects in a cascade. One representative project which is feasible at least cost has been then chosen for the pre-investment study. It is felt that the remaining projects can also be further investigated on the same lines by TANESCO through its various field offices and facilities which are near some of the project areas.

This report examines the revised layout details for the Igamba falls project in Kigoma region. The study was initiated in mid 1996 supplemented with extensive visits to the project area. In December 1997, a pre feasibility report was submitted to ESMAP and TANESCO outlining the findings of the SECSD team. The SECSD approach was approved and clearance given to carry the study forward to the present final phase resulting in the preparation of this pre investment report.

Presently TANESCO is faced with the challenging task of meeting the demand in the HV grid which supplies urban areas and industries in Dar, Morogoro, Tanga, Arusha etc. These areas are also the source of a significant part of revenues. The expansion and maintenance of this system calls for large blocks of power generation to be added periodically and hence creates pressure on TANESCO.

In developing countries, most power projects have been built by the government run electric utilities which either have established credit standing or have benefited from soft term loans from various institutions. Even then some of these utilities are not able to generate sufficient funds internally from revenues to carry out expansion. This makes it seem worthwhile to involve the private sector in meeting the demand for small and medium scale electrification projects.

Many private companies and industries in Tanzania have expressed willingness to participate in private power. Other advantages of this approach are the involvement of rural agencies and NGO's in management and administration, minimal cost overrun due to delays, scarce foreign exchange required can be met by equipment supplier's credit due to consortium formed between local companies and the supplier, efficient operation of the plant, adequate maintenance, committed project milestones and deadlines, and the state utility is relieved of construction management and administration especially in distant areas. On the other hand a project under private financing always requires an understanding to be reached between many cooperating teams which may initially take a long time to achieve. Nevertheless, initiation of private sector involvement in power projects will set the stage for creating a legal framework that will attract lenders and investors. The country's macro economic and political environment is stable, hence, with the current trend in promoting private sector involvement in many developing countries, it is necessary to initiate in Tanzania also, the involvement of the private sector initially in generation through small hydropower projects.

It is interesting to note that some missions in the region have installed their own micro-hydro generating set on small perennial streams. One such installation was visited by SECSD team. Photographs of the diversion structure and falls is given in chapter 17.

Both the World Bank and TANESCO also actively support the role which private sector participation can play in generation. Private sector participation has long been established as successful in meeting the demand growth for the financially pressed public utilities of developing countries.

The Kigoma region is located in western Tanzania on the shores of Lake Tanganyika. The economy of the region is based predominantly on agriculture and fishing. The region is served by railway and scheduled flights. Road connections with other parts of the country are poor and difficult especially during the rainy season. The region is not linked with the national transmission grid, with the result that economic growth has been rather slow. The present low demand for power and the vast distance from the nearest town Tabora having grid supply (450km) makes grid connection option very expensive. Thus an abundant source of cheap power has to be developed within the region if the pace of development and economic growth is to be accelerated. There are at present very few industries in the region which consume electric power for their production operations. If cheap electric power is made available, industries connected with agricultural products such as food processing are likely to come up in the region. Such industries and entrepreneurs may also be interested in developing generation facilities using hydro resources as many companies in Tanzania are capable of financing the small hydro projects entirely or by forming consortia. Thus the region is suitable to demonstrate the participation of private sector in power generation. Participation may be started with the traditional BOOT approach which is the strategy adopted in many developing countries.

The primary role of the cascade mini hydro projects identified in this study on Malagarasi river will be to cater to the present and future electric power demands of the small scale industries, towns and villages in the Kigoma region which is situated in the western most part of Tanzania. The greatest advantage of the power obtained from the projects in the cascade will be its reliability and low production cost since it will exploit the natural hydropower potential of the Malagarasi which has flowed to the Lake Tanganyika without any use. Due to the stable run off characteristics of this river, the sufficient quantity of cheap electric power which will be available through the construction of the Malagarasi cascade will promote a faster economic growth in the region. This will be of great importance in raising the living standards of the inhabitants of this region. The cascade design is such that its installed capacity can be augmented in stages to fully meet the anticipated maximum power and energy demands of the region for the next thirty years especially for the towns Kigoma, Ujiji, Uvinza, Kasulu, Kibondo, Simbo etc. This means that capital requirements for implementation will be moderate and phased according to the growth of load demand thereby avoiding heavy financial burden at the beginning. The proposed cascade development will also make possible an increase in the planned consumption of electric power in these areas. It would be possible to build new small scale industries in the region to better utilize its resources as well as modernize existing facilities. Thus this approach to the development of a strong regional grid will ultimately lead to a link with the national grid in the future at which time it will be feasible, necessary and economic to develop large generating stations on the Malagarasi and other rivers of this region.

The social consequences of electrification of households in Kigoma region are likely to be considerable. Access to electricity gives society a much greater opportunity to participate in national development. Electric lighting permits longer hours of work, study or leisure as well as greater security which is afforded by street lighting. Public health can benefit directly from electricity for the pumping of water supplies. Education will also be benefited considerably through greater dissemination of information by television and radio. The electrification of Kigoma is likely to have considerable beneficial impacts.

The most important consideration for a developer of a private power project is that the project is bankable or capable of being financed. The company which implements the project may be a newly established company which has no prior experience in hydropower or credit standing. This means that the project company will resort to non-recourse method as opposed to balance sheet financing used by state utilities. Investors in the project company will look towards the cash flow which the project will provide during operation as collateral. The project must also assure return on equity to participants. These constraints necessarily require that returns on investment must start accruing early, the rate of return must be sufficiently high, the returns must be stable which in turn depends on the hydrology of the selected river and load demand characteristics of the area. Also the tariff which the developer charges should be competitive. All of these imply that the project design should be simple, economical and easy to implement without cost overruns. In view of the foregoing discussion, this report effectively examines methods whereby the cost of installed capacity of a representative project in the Kigoma region which was initially planned for development on conventional lines, has been reduced so as to make it attractive for rural electrification and also private sector participation in its development. The main scope of this study has been to fix the basic project configuration which will not pose any delays and problems thereby making the project attractive to the private sector for development. This report will hence prove to be useful to potential developers as most of the preliminary project design and configuration have been fixed under this study to a sufficient detail. Thus it will be able to attract qualified developers who can quickly evaluate project needs and risks as the IPP will be able to get a clear background of the project and will be able to concentrate immediately on other more important aspects such as power purchase agreements, financial, commercial, licensing issues and risk analyses. It is also of the view that based on the basic material presented in this study seasoned Independent Power Producers interested in developing the project would perform further studies and analysis using approaches which they are accustomed to in appraising such potential projects. This approach whereby the basic project configuration is pre defined, will reduce the time spent on defining the basic optimal and economical project configuration by the IPP which normally takes a long time in the case of hydro projects and imposes a burden on the IPP which it may not be willing to assume.

The Terms of Reference for the present study required a review of the proposals by earlier consultants. Hence, this report also presents the planning and design suggested by other previous consultants by including relevant key sections of the earlier reports so as to enable an easy comparison with the present revised layout which significantly reduces the implementation cost and time.

The present study can also be used by TANESCO in preparing a structured RFP ("Request for Proposals") package which will be useful in soliciting proposals from Independent Power Producers for the development on a competitive basis. Such a package has usually associated with it a comprehensive pre-feasibility study which addresses Site related data such as location, access, grid interconnection Technology and design, Dispatch, Cost and Environmental Impact. The present study treats all these aspects and hence can be augmented with draft Implementation, Power Purchase, Conveyance agreements to give the complete RFP package. As the study brings out the costing of the project, it will also be easy to select competitive proposals from developers. The report will also be useful to the planning engineers of TANESCO so that they will be able to investigate, design and create an inventory of projects on similar lines suggested in this report.

This pre-investment study presents the project configuration, describes the key design aspects, integrates all the necessary hydrologic, topographic, geological and engineering information, estimates construction, operating and maintenance costs and contains all project information that establishes the project requirements and serves as a basis for the project procurement.

This report will also be of assistance to project appraisal teams of the World Bank or other International Financial Institutions which may be interested in providing funds for development to TANESCO.

The study is presented as per the following sections. The scope of each section is summarized below.

Section 2 Project Area

The characteristics of the Kigoma region with respect to general features, economy, demography, climatological conditions and most importantly the load demand forecast are discussed in Chapter 2. It is estimated that the present load demand in Kigoma is about 3MW with annual energy demand of about 18GWh. This may develop at rates anywhere between 2.5% to 6% per year. The other small towns will have a combined demand of about 1MW. Growth rates however may not exceed 3%. The comparison of energy use in the region from traditional non commercial fuels versus electricity is as below taken from a 1981 estimate with updated figures for electric energy consumption.

Box 1-1: Estimated Energy Balance for Kigoma Region

Total Energy Consumption (PJ)	Per capita Consumption (kg oil eqv)	Total Energy Consumption (GWh)	Electric Energy Consumption (GWh)	% Energy Consumed as Electricity
4.7	150	1300	9.6	0.73

The above shows that electricity use is very insignificant. Most of the energy use in rural Kigoma is hence from traditional fuels such as firewood, charcoal etc. As these fuels become increasingly expensive and difficult to obtain they can be substituted with electricity and there is likely to be considerable benefits achieved through electrification.

Section 3 Revised Planning

As previously mentioned, the original project configuration was modified to reduce the implementation cost and make it suitable for IPP participation or implementation by TANESCO. Hence, a description of the original project layouts as proposed by two earlier consultants is given in chapters 3 and 4 and the revised layout as per SECSD is discussed in chapter 5. The original configurations had an unit investment cost of $3925 and $5000 per kW and an energy cost of $0.107 and $0.0807 per kWh all exclusive of IDC in 1983. As per the revised approach the unit investment cost will be about $1640 per kW inclusive of IDC and energy cost 3.42 US cents per kWh assuming market for the entire generated energy in 1999 value even with project type loan from Financial Institutions. The project will hence be competitive and suitable either for IPPs or for Government implementation with assistance from World Bank.

Section 4 Topographic Features and Surveys

The proposed intake dam is located downstream of the deep and long gorge from which the Malagarasi river exits and makes a right turn. The proposed power station is a further 500 m downstream. The topography of the intake dam site consists of vast gently undulating land of elevation about 900m. At the diversion site, the left bank of the river rises gently to about 890m whereas the right bank rises more steeply. The river is about 300m wide and the river gradient downstream of the proposed diversion site is very steep.

The detailed aerial photography and topographic survey on 1:10000 scale has already been performed for a considerable stretch of the river from the mouth of the gorge for a distance of 5 km downstream. This data is adequate for the revised planning and no further aerial mapping is required. At the full feasibility stage, survey of the diversion weir and power house site will be performed. These aspects are discussed in chapter 6.

Section 5 Geology

The geology of the Malagarasi River basin consists of a basement complex of metamorphosed and folded Pre cambrain rocks of both igneous and sedimentary origin, overlain in the western part of the basin by unmetamorphosed Precambrain and Paleozoic sediments.

The proposed structures are located close to one of the major structural and physiographic features in Africa, which is the Rift valley. The rift valley is the cause for the formation of Lake Tanganyika. Its eastern edge is 25 to 30 km west and downstream of the proposed development.

The bedrock is exposed almost the entire way along the river from the end of the gorge upto the end of the rapids.

The rock formation belongs to the Bukoban series which was formed in late pre cambrium and early paleozium. Along the river, the bedrock consists of massive sandstone beds with strike approximately N-S, dipping slightly west. The plateau formations in the area are a result of the near horizontal rockbeds. This is formed by competent rock which has been weathered.

With the exception of the formation of the rift valley, the area has been relatively stable since Precambrium. This is confirmed in the low degree of metamorphosis, occasional wave patterns in sandstone and lack of tectonic folds in the area.

All rocks have ample bearing capacity. All structures envisaged are on the ground surface and are very simple. Hence there will be no need for any elaborate or detailed geological investigations which will influence the feasibility or cost of the project. These aspects are more fully described in chapter 7.

Section 6 Hydrology

The Malagarasi catchment has 55 precipitation stations including 11 meteorological stations. The locations are shown in figure 8-3. The annual rainfall varies from 2000mm in mountainous areas to 800mm near Tabora. The mean annual rainfall over the catchment by using the Thiessen polygon method with eleven rainfall stations is 1049mm.

The river is also gauged at several locations. Most of the stations were established about 20 years ago.

Out of the above data set, the most useful is the river discharge measured by station 4A9 which is located at Mbelagule. This station is located about 10km downstream of Uvinza and slightly upstream of the proposed project site.

The station comprises a staff guage with twice daily readings and an automatic recorder. The control consists of a rock sill. The data available is for a very short period from 1975 to 1982. Subsequently it appears that the operation has been discontinued.

From the river runoff measurements, the mean annual flow over the six years of complete record 1976-81 is 139.1 cumecs. This is equivalent to 35.4 mm runoff. The mean annual flow varies from 59.3 cumecs in 1976 to 374.3 cumecs in 1979. The specific runoff is 1.30l/s/sqkm. Analysis of long term flow duration curve indicates that the mean annual flow is exceeded for 31% of time. and the 90% exceeded flow is 19.8 cumecs.

The Flood magnitude is estimated to be 3000 cumecs for 1000 year return period which is selected for the design of the structures.

A more detailed treatment is given in chapter 8. Also discussed are climatology, flood studies and sedimentation.

Section 7 Power and Energy Studies

The proposed diversion site is located a few km downstream of the gauge site 4A9 at Mbelagule. As only a few seasonal streams join the Malagarasi in the reach from the gauge site upto the proposed intake dam, the flow at gauge site is taken to be the inflow at the diversion site.

The 1:10000 topographic survey maps have been used to work out the reservoir area and capacity curves which is given in figure 9-1.

The average annual continuous flow at the diversion weir site is 139 cum/sec.

The year in which the mean flow is close to this is 1981 with a mean flow of 113 cum/sec and a corresponding annual yield of 3570 MCM. Thus the year 1981 is a mean hydrologic year. Similarly the year with maximum yield is 1979 with a mean annual flow of 374 cum/sec and yield of 11805 MCM and the year with the least annual flow is 1976 with a flow of 59 cum/sec and yield of 1871 MCM.

The power and energy studies were carried out for the average year, dry year and wet year for an installed capacity of 2 x 4 MW. The detailed working tables are given in the Tables 9-1, 9-2 and 9-3.

From the results of the study, it has been decided that the power plant will have 2 units of 4 MW each. Most of the years have flow equal to or greater than the average year in the spell 1975 to 1982, thus 64GWh is assured. In a wet year the energy output rises to about 72 GWh and falls to 56 GWh in a dry year.

The computations were performed with a computer program which models all the main features of the power plant and accounts for hydraulic losses in waterways, consumption within station, electrical losses of generator and transformer and operational constraints which may be imposed by head and tailwater level condition.

Further, energy curves which represent the area under the duration curves were plotted for head of 25m and efficiency of 90%. The most optimal installation is 2 x 4 MW which gives 65GWh per annum. There is scope for overload capacity and hence 2 x 4.25 MW is also considered. These aspects are dealt with in detail in chapter 9 wherein the detailed simulation methodology used for predicting the power and energy output of the plant in each of the above hydrological years with the resultant predicted hydraulic variables such as reservoir levels, net heads, losses, and electric variables such as power, energy etc are presented graphically. The major results of the simulation are given in Box 1-2.

Box 1-2 Summary of Energy Outputs

Installed Capacity (MW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
1 x 4	34.9	35.0	33.2
1 x 6	52.6	52.6	45.8
2 x 4	64.4	71.6	56.2

Section 8 Civil Works

A hydropower project will normally require an access road, a diversion weir to create head and store water or route the river flow into the intake of the waterway, a waterway which is used to bypass the water from the natural river course and simultaneously concentrate the natural head on the turbine, the power house which houses the electromechanical equipment such as turbines and generators and a tailrace which leads the water back into the river. These constitute the civil works of the project. A brief outline of each component is given below. More thorough treatment is given in chapter 10 with the preliminary design and description of the various structures like diversion weir, intake structure, waterways, power house and tailrace and their outline drawings

Part I ***Access Road.***

There is an existing motorable forest track leading to the right bank near the project site, from Lugufu but not in good condition. Hence a new road will have to be built. The access to the power house site will be from the left bank and hence a bridge to cross the river has to be provided.

Part II ***Diversion Weir.***

This will be a rockfill structure founded on the rock. It will be ungated and of overflow type and the crest will be at 865m. The crest length of the diversion weir is about 340 m. A RCC flip bucket is provided at the bottom to dissipate the energy of the flood water. Upstream face is protected with a concrete slab. The elevation of the non overflow section is 867m. This type of dam is considered as the construction material is available in the immediate vicinity and hence will be very economical. The selected site is such that it is also suitable for a dam with rubble as the hearting. This alternative will be also very economical. Thus requirement of concrete for the project is reduced considerably.

Part III ***Intake and Waterway.***

The intake structure is located on the left bank. It is a concrete structure about 10m in width. It admits water to an open trapezoidal power canal with FSL 865m. The maximum flow is 40 cumecs. The canal is about 500m in length and conveys the water to a forebay. In view of the short length and the proximity of the reservoir, wave surges will not be a problem. The forebay is constructed in an excavation in the soft rock immediately above the power station with side slopes 1:1 and is lined with concrete on three sides. On the other side, a gravity type retaining wall houses the bellmouths which form the entrance to two penstocks of 2.15m diameter and length of about 100m each with separate inlet gates. They are laid in a shallow excavation on the ground and convey the water to the power station located near the left bank of the Malagarasi river where the water level is 840m.

Part IV *Power House.*

The power house will be of surface type. It is designed as a conventional rectangular building with concrete substructures. It will accommodate two vertical shaft Kaplan turbine generator units and all their auxiliaries. A service bay will be provided. The Malagarasi river is wide and also the river gradient is appreciable, near the power house area so the high flood level will not be a problem with the result that no expensive flood protection structures are required.

Part V *Tailrace*

The tailrace will be an open channel which joins the river. It will be short in length. Its bottom and sides will be suitably lined. The crest of the tailrace control weir will be at 840.0m.

Section 9 Electromechanical Equipment

The turbines and generators are termed as the electro mechanical equipment. The power station will house two vertical shaft Kaplan turbines with steel spiral cases. The runner diameter will be 1800mm. The turbines will be coupled to synchronous three phase generators. The design flow through the turbines will be 20 cumecs each. The generators will be rated at 4.75 MVA each. The turbine and and generator sets are direct coupled. The speed of the set is 300 rpm. Outline of electromechanical equipment and specifications are given in chapter 11. This section will be useful to the supplier of the generating equipment.

Section 10 *Transmission* and Utilisation

The power will be generated at 6.6kV. It will be stepped upto to 66 kV by outdoor transformers. The scheme of transmission envisaged is to construct a 100km 66kV single circuit line from the power station to Kigoma. These arrangements are discussed in chapter 12. This section also discusses the control, protection, metering strategy of the power station, switchyard, and transmission system.

Section 11 Implementation Cost

An estimate of the quantities of the civil works has been made. The implementation cost is worked out on the basis of unit rates of these items and the proforma invoice of the electro mechanical equipment received from prospective equipment manufacturers. The estimated quantities of various items of civil works are multiplied by the unit rates to give the cost. Further allowances have been made for transmission lines, contingencies and environmental considerations. These aspects are dealt with in chapter 13. In the present proposal the cost is reduced to US$11.25 million as compared to the estimated US$32 million in 1983. This makes the project attractive for implementation by TANESCO or IPPs by project type of funding.

Section 12 Economic, Financial and Sensitivity Analysis

Since the project is intended to serve a new isolated system which will grow as the demand develops, the economic analysis is carried out by valuing the energy produced from the project as equivalent to that produced by a diesel station of equivalent capacity with the quantum of energy equal to the base year demand of 25 GWh as well as full project potential of 65 GWh..

The economic value of energy produced ranged from US cents 19.04 for annual generation of 25GWh to US cents 13.70 for generation of 65GWh. The following were obtained for a discount rate of 12%

Box 1-3: Benefit Cost ratios

	Demand = 25GWh Growth = 2.5% p.a	Demand = 65 GWh Growth = 0% p.a
Base Case / No rise in fuel cost/	3.46	7.84
Base Case + 20% Cost / No rise in fuel cost	2.89	
Base Case + 5% Inflation in fuel cost	5.34	

Based on this the Benefit cost ratio of the project is found to be 7.84. Various sensitivity tests have been carried out for different worst case scenarios such as no growth in demand, no fuel cost escalation, 20% project cost escalation etc.

The economic Benefit cost ratio does not go below 2.50 for any of the conditions and hence the project is economically sound.

The financial analysis has been carried out by working out the total benefits from the project over its economic life of 30 years. The value for which energy produced can be sold is fixed at 7 US cents per kWh. This is about the average tariff charged by TANESCo.

Since the project may be financed on the basis of project financing or limited recourse financing the analysis has been performed with such a financing option. The project's financiers and lenders will base their decisions on project's cash flow for repayment of principal and interest and for returns on investment. The return to equity participants and IRR is also important and is evaluated.

Suitable sensitivity test have been carried out with different worst case scenarios such as no inflation in purchase price of electricity nor rise in demand. The results have shown that the project benefit cost ratio is sufficiently high and no major cash flow deficits arise in servicing the debt, operation and maintenance cost streams. More aspects are given in chapter 14 where it is demonstrated that the project is feasible with project type funding.

Section 13 Implementation Aspects

Due to the revised layout, the construction period of the project has been reduced to 24 months. The execution of the project is not complicated as all the structures are relatively simple, conventional and no underground structures are involved. No problems are likely to be encountered due to uncertain geological conditions etc. A construction schedule where the time frame required to implement each of the major project components is given. All these aspects are discussed in chapter 15.

Section 14 Environmental Considerations

The project area is located in an uninhabited area some 60km South East of Kigoma. The construction of the project will have minimal impact on the ecology and environment of the area. The only significant impact will be during the low flow period when there will be reduced flow over the falls in a short 500m stretch of the river due to diversion of water through the power house. This may affect the breeding of a few invertebrates and algae apart from creating a visual impact. However as the falls are not at present a tourist attraction there will be no adverse effect on tourism.

The improved access to the area which will be caused by the building of the project may encourage new settlements and tourism in the area . The area in the immediate vicinity is uninhabited and is in wilderness. Consequently no land will need to be acquired by paying compensation, nor is there any human settlement in this stretch which may require water. The construction of the diversion weir across the river will confine the lake to the river channel and hence no farm, plantation or house will be submerged. In fact, the lakes created could be used for development of small scale fisheries. The power station when in operation will not produce any effluents or noise which will disturb the natural calm of the area. The only negative impact which may arise is during construction when the noise may scare away the wild animals in the area. The animals which have been spotted on the right bank are wild pigs, deer, lions and hyenas.

Section 15 Conclusions and Recommendations

Based on the findings of this study, the conclusions that have been drawn and the recommendations are given in chapter 16.

Section 16 Photo Documentation

Photographs of the project area showing the river with falls and rapids is given which will be useful to the implementing agency.

Section 17 Annexures.

The following annexure volumes have been developed which support the study.

<u>Annexure-A: Evaluation of Flow Records:</u>

The available daily historic flow data useful for the project design observed at gauge size 4A9 for the years 1975 to 1982 is presented. The data is then presented graphically as per the following charts and figures.

Daily Observed Discharge data for each year with 30 day maximum, minimum, and mean values for each month

30 day Runoff depth and volume with mass runoff

30 day average specific discharge

Bar chart representation of runoff with logarithmic scale

Annual Mass runoff

30 day minimum observed flows for the period 1975 to 1982 with the maximum, minimum, mean, volume and runoff values for each month

30 day maximum observed flows for the period 1975 to 1982 with the maximum, minimum, mean, volume and runoff values for each month

30 day mean observed flows for the period 1975 to 1982 with the maximum, minimum, mean, volume and runoff values for each month

Flow duration curve for each year with normal and log scales to enable reading of low flows.

Hydrograph for each year with normal and log scales to enable reading of low flows.

Flood hydrographs for each year and the recession curve.

Annexure - B: Precipitation Data of Malagarasi Basin

Precipitation data of important rainfall stations in the catchment along with graphical presentation is given for Kibondo, Kigoma, Lumbe, Ngara, Nguruka, Sikonge and Urambo.

Chapter 2 Overview of Kigoma Region and Project Area

Section 1 General

The Kigoma region is situated in the western part of Tanzania, on the shores of Lake Tanganyika. The region comprises the major towns Kigoma, Ujiji, other small towns Uvinza, Kibondo, Kasulu, Simbo and a number of small villages. The region is bordered by Lake Tanganyika on the west, Burundi on the north, Kagera region on the north east, Shinyanga and Tabora regions on the east and Rukwa region on the south. A considerable portion of the region comprises the Moyowosi Game Reserve. Map of the region is given in figure 2-1.

Section 2 Access

The regional capital Kigoma is served by the national airline Air Tanzania's scheduled flights twice a week from Dar Es Salaam via Tabora and by Tanzania railways passenger service to Tabora. The port at Kigoma is very important to the regional economy and is involved in the shipment of goods with other countries surrounding lake Tanganyika such as Burundi, Zaire and Zambia. A number of airstrips are available throughout the region for small charter aircraft. Access by roads from other parts of the country is however difficult especially during rainy season. The most important road is the B8 which is principally gravel which goes to Bukoba in Kagera region via Kasulu and Kibondo. The distance is 545km.

Section 3 River Basins

The principal rivers draining this region are the Malagarasi and the Luiche. Both rivers drain into lake Tanganyika. The two basins have markedly contrasting features. The Luiche basin is small, receives good precipitation, is more densely populated and is better served by access roads. On the other hand, the Malagarasi basin is vast with about 123000 km2 catchment area and encompasses a vast portion of central Tanzania. Most of its catchment receives below average rainfall. It is also sparsely populated and exists to this day in its natural state. One of the distinctive features of the Malagarasi catchment is the presence of huge swamps which absorb floods and give regulated discharge in the dry season.

The Malagarasi River originates in the highlands and intermediate agroecological zones of the northwest section of Tanzania in close proximity to Lake Tanganyika into which it empties. But the river initially flows in a direction away from Lake Tanganyika in a northeasterly direction along the border between the countries of Tanzania and Burundi before turning south west to describe an almost circular path. It passes through the centre of Kigoma Region and empties into Lake Tanganyika about 100km south of its source. On this journey it is joined by major tributaries Ugalla, Gombe, Kigozi, Nikonga and Moyowesi on the left bank coming from the dry heartland of Tanzania. In its central basin area, the Malagarasi River is part of an extensive swampy area stretching to the northeast along the Moyowesi River and to the south east along the Ugalla River. Two prominent lakes Nyagamoma and Sagara are located in this reach. On leaving this swampy area, the Malagarasi proceeds in a westerly direction via a steep, narrow gorge and then enters Lake Tanganyika at Ilagala, where it has formed an extensive delta. The miombo forests and swampy areas lying along the midsection of the Malagarasi River are virtually uninhabited because of tsetse fly infestation.

Section 4 Topography

The topography of the region consists of gently rolling hills. The Malagarasi river, shown in figure 2-1, occupies a large portion of North western-central Tanzania. The basin stretches from Lake Tanganyika on the west some 380 km to Tabora on the east . From near the southern limit of Lake Victoria on the north, it extends south 450 km as far as Rungwa.

The western and southern basin boundaries are marked by the highlands which extend discontinuously southward from Burundi, along the east coast of Lake Tanganyika to the region north of Lake Rukwa. These highlands reach elevations of more than 1,500 m. The Malagarasi drains into lake Tanganyika, at elevation approximately 770 m, through a break in the mountainous zone south of Kigoma.

To the east, the topography is of lower relief, but one where steep erosion scarps and relatively deeply incised river valleys have formed in the relatively soft sedimentary rocks. These erosion features may reach heights of several hundred metres and are most pronounced along the courses of perennial rivers. West of Uvinza, the elevation of the terrain is generally less than 1,000m and a gorge over 400 m deep has been carved in the sandstone formation.

Most of the basin east of Uvinza occupies a down warp in the precambrian peneplain. Here the topography is low relief, generally less than 1,500 m in altitudes, and is controlled by the crystalline basement rock. As a result, much of the central, southern and eastern parts of the basin are covered by mainly seasonal and partly perennial swamp.

Section 5 Economy

The primary income of the inhabitants of the region is from rain fed agriculture. All farming is mainly for subsistence. The crops cultivated include maize, beans, cassava, sweet potatoes and fruit. The cash crops include cotton, tobacco and some coffee. Cattle production is limited to the highland areas.

Fishing in Lake Tanganyika is a very significant component of the Kigoma Region economy. Approximately 50,000 tonnes of fish are harvested annually by approximately 1,000 fishing boats in the region.

At Uvinza, salt mines employ some 500 people. These operations require large quantities of water for flushing the brine pits. Other small industries in the region are located in the population centers in the west and north.

The gross per capita income in Kigoma Region is slightly above the national average.

Although a major portion of the Malagarasi basin is at considerable distance (1,600 km) from Dar es Salaam and the coast, it is linked by the Central railway line and by poor, circuitous roads. However, much of the center of the basin is lacking adequate access. Transport connections exist with Burundi, Zaire and Zambia which are Tanzania's most prominent trading partners. The port of Kigoma handles approximately 200, 000 tonnes of exports and imports annually to and from these countries.

Section 6 Climatic Conditions

The basin is situated in the dry, hot heartland of Tanzania where ground elevation averages between 1,100 and 1,400m. Average temperature variation through the year is quite minimal, ranging from 19.C to 28.C on the west side, and from 16,5 C to 29.5 C on the east side. Annual precipitation also varies throughout the basin.

Generally, average annual rainfall is 980 mm on the west side, in the Kigoma/Uvinza area, reducing going eastward to 880 mm at Tabora. The exception is the area to the northwest along the Burundi border, where orographic effects increase average annual rainfall to 1,260 mm in the Kibondo area.

The annual rainfall pattern in the basin is characterized by one long rainfall period from November to May. This period is dominated by the northeast monsoon air currents, known as the Kaskazi season. These air currents meet westerly air masses originating out of the Congo basin. The convergence area of these two air masses cause the heavy rainfall occurrences. This convergence area also links with the major ITCZ, which at this time of year is located to the south of Tanzania, but does not have any direct influence on rainfall during this time. This 4-month period accounts for about 60 to 65 percent of the total annual rainfall in the basin. During mid-March to mid-May, the ITCZ moves north across the country carrying an additional 19 percent of the annual rainfall.

From June to September, the southeast monsoon or Kusi air currents prevail. This produces the driest period in the basin, as well as in the majority of the country. This is mainly due to the dryness of the air mass itself which is of continental origin. Average rainfall over this period is less than 4 mm/month.

The remaining part of the year, from October through November, sees the ITCZ move southward across the country quite rapidly in comparison to its northward rate of travel. When passing through the Malagarasi basin the ITCZ has very minimal effects. Less than 5 percent of annual total rainfall in the Malagarasi basin is produced during the "Short rains" period. In November, the convergence zone associated with the air masses of the Kaskazi and Congo basin establishes quite rapidly bringing heavy rains to the basin, which average between 15 and 20 percent of the total annual rainfall.

Potential evaporation is quite high throughout the basin, ranging from an average of 1,700 mm/year at Uvinza to almost 2,000 mm/year at Tabora.

Section 7 Demography

Kigoma Region has a population density of approximately 20 people/km2 and the annual growth rate is very uneven, The majority of the people live in the highland zone along the Tanzania-Burundi border. The area received many refugees during the 70s who were resettled in many camps. The UNHCR has a presence in Kigoma.

Section 8 Environment

In addition to the highland and intermediate agroechological zones in the northwest section of the basin, the miombo zone dominates the midsection of the watershed while the lake shore zone is situated near the river mouth. Ten forest reserves covering 9,000 km^2 are present in Kigoma Region. The primary uses of these areas are for timber, firewood, charcoal and building poles rather than for protection of the environment.

The Malagarasi swamp covers approximately 1,900 km^2 and is considered to be an important refuge for wildlife. This is especially true of the southeast portion of the wet land where the Ugalla River Game Reserve is located. This area is known for its significant concentrations of roan, sable and kudu. Other common species include warthog, common duiker, sable, topi, reedbuck, harteneest and hippopotamus.

Primary education facilities are present in about 93 percent of the villages in Kigoma Region. Dispensaries are available in roughly 48 percent of the villages.

The major health issue in the Malagarasi basin, specifically in the low-lying miombo woodlands and swamp which occupy 70 percent (20,000 km^2) of the Kigoma Region, is tsetse fly infestation. Although vaccinations and treatment are available for sleeping sickness (trypanosomiasis), this tsetse fly infestation restricts a large amount of the Malagarasi basin from habitation by human and livestock.

Other common diseases of the area include water-borne diseases, water-waste diseases and water-related insect vector diseases.

Section 9 Demand Supply Situation

The present source of the electricity in the region is entirely from diesel generators. The units are operated by TANESCO. They were installed initially to provide electrification of the main part of the Kigoma town excluding perhaps the growing sub urban areas. The service area is limited to only Kigoma and Ujiji. The total installed capacity is about 1900kW. The generators are quite old and are not operating at full capacity. Moreover, considerable costs are involved in running them as fuel is very expensive and has to be transported from Dar es Salaam over a distance of 1200km. In Uvinza, there is the Nyanza salt mine which has its own diesel generators. The power is used for lighting and not for the manufacturing process. The supply conditions are very erratic and during the reconnaissance visits to the area it was found that the generators were shut down due to non availability of diesel. The rest of the Kigoma region is not electrified. Even important towns such as Simbo, Kasulu, Kibondo, Nkumgwe do not have electricity. Present estimate of the cost of supplying electricity by diesel may be about 12 to 15 US cents per kWh. The average tariff in the area is about 7 US cents per kWh.

It is interesting to note that some missions in the region have installed their own micro hydro power station on some small streams. One such mission is located about 30km from Kigoma and was visited by the SECSD team.

Detailed studies on the potential electric power demand of the region were carried out in 1982 by Norconsult. The results are given in table 2-1. The forecast was made upto the year 2015. The study was based on the assumption that a 7.6MW power plant would be commissioned on the Malagarasi at Igamba falls in 1986 which however was not implemented. Hence it may be assumed that the present demand has not risen to the levels which were forecast in the study. The modified load demand forecast is given in table 2-2. This is based on actual demand observed for the period 1971 to 1979 in Kigoma when there was surplus capacity. This period was also one where the economic growth in Tanzania was good. The demand is plotted year wise and an exponential curve is fitted by method of least squares. The curve is then extrapolated to give the demand in the years from 1990 to 2030. Similar curve has been fitted for the energy demand. Based on this the current demand in 1997 is about 2750kW. Comparison with the actual maximum generation at Kigoma station in 1997 shows that the maximum generation was about 1970kW. By extrapolation, the demand is expected to grow to about 3000 kW in 2000, 5000kW in 2005 and to 8000kW in 2010. The towns of Uvinza, Kasulu etc will have a demand of about 1000kW in 2000 rising to about 5000kW in 2010.

It should be noted that demand at present is suppressed due to constraints on generation as well as high prices of electrical gadgets.

Generation data as obtained from TANESCo's diesel power station at Kigoma is given in tables 2-3 to 2-5. Table 2-3 gives the maximum demand recorded during the year 1997 in the morning. The maximum demand recorded was 1750kW on February 3rd.

Table 2-4 gives the maximum demand recorded during the year 1997 in the evening. The maximum demand was 1970 kW on March 25th.

Table 2-5 gives the daily energy generation during the year 1997. Maximum daily energy demand was in the month of June with 34,270kWh. The total annual generation was 9.901GWh. For an installed capacity of 3 x 650kW, this gives a load factor of 57.4%.

From tables 2-3 and 2-4, it is observed that load suddenly drops during a month to a low values as compared to most of the other days in the same month. This may be attributed to units going offline either due to maintenance or fuel shortage.

Table 2-5 gives the various categories of days during the year such as weekday, weekend etc along with the daily maximum demand variation

Figure 2-2 gives the load duration curve for the year 1997 from data compiled from the morning and evening maximum demands. It shows a minimum demand of about 900kW with a demand of 1400kW being exceed 50% of the time, and 1600kW being exceed 15% of the time.

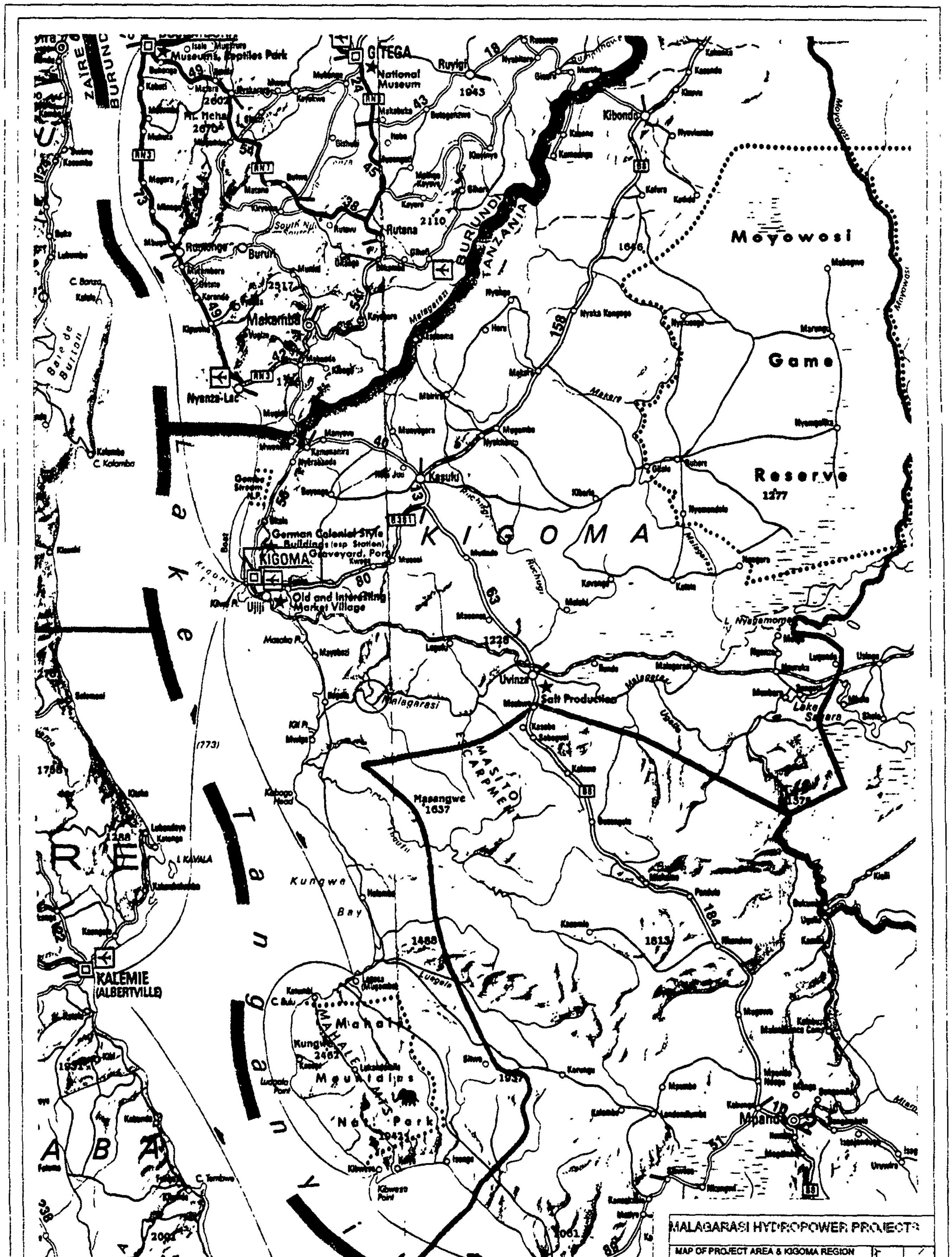

MALAGARASI HYDROPOWER PROJECTS
MAP OF PROJECT AREA & KIGOMA REGION
SCALE 1:1,500,000
FOR THE WORLD BANK/TANESCO
DWG NO FIG 2-1
PLANNING DESIGNS & CAD BY
GIVACURU ENERGY CONSULTANTS
Lake Tanganyika
KIGOMA
Moyowosi Game Reserve
Kigoma
Ujiji
Uvinza
Kasulu
Kibondo
Mpanda
Malagarasi
Salt Production
Masito Carpment
Masangwe 1637
Kungwa Bay
Mahale Mountains Nat. Park
KALEMIE (ALBERTVILLE)
Old and Interesting Market Village
German Colonial Style Buildings (esp Station) Graveyard, Port
Gombe Stream N.P.
BURUNDI
TANZANIA
ZAIRE
GITEGA
National Museum
Nyanza-Lac
Makamba
Rutana
Ruyigi
Lake Sagara
Baie de Burton

TABLE 2-1
POWER AND ENERGY/DEMAND FORECAST FOR KIGOMA REGION (1983)

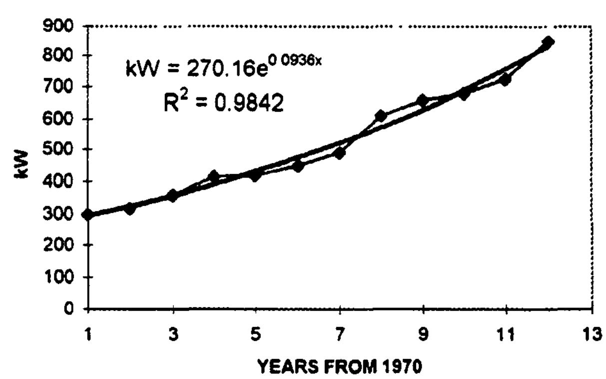
Area		1990		2000		2010		2015	
		Energy Demand GWh	Power MW	Energy Demand GWh	Power MW	Energy Demand GWh	Power MW	Energy Demand GWh	Power MW
Kigoma / Ujiji urban	High Low	11.0 9.7	2.5 2.2	25 9 19 9	5.9 4.5	56.1 37.8	12 8 8.6	81 9 51.7	18.7 11.8
Kigoma rural	High Low	12 7 12.1	2 9 2.8	18 1 16 1	4.1 3 7	26.3 21 3	6.0 4.9	32 0 24 6	7 3 5 6
Kasulu town	High Low	0 7 0 7	0 2 0 2	1 4 1 1	0 3 0 3	2 5 1.9	0 6 0.4	3.3 2 3	
Kasulu rural	High Low	7 3 6 7	1 7 1.5	13 7 11 3	3.1 2.6	23.4 17.5	5.3 4 0	30.2 21.5	
Uvinza		6 5	1.5	6 7	1.5	-	-	-	
Areas along Alternative 3 transmission line	High Low	21 4 19 7	4 9 4 5	39.7 32.4	9 1 7 4	75 3 53.7	17.2 12.3	104 9 69.9	
Total	High Low	53 1 48 9	12.2 11,2	98 8 80 8	22.5 18 5	183.6 132 2	41.9 30 2	252 3 170 0	

Load factor = 0. 5

TABLE. 2-2
REVISED POWER AND ENERGY FORECAST FOR KIGOMA

YEAR	YEAR	POWER DEMAND ACTUAL (kW)	POWER DEMAND PREDICTED (kW)	ENERGY DEMAND ACTUAL (GWh)	ENERGY DEMAND PREDICTED (GWh)
1	1970	300	293	1.262	1.26
2	1971	320	319	1.431	1.38
3	1972	360	346	1.566	1.51
4	1973	416	376	1.633	1.66
5	1974	420	409	1.729	1 81
6	1975	450	444	1 903	1.99
7	1976	490	483	2.19	2.17
8	1977	610	524	2.291	2.38
9	1978	660	570	2 707	2.60
10	1979	680	619	2 912	2.85
11	1980	725	673	3.271	3 12
12	1981	850	731	3 287	3.41
28	1997	2000	2758	9 901	14.48
30	1999		3257		17.34
36	2005		5358		29.81
41	2010		8115		46.83
46	2015		12289		73.55
51	2020		18609		115.52
56	2025		28182		181.45
61	2030		42677		285.00

GROWTH IN DEMAND



GROWTH IN ENERGY GENERATION

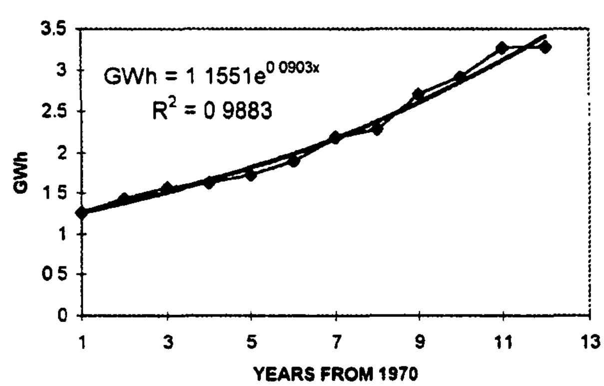
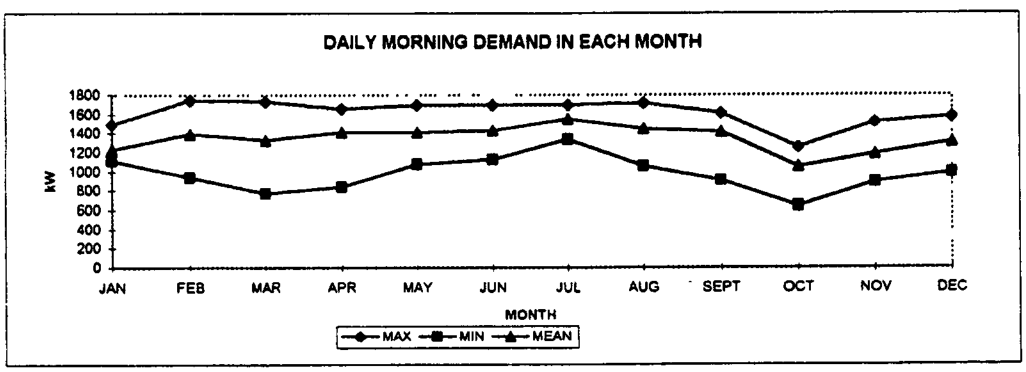


TABLE 2-3
DAILY MORNING MAXIMUM DEMAND FOR KIGOMA POWER STATION

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1	1120	1570	1040	1230	1520	1300	1520	1610	1620	1000	1120	1330	
2	1280	1380	770	1570	1380	1470	1620	1460	1540	980	1090	1580	
3	1280	1750	810	1430	1390	1640	1700	1520	1470	1140	1160	1370	
4	1290	1500	1040	1220	1620	1340	1340	1620	1600	1070	1190	1430	
5	1210	1450	1280	1340	1290	1420	1540	1550	1620	900	1170	1390	
6	1240	1490	1290	1410	1470	1650	1600	1700	1600	980	1080	1350	
7	1160	1460	1230	1430	1360	1500	1510	1280	1350	1080	1150	1410	
8	1160	1420	1010	1480	1260	1480	1520	1460	1620	1180	1120	1500	
9	1300	1600	1050	1380	1350	1640	1660	1240	1520	1160	1080	1390	
10	1280	1400	1260	1530	1440	1460	1600	1580	1460	830	1060	1120	
11	1160	1410	1160	1480	1140	1600	1600	1600	1370	640	1140	1310	
12	1160	1610	1320	1490	1310	1530	1560	1660	1560	1060	1250	1440	
13	1240	1500	1310	1290	1400	1560	1470	1060	1020	1130	1060	1020	
14	1170	1550	1320	1480	1140	1570	1660	1480	1140	1260	1200	990	
15	1300	1400	1190	1520	1420	1590	1420	1160	1480	1020	1160	1260	
16	1180	1450	1410	1360	1540	1630	1660	1450	1370	1100	1220	1220	
17	1200	1420	1310	1290	1180	1630	1590	1600	1480	1150	1190	1360	
18	1150	1420	1740	1330	1280	1620	1640	1560	1440	800	1260	1480	
19	1220	1500	1390	1530	1360	1700	1540	1560	1400	950	890	1260	
20	1210	1430	1670	1480	1330	1500	1450	1600	1540	1230	1120	1240	
21	1200	1550	1520	1480	1540	1230	1520	1720	1460	1080	1220	1270	
22	1500	1310	1550	1500	1430	1380	1580	1560	1420	1010	1240	1480	
23	1280	1120	1580	1570	1600	1280	1620	1470	1380	1060	1360	1070	
24	1200	1140	1620	1360	1080	1130	1660	1420	1240	920	1520	1340	
25	1320	1110	1590	1630	1340	1240	1560	1540	1400	1080	1300	1540	
26	1220	1170	1470	1340	1490	1210	1510	1560	1380	1080	1220	1190	
27	1340	940	1540	840	1530	1240	1480	1260	1300	1160	1270	1330	
28	1220	1040	1460	1660	1700	1180	1600	1240	1440	1200	1200	1270	
29	1330		1500	1420	1600	1160	1460	1170	1500	1080	1260	1220	
30	1120		1480	1370	1640	1160	1430	1150	910	1160	1270	1290	
31	1210		1460		1700		1600	1140		1150		1340	
DAYS	31	28	31	30	31	30	31	31	30	31	30	31	365
MAX	1500 00	1750 00	1740 00	1660 00	1700 00	1700 00	1700 00	1720 00	1620 00	1260 00	1520 00	1580 00	1750 00
MIN	1120 00	940 00	770 00	840 00	1080 00	1130 00	1340 00	1060 00	910 00	640 00	890 00	990 00	640 00
MEAN	1233 87	1396 07	1334 52	1414 67	1413 87	1434 67	1555 48	1450 97	1421 00	1052 90	1185 67	1315 81	1350 27



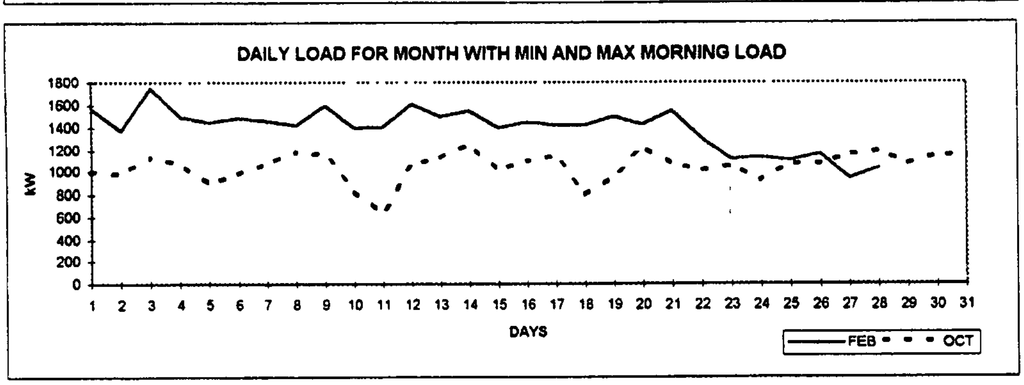
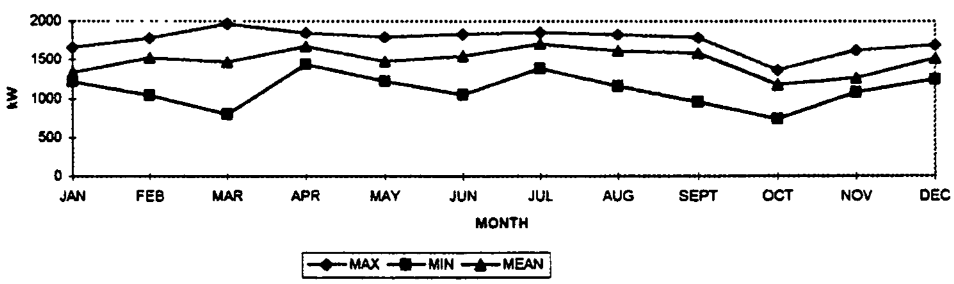


TABLE 2-4
DAILY EVENING MAXIMUM DEMAND FOR KIGOMA POWER STATION

YEAR 1997
UNITS kW

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1	1240	1680	1310	1810	1730	1550	1820	1810	1760	1050	1180	1310	
2	1340	1720	800	1810	1500	1530	1750	1750	1750	1200	1240	1580	
3	1210	1690	870	1760	1780	1550	1520	1810	1730	1200	1160	1460	
4	1260	1700	1120	1660	1520	1530	1750	1700	1720	1120	1210	1580	
5	1300	1750	1250	1440	1490	1640	1860	1810	1580	1180	1220	1680	
6	1220	1630	1260	1740	1360	1830	1820	1780	1640	1200	1210	1450	
7	1330	1670	1150	1700	1220	1530	1760	1620	1770	1260	1220	1650	
8	1300	1670	1160	1840	1380	1770	1830	1400	1660	1220	1200	1600	
9	1400	1580	1230	1820	1420	1600	1750	1790	1750	1140	1140	1470	
10	1320	1350	1230	1820	1280	1790	1830	1780	1790	740	1270	1500	
11	1350	1490	1240	1850	1530	1740	1830	1420	1680	1160	1350	1580	
12	1340	1670	1180	1560	1670	1660	1740	1460	1230	1340	1100	1320	
13	1230	1540	1210	1620	1470	1700	1410	1500	1340	1320	1200	1370	
14	1210	1630	1210	1500	1400	1820	1520	1200	1660	1160	1080	1240	
15	1340	1780	1360	1560	1460	1720	1600	1620	1560	1220	1160	1400	
16	1290	1710	1540	1590	1370	1780	1740	1830	1560	1260	1290	1510	
17	1280	1610	840	1600	1250	1720	1760	1700	1750	910	1210	1530	
18	1390	1520	1920	1680	1300	1760	1710	1800	1440	1120	1100	1340	
19	1280	1440	1750	1740	1480	1700	1780	1600	1580	1200	1190	1440	
20	1340	1770	1950	1580	1620	1840	1700	1720	1620	1230	1160	1500	
21	1580	1660	1910	1690	1370	1400	1380	1790	1520	1170	1470	1550	
22	1400	1320	1460	1640	1570	1050	1580	1640	1440	1360	1570	1610	
23	1400	1150	1890	1660	1220	1320	1810	1760	1680	1120	1560	1690	
24	1270	1120	1800	1700	1410	1310	1680	1800	1670	1160	1620	1650	
25	1290	1150	1970	1740	1520	1260	1580	1660	1660	1200	1260	1400	
26	1320	1040	1800	1610	1490	1140	1750	1730	1540	1220	1240	1620	
27	1230	1170	1940	1580	1330	1220	1720	1200	1710	1080	1280	1650	
28	1400	1310	1860	1780	1700	1280	1600	1260	1650	1100	1260	1480	
29	1320		1800	1580	1470	1080	1740	1160	980	1310	1320	1600	
30	1260		1840	1720	1800	1620	1780	1310	960	1160	1370	1650	
31	1660		1610		1560		1770	1700		1230		1510	
DAYS	31	28	31	30	31	30	31	31	30	31	30	31	365
MAX	1660 00	1780 00	1970 00	1850 00	1800 00	1840 00	1860 00	1830 00	1790 00	1360 00	1620 00	1690 00	1970 00
MIN	1210 00	1040 00	800 00	1440 00	1220 00	1050 00	1380 00	1160 00	960 00	740 00	1080 00	1240 00	740 00
MEAN	1325 81	1518 57	1466 45	1679 33	1473 23	1548 00	1705 48	1616 45	1579 33	1172 26	1261 33	1513 55	1487 75

DAILY EVENING DEMAND IN EACH MONTH



DAILY LOAD FOR MONTH WITH MIN AND MAX EVENING DEMAND

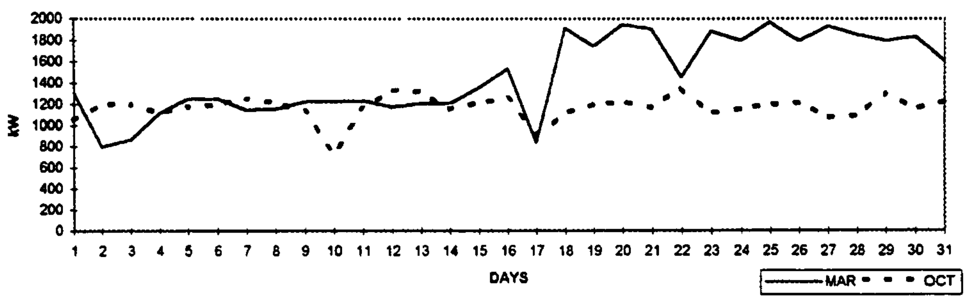
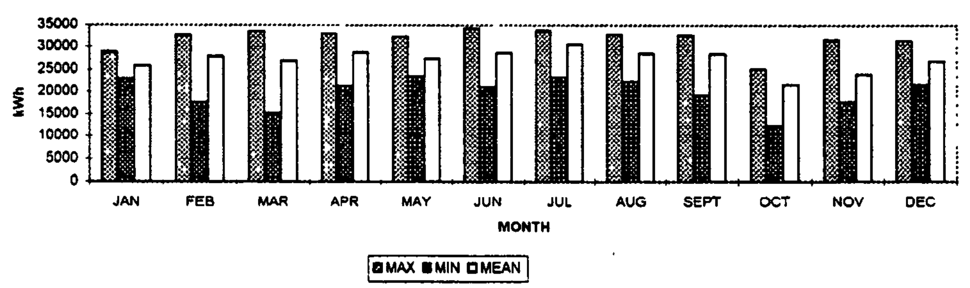


TABLE 2-5
DAILY ENERGY GENERATION AT KIGOMA POWER STATION

YEAR 1997
UNITS kWh

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1	25410	32780	17640	25720	32180	28330	30660	32660	31710	21140	24720	24950	
2	27100	29410	15190	32310	29270	30400	33350	31180	30300	20790	24390	31370	
3	25960	30840	17440	29480	29980	29560	29590	31900	31830	20790	24560	27540	
4	26210	31420	21050	27630	28190	28150	28770	29320	32670	22920	25490	27740	
5	24480	29980	22980	28750	25560	29770	32480	30830	28720	21230	23210	28140	
6	24190	31090	25250	29620	23600	33120	32570	29830	32640	21430	22710	30230	
7	23020	31330	23720	28430	24790	31380	31430	28510	29230	21690	24360	30230	
8	25270	31190	21120	30210	27050	31880	31740	26890	30280	24270	23770	28300	
9	26320	30450	22030	28140	27400	29370	32720	28890	29490	23410	23220	25980	
10	26690	27620	23280	31220	24970	30110	32610	32370	28940	12470	21470	26110	
11	25910	31030	24050	26300	25680	32060	31890	28730	27680	17500	17790	26120	
12	27160	30210	21390	29550	29780	30650	31950	27850	27870	24740	20880	21640	
13	26440	29540	25070	28420	25320	31780	29150	25570	22440	25050	22010	22100	
14	23230	31420	25050	27440	24820	31450	23230	24140	28960	22610	21670	22350	
15	26570	27010	26450	27470	25510	30940	28210	24640	29560	22150	25510	24140	
16	25890	28560	29050	28860	28330	32820	29170	32370	28090	24720	25290	26520	
17	25890	29430	31120	27370	25100	31770	29360	31600	29080	17820	26100	26040	
18	25200	29100	33400	29030	24540	31960	32980	30690	28650	18080	22440	27210	
19	24910	28870	28870	31440	26450	34270	33830	24900	27750	22700	18690	26600	
20	26390	30440	33300	30540	24610	29920	32360	30190	29770	24800	22440	28460	
21	25350	31010	33510	28940	27080	24430	28490	32910	27200	21750	25160	26370	
22	29000	19950	31540	28940	29410	26230	27760	30200	29000	22450	26470	28120	
23	26080	21490	30620	30280	26180	25080	30890	30680	27420	20040	29550	24860	
24	25690	23230	30360	27870	23500	21150	31570	29750	26800	15910	31670	28880	
25	25860	21960	31110	32740	28500	24190	29710	30290	30530	22250	24970	29950	
26	25330	22480	33180	26570	26760	23940	28810	29900	26670	23190	22560	28030	
27	27920	20540	32390	21310	31390	23600	30290	23080	27410	21120	23960	28990	
28	26420	17580	31850	33060	30140	24210	29130	22350	28510	22430	23100	27660	
29	26120		32420	28700	30130	22670	29790	23530	24390	22990	25660	25750	
30	25450		31180	28760	32370	26210	31620	23470	19190	24160	23770	24400	
31	28020		30190		31170		31550	25820		23220		27270	
DAYS	31	28	31	30	31	30	31	31	30	31	30	31	365
MAX	29000	32780	33510	33060	32370	34270	33830	32910	32670	25050	31670	31370	34270
MIN	23020	17580	15190	21310	23500	21150	23230	22350	19190	12470	17790	21640	12470
MEAN	25919	27856	26961	28837	27412	28713	30570	28550	28459	21607	23920	26840	27127
TOTAL	803480	779960	835800	865100	849760	861400	947660	885040	853780	669820	717590	832050	9901440
CUMUL	803480	1583440	2419240	3284340	4134100	4995500	5943160	6828200	7681980	8351800	9069390	9901440	

DAILY ENERGY GENERATION MONTHWISE



ENERGY GENERATION

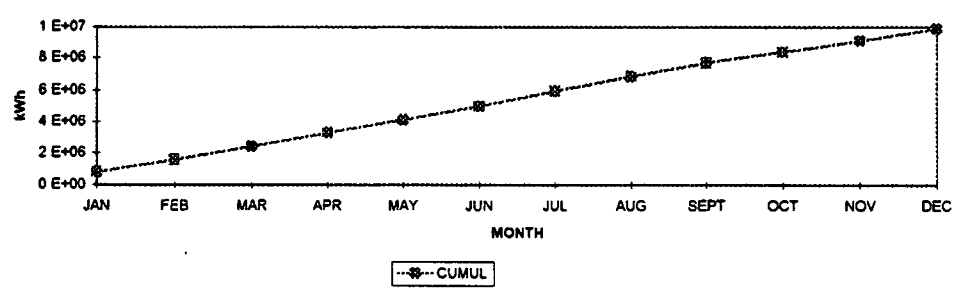


TABLE: 2-6
DAYS WITH MAXIMUM DAILY DEMAND

YEAR. 1997
UNITS . kW

DATE	HIGHEST MORNING 2/12/97	HIGHEST EVENING 23/12/97	HIGHEST SATURDAY 21/12/97	HIGHEST SUNDAY 7/12/97
TIME				
1	1512.0	945 0	1071.0	1291.5
2	1323.0	913 5	1039.5	1244.3
3	1260.0	882 0	1039.5	1212 8
4	1354.5	850 5	1102.5	1212.8
5	1386.0	882 0	1134.0	1212.8
6	1480 5	913 5	1165.5	1291.5
7	1580 0	960 8	1197.0	1401.8
8	1449 0	976.5	1291.5	1323 0
9	1449.0	1071 0	1071.0	1323 0
10	1386 0	945 0	1197 0	1291 5
11	1260 0	945.0	1165 5	1291.5
12	1323.0	1228 5	1118.3	1244 3
13	1417 5	1228.5	1354.5	1244 3
14	1323.0	1291.5	1197.0	1244.3
15	1291 5	1197.0	1181.3	1165.5
16	1234.8	1244 3	1338.8	1260.0
17	945.0	1260.0	1181.3	1102.5
18	1386.0	1197.0	1228.5	1260 0
19	1323.0	1149.8	1275.8	1323.0
20	1575 0	1690.0	1653.8	1653.8
21	1559 3	1606 5	1653 8	1606.5
22	1512.0	1134 0	1480.5	1543.5
23	1417.5	1228.5	1386.0	1660.0
24	1323.0	1212.8	1197.0	1373.4
ENERGY	31370	24860	28990	30230

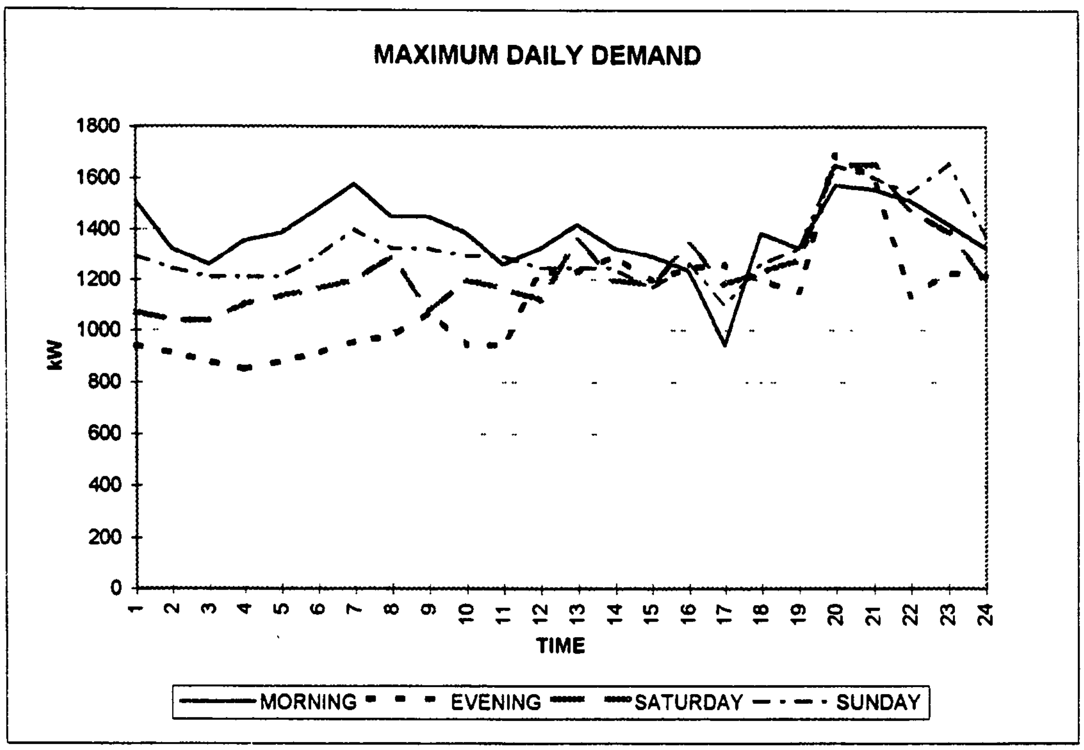
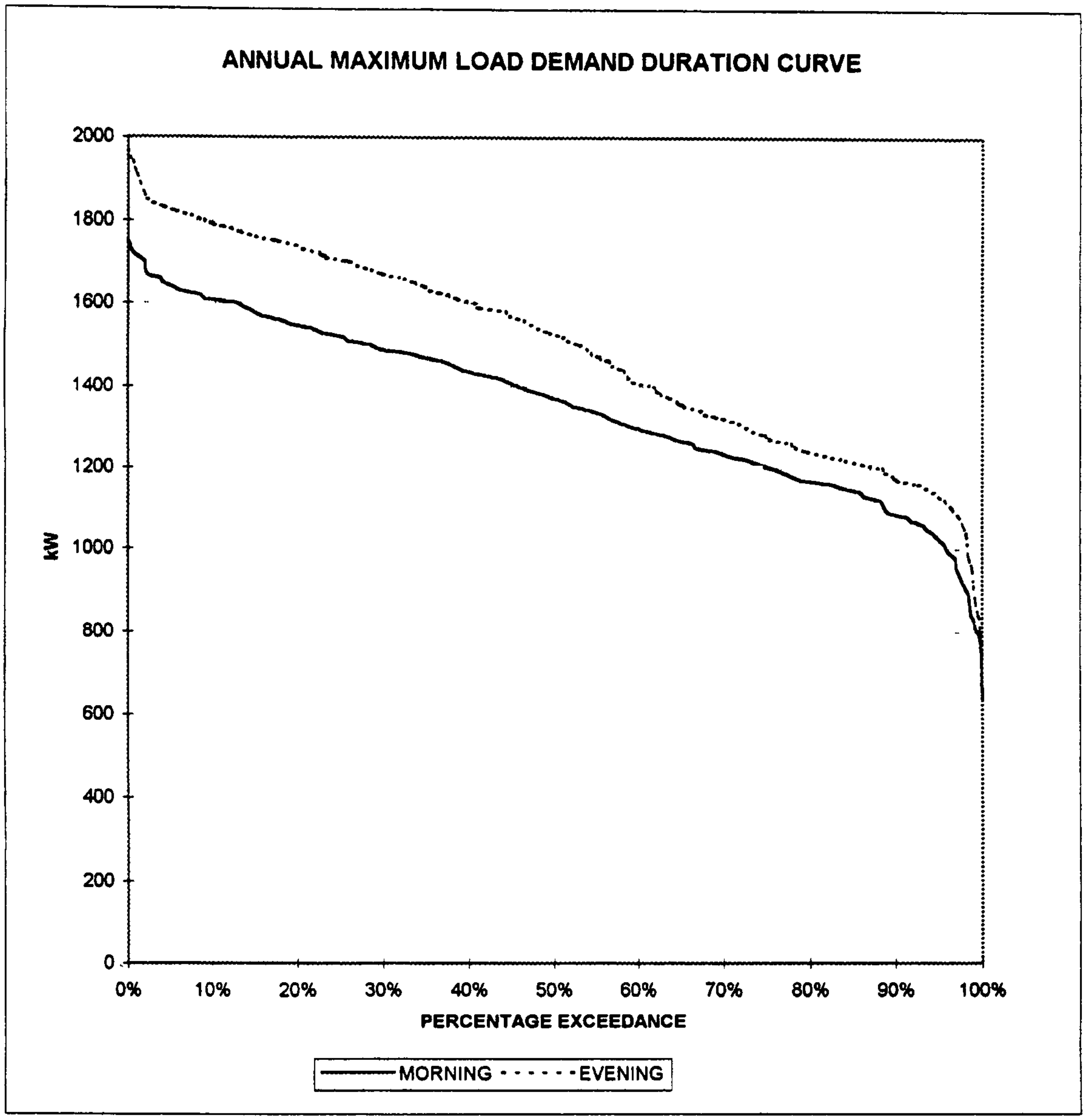


FIGURE 2-2
ANNUAL LOAD DURATION CURVE FOR KIGOMA POWER STATION



Chapter 3 Review of Previous Proposals (Norconsult)

Section 1 Alternatives

During 1982-83 Norconsult carried out a feasibility study on development of mini hydropower in the region. The study explored the possibilities of hydropower development on Luiche river and Malagarasi river which are both close to Kigoma.

On the Malagarasi river, six alternatives all being run of river type were studied concentrating on the stretch of the river known as Igamba falls which is about 60km South East of Kigoma. These alternatives are as follows and are also shown in figure 3-1.

- ALT-1A & 1B Headrace Tunnel on the south side of river
- ALT-2A & 2B Headrace canal on the south side of river
- ALT-3A & 3B Headrace Tunnel on the north side of river.

Box 3-1: Alternatives on Malagarasi River by Norconsult

	TUNNEL LENGTH	CANAL LENGTH	PENSTOCK LENGTH	TAILRACE LENGTH	POWER HOUSE
1A & 1B	3500	-	140	350	SURFACE
2A & 2B	-	4400	140	350	SURFACE
3A & 3B	6500	-	1150	-	SURFACE

Alternatives 1A, 2A, 3A are based on power discharge of 9 cumecs which is exceeded 98% of the time and 1B, 2B and 3B are based on power discharge of 20 cumecs which is exceeded 90% of the time. All alternatives require construction of a 24km access road from near Lugufu which is on the Dar Es Salaam - Kigoma railway and about 200km of 33kV transmission lines to supply Kigoma, Ujiji, Uvinza and Kasulu.

After studying the above possibilities the following preliminary cost estimates were developed which enabled identification of the most economic alternative.

Box 3-2: Preliminary Costs of various alternatives on Malagarasi (Norconsult)

ALT	INSTALLED CAPACITY (MW)	FIRM POWER (MW)	FIRM ENERGY (GWh)	PLANT COST (MUSD)	PROJECT COST (MUSD)	PROJECT COST/FIRM ENERGY (USD/kWh)	PROJECT COST/INSTALLED CAPACITY (USD/kW)
1A	6.4	4.4	38.3	27.5	33.5	0.87	5234
1B	14.2	9.7	83.1	35.0	44.0	0.53	3098
2A	6.4	4.4	38.6	29.0	35.0	0.91	5468
2B	14.2	9.8	83.8	38.8	47.8	0.57	3366
3A	6.2	4.3	37.6	34.8	40.8	1.09	6580
3B	14.1	9.6	82.3	45.1	54.1	0.66	3837

Hence alternative 1B was selected.

On the Luiche river three alternatives were studied near the Nkumgwe village about 20km east of Kigoma.

- ALT-1: Lower damsite as a 10 year minimum annual runoff development.
- ALT-2: Lower damsite as a Mean annual runoff development.
- ALT-3: Upper damsite as a 10 year minimum annual runoff development.

Project Features which were identified are as below.

Box 3-3: Alternatives on Luiche River (Norconsult)

ALT	DAM	HEIGHT (m)	LENGTH (m)	STORAGE (MCM)	OTHER COMMENTS
1	CONCRETE GRAVITY	30	110	73	20% of Nkumgwe flooded
2	EARTH/ ROCKFILL	75	360	590	Nkumgwe completely flooded
3	CONCRETE GRAVITY	40	330	62	No flooding of Nkumgwe

All alternatives are based on a new access road of about 6km from Nkumgwe to the dam site and improvement of a 14km stretch of road from Kigoma - Kasulu road to Nkumgwe village. Also included in cost estimates is a 33kV line to Kigoma (25km) and Kasulu and Uvinza (130km).

Preliminary cost estimates were developed as below.

Box 3-4: Preliminary Costs of various Alternatives on Luiche (Norconsult)

ALT	INSTALLED CAPACITY (MW)	FIRM POWER (MW)	FIRM ENERGY (GWh)	PLANT COST (MUSD)	PROJECT COST (MUSD)	PROJECT COST/FIRM ENERGY (USD/kWh)	PROJECT COST/INSTALLED CAPACITY (USD/kW)
1	4.0	1.9	16.4	20.4	25.0	1.52	6250
2	15.3	7.8	68.6	64.0	68.7	1.00	4490
3	5.5	3.2	28 4	68.9	73.6	2.59	13381

Alternative 2 was hence selected for further studies.

After the above preliminary investigations and on comparing the two most economical alternatives available in both basins, it was decided to take up Feasibility study of the alternative 1B on Malagarasi river as it better satisfies the primary objective of power generation. Among the reasons given in favour of Malagarasi were

- Lower energy production cost as compared to Luiche
- Larger installed capacity is possible and hence load demand will be met for a longer period
- Luiche River development was recommended to be multi purpose so as to have benefits of Irrigation, flood control, fisheries and power inline with the 1966 report by Sir William Halcrow and partners titled The Economic Feasibility of Flood control, Irrigation and Hydroelectric Works in the Luiche River Basin.

Alternative 1B on Malagarasi was hence taken up for detailed feasibility study.

Section 2 Project Features

Norconsult proceeded with development of feasibility report for alternative 1B. An outline of the project as proposed by Norconsult is given in figures 3-1 to 3-5. The key project features of the proposed project as per the feasibility study were

1. An access from Lugufu village which is 24km from the project site. Lugufu is situated on the railway from Kigoma to Uvinza and is accessible by parallel service road. As the project is situated on the south side of the river, a 162m

long Bailey bridge across the Malagarasi is included as part of the access works. These are shown in figure 3-2.

2. A low concrete diversion weir across the Malagarasi about 400m downstream of where it flows out of the narrow gorge is proposed. The weir is ungated. The maximum height is 2.5m and the length is 130m. Crest elevation was fixed at 862.2m.

3. The intake structure is located about 200m upstream of the diversion weir on the left bank. It is a concrete structure about 21.5m wide with concrete sill at 861.2m. Trash rack is provided. Control is by means of wooden stoplogs which are manually placed.

4. The water conveyance system comprises a 7m wide, 590m long headrace canal with a slope of 1:250 which leads to the entrance of the headrace tunnel. During floods, the headrace canal will be submerged and hence has to be designed so that it is not damaged. Details are shown in figure 3-3.

5. From the headrace canal, water enters the headrace tunnel through the inlet structure which is a rectangular inlet with sill at 856.3m. Trash rack 7m wide by 6m high is provided along with a 3m by 3m manually operated intake gate. Settling basin is not provided as costs are very high. Details shown in figure 3-3.

6. The headrace tunnel is 3.2km in length and about 20 sqm area. It includes a 85m long sandtrap with cross sectional area of 50 sqm and a 120m long penstock tunnel with cross sectional area of 27.3 sqm. A surge shaft 72m long and 15sqm area and surge chamber 17.5m long with 80 sqm area is also provided. Access to the headrace tunnel is by means of a 120m long tunnel with 25sqm area. A single penstock of 205m length and 3m diameter will lead to the turbines located in the power house. Branching is provided at the power house. Cross sectional area of the tunnel is provided so as to allow installation of the third unit. The tunnel alignment is in sandstone and shale. Grouting and support wherever required will be provided. Details are shown in figure 3-4.

7. The power house is located at the foot of the hill close to the main river course. It measures 27.5m by 12.5m and is 19m high. Main floor is at 806m. It is to

house two vertical turbine generator units with auxiliaries with a provision for a third unit at a later date. Details are shown in figure 3-5.

8. Two vertical shaft Francis turbines each of 3.8MW capacity will be installed in the power house. The maximum discharge will be 8 m3/s at a design net head of 55m after accounting for losses. The design rotating speed is 375rpm. Butterfly valves will be installed at the inlet of each turbine with diameter of 1400mm.

9. The generators will be of synchronous type rated at 4.5MVA each and synchronous speed 375 rpm. The step up transformer and switchyard will be located outside. The units will be provided with all the controls and protection required by practice.

10. The tailwaters will discharge into a small stream joining Malagarasi which will be joined by a tailrace canal 6m wide and 350m in length. Tailwater level is 800.5m. Details are shown in figures 3-3 and 3-5.

11. The power generated will be transmitted through an isolated grid system which will cover Kigoma, Ujiji, Kasulu, Simbo and Uvinza apart from supplying small villages along the transmission route. The total distance comes to about 200km of 33kV lines with the individual distances being 95km to Kigoma and Ujiji, 26km to Uvinza and 65km to Kasulu. The line conductors are to be ACSR 402, 80 and 40 respectively. Details are shown in figure 3-2.

12. The project cost in 1982 terms is 29.84 M USD which brings the cost of installed capacity to $3925 per kW inclusive of transmission works but excluding IDC, duties and taxes. An extract showing quantities, rates and costs from the detailed estimate is given in table 3-1.

13. The total annual energy was estimated to be 67.2GWh. The cost of generation was worked out to be 10.7 US cents per kWh.

14. The economic evaluation of the project was performed as avoided cost of diesel generation. The Benefit cost ratio was 1.54 and the EIRR was 16.6%.

15. Implementation period of the project was estimated to be four and half years comprising one year for geo-technical investigations, tender documents, six

months for mobilization, one year for access works and two years for construction.

Section 3 Cost Estimates

Detailed Cost estimates were presented in the feasibility study which have been presented in table 3-1. The cost categories have then been summarized in box 3-5 below.

Box 3-5: Summary of Implementation Cost (Norconsult)

Work Item	Local MUS$	Foreign MUS$	Total MUS$
General & Preparatory Works			
Construction Plant	0.130	1.170	1.300
Camps	0.040	0.360	0.400
Transportation	0.660	1.140	1.800
Miscellaneous	0.195	1.105	1.300
Civil Works			
Access	0.348	2.285	2.632
Dam	0.032	0.218	0.250
Intake and Headrace Canal	0.107	0.895	1.002
Headrace Tunnel	0.514	4.176	4.690
Penstock	0.043	0.345	0.388
Power House	0.063	0.573	0.636
Tailrace Canal	0.049	0.356	0.405
Electro-mechanical Equipment	0.357	3.045	3.402
Transmission	1.583	3.824	5.407
Administration and Engg	0.640	2.580	3.220
Duties and Sales Taxes	2.600	-	2.600
Contingencies	0.727	2.535	3.261
Grand Total	8.088	24.605	32.693

The disbursement pattern for the funds was as follows

Box 3-6: Funds Disbursement schedule in MUSD (Norconsult)

Year	1983	1984	1985	1986	1987
Local	-	0.47	1.25	1.75	1.76
Foreign	0.10	2.80	5.68	8.03	8.00
Total	0.10	3.27	6.93	9.78	9.76

The study also calculated probable escalation of costs as per following price indices.

Box 3-7: Cost Escalation Indices (Norconsult)

Year	1983	1984	1985	1986	1987
Local	1.140	1.288	1.443	1.616	1.826
Foreign	1.080	1.161	1.242	1.317	1.396

As per the above indices, the following modified funds disbursement schedule was presented.

Box 3-8: Funds Disbursement with Escalation (Norconsult)

Year	1983	1984	1985	1986	1987
Local	-	0.61	1.80	2.83	3.21
Foreign	0.11	3.25	7.05	10.58	11.17
Total	0.11	3.86	8.85	13.41	14.38

The total cost with escalation was estimated to be USD 40.61M without considering duties and taxes.

As the project is to be implemented in an area with no existing grid supply and low use of electricity, the energy demand was predicted to grow as shown in Box 3-9. Thus all the capacity of the plant would not be used till about 2008 with the result that revenue from sales would be restricted till the demand grows and full benefit from revenues will be realized in 2005 that is 17 years after the project starts generating.

Box 3-9: Growth in Demand for Electricity (Norconsult)

YEAR	1988	1990	1995	2000	2005	2010	2015
MW	6.0	6.8	9.2	12.6	17.3	23.9	33.3
GWh	23.7	26.7	36.1	49.7	68.2	94.1	131.1

The study calculated the economic benefit of the project by valuing the energy generated at 16.4 US cents per kWh. This value is shown to be the energy from the next least cost option instead of hydropower and is produced by a diesel set with fixed energy cost of 7.2 US cents and fuel cost of 9.2 US cents.

The following were worked out at a discount rate of 12%. The FIRR was worked out with a tariff of 1 Tsh per kWh which at that time is equal to 10.52 US cents/kWh.

Box 3-10: Economic and Financial Evaluation (Norconsult)

	BC	NPV	EIRR	FIRR
Base Case	1.54	10.2	16.6	8.5
Base Cost + 20%	1.28	6.4	14.5	7.0
Base Cost - 20%	1.92	14.1	19.4	10.4
Low Demand Forecast	1.32	6.1	15.0	7.1
High Demand Forecast	1.92	17.7	19.3	10.4

The financial analysis of the project studied three options for source of funds for implementation which ranged from grants to full project loan. The various assumptions are given below along with the main results.

Box 3-11: Financing Options examined by Norconsult

	Grant	Loan	Grace Period (years)	Repayment Period (years)	Interest (%p.a)	IDC MUSD	Cash Flow
Option-1	10%	90%	5	20	10%	6.6	Deficit till 1993
Option-2	70%	30%	5	20	10%	0.9	Surplus in first year
Option-3	0%	100%	4	15	12%	17.6	Deficit till 1997

Section 4 SECSD Observations

With the above details extracted from the Norconsult report, the following observations can be made on the proposal.

1. The total waterway is about 4000m long.

2. Out of a gross head of 62m, 7m is lost in hydraulic losses i.e 11.3% of the head. This will be about 16% if the third unit is considered at a later stage.

3. The total civil works cost of the project is US$ 14.4 M. Out of this US$ 7.121 is spent on the waterway i.e 50% of civil works and 24% of the total project cost.

4. In the chapter on geology the following observation has been made at page 2-2 of Volume 2 "The sandstone and limestone at the Malagarasi river is of a moderately weak to moderately strong rock quality. It is assumed that fairly good quality sandstone and limestone can be quarried and used as aggregates for concrete constructions". Thus source for concrete aggregates has to be investigated as concrete volume required is extensive.

5. In page 2-13 of volume 2 "At the detailed design stage, ground investigations such as core drilling with core recovery, test borings, sampling and seismic refraction tests are recommended to determine the optimum elevation and design of tunnel, tunnel openings and foundations"

6. Hence as per the above observation, there is an uncertainity in the geological conditions of the tunnel which cannot be verified till the geological investigation is completed. Hence project feasibility will be determined only after the investigation. This was also the view of ACRES which dropped the idea of tail tunnel for its proposal in the area (discussed in following chapter).

7. The cost of installed capacity is calculated without adding duties, taxes and is $3925 which is very high. If these are added then cost will be $4302 per kW.

8. The cost of installed capacity is calculated without adding Interest During construction which is 6.6 million. With this and duties, cost of installed capacity is US$ 5170 per kW.

9. The study does not give simulation of the operation of the power station with parameters such as monthly power, energy, turbine discharge, water levels, losses for different hydrological conditions

10. The energy cost of 10.75 cents is assuming sale of entire 65GWh. If duties and IDC are added then energy cost is 14.15 cents. The FIRR is low.

11. Because of the waterway, the installed capacity is limited to 11.4MW. Thus if rapid development in the region takes place, then the project will not be able to serve the demand for a long period as it will be difficult to allow more discharge in the tunnel due to increased hydraulic losses.

12. Features such as tunnel, surge shaft etc require a large construction plant with many expatriates for construction and supervision with the result that US$ 4.8M is allocated for plant, camps, travel, general costs and other expenses.

13. As the civil works are extensive, especially with considerable excavation and concrete, if the projected cost escalation takes place, then the cost of installed capacity can become prohibitive.

An attempt has been made to update the economics on the lines adapted in Chapter 14. For this the economic value of energy has been revised to US cents 19 per kWh. The base year demand is 25 GWh, growing at 2.5% p.a. Inflation of 5% p.a is also included to cover for fuel cost escalation. Discount rate is 12%. Contingencies and IDC are included but duties are excluded. Results are shown in Box 3-12.

Box 3-12: Updated Economics with Demand of 25 GWh (SECSD)

	Project Cost M USD	Cost /kW USD	B/C	Energy Cost USc/kWh
Cost with Contingencies, and IDC (option-1)	31.761	4179	2.26	10.18
Cost with Contingencies and IDC (option-2)	36.501	4802	1.22	31.90
Cost with Contingencies and IDC (option-3)	36 501	4802	1.24	25.68

The financial analysis is carried out assuming the project is implemented with financing with the following options.

Option-1: Loan Interest = 3%, Payback period = 30 years
Option-2: Loan Interest = 10%, Payback period = 7 years
Option-3: Loan Interest = 10%, Payback period = 10 years

The financial analysis is carried out with 25 GWh of energy sold with a growth rate of 2.5% p.a, and the financial analysis is carried out with the average system wide rate charged by TANESCO which is about 50TSh/kWh, (7.0 cents/kWh) and escalation of 5% p.a is included in the calculations. The financial benefit cost ratio which would accrue to the project developer and the first year energy production cost are given in Box 3-13.

Box 3-13: Updated Financial Evaluation with finance options (SECSD)

	Finance Option	Project Cost M USD	IDC	Total Cost	Cost /kW USD	Energy Cost USc/kWh	Financial B/C Ratio
Cost with Contingencies	1	29.835	1.926	31.761	4179	10.18	1.280
Cost with Contingencies	2	29.835	6.666	36.501	4802	31.90	0.709
Cost with Contingencies	3	29.835	6.666	36.501	4802	25.68	0.721
Cost with Contingencies and Duties	1	32.695	2.111	34.806	4579	11.15	1.170
Cost with Contingencies and Duties	2	32.695	7.305	40.000	5263	34.96	0.647
Cost with Contingencies and Duties	3	32.695	7.305	40.000	5263	28.14	0.658

On the basis of the above results, one can conclude that only if the project is financed under soft term loan will the projects life cycle benefit cost be greater than one. For project type funds the benefit cost is less than one and the energy produced is very expensive due to the debt service. Large deficits in cash flow also arise upto the extent of USD 4 million per year.

The above hence clearly rules out the participation of IPPs and even funding from World Bank.

The afore mentioned project configuration was not implemented. The primary reason was probably inability to secure the requisite funds from a suitable donor country. The economic and financial analysis also appear to be far from satisfactory. The project is also not suitable for implementation by TANESCO as it imposes a heavy financial burden due to restricted demand in the initial years.

In order to make the project suitable for IPPs and to reduce the financial burden if TANESCO wants to implement the project, the design should be such that the following criteria are satisfied.

1. Even with the demand less than the potential of the project that is rising from a base market demand of 25GWh, with low growth of 2.5% p.a, the cost of production should be less than 10 cents per kWh so that the implementing agency and financing agency are willing to take up the project as large deficits do not arise.

2. The financial benefit cost ratio based on the project benefits as determined from the market value for energy should be high so that the implementing agency makes a profit from the project development.

3. In case the demand rises rapidly, the project should be able to meet the demand for a reasonable period. So the design should be such that extra capacity can be added at suitable intervals.

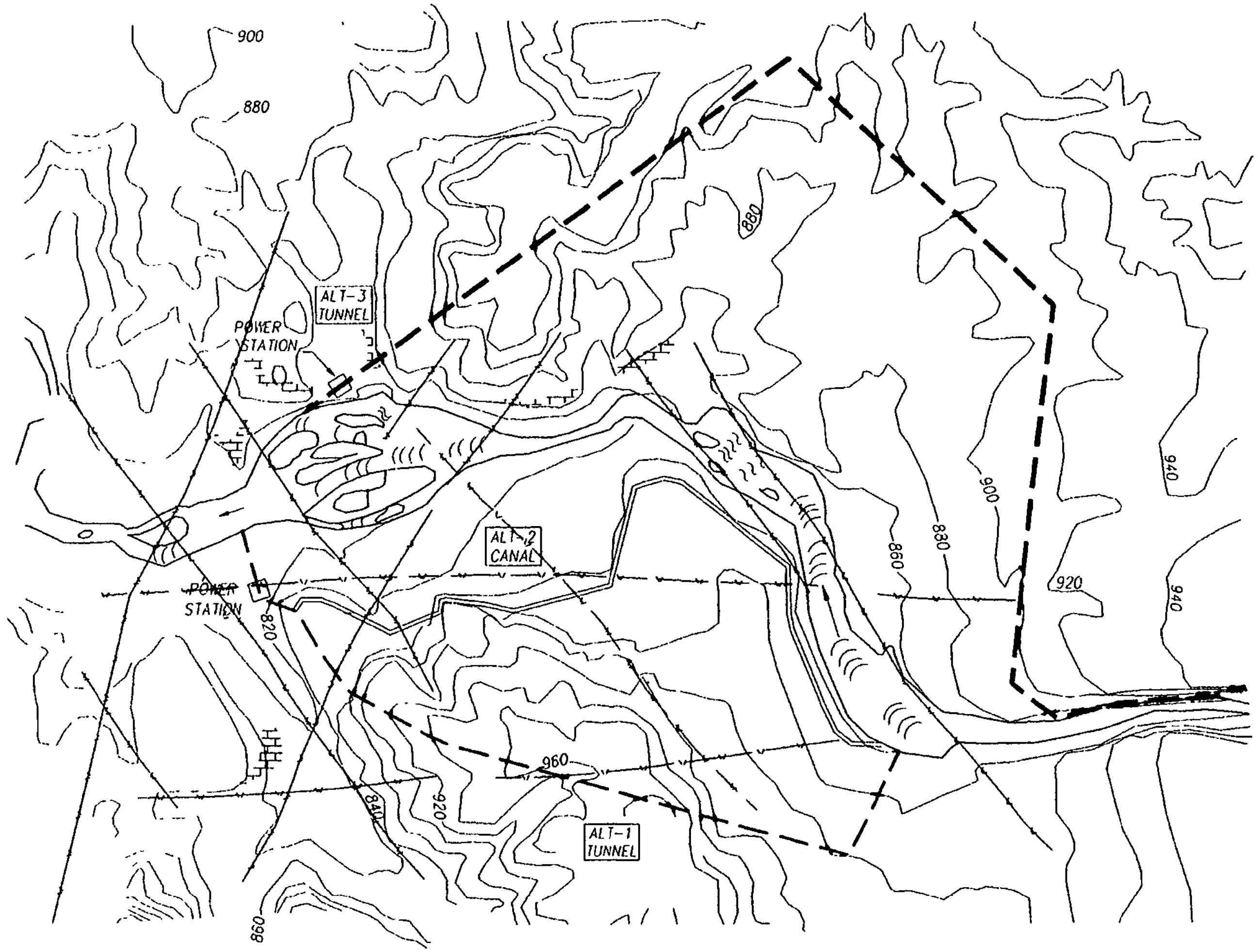
4. Implementation period should be reduced so that the IDC and cost escalation do not increase the cost of the project.

5. Locally available materials should be used so that cost can be cut down. Use of concrete should be reduced as sources of aggregate may be difficult to find and transportation is difficult.

6. Simulation of the operation of the power station for low, high and mean runoff years with all relevant features such as monthly power, energy, water levels, hydraulic losses etc should be given.

7. As the region is sparsely populated, with widespread towns, transmission costs are significant with attendant losses. The project design should be such that the costs of transmission lines and losses are offset by reduction in the civil works.

In updating the above feasibility study, so that the above criteria are satisfied, SECSD have revised the layout as per the guidelines and findings enumerated earlier with the objective of reducing the implementation cost and considerably improving the economics. This revised layout is discussed briefly in the chapter 5 and elaborated further in the remainder of this report.



LAYOUT ALTERNATIVES

NOTES

This drawing shows the alternatives for layout of the Malagarasi hydropower project
Alternative I is a tunnel (left bank) with surface penstock and power house
Alternative II (canal) along the Malagarasi river on the left bank
Alternative III is a tunnel on the right bank

FEATURES OF ALTERNATIVES BY NORCONSULT 1983

PARTICULARS		ALTERNATIVES		
		I	II	III
Head Race Tunnel	(m)	3500	–	6500
Head Race canal	(m)	–	4400	–
Penstock	(m)	140	140	1150
Power House		surface	surface	surface
Tail canal	(m)	350	350	350
Installed Capacity	(MW)	6 4/14 2	6 4/14 2	6 2/14 1
Annual Energy	(GWh)	38 3/83 1	38 6/83 8	37 6/82 3
Access from Lugufu	(km)	24	24	24
Transmission Route	(km)	200	200	200
Total Project Costs (1983)	(MUSD)	33 5/44	35/47 8	40 8/54 1
Energy Cost	(US$/kWh)	0 87/0 53	0 91/0 57	1 09/0 66

LEGEND:

MAJOR FRACTURE ZONES
MINOR FRACTURE ZONES
LIMESTONE
FALLS
RAPIDS

REFERENCE

FEASIBILITY STUDY REPORT – MALAGARASI HYDROPOWER PROJECT KIGOMA REGION BY NORCONSULT 1983

0 1 2

SCALE (km)

MALAGARASI HYDROPOWER DEVELOPMENT

PROJECT LAYOUT - ALTERNATIVE WATER (NORCONSULT'S) CONDUCTOR SYSTEM

FOR: IBRD/TANESCO

DWG NO FIG 3-1

PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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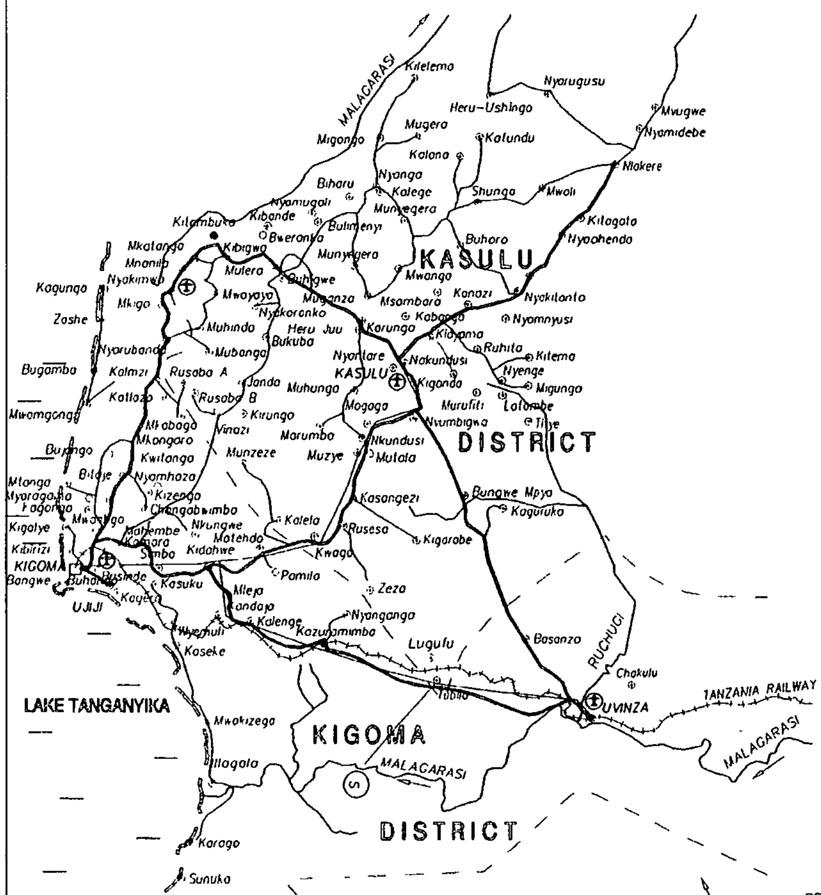
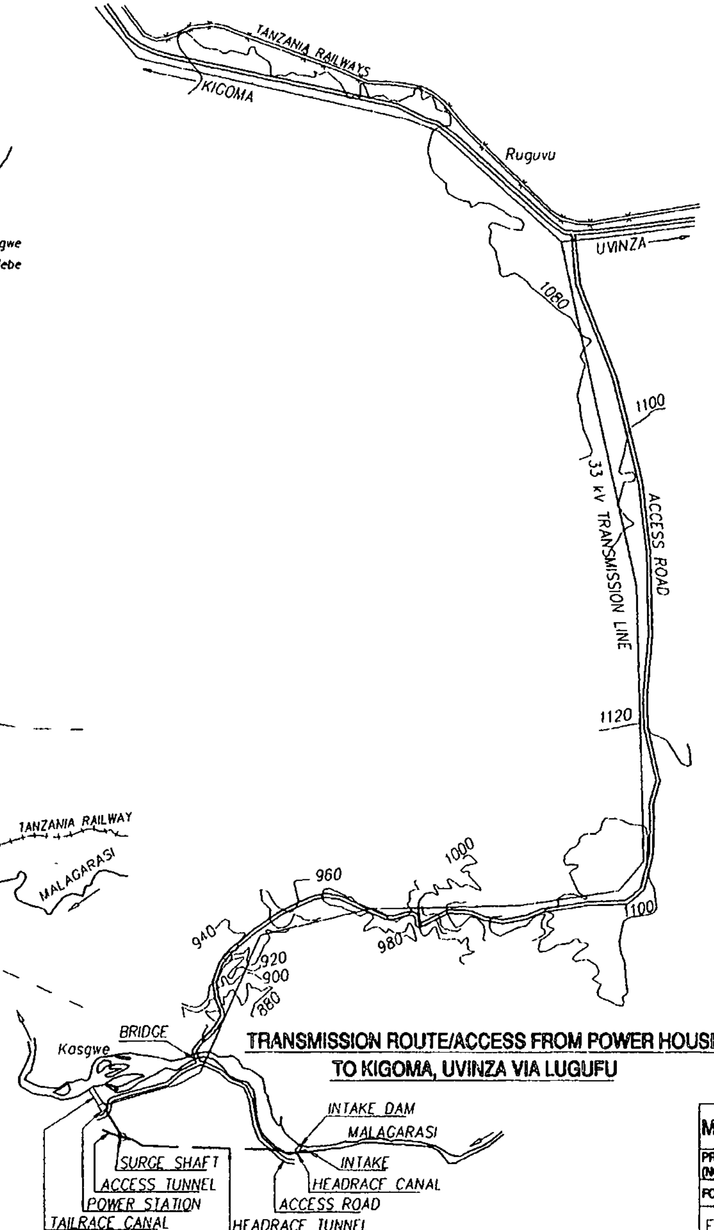


TRANSMISSION ROUTE TO TOWNS KIGOMA, UVINZA AND KASULU



TRANSMISSION ROUTE/ACCESS FROM POWER HOUSE TO KIGOMA, UVINZA VIA LUGUFU

NOTES

This drawing shows the transmission route to supply Kigoma, Uvinza, Kasulu etc with power from the Malagarasi project

LEGEND:

——	TRANSMISSION LINE
Ⓢ	POWER STATION
━━	MAIN ROADS
——	MINOR ROADS
┼┼┼	RAILWAY LINE
— —	DISTRICT BOUNDARY
⊕	AIRPORT/AIRSTRIP
⊙ Migunga	VILLAGE WITH NAME

REFERENCE

FEASIBILITY STUDY REPORT
MALAGARASI HYDROPOWER PROJECT
KIGOMA REGION BY NOROCONSULT 1983

MALAGARASI HYDROPOWER DEVELOPMENT

PROJECT LAYOUT - TRANSMISSION ROUTE (NORCONSULTS 1982)

FOR IBRD/TANESCO

FIG 3-2 | PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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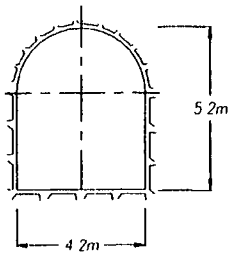
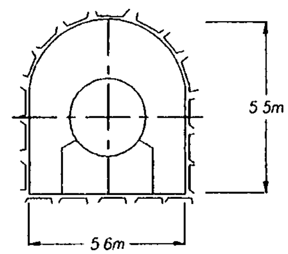
NOTES

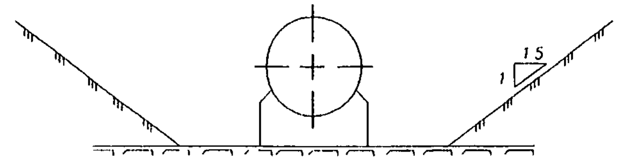
This drawing shows the details of Tunnel, canal and penstock as for Alternative 1 of Norconsult's design



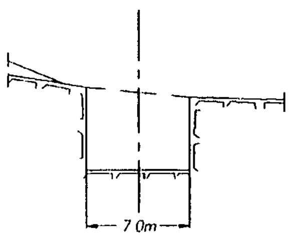
HEADRACE TUNNEL



PENSTOCK TUNNEL



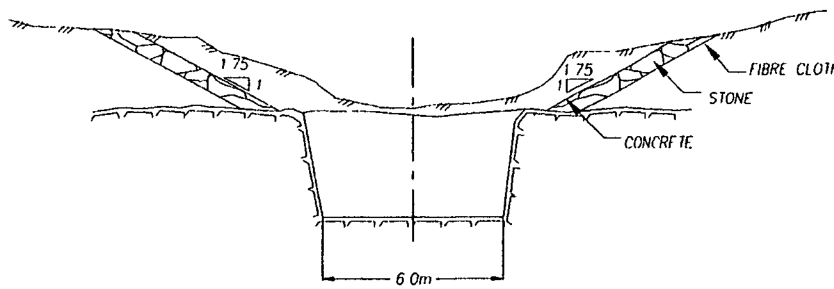
PENSTOCK EXCAVATION



SECTION B-B

FIG 5

HEADRACE CANAL



TAILRACE CANAL

REFERENCE

FEASIBILITY STUDY REPORT
MALAGARASI HYDROPOWER PROJECT
KIGOMA REGION BY NOROCONSULT 1983

MALAGARASI HYDROPOWER DEVELOPMENT	
PROJECT LAYOUT - TUNNEL, CANAL AND (NORCONSULT'S) PENSTOCK DETAILS	
FOR IBRD/TANESCO	
DWG NO FIG 3-3	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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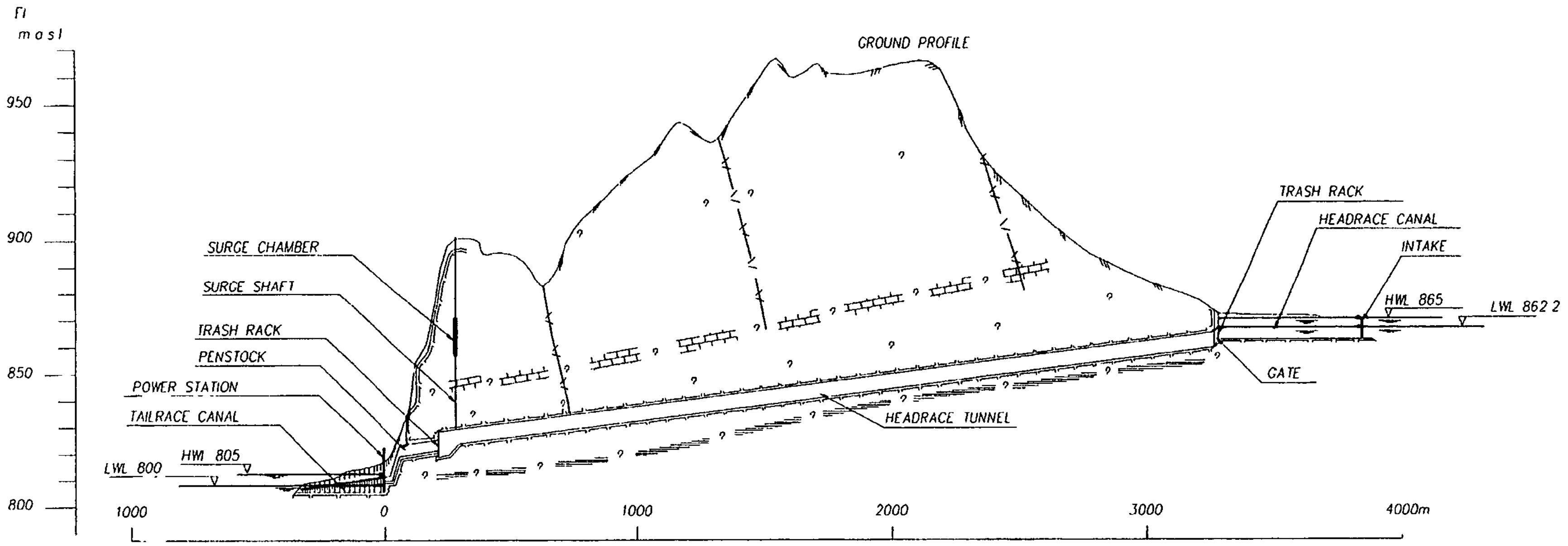

LONGITUDINAL SECTION OF PRESSURE TUNNEL

LEGEND:

MAJOR FRACTURE ZONES
MINOR FRACTURE ZONES
SANDSTONE
SHALE
LIMESTONE
ANTICIPATED LOCATION ROCK BED

MALAGARASI HYDROPOWER DEVELOPMENT

PROJECT LAYOUT - L SECTION OF PRESSURE TUNNEL (NORCONSULTS)

FOR. IBRD/TANESCO

FIG 3-4 PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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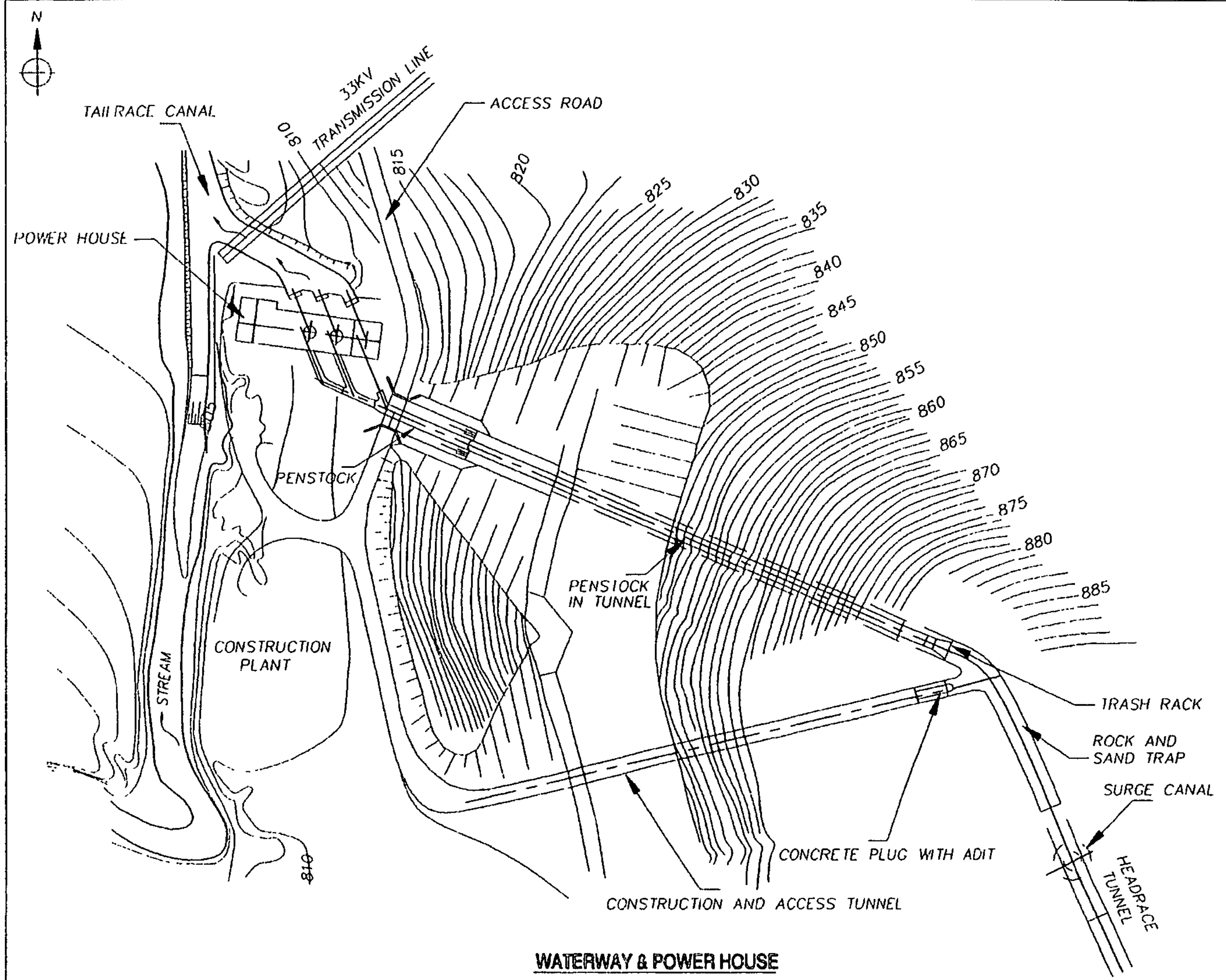

WATERWAY & POWER HOUSE

NOTES:

This drawing shows the Headrace tunnel, penstock and power house layout for Alternative 1 of Norconsult

MALAGARASI HYDROPOWER DEVELOPMENT	
PROJECT LAYOUT (NORCONSULT)	**ACCESS, TUNNELS AND POWER HOUSE**
FOR: IBRD/TANESCO	
DWG NO: FIG 3-5	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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TABLE 3-1
QUANTITIES AND DETAILED COST ESTIMATE BY NORCONSULT

1	CIVIL WORKS	Unit	Unit Price USD	Quantity	Cost USD	Total Item Cost USD	Total Cost USD
a	**General & Preparatory Works**						
i	Construction Plant	lumpsum	1,300,000	1	1,300,000		
ii	Camp & Administration Centre	lumpsum	400,000	1	400,000		
iii	Transportation	lumpsum	1,800,000	1	1,800,000		
iv	Running & General Costs	lumpsum	1,300,000	1	1,300,000	4,800,000	
b	**Access Roads**						
i	Improving Kidahwe to Lugufu and Uvinza	lumpsum	100,000	1	100,000		
ii	Lugufu to Project site	km	30,000	27	810,000		
iii	Bridge Across Malagarasi River	lumpsum	1,250,000	1	1,250,000		
iv	Maintenance of Roads for 3 years	km	4,500	105	472,500	2,632,500	
c	**Intake Dam**						
i	Cofferdam, Care of Water	lumpsum	30,000	1	30,000		
ii	Excavation & Surface Preparation	lumpsum	20,000	1	20,000		
iii	Concrete	m3	300	500	150,000		
iv	Grouting	lumpsum	30,000	1	30,000		
v	Miscellaneous	lumpsum	20,000	1	20,000	250,000	
d	**Headrace Canal**						
i	Cofferdam, Care of Water	lumpsum	40000	1	40,000		
ii	Rock Excavation	m3	28	24000	672,000		
iii	Rock Support	lumpsum	100,000	1	100,000		
iv	Grouting	lumpsum	20,000	1	20,000		
v	Concrete for Intake structure	m3	400	300	120,000		
vi	Miscellaneous	lumpsum	50,000	1	50,000	1,002,000	
e	**Headrace Tunnel**						
i	Cofferdam, Care of Water	lumpsum	20,000	1	20,000		
ii	Earth Excavation in forebay	m3	5	55000	275,000		
iii	Rock Excavation in forebay	m3	25	8500	212,500		
iv	Rock Excavation for intake & Sandtrap	m3	35	2500	87,500		
v	Excavation for Adit/transportation Tunnel	m	940	120	112,800		
vi	Excavation for Headrace Tunnel	m	850	2995	2,545,750		
vii	Excavation for Penstock Tunnel	m	980	120	117,600		
viii	Excavation for Surge Shaft	m	1,700	73	124,100		
ix	Excavation for Surge Chamber	m3	50	1300	65,000		
x	Rock Support	lumpsum	600,000	1	600,000		
xi	Concrete works in Intake	m3	400	100	40,000		
xii	Concrete works for penstock,shafts,adit	m3	400	700	280,000		
xiii	Grouting	lumpsum	110,000	1	110,000		
xiv	Miscellaneous	lumpsum	100,000	1 00	100,000	4,690,250	
f	**Power House**						
i	Earth Excavation	m3	5	2500	12,500		
ii	Rock Excavation	m3	28	3000	84,000		
iii	Concrete	m3	400	1000	400,000		
iv	Structural Steel	t	2,000	20	40,000		
v	Miscellaneous	lumpsum	100,000	1	100,000	636,500	
g	**Tailrace Canal**						
i	Earth Excavation	m3	5	6000	30,000		
ii	Rock Excavation	m3	28	8500	238,000		
iii	Rock Support	lumpsum	30,000	1	30,000		
iv	Grouting	lumpsum	5,000	1	5,000		
v	Protection against Erosion	m3	15	3500	52,500		
vi	Concrete works	m3	400	50	20,000		
vii	Miscellaneous	lumpsum	30,000	1	30,000	405,500	
	TOTAL CIVIL WORKS COST						14,416,750

TABLE. 3-1Contd
QUANTITIES AND DETAILED COST ESTIMATE BY NORCONSULT

2	MECHANICAL WORKS	Unit	Unit Price USD	Quantity	Cost USD	Total Item Cost USD	Total Cost USD
a	Turbine	lumpsum	1,142,000	1	1,142,000		
b	Valves	lumpsum	93,000	1	93,000		
c	Cooling System	lumpsum	33,000	1	33,000		
d	Overhead Travelling Crane	lumpsum	30,000	1	30,000		
e	Penstock	lumpsum	388,000	1	388,000		
f	Gates and Trash Racks	lumpsum	120,000	1	120,000		
g	Spare Parts	lumpsum	30,000	1	30,000	1,836,000	
3	ELECTRICAL WORKS						
a	Generators	lumpsum	994,000	1	994,000		
b	Transformers	lumpsum	90,000	1	90,000		
c	Switchgear, Control equipment & auxiliaries	lumpsum	690,000	1	690,000		
d	Spare Parts	lumpsum	150,000	1	150,000		
	Tools	lumpsum	30,000	1	30,000	1,954,000	
	TOTAL ELECTROMECHANICAL COST						3,790,000
4	TRANSMISSION						
a	Uvinza Branch ACSR 40, 25km	lumpsum	224,000	1	224,000		
b	Kasulu Branch ACSR 80, 65km	lumpsum	851,000	1	851,000		
c	Main line ACSR, 402, 95km	lumpsum	2,945,000	1	2,945,000		
d	Uvinza Substation	lumpsum	128,000	1	128,000		
e	Kasulu Substation	lumpsum	128,000	1	128,000		
f	Kigoma Substation	lumpsum	373,000	1	373,000		
g	Vehicles	lumpsum	400,000	1	400,000		
h	Tools	lumpsum	137,000	1	137,000		
I	Spare Parts	lumpsum	80,000	1	80,000		
j	Freight	lumpsum	141,000	1	141,000	5,407,000	
	TOTAL TRANSMISSION COST						5,407,000
5	IMPORT DUTIES & SALES TAXES						
a	Bailey Bridge		96,000	1	96,000		
b	Construction Equipment		670,000	1	670,000		
c	Gates, Trash Racks, Penstock		185,000	1	185,000		
d	Turbines, Valves, Cooling system, Crane		577,000	1	577,000		
e	Generators, Transformers, Switchgear		280,000	1	280,000		
f	Transmission Line Materials		406,000	1	406,000		
g	Substation Materials		78,000	1	78,000		
h	Construction Equipment		308,000	1	308,000	2,600,000	
	TOTAL DUTIES AND TAXES						2,600,000
6	OTHER COSTS						
a	Geological Field Investigations	lumpsum	150,000	1	150,000		
b	Engineering and Supervision of Project	lumpsum	2,470,000	1	2,470,000		
c	Line Survey of Transmission Lines	lumpsum	120,000	1	120,000		
d	Engineering and Supervision of Transmission	lumpsum	480,000	1	480,000	3,220,000	
	TOTAL OTHER COSTS						3,220,000
7	CONTIGENCIES						
a	Civil Works	percent	15		2,162,513		
b	Electromechanical Works	percent	10		379,000		
c	Transmission	percent	13		460,000		
d	Duties and Taxes	percent	10		260,000	3,261,513	
	TOTAL CONTINGENCIES						3,261,513
8	TOTAL IMPLEMENTATION COST						32,695,263

Chapter 4 Review of Previous Proposals (ACRES)

Section 1 Alternatives

In 1984 subsequent to the Norconsult study, another study was undertaken by ACRES International on hydropower development of Three western Rivers in Tanzania which were Rumakali, Ruhuhu and the Malagarasi rivers. The main objective of the study was to explore all possible sites in the afore mentioned basins for addition of generating capacity to the TANESCO interconnected system so as to satisfy the low forecast study in the 1981 Acres Power Sector Study Report. The interconnected grid at that time covered Dar, Moshi, Arusha, Tanga, Iringa, Mufundi and Mbeya with extension to Dodoma, Singida, Shinyanga, Tabora, Mwanza and Musoma in engineering phase. This is shown in figure 1-2.

As per the above report, it was decided that the optimal size of station required is around 90MW and with about 500GWh energy output to satisfy load demand in the grid for a period of 4 to 6 years.

The study then concluded that out of the three river basins, Malagarasi was the least attractive and hence Rumakali and Masigira be candidate developments in system expansion. A list of projects identified on the Malagarasi is given below.

Box 4-1: Potential Sites in Malagarasi Basin (ACRES)

PROJECT	HEAD (m)	FLOW (m3/s)	I.C (MW)	LIVE STORAGE (MCUM)	DAM HEIGHT (m)	DAM LENGTH (m)	FIRM ENERGY (GWh)	MEAN ENERGY (GWh)
MASOFYA	37	124	35	3450	25	350	200	220
UVINZA	40	124	30	nil	40	1000	200	315
IGAMBA 1(a)	160	144	70	500	110	500	400	480
IGAMBA 1(b)	160	144	170	3950	110	500	1000	1450
IGAMBA 2	110	144	120	3950	110	500	690	1000
LOWER MALAGARASI	60	144	60	nil	55	400	375	545

In the above Igamba (1b) and Igamba (2) assume that Masofya project is constructed first to give considerable regulated discharge.

The following are extracts from the report which gives the potential sites in the Malagarasi basin.

Examination of available 1:50,000-scale topographic mapping along the main stem course of the Malagarasi River as it approaches the shore of Lake Tanganyika from the east, reveals four possible sites for Hydropower Development. These are shown both in plan and in elevation in figure 4-1.

Part I Ilagala

The lowest, 'Lower Malagarasi' site is located near Ilagala in a low ridge running more or less parallel to the Lake Tanganyika shore, some 15 km upstream from the lake. A dam at this site would develop a head of about 55 to 60 m, providing a reservoir of limited volume relative to the runoff to the site, that extends to the foot of the Igamba Falls 42km upstream from the lake.

Part II Igamba Falls

About 7 km upstream from the Igamba falls, the river exits from its passage through a deep narrow gorge. At this point, a 110-m high dam could be constructed, backing the river up to the town of Uvinza about 45 km upstream and developing a total head through to the foot of Igamba Falls of 160 m. The reservoir thus created will, because of the narrowness of the gorge store water for flow regulation. In the reconnaissance phase of the study, this was referred to as the 'Upper Malagarasi' site, but it has since been re designated as the 'Igamba Falls' project.

A higher dam at the Igamba Falls site, although topographically possible, could not be realistically contemplated, as a reservoir level higher than elevation 980 m would encroach on the town of Uvinza.

An alternative for the Igamba Falls potential would be divide the development into two parts. A high dam could be constructed as previously indicated along with a power facility designed to utilise the head in the immediate vicinity of the dam. Development of the head through the falls themselves could be accomplished with a separate run-of-river project. While a smaller development at the falls might be appropriate to meeting regional energy demands at an earlier date, it would detract from the yield of the larger project. Thus, for purposes of the reconnaissance phase of the study, it was assumed that the total potential would be developed in a single large scheme. This assumption was reconsidered in the pre feasibility phase, after a geo technical field visit.

Part III Masofya

In view of the limited storages at the Igamba Falls site, location of an upstream damsite with the potential for providing a significant amount of flow regulation was given high priority. Such a site was found at Masofya hill, some 25 km upstream from Uvinza. A dam at his location would back the Malagarasi waters up into the seasonal swamp area and into Lake Sagara on the Ugalla tributary. At first inspection, it would appear possible to develop regulation of the flow to this point. There are, however, limits to the elevation to which a reservoir can be raised in the large, flat swamp area.

First, the central line of Tanzania Railway Corporation traverses the area, crossing the main stem of the Malagarasi River with a 1-km long embankment and bridges structure about 30 km upstream from the Masofya site. Second, the seasonal swamp area, considered to be ecologically sensitive, is one of Tanzania's more noted natural resources. Thus, it was assumed to be prudent for purposes of this study to select a maximum level which would encroach insignificantly on either features of the area.

The minimum rail elevation on the Malagarasi crossing is about 1,059 m, while the minimum toe elevation of the embankment, at the bridge section, is near 1,054m. Though the level of Lake Sagara varies seasonally, occasionally reaching an elevation 1,060 m or more, its 'normal' level appears to be near 1,057 m. This elevation was thus adopted as providing minimum disruption to the natural and man-made features of the area. On this basis, significant (but not full) regulation of river can be achieved.

Part IV Uvinza

The remaining project site identified from the mapping is immediately upstream from the town of Uvinza. Although the river cross section at this point is rather wide, a dam here could develop the remaining 40 m of head between the Igamba Falls reservoir level and the Masofya Hill tailwater level.

While the main, central and eastern areas of the Malagarasi basin are flat and dry and, thus, have no promising prospects for hydroelectric power developments, the northwest area of the basin is in the Kagera range of hills where there are relatively high rainfall. Examination of mapping of the outlets from the hills of the larger tributaries did not reveal any prospects of significant promise. However, the extent of 1:50 000 topographic mapping available did not permit a complete examination of the whole area.

Section 2 Igamba Falls

The study concluded that out of all the available options on Malagarasi river, Igamba falls option 1(a) is the only option which satisfies the interconnected grids power and energy requirement of about 90MW with 500GWh. Thus this project was carried forward to the pre-feasibility stage. In the pre-feasibility stage, after the geo-technical field visits, it was recommended that the head provided by the falls should not be combined with the 110m head created with the dam as the tail tunnel and underground power house were thought to be not feasible and hence eliminated because of serious doubts about the stability of the rock once excavated. Thus the final recommendation for the Igamba falls site was,

Box 4-2: Final Recommendation by ACRES

Type	Head (m)	Q (m3/s)	IC MW	Firm Energy (GWh)	Average Energy (GWh)	FSL (m)	TWL (m)
Grid	110	87.2	2 x40	464	-	980	865
Isolated	110	87.2	2x 40	-	494	980	865

A brief description of project features which were proposed is given below.

1. There will be a main and saddle dam constructed of rockfill with concrete upstream faces. Rockfill required is 4.15 million cubic meters for the main dam and 210,000 cubic meters for the saddle dam.

2. Diversion tunnel capable of passing 910 cumecs with inlet and outlet structures.

3. An intake with 180,000 cubic meters of rock excavation and 110,000 cubic meters of concrete. There will be two 4.5 m diameter penstocks

4. A spillway and plunge poll requiring 4.59 million cubic meters of rock excavation and 110,000 cubic meters of concrete. There will be five radial gates of 13.5 x 13m and an apron of 400m length.

5. A power house with 16m width and 36m length housing two vertical Francis units of 2 x 40 MW. About 5060 cubic meters of concrete is required.

6. A 300km long 220kV transmission line to transmit the power to Tabora.

7. Construction period was estimated to take six and half years.

8. Estimated cost was US$ 404 million without IDC, which results in a cost of $5060 per kW installed.

9. Energy cost at 10% interest rate was estimated to be 8.7 cents per kWh

A summary of the cost estimate is given below.

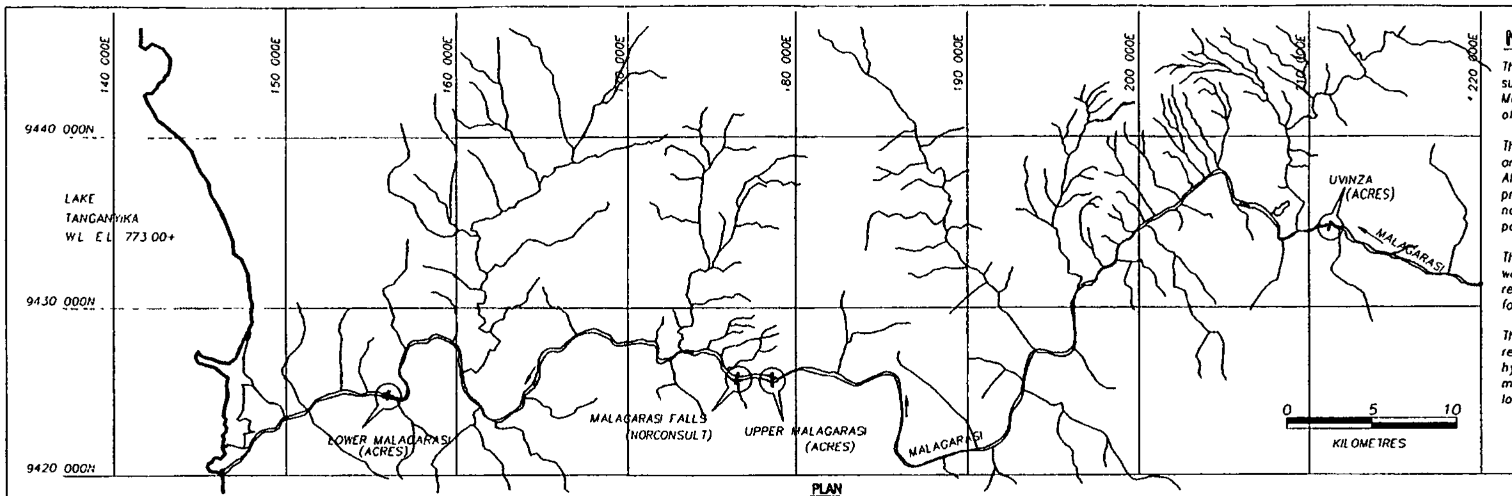
Box 4-3: Cost Estimate by ACRES

SL	DESCRIPTION	LOCAL M US$	FOREIGN MUS $	TOTAL M US$
1	Infrastructure	22.620	33.930	56.550
2	Reservoir Clearing	1.500	-	1.500
3	Diversion Tunnel	5.760	21.610	27.370
4	Main and Saddle Dams	13.530	40.590	54.120
5	Spillway	41.080	85.170	126.250
6	Intake	4.525	10.545	15.070
7	Penstocks	0.940	8.470	9.410
8	Civil works in Power House	1.900	3.540	5.440
9	Electro mechanical equipment	1.120	21.250	22.370
10	Tailrace channel	0.180	0.420	0.600
11	Switchyard	0.030	0.810	0.840
12	Transmission lines	14.490	33.810	48.300
13	Engineering and Management		36.780	36.780
14	Total	107.680	296.930	404.610

The report then recommended that the head available from the falls (about 50 to 60m) should be developed separately as a run of river scheme to serve the regional energy requirements and the towns Kigoma, Uvinza, Kasulu etc. However, no layout or design of such a scheme was suggested in the report.

Section 3 SECSD Observations

As is evident from the above the development was to be of large scale and involved considerable costs. The detailed feasibility was not carried out. As it is important to electrify Kigoma and other rural areas early, this project configuration is not suitable.



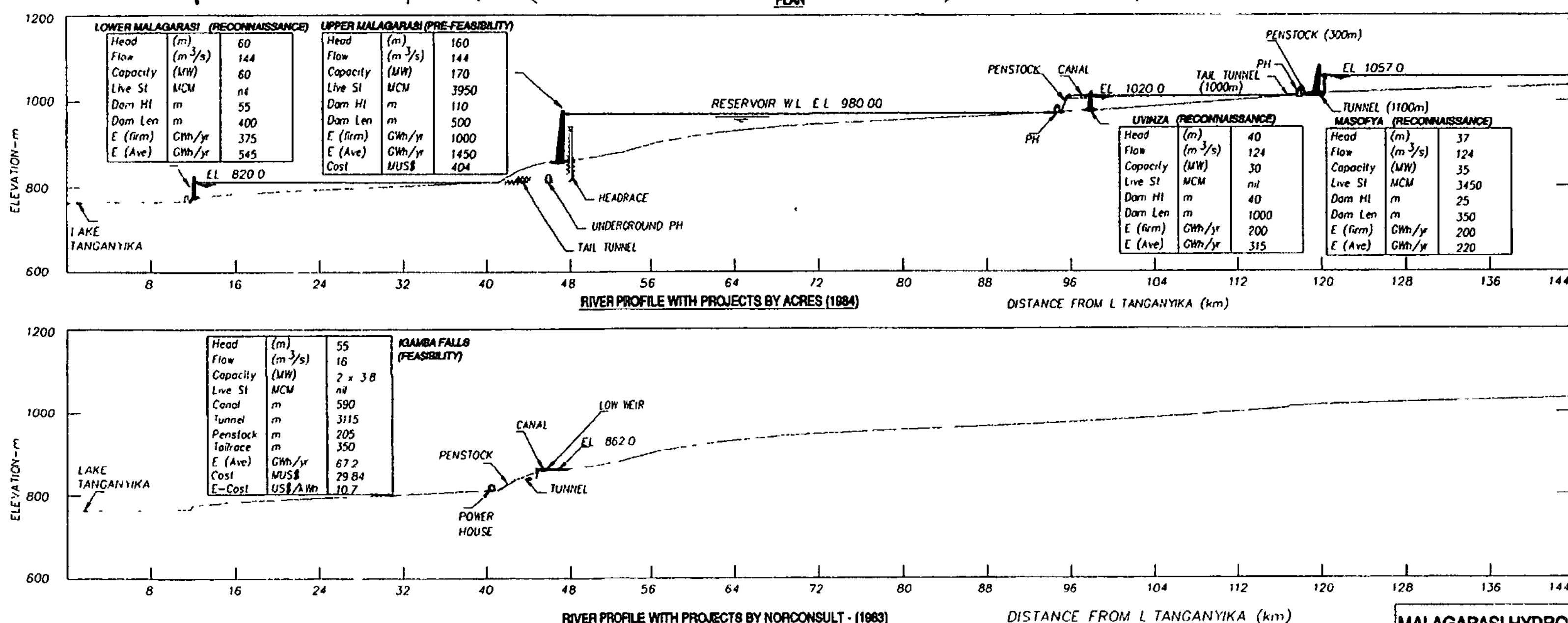
NOTES

This drawing shows the hydropower projects suggested by ACRES and Norconsult for the Malagarasi River and the various stages of study and investigation

The projects by ACRES involve large dams and storages with extensive tunnels etc. Also large installed capacity of the proposed power stations requires link to national grid for transmission of surplus power major load centres

The project by Norconsult involves extensive water conductor (especially tunnel) which require considerable investigation and foreign technology in construction

The planning for these have hence been reviewed by SECSD and simplified to mini hydro projects shown in figure 5-1 with minimum length of waterways and use of local technology



LOWER MALAGARASI (RECONNAISSANCE)

Head	(m)	60
Flow	(m^3/s)	144
Capacity	(MW)	60
Live St	MCM	nil
Dam Ht	m	55
Dam Len	m	400
E (firm)	GWh/yr	375
E (Ave)	GWh/yr	545

UPPER MALAGARASI (PRE-FEASIBILITY)

Head	(m)	160
Flow	(m^3/s)	144
Capacity	(MW)	170
Live St	MCM	3950
Dam Ht	m	110
Dam Len	m	500
E (firm)	GWh/yr	1000
E (Ave)	GWh/yr	1450
Cost	MUS$	404

UVINZA (RECONNAISSANCE)

Head	(m)	40
Flow	(m^3/s)	124
Capacity	(MW)	30
Live St	MCM	nil
Dam Ht	m	40
Dam Len	m	1000
E (firm)	GWh/yr	200
E (Ave)	GWh/yr	315

MASOFYA (RECONNAISSANCE)

Head	(m)	37
Flow	(m^3/s)	124
Capacity	(MW)	35
Live St	MCM	3450
Dam Ht	m	25
Dam Len	m	350
E (firm)	GWh/yr	200
E (Ave)	GWh/yr	220

KIAMBA FALLS (FEASIBILITY)

Head	(m)	55
Flow	(m^3/s)	16
Capacity	(MW)	2 x 3 8
Live St	MCM	nil
Canal	m	590
Tunnel	m	3115
Penstock	m	205
Tailrace	m	350
E (Ave)	GWh/yr	67 2
Cost	MUS$	29 84
E-Cost	US$/kWh	10 7

MALAGARASI HYDROPOWER PROJECTS

PROJECTS BY ACRES/NORCONSULT

FOR. IBRD/TANESCO

DWG NO FIG 4-1 | CAD BY SIVAGURU ENERGY CONSULTANTS

MAL-LS01 DWG

Chapter 5 Revised Layout of the Project (SECSD)

Section 1 General

The feasibility study by Norconsult was exhaustive and led to the assimilation of important and useful topographic, geological and hydrological data which was useful for the present study. The main topographic data is the aerial photography of the project area and ground surveying from which were constructed maps of 1:10000 scale of the stretch of the Malagarasi river from its exit from the gorge till the end of the stretch with falls and rapids.

Section 2 Revised Layout

Part I Planning

The above topographic information was studied in detail by SECSD and relevant topographic data extracted from this map is given in figure 5-2. This drawing is based on drawing No. M13 titled site map Malagarasi of scale 1:10000 with 5m contour interval produced by Norconsult in March 1983 in their report titled Malagarasi Hydropower Project. It shows the stretch of the Malagarasi river from bed level 860m near its exit from the Gorge upto bed level 800m downstream of the Igamba falls and rapids close to the village Kasagwe which is situated on the right bank.

The fracture zones are taken from figure 2.5 titled Final layout and Longitudinal profile with indications of Fracture Zones and Geological Observation developed in August 1983 by Norconsult.

The EDM stations and traverse point locations are taken from a series of sheets in various scales titled Malagarasi - Traverse points from the volume 2 on investigations by Norconsult.

After integrating the above information into a single drawing, the drawing shows the revised planning and proposed projects , taking into account field visit by SECSD.

From the above topographic data is plotted the longitudinal profile of the river from bed level 865m to 800m in figure 5-3.

From the figures it is seen that downstream of the gorge, the river banks are much gentler and the river makes two sets of right and subsequently left turns before proceeding in its original westerly direction. The second of these turns is placid. In the first set of turns, which are about 5km length, the river has rapids and small waterfalls. Notable of these are three stretches where the fall in riverbed is considerable the first being in the vicinity of the left turn where it drops by 20m from 860m to 840m , the second from 835m to 830m and the third in a stretch where the river suddenly widens considerably and is braided. Here the river bed drops by another 15m from 825 to 810m. These drops are interspersed with milder drops in river bed of 5m at four locations (865 to 860), (840 to 835), (830 to 825), (810 to 805). In all the river drops by 65m in a stretch of 5km.

The Norconsult proposal aimed at development of a total gross head of 65m available in all the above drops through a single stage development by construction of a intake dam near bed level 865m and bypassing the rapids upto 800m elevation with a total water conductor of about 4000m.

In the present proposal, the strategy is to harness the potential available in the three drops by having individual power stations. This is found to be more economical than exploitation in a single stage. The planning is as below. The present load demand is about 3MW in Kigoma and about 1MW in the other areas. This is projected to grow to about 8MW by 2010. The minimum flow in the river is about 20 cumecs. This is sufficient to generate about 4MW through a 25m head. As a discharge of 40 cumecs is exceeded 80% of the time a capacity of 8MW will be available 80% of the time. Thus as per the discussion on the river bed profile above, the first stage which can exploit the natural head can be located in the vicinity of the drop from 865m to 840m. The proposal is to have a diversion weir across the river with FSL 865m just upstream of the drop at bed level 857.5m. This has the advantage of requiring a short canal of only 500m length to bypass the drop from 855 to 840m. The diversion weir also gives a large pondage with an area 590,000 sqm.

The planning as above will serve the demand for at least 10 years, later as the demand rises, it will be beneficial to provide some storage to take care of a dry year. Thus it is proposed to create a storage by constructing a dam to utilize the natural storage characteristics provided by the gorge which is just upstream. The FSL is fixed at 890m and this will create a head of 25m. The power station is proposed at the toe of the dam on the left bank. The plant flow is fixed at 40 cumecs. This will provide an additional installed capacity of 8MW.

With the planning as above for the above first and second stages, the last stage which utilizes the drop from 840m to 805m is planned with a diversion weir at the narrowest section of the river just upstream of the proposed bridge site. This will give a small lake with FSL 840m. A canal along the left bank will convey the water to the forebay. From here, penstocks will convey water to the power station located near the river banks. The tailwater level is 805m. The plant flow is 40 cumecs with head of 35m. Installed capacity is 3 x 4MW.

Thus the proposed hydropower development of the Igamba falls stretch of the river involves a cascade consisting of three stages. The projects are indicated in figure 5-1 in plan and profile for comparison with figure 4-1 which shows earlier proposals as well as in figure 5-3 which shows the profile of the stretch of the river as drawn from figure 5-2. The features of each stage are given below.

STAGE-1 PROJECT: This stage involves construction of an arch/gravity type dam located just upstream of the end of gorge from which the river makes an exit before turning right and widening. The FSL is 890m and TWL for the Power house is 865m. Power house is located at the toe of the dam with plant flow of 40 cumecs and an installed capacity of 2 x 4MW. Project will be useful to provide regulated discharge after a few years to augment the baseflow of the Malagarasi and hence generation of downstream stages.

STAGE-2 PROJECT: This stage involves exploiting the head created by a natural 15m drop from 857.5m to 840m in a short stretch of the river of about 500m. A 7.5m high overflow rockfill diversion weir of about 340m length with FSL 865m is to be built at the head of the rapids. This will create a large lake about 590000 sqm area. This is expected to provide about 2 Million cubic meters storage.

The power canal designed for 40 cum/s flow and about 500m length will be located on the left bank. The power house is located on the left bank of the river with an installed capacity of 2 x 4MW. This stage will be constructed first to provide electricity to Kigoma and surrounding areas.

STAGE-3 PROJECT

This stage involves creating a pondage with FSL 840m and utilizes a further 35m natural drop in river due to rapids from 835m to 830m. In a river distance of about 1500m.

The diversion weir will be designed to also serve as a bridge to cross the river. The lake of surface area 97000 sqm will provide a storage of about 0.5MCM. The power canal designed for 40 cumecs is about 1750m in length. Penstock of about 270m length conveys the water from the canal to the Power house which is located below near the left bank of the river. Installed capacity is 3 x 4MW. This stage will be the last to be implemented and will be built when the demand has grown to more than 16MW.

CASCADE FEATURES

The total installed capacity of the cascade is thus 28MW. Initially, even only single units can be developed starting with stage 2. This will be able to meet the immediate load demand of region. Further stages can be built in sequence keeping in step with the growth of the load demand. Even after the demand grows to more than 28MW, it is feasible to increase the size of waterways or build additional parallel ones as they are surface canals and are very short to give increased installed capacity. Construction is simplified due to very short waterways involved for all stages. Total length of waterway required to develop a head of 85m is 2225m. Out of this 50m head is exploited through stages I and II with a total waterway of only 500m.

The above planning results in a nearly standardized design of three power stations with respect to the electro mechanical equipment and also a part of the civil works. This will have the benefit of reducing the cost of the equipment and designs. As the stage 2 project exploits the natural potential, and is the most feasible, the present volume is devoted to the development of pre-investment report on this project. Similar studies for the other schemes can easily be repeated on lines similar to that adopted by SECSD.

Features of the cascade are given below.

Box 5-1: Proposed Cascade Development of Malagarasi

Location	PROJECT	FSL (m)	TWL (m)	Q (cum/s)	H (m)	Power (kW)	Energy (GWh)
Uvinza	Uvinza	1000	980	25	20	2 x 2000	35
Igamba Falls	Stage-1	890	865	40	25	2 x 4000	65
Igamba	Stage-2	865	840	40	25	2 x 4000	65
Igamba	Stage-3	840	805	40	35	3 x 4000	91
Illagala	Illagala	800	775	40	25	2 x 4000	70
TOTAL						40,000	326

The benefits derived from the stage 2 project over the previous layout are

1. Very short waterway which significantly cuts down construction period and cost.

2. The installed capacity of 8,000 kW for stage 2 is equal to that of the Norconsult proposal wherein a total head of 62m was utilized in a single stage development. In the present proposal, with a waterway restricted to about 500m length and head of 25m, no sacrifice is made with respect to capacity and energy of the previous proposal. In fact an additional capacity of 20MW is available in the same stretch of the river as two additional projects have been planned and can be executed independently. These additional projects also have very short waterway. Thus stage 2 project alone is equivalent to the original proposal and hence can be compared directly.

3. Requirement of excavation and concrete is reduced considerably as the tunnels, surge chamber, etc are avoided. The dam is rockfill and the material is available in abundance in the vicinity.

4. Implementation cost is US$13 million as compared to US$36 million in 1983. with identical financing options. Thus cost is reduced to nearly 35%

5. A reservoir with more storage and hence better peaking capacity. The volume is increased to 2 MCM.

6. Better transient operating conditions.

7. As the penstock is short, separate penstocks can be installed. This avoids bifurcation upstream of power house.

With the above revised planning, hydrology, power studies and costing were performed. Important features of the project is given in Box 5-2. Full details are given in table 5-1.

Box 5-2 Project at a glance

<u>Main Features</u>

Type of Project	Hydro electric run of river type
Installed Capacity	2 x 4.0MW. (Vertical Shaft Kaplan turbines)
Average Net Head	24.0m
Power Station Discharge	40 cubic metres per second.
Mean Annual Energy	64.4 GWh
Construction Cost	11.25 M USD (exclusive of IDC)
Construction Period	2 years

<u>Financial analysis @ US 7 cents/kWh</u>

	<u>IPP financing</u> (I = 10%, n = 10 years)	<u>Soft Term Loan</u> (I = 3%, n = 30 years)
IDC	1.75 MUSD	0.511 MUSD
Cost per kW	1625 USD	1470 USD
Financial Benefit Cost	4.00	6.85
Cost/kWh (1st year)	3.53 US cents	1.46 US cents

As the report has been prepared taking into consideration much of the field investigations already performed by other consultants who have conducted feasibility studies, the expenditure on such investigations have been kept to a minimum.

The results of the economic and financial analysis show the project to be sound and suitable for even IPP participation which normally involve high cost of capital and short loan repay periods.

Part II Topography

The present layout is based on 1 in 10,000 and 1:50000 topographic sheets and several reconnaissance visits to the dam site and project area. Additional detailed topographic mapping and surveying would be conducted later if required and incorporated in the final design drawings. The project is situated in a reach about 1.5 km downstream from where the river exits from a deep gorge. The site controls a catchment area of 125,000km^2 which for the most part is very sparsely inhabited. The project area in the immediate vicinity is woodland. The river in this reach is considerably steep and the river banks are gently rising. There is vegetation along the banks of the river. There is rock on the banks and the river bed is also similarly rocky. Many suitable sites are available in this reach. The site selected is such that power canal length is least. Abundant sources of construction material are available in the vicinity.

Part III Access

The proposed hydropower project is situated in an area rather remote from human settlements on the south side of the Malagarasi River, approximately 35 km due west of Uvinza town and about 60 km directly southeast of Kigoma town. The coordinates of the site are approximately latitude 5^{0}10'S and 30^{0}10'E

The northern riverbank of the project area can be reached with a 4WD by a motorable track, about 24 km long, branching off from the Kidahwe-Lugufu-Uvinza road about 5.5 km west of the Lugufu River crossing. The distance along the road and track from Kigoma town to the river at the project site is altogether approximately 100 km. Lugufu is located on the Dar es Salaam-Kigoma railway and Parallel service road.

The proposed access to the scheme will be by a new road to be built branching off from the Kidahwe-Lugufu-Uvinza road about 4 km west of the Lugufu River crossing, as shown in figure 3-2, and the route of the new road will lie east of the existing track, following a north-south direction over the first 13 km, then turning westward about 6 km, and finally in a southwest direction over the last 3 km, to the river. The proposed route of the road follows ridges and boundaries of watersheds so as to minimize the number of rivers to be crossed. Road construction along the proposed alignment is expected to be straight-forward. Construction materials of sufficient quantity should be available along the route.

As part of the access road, a 162 m long bridge will be constructed across the Malagarasi River. A "Bailey" bridge, triple single reinforced, over three spans, 55 m, 55 m and 52 m respectively, and with a standard width of 3.76 m is recommended for this purpose. The bridge will be located as shown in figure 5-1 downstream the power station area.

Part IV Civil Structures

For the diversion structure a rockfill dam is considered. It will have the feature of passing surplus flood water over its crest.

The rockfill portion of the diversion weir dam will be about 340 m in length, about 7.5 m in height and will be ungated. The features are shown in figure 10-1. The water will be diverted into a canal with FSL 865m which leads to a forebay.

The power house will be surface type located about 500m downstream of the diversion weir along the river course. Its tailrace will be led into the Malagarasi river in the immediate vicinity of the power house. The installed capacity will be 2 x 4 MW. The maximum design flow for the power station has been fixed at 40 m^3/s

Part V Generation, Transmission and Utilisation

With regard to the magnitude of discharge, change in head and varying demand, two units of vertical shaft Kaplan turbines coupled with generators (2 x 4.75 MVA) are considered.

The generators would be designed for operation with the power factor cos phi = 0.85. With this, sufficient wattless output for the loads in the 66 kV grid will be ensured if required.

The two generators will be connected to individual 3 phase step up power transformer. The outlet line will be provided only with circuit breaker, lightning arresting device and disconnecting switch. A 66 kV switchyard shall be built in the immediate vicinity of the water power station on the left bank. This switchyard will be supplied by both sets.
With its output of 8,000 kW, the Malagarasi stage-2 power station will exceed the immediate demand for electricity in the region. Its output is sufficient for the towns of Kigoma, Ujiji and other small places. The power station will thus need to be connected to a new regional grid, so that generated electricity is transmitted to the existing load centers. Having regard to the natural and uniform regulated river flow of the Malagarasi river and therefore to its guaranteed output, this power station will be able to reliably and economically provide electricity supply to the region which would otherwise have to come from the major power stations to this part of the country.

The Scheme of electrical connection will be adjusted if necessary at the final design stage. The power station will be connected to the town of Kigoma with a new 100km 66kV double circuit transmission line which goes from the switchyard to the new Kigoma substation.

With the supply of electricity to Kigoma and the surrounding areas from the Malagarasi power station, the load on the diesel generators at Kigoma will be eliminated. This will enable them to become emergency standby units or they could be shifted to other remote locations. The saving on diesel fuel is estimated to be about 1.5MUSD per annum at a running cost of about 14 cents per kWh. These savings can be used to carry out 11kV rural electrification schemes.

Part VI Environmental Impact

The maximum reservoir elevation was determined in relation to the morphology of the flooded area, the elevation of the lands on the banks. After the detailed topographical survey this elevation may be slightly changed. The backwater of the resulting reservoir with a small volume will not flood any land inclusive of the portions which are already subject to annual flooding by the river. In the flooded area there are neither industrial plants nor communications. However lumpsum provision has been made for any unforseen item in table 13-1 on mitigation costs. The created pondage is of relatively small volume and will partly regulate the flows for the other proposed downstream projects.

Part VII Costing & Economics

It is estimated that the total construction cost of the scheme will be US$ 11.25M without accounting for IDC which is 1.75 MUS$ for financing at 10% interest and 10 years loan period. The economic Benefit Cost ratio to the national economy is 7.85 at 12% discount rate. The financial benefit cost to the developer is 4.00 and the net cost of energy is about 3.53 US cents per kWh in the first year of operation (all figures are inclusive of IDC assuming sale of entire energy). Further details are given in chapter 14.

Table:5-1

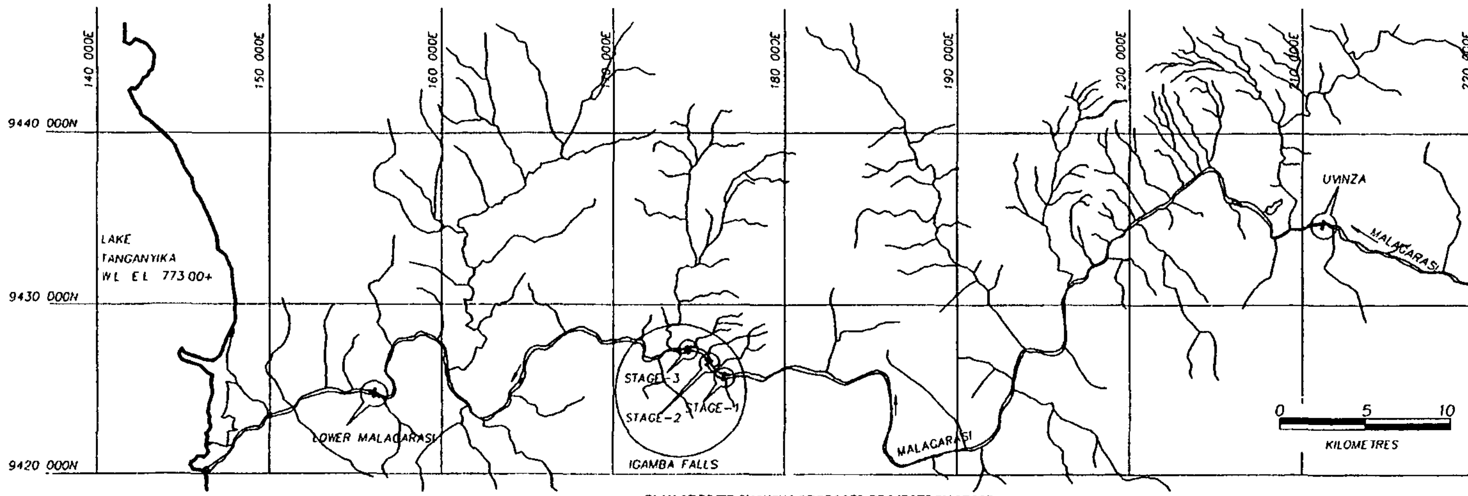
MAIN FEATURES OF MALAGARASI STAGE-2 HYDRO ELECTRIC PROJECT

	Project Particulars	Description
1	**General**	
a	Type of Project	Run of River Type Hydro Electric generating project
b	Location	on Malagarasi River near Igamba falls in Kigoma region about 24km South of Lugufu village on Uvinza-Kigoma railway
c	Installed Capacity	8000 kW
d	Catchment Area	125,000 sqkm.
e	No of Units	2 units
f	Annual Energy Output	65 GWh (average year), 72 (wet year), 56 (dry year)
g	Plant Load Factor	91 3% (average year), 100%(wet year), 80 1%(dry)
2	**Diversion Weir**	
a	Non Overflow Section	
i	Type	Rockfill or Rubble Masonry
ii	River Bed Level	857 5
iii	Full Supply Level	865m
iv	Minimum Drawdown Level	862m
v	Gross Storage Capacity	1,800,000 cubic meters
vi	Length	40 m
vii	Maximum Height	7 5m
b	Overflow section	
i	Type	Rockfill or Rubble Masonry
ii	Crest Level	865m
iii	Gates	None
iv	Size of Gates	-
v	No of Gates	-
3	**Waterway**	
i	Type	Trapezoidal power canal
ii	Bed Width	2.25m
iii	Maximum Discharge	40 cumecs
iv	Length	500m
v	Penstocks	Steel Penstock laid on ground with supports
vi	Diameter	2.15m
vii	Length	100m
4	**Power House**	
i	Type	Surface Type with superstructure
ii	Length	24.5m
iii	Width	13.0m
iv	Floors	Two
5	**Electromechanical Equipment**	
a	Turbine	Vertical Shaft Kaplan turbine with elbow draft tube
i	Rated Head	24m
ii	Rated Discharge	20 cumecs
iii	Minimum Net Head	22 7m
iv	Maximum Net Head	24 3m
v	Speed	300 rpm
vi	Governor	Electronic Digital Governing system
vii	Runner Diameter (approx)	1800mm
viii	Inlet Gates	Servo operated quick acting
b	Generators	3 phase AC 50Hz
i	Type	Synchronous
ii	Poles	20
iii	Speed	300 rpm
iv	Rating	6.6 kV, 4.75 MVA, 0.85 pf
v	Exciter	Static excitation system

TABLE 5-1 Contd

MAIN FEATURES OF MALAGARASI STAGE-2 HYDRO ELECTRIC PROJECT

6	**Electrical Equipment**	
a	Transformer	2 Nos (Ultimate)
b	Rating	6 6 / 66 kV, 4.75 MVA
c	Switchyard	Double bus arrangement with air breakers
d	Transmission Line	66 kV line from station to new Kigoma Substation approximately 90km length
7	**Environmental Impacts**	No significant impact and lake will be confined to river banks. No deforestation required Project does not produce effluents/pollutants, No change in downstream water flow patterns as storage provided is negligible
8	**Other Benefits**	
	Fisheries	Only small scale development possible
	Navigation	Small boats can use the lake
	Recreation	Lake becomes swimmable and fishable
	Water supply	Can be used for water supply
	Irrigation	Through lift if required. No provision made at present.
9	**Economics**	
a	Civil Works Cost	US$ 3.362M
b	Electromechanical and Allied works	US$ 3 866 M
c	Transmission	US$ 2 500 M
d	Construction Cost	US$ 9 728M
e	Engg, Administration, Environment & Contingencies	US$ 1 500M
f	Construction Period	24 months
g	Interest During Construction @10% interest rate	US$ 1 75 M
h	Total Implementation Cost	US$ 11 25M
i	Cost per kW installed without IDC	US$ 1406
j	Annual Debt Service (10 year Project loan @10%)	US$ 2 115M
k	Annual Operation and Maintenance	US$ 0 113M
l	Depreciation	US$ 0 068M
m	Total Annual Costs	US$ 2 296M
n	Maximum possible Energy generation	65 GWh
o	Grid Wheeling charges	NIL
p	Banking charges	NIL
q	Water Royalty	NIL
r	Net Energy for sale	65 GWh
s	First year Generation Cost per kWh for 65GWh	US 3 53 cents
t	Life cycle Generation cost per kWh	US 0 7 cents
u	Economic Life	30 years
v	Ratio of Life Cycle Benefits/ Life Cycle Costs	4 00
x	Cost per kW installed with IDC	US$ 1625



PLAN OF RIVER SHOWING PROPOSED PROJECTS BY SECSD

NOTES

This drawing shows the revised planning for the Malagarasi river by SECSD

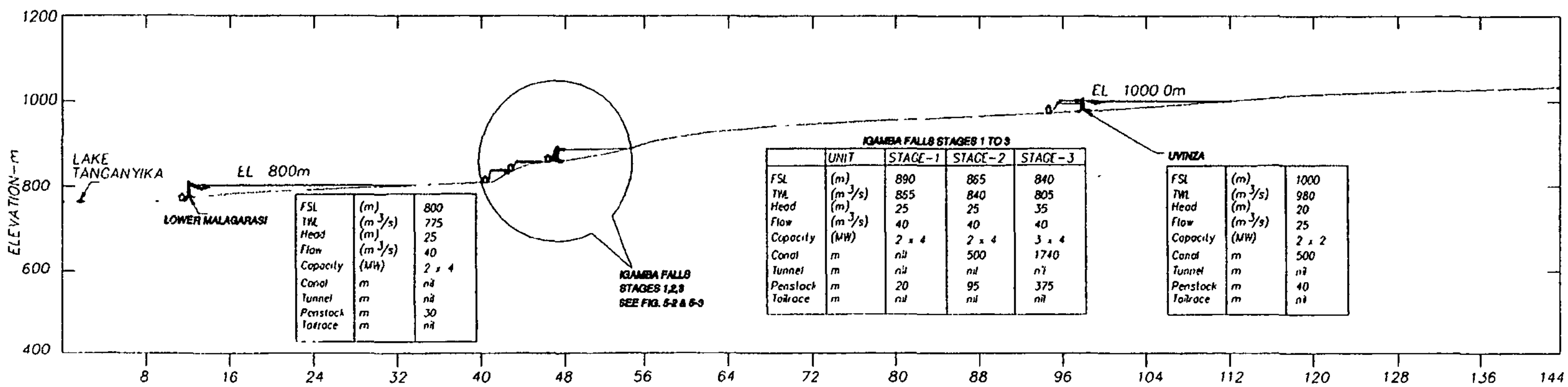
The proposed projects are such that the civil works are simplified using local materials and it is possible to construct within one or two years

The electricity which is generated can be fully utilised within the Kigoma region and transmission is 66kV

Initially Igamba falls stage 2 can be taken up which will provide 8MW and is sufficient for Kigoma Kasulu Simbo Uvinza etc As the load demand increases additional stages can be built As the Igamba falls project area has been already investigated it will require less time on further investigations

The lower Malagarasi project can also supply Kigoma and Illagala but needs to be fully investigated

Uvinza project can supply salt mines and the town of Uvinza and can be taken up independent of the stage 2 project



LOWER MALAGARASI

FSL	(m)	800
TWL	(m 3/s)	775
Head	(m)	25
Flow	(m 3/s)	40
Capacity	(MW)	2 x 4
Canal	m	nil
Tunnel	m	nil
Penstock	m	30
Tailrace	m	nil

IGAMBA FALLS STAGES 1 TO 3

	UNIT	STAGE-1	STAGE-2	STAGE-3
FSL	(m)	890	865	840
TWL	(m 3/s)	865	840	805
Head	(m)	25	25	35
Flow	(m 3/s)	40	40	40
Capacity	(MW)	2 x 4	2 x 4	3 x 4
Canal	m	nil	500	1740
Tunnel	m	nil	nil	nil
Penstock	m	20	95	375
Tailrace	m	nil	nil	nil

UVINZA

FSL	(m)	1000
TWL	(m 3/s)	980
Head	(m)	20
Flow	(m 3/s)	25
Capacity	(MW)	2 x 2
Canal	m	500
Tunnel	m	nil
Penstock	m	40
Tailrace	m	nil

RIVER PROFILE WITH PROJECTS BY SECSD (1999)

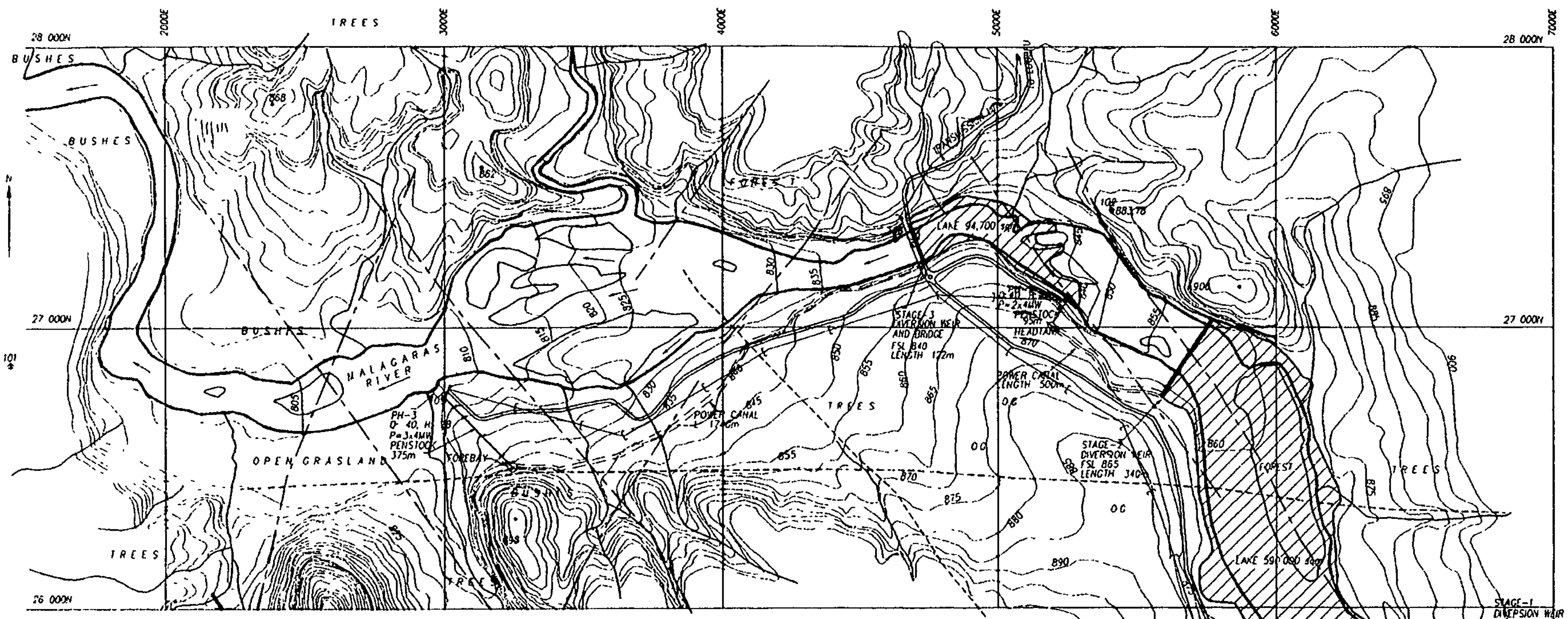
MALAGARASI HYDROPOWER PROJECTS

PROJECTS PROPOSED BY SECSD

FOR: IBRD/TANESCO

DWG NO FIG 5-1 | PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

MAL-LS03.DWG



PLAN OF STAGES I, II AND III POWER PROJECTS AT IGAMBA FALLS

NOTES

This drawing shows the stretch of the Malagarasi River from bed level 860m near its exit from the Gorge upto bed level 800 downstream of the Igamba falls and rapids close to the village Kasogwe which is situated on the right bank

The drawing is based on drawing No M13 titled Site Map Malagarasi of scale 10000 with 5m contour interval produced by Norconsult in March 1983 in their report titled Malagarasi Hydropower Project

The fracture zones are taken from figure 2.5 titled Final Layout and Longitudinal profile with indications of Fracture Zones and Geological Observation developed in August 1983 by Norconsult

The EDM stations and traverse point locations are taken from a series of sheets in various scales titled Malagarasi - Traverse points from the volume on Investigations by Norconsult

After integrating the above information into a single drawing, the drawing shows the revised planning taking into account field visit by SECSD The features of the various stages are given below The proposed hydropower development of the stretch of the river involves a cascade consisting of three stages.

STAGE-1 PROJECT

This stage involves construction of an arch/gravity type dam located just upstream of the end of gorge from which the river makes an exit before turning right and widening The FSL is 890m and TWL for the Power house is 865m Power house is located at the toe of the dam with plant flow of 40 cumecs and an installed capacity of 2 x 4MW

STAGE-2 PROJECT

This stage involves exploiting the head created by a natural 17.5m drop from 857.5m to 840m in a short stretch of the river of about 300m A 7.5m high overflow rockfill diversion weir of about 340m length with FSL 865m is to be built at the head of the rapids. This will create a large lake of about 590000 sqm area This is expected to provide about 2 Million cubic meters storage
The power canal designed for 40 cum/s flow and about 500m length will be located on the left bank The power house is located on the left bank of the river with an installed capacity of 2 x 4MW

STAGE-3 PROJECT

This stage involves creating a pondage with FSL 840m and utilising a further 30m natural drop in river due to rapids from 835m to 805m in a river distance of about 1500m

The diversion weir will be designed to serve as a bridge to cross the river The lake of surface area 97000 sqm will provide a storage of about 0.5MCM canal designed for 40 cumecs is about 1750m in length Penstock of about 270m length conveys the water from the canal to the Power house which is located below near the left bank of the river Installed capacity is 3 x 4MW

CASCADE FEATURES

The total installed capacity of the cascade is thus 28MW Initially only single units can be developed starting with stage 1 or stage 2 This will be able to meet the immediate load demand of the region Further stages can be built in sequence keeping in step with the growth of the load demand Construction is simplified due to very short waterways involved for all stages except the third stage Total length of waterway required to develop a drop of 90m is 2225m Out of this 50m head is exploited through stages I and II with a total waterway of only 500m

LEGEND

MAJOR FRACTURE ZONES
MINOR FRACTURE ZONES
PONDAGE OR LAKE
EDM STATION

EDM TRAVERSE POINTS EST'D BY NORCONSULT

EDM STATION	CORDINATES		ELEVATION
101	26870.00	1445.00	984.50
102	27413.34	5410.73	883.88
103	25721.87	6167.95	863.13
104	25672.67	6466.29	865.46
105	26749.53	2998.94	808.89
138	27313.02	4621.64	843.41
139	27295.77	4688.48	828.27
140	25688.04	6533.89	863.52

0 1000
SCALE (m)

MALAGARASI HYDROPOWER PROJECTS (STAGES I TO III)

PROJECT OUTLINE SCHEMATIC

FOR. THE WORLD BANK/ TANESCO

DWG NO: FIG. 5-2

PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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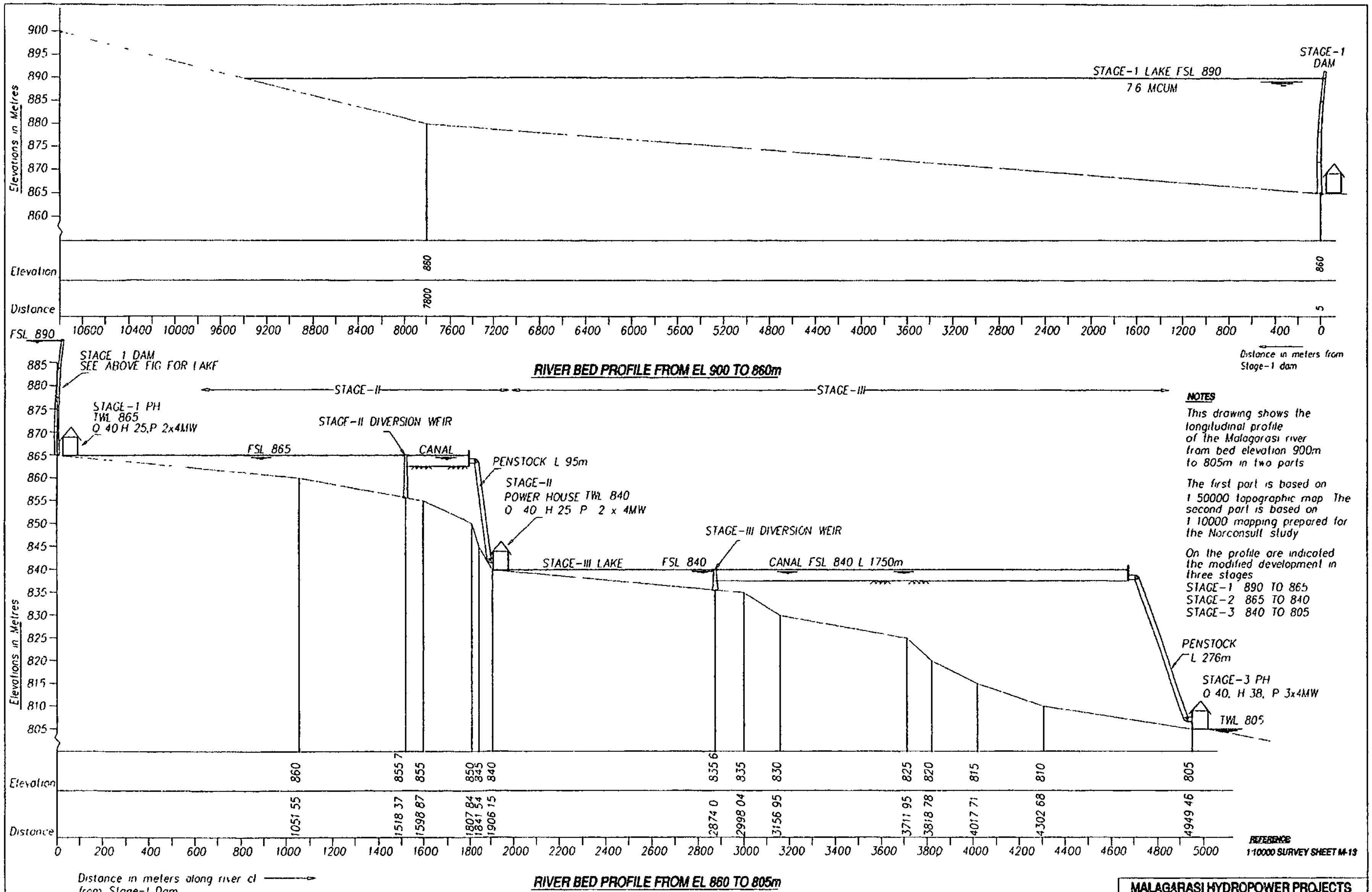

NOTES

This drawing shows the longitudinal profile of the Malagarasi river from bed elevation 900m to 805m in two parts

The first part is based on 1 50000 topographic map The second part is based on 1 10000 mapping prepared for the Norconsult study

On the profile are indicated the modified development in three stages
STAGE-1 890 TO 865
STAGE-2 865 TO 840
STAGE-3 840 TO 805

MALAGARASI HYDROPOWER PROJECTS (STAGES I TO III)	
RIVER BED PROFILE AND POWER STATIONS IN CASCADE	
FOR: IBRD/TANESCO	
DWG NO FIG 5-3	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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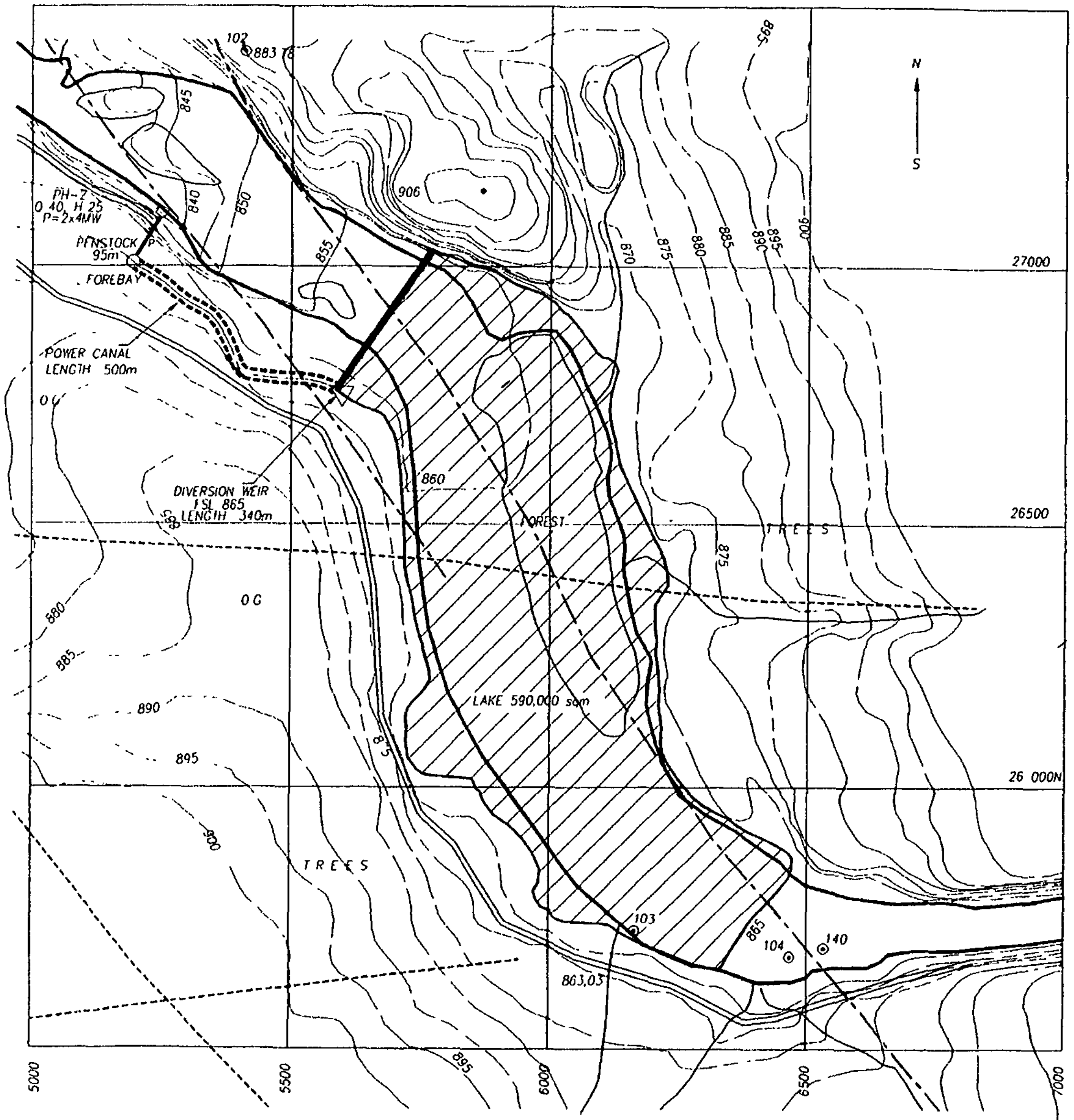

PLAN SHOWING ACCESS, DIVERSION WEIR, LAKE SPREAD, WATER CONDUCTOR AND POWER HOUSE

NOTES

This drawing shows the general layout of the stage II project with diversion weir, power canal, forebay, penstock and power house arrangement

LEGEND

- RIVER
- STREAM
- ACCESS ROAD
- MAJOR FRACTURE ZONES
- MINOR FRACTURE ZONES
- LAKE
- 104 EDM STATION
- 865 CONTOUR WITH ELEVATION
- CANAL
- FOREBAY
- PENSTOCK
- POWER HOUSE

0 — 500
SCALE (m)

MALAGARASI HYDROPOWER PROJECTS (STAGE-II)	
LAKE, DIVERSION WEIR AND POWERHOUSE - LAYOUT	
FOR: THE WORLD BANK/ TANESCO	
DWG NO FIG 5-4	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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Chapter 6 Topographic Features and Surveys

Section 1 Topography

The proposed mini hydropower development is located in the Kigoma Region, approximately 35 km west of Uvinza town and about 60 km south-east of Kigoma. In this area the Malagarasi River runs towards Lake Tanganikya through a highland plateau with elevation between 1000 and 1300 m above sea level.

Upstream of the project area the river has cut a deep and narrow gorge through the plateau. The proposed power plant is located where the gorge widens out to an open landscape with flat plains along the river.

The terrain becomes more hilly with minor mountains towards the plateaus. The landscape is generally covered with forest, but areas with open grassland occur.

Through this reach, the river elevation drops in several steps from approx. 865 m.a.s.l. at the end of the gorge to 805m near the stage 3 power station site.

Section 2 Survey

The project area is mapped by Survey of Tanzania topographic sheets in 1:50000 scale with contours at 20m intervals. The map index number is 113/1. An extract of the relevant area of interest is given in figure 3-1.

This stretch of the Malagarasi river and both banks are also mapped by specially prepared survey sheets by Norconsult in 1983 as per details below.

There were no existing triangulation points with UTM-coordinates close to the mapping area and the survey sheets are therefore in a local coordinate and elevation system.

The elevation system is approximately the same as the system on the existing 1:50 000 map, with terrain points on the 1:50 000 map as reference points.

Four traverse points were established to cover the ground survey for the 1:10 000 mapping. (Points 101 - 104). Another 36 traverse points were established for the detailed mapping in scale 1:200 and 1:500. (Points 105 - 140).

A description of the coordinates and altitudes of the traverse stations developed and used in the Malagarasi Survey and their locations is given in figure 5-2.

Part I **Aerial Photography & Ground Control**

Aerial photography used for the studies in the Malagarasi area was produced in 1974 and supplied by the Government of Tanzania. Changes that took place after 1974 are therefore not recorded. The photography used was taken from Flight CAN-11, exposures 194 and 195.

Only one model was used in ground control for the construction of the 1:10 000 map. The control points observed in the field were given numbers from 1001 to 1050.

Part II **Mapping and Profiling**

The following maps have been compiled:

- Mapsheet Index of EDM Traverses: scale 1:10 000, contour interval 5 m, 1 sheet, map no. M2.
- Intake area: scale 1:200, 1 sheet, map no. M3.
- Power Station area: scale 1:500, 8 sheets, map no. M4 - M11.
- A profile across Malagarasi river on the proposed bridge site, map no. M12.
- Malagarasi Site Map: scale 1:10 000, 1 sheet, map no. M13.

Section 3 Results

All the revised project features are within the limits of the survey information available in the Norconsult report. Hence for the new layout no additional surveying is required to be done. Requisite information has been extracted from map M13 and other available sheets and is presented in figure 5-2. Additional information inferred from the above include

1. The cross section of the river at the proposed diversion site to bring out the longitudinal section of the diversion weir.

2. The reservoir area and capacity data to be used in the hydrology, power and energy studies.

3. The ground profile along the waterway to compute the quantities of civil works and penstock alignment.

4. Lake spread with any potential environmental impacts.

Chapter 7 Geology

Section 1 General

The geology of the site is considered from the available geological information to be adequate for the construction of all the contemplated project features. Also the formation of the proposed impoundment will not give rise to any slips or settlements in the bed or banks of the reservoir.

Section 2 Regional Geology

The Malagarasi basin, occupies a major portion of northwestern - central Tanzania. The basin stretches from Lake Tanganyika on the west some 380 km to Tabora on the east. From near the southern limit of Lake Victoria on the north, it extends south 450 km as far as Rungwa.

The western and southern basin boundaries are marked by the highlands which extend discontinuously southward from Burundi, along the east coast of Lake Tanganyika to the region north of Lake Rukwa. These highlands reach elevations of more than 1,500 m. The Malagarasi River drains to the west into Lake Tanganyika, at elevation approximately 770 m, through a break in the mountainous zone east of Kigoma.

To the east, the topography is of lower relief, but one where steep erosion scarps and relatively deeply incised river valleys have formed in the relatively soft sedimentary rocks. These erosion features may reach heights of several hundred meters and are most pronounced along the courses of perennial rivers. West of Uvinza, a gorge over 400 m deep has been carved by the action of the Malagarasi River on the underlying sandstone formation. West of Uvinza, the elevation of the terrain is generally less than 1,000 m.

Most of the basin east of Uvinza occupies a down warp in the Precambrian peneplain. Here the topography is low relief, generally less than 1,500 m in altitude, and is controlled by the crystalline basement rock. As a result, much of the central, southern and eastern parts of the basin are covered by mainly seasonal and partly perennial swamp.

The geology of the Malagarasi river basin consists of the basement complex of metamorphosed and folded Precambrian rocks of both igneous and sedimentary origin, overlain in the western part of the basin by unmetamorphosed Precambrian and Paleozoic sediments and volcanics. Occupying a large area in the north central part of the basin, and other smaller isolated areas to the east, are alluvial deposits of Neogene age.

The Precambrian rocks exposed in the eastern half of the basin are synorogenic Archaean granite, granodiorite and migmatites of the Ukingan Series and Archaean schists, gneisses and migmatites of the Dodoman Series. These rocks are part of a stable craton that was disturbed little by subsequent surrounding geological activity. The Archaean schists, gneisses and granulites of the Ubendian Series were later formed to the west of this stable block and mark the limit of the basement complex. The Ubendian rocks have been strongly folded with axes trending northwest to north-northwest.

The Bukoban sediments are of Proterozoic and Paleozoic age and lie unconformably on the older rocks. They are represented from top to bottom by the sediments of the Uha Group consisting of sandstone, red beds, dolomitic limestones and amygdaloidal lavas; by the Kigonero Flags, consisting of sandstones, shales and limestones; and by the Busondo Group, consisting of sandstones, shales and quartzite.

Within the basin, the Bukoban sediments are generally subhorizontal or dip gently to the west. Gentle folding of the strata has produced occasional anticlinal and synclinal structures.

Of great structural importance in the western basin area is the Western Rift zone, which extends northward from Lake Nyasa, through Lake Rukwa and Lake Tanganyika. The Rukwa Graben was formed in Cretaceous time prior to the formation of the Lake Tanganyika depression. Following a period of stability and inactivity, trough and block faulting recommended in Miocene-Pliocene time along the line of Lake Tanganyika and northward. Faults of the Western Rift system trend generally to the northwest. North of Kigoma, they change to a north to north-northeasterly trend. Faults are steeply dipping and are generally down-thrown to the west. Some rift faulting has been observed within the basin limits in the

Bukoban sediments to the south and west of Uvinza. The Western Rift zone is considered to be presently active.

Section 3 Site Geology

Preliminary studies on engineering geology have shown that the bearing capacity for all the proposed structures is adequate and no major problems are likely to emerge.

A strong connection between topography, geological formations and tectonics in the area is apparent. The proposed power plant is located close to one of the major structural and physiographic features in Africa, the Western Rift Valley. The Western Rift Valley, which among other features, has formed Lake Tanganikya, is a graben formation with the eastern edge 25-30 km west and downstream of the proposed power plant. Topography and tectonics in the power plant area have probably been influenced by the formation of the Rift Valley.

Due to the down-warping of the Rift Valley, tensile stresses may have been introduced in the surrounding rock masses.

Along already existing joints the rock masses may, due to the tension, have been moved apart. After separation and opening of the joints, water intrusion and erosion have commenced. The landscape at the project area seems to be this type "cracked" consisting of hilltops and small mountains separated with valleys following the major joint lineaments.

The major tectonic features (joint lineaments and fracture zones) which appear in the aerial photography in the power plant area are shown in figure 5-1.

The direction of the most frequent joint lineament is NW-SE. Fracture or joint zones in NE-SW and E-W direction are quite common while N-S joint lineaments can occur. When crossed by the river these lineaments have formed several rapids and minor waterfalls.

Observations in the field correspond well with the "tension/- joint opening" - theory which has been described.

Some of the fracture zones forming rapids and waterfalls consist of big rock blocks separated by open joints. Parts of the river disappear into the near vertical joints upstream of the waterfalls. The water follows joints and bedding planes and appears up to some hundred meters downstream of the water falls. The permeability of the rock masses in these zones is therefore believed to be high.

Five sets of joints have been observed in the field :

Box 7-1: Observed Joints

JOINT SET	STRIKE	DIP
I	N385-25°	0-5° W
II	N5-10°	80-100° W
III	N30-40°	90-100° SE
IV	N105-140°	80-100° N
V	N50-75°	90-100° NW

Bedrock is exposed almost the entire way along the river from the end of the gorge to the end of the rapids.

The rock formation belongs to the "Bukoban series" which was formed in late precambrium / early paleozoicum. Along the river, the bedrock consists of massive sandstone beds with strike approximately N-S, dipping slightly (2-5°) west. The plateau formations in the area are a result of the near horizontal rockbeds. The plateau landscape is formed by competent caprock protecting less competent bedrock against erosion.

Erosion has commenced along joint pattern in the caprock, cut valleys through underlying incompetent rock down to the next bed of more competent rock where new plateaux have been shaped. Today, such a new plateau or base level consisting of massive sandstone is being formed along the Malagarasi River in the Power plant area.

Competent limestone is observed at the upper plateau around el. 1000 m.a.s.l. Between the upper plateau and the base level of the Malagarasi River, minor plateaux are formed, associated with outcropping limestone or sandstone beds. In the hillsides, scattered outcrops of limestone beds occur, while occasional exposures of shale is observed in the minor stream beds.

Between the plateau formations the hills are covered with residual soil and talus. The talus material consists of a mixture of residual and organic soil, pieces of limestone, sandstone, shaly sandstone and shale.

It is assumed that the rock between the plateau consists mostly of shaly sandstone or shale, largely less competent than the overlying caprock. A few exposures of jointed and fissured shale can be observed in some of the minor streams. Due to the very limited outcrops of shale, it is difficult to estimate the location and thickness of the shaly beds.

With exception of the formation of the rift valley, the area has been relatively stable since precambrium. This is confirmed in the low degree of metamorphosis, occasional wave patterns in sandstone and lack of tectonic folds in the area.

Probably due to the low degree of metamorphosis, the sandstone is partly poorly cemented. The low degree of cementing has permitted the formation of erosion patterns and shallow holes.

Soil deposits which occur along the river mainly consist of partly cemented alluvial sand and silt. The soil overburden depth increases towards the hills. The hillsides are almost entirely covered with residual soil and talus.

Section 4 Engineering Geology

The proposed access route from Lugufu requires a bridge for crossing the river to approach the power house and canal.

At the proposed bridge, the soil overburden at the bridge abutments is shallow, and the bedrock consists of competent sandstone.

On both sides of the river the geological and geotechnical conditions are generally similar with respect to rock types, tectonics and soil. The site is suited for the construction of the rockfill dam.

From the intake to the forebay, the canal alignment follows more or less along the contour lines at elevation 865m. The total length of the headrace canal is approximately 500m. Bedrock of massive sandstone is exposed almost the entire way along the alignment. Because of the fracture zones, open joints in rock may occur.

During construction it is expected that the canal would require rock excavation, and some sealing or grouting of open joints,

The canal would not be exposed to erosion and slope stability problems.

Section 5 Construction Materials

A thorough investigation of source of construction materials has been done by Norconsult. The same is considered adequate.

Only very small sources of gravel were found during the site investigations. Alluvial deposits of sand and silt are located along the stream. The deposits are partly cemented.

Talus deposits along the hillsides are mixed with residual or organic material. It is thus assumed that soil deposits suitable for concrete aggregates may be difficult to find.

The most competent bedrock exposed consists of near horizontal beds of limestone and sandstone. The exposures of limestone are scattered.

The sandstone beds are exposed almost the entire way along the Malagarasi River. Thickness of the beds varies between 1 and 5 m and the joint spacing is generally high. However, the degree of cementation is variable. This will be the most suitable source of material for the dam.

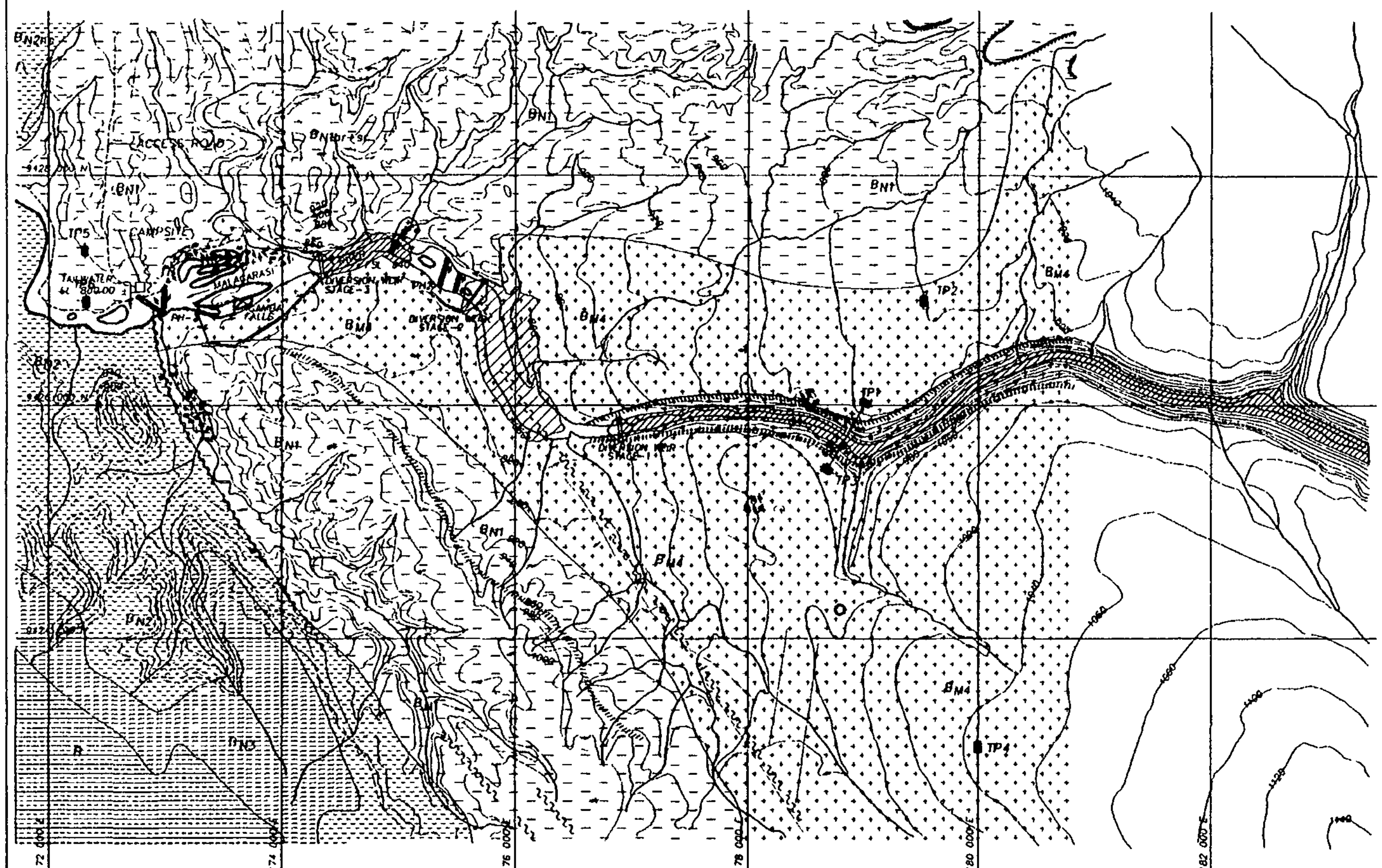
During the site visits, investigations such as geological and geotechnical survey, test pit excavations and sampling have been undertaken.

The depth of gravel in test pits shallow and hence due to the very limited quantity of gravel the deposit is considered not feasible as concrete aggregate source.

The only suitable source of concrete aggregate observed in the area is competent sandstone and limestone beds. Rock samples of sandstone and limestone have been tested at the University of Dar Es Salaam. Laboratory test results are shown below

Box 7-2: Laboratory Test Results

Sample	R1 Sandstone	R2 Limestone
Aggregate crushing Value	25.5%	21.5%
Bulk density	1.30 g/cm^3	1.37 g/cm^3
Unconfined compressive strength q_u	55 MPa	



NOTE

THIS DRAWING SHOWS THE GEOLOGY OF THE MALAGARASI RIVER AND THE STAGES 1 TO 3 DEVELOPMENT

GEOLOGY TAKEN FROM QUARTER DEGREE SHEET 113 AND SUPPLEMENTED WITH INFORMATION OBTAINED DURING SITE PREFEASIBILITY INVESTIGATION

GEOLOGY TAKEN FROM QUARTER DEGREE SHEET 113 AND SUPPLEMENTED WITH INFORMATION OBTAINED DURING SITE PREFEASIBILITY INVESTIGATION

LEGEND

- B — COARSE WHITE SANDSTONE SOMETIMES CONGLOMERATIC AT BASE

BUKOBAN:
- BN3 — MAROON SHALES, SILTY SHALES FINE - GRAINED SANDSTONES
- BN2 — SOFT PINK AND WHITE CALCAREOUS SHALES (nc) WITH HEMATITE FLAKES, AND INTERBEDDED THIN PINK WHITE OR GRAY PORCELLANOUS LIMESTONES
- BU — MARRON AND BROWN SANDSTONES (sr) AND SHALES (hr)
- BM4 — MEDIUM - TO COARSE - GRAINED WHITE AND PALE FAWN CROSSBEDDED SANDSTONES WITH OCCASIONAL THIN SHALE HORIZONS.(MALAGARASI SANDSTONE)

SYMBOLS

- GEOLOGICAL BOUNDARY
- CONSTANT LITHOLOGICAL HORIZON
- HORIZONTAL STRUCTURE
- VERY LOW DIP STRUCTURE
- LOW DIP STRUCTURE
- MEDIUM DIP STRUCTURE
- FAULT (MARK ON DOWNTHROWN SIDE)
- FAULT (ASSUMED)
- JOINT
- JOINT (OBSERVED) (DIP 70 DIP 90)
- BEDROCK OUTCROP (OBSERVED)
- TP2 TEST PIT
- STEEP SLOPE OR ESCARPMENT
- WATERFALL
- SURVEY LINE
- LAKE

SCALE

0 500 1000

METRES

MALAGARASI HYDROPOWER PROJECTS

GEOLOGICAL FEATURES AT STAGES 1 TO 3

FOR: IBRD/TANESCO

DWG NO FIG 7-1	CAD BY SIVAGURU ENERGY CONSULTANTS

File Name - MAL-GEO DWG

Chapter 8 Hydrology

Section 1 Drainage Network

The source of the Malagarasi river lies in the mountainous area close to the Burundi border, at an altitude of 1750 m. From there, it flows in a north-easterly direction, through the hilly and mountainous landscape towards Kibue, before it turns southwards into the flatter and undulating area east of the Kasulu-Kibondo road. In this reach, the gradient is gentle and the river flows in large meanders before entering the Malagarası swamps in the southeastern part of the region. At this point, near Nguruka, a large tributary from the Tabora Region, the Moyowosi River joins the Malagarasi in the seasonal lake Nyamagoma. From here, the river runs more or less directly west and after breaking through the Misito Escarpment, forms rapids and waterfalls before entering Lake Tanganyika at Ilagala. On this last stretch, the river picks up two main tributaries, the Ugalla and the Ruchugi.

The Malagarasi swamps are a distinct hydrological feature of the area, turning from small, scattered ponds in the dry season to enormous, shallow lakes during the rainy season. The drainage map and meteorological stations in the catchment are illustrated in figure 8-2 titled meteorological stations in the basin.

Section 2 River Flow Data

There are river gauging stations on the various tributaries. The river gauging stations in the catchment have been indicated in figure 8-3 titled Hydro-meteorological stations. There are a total of six stations. The drainage area, mean annual flow and other particulars are shown in the drawing. The figure also shows the water balance by comparing the flows in the tributaries to that after their confluence.

The figure shows that after receipt of flows from Taragi, Makere, Pwaga, and Ugalla, the aggregate flow should be 98.1+16.4+164.7 = 279.2 cumecs against 135.43 recorded at Mbelagule. Detailed water balance study in the river basin may indicate influence of swamps and evaporation from swamps. It has also been pointed out by earlier consultants, that the measurements done at Sindi on Ugalla are incorrect and hence the error. Thiessen polygons for computing weighted rainfall are also shown.

Box 8-1: Hydrometric stations in Malagarasi basin

STATION	NAME	RIVER	CATCHMENT AREA (sqkm)	STAFF GAUGE RANGE	AUTOMATIC RECORDER	CONTROL
4A5	Taragi Br	Malagarasi	8525	0 - 6m	no	Bridge Foundation
4AB1	Makere	Makere	783	0 - 5m	no	Road Bridge for high flows, Open channel for low flows
4AA2	Pwaga	Ruchugi	2989	0 - 6m	yes	Rock sill of German Bridge
4A9	Mbelagule	Malagarasi	123000	0 - 8m	yes	Rock sill
4A8	Malagarasi Railway Br	Malagarasi	66300	0 - 7m	no	Bridge foundation for low flows, open channel for high flows
4AH1	Sindi	Ugalla	51775	0 - 4m	yes	Scattered rocks

Box 8-2: Calculation of Mean Basin Rainfall

STATION	CODE	PERIOD OF RECORD	LENGTH OF RECORD	MEAN ANNUAL RAINFALL (mm)	POLYGON AREA (sqkm)	WEIGHTING FACTOR	MEAN
Heri Mission	94.2908	1957 - 76	13	1496	6194	0.0476	71
Kibondo Mission	93.3000	1931 - 58	27	1114	19901	0.1530	170
Ushirondo Mission	93.3101	1943 - 71	22	923	17000	0.1307	121
Kahama	93.3200	1926 - 80	54	1035	5816	0.0447	46
Nzega	94.3300	1926 - 80	52	783	4465	0.0343	27
Tabora Obs	95.3200	1926 - 80	52	888	12010	0.0924	82
Kisengi Sisal Estate	95.3301	1957 - 76	13	1136	2784	0.0214	24
Kirunda Mission	96.3300	1957 - 73	12	938	13670	0.1049	98
Mpanda Borra	96.3105	1959 - 80	18	1276	10840	0.0834	106
Uvinza Salt mine	95.3000	1928 - 74	43	965	11780	0.0906	87
Urambo Farm 10	95.3215	1975 - 81	22	1104	25600	0.1969	217
TOTAL						1.000	1049

From the point of view of the power and energy studies for the proposed site, the most important flow data is that obtained from gauging station 4A9 which is at Mbelagule about 10km downstream of Uvinza. The location is shown in figures 8-2 and 8-3. No major stream or tributary joins the Malagarasi downstream of the gauge site upto the proposed diversion weir site . Hence the flow at gauge site closely represents the flow at the diversion site. The station comprises a staff gauge with readings taken twice daily together with an automatic water level recorder. The control consists of a rock sill. The daily observed data is available for a six year period. No readings are available subsequently. The data with analysis is given in the separate volume annexure A.

Section 3 Observations

The catchment area at the gauge site is 123,300 sqkm. From the measured flow data, the average run off is found to be 139.2 cum/s corresponding to a runoff depth of 35.4 mm. The average precipitation over the catchment is 1049 mm giving a run off coefficient of 3.37%. The low value of runoff coefficient may be attributed to the dryness of the eastern and southern parts of the catchment as also to the vast swamps and lakes which are formed during the wet season and the resulting high evaporative losses. A look at the annual runoff plot in Table 5-1 in annexure A shows that the total annual runoff for the years increased from 1975 to 1979 and then decreased upto 1982. The following important observations can be made

- The river does not dry and has a base flow.
- The pattern of flow is suited for production of hydropower.

Section 4 Yield at Diversion site

The proposed diversion site is located a little downstream of the gauge site. The catchment area at the proposed diversion site is about 125,000 sqkm representing an increase of only 1%. No major stream or tributary joins the Malagarasi between the gauge site and the proposed diversion site nor is there any abstraction of water in this reach. Hence the yield at the diversion site is taken to be equal to the measured flow. The error involved in the assumption will be less than 0.1%.

Analysis of the flow data by monthwise partial flow duration curve gives the exceedance values shown in Box 8-3 which are partly reproduced from table 8-1 of annexure A.

From the above the month of May has the peak flow. The discharge exceeded 40% of the time in this month is 268.2 cumecs. Minimum flow occurs in the month of November. The minimum recorded flow is 10.6 cumecs in November 1976. The firm flow which is defined as the flow that is exceeded 90% of the time is 14.4 cumecs.

Box 8-3: Percentage Exceedance of Flows

%	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
10	185.7	282 4	299.6	504.2	925.1	778.2	463.5	251.9	114.5	49.1	44 9	142.6
20	146.8	136 5	264.5	368.5	556.9	403.4	209.4	115.3	59.3	31.6	36.7	89.5
40	107.6	117.9	133 8	203.8	268.2	247.6	145.4	76.5	39.5	22.9	24.9	56.9
60	72.6	92 5	98.4	166.7	192.8	130.9	81.6	37.8	19.4	19.6	20.4	42.3
80	62.4	81.4	90.4	107.9	122.5	105.1	54.1	26.5	18.2	16.3	15.7	27.2
90	55.8	71 7	75.9	92.9	103.8	93.0	44 4	22.7	16.0	14.4	13.2	23.4
100	32.1	61.9	61.9	22.0	97.8	64.8	32.9	18.6	13.9	12.0	10.6	17.5

Section 5 Flood Studies

The maximum daily discharge recorded at the 4A9 gauging station for the years 1975 to 1982 is given in table 3-1 of annexure A. The maximum flow of 1001 cumecs occurred in April 1979.

As the period for which historic data is available is very short, it is not reliable to derive flood magnitudes for various return periods from it. During 1983 a comprehensive water development masterplan study was undertaken in Kigoma which developed a regional flood frequency analysis.

The results of the study are given below which are based on log Pearson distribution.

Box 8-4: Flood Estimates

Return Period	10	20	100	1000
Flood (cumecs)	810	1025	1630	2840

The April 1979 flood discharge at the gauge site, mentioned in the preceding section, is estimated to have been from a flood with a magnitude corresponding to a 20-year return period. For the design of the overflow section a discharge of 3000 cumecs is fixed. For the construction a design of 1000 cumecs is fixed corresponding to 20 year flood.

Section 6 Climatology

Climatic features in Tanzania are mainly caused by changes in circulation of air over eastern Africa. From December to March, high surface temperatures occur over much of the continent. These create a large low-pressure centre at about 10^0

to 15^0 S. At the same time, a high-pressure centre develops over North Africa and the Arabian Peninsula. Since air masses move from high to low pressure areas, East Africa is influenced by a northeasterly airstream, the northeast monsoon, during this period. This air current generally brings rather dry air masses. This produces the dry season in the northeastern regions of Tanzania.

By the time this airstream has reached the southern parts of Tanzania, its main characteristics have changed. Its direction becomes more westerly and its speed is reduced. It meets other air masses and a convergence, resulting in rising air movements and an increased instability, is initiated. When these air masses are uplifted, they produce large amounts of rain.

One area of widespread convergence, the most significant, is near southern Tanzania. Here the northeast monsoon encounters air masses from the southeast at the Inter-Tropical Convergence Zone. (This zone is generally located south of Tanzania during this period, but its location varies and its effects of heavy rainfall frequently extend into the southern part of the country).

Another convergence area is situated near the western boundary of Tanzania. Here the northeast monsoon meets a westerly airstream from the rather humid Congo Basin. Though the main position of this convergence area is also outside Tanzania, its effects are felt throughout the entire Kigoma region where significant rainfall occurs.

The meteorological observation network in Kigoma region consists of five stations. Four stations are under the operation and maintenance of MAJI. One station, Kigoma met. is run by the Directorate of Meteorology (DOM). The basic climatic factors recorded at the meteorological stations include temperature, relative humidity, wind velocity, sunshine duration, solar radiation, evaporation and rainfall.

Part I Temperature

The mean annual air temperature at Kigoma ranges between 22.5-24.5^0 C. While the seasonal variation in mean monthly temperature is small, the spatial variation can be much greater, due to altitude differences. The temperatures are high during September-October and February-March when the sun is overhead. The temperatures are low from May to August when the sun is far north. The dry and cool south-easterly winds are predominant in the area at this time.

Temperatures are warmer along Lake Tanganyika as indicated by temperature observations at Kigoma met. station. Kibondo and Kagera which are located at a higher altitude compared to Kigoma, record lower temperatures.

Seasonal variation in temperature is small but both temperature and evaporation vary inversely with elevation. The mean annual air temperature at Kigoma for 1934-70 was approximately +24° C. the extremes during the same period were respectively, +36.8° C and +13.2° C. The monthly variation for five locations in the region are shown in figure 8-7.

Part II Rainfall

The Region has a tropical rain climate and experiences one long wet season (lasting from November to May) and one long dry season. This contrasts with other parts of Tanzania, especially the northern and eastern regions, where the rainy season is divided into two (the "short rains" in November and December, and the "long rains" from the end of March to the end of May).

While both wind and rainfall are mostly influenced by seasonal variations, they can also be influenced by topography. This is the case in certain areas of the Kigoma region. For example, north of Kigoma Town at the western slopes of the mountains towards the lake, the annual rainfall amount is close to 2000 mm. This heavy rainfall, the highest measured in the Region, is caused by orographic lifting of air masses. At Kigoma Meteorological Station the, predominant wind directions observed are easterly (offshore) winds in the early morning and westerly (onshore) in the afternoon, as might be expected at a location near a large body of water.

In very general terms, the country as a whole receives relatively modest amounts of rainfall. Seasonal and topographical variations, however, can actually be quite large. Annexure B contains precipitation records for some of the stations in the catchment. Mean rainfall at various stations in the catchment is indicated in figure 8-1. The hydrometerological stations are indicated in figures 8-2 and 8-3. Mean catchment rainfall calculated by applying Thiessen weights is given in figure 8-3. The mean rainfall is 1049mm.

Part III Wind

Winds start to increase in June/July with the strongest winds occurring in August/September after which a slight decrease can be observed. The wind speed are at their lowest during the rainy season from December to May.
Wind variations from station are mainly due to topographic factors. Kagera met. station record very low wind speed compared to the rest of the stations. The forests around the area most probably act as wind breakers, but the exact reason is not known. The mean monthly variation at five locations in the region are shown in figure 8-7.

Part IV Sunshine

Data records for sunshine durations for most of the stations are quite short and not continuous due to lack of recording charts.

The longest sunshine duration is observed in the period from May to October when the sky is clear. The shortest duration are observed during the rainy season when the sky is covered with clouds and thus less sunshine observed. Mean monthly variation at five locations in the region are shown in figure 8-8.

Part V Radiation

Radiation intensity is high in September when the sun's rays striking the ground vertically and the sky is clear.

The variation of radiation from station to station is not much, except for Kigoma station which is recording much lower radiation. There is no explanation why the radiation observed at Kigoma should differ much from the rest of the stations. The difference is most probably due to the procedures used to determine the calibration constants for the recording instruments. Mean monthly variation at five locations in the region are shown in figure 8-8.

Part VI Evaporation

Lack of pan evaporation data for most of the meteorological stations in Kigoma region has limited the use of the direct method to estimate evaporation.

The evaporation data available for Kigoma region is based on Penman estimates. The seasonal variations and the general evaporation pattern in the region has been investigated on the basis of available information. Mean monthly variation at five locations in the region are shown in figure 8-9.

Box 8-5: Monthly Evaporation in mm

PLACE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
KIBONDO	131	127	140	128	135	138	161	167	173	161	126	121
KAGERA	130	123	138	128	136	125	138	151	157	158	132	126
UVINZA	140	129	148	134	140	143	151	162	180	168	137	136
NGURUKA	138	137	152	142	154	147	153	169	175	176	146	133
KIGOMA	131	125	148	132	146	148	157	165	162	157	123	124

Section 7 Sedimentation

Visual appearance of the Malagarasi flow during September and October showed the water to be clear with a greenish tinge.

The expected sedimentation consists of the suspended load and the bed load. The suspended load consists of silt which for this purpose has been defined as a material that obeys Stokes law and has effective mean diameter of less than 0.08 mm.

The bed load comprises boulders, pebbles, gravel, and sand. The rate of translatory movement varies inversely to the size of the particles, so that a sorting process by the river is taking place where the particle size ranges from boulders in the hills to fine silt in the lower reaches near the sea. The process of size reduction is aided by extremely slow dissolution, by the abrasion, particularly where the velocity of flow is great and the material comprising the bed load is large.

Large boulders move only under extreme flood conditions and in general so slowly that they are never found very far from the hills. Pebbles, rounded by abrasion, also progress intermittently and very slowly, while gravel travels much faster, especially where the depth of flow is small.

Sand movement takes place in ripples or under extreme conditions by sheet movement. With ripples, the coarser particles tend to settle at the bottom of each trough and may not move on when exposed to the action of flowing water. Slightly finer particles roll up the sloping face and drop into the succeeding trough, repeating the process as each ripple passes. Still finer particles jump from ripple to ripple, while yet finer particles are thrown into temporary suspension, returning to the bed some considerable distance downstream - these two processes are termed saltation.

Experiment indicates that the bed load is most important in those stream sections with sandy bed, where the size of the material in suspension approaches the size of the bed material and where the quantity of the suspended material is small. As the difference between the size of the sediment in suspension and the size of the material in the bed increases, the relative importance of the bed load decreases.

The following scouring velocities may be given :

Box 8-6: Normal scouring velocities.

SL	MATERIAL	VELOCITY ft/s	VELOCITY mph
1	Fine Clay and mud	0.25	0.17
2	Fine sand and silt	0.50	0.34
3	Coarse sand (peas)	1.00	0.68
4	Fine gravel (beans)	2.00	1.36
5	Coarse gravel (1in)	3.00	2.04
6	Pebbles (1.5 in)	4.00	2.72
7	Heavy Shingle (3 in)	5.00	3.40

In the case of the Malagarasi project, silt load is likely to be more important than bed load and more attention must be paid to this matter in the future control.

Preliminary reconnaissance studies indicate that there is no great danger of sedimentation to the proposed reservoir. It is especially necessary to reduce the rate at which the products of land erosion removed by the rivers that is to say by soil conservation in the basin.

The method used for predicting sediment inflow and deposition amount in the reservoir is outlined below.

The first method which can be used is the prediction of an annual average sedimentation volume using an empirical formula based on surveys of existing reservoirs. However, there are no such records for any reservoir on the Malagarasi.

Method of comparison with known annual average sedimentation in similar river basin. This method is also inapplicable, as no measurement records are available on annual average sedimentation at other river basins with similar geology, topography, vegetation, and precipitation.

However, a group of U.S. geologists (Witzig, Brune-Allen, Brown-Jarvis, Churchill, and Borland) have derived the following general equation from sedimentation data of storage reservoirs where there is a mixture of bed load and suspended load.

$q_s = K \times (C/F)^{0.569}$

where q_S : average annual sedimentation ratio (cu.m/sq.km/yr)
C storage capacity (cu.m)
F is the catchment area (sq.km)
K = 0.501 as average value

Applying this equation to the Malagarasi site results in the following estimate :

$q_s = 0.501 \times (2{,}000{,}000/125{,}000)^{0.569}$ = 2.43 cum/sqkm/yr

Q_S = qs x Catchment area = 2.43 x 125,000 = 303,313 cu.m/yr

Most of this suspended load will be carried along the restricted width of the pondage and over the weir crest. For working out the deposition in the reservoir, the capacity inflow ratio may be computed.

Cr = Reservoir volume/Average annual inflow
= $2{,}000{,}000/4391 \times 10^6$ = 0.00045

As per Brune's relationship diagram, the trap efficiency of the reservoir is found to be about less than 0.5%.

Thus annual sediment trapped = 0.005 x 303,313 = 1516 Cubic meters

Over a period of 40 years, total sediment volume = 60,660 cubic meters or about 3% of the gross storage of the reservoir. Hence there will be no problem with respect to silitation.

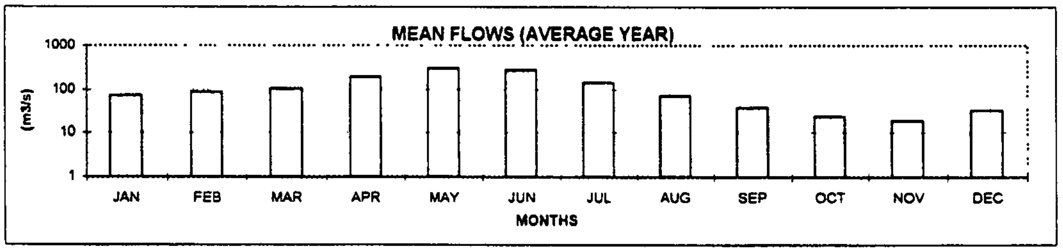
SITE MBELAGULE-4A9
STREAM MALAGARASI
BASIN MALAGARASI

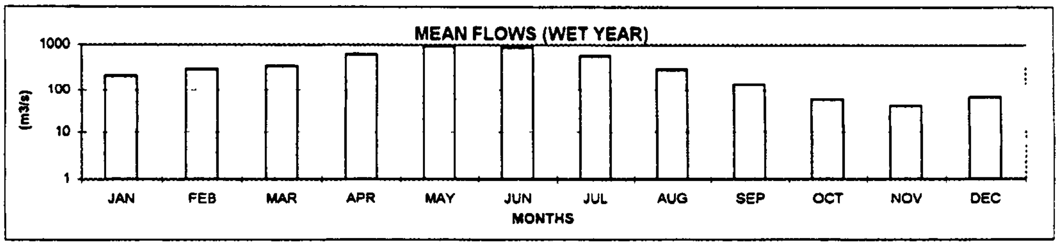
TABLE 8-1
OBSERVED MEAN FLOW AT GAUGE SITE 4A9

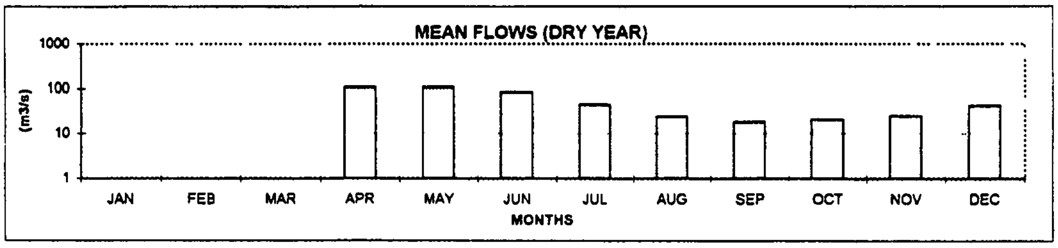
UNITS m^3/s
CATCHMENT 123,300 km^2

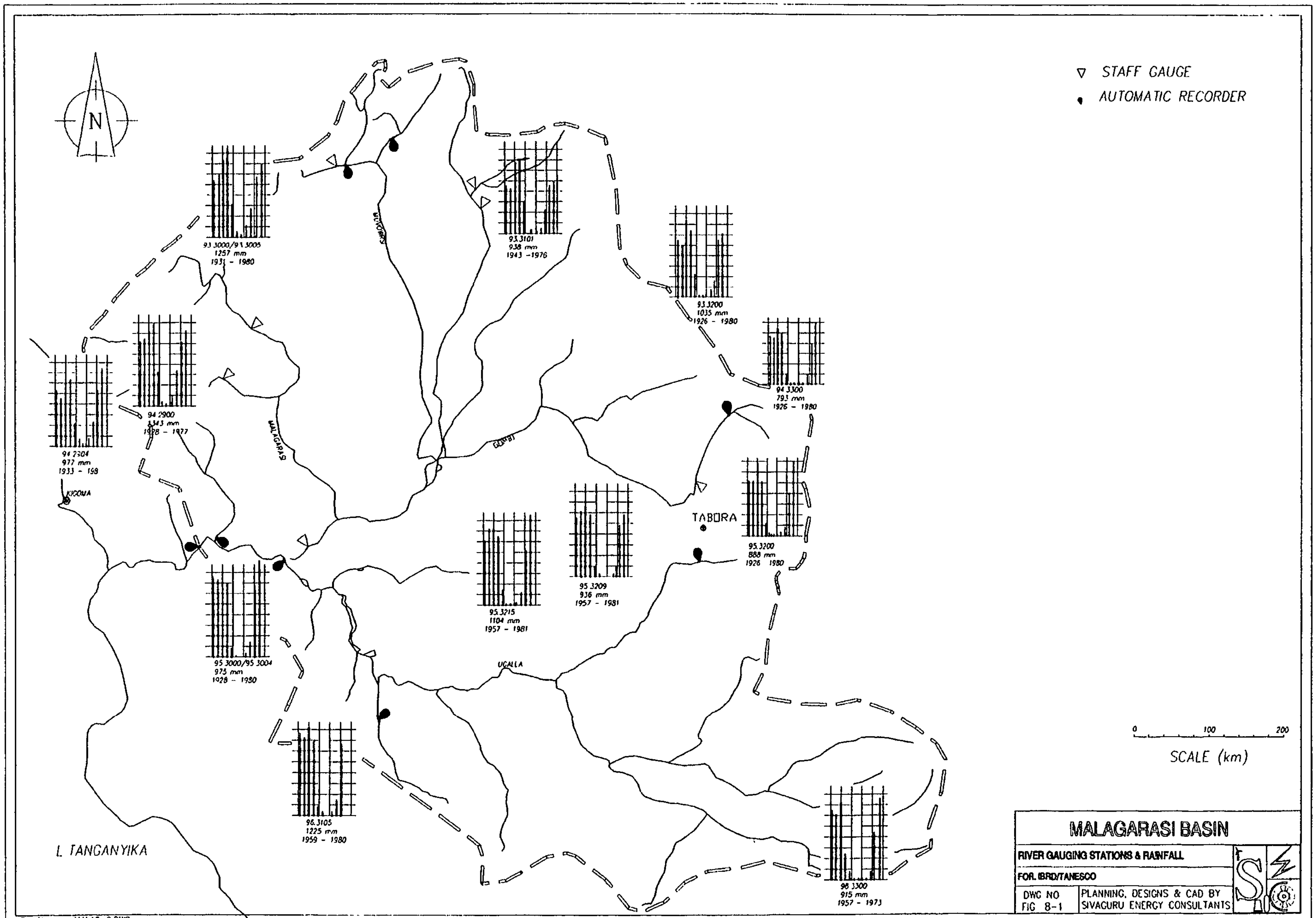
DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL MEAN	YIELD (MCM)
1967														
1968														
1969														
1970														
1971														
1972														
1973														
1974														
1975	N A	N A	N A	112 26	111 33	86 67	45 25	24 17	18 23	20 33	24 57	42 78	50 25	1124 5
1976	62 47	82 60	73 64	134 11	111 01	100 49	51 95	26 50	15 60	14 20	12 98	26 27	59 12	1869 5
1977	61 03	79 36	90 25	182 32	258 16	239 04	163 19	82 94	38 13	19 94	29 31	91 18	111 38	3512 4
1978	136 39	146 64	255 40	383 65	565 15	423 94	228 77	108 16	56 14	30 45	34 89	144 67	209 87	6618 5
1979	218 30	302 00	349 60	620 50	952 74	871 79	568 25	300 50	141 21	58 65	41 48	66 16	374 37	11806 2
1980	121 37	124 39	136 73	190 23	215 84	142 58	73 51	30 89	18 54	15 06	17 30	36 72	93 44	2954 9
1981	71 27	88 42	105 00	191 13	298 58	273 37	144 14	69 04	37 60	23 29	18 37	31 66	112 66	3553 0
1982	67 42	88 54	103 68	91 58	151 13	126 63	81 21	N A	N A	N A	N A	N A	101 57	1860 4
1983														
1984														
1985														
1986														
1987														
1988														
1989														
1990														
1991														
1992														
MEAN													139 08	4162 4
YEARS	7	7	7	8	8	8	8	7	7	7	7	7	88	
MAX	218 30	302 00	349 60	620 50	952 74	871 79	568 25	300 50	141 21	58 65	41 48	144 67	952 74	
MIN	61 03	79 36	73 64	91 58	111 01	86 67	45 25	24 17	15 60	14 20	12 98	26 27	12 98	
MEAN	105 46	130 28	159 18	238 23	332 99	283 06	169 53	91 74	46 49	25 99	25 56	62 78	139 27	
VOLUME	282 48	315 17	426 36	617 48	891 89	733 70	454 08	245 72	120 51	69 61	66 24	168 14	4391 37	
RUNOFF	2 29	2 56	. 3 46	5 01	7 23	5 95	3 68	1 99	0 98	0 56	0 54	1 36	35 62	

NOTES MAX, MIN, MEAN in cumecs VOLUME in MCM RUNOFF & MASS in mm

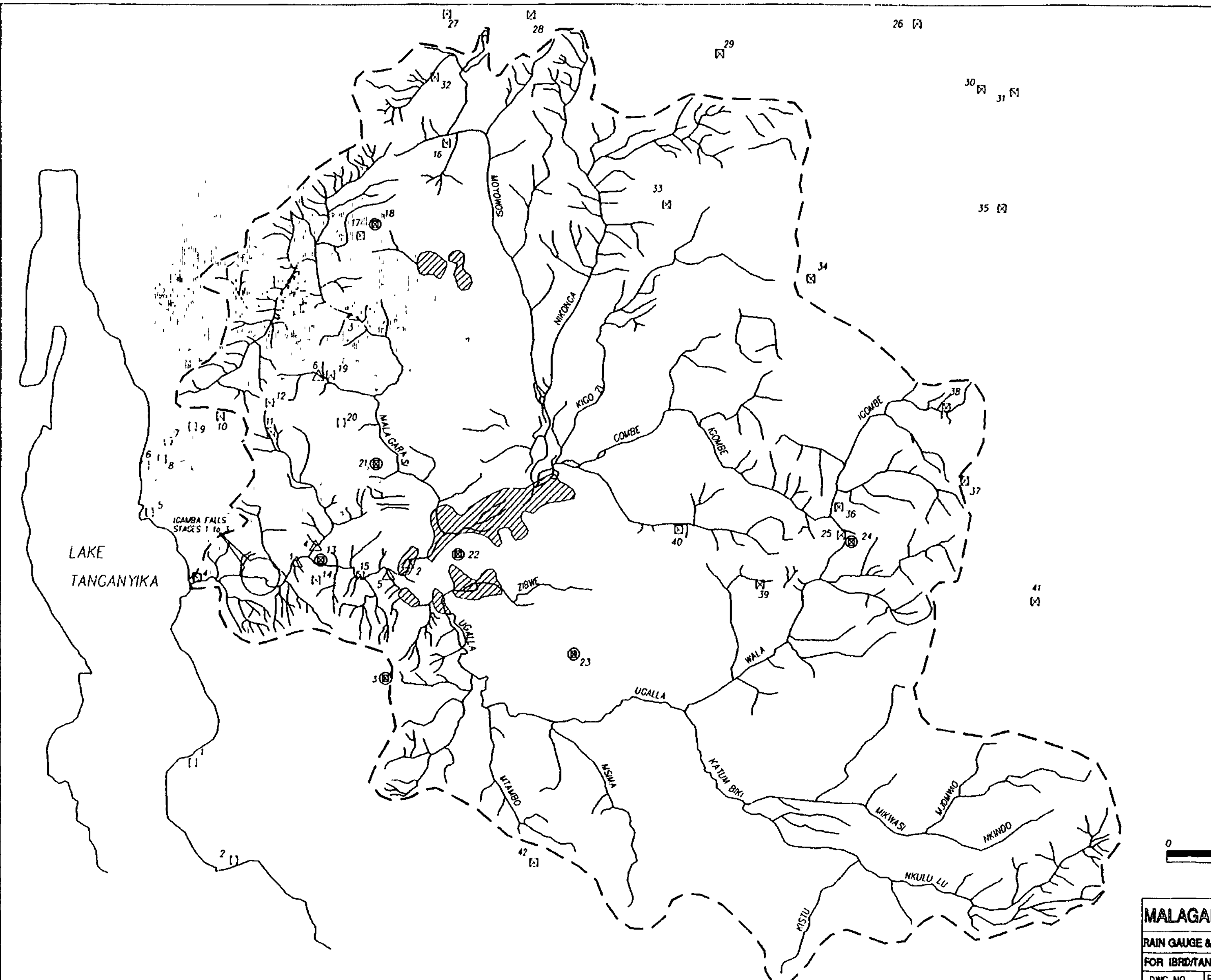








N
STAFF GAUGE
AUTOMATIC RECORDER
93.3000/93.3005
1257 mm
1931 - 1980
93.3101
938 mm
1943 -1976
93.3200
1035 mm
1926 - 1980
94.3300
793 mm
1926 - 1980
94.2900
1343 mm
1928 - 1977
94.2304
977 mm
1933 - 198
KIGOMA
MALAGARASI
GOMBE
TABORA
95.3200
888 mm
1926 1980
95.3209
936 mm
1957 - 1981
95.3215
1104 mm
1957 - 1981
95.3000/95.3004
975 mm
1928 - 1980
UGALLA
96.3105
1225 mm
1959 - 1980
98.3300
915 mm
1957 - 1973
L. TANGANYIKA
0
100
200
SCALE (km)
MALAGARASI BASIN
RIVER GAUGING STATIONS & RAINFALL
FOR. IBRD/TANESCO
DWG NO
FIG 8-1
PLANNING, DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS
File Name - MALAG-6.DWG



LEGEND

- RAINFALL STATIONS
- METEROLOGICAL STATION
- SWAMPS

STREAM GAUGING STATIONS		
	NUMBER	NAME
1	10/4A9	MBELAGULE
2	111/4A8	RAILWAY BDGE
3	11/4A5	TARAGI
4	12/4AA2	PWAGA
5	57/4AH1	SINDI
6	13/4AB1	MAKERE

RAIN GAUGING STATIONS		
	NUMBER	NAME
1	95 2901	MGAMBO
2	96 3005	KALGA
3	95 3007	MAGUNGA
4	95 2900	ILAGALA
5	94 2904	KIGOMA
6	94 2909	KASEGELA
7	94 2907	MATIAZO
8	94 2911	KALINZI
9	94 2906	HERI
10	94 2900	MULERA
11	94 3000	KASULU
12	94 3003	BUHERO BUGANDA
13	95 3008	UVINZA
14	95 3000	UVINZA SALT MINES
15	95 3003	JNYONGA
16	93 3002	KAKONKO
17	93 3005	KIBANDA
18	93 3007	KIBONDO
19	94 3002	MAKERE
20	94 3006	KWITANGA
21	94 3009	KAGLRA
22	95 3105	NGURUKU
23	95 3108	LUMBE
24	95 32012	TABORA
25	95 32000	TABORA OBS
26	92 33044	UKIRIGURU
27		NYAMBUGOMBF
28		BIHARAMULU
29		GEITA GOLD MINE
30		NGUDA
31		MALYA DAM
32	93 3003	NYARWONGA
33		USHIROMBO
34		KAHAMA
35		OLD SHINYANGA
36		ITAGA
37		NDALA
38		MWANHALA
39		USOKE
40		URAMBO
41		KISSENGI
42		URUWIRA

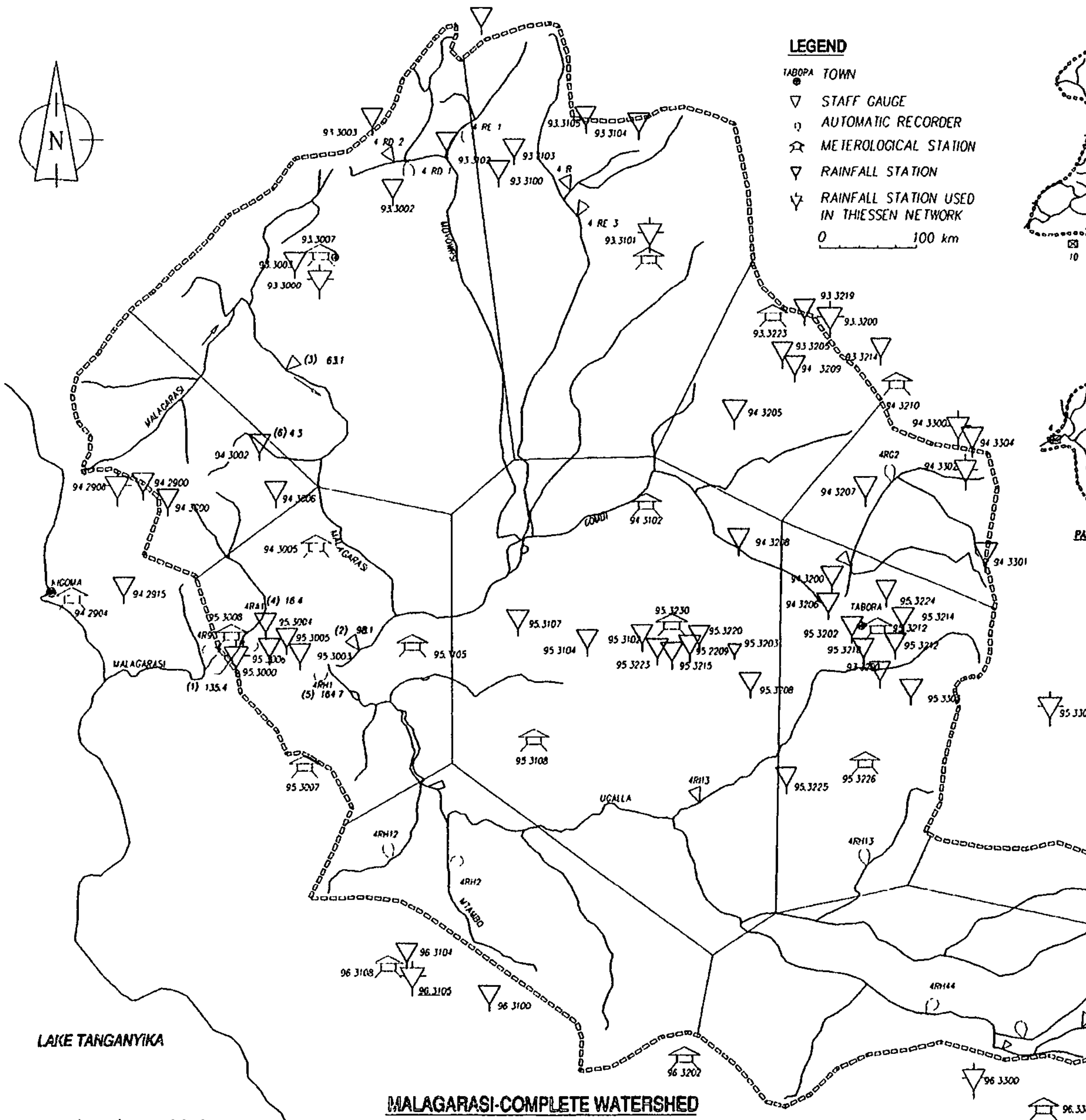
MALAGARASI DRAINAGE NETWORK

RAIN GAUGE & METEOROLOGICAL STATIONS

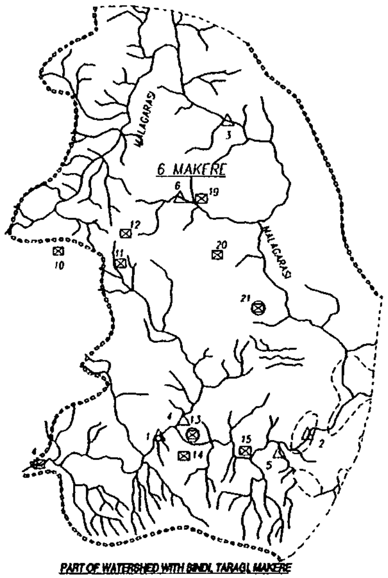
FOR IBRD/TANESCO

DWG NO FIG 8-2	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

File Name - MAL-CAT DWG



MALAGARASI-COMPLETE WATERSHED



PART OF WATERSHED WITH SINDI, TARAGI, MAKERE RAILWAY BRIDGE, PWAGA and MELEGULE

STREAM GAUGING STATIONS

△ STREAM GAUGING STATIONS

STATION	NUMBER	NAME
1	10/4A9	MBELAGULE
2	111/4A8	RAILWAY BR
3	11/4A5	TARAGI
4.	12/4AA2	PWAGA
5	57/4AHI	SINDI
6	13/4ABI	MAKERF

(2) 98.1 STATION NUMBER WITH MEAN ANNUAL FLOW (m^3/s)

0 40 80
KILOMETRES

SINDI (57/4AH1)----(5)
TARAGI ----------(3)
MAKERE ----------(6)
RAILWAY BRIDGE----(2)
PWAGA ----------(4)
MELEGULE --------(1)

DETAILS OF GAUGE SITE & FLOW RECORDS

TARAGI BRIDGE (11/4A5)
D A 8525km²
P R 1971–80 (10Years)
O = 63 1m³/sec

MAKERE RIVER (12/14 AB1)
D A 550km²
P R 1962–82 (21Years)
O = 4 3m³/sec

CENTRAL RAILWAY BRIDGE (111/4A8)
D A 66,300km²
P R 1977–80 (4Years)
O = 98 1m³/sec

UGALLA RIVER (SINDI 57/4AH1)
D A 51,780km²
P R 1976–80 (5Years)
O = 164 7m³/sec

RUCHUGI RIVER (PWAGA 12/4AA2)
D A 2825km²
P R. 1975–82 (8Years)
O = 16 4m³/sec

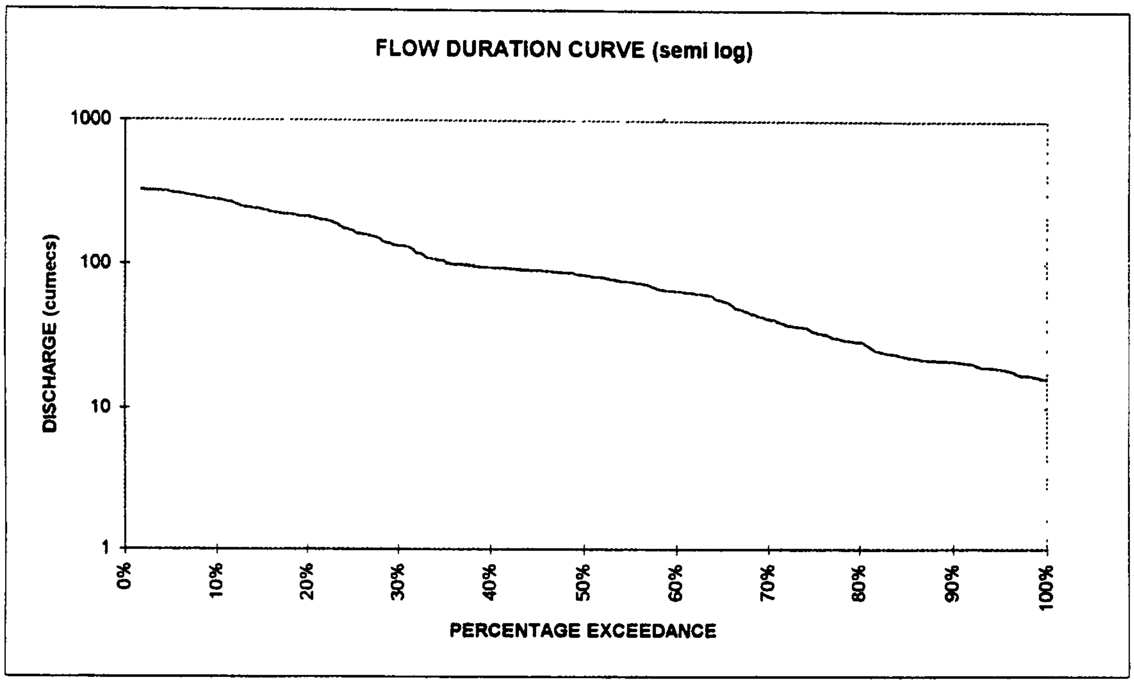
MBELEGULE (10/4A9)
D A 123,300km²
P R 1975–82 (8Years)
O = 135 4m³/sec

NOTES:

After recipt of flows from TARAGI, MAKERE, PWAGA, and UGALLA the aggregate flow should be 98 1+16 4+164 7 = 279 2 against 135 43 recorded at MBELEGULE Detailed water balance study in the River Basin may indicate influence of swamps and Evaporation from swamps

MALAGARASI BASIN	
HYDROMETEROLOGICAL STATIONS & WATER BALANCE	
FOR. IBRD/TANESCO	
DWG NO FIG 8-3	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

FIGURE : 8-4
FLOW DURATION CURVE IN AVERAGE YEAR



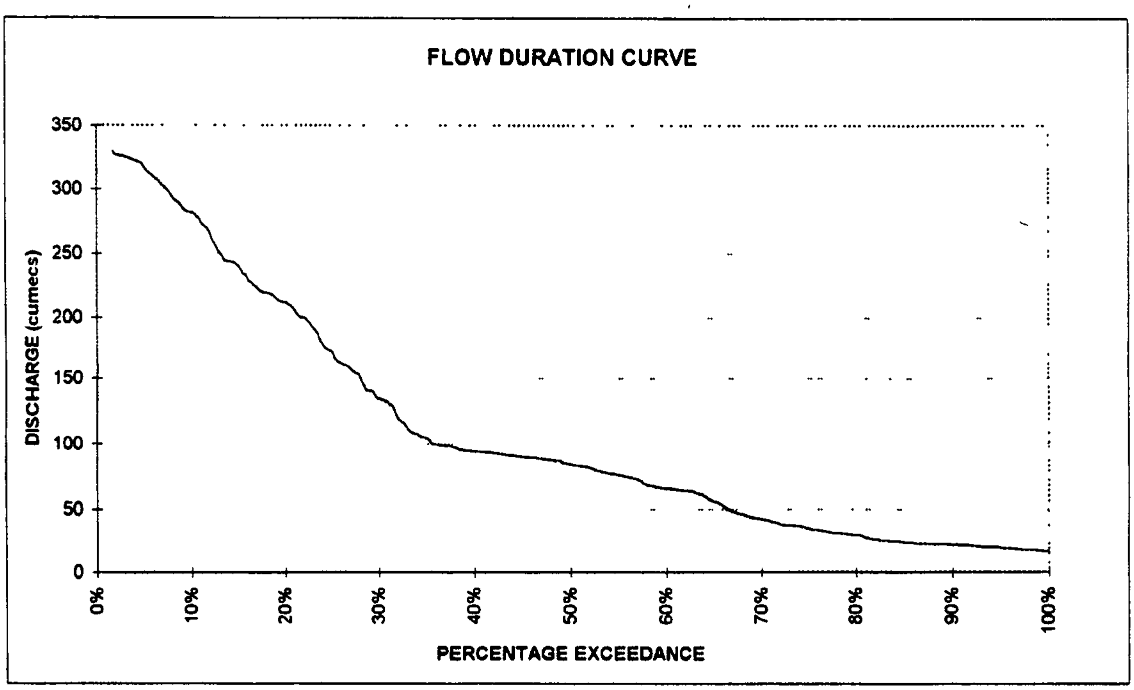
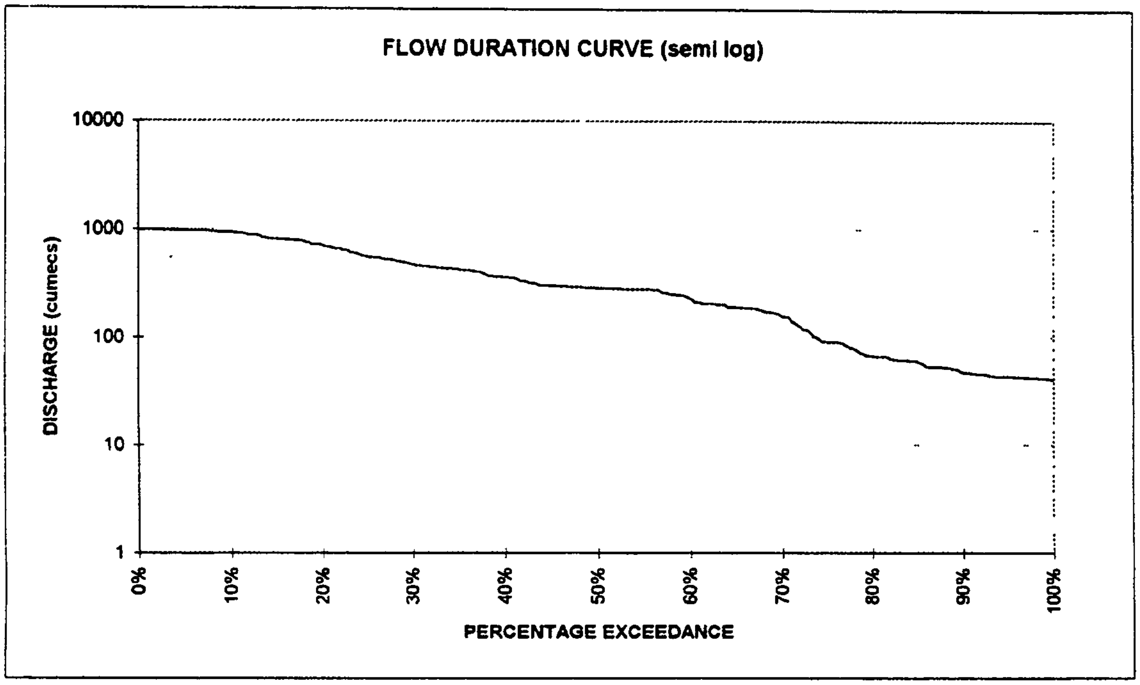


FIGURE : 8-5
FLOW DURATION CURVE IN A WET YEAR



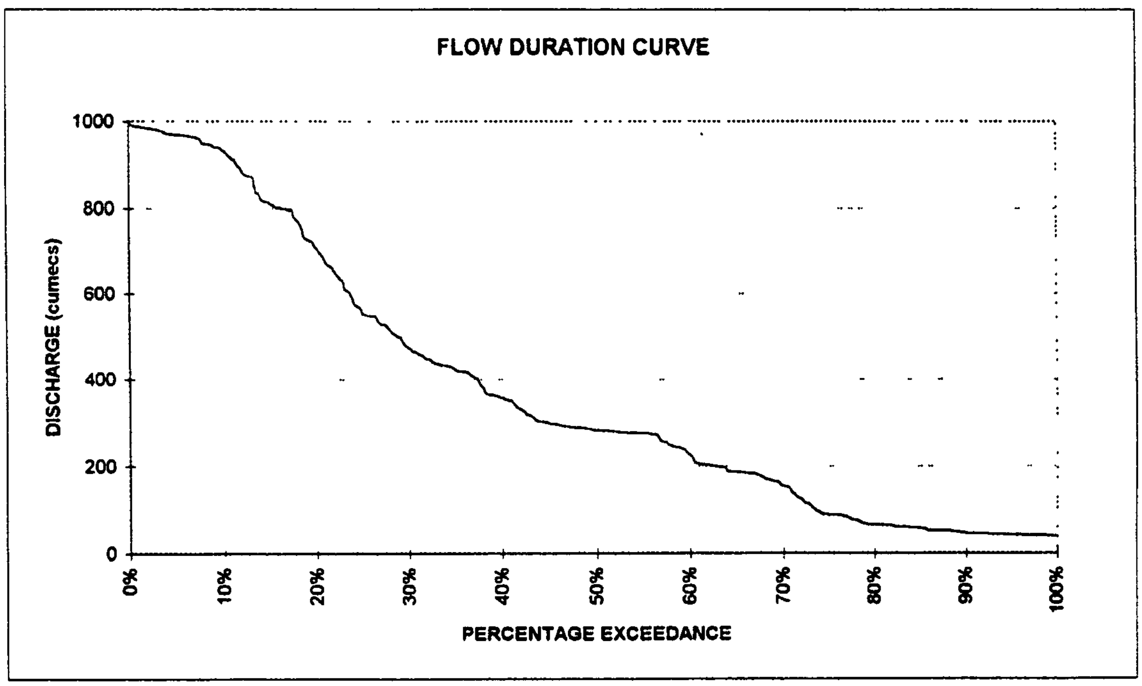
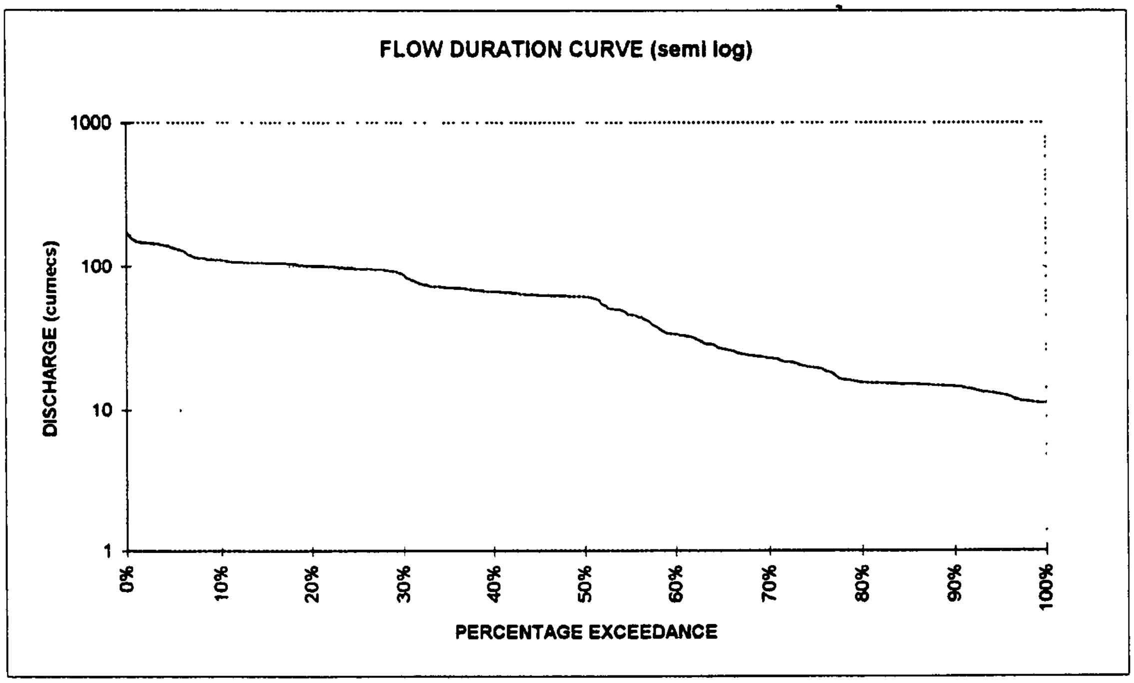
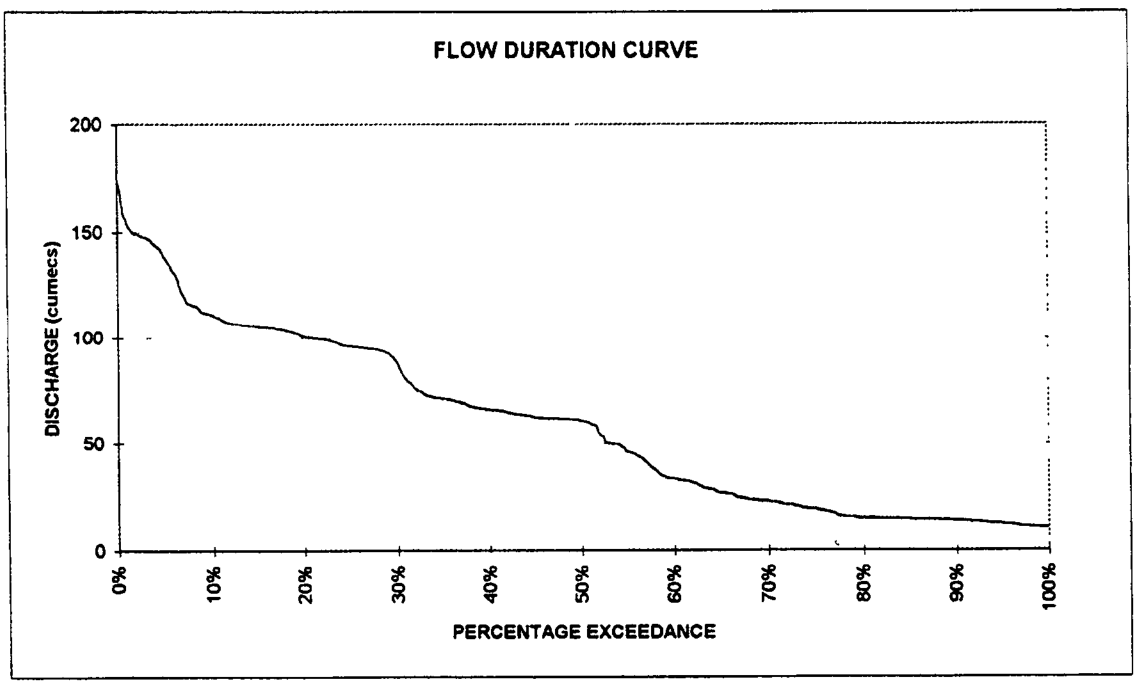
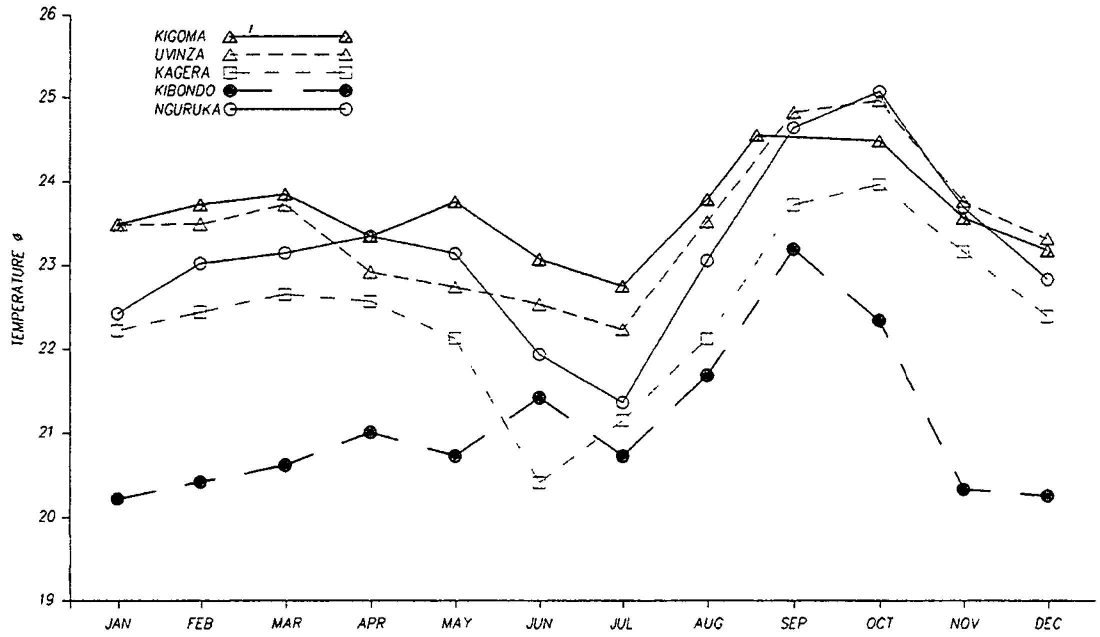


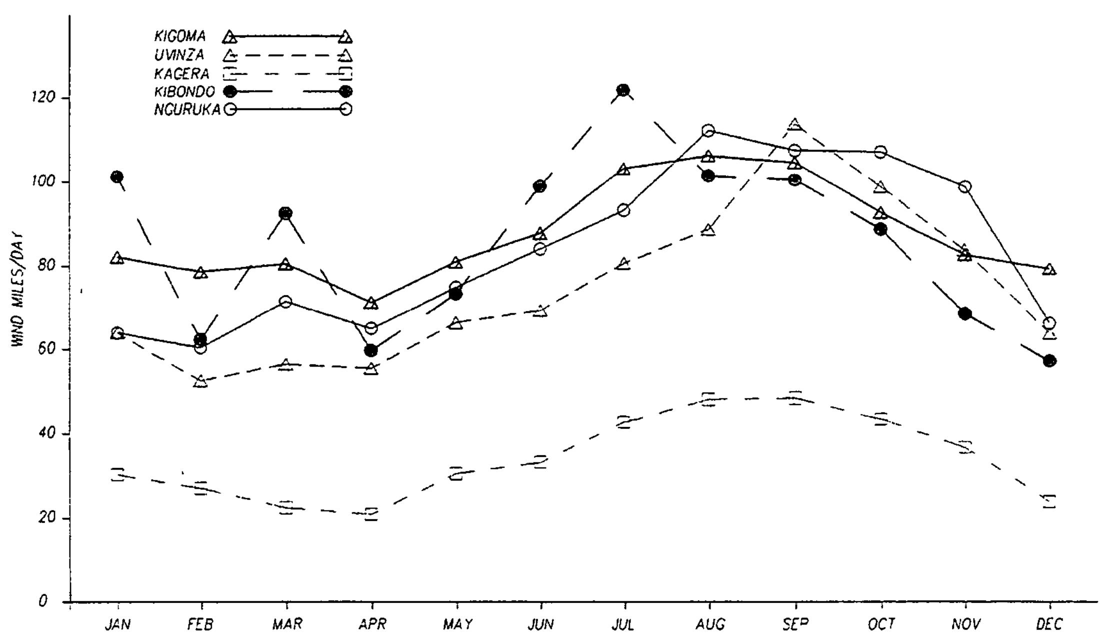
FIGURE . 8-6
FLOW DURATION CURVE IN A DRY YEAR







MEAN MONTHLY TEMPERATURE 1976-1988, (1971-1988 KIGOMA MET)



MEAN MONTHLY RUN OF WIND IN MILES/DAY 1976-1988, (1971-1988 KIGOMA MET)

MALAGARASI HYDROPOWER PROJECTS

MEAN MONTHLY TEMPERATURE AND WIND RUN IN KIGOMA REGION

FOR THE WORLD BANK/TANESCO

DWG NO FIG 8-7

PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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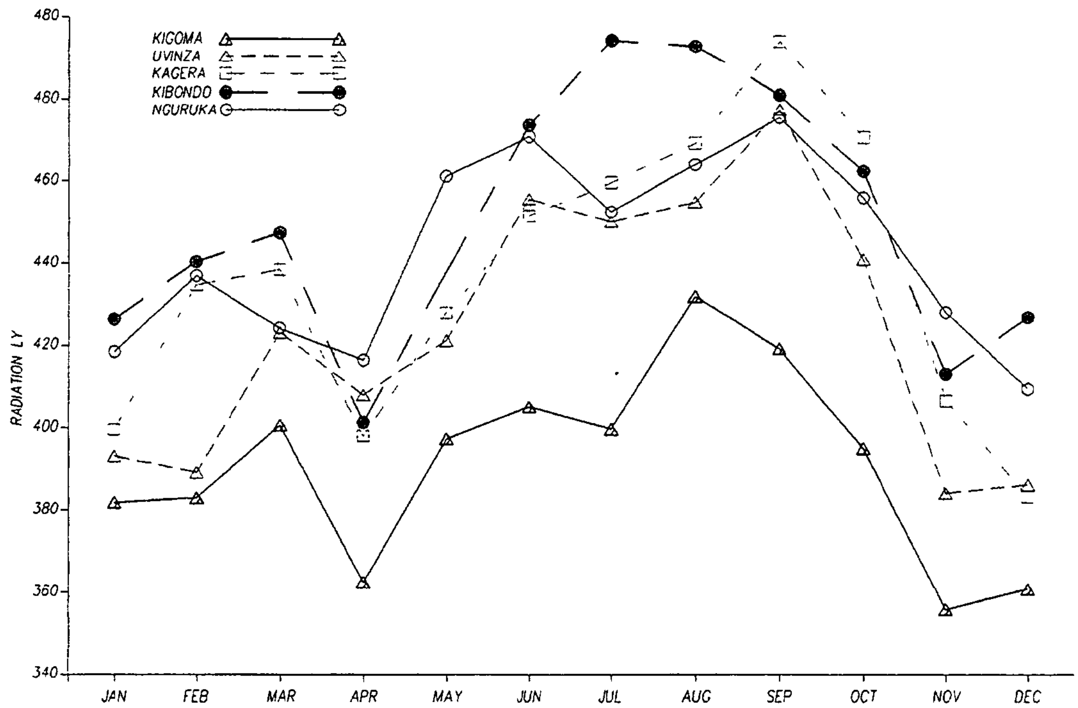
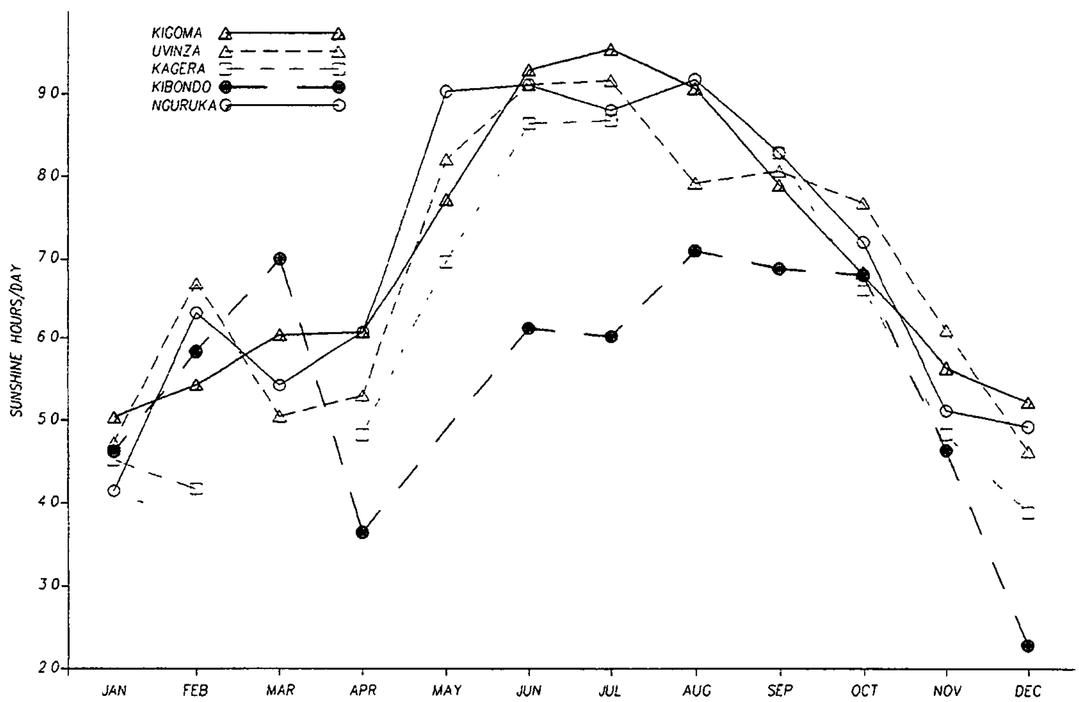


MEAN MONTHLY RADIATION 1977-1988, KIGOMA (1971-1988)



MEAN MONTHLY NUMBER OF SUNSHINE HOURS/DAY 1977-1988, KIGOMA (1871-1988)

MALAGARASI HYDROPOWER PROJECTS

MEAN MONTHLY RADIATION AND SUNSHINE HOURS IN KIGOMA REGION

FOR: THE WORLD BANK/TANESCO

DWG NO	PLANNING DESIGNS & CAD BY
FIG: 8-8	SIVAGURU ENERGY CONSULTANTS

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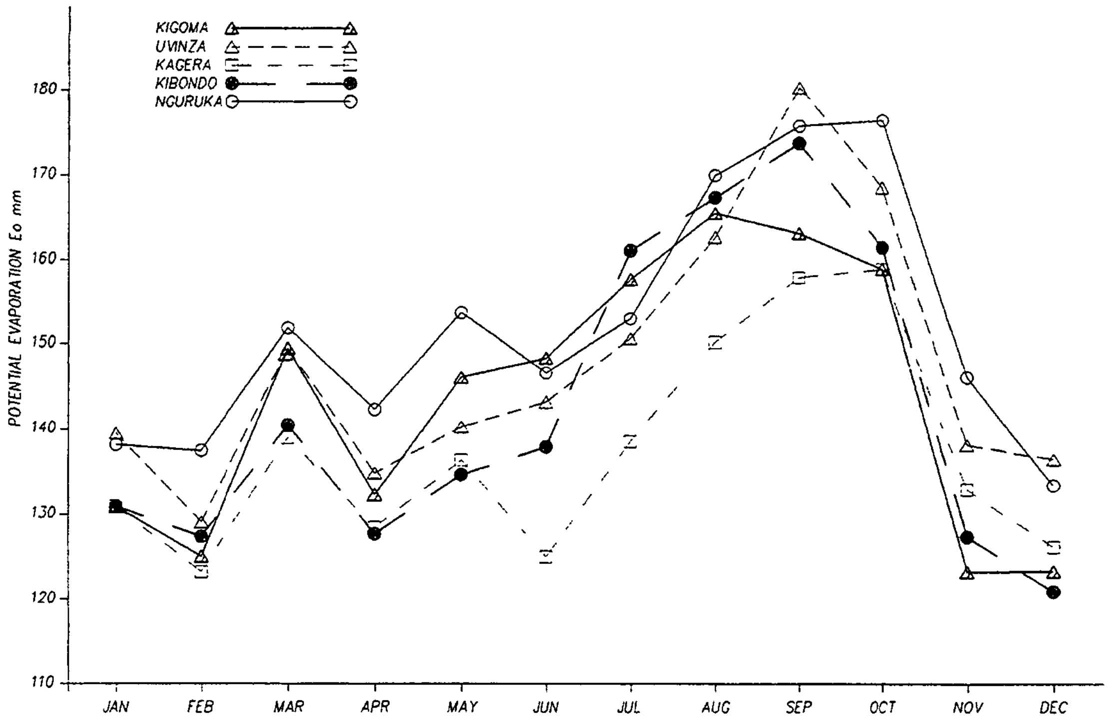

MEAN MONTHLY POTENTIAL EVAPORATION KIGOMA REGION

MALAGARASI HYDROPOWER PROJECTS	
MEAN MONTHLY POTENTIAL EVAPORATION IN KIGOMA REGION	
FOR: THE WORLD BANK/TANESCO	
DWG NO: FIG: 8-9	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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Chapter 9 Power and Energy Studies

Section 1 Description

The power and energy studies are carried out to predict the pattern of power, energy output of the plant, estimate losses and arrive at the optimal installed capacity of the power plant based on the available flow at the project site. Other features of the study include formulating operating strategies of the power plant.

Section 2 Reservoir Characteristics

For carrying out the power and energy studies, the reservoir characteristics were calculated from the 1:10000 aerial topographic maps which are existing. The contours on the map were digitized and the contours were further interpolated to contour intervals of 1m by use of a Digital Terrain modelling software. The area enclosed by each contour at the diversion weir site was calculated. The incremental storage between any two levels h_1 and h_2 is given by the following cone formula.

$A = A_1 + A_2 + \sqrt{(A_1A_2)}$ where A_1 and A_2 are area in m^2 at elevation h_1 and h_2 respectively.

$\Delta V = A(h_1 - h_2)/3$ cubic meters.

$V = \Sigma\Delta V$ cubic meters.

The area capacity characteristics are given in figure 9-1.

Section 3 Methodology

The methodology used for deriving the inflow sequence at the proposed diversion site has been dealt with in chapter 8. Here we discuss how this sequence has been used to compute the power and energy output of the power station.

A continuous period of at least ten years is usually acceptable for hydropower studies for small and medium projects. In the present case, flow records are available for only a six year period. As the proposed utilization of flows for generation is small in magnitude compared to the annual mean flow, and the project does not posses any regulation capabilities, the six year period is taken as sufficient to be representative of the extreme hydrological conditions which were likely to recur during the lifetime of the project. This representative period is the hydrological years 1975 to 1982. The average yield of Malagarasi for this period at the proposed site is 139.1 cumecs with a yield of 4391 MCM. A set of extreme conditions in the above period were identified to carry out the power and energy studies.

The year with maximum yield was 1979 with a mean annual flow of 374.4 cumecs and a yield of 11806.2 MCM, the year with minimum yield was 1976 with a mean annual flow of 93.4 cumecs yield of 1869.5 MCM. The year in which the yield was closest to the six year mean with monthly distribution of runoff corresponding to the average of the six years is 1981 with a mean annual flow of 112.6 cumecs and yield of 3553.0 MCM. Thus 1981 is an average year, 1979 is a wet year, and 1976 is a dry year. In any actual year, the energy output from the plant would be between the extreme values as determined from the above.

Thus the evaluation was carried out according to the series of daily average discharges for the 6-year period 1975 to1982.

The installed capacity and the choice of the number of units was dictated with respect to the load demand. The demand expected when the plant becomes operational is about 4MW. The number of units was decided by the pricing of the turbines and generator as well as to provide flexibility in operation. Various sets of calculations on energy output were performed with different installed capacities. Based on above it has been decided that for an optimum development the installed capacity should be 8MW and the power station will consist of two units. (2 x 4MW). As a drawdown of about 2m is permitted, considering the fairly uniform head which will be obtained during the year, vertical shaft Kaplan turbines with adjustable blades and wicket gates have been preferred and shown in the design drawings.

Section 4 Important Features of the Calculations

The power and energy studies have been carried out with a computer program which uses the daily flow data series at the diversion weir site. The program models all the important conditions and constraints which are likely to be encountered during actual operation of the project. Some of the key features of the software include :

1. Use of daily flow data in working out the power and energy computations. This is necessary as the reservoirs is quite small and the water levels increase rapidly for moderate inflows thus giving rise to rapid increase in head. Use of monthly models which assume linear variation of head during the month as well as those based on calculating the area under the duration curve underestimate the average head severely and consequently gives a pessimistic value of the power and energy.

2. Accounting for the efficiency variation of the turbines which is a function of head and discharge. This was accounted by using model test characteristics obtained from equipment manufacturers and adjusting them to prototype values.

3. Operating constraints on power output caused by head which dictates the maximum discharge which the turbine can allow.

4. Accounting of all hydraulic losses which would occur in the waterways such as intake, canal, penstock, draft tube and tailrace.

5. Operating the power station to maximize the energy production from available flows. This is achieved by operating the units at best efficiency operating point during the dry season and full gate position during the wet season. The determination of the best efficiency and full gate position in case of projects with long waterways is obtained through the solution of non-linear simultaneous equations.

6. Giving due consideration to all other conditions such as evaporation from lake, mandatory releases for downstream users, irrigation requirements etc.

7. Accurate prediction of spill volume on hourly basis and spill hours which is used in predicting the high tail water level as this affects the power output.

8. Summarising the daily computation results into monthly aggregates for easy comprehension. The summary tables of the power study provide the starting and ending values of the water levels, heads and storages for each month and the true average of various levels, heads and power taking into account the non-linear variations in these parameters during the month.

It was noted that the difference in energy output between the conventional monthly computations and the daily computations is as much as 30%. Thus in effect a simulation of the entire system has been performed giving an accurate picture of the power and energy output which would be obtained during actual operation.

Section 5 Case Studies

The following case studies for the power and energy output were done. They are indicated below.

1. Operation of the power station in a typical average year 1971 with an installed capacity of 1 x 4MW, 1 x 6MW and 2 x 4MW.

2. Operation of the power station in a typical wet year 1979 with an installed capacity of 1 x 4MW, 1 x 6MW and 2 x 4MW.

3. Operation of the power station in a typical dry year 1976 with an installed capacity of 1 x 4MW, 1 x 6 MW and 2 x 4MW.

Section 6 Results

Detailed performance and operating tables are presented in tables 9-1, 9-2 and 9-3 for the average, wet and dry years respectively for the 2 x 4MW option. Each table brings out among other things, the following basic twenty five quantities summarized to monthly values which are sufficient to completely describe the operation of the power plant.

1. Start Volume: The volume of water available in the reservoir on the first day of the month in MCM.

2. Start Level: The level of the lake calculated from the level vs volume characteristics of the reservoir given in figure 8-1 for the start volume of water above. The value is given in masl.

3. Inflow Volume: The total inflow into the reservoir in MCM for the month as determined from the section on hydrology. This includes the flow of the river as

well as the regulated power station discharge of any upstream stations which are included in the model.

4. Turbine Volume: The total quantity of water routed through the turbines in the entire month for power production in MCM.

5. Lake Surface: The mean surface area of the lake during the month in square km. This influences the quantity of water which evaporates from the surface.

6. Evap Volume: The total quantity of water which evaporates from the free surface of the lake during the month in MCM. This is dependent upon the climatological conditions and are fixed through the pan evaporation data.

7. Irrigation release: This gives the quantity of water abstracted for irrigation from the lake either through lift or gravity. This is assumed to be nil in this study as the project is designed mainly for power production.

8. Mandatory release: This gives the quantity of water which must be released for downstream uses. Assumed to be nil in this study as the projects are run of river and the design and operation is such that no change in flow pattern of the river is contemplated.

9. Spill Volume: The volume of water which have to be let out over the spillways in MCM due to limitation of the turbine capacity and absence of incremental storage in the reservoir. This is also the quantity which at the present stage cannot be economically routed through the turbines.

10. Spill Hours: The number of hours for which this spill occurs in a month.

11. Finish Storage: The volume of water available in the reservoir in MCM on the last day of the month after distributing the inflow between the power station and spill, storage and accounting for evaporation.

12. Finish Level: The water level in the reservoir on the last day of the month corresponding to the above computed finish storage. Values are given in masl level.

13. Change in Storage: The net volume change in the reservoir for each month. Positive values indicate that the reservoir was built up and negative values indicate that the reservoir was drawn down.

14. Average Station discharge: The discharge through the turbines in the particular month in cubic meters per second.

15. Hours Run This indicates how many hours the power station could be operated in any day of the month at the particular station discharge above. In the wet season this is 24 hours and the station generates continuously. In the dry season a value of 6 hours indicates that the inflow is stored for 18 hours and used through the turbines in 6 hours for peaking. The total operating hours is given in the last row.

16. Units Run: This indicates the number of machines which are on load.

17. Average Gross Head: This indicates the gross head available to the turbines. It is calculated as the difference between the reservoir level and the tailwater level.

18. Average Loss: This indicates the sum of the hydraulic losses in the waterways. Typically this includes the intake, trash rake, draft tube etc but does not include the losses in the turbine.

19. Start Net Head: The net head available to the turbine on the first day of each month

20. Finish Net Head: The net head available to the turbine on the last day of each month

21. Average Net Head: The mean net head during the month. This value is not the average the quantities 18 and 19 as the variation of net head may not be linear during the month

22. Average TWL: This is the average tailwater level during the month given in meters above sea level.

23. Average power: This value gives the average power output available from the HT Terminals of the step up transformer in MW. This is calculated by computing the mechanical power output of the turbine as per the net head and discharge, then subtracting losses in generator to get generator output. A further one percent of this is subtracted for consumption within the power house for various auxiliaries. Then the losses in the power transformer and bus is subtracted to give the net power available.

24. Energy: This gives the monthwise production of energy in GWh.

25. Net Storage: The net change in the reservoir volume for the year. This should be as small as possible so that the cycle may be repeated in the following year.

In the last row of the table, the mean and sum of various quantities are given. The above figures are sufficient to fully describe the performance of the plant in any particular type of hydrological year. From the above results the following may be inferred.

Section 7 Conclusions

The results of the studies are summarized below.

Box 9-1 Summary of Energy Outputs

Installed Capacity (MW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
1 x 4	34.9	35.0	33.2
1 x 6	52.6	52.6	45.8
2 x 4	64.4	71.6	56.2

The annual energy production in an average year is about 65.0 GWh. The inflow volume is 3570 MCM and out of this 1132 MCM were routed through the turbines giving an utilization of 31.7%. In a wet year the inflow volume was 11808 MCM and 1261 MCM were routed through the turbines giving an utilization of 10.7%. In a wet year the flows are significantly more. But only one year in the selected cycle has flows equal to the wet year. The annual inflow volume in a dry year is 1862 MCM and 986 MCM were routed through the turbines giving an utilization 52.9%.

In the selected hydrological period only one year is with the reduced flow equal to the dry year whereas most of the years have flows exceeding the average year. Thus in most years 65 GWh is assured.

The plant load factor for each type of year is
Average year = 91.3%, Wet year = 100% and dry year = 80.1%

Further from the tables, it is seen that in an average year, 8MW can be generated continuously for the months January to September. In October, the power output drops to 4.87MW and in November to 3.79MW. In December, the output rises to 6.57MW.

In a wet year, 8MW can be generated continuously throughout the year

In a dry year, 8MW can be generated continuously from January to July. During the month August generation drops to 5.53 MW, and falls to a minimum of 2.66 MW in November.

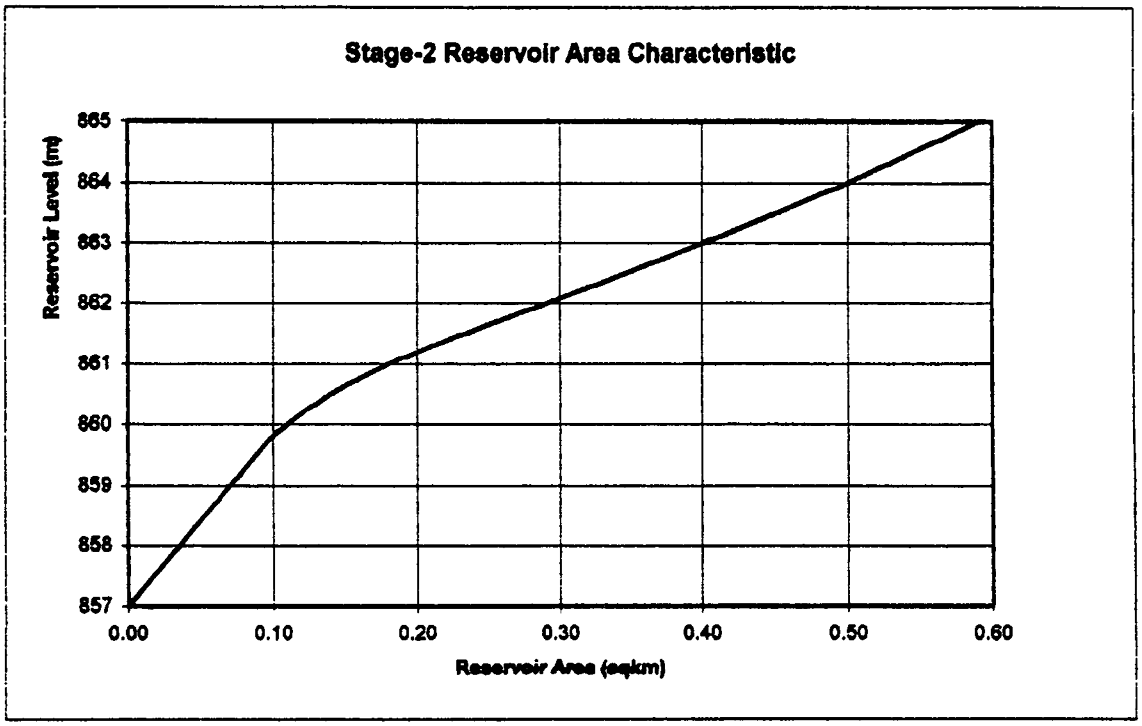
A Kaplan turbine can operate satisfactorily down to about 60% of its rated power by adjusting the wicket gates and runner blades. Hence if 2.66MW corresponds to 60% capacity, the turbine rating is 4.5MW. Hence unit capacity is fixed at 4MW.

As initially, the power plant will be the only generating plant operating into the Kigoma grid system and because during the initial years load may be only about 4MW, it is instructive to examine the adequacy of capacity and energy. The only period when capacity and energy shortage is likely to develop is during the months of September, October and November of a very critical year such as 1976. But these hydrologic conditions are very rarely going to arise. Also it will be easy to provide the required additional capacity either by use of the existing diesel station or curtailing unimportant load for the short period.

Hence summarizing, the proposed installed capacity is adequate to serve the immediate load demand of the region and provision has been made for growth in the demand. When the demand rises to 8MW, then additional cascade stations can be implemented to take care of the peak load.

In the initial period, the units can be alternately operated every month so as to ensure adequate maintenance and extend the operating life.

FIGURE: 9-1
STAGE 2 LAKE AREA AND CAPACITY CURVES



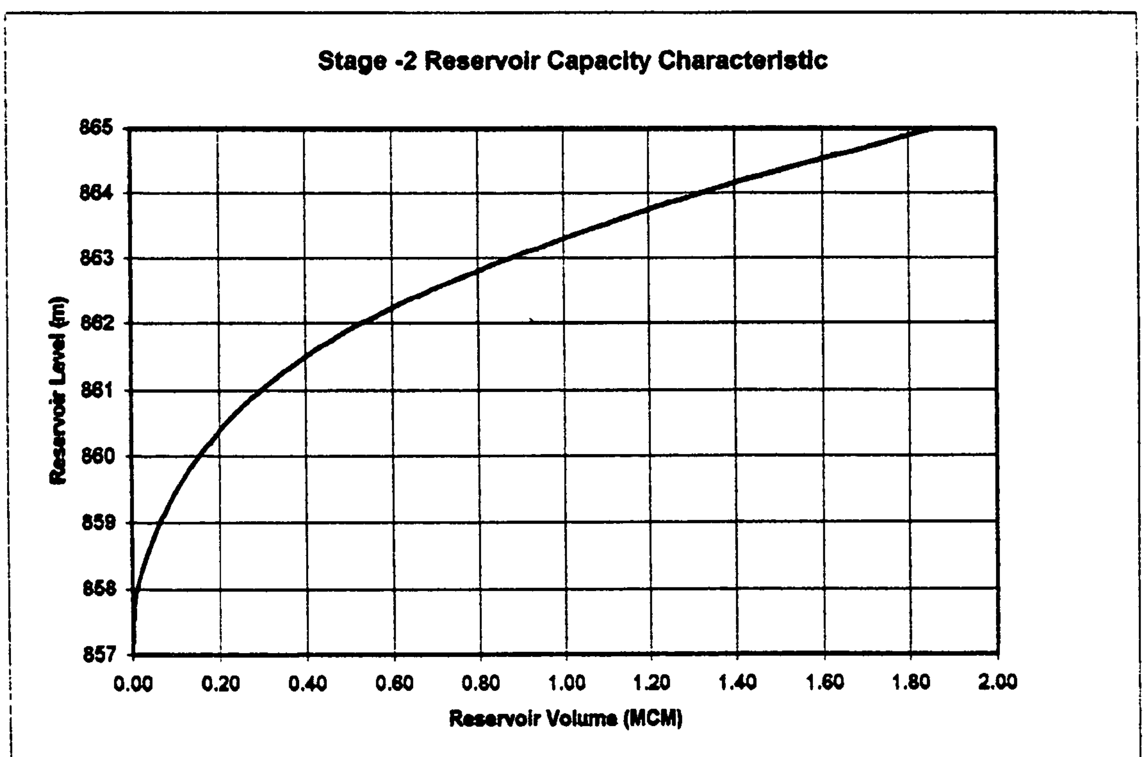
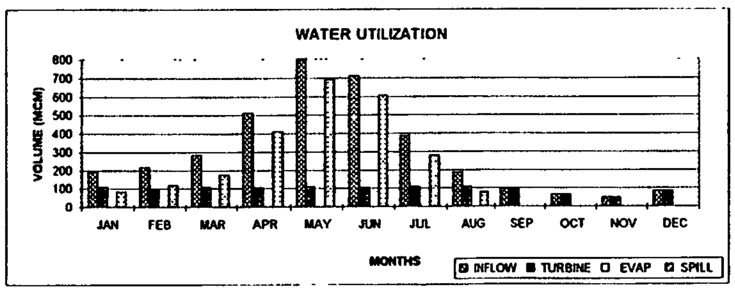
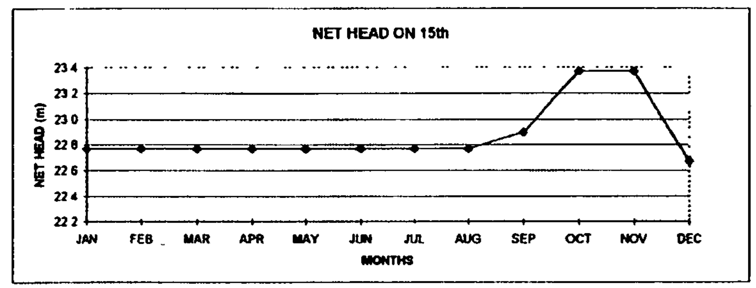


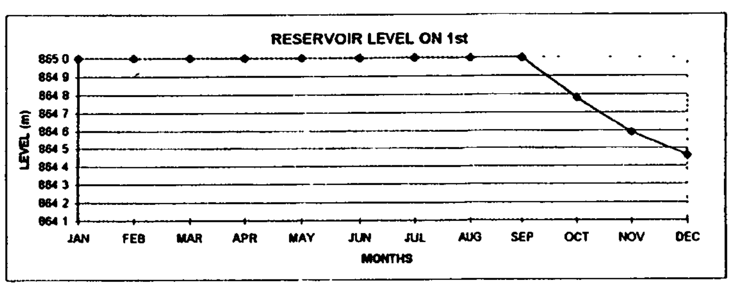
TABLE 9-1
MALAGARASI STAGE-2 PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL AVERAGE YEAR FOR 2 x 4 MW (1981)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM	MAND RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS
JAN	1.87	865.00	190.97	107.14	0.59	0.08	0.00	0.00	1.87	865.00	83.75	744.00
FEB	1.87	865.00	213.86	96.77	0.59	0.08	0.00	0.00	1.87	865.00	117.01	672.00
MAR	1.87	865.00	281.23	107.14	0.59	0.08	0.00	0.00	1.87	865.00	174.01	744.00
APR	1.87	865.00	512.44	103.68	0.59	0.08	0.00	0.00	1.87	865.00	408.68	720.00
MAY	1.87	865.00	799.77	107.14	0.59	0.09	0.00	0.00	1.87	865.00	692.55	744.00
JUN	1.87	865.00	708.65	103.68	0.59	0.09	0.00	0.00	1.87	865.00	604.88	720.00
JUL	1.87	865.00	385.96	107.14	0.59	0.11	0.00	0.00	1.87	865.00	278.72	744.00
AUG	1.87	865.00	184.81	107.14	0.59	0.12	0.00	0.00	1.87	865.00	77.56	744.00
SEP	1.87	865.00	97.46	97.46	0.59	0.12	0.00	0.00	1.75	864.78	0.00	0.00
OCT	1.75	864.78	62.41	62.41	0.57	0.10	0.00	0.00	1.64	864.59	0.00	0.00
NOV	1.64	864.59	47.69	47.69	0.55	0.07	0.00	0.00	1.57	864.46	0.00	0.00
DEC	1.57	864.46	84.91	84.91	0.54	0.07	0.00	0.00	1.50	864.33	0.00	0.00
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)
		864.90	3570.15	1132.27	0.58	1.09	0.00	0.00		864.85	2437.15	5832.00

MONTH	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	6.07
FEB	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	5.48
MAR	0.00	40,00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	6.07
APR	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	5.87
MAY	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	6.07
JUN	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	5.87
JUL	0.00	40.00	24.00	2	24.45	1.69	22.77	22.77	22.77	840.55	8.15	6.07
AUG	0.00	40.00	24.00	2	24.45	1.69	22.77	22.90	22.77	840.55	8.18	6.08
SEP	-0.12	37.60	24.00	2	24.48	1.57	22.90	23.37	22.90	840.52	7.79	5.61
OCT	-0.10	23.30	24.00	2	24.40	1.03	23.37	23.37	23.37	840.38	4.87	3.63
NOV	-0.07	18.40	24.00	2	24.27	0.90	23.37	22.67	23.37	840.33	3.79	2.73
DEC	-0.07	31.70	24.00	2	23.99	1.32	22.67	23.67	22.67	840.47	6.57	4.89
	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
	-0.36	35.92	8760.00		24.40	1.53	22.87	22.95	22.87	840.51	7.36	64.42







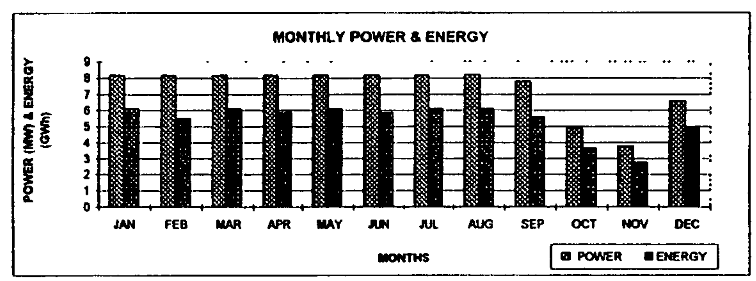
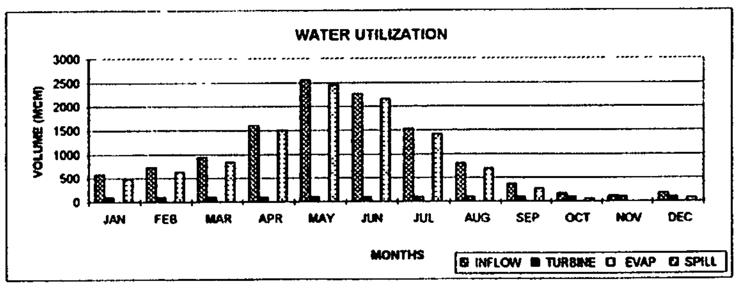
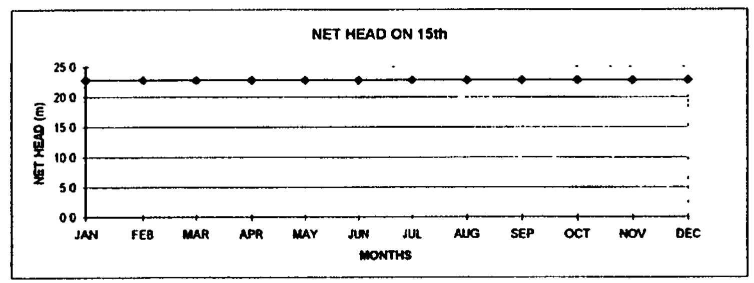


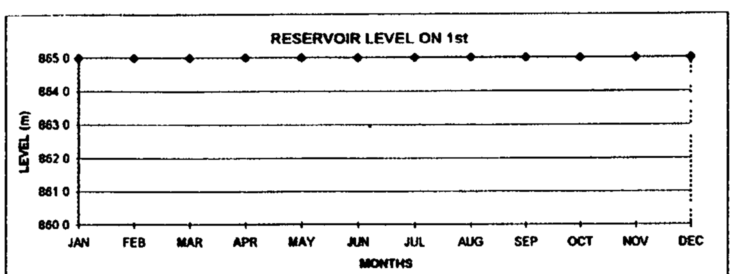
TABLE 9-2
MALAGARASI STAGE-2 PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL WET YEAR FOR 2 x 4 MW (1979)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM	MAND RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS
JAN	1 87	865 00	583 89	107 14	0 59	0 08	0 00	0 00	1 87	865 00	476 67	744 00
FEB	1 87	865 00	730 60	96 77	0 59	0 08	0 00	0 00	1 87	865 00	633 75	672 00
MAR	1 87	865 00	937 44	107 14	0 59	0 08	0 00	0 00	1 87	865 00	830 22	744 00
APR	1 87	865 00	1607 04	103 68	0 59	0 08	0 00	0 00	1 87	865 00	1503 28	720 00
MAY	1 87	865 00	2552 52	107 14	0 59	0 09	0 00	0 00	1 87	865 00	2445 29	744 00
JUN	1 87	865 00	2260 22	103 68	0 59	0 09	0 00	0 00	1 87	865 00	2156 45	720 00
JUL	1 87	865 00	1521 33	107 14	0 59	0 11	0 00	0 00	1 87	865 00	1414 09	744 00
AUG	1 87	865 00	806 20	107 14	0 59	0 12	0 00	0 00	1 87	865 00	698 95	744 00
SEP	1 87	865 00	365 47	103 68	0 59	0 12	0 00	0 00	1 87	865 00	261 67	720 00
OCT	1 87	865 00	158 03	107 14	0 59	0 11	0 00	0 00	1 87	865 00	50 78	744 00
NOV	1 87	865 00	108 86	103 68	0 59	0 08	0 00	0 00	1 87	865 00	5 11	720 00
DEC	1 87	865 00	176 77	107 14	0 59	0 08	0 00	0 00	1 87	865 00	69 56	744 00
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)
		865 00	11808 37	1261 44	0 59	1 10	0 00	0 00		865 00	10545 83	8760 00

MONTH	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
FEB	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 48
MAR	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
APR	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
MAY	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
JUN	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
JUL	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
AUG	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
SEP	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
OCT	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
NOV	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
DEC	0 00	40 00	24 00	2	24 45	1 69	22 77	24 33	22 77	840 55	8 43	6 27
	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
	0 00	40 00	8760 00		24 45	1 69	22 77	22 90	22 77	840 55	8 18	71 62







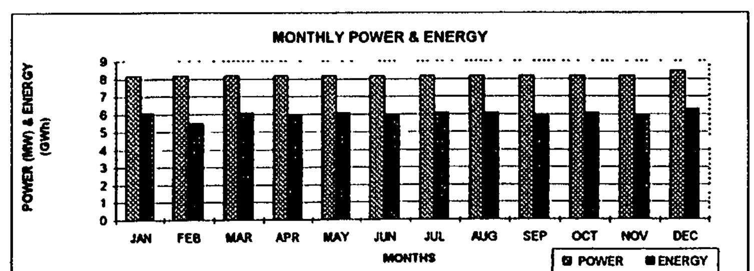
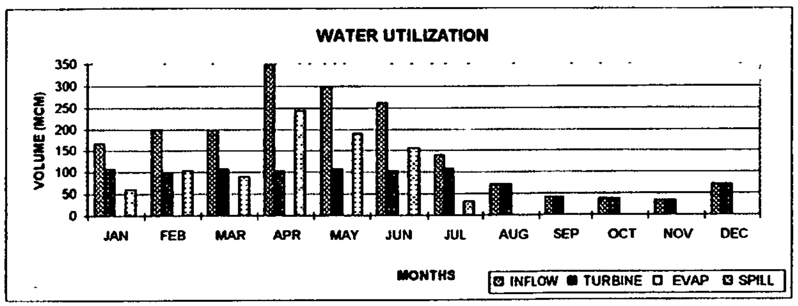
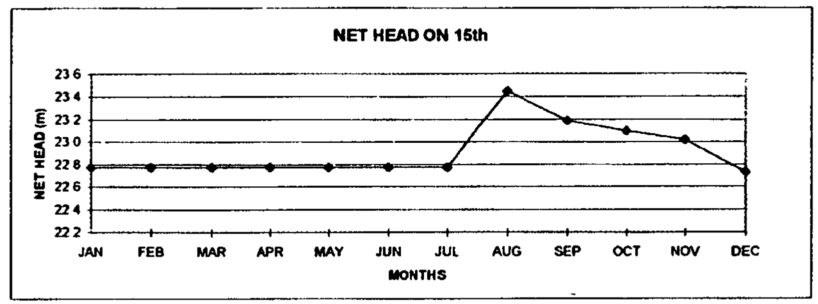
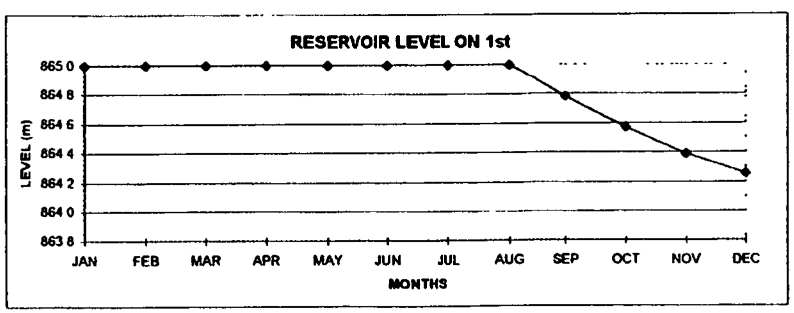


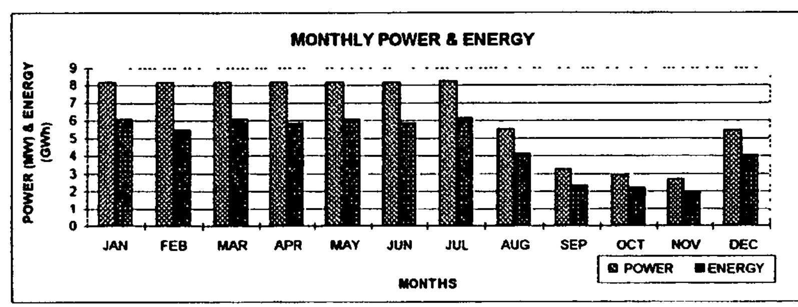
TABLE 9-3
MALAGARASI STAGE-2 PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL DRY YEAR FOR 2 x 4 MW (1976)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM	MAND RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	1 87	865 00	167 40	107 14	0 59	0 08	0 00	0 00	1 87	865 00	60 18	744 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
FEB	1 87	865 00	199 83	96 77	0 59	0 08	0 00	0 00	1 87	865 00	102 98	672 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 48
MAR	1 87	865 00	197 13	107 14	0 59	0 08	0 00	0 00	1 87	865 00	89 91	744 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
APR	1 87	865 00	347 59	103 68	0 59	0 08	0 00	0 00	1 87	865 00	243 83	720 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
MAY	1 87	865 00	297 30	107 14	0 59	0 09	0 00	0 00	1 87	865 00	190 08	744 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	6 07
JUN	1 87	865 00	260 50	103 68	0 59	0 09	0 00	0 00	1 87	865 00	156 72	720 00	0 00	40 00	24 00	2	24 45	1 69	22 77	22 77	22 77	840 55	8 15	5 87
JUL	1 87	865 00	139 28	107 14	0 59	0 11	0 00	0 00	1 87	865 00	32 04	744 00	0 00	40 00	24 00	2	24 45	1 69	22 77	23 45	22 77	840 55	8 27	6 16
AUG	1 87	865 00	70 98	70 98	0 59	0 12	0 00	0 00	1 75	864 78	0 00	0 00	-0 12	26 50	24 00	2	24 58	1 13	23 45	23 19	23 45	840 42	5 53	4 12
SEP	1 75	864 78	40 44	40 44	0 57	0 11	0 00	0 00	1 63	864 57	0 00	0 00	-0 11	15 60	24 00	1	24 49	1 30	23 19	23 10	23 19	840 29	3 23	2 33
OCT	1 63	864 57	38 03	38 03	0 55	0 10	0 00	0 00	1 53	864 39	0 00	0 00	-0 10	14 20	24 00	1	24 30	1 20	23 10	23 02	23 10	840 27	2 93	2 18
NOV	1 53	864 39	33 70	33 70	0 54	0 07	0 00	0 00	1 47	864 26	0 00	0 00	-0 07	13 00	24 00	1	24 13	1 11	23 02	22 73	23 02	840 26	2 66	1 92
DEC	1 47	864 26	70 44	70 44	0 52	0 07	0 00	0 00	1 40	864 14	0 00	0 00	-0 07	26 30	24 00	2	23 85	1 12	22 73	23 47	22 73	840 41	5 44	4 05
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		864 83	1862 60	986 26	0 58	1 08	0 00	0 00		864 76	875 74	5088 00	-0 47	31 30	8760 00		24 38	1 47	22 91	22 96	22 91	840 46	6 42	56 16









Chapter 10 Civil Works

Section 1 Description

The major components of civil works involved in the construction of the hydroelectric project will be

1. Construction of an access road to the proposed diversion weir and power house areas.
2. Preliminary preparation of the site including setting out, surveys, erection of storage areas for materials and area for personnel.
3. Excavation for diversion weir and construction of the non overflow, overflow sections.
4. Construction of the intake structure for the waterway.
5. Construction of waterway comprising excavation and concreting for canal, forebay and installation of penstocks.
6. Excavation for the turbines, their installation and subsequent concreting to form the substructure of the power house.
7. Erection of super structure of the powerhouse for accommodating auxiliaries, controls and protection.
8. Excavation of the tailrace and concreting which will afford passage of water after exit from the turbines back into the river.

The preliminary design and scope of works involved for each of the above components is discussed more fully below.

Section 2 Access Road

For the construction of the project the access road is of primary importance. Other works involved are the improvement of existing second class road which are to be made suitable for transport of the machinery, especially through provision of some small culverts across streams. The access road will be used to transport all the equipment required to construct the project. The road is proposed to be 7.20m wide with shoulders 1m wide. A simple bridge has to be provided to cross the river to the from right bank to left bank whère the power house is located. During the project construction, it is not necessary to surface the road.

Section 3 Preliminary Design

Part I Diversion Weir

The diversion weir can be either a rockfill or dry laid rubble masonry structure about 7.5 m in height. Considering that the diversion site is about 325m wide, this type of design is considered to reduce the amount of concrete and make use of materials available in the immediate vicinity. The average inflow at the intake dam site described in the section on hydrology exceeds the 40 m^3/sec maximum power discharge for about 270 days in an average year. The surplus water will be discharged downstream by the ungated spillway. Before placement of rockfill, the foundations should be consolidated by low pressure grouting through suitable holes. A description of the features of each type is given below. The details of the diversion weir types is given in figure 10-1.

Dry Laid Rubble Masonry Type

The hearting area of the dam is dry laid rubble with an average porosity of 20% corresponding to a unit weight of 2.1t/cubic meter. The upstream zone comprises cement-mortar masonry and sprayed with wire fabric shotcrete. The upstream slope is 1:0.65 and the downstream is 1:1.2. The upstream impervious membrane is made of concrete slabs of shotcrete over wire mesh. The downstream face is kept non-vaccum during overflowing and is of cement mortar ashlar stones laid on edge or PCC. Training walls are in cement mortar masonry.

Rockfill Type

The second type is an overflow rockfill dam. Floods can be passed over the crest. The upstream face consists of concrete slabs sandwiched between two layers of cement mortar masonry. The lower layer is laid on rubble masonry. On the downstream face, cement masonry is laid over rubble masonry. On the downstream face, cement mortar masonry is laid over rubble masonry. The spill flow is confined between mortar laid training walls. A cement mortar layer of 5cm thickness is provided on the upstream face.

The height of the non-overflow section of the dam is obtained by the following equations

If the design water level is normal high water level then

$h_f = h_w + h_e + h_a$

but if the design water level is design flood water level

$h_f = h_w$

The larger of the two values above is to be adopted,

where,

h_f : addition to required water level (m)

h_e : wave height due to earthquake (m)

h_w : wave height due to wind (m)

h_a : addition depending on existence or non-existence of spillway (0.5 m)

a) Wave Height due to Earthquake

$h_e = 1/2\ (kr/\pi)\ (\sqrt{gH_o})$

where,

k : horizontal seismic coefficient (0.15).

r : period of seismic wave (1 sec).

H_o : water depth of regulating pond from normal high water level (7.5 m)

Substituting

$h_e = 1/2 \times ((0.15 \times 1)/\pi) \times \sqrt{(9.8 \times 7.5)}$

$= 0.204m$

b) Wave Height due to Wind

$H_w = 0.0086\ V^{1.1}\ F^{0.45}$

where,

F is the fetch (= 100 m)

V is the 10-minute average wind speed (12 m/sec)

H_w : $0.0086 \times 12^{1.1} \times 100^{0.45} = 1.43m$

Height of Non-overflow Section

Where design water level is normal high water level

$h_f = h_w + h_e + h_a$

$h_f = 1.43 + 0.20 + 0.5 = 2.13m$

Elevation of non-overflow section = $865 + 2.13 = 867.13$ m.

The elevation of the top of non-overflow section is fixed at 867m.

Part II Intake

The intake structure is located in the immediate vicinity of the diversion structure. It is designed to be an independent structure with control for admission of water to the power canal. The structure is founded on the rock which form the left bank of the river. There is provided a trash rack structure to prevent any debris from entering the canal. Admission is controlled by means of a slide gate operated by a hoist. The design of the structure is conventional.

Part III Power Canal

The power conduit consists of a trapezoidal section excavated in the rock on the left bank s shown in the drawing. The overburden to be removed is very small The bed width of the canal is 2.25m with a side slope of 1:1 as most of the excavation is soft rock. The width at the top is 9.25m. The total length is about 500m. The alignment is straight and proceeds close to the river. The lining is made up of concrete slabs or shotcrete. The bed slope provided is 1:1500. Thus water level at the forebay is 864.67m. This is sufficient to convey the maximum power discharge of 40 cumecs. Manning's formula was used in fixing the dimensions with n = 0.011. The velocity of flow obtained is 2.8 m/s. The details are shown in figure 10-2.

Part IV Forebay and Penstock

The forebay is a rectangular structure excavated in the ground. It measures about 30m x 30m. at the top. Three sides are lined with concrete with a side slope of 1:1. On the side with the penstock, a gravity type retaining wall is constructed. The penstock is the final component in the waterway. Two penstocks of diameter 2.15m each are provided. They are laid on an excavated trench with 1:2 side slope. They are supported on anchors. Each penstock is made from steel plates of 10mm thickness. The total length of each penstock is about 100m. Loss was estimated by the Scobey's formula with K = 0.34, v = 5.51 m/s, D = 2.15m. The loss at maximum flow is 0.97 m. Thus total loss is 1.3 m without taking into account losses in intake. The cross section of penstock is shown in figure 10-2 and the longitudinal profile in figure 10-3.

Part V Power House

The power station building is to be situated adjacent to the river channel about 500m downstream of the diversion weir and intake structure.

The bottom structure of the power plant (from the foundations up to the machine hall floor level) forms two concrete blocks founded on solid rock and separated by expansion joints. The top structure is formed by a 9m high reinforced concrete framework filled with brickwork or precast panels, against which their lean, on upstream side, lower annexed buildings 8m high.

The power plant consists of the machine hall, service bay, substructures, control room and space to house all auxiliaries. The access to the power plant is from a branch of the main access road immediately after crossing the river and before the branch which leads to the top of the dam. This approach road has a downward gradient from elevation of 850m and leads to the approach and unloading area which is at elevation of the machine hall floor. In front of the entrance a wide level space is provided to enable vehicles to turn and to temporarily stock unloaded articles. Access to the machine hall is by a 3.6m wide gate at the north end of the service bay. This whole area along with the approach area is above the 1000 year high flood level as seen from figure 10-4 and 10-5.

The main structure of the power plant has a length of 24.5 m and a width of 10 m. The turbine floor is at elevation 842. In the machine hall are provided stairway whereby access can be had to the regulating mechanism and runner chambers. The power house will have an overhead travelling crane of about 7.5t capacity. This will enable lifting of the turbine and generator equipment.

It has been decided to use the space above the penstock on the upstream side, to accommodate the power transformers, This space is accessible from the approacn area and has transformer tracks from the approach area. Also installed here are diesel electric set and air conditioning equipment. In between the power transformers and the main building is a level space over the penstocks which is available for all the auxiliary equipment its elevation being +842m. In this space is constructed the lower annexe building which has control room, cable spreading room workshop, battery system, and office.

On the downstream side is provided a fill over the draft tube to provide a level area for a travelling hoist for operating the draft tube outlet gates by means of a crane. The elevation is kept at 842m to isolate the power house from the 1000 year flood.

The generators are supported on a concrete generator barrel which also houses the shaft and the coupling. Access is possible into the barrel from the turbine floor for inspection of the guide vane apparatus. The top of the generators is at 844.80 above the turbine floor and entrance which are at EL. 842.20. Stairs are provided on the periphery of the barrel to climb to this level from the turbine floor

Behind the control room there are installed two 4.75 MVA transformers, from which the line goes to the 66kV switchyard located adjacent to the approach road.

The control room is situated alongside the machine hall. Its dimensions are tentatively designed to be about 3m x 24.5m. The elevation is +844.80m and is thus situated at the generator floor level. This arrangement will provide a clear view of the generator flooor and the service bay. The wall facing the generator floor will be fully glazed.

Under the control room is a cable compartment and a 6.6 kV switch room. Also located at this same level is a storage battery associated with its corresponding charger.

At the lowest elevation, is the sump pit at an elevation of +835, for de watering the draft tubes and the evacuation of seepage water by pumps.

The elevation of the centre line of the turbine runner will be 839.65m, a value determined in consideration of the normal tailrace water level (EL. 840.0 m) and the draft head. The cross section of the power house is shown in figure 10-5.

The power house will be ventilated by artificial means to maintain the inside temperature especially the machine hall which will be warm due to some heat dissipation from the generators and the tropical climatic condition. The interior compartments of the power station will be ventilated by forced draught. The control room and offices will need to be air conditioned in view of the tropical weather conditions and sensitive equipment located in the control room.

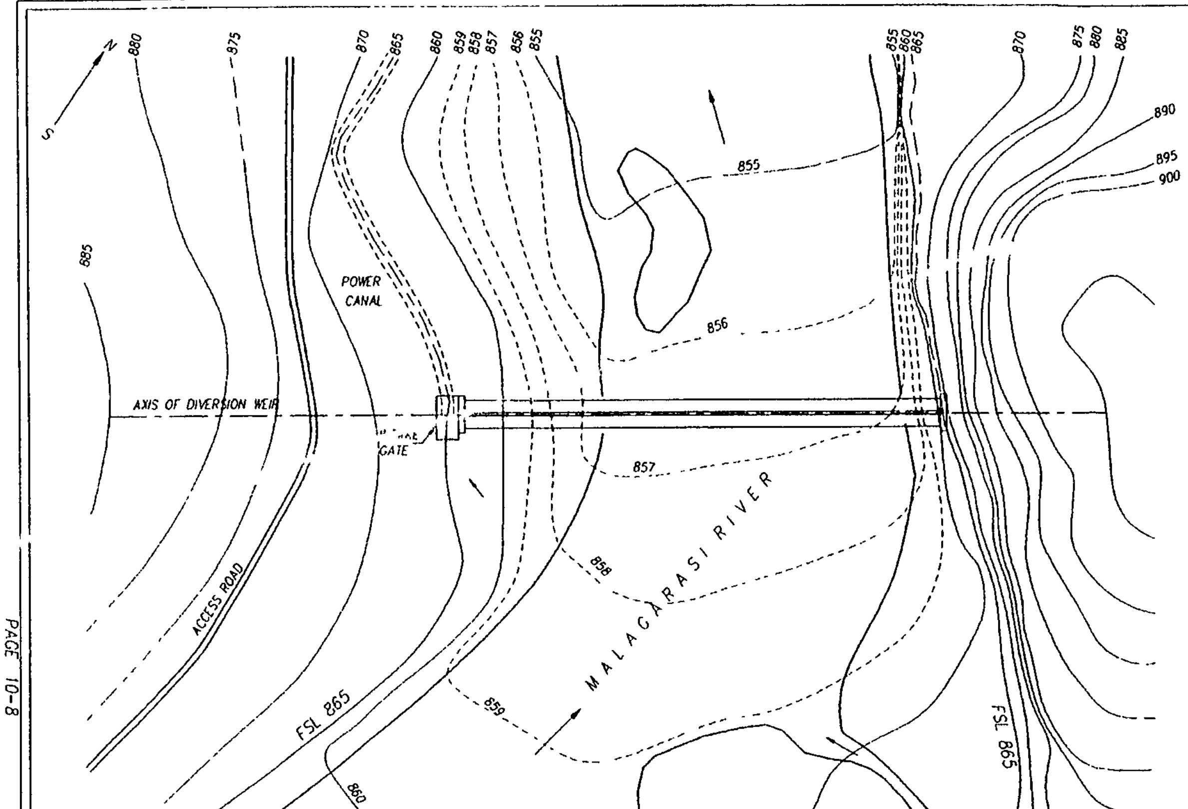
Part VI Tailrace

A open tailrace channel of trapezoidal section with 1:2 slope will be excavated on the left bank. It will be about 25 m wide at the top and about 20 m in length. It will be lined. It is expected that most of the excavation involved will be soft rock excavation. A service road is provided on both sides. A berm is provided 2m above the normal water level of 840m.

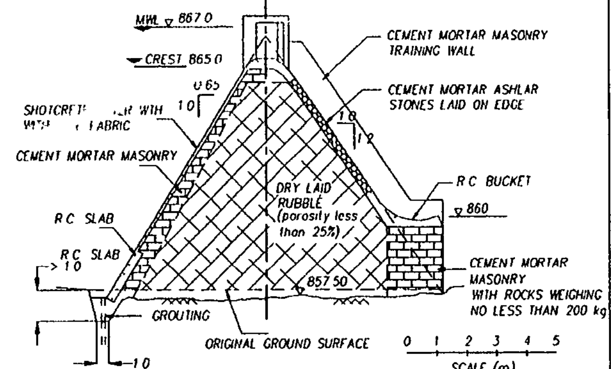
The draft tubes are shut off by 4 vertical-lift gates placed in position by a 3-t hoist traversed along the flood platform at an elevation of +842m. The draft tube outlets can be closed by means of four stop logs measuring about 2.5m x 2.5m.

Part VII Reservoir

The pondage which will be formed is mainly confined to the river channel which is already subject to annual flooding. Hence no problem is likely to arise.

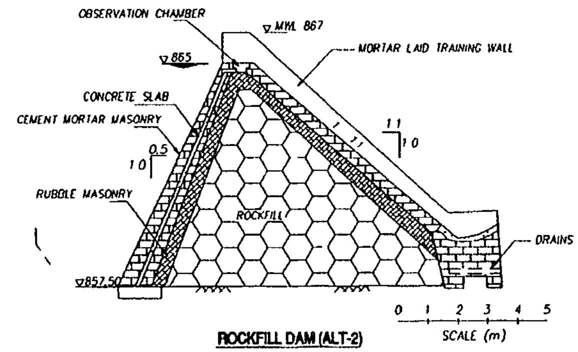


PLAN OF DIVERSION WEIR



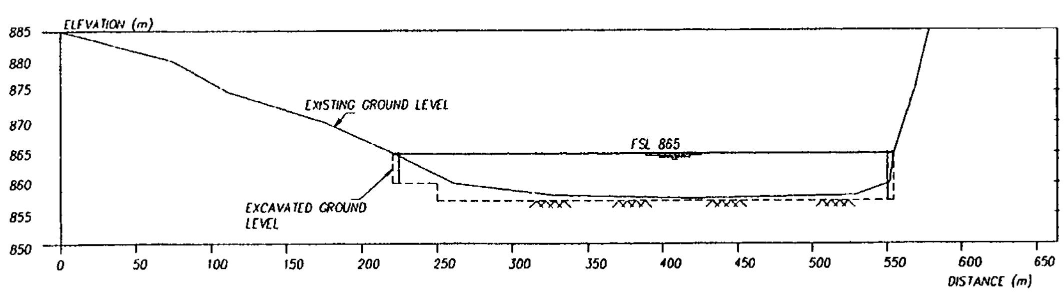
DRY LAID RUBBLE MASONRY DAM (ALT-1)

The above section shows an overflow rockfill dam. The hearting area of the dam is dry laid rubble, with an average porosity of 20% corresponding to a unit weight of 2.1t/cubic meter. The upstream zone comprises cement-mortar masonry and sprayed with wire fabric shotcrete of 2 x 3.5cm. The upstream slope is 1:0.65, and the downstream is 1:1.2. The upstream impervious membrane is made of concrete slabs or shotcrete over wire mesh. The downstream face is kept non-vaccum during overflowing and is of cement mortar ashlar stones laid on edge or PCC. Training walls are in cement mortar masonry.



ROCKFILL DAM (ALT-2)

The above section shows an overflow rockfill dam. Floods could be passed over the crest. The upstream face consist of concrete slabs sandwiched between two layers of cement mortar masonry. The lower layer is laid on rubble masonry. On the downstream face, cement mortar masonry is laid over rubble masonry. The spill flow is confined between mortar laid training wall. A cement mortar layer of 5cm thick is provided on the upstream face.

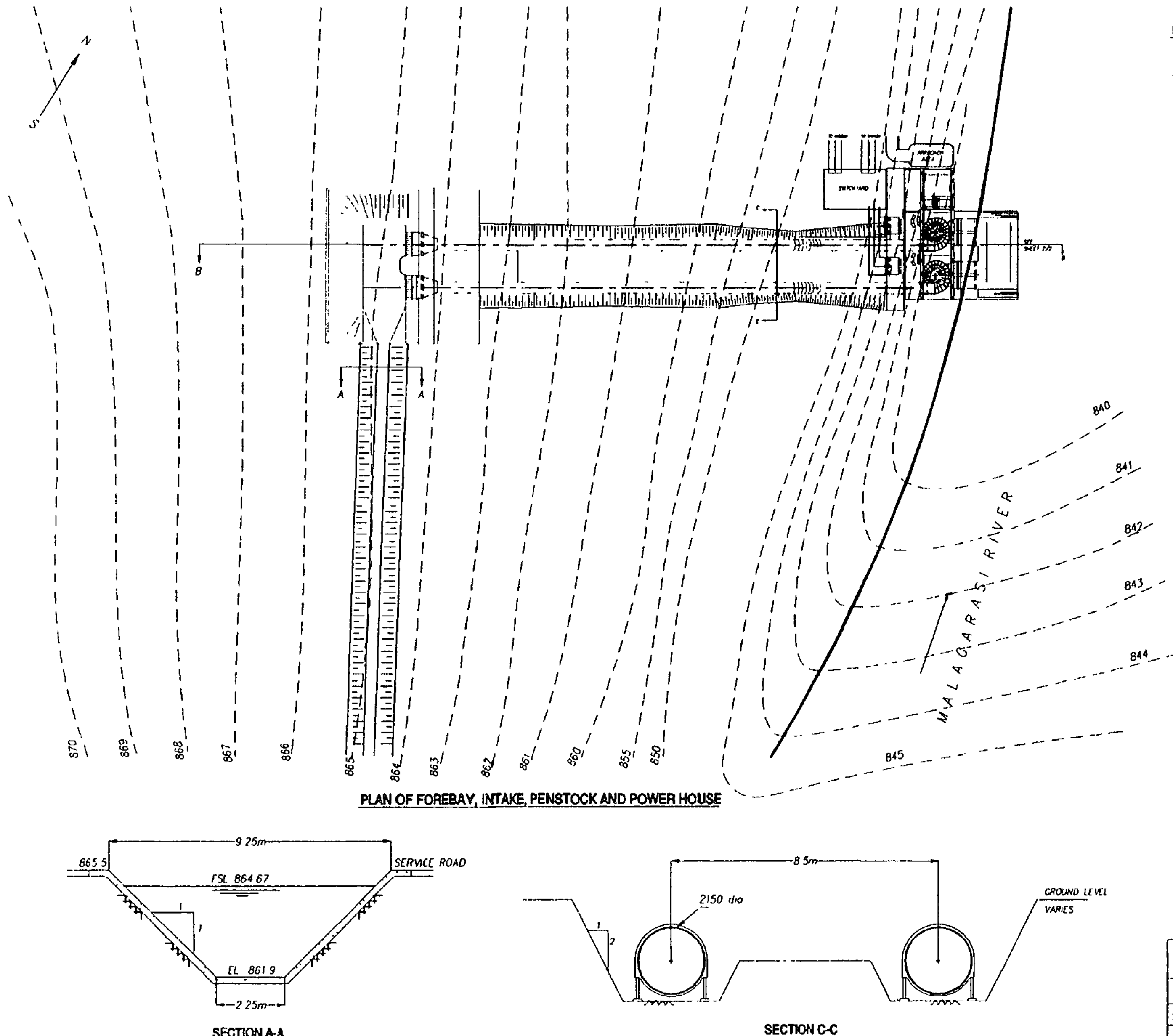


L-SECTION OF DIVERSION WEIR

MALAGARASI HYDROPOWER PROJECTS (STAGE-II)	
DIVERSION WEIR - PLAN, PROFILE & SECTIONS	
FOR: THE WORLD BANK/TANESCO	
DWG NO. FIG. 10-1	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

NOTES

This drawing shows the plan of the canal forebay, penstock and power house of the stage 2 project. Refer to sheet 2 of 2 for details



0 10 20 30 40
SCALE (m)

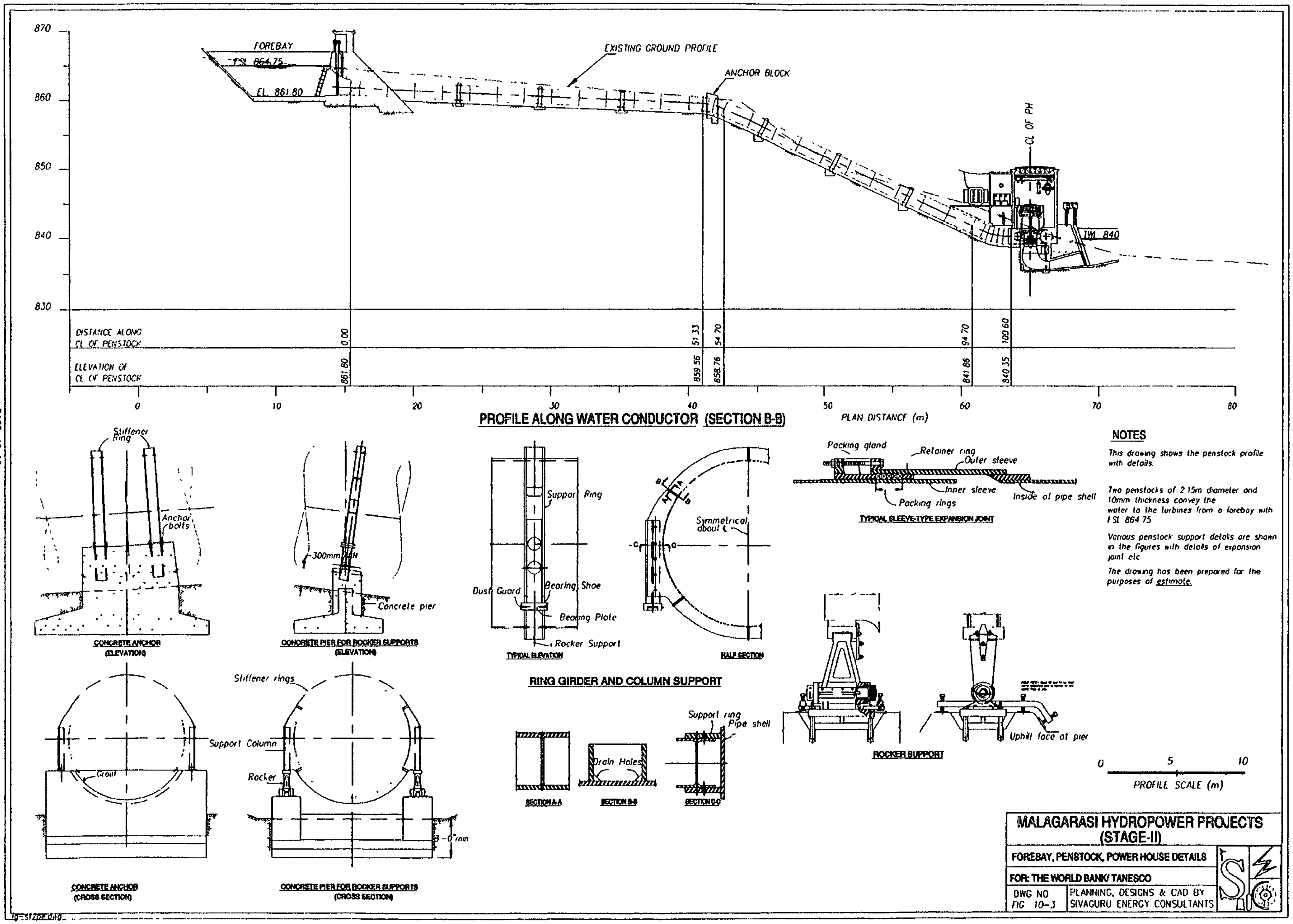
MALAGARASI HYDROPOWER PROJECTS (STAGE-II)

FOREBAY, PENSTOCK, POWERHOUSE DETAILS

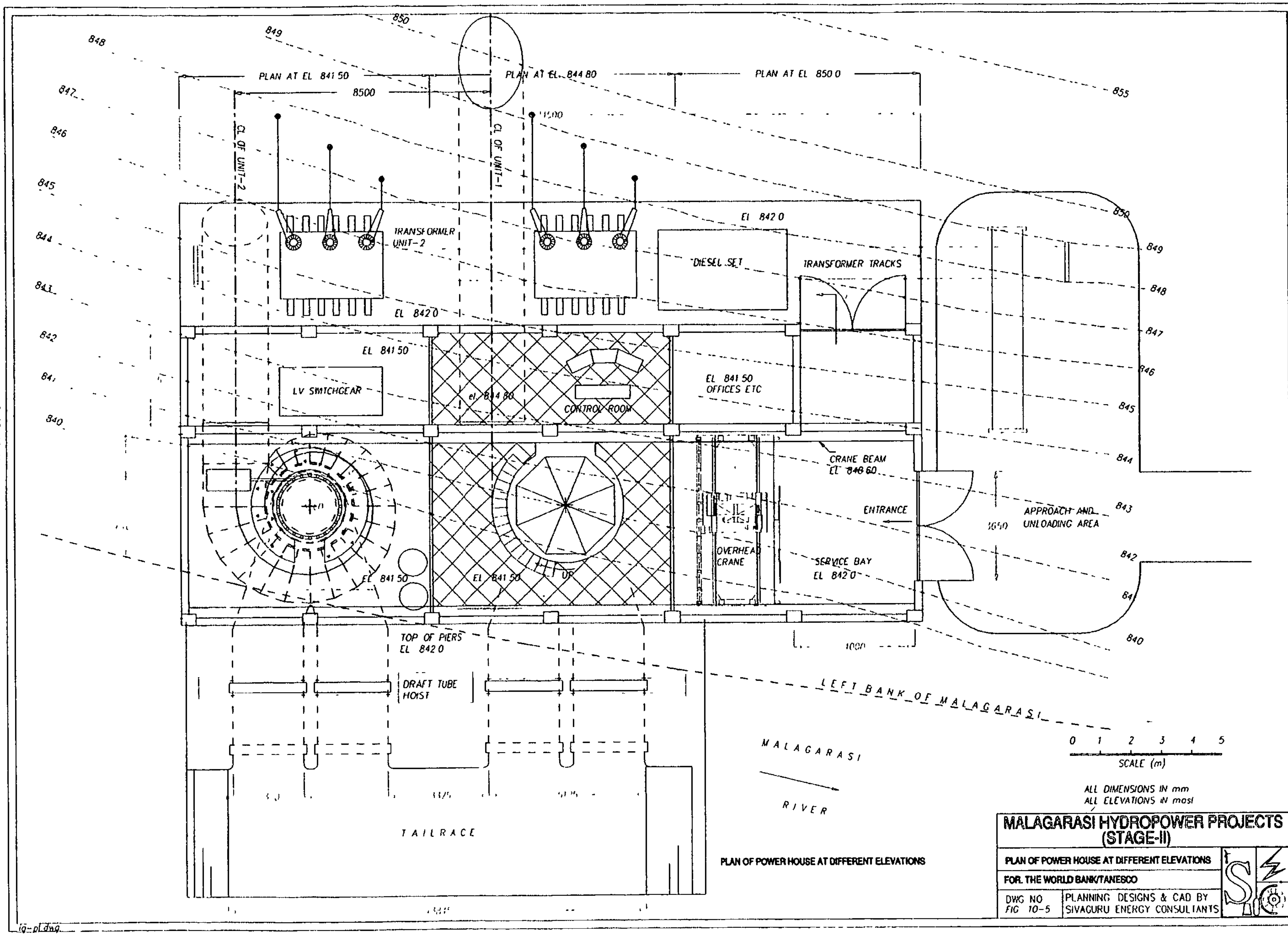
FOR: THE WORLD BANK/ TANESCO

DWG NO FIG 10-2	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

fig=st2wp.dwg



FOREBAY
FSL 864.75
EL 861.80
EXISTING GROUND PROFILE
ANCHOR BLOCK
CL OF PH
TWL 840
870
860
850
840
830
DISTANCE ALONG CL OF PENSTOCK
0.00
51.33
54.70
94.70
100.60
ELEVATION OF CL OF PENSTOCK
861.80
859.55
658.76
841.86
840.35
0
10
20
30
40
50
60
70
80
PLAN DISTANCE (m)
PROFILE ALONG WATER CONDUCTOR (SECTION B-B)
Stiffener Ring
Anchor bolts
CONCRETE ANCHOR (ELEVATION)
300mm
Concrete pier
CONCRETE PIER FOR ROCKER SUPPORTS (ELEVATION)
Support Ring
Dust Guard
Bearing Shoe
Bearing Plate
Rocker Support
TYPICAL ELEVATION
Symmetrical about ℄
HALF SECTION
RING GIRDER AND COLUMN SUPPORT
Packing gland
Retainer ring
Outer sleeve
Inner sleeve
Inside of pipe shell
Packing rings
TYPICAL SLEEVE-TYPE EXPANSION JOINT
NOTES
This drawing shows the penstock profile with details.
Two penstocks of 2.15m diameter and 10mm thickness convey the water to the turbines from a forebay with FSL 864.75
Various penstock support details are shown in the figures with details of expansion joint etc
The drawing has been prepared for the purposes of estimate.
Stiffener rings
Support Column
Grout
Rocker
0" min
CONCRETE ANCHOR (CROSS SECTION)
CONCRETE PIER FOR ROCKER SUPPORTS (CROSS SECTION)
Drain Holes
Support ring
Pipe shell
SECTION A-A
SECTION B-B
SECTION C-C
Uphill face of pier
ROCKER SUPPORT
0
5
10
PROFILE SCALE (m)
MALAGARASI HYDROPOWER PROJECTS (STAGE-II)
FOREBAY, PENSTOCK, POWER HOUSE DETAILS
FOR: THE WORLD BANK/ TANESCO
DWG NO FIG 10-3
PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS



ALL DIMENSIONS IN mm
ALL ELEVATIONS IN masl

PLAN OF POWER HOUSE AT DIFFERENT ELEVATIONS

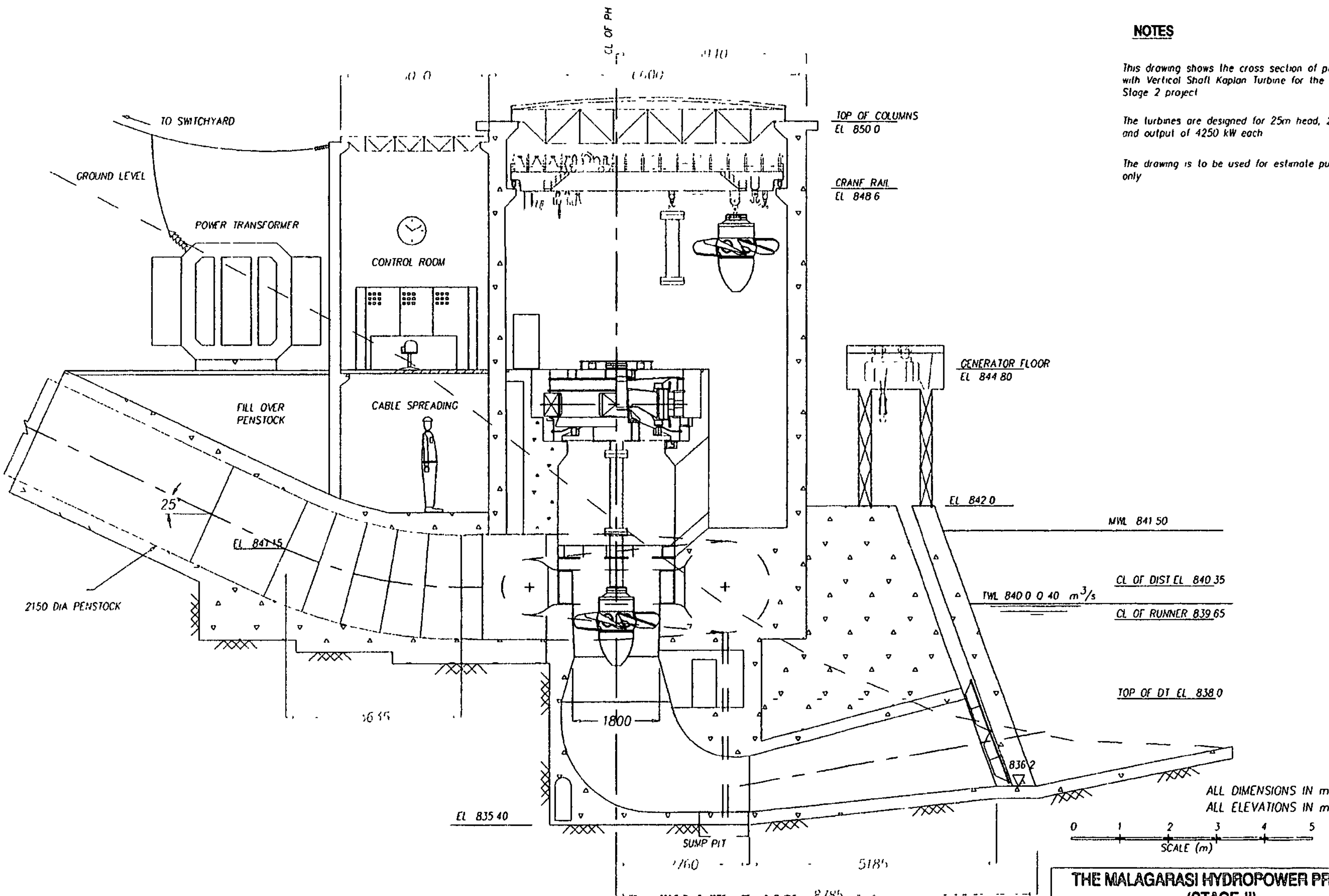
MALAGARASI HYDROPOWER PROJECTS (STAGE-II)	
PLAN OF POWER HOUSE AT DIFFERENT ELEVATIONS	
FOR. THE WORLD BANK/TANESCO	
DWG NO FIG 10-5	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

NOTES

This drawing shows the cross section of power house with Vertical Shaft Kaplan Turbine for the Malagarasi Stage 2 project

The turbines are designed for 25m head, 20 cumecs and output of 4250 kW each

The drawing is to be used for estimate purposes only



CROSS SECTION OF POWER HOUSE

THE MALAGARASI HYDROPOWER PROJECT (STAGE-II)	
CROSS SECTION OF POWER HOUSE	
FOR: THE WORLD BANK/TANESCO	
DWG NO FIG 10-5	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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Chapter 11 Electro Mechanical equipment

Section 1 Description

The main electro-mechanical equipment consists of the turbine and generator, Also included in the scope are the equipment necessary for controlling the waterways to the turbine The electromechanical equipment of the power plant was .selected based upon the results of the power and energy studies. The preliminary dimensioning was carried out with a set of equations as well as database of turbine data obtained from various manufacturers. The equipment outline based on these dimensions are shown in figure 11-1.

Section 2 Turbine

Part I Dimensions

On the basis of detailed hydrological studies it has been decided that the power plant will consist of two units of 4 MW each so that maximum energy can be produced. The maximum net head for the plant at full load is about 24.3m. The minimum operating head will be about 22.7m. The most important factor in the dimensioning of the power house are the size of the turbine and generator.

For the given parameters Q, H_{max}, H_{min} obtained from the power and energy studies there is considered, a Kaplan type hydraulic turbine with adjustable wicket gates and runner blades. The adoption of this type is advantageous from the operational point of view with the variation of discharge which will be required to adjust power output according to the load demand, as compared to the types with fixed runner blades, as high orders of efficiency are achieved, regardless of service conditions

Rigorous attention should be paid to resistance to cavitation of the runner blades, this undesirable effect prevented by selecting a low running speed or by placing the runner at a sufficient depth below the downstream water level. The required value has been safely figured through manufacturer's model tests. In the present design, the runner center line has been placed about 0.35m below the minimum tailwater level and a lower running speed is selected to minimize excavation.

The type of turbine chosen for installation places more exacting demands on the draft tube which takes over the water coming from the blades of the runner. By model investigation it is possible to determine exactly the optimum shape of the draft tube, so that the flow is uniform under any service conditions and shows no irregularities whatever. The draft tube profile shown in the drawing is as per current practice. The operation of the turbine is smooth and quiet, without oscillations that would adversely affect the electric power output of the generator.

The dimensions of the turbine were calculated based upon experience curves. The resulting dimensions were then compared with actual equipment manufactured and installed for similar hydraulic conditions. The results were in close agreement. Any further small final changes in the dimensioning of the equipment will not materially affect the civil works quantity estimates which are used to work out the implementation cost.

The trial specific speed is given by
$n_s' = 2334/\sqrt{h_d} = 2334/\sqrt{24} = 476.43$ rpm (typical values for Kaplan units)

A trial specific speed of 476.43 rpm was fixed.

Trial speed $n' = n_s' \times H^{5/4} / \sqrt{P}$
where P is in metric horsepower. A turbine output of 4250kW corresponds to 5261 mhp

where H = 24 m, P = 5261 mhp

So n' = 348.9 rpm

Nearest synchronous speed = 300, 333.3 rpm

for poles = 20 or 18

The 300 rpm running speed was selected.

Thus Design Specific speed $= n_s = (n \times \sqrt{P})/H^{5/4}$
$= 409.63$ rpm

Discharge coefficient $\phi = 0.0233 n_s^{2/3}$
$= 1.3112$

Diameter $= 84.47\phi\sqrt{H}/n$ = 1.808m.

Based upon the operating conditions which are to be met it has been decided that the turbine will have a runner of 1800mm diameter

The other parameters are estimated as follows.

$W_{runner} = 607 D_{max}^{2.75}$ kg = 3056 kg
$W_{turbine} = 15175 D_{max}^{2.33}$ kg = 59.7t

Shaft diameter = $(70P_d/n)^{0.33}$ in = 10.5in = 270mm approx
Flange diameter = 1.75 x 270 = 472.5mm
Flange thickness = 0.20 x Flange diameter = 95mm

Thoma's Cavitation coefficient

$\sigma = n_s^{1.64}/50,324$ = 0.382

The elevation of the power house area = 840m

Atmospheric pressure H_a = 9.363m of water at elevation 840m.
Mean temperature of river water = 25°C
Vapour pressure H_v = 0.324 m of water

Barometric pressure $H_b = H_a - H_v$ = 9.363 - 0.324 = 9.039 m of water.
H_{cr} = critical head = 24.5 m
σ_P = (plant sigma) = 0.38 (In the final design stage when the manufacturers sigma is obtained the plant sigma may be fixed). However this will not result in any major changes in the excavation volumes for the power house.

H_s (suction head) = $H_b - \sigma_P H_{cr}$ = -0.27m

Now average minimum tailwater level = 840.40m from power study.

Elevation of turbine runner = TWL +Hs = 839.72m.

The elevation is fixed at 839.65m

Part II Specifications

The turbines are fitted with four blades, of cast steel 13 % Chromium, 4 % Nickel. The runner servomotor is located in the runner cone or hub with the oil supplied through the shaft. The discharge ring is made up of shells of stainless steel plates in the range of the runner blades. The runner hub is made of cast steel. The runner cone will be made of fabricated steel.

The shaft is made of forged steel with integrally forged flanges on both sides for coupling with the runner and the generator rotor; with bore for oil supply to and oil return from the runner servo motor.

The spiral casing is stress relieved with internal ribs. An access hatch is provided. The casing is embedded in concrete at the site.

The guide vanes are cast in 13/1 Nickel Chromium stainless steel. The guide vane end sealing plates and throat ring below the runner are clad with stainless steel thus the whole of the flow passages in the region of high velocity from speed ring to draft tube are of stainless steel.

The turbine guide bearing is of a self lubricating type in which metal pads are rigidly secured round the shaft journal. The spiral casing of steel plate fabrication is welded to a cast steel speed ring. The spiral casing is stress relieved with internal ribs. An access hatch is provided. The casing is embedded in concrete at the site.

The main shaft seal consists of shaft seal body with labyrinth, a clamp ring of stainless steel, lip ring of Perbunan rubber, seal ring with ceramic overlay and maintenance seal.

The bearing system is made up of two-bearing arrangement; turbine guide bearing and combined thrust guide bearing on the generator side, the thrust guide bearing being designed for axial thrust in both directions. The bearings are oil-pressure lubricated, the lubricating oil will be pumped from the oil sump tank to the overhead oil tank and supplied to the bearings. This arrangement guarantees the lubrication of the bearings even if a failure of the DC emergency system occurs. Oil is cooled by use of an oil-air cooler. A high pressure oil pump is installed for start-up or shut-down of the unit. Quantity of oil for the individual bearings is adjusted by regulating valves.

The gate mechanism consists of fabricated wicket gates; stems and trunnions supported in self-lubricated bearings; operated by the regulating ring through levers and gates links.

The draft tube liner is made of welded steel plates. It will be sectionalized as required for transportation. There will be a machined flange for mounting a flexible connection to the discharge ring.

Apart from these usually included in the scope of supply will be drainage system, cooling water and oil supply system and one set of special tools and equipment.

Part III Control

The generating unit will be equipped with an automatic control enabling start up or shut-down through depression of a single push button. This automatic control also permits a shut-down of the set in case of any breakdown which might call for such an immediate shut-down. All of these controls are normally integrated into the governor which will be of the electronic digital hydraulic type with electronic speed sensing and stabilizing circuits and hydraulic valves to control the position of the servo motors.

The regulators which control the turbine are designed to warrant a uniform and balanced run of the turbines under any service conditions, at an equivalent rated speed. In case of important and rapid alternations of the turbine load, temporary alterations of speed within specified limits must be allowed for.

The regulators themselves are envisaged to be of an electric type with an electronic hydraulic converter to the power part of the regulator which acts upon the control equipment of the turbine. The response of the regulators is high, so that the generating unit immediately responds to the slightest alternation of conditions in the system.

As an accessory equipment of a regulator there are pumping sets including pumps and air chambers with a reserve of regulating oil in such a quantity as to safeguard a shutdown of the turbine under even the most unfavourable conditions. In some cases of variant design, where it would not be advantageous to install quickly operating emergency gates on the intake, the regulating mechanism is fitted with an additional safety air chamber which might replace the emergency gates.

Section 3 Generator

The generator parameters are determined by the outlet output of the turbine and by the needs of the power system. Excitation for the generator will be obtained by rectification of the generator ac voltage by means of electronic three phase rectifiers.

The generator shall be designed by taking into consideration the voltage conditions of the system to which the power plant will be connected, all estimated power station consumption and their average power factors. On the basis of these, the proposed generator power factor is cos $\gamma = 0.85$. This generator power factor also corresponds to the demand on compensation of the 66 kV system in a given place, at the same time. The generator will duly secure a supply of the required compensation capacity.

The generator is driven by the turbine and located above the turbine. All forces and torques occurring are transmitted into the concrete structure by the barrel.

The generator will be of the three phase synchronous type running at 300 rpm. Each will be direct driven by the turbine. As the speed of the units is high, the umbrella type of installation will be unsatisfactory due to vibration. Hence the suspended type of arrangement is contemplated. The thrust bearing will be located on the generator stator on cross brackets. One guide bearing will be located below the generator. and also supported on cross brackets. Further specifications are given in the table 11-1 on electromechanical equipment. The actual dimensioning of the generator will be done by the manufacturer in consultation with the turbine manufacturer. The preliminary dimension obtained here and used for the sizing of the power house are based on empirical formulae.

Section 4 Transformer

Both the units will work into unit power transformers. The power transformer will be three phase step up 6.6kV/66kV rated at 4.75MVA. It will be installed outdoors on the roof of the power house. Under the transformers a sump will be provided to trap the oil which might leak out of the transformers. The HV bushing will have the CT built in. A short 66kV aerial line will connect the transformer to the switchyard. The transformer will be oil immersed and cooled by air. A surge arresting device will be provided at the transformer to protect the transformer.

Section 5 Intake Equipment

The intakes to the power conduit are fitted with coarse and fine screens. Cleaning of the fine screens is afforded by a screen rake traversed along the intake structure crest. Emergency shut-off of the intakes is provided by vertical-lift gates, suspended in the grooves provided for them in each intake. The gates are operated by a hydraulic.

For manipulation of the mechanical equipment of the intakes, hoisting mechanisms and devices are provided (trestles used for erection, stoplog cranes or similar equipment).

Section 6 Auxiliaries

The correct operation of a turbine is assisted by accessory mechanical equipment installed within the premises of the power plant. This equipment comprises the following units:

1. Lubrication system consisting of oil pumps, oil filters etc. Lubricating oil, which, during its passage across the surfaces of the bearings of a generating set removes the heat produced there, is cooled down as it continues its passage, filtered and restored to the bearings. In the case under review the lubricating circuits are designed separately for the thrust bearing of the generating set including the upper guide bearing of the generator. The bearings are even submerged in an oil bath, a perfect and close contact between the oil and the contact surfaces thus being fully ensured. The turbine bearing also has a separate lubricating system has been dimensioned so as to warrant a safe and trouble free run of the hydraulic turbine.

2. The cooling system serves to cool down the heated-up lubricating oil, take over all of its heat and remove it, by way of the water discharged to the stream bed. Heat transfer is accomplished by contact of the cooling water in the pipes with the oil coming from the bearings, this direct contact between the two elements being produced in coolers.

3. The cooling water should be free from any sort of contamination. In our case it is obtained straight from the penstock, since the existing pressure is sufficient to ensure an ample flow volume for cooling. Prior to being put to this use, the water is passed through water filters.

4. The system of draft tube unwatering by pumping involves primarily the pumps situated in a shaft into which there is channelled the water from the draft tubes whenever an inspection of the mechanical equipment has to take place. The pumps have been dimensioned so as to obtain the dewatering of the draft tube in the time specified, under consideration of seepage past the gate joints.

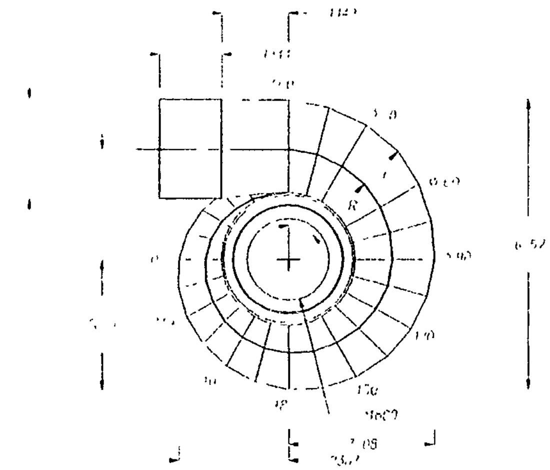
5. The equipment for dewatering the power plant premises primarily comprises the pumps situated in the lowermost compartments of the power plant to which all seepage water from the power plant premises is drained. The equipment works automatically according to the seepage water level in the shaft. The water is then evacuated by pumps to the downstream river tract.

6. The oil system comprises, in the first place, oil reservoirs for lubricating and regulator oil and vaseline storage. The oil conservation system comprises portable oil pumps, filtering equipment etc. The extension of this system is not determined directly by the size of the generating set and no detailed design of the same has been undertaken in the study; in the next design stage it will be shown in more detail.

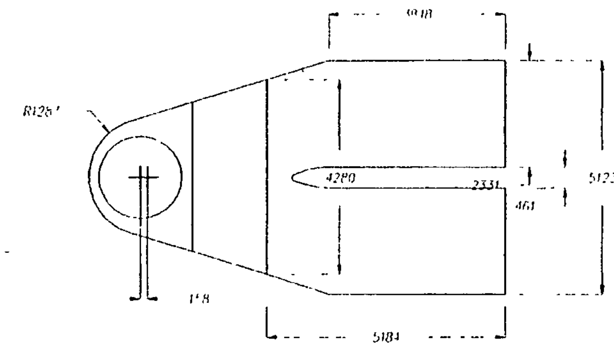
7. The compressor plant contains, as the main item, a high-pressure compressor with an air chamber, where there is provided a pressure air reserve for the first charge of the air chambers of the pumping sets. Compressed air is also put to other uses, such as cleaning the equipment, etc.

SPIRAL CASE DIMENSIONS

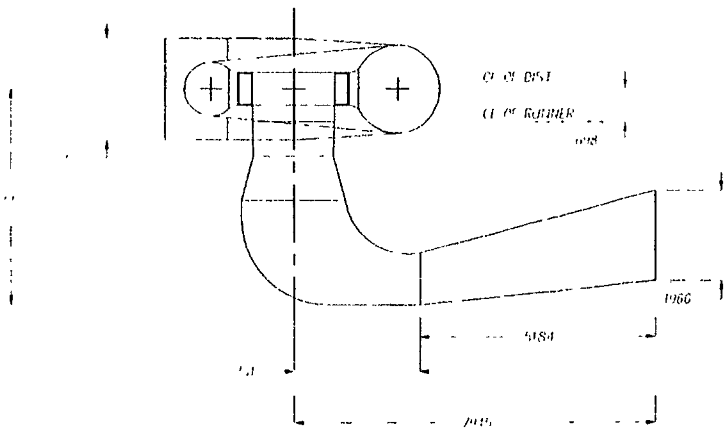
ø	R	r	ø	R	r
0°	2417	1086	180	2073	781
15	2393	1064	195	2036	751
30	2369	1042	210°	1997	719
45°	2343	1021	225	1956	686
60°	2317	995	240°	1911	651
75	2290	970	255	1863	615
90	2262	946	270	1809	578
105	2234	920	285	1748	538
120	2204	894	300°	1678	498
135°	2173	867	315	1591	450
150°	2141	839	330°		
165°	2108	811	345		
			360		



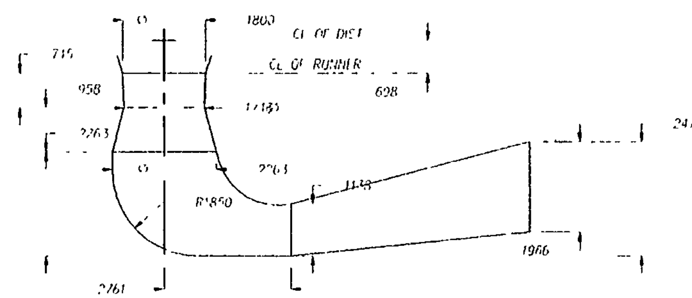
SPIRAL CASE PLAN



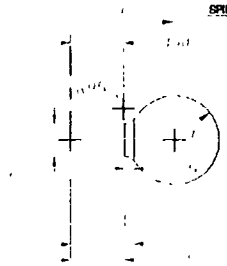
DRAFT TUBE PLAN



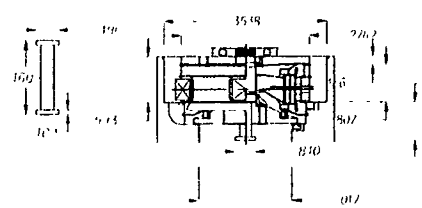
SPIRAL CASE & DRAFT TUBE



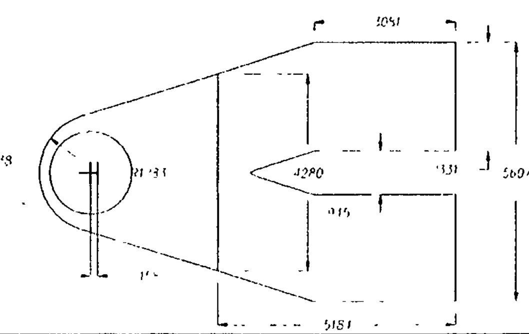
DRAFT TUBE PROFILE



SPIRAL CASE DETAILS



GENERATOR CROSS SECTION



THIS DRAWING WITH DIMENSIONS ARE TENTATIVE AND FOR ESTIMATE PURPOSES ONLY

MALAGARASI HYDROPOWER PROJECTS (STAGE-II)	
PRELIMINARY DIMENSIONS OF ELECTROMECHANICAL EQUIPMENT	
FOR: THE WORLD BANK/TANESCO	
DWG NO FIG 11-1	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

TABLE 11-1
SPECIFICATIONS OF ELECTROMECHANICAL EQUIPMENT

	EQUIPMENT PARAMETER	DESCRIPTION
	Turbine	
	Type	Kaplan type double regulated vertical installation
	Number of Units	Two units
	Maximum Gross Head	25 0 meters
	Maximum Net Head	24.30 meters
	Minimum Net Head	22 70 meters
	Design Head	24.00 meters
	Rated Head	24.00 meters
	Rated Discharge	20 cubic meters per second
	Turbine Rating	4000 kW nominal
	Overload	5%
	Runner Diameter	1800 mm
	Speed	300 revolutions per minute
	Specific Speed	409.63 revolutions per minute
	Auxiliaries	Hydraulically operated servomotors
	Governor	
	Type	Electronic - Digital Type
	Inlet Gates	
	Type	Vertical slide Gates quick acting
	Size	5m x 5m
	Draft Tube	
	Type	Cone of Welded structural steel. Liner reinforced by suitable ribs
	Generator	
	Type	Three Phase AC Synchronous Generator
	Frequency	50 cycles nominal
	Rating	4 75 MVA
	Voltage	6.6kV (final choice left to manufacturer)
	Power Factor	0.85
	Speed	300 rpm
	Poles	20
	Cooling	Water cooled
	Coupling	Flange coupling
	Number of Units	Two units
	Excitation	
	Type	Brushless Exciter (as recommended by supplier of alternator)
	Power Transformer	
	Type	Three phase
	Cooling	Oil immersed and cooled by air
	Rating	4 75 MVA
	Number of Units	Two units
	HV Terminal	66kV bushing with CT built in

Chapter 12 Electrical Works

Section 1 Description

The electrical works consists of all the works associated with connecting the generator to the step up power transformer, transformer to switchyard and switchyard to the grid interconnection. The scope also includes design, supply and erection of the equipment required for control, protection and metering of the power station, lighting, and unit auxiliaries etc. In the power plant are installed two generators of 4.75 MVA coupled to Kaplan turbines. Two 4.75-MVA, 6.6/66 kV transformers are located outside. General features of the electrical works are given in table 12-1.

Section 2 Generator

Part I Description

The generator is embedded in the generator barrel above the turbine floor. It may be inspected by means of removable segmental steel covers. The cooling will be by forced means. A low voltage circuit breaker and isolator will be installed for disconnecting one of the generators from the generator bus for service or inspection and located beneath the control room.

Each generator is connected to the 6.6kV bus through a generator circuit breaker. Each generator neutral may be connected to earth by a reactor if necessary to limit the short circuit currents. The generator windings are protected differentially.

Part II Protection

The following system of protection is considered sufficient for the generator.

1. Differential relay, common also for the block transformer and working also when an inside as well as outside short-circuit fault of the generator occurs in the protected section i.e. the section between the current transformers.

2. Instantaneous over current relay which serves as a back-up protection for the differential relay. In order prevent a wrong function of this relay when an outside short circuit fault, should occur, its operation is interlocked by an under voltage relay,

3. Over voltage relay operating during a sudden generator voltage increase e.g. when over speeding or a failure of the voltage regulator, occur in the generating set,

4. Time over current relay against an overload of the generator signals a dangerous current overload of the generator,

5. Field ground relay signals an occurrence of the first dead earth of the generator rotor,

6. Ground fault voltage relay.

In addition to these the generator will be provided with a field circuit breaker. This extent of protection is sufficient for machines with fully automatic operation. In view of the relatively small machine output it is not necessary to have other protection (for instance split winding protection, double ground fault voltage relay, back-up watt relay) necessary.

Section 3 Transformers

Part I Power Transformer

The block transformers are only fitted with lightning arresting device. The remaining instruments of the outlets, particularly the circuit breaker and the isolating switches, are installed in side the 66 kV switchyard.

Part II Protection

The transformer will be protected by

1. Differential relay (F1),

2. Instantaneous over current relay which is considered as a back-up protection for the differential relay. It is completed by an interlocking under voltage relay. The instantaneous over current relay is connected to the current transformers on the 66 kV side,

3. Oil pressure relay (Bucholtz protection), which acts when gases from in the transformer tank (for instance when the transformer temperature, is

excessively raised or when trouble occurs inside transformer) and reacts even to the pressure of air in the transformer tank. It acts in two steps on the first of which it only signals and on the second switches the 66 kV circuit breaker off.

Part III Station Transformer

The station transformer is fed from the generator bus. In view of the small output of this transformer the Engineer recommends a protection by fuses on the H.T. side and a thermal over current coil and duly rated fuses on the L.T. side. Measurement of energy, current and power for station service is proposed at station service consumption transformers.

Section 4 Control Protection and Monitoring

The one line diagram of the power station is shown in figure 12-1 titled Control, Protection and Metering strategy. The main step up power transformers are connected between the 6.6kV bus and the 66kV bus. It is differentially protected with the other usual protection arrangements.

The control room is separated from the machine hall and is situated with a view of bringing the entire electrical equipment together, an arrangement which involves notable operational and economic advantages (for example, the lengths of the connecting cables are kept down to a minimum), and the operators can readily and promptly effect an inspection and checkup of the entire equipment.

The separation of the control room from the machine hall facilitates its air conditioning and thus creates an amenable working environment for the personnel and for the more sensitive instruments of the control board and the relay switchboard.

For clear visibility and orientation, the control board is arranged in an U-shape. In front of the control board a desk is installed for the operator. At the sides of the control board are installed auxiliary switchboards with protective devices, registering instruments and the automation gear.

For an easy and clear arrangement of the cable connections there is, under the control room, a cable compartment linked up to a cable gallery that extends along the entire machine hall. Into this gallery there are brought out all the cable lines coming from the machine control panels, from the switchboards of the generator outlets, as well as all the cable connections coming from the block transformers.

The main station service panel is situated in an unoccupied part of the cable room under the control room.

The electrical equipment for power supply to the auxiliary equipment of the generating set, together with the essential measuring and control instruments directly related to the operation of the generating set, are installed in two machine panels. The power part of these control panels is also in the unoccupied part of the cable compartment under the control room, opposite the respective generating sets.

For providing emergency station service consumption, a 100 kVA diesel electric set is installed. For provision of D. C. voltage an alkaline storage battery and charging system is also installed.

It is necessary to ventilate the machine hall of the power plant in order to remove the part of waste heat of the generator which passes to the interior of the hall through convection and radiation.

On the basis of the general design and control of the 66 kV power system in Tanzania and on the basis of local conditions, consideration was given to the possibility of the power plant operation with permanent attendance as well as without it.

It has been decided to operate the Malagarasi water power plant with permanent attendance for the following reasons :

a) the mechanical and electrical equipment of the water power plant is relatively complicated and needs a continuous maintenance,
b) In view of the size of the installed capacity and location.

On the other hand the 66 kV switchyard by its proximity to the power plant, by its method of operation and by its relative simplicity is to operate without permanent attendance and by remote control from the power station control room.

For these reasons the control of the power plant as well as of the 66 kV switchyard will be centralised into one place, i.e. into the control room of the water power plant where all control, signalling and measuring apparatus and instruments necessary for the operation control of the power plant as well as of the switchyard will be installed.

According to current practice the operation control of water power plants is either semi or fully automatic. In the first case the personnel carry out a large part of the operations by hand, i.e. starting the generating unit, connecting it with the power system, loading and shutdown. The generating unit is provided with control devices which in the case of an emergency signal a trouble state and when the trouble is serious the operator stops the generating unit. In the latter case however the starting and stopping of the generating units are automatic. This is achieved by an automatic equipment on receipt of a single control impulse. When the control of a generating unit is fully automatic the operation of the generating set is also controlled by automatic devices which signal trouble and if necessary shut the machine-set off. In both cases the operation of different auxiliary drives and equipment is fully automatic, for instance the pumping of leaking water or oil, the pressure boosting into the air-oil reservoirs of governors and into receivers of compressor stations, the charging of accumulator batteries etc.

After considering both options it is recommended to adopt a fully automatic control of the Malagarasi power plant. This control has following advantages :

a) Better machine safety as automation eliminates trouble caused by improper handling by the personnel.
b) Improved power system operation by reducing undesirable machine trouble.
c) Increase of power plant operation ability (i.e. flexibility) (for instance by decreasing the time needed for running up the generating set), possibility of remote control of the power plant from a secondary dispatcher's office at a later stage.
d) reduction in the number of the service crew and lower demands on their qualification.

The price difference between a fully automatic and semiautomatic generating unit is minimum. In other countries there are a great number of water power plants with fully automated operation running reliably.

Fully automatic operation of the generating unit requires an automatic synchronising equipment an automatic voltage regulation of the generators and a reliable auxiliary supply of power station.

The automation of the machine operation will make it possible to centralise the generating unit control into the control room, and to establish a remote control system of the power plant operation from the dispatcher's office in the future.

The extent of the measurement and recording of electric values may also be seen on drawing 12-1. This is in accordance with current practice and gives a complete survey of the immediate condition of the electric equipment for use of the local operation control.

The control room will also have an alarm system with an audible and visual signalling of defects in the water power plant as well as in the switchyard. Preference will be given to a simple well-tested system which is modest in demands on space.

Electric machines, the switchyard and the transmission line will be protected by electric protection relays which will assure the safe switching off of the outlet the moment any kind of trouble occurs and thus reduce the extent of possible damage to a minimum. The operation of protection relays will at the same time be signalled visually as well as audibly in the power plant control room. The extent of the protection is dealt with under each category of equipment. The overall strategy is given in figure 12-1.

Section 5 Switchyard

The most suitable site has been chosen in order to make possible a connection with the power plant by means of a free line and to decrease the necessary ground work to the smallest possible extent.

The power inlet to the 66 kV switchyard is by a short overhead transmission line. The outgoing conductors are anchored to the machine hall building. The switchyard is located as shown in the drawings showing the various project features. The switchyard is designed for 66kV operation. The schematic of the switchyard is shown in figure 12-1. The double bus arrangement is preferred with a coupling arrangement between the two buses to enable changeover on load from one bus to another. The control power will be supplied by means of a cable from the power station. The entire switchyard will be fenced off and the fencing adequately earthed. Facility is provided to monitor the line flows. The design of the switchyard will have to be done in accordance with rules and regulations of TANESCO . In view of the proximity of the switchyard to the power plant it is recommended that the switchyard be remote controlled from the power plant.

This switchyard will in the final construction contain two inlet lines from the power plant and one outlet field to Kigoma substation. Further enlargement is not envisaged till stage I and III projects are taken up.

The service consumption of the 66 kV switchyard is fed by a 400 V voltage from the power plant by cables. The auxiliary electric equipment is located in an one-storey building of minimum size. There are a L.T. panel, auxiliary panel for protecting devices, a D.C. equipment, a compressor station and accessories for the compressed-air control of switching devices of E.H.T.

The switchyard operation is by remote controls from the power plant control room. The emergency local control of the 66 kV equipment will be possible from outdoor control boxes located in each switchyard field.

The panel control board or the control desk will be provided with a diagram and status of the switching device position as well as with control devices. In practice status indication can be for instance by means of two signalling lights of different colours and with a separate control switch, or by a combined control and signal switch by a light-dark method. In view of the small switchyard, it is recommended to adopt the simpler light-dark method or another simple system of signalling. To switch the outlets which have to be synchronised the Engineer recommends the use of automatic synchronising equipment which eliminates all possible mis handling and makes possible the use of remote control of breakers. The manual synchronising will be done only exceptionally.

The connection by control, signal and measuring cables is done in cable ducts from the switchyard to the single level building, and further to the power plant, in a cable trench.

The main grounding system will be grid type made of steel strips galvanised in fire. The total ground resistance will be less than 1 ohm. In the cable routes between the switchyard and the power plant the outgoing earthing strips will be laid in a length of about 150-200 metres from the power plant in order to decrease an induced voltage occurrence at one-phase short-circuit faults, as well as their introduction by metal cable sheaths into the power plant.

The whole area of the switchyard is to be fenced off. Inside the switchyard a safety fence is also proposed in places accessible to the staff during operation time and where the safety clearance to the energized parts was not maintained.

Section 6 Transmission

Part I Description

The route follows the existing and planned roads as much as possible, so as to facilitate approach in the rainy season as major parts of the terrain along the route will be impassable to vehicles which may cause prolonged disruption in the event of damage to the line.

The main consumers of the power produced by the Malagarasi facility are Kigoma, Ujiji, Kasulu and Uvinza. The route is shown in figure 3-2. In addition to the main load centres, the chosen routes will simplify the future electrification of villages.

From the power plant at Malagarasi the route follows the planned access road up to Igunzi where the branching point for the line to Uvinza should be located. The Uvinza branch should follow the existing road all the way to Uvinza.

The main line to Kigoma/Ujiji should follow the existing road along the railroad on the southern side to Kazuramimba where the railroad should be crossed, and further along the road north of the railway via Kalenge and Kandanga towards the southern part of Kidahwe village, where the branching point for the line to Kasulu should be located. The Kasulu line should follow the other main road, B381, on the southern side up to junction 14 km south of Kasulu, and then follow the western side of the road to Kasulu.

From the branching point at Kidahwe the line should follow other roads towards Simbo, turn south of Kasuku, cross the swampy area between Kasuku and Ujiji and then pass south of the airport and up to Kigoma.

The total length of the transmission lines in this system is approximately 186 km and 66kV is selected even though 33kV will make it easy to electrify villages on the route. But the regulation and efficiency of transmission were found to be poor.

Almost all of the way along the route from Malagarasi to Uvinza and Kidahwe is made up of relatively dense forest with minor areas of open land. Further on up to Kigoma the route consists of mainly open land. The route is mostly moderately undulating, although there are also some extensive flat areas. The soil is firm along the entire route except for minor areas between Kazuramimba and Ujiji where swamps exist. The swamps are not expected to cause serious difficulties for the tower foundations, since wooden pole towers are recommended to be used, and there are several ways to secure a stable foundation.

Before a detailed design of these foundations can be executed, soil survey on the tower sites will have to be done.

The distances and conductor details are given below.

The details of the transmission line support are shown in figure 12-2. The towers can be either of steel or wood poles. The performance of the line was evaluated for transmission of entire 8MW to Kigoma for both 33kV and 66kV. The 33kV option requires capacitors at Kigoma to avoid an excessive voltage drop apart from requiring large conductors. As 66kV voltage exists in Tanzania, it is preferred to have 66kV double circuit towers with single circuit stringing initially and later have another circuit when an additional stage in the cascade is built.

The conductors are proposed to be Partridge with area of about 135 sqmm.

Box 12-1: Features of Transmission Lines

LINE	CONDUCTOR	SPAN (m)	INSULATOR	TOWER	LENGTH
Malagarasi - Kigoma	ACSR 135	150	Suspension	H type - Wood	95km
Igunzi - Uvinza	ACSR 40	150	Pin	Double pole - Wood	26km
Kidahwe - Kasulu	ACSR 80	150	Pin	Double pole - Wood	65km

The conductor size is such that total generation of 8MW can be transmitted to Kigoma with maximum voltage drop not exceeding 10%. The performance of the main line Malagarasi - Kigoma for 8MW total load at power factor of 0.85 lagging is given in table 12-1. The line parameters and other features are indicated.

It is seen that for a load in Kigoma of 8MW at 0.85 pf lagging, the sending end voltage is 1.085 pu or in other words the voltage drop is 8.56%. The transmission efficiency is 85.2%. For loads upto 4MW the drop is only 4.2% with 92% efficiency.

All towers should be constructed of galvanized steel and the wooden poles of creosote-treated wood with galvanized steel cross arms.

Box 12-2: Power Loss and Voltage drop in Transmission Line

Load in Kigoma (MW)	Power factor (lag)	Voltage Drop (%)	Efficiency (%)
1000	0.85	1.061	97.88
2000	0.85	2.124	95.84
4000	0.85	4.259	92.02
6000	0.85	6.405	88.50
8000	0.85	8.412	85.23

Part II **Protection of the Line**

With regard to the radial nature of the line sections the protection by distance relaying and or over current relaying is sufficient for all line troubles. It is not necessary to supplement it by another back-up protection.

Section 7 Substations

Substations in Kigoma, Kasulu and Uvinza are necessary. The single line diagrams for the substations are shown in figure 12-2 for Kigoma, Uvinza and Kasulu substations.

Shunt capacitors which would be necessary in case of 33kV transmission installed in the substations, Kigoma/Ujiji, Kasulu and Uvinza, to control the voltage level and the flow of reactive power are not required with 66kV.

In Kigoma the substation is proposed to be of the open type, with necessary buildings. The transformers and switchgear will be outdoors.

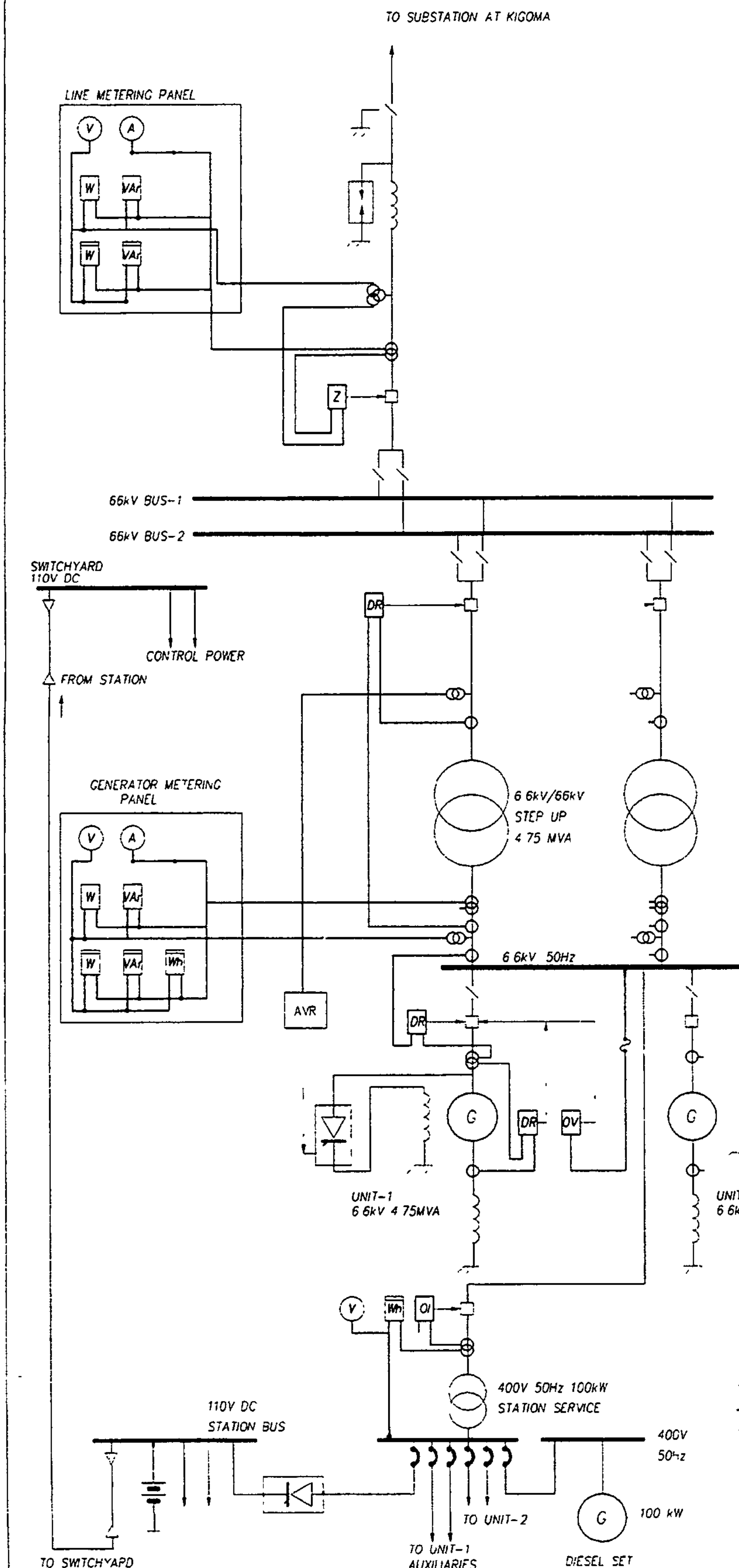
In Kasulu and Uvinza all arrangements are proposed to be outdoors with pole-mounted isolators and lightning arresting devices.

Box 12-3: Features of Substations

SUB STATION	TRANSFORMER RATIO (KV)	CAPACITY (MVA)	OUTGOING BAYS
KIGOMA	66/11	8	4
KASULU	66/11	2	2
UVINZA	66/11	2	2

Circuit breakers with protective relays will be beneficial both in reducing the number of outages and in protecting the system. Therefore, circuit breakers on the 66 kV level are proposed in front of the transformer at all substations. Line protection must be considered at the design stage. Circuit breakers with protective relays will be beneficial both to reduce the number of outages and from a protective point of view. The design of the substations is simple without too many redundancies.

The project cost estimate does not include the Kasulu and Uvinza lines. Their costs are not high and can be included along with the costs of electrification of numerous villages on these routes.



NOTES

This drawing shows the single line diagram of the Malagarasi Power station with the control protection and metering strategy A brief description is given below

The generator is connected to the generator bus through a generator circuit breaker This breaker will be tripped in case of overvoltage faults within the machine loss of excitation etc Station service will still be available through the main power transformer provided one unit is running The transformer is differential protected with a circuit breaker on the HV side A temperature and pressure relay can also trip this breaker The station service transformer is connected to the generator terminals Station consumption can be metered with an energy meter This transformer is protected by an over current relay on the HV side

The switchyard will be of the double bus type

A single circuit line to the receiving station at Kigoma is shown

Impedance type relaying is considered adequate for the protection of the lines

Both generator power as well as all the incoming and outgoing line flows are monitored with each panel containing Ammeters, Voltmeter, indicating wattmeters and varmeters, recording wattmeters and varmeters and a recording energy meter

LEGEND

- ISOLATOR
- CIRCUIT BREAKER
- 2 WINDING PT
- SINGLE WINDING PT
- 2 WINDING CT
- IMPEDANCE RELAY
- OVERVOLTAGE RELAY
- DIFFERENTIAL RELAY
- AIR CIRCUIT BREAKER
- AMMETER
- VOLTMETER
- INDICATING WATTMETER
- INDICATING VARMETER
- RECORDING WATTMETER
- RECORDING VARMETER
- RECORDING ENERGY METER
- BATTERY
- GENERATOR
- POWER TRANSFORMER
- POWER
- MEASUREMENT
- CONTROL
- LIGHTNING ARRESTOR

MALAGARASI HYDROPOWER PROJECTS STAGE-II

SINGLE LINE DIAGRAM WITH CONTROL, PROTECTION & MONITORING SCHEME

FOR. THE WORLD BANK/TANESCO

DWG NO	PLANNING, DESIGNS & CAD BY
FIG 12-1	SIVAGURU ENERGY CONSULTANTS

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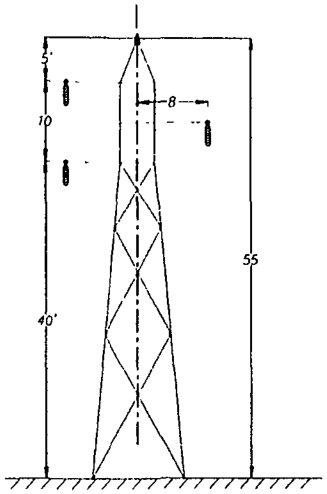
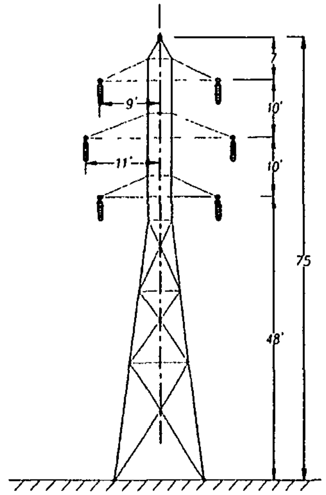
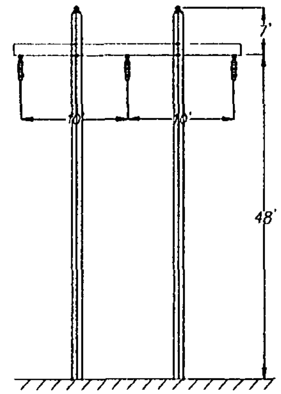


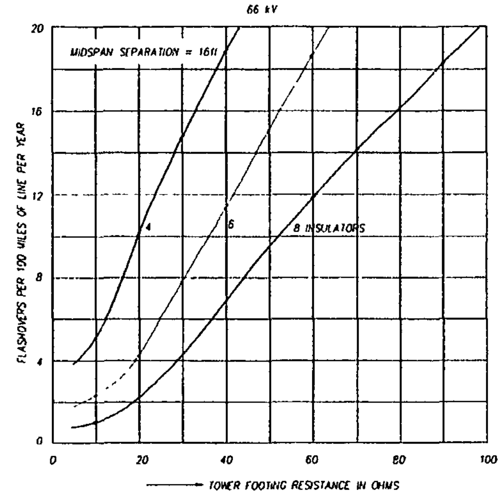
66kV SINGLE CIRCUIT STEEL TOWERS
AVERAGE SPAN-600 FT.

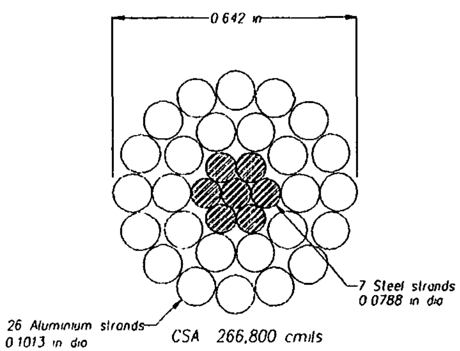


66kV DOUBLE CIRCUIT STEEL TOWERS
AVERAGE SPAN-600 FT

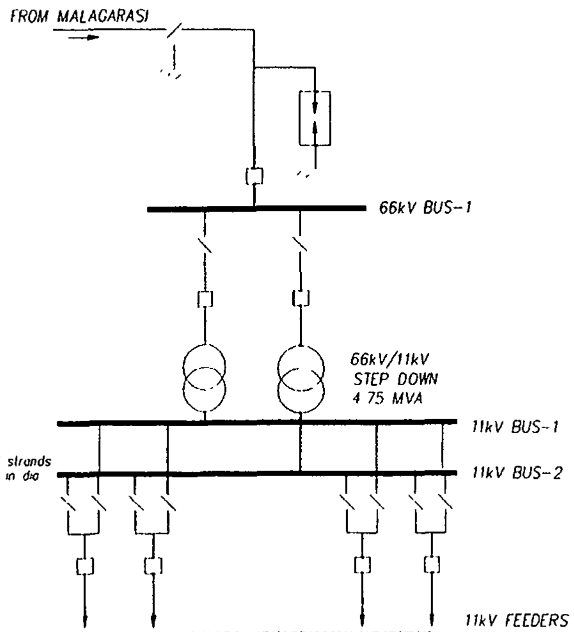


66kV WOOD POLE
AVERAGE SPAN-600 FT

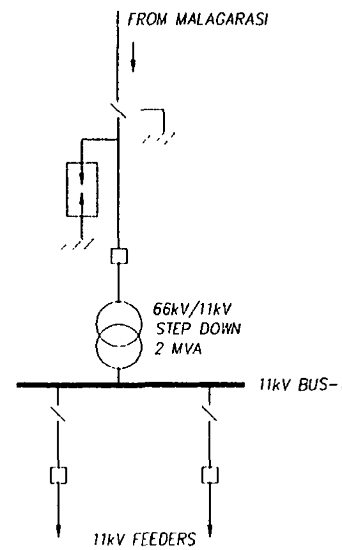




CONDUCTOR CROSS SECTION
MALAGARASI-KIGOMA LINE



SINGLE LINE DIAGRAM OF KIGOMA SUBSTATION



SINGLE LINE DIAGRAM OF UVINZA & KASULU SUBSTATIONS

MALAGARASI HYDROPOWER PROJECTS STAGE-2

TRANSMISSION LINE DETAILS

FOR. THE WORLD BANK/TANESCO

DWG NO FIG 12-2	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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TABLE 12-1
PARAMETERS OF TRANSMISSION LINE AND PERFORMANCE CALCULATION

	Parameters		
	Line Voltage	kV	66
	Frequency	Hz	50
	Electrical system		Single Circuit 3 phase 3 wire
	Base MVA	MVA	10
	Receiving End power	kW	8000
	Receiving End power factor		0 85
	Line Length	miles	59
	Conductor Code Word		Partridge
	Conductor cross section area	cmils	266800
	Resistance per mile of Conductor	Ohms	0.385
	Inductive Reactance per mile of Conductor at 1ft	Ohms	0.387
	Capactive Reactance per mile of Conductor at 1ft	Mohms	0 129
	Equivalent Spacing of conductors	ft	12.28
	Inductive Reactance per mile at equivalent spacing	Ohms	0 2536
	Capactive Reactance per mile at equivalent spacing	Mohms	0.0893
	Current Carrying capacity 50 deg C temp of cond	Amps	460
	Aluminium strands	No	26
	Strand dia	in	0 101
	Steel strands	No	7
	Strand dia	in	0 079
	Ultimate strength	lbs	11250
	Weight of conductor per mile	lbs	1936
	Outside diameter	in	0.642
	Insulators	Type	String type
	Support		Double circuit Steel towers with single circuit vertical arrangement
	Base Impedance	Ohms	435.6000
	Base Current	A	87 4773
	Line Resistance	Ohms	22 7150
	Line Inductive Reactance	Ohms	37.7934
	Line Capactive Reactance	Mohms	12 8734
	Line Resistance in per unit	per unit	0.0521
	Line Inductive Reactance in per unit	per unit	0 0868
	Line Capactive Reactance in per unit	per unit	29553.1599
	Line Impedance in per unit		5 21464646464646E-002+8.67616102106108E-002i
	Receiving End Voltage	per unit	1
	Receiving End Current	A	82.3316
	Receiving End Current Vector Re	per unit	0.8500
	Receiving End Current Vector Im	per unit	-0 5268
	Receiving End Current Mag in pu	per unit	0 9412
	Receiving End Current Phasor	per unit	0.85-0.526782687642637i
	Receiving End Current	per unit	0.8-0.495795470722482i
	Series Drop	per unit	8 47331850921 82E-002+4.35553071825815E-002i
	Sending Voltage	per unit	1 08473318509218+4.35553071825815E-002i
	Sending Voltage Magnitude	per unit	1 0856
	Regulation	percent	8 5607
	Loss	per unit	0 1386
	Loss	MW	1 3858
	Efficiency of Transmission Line	percent	85.2355

TABLE 12-2
ELECTRICAL WORKS SPECIFICATIONS

	Equipment Category	Units	
1	**Bus Bars**		
	Type		Copper bus bars in bus ducts
	Voltage	kV	6.6kV
	Current per phase	A	200
	Protection		Differentially protected
2	**Generator Circuit breaker**		
	Type		
	Rating	MVA	To be selected in design stage
	No of breakers		2
3	**Switchyard**		
	Location		External and located about 100m from power house
	Voltage	kV	66
	Design		As per TANESCO guidelines
	Type of Arrangement		Double bus bar type
	Incoming Lines		Two incoming lines from Power Station
	Outgoing Lines		One outgoing line to the KigomaSubstation
	Circuit breaker type		Vaccum circuit breakers/air blast
	No of Circuit breakers		3
	Isolators		Motorized post mounted rotary double break type
	No of isolators		7
	Earthing Switch		Earthing blade integral with isolators
	Lightning Arrestors		Post type mounted on insulator post
	Current transformers		Post type mounted on insulator post
	Potential transformers		Capacitve type
	Control power	V	110 V DC supplied from power station by cable
4	**Earthing**		
	Generator		Neutral solidly earthed
	Station & Switchyard		Grid mat with suitable connections to all electrical
			equipment and metal parts
5	**Unit Auxiliaries**		
	Auxiliaries Supply	V	400 V 50 Hz ac
	Auxiliaries source		6 6kV/400V step down from generator terminals
	Type of scheme		Single station service transformer
	Type of distribution		LT distribution panel with individual circuit breakers
	Metering		Voltage, kWh and current
6	**Emergency Equipment**		
	Battery		110V sealed maintenance free battery system
	Charging system		Electronic controlled charging
	Lighting	V	110 V DC supplied from batteries in battery room
	Black start		Diesel Electric set 100 kVA mounted outside station
7	**Protection**		
	Turbine		Overspeed, Bearing temperatures, Oil temperatures
	Generators		Loss of excitation, Negative sequence, stator faults
			Overspeed, Field short circuit
	Transformer		Differential protection, Bucholz, tank grounding
	Transmission		Distance protection.
8	**Transmission**		
	Voltage	kV	66
	Type		Double circuit towers with single circuit
	Final Receiving Station		Kigoma substation
	Length	km	95
	Conductors		Partridge 135 sqmm ACSR

Chapter 13 Implementation Cost

Section 1 Description

To compute the implementation cost of the project, the cost of civil works and equipment are estimated on the basis of the quantities of works required for the project and aggregated unit prices applied to the main categories of works and equipment.

The direct construction costs, and the estimated contingencies, are added to the environmental impact mitigation cost, engineering and administration costs, to yield the total implementation cost. The breakdown of the implementation cost is therefore as follows

Box 13-1: Components of Implementation Cost

Item	Amount
CIVIL WORKS Miscellaneous and contingencies 12 %	A 0.12 A
TOTAL CIVIL WORKS	1.12 A
EQUIPMENT Miscellaneous and contingencies 5 %	B 0.05 B
TOTAL DIRECT CONSTRUCTION COST	*D = 1.12 A + 1.05 B*
OTHER COSTS Engineering (Investigations, Detailed Design and Construction Supervision) 5% Administration 3%	 0.05 D 0.03 D
TOTAL OTHER COSTS	O = 0.08 D
TOTAL CONSTRUCTION COST	C = D + O
ENVIRONMENTAL IMPACT MITIGATION	E
TOTAL IMPLEMENTATION COST	T = C + E

The different elements of this table are described hereafter in each section.

The cost estimate was based on the conditions prevailing in August 1999 and the currency of the estimates is US Dollar.

Section 2 Civil Works

The cost estimate for the civil works is confined to the major items of work involved in the diversion weir, power house, tailrace etc. Miscellaneous items of work such as painting, doorwork, windows, lintels, decoration, false ceiling, flooring are simply taken care of in contingencies for Civil Works. It is of the opinion that these items of work are negligible compared to the major items and their detailed inclusion at this stage is not necessary. The contingency allowance provided for these items is considered to be more than adequate.

The aggregated unit prices used for the cost estimates of civil works include all direct costs of labour, use of construction equipment and materials increased by overheads and profit, costs of any temporary storage facility installation and clearance.

The aggregated unit prices result from a collection and review of costs extracted from actual construction costs prevalent in the region.

The prices reflect the geographical location of the site and its relative remoteness from main centres of economic activity.

The actual quantities of works have been taken into account, and some variations of unit prices have been considered according to the quantities of works. The aggregated unit prices for the cost estimates are presented hereafter.

Section 3 Electro-mechanical Equipment

The cost of the main generating equipment i.e Turbine, Generator, Electronic Governor and static excitation system, was calculated, based on budgetary prices and offer obtained from reputed manufacturer for the same type of equipment (2 or 3 units, of turbines of the Kaplan type, vertical axis) increased by overheads to account for cost of transport from country of manufacture to port in Tanzania and then to project site. The offer was lumpsum and did not give break up of the price. The scope of supply includes

- Design, manufacturing, transport, delivery, installation, start up and testing of the following main equipment, all conforming to the relevant latest international standards such as ISO, ASME, SAE, DIN etc and provided with performance, cavitation, pressure and speed rise guarantees as per IEC.
- Turbine - 2 units of Kaplan type turbine rated at 4.0 MW at 24 m speed 300 rpm complete with runner of 13%Cr & 4%Ni, main shaft, main shaft seal, guide bearing, wicket gate mechanism, gate operating ring, discharge ring, draft tube, oil supply head, oil piping, drainage and dewatering system, instruments and devices and complete set of platforms, ladders and stairs, drawings showing details of foundation requirements, embedding of supports and anchors in first and second stage of concrete.
- Generator - 2 units of synchronous generators rated 4.75 MVA, 6.6kV, 50 Hz, cos phi 0.85, 300 rpm complete with cooling system, oil system for bearings, brake, bearing supports.
- Governor - 2 units of electronic-hydraulic type with manual and automatic modes complete with speed sensing, stabilizing circuits, adjustable rated speed, permanent and temporary droop with dead band. The supply also includes hydraulic oil supply, hydraulic valves, pressure tank, compressed air supply system, instruments and devices.
- Excitation system - 2 units of microprocessor controlled static thyristor excitation system complete with voltage regulator, excitation transformer, cooling, rotor over voltage protection with digital sequencing and installation in cubicles with all operating panels and displays.
- Supply of one set of relevant spare parts and tools for above equipment
- Adequate corrosion protection during transport to site.

As the equipment is imported, as per Government of Tanzania rules any import duty and further taxes which may be levied are not taken into account.

Section 4 Auxiliaries

The following equipment and works are outside the scope of supply of electro mechanical equipment and are classified as auxiliaries and are separately accounted in the table 13-1. The items are

- All electric connecting cables and bus bars and ducts.
- Overhead crane,
- Control Panels
- Protection system
- Ventilation, cooling and air conditioning
- Synchronising equipment,
- Station service transformer, Emergency lighting, illumination and black start power,
- UPS and Battery system
- Fire fighting

The cost of the auxiliaries in the plant including all mechanical and electrical equipment of the power plant from the power intake to the power plant switching station (included) was calculated based on prices prevailing for similar equipment.

Section 5 Hydro-mechanical Equipment

The cost of the intake gates and bottom outlets and inlet and outlet gates was calculated on the basis of the area of fixed parts and moving parts, and on the following unit cost of metal work : The main groups of equipment to be installed within this section are :

1. Bottom outlets with operating mechanisms
2. Inlet Valves and/or gates.
3. Draft tube gates

The unit costs used for the equipment cost estimates include manufacturing prices, transportation and installation costs.

Gates etc. - $800 per sq.m.

Section 6 Switchyard

The costing includes the cost of land, land clearing, fencing, earthing, lighting, fire fighting, Main power transformer, Auxiliary transformer, switchgear and all other equipment required for the proper and reliable operation. The switchyard is 66kV.

Section 7 Transmission

The costing includes the transmission lines and equipment for connection to the existing substations or new substations. The cost of line to Kigoma includes cost of new transmission lines and substation. The total transmission is about 100 km. It should be noted that cables/conductors are manufactured in Tanzania and hence costs will be lower than if imported. The costing for lines to Uvinza and Kasulu is not included. The costs for these lines are not significant as loads are small.

Section 8 Miscellaneous and Contingencies

The cost of construction is calculated by applying unit cost estimates to the calculated quantities of the works identified as the main components of the project. The total cost resulting from these calculations should be increased by a contingency allowance of 12% for the civil works, 5% for the hydro-electric equipment. These contingency allowances represent the miscellaneous expenses that have not been listed in the table on quantities and implementation and that which might not have been identified properly, especially when the topographical and geological conditions of the site, as well as the design of the works, have not reached the level of precision of later stages.

Section 9 Engineering and Administration

A provision of 5% of the total direct construction costs has been considered for engineering services until the end of construction. This amount includes further topographical survey, geological and geo-technical investigations, feasibility and detailed design studies, environmental impact assessment and resettlement program, supervision of construction etc.

The cost of administration of the project by the Owner was estimated to be 3 % of direct construction costs.

Section 10 Environmental Mitigation

Further detailed topographic surveys are necessary to accurately assess the environmental impact. Prima facie it is evident from site visits that no significant impact will occur. At this stage a lumpsum amount of US$25,000 has been provided for environmental impact cost.

The percentage of the environmental costs for project will not exceed 1% of the total implementation cost.

Section 11 Total Implementation Cost

The total implementation cost as determined with the item wise break up is given in table 13-1. The implementation costs here above should still be regarded at this stage to incorporate a certain range of uncertainty , which has two origins :

I) an uncertainty on the unit costs, which is related to the high variations in the actual tender prices commonly observed, and to the economic conditions that will prevail until the time of construction, and

ii) an uncertainty of a technical nature related to the exact natural conditions which prevail on the sites (with a particular influence of geology), and which will gradually be better known as investigations and studies proceed until the time of construction.

This range of uncertainty is estimated to be from - 15 % to + 20 % .

The project is economically and financially viable even with this range of uncertainity with respect to the implementation cost.

TABLE· 13-1
QUANTITIES AND IMPLEMENTATION COST

1	CIVIL WORKS	Unit	Unit Price USD	Quantity	Cost USD	Total Item Cost USD	Total Cost USD
a	Access Road	km	20,000	24	480,000	480,000	
b	Bridge	lumpsum	200,000		200,000	200,000	
c	Construction Camp	lumpsum	50,000		50,000	50,000	
d	Diversion Weir Preliminaries						
i	River Diversion	lumpsum	25,000	1	25,000		
ii	Site Clearing and Grading	m2	3	7475	22,425	47,425	
e	Diversion Weir						
i	Soft Rock Excavation	m3	8	5350	42,800		
ii	Rock Excavation	m3	13	5350	69,550		
iii	Rockfill	m3	20	11375	227,500		
iv	Rubble Masonry	m3	25	2275	56,875		
v	Cement Mortar Masonry	m3	30	3721	111,630		
vi	Cement Concrete Slab	m3	300	650	195,000		
vii	RCC Bucket	m3	384	130	49,920		
viii	Backfill	m3	8	2895	23,160		
ix	Grouting	m	300	600	180,000	956,435	
*	Total Cost of Diversion Weir						1,003,860
f	Intake & Water Conductor						
i	Land Clearing and Preparation	m2	3	5000	15,000		
ii	Soft Rock Excavation	m3	8	10500	84,000		
iv	Cement Concrete	m3	300	1025	307,500		
vi	Penstocks etc inclusive of fabrication	t	5,000	55	275,000	681,500	
g	Forebay						
i	Land Clearing and Preparation	m2	3	900	2,700		
ii	Soft Rock Excavation	m3	8	2957	23,656		
iii	Backfill	m3	8	1000	8,000		
iv	Concrete	m3	300	895	268,500	300,156	
*	Total Cost of Water Conductor						981,656
h	Power House						
i	Soil Excavation	m3	4	200	800		
ii	Soft Rock Excavation	m3	8	200	1,600		
iii	Hard Rock Excavation	m3	13	400	5,200		
iv	Mass Concrete	m3	300	1300	390,000		
v	Reinforced Concrete	m3	384	375	144,000	541,600	
i	Tailrace						
i	Soil and Soft Rock Excavation	m3	8	200	1,600		
ii	Rock Excavation	m3	13	0	0		
iii	Concrete	m3	300	174	52,237		
iv	Reinforced Concrete	m3	384	135	51,840	105,678	
	TOTAL CIVIL WORKS COST						3,362,794
2	ELECTROMECHANICAL EQUIPMENT						
a	Turbine & Generator	kW	450	8000	3,600,000		
b	Auxiliaries	kW	25	8000	200,000		
c	Emergency Gates	lumpsum	25,000	2	50,000		
d	Draft Tube Outlet Gates	m2	800	20	16,000		
e	Transmission & Substation	km	25,000	100	2,500,000	6,366,000	
	TOTAL ELECTROMECHANICAL COST						6,366,000
3	TOTAL CONSTRUCTION COST						9,728,794
4	OTHER COSTS						
a	Engineering	percent	5		486,440		486,440
b	Administration	percent	3		291,864		291,864
5	CONTIGENCIES						
a	Civil Works	percent	12		403,535		403,535
b	Electromechanical & Others	percent	5		318,300		318,300
6	ENVIRONMENTAL IMPACT COST	lumpsum			25,000		25,000
7	TOTAL IMPLEMENTATION COST						11,253,932
8	COST PER kW INSTALLED	USD			1,407		

Chapter 14 Economic and Financial Analysis

Section 1 Description

The economic analysis is carried out to evaluate the viability of the project from the viewpoint of Tanzania's national economy.

The Benefit Cost ratio method is used to evaluate the economic feasibility. The benefit is defined as the discounted value of all future net profits without considering taxes and the cost is defined as the discounted sum of all expenditures incurred in planning, designing, constructing and operating the project over its economic lifetime. The benefit from the project is the energy which it generates. For comparing this with the costs incurred, it is necessary to fix a suitable monetary value for the energy which is produced. In this case, it is fixed as the avoided cost of energy produced by the next least cost option which is usually from a diesel set providing an equivalent capacity and energy which would have to be implemented instead of the proposed hydropower project. Another fact to consider is that the project is likely to give other benefits such as fisheries, recreation etc. But from the point of view of the IPP these are considered as intangibles and the benefit is considered to be insignificant. The benefit cost must be at least one for the project to be economically viable.

As the project may be implemented on non recourse financing in which the lenders and investors treat the project assets as a collateral, the financial analysis is carried out to determine cash flows and is the most important study for the project developers, the lenders and investors.

The financial analysis hence shows the pattern of cash flow which the project provides over its economic life. It also determines the ability to pay the debt service, operating and maintenance cost and brings out any cash flow deficits which may arise. Ideally the net cash flow should be an inflow as otherwise other short term loans have to be negotiated to cover these deficits during project operation. In evaluating the cash flow all expenditures such as debt service, operation and maintenance, depreciation, income from sale of electricity are lumped into end of year payments

Section 2 Economic Analysis

Part I Assumptions

To carry out economic analysis, it is necessary to determine the economic value of the energy generated from hydropower.

This is done by calculating the avoided cost of generation of an equal quantum of power and energy obtained from a diesel plant of 8MW located in Kigoma. The transmission cost will be negligible.

Total annual cost for hydro and diesel plant are computed and the energy cost from each is calculated as follows.

Box 14-1: Calculation of Economic Value of Energy from Hydropower

	Unit	Diesel	Diesel	Hydro	Hydro
Net Annual Energy	GWh	25	65	25	65
Cost of Installed capacity	USD/kW	1100	1100	1625	1625
Maintenance + Outage	% p a	8+6 = 14	8+6 =14	nil	nil
Installed Capacity	kW	9300	9300	8000	8000
Capital Cost	MUSD	10.23	10.23	13.00	13 00
Fuel Consumption	g/kWh	250	250	nil	nil
Station Energy Consumption	%	5	5	nil	nil
Fixed Annual O & M cost	% of CC	5	5	1%	1%
Variable Annual O & M cost	USD/MWh	6	6	nil	nil
Fuel Cost	USD/t	320	320	nil	nil
Capital Recovery Factor	% p.a	16.27	16.27	16.27	16.27
CO_2 emission cost	US cents/kWh	1.3	1.3	nil	nil
Gross Annual Energy	GWh	26.31	68.42	25	65
Annual Debt Service	MUSD	1.664	1.664	2.115	2.115
Annual fixed O & M Cost	MUSD	0.511	0.511	0.130	0.130
Annual variable O & M Cost	MUSD	0.158	0.410	nil	nil
Fuel Cost	MUSD	2.105	5.473	nil	nil
Total Annual Costs	MUSD	4.438	8.058	2.245	2.245
Cost/kWh	US cents	17.75	12.40	8.98	3.45
Cost/kWh including CO_2 cost	US cents	19.05	13.70	8.98	3.45

The Implementation cost of the hydro project is US$ 11.25 million for 8000KW which has been worked out in the statement on quantities and implementation cost. It is assumed that the entire cost of the project is met from borrowed capital. The interest rate is taken to be 10% and the loan return period is 10 years (typical values from International Financial Institutions for loans to project developers). Based on this the capital recovery factor is about 16.27%. Based on the 24 month construction period, the IDC is US$ 1.77 million. Total cost is then obtained by adding the two amounts which is USD 13 M.

Similarly the total annual costs of the diesel plant are calculated as shown in Box 14-1. The World Bank has recently started taking the CO_2 pollution cost of thermal stations into the economic analysis. It has recommended a value of US$20/t of CO_2 emitted which comes to 1.3 US cents/kWh.

From the above, it can be seen that if the market demand for energy starts from 25GWh, then the cost of generation from diesel set is 19.05 US cents/kWh. In case all the energy produced can be sold, then the generation cost from diesel comes down to 13.70 cents/kWh. For any intermediate conditions the average is computed which is 16.38 cents/kWh. Based on this and initially without applying discounting, the following first year benefits can be calculated.

Box 14-2: Economic Feasibility without considering lifetime costs/benefits

Economic Price of Energy	US cents/kWh	13.70	16.38	19.05
Energy from Hydro	GWh	65	45	25
Value of Benefits	MUSD	8.905	7.371	4.762
Costs	MUSD	2.138	2.138	2.138
B/C ratio		4.165	3.447	2.227

Discounting is now applied with the following additional data so as to calculate lifetime costs and benefits with the above economic values of energy,

An inflationary factor of 5% p.a has been included in the calculations for the economic price of electricity as well as the Operations and Maintenance costs. This is justified because the diesel fuel has to be transported over a long distance and hence inflation is likely to affect the transport costs.

The analysis is done as given in section on methodology. The following critical conditions were also examined where the sale of energy is limited to 25GWh in the first year and rises at a low growth rate of 2% p.a. The following are the base case conditions

Cost = 11.25MUSD, IDC = 1.77 MUSD, Interest = 10%, Payback = 10 years, Discount = 12%, Inflation = 5%. The cases examined are indicated in box 14-3 wherein the changes from the base case condition is indicated with a '/'.

Box 14-3: Economic Analysis with Sensitivity

Case	Condition	Base Demand	Demand Growth	B/C Ratio	NPV	EIRR
1	Base / Discount 8%	25 GWh	0.0%	7.34	108.41	> 30
2	Base / Discount 10%	25 GWh	2.5%	6.26	80.76	> 30
3	Base / Discount 12%	25 GWh	2.5%	5.45	61.80	> 30
4	Base / Cost + 20%	25 GWh	2.5%	4.54	59.06	> 30
5	Base / Inflation 0%	25 GWh	5.0%	4.21	43.02	> 30
6	Base / Inflation 0%	25 GWh	0.0%	2.85	24.85	> 30
7	Base / Inflation 2.5%	25 GWh	5.0%	5.34	59.01	> 30
8	Base / Discount 12%	45 GWh	5 0%	8.56	104.94	> 30
9	Base / Cost + 20%	45 GWh	0.0%	5.41	73.57	> 30
10	Base/ Discount 12%	65 GWh	0.0%	7.84	94.90	> 30

From the above, the benefit cost ratio is very satisfactory for all the above test conditions. Of particular interest is case 6 where the demand does not grow, nor is there any inflation in diesel fuel cost and discount rate is high 12%. Even in this case the benefit cost ratio is 2.85.

Section 3 Financial Analysis

The financial analysis is indicated in table 14-1 for one case, with the conditions indicated in the table.

The purchase price for electricity in the base year is taken as US$ 0.07 per kWh. This is the current average tariff prevalent in the area, and is the rate which can be readily obtained from sale of power.

Section 4 Methodology

Based on the above, a computer program was used to perform the analyses and the results are presented in the table 14-1. The table brings out the debt service, depreciation, operation and maintenance and revenue flow as well as the discounted flows.

A brief description of the model is given below.

The capital Cost of the Project is given by C as determined from the unit costs of materials and quantities. For the project then

$C = 11.25$ M\$ (1)

The Interest paid during construction is computed based upon the disbursement of the loan over the construction period as explained in the foregoing section

$IDC = I_1 + I_2$ (2)

where

$I_1 = C_1 i$, where $C_1 = 0.5C$ (3)

$I_2 = (I_1 + C_1 + C_2)i$, where $C_2 = 0.5C$ (4)

and i is the interest rate (cost of capital) = 10% pa.

so that $C_1 + C_2 = C$ (5)

Hence Total Capital Cost

$P = C + I$ \$ (6)

The loan is assumed to be recovered in 10 equal payments. Hence the annual payment in the nth year is

$L_n = P\, i(1 + i)^n/((1 + i)^n - 1)$ \$ for $1 <= n <= 10$.

$L_n = 0$ \$ for $n > 10$ (7)

where multiplier term above is also called as the capital recovery factor.

The mean annual Energy Output as determined from the power and energy studies

$E_m = 65,000,000$ kWh (8)

All the energy which can be produced cannot be marketed as the demand is yet to grow. Hence the demand in the base year is given by

E_b = 25,000,0000 kWh and growth rate by g = 2.5, 5% etc.

Thus in any year n,
$E_n = E_b(1 + g)^n$ kWh for $E < E_m$ and $E = E_m$ for $E > E_m$ for n = 0 to 29.

The base price for electricity in the first year is T cents/kWh The escalation rate for the electricity price (e) = 5%

where T = 19.04 US cents for economic analysis with demand = 25 GWh
T = 13.70 US cents for economic analysis with demand = 65 GWh
and T = 7.00 US cents for financial analysis

Thus e = 0.05 (9)

In any year n after commercial operation starts, annual revenue

$R_n = ET(1 + e)^n$ \$ for n = 0 to 29 (10)

The annual operation and maintenance expenditure is 1% of the capital cost of the project = 0.01 escalating at the escalation rate (e)

In any year n after operation starts

$OM_n = 0.01C(1 + e)^n$ \$ for n = 0 to 29 (11)

Due to wear and tear of the equipment its necessary to account for depreciation. The depreciation is accounted by setting aside equal yearly payments into the bank such that at the end of the economic life the capital cost of the project is realised due to earning of interest.

$D_n = Ci/((1 + i)^n - 1)$ where n = 30. (12)

The total net income in any year

$NI_n = R_n - L_n - OM_n - D_n$ (13)

The present worth of any payment accruing in the nth year is given by multiplying the payment by the present worth factor PWF

$PWF_n = 1/(1 + i)^n$ (14)

The present worth of the loan payment, depreciation, O&M and revenue streams are multiplied by the PWF to get the present worth of these future payments.

These are then summed to get the total present worth of all these payments

Thus total present worth of benefits from project
$B = \Sigma R_n PWF_n$ for $1 <= n <= 30$ years (15)

Similarly the total present worth of costs

$OM = \Sigma OM_n PWF_n$ for $1 <= n <= 30$ years (16)

The total lifetime costs $S = P + OM$ (17)

Benefit Cost Ratio $= B/S$ (18)

The Net Present Value $NPV = B - S$ (19)

The IRR is determined by trying various values of i such that $NPV = 0$.

The unit cost of energy over the lifetime of the project is calculated by summing the present value of lifetime costs divided by

$c = (OM + D + P)/\Sigma E_n$ (20)

The cost of generation in the first year is given by
$L_1 + D_1 + OM_1/E_1$ \$/kWh.

For each year the cash flow is computed as

$F_n = R_n - L_n - D_n - OM_n$ (21)

which when positive indicates net inflow and when negative indicates net outflow of funds.

Above calculations are presented in the table and a brief description is given here. Column labelled as %CC gives the percentage of total implementation cost expended each year. Column 1 gives the amount to be invested each year during construction and during the operating period. Column 2 gives the IDC. Column 3 gives the uniform annual payments required to service the project loan and is worked out by the capital recovery factor method. Column 4 gives the depreciation amount to be paid. This is worked out by assuming uniform payments which earn interest to give back the capital cost at the end of the economic life. Column 5 gives the O&M cost each year taking into account the inflationary rate. The costs in columns 3,4 and 5 are added and divided by the annual energy to give the cost of production of 1kWh. Column 6 gives the revenue earned each year starting from the specified base year tariff which is increased each year by the inflationary rate. Column 7 gives the net income each years by subtracting the sum of columns 3,4 and 5 from 6. Column 8 gives the present worth factor obtained by using the specified discount rate. Columns 9, to 11 give the present worth of each annual payment such as the annual cost, energy cost, revenue and cashflow obtained by multiplying the corresponding value by the PWF. The last row of the table gives the total values in each column. The totals in columns 9 to 11 are the present worth of all future amounts.

Section 5 Sensitivity Analysis

Since some of the conditions assumed for the financial analysis may vary in actual practice, sensitivity analysis as below was carried out to determine the variation.

A sample calculation for case No. 1 is indicated in table 14-1. The results for the cases are presented in figures 14-1,14-2 and 14-3.

All the cases show that very little on no cash flow deficits arise and the project is bankable.

It should be noted that the tests are made with adverse conditions listed below

- 100% Project loan at 10% interest and payback in 10 years
- Sale of only 25GWh in the base year with a low growth rate of 2.5% in demand.
- Low price for electricity sold which is US 7 cents/kWh escalating at 5% p.a.

Box 14-4: Cases for Financial Sensitivity Analysis

CASE	PARAMETER	COST	LOAN PERIOD	INTEREST	PURCHASE PRICE	DISCOUNT RATE
1	B/C RATIO	11.25	10	5% to 15%	0.07	12%
2	ENERGY COST	11.25	10	5% to 15%	0.07	12%
3	B/C RATIO	11.25	10	10%	0.05 to 0.10	12%
4	ENERGY COST	11.25	5 to 10	10%	0.07	12%
5	ENERGY COST	10-15	10	10%	0.07	12%
6	B/C RATIO	10-15	10	10%	0.07	12%
7	B/C RATIO	11.25	10	10%	0.07	10% to 30%
8	NPV	11.25	10	10%	0.07	10% to 30%
9	LIFE CYCLE ENERGY COST	11.25	10	10%	0.07	10% to 30%
10	BENEFITS AND COSTS	11.25	10	10%	0.07	10% to 30%
11	NPV	11.25	10	5% to 15%	0.07	10% to 30%
12	B/C RATIO	11.25	10	5% to 15%	0.07	10% to 30%
13	ENERGY COST vs ENERGY	11.25	10	10%	0.07	12%
14	B/C RATIO vs ENERGY & GROWTH	11.25	10	10%	0.07	12%

Following observations can be made on each of the cases above.

1. Case-1: Even for a high financing rate of 15% the project benefit cost ratio does not fall below 1.5
2. Case-2: Even for a high financing rate of 15%, the energy cost in the first year does not exceed 12 cents.
3. Case-3: Even if the purchase price per kWh falls to 5 cents, the benefit cost ratio is 1.5
4. Case-4: Even for a short loan payback period of 7 years, the first year energy cost is only 10 cents
5. Case-5: Even if the capital cost increases by 50%, energy cost does not exceed 12 cents
6. Case-6: Even if the capital cost increases by 50% benefit cost ratio is 1.5
7. Case-7: Even for a high discount rate of 20%, the benefit cost ratio exceeds 1.25
8. Case-8: Even for a high discount rate of 20%, the NPV is positive.

9. Case-9: The life cycle energy cost in present value is only 1.4 US cents
10. Case-10: The plot of benefits and costs versus discount rate intersect at a large enough value of discount rate. Thus FIRR is high.
11. Case:11: Combined plot of NPV versus discount and interest rate shows that NPV is positive for all combinations
12. Case:12: Combined plot of BC ratio versus discount and interest rate shows that B/C ratio is greater than one for all combinations.
13. Case-13: Production cost falls with increase in the first year demand. If all the energy can be sold, production cost is only 3.4 cents/kWh.
14. Case-14: Project Benefit cost ratio is given for different first year demands with different growth rates. It shows that the minimum B/C ratio is 2 even for low demand of 25 GWh with low growth rate of 2.5%.

Summarizing the project is highly feasible from economic and financial terms.

TABLE: 14-1
ECONOMIC AND FINANCIAL ANALYSES
(ADVERSE CONDITION EXAMPLE)

Capital Cost	11.250	M US$	Maximur	65.00 GWh
Interest Rate	10	percent		
Payback Period	10	years		
CRR	0.1627			
Discount rate	12	percent		
Base year Demand	25 000	GWh		
Base Price of Energy	0 07	$/kWh		
Inflation Rate	5	percent		
O&M	1	percent		
IDC	1.744	M US$		
IDC + Capital Cost	12 994	M US$		
Economic Life	30	years		
Demand Growth	2 5	percent		

Years	% CC	Investment M US$ 1	Sigma inv	IDC M US$ 2	Debt Service M US$ 3	Depre-ciation M US$ 4	O & M M US$ 5	Energy Sold GWh	Gen Cost $/kWh	REVENUE M US$ 6	NET INCOME M US$ 7	PWF 8	PRESENT WORTH RUNNING COSTS M US$ 9	ENERGY COST $/kWh	REVENUE M US$ 10	CASH FLOW M US$ 11
-2	50	5 625	5 625	0 563												
-1	50	5.625	11 250	1.181												
											(6)-(3+4+5)		(8)x(3+4+5)		(8)x(6)	(10)-(9)
1		0 000			2 115	0 068	0 113	25 000	0.092	1 750	-0 546	0.893	2.050	0 082	1 563	-0 487
2		0 000			2 115	0 068	0 118	25 625	0 090	1 883	-0 418	0 797	1 834	0 072	1 501	-0 333
3		0 000			2 115	0 068	0 124	26 266	0 088	2.027	-0 280	0.712	1 642	0 063	1 443	-0 199
4		0 000			2 115	0 068	0 130	26.922	0 086	2 182	-0.132	0 636	1 470	0 055	1 386	-0 084
5		0 000			2 115	0 068	0 137	27.595	0 084	2 348	0 028	0 567	1.316	0.048	1.332	0 016
6		0 000			2 115	0 068	0 144	28.285	0.082	2.527	0.200	0.507	1 179	0.042	1 280	0 102
7		0 000			2 115	0 068	0 151	28 992	0 080	2 720	0.386	0 452	1 056	0 036	1 230	0 175
8		0 000			2 115	0.068	0 158	29 717	0 079	2 927	0.586	0 404	0 946	0.032	1 182	0 237
9		0 000			2.115	0.068	0 166	30 460	0.077	3 150	0.801	0 361	0.847	0 028	1 136	0 289
10		0 000			2 115	0.068	0 175	31 222	0.076	3.390	1.033	0 322	0.759	0 024	1 092	0 333
11		0 000			0 000	0 068	0.183	32.002	0 008	3 649	3.397	0.287	0 072	0 002	1 049	0 977
12		0.000			0.000	0 068	0 192	32.802	0 008	3 927	3.666	0.257	0 067	0.002	1.008	0 941
13		0 000			0 000	0 068	0.202	33 622	0 008	4.227	3 956	0.229	0.062	0 002	0 969	0 907
14		0.000			0.000	0 068	0 212	34.463	0 008	4 549	4.268	0.205	0.057	0 002	0 931	0 873
15		0.000			0 000	0 068	0 223	35.324	0 008	4.896	4.605	0 183	0 053	0.002	0.894	0 841
16		0 000			0 000	0 068	0.234	36.207	0 008	5 269	4 967	0.163	0 049	0 001	0.860	0 810
17		0.000			0 000	0 068	0 246	37 113	0 008	5.671	5 357	0 146	0 046	0 001	0 826	0 780
18		0 000			0 000	0 068	0 258	38.040	0 009	6 103	5.777	0 130	0 042	0 001	0.794	0 751
19		0 000			0 000	0 068	0 271	38 991	0 009	6.569	6 229	0 116	0.039	0 001	0 763	0 723
20		0 000			0 000	0 068	0 284	39 966	0 009	7 069	6 717	0 104	0.037	0 001	0 733	0 696
21		0 000			0.000	0.068	0 298	40.965	0 009	7.609	7 242	0.093	0.034	0 001	0.704	0 670
22		0 000			0 000	0 068	0 313	41 990	0 009	8 189	7 807	0 083	0.032	0.001	0 677	0 645
23		0 000			0 000	0 068	0 329	43 039	0 009	8 813	8 416	0.074	0 029	0.001	0 650	0 621
24		0 000			0.000	0 068	0 346	44.115	0.009	9 485	9 071	0.066	0.027	0.001	0 625	0 598
25		0.000			0.000	0.068	0.363	45.218	0 010	10.208	9 777	0.059	0.025	0.001	0.600	0.575
26		0 000			0.000	0 068	0 381	46 349	0.010	10.987	10 537	0.053	0.024	0.001	0 577	0 553
27		0 000			0 000	0 068	0 400	47 507	0.010	11.824	11.356	0.047	0 022	0 000	0 554	0 533
28		0 000			0.000	0.068	0 420	48 695	0.010	12 726	12.238	0.042	0 020	0.000	0 533	0 512
29		0 000			0.000	0.068	0.441	49.912	0.010	13.696	13 187	0.037	0.019	0.000	0 512	0.493
30		0.000			0.000	0 068	0 463	51.160	0 010	14 741	14 209	0.033	0.018	0.000	0 492	0 474
									MEAN					MEAN		
TOTAL		11 250		1.744	21 147	2 052	7 474	1098	0 034	185.111	154.439		13.875	0.017	27.896	14 022

PW of Total Life Cycle Benefits	27.896	M US$	
PW of Total LCC (OM+Cap+IDC+De	13.875	M US$	
Benefit Cost Ratio	2 011		
Average Cost of Energy	0.013	$/kWh	Computed over lifetime energy
Net Present Value	14.022	M US$	

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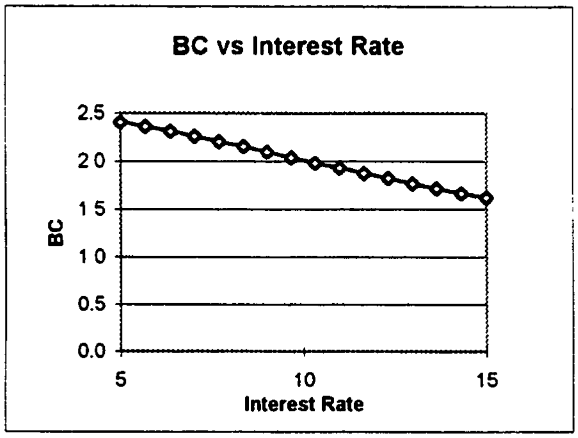
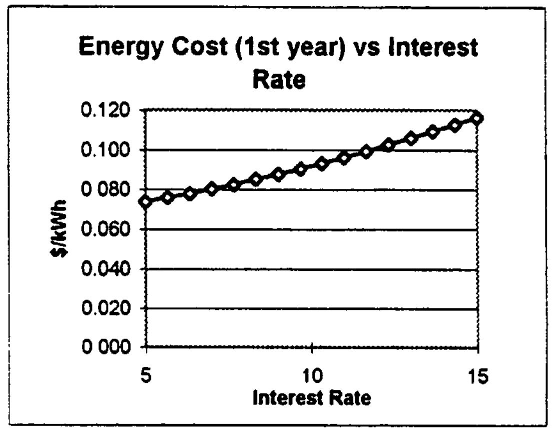
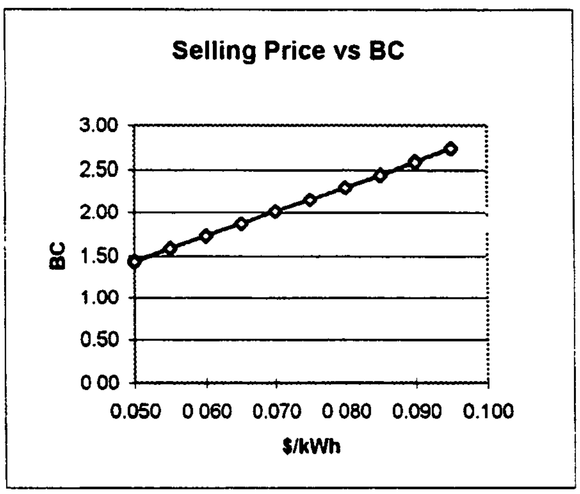
FIGURE. 14-1
FINANCIAL SENSITIVITY ANALYSES CASES 1 to 6



Case-1



Case-2



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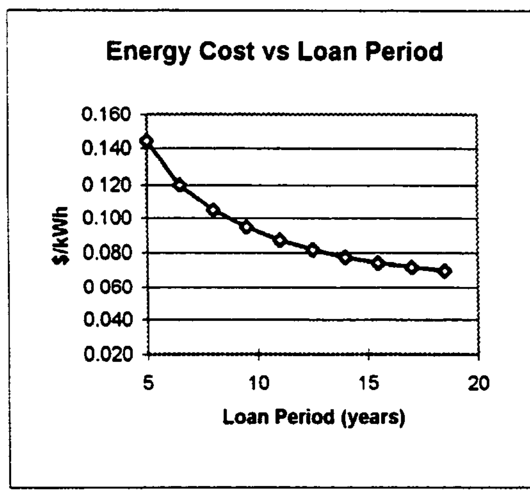

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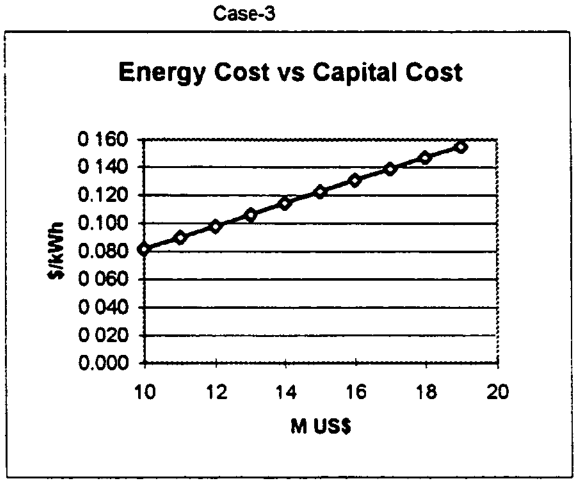

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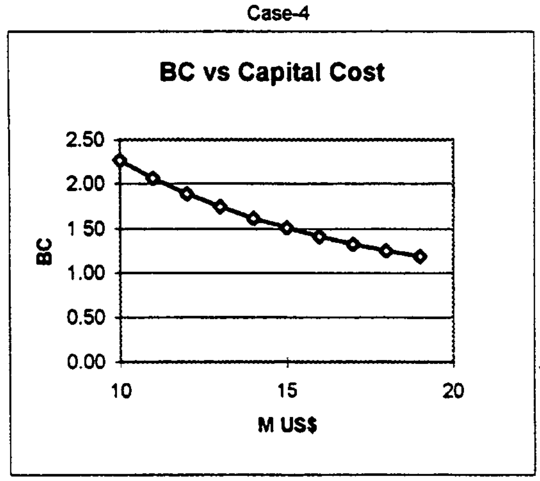
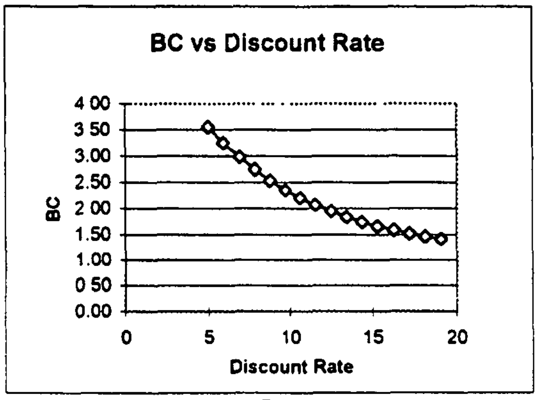


Case-6

FIGURE 14-2

FINANCIAL SENSITIVITY ANALYSIS CASES 7 to 12



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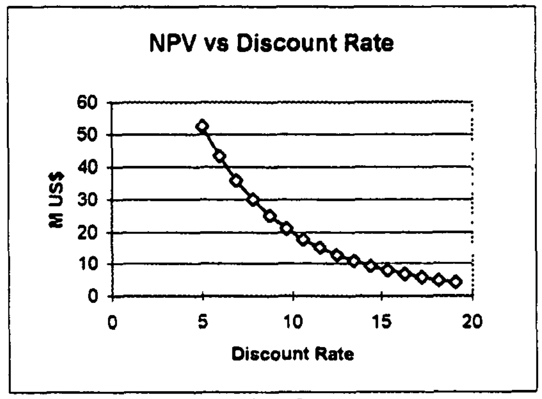

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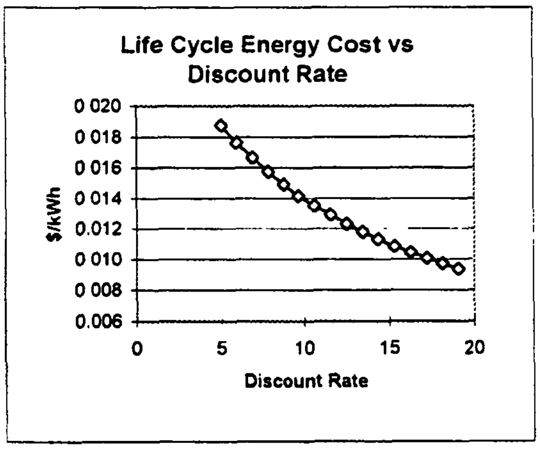
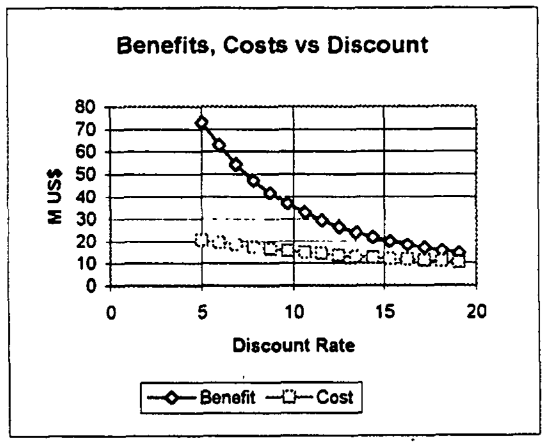
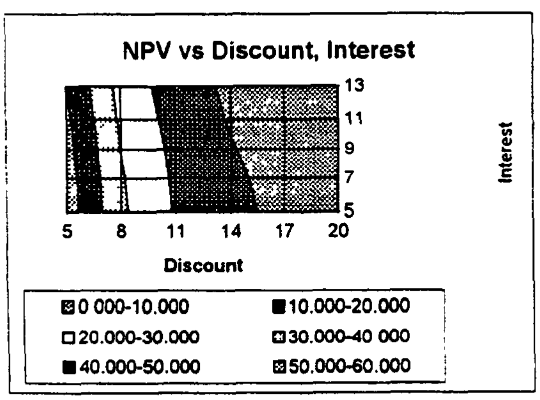


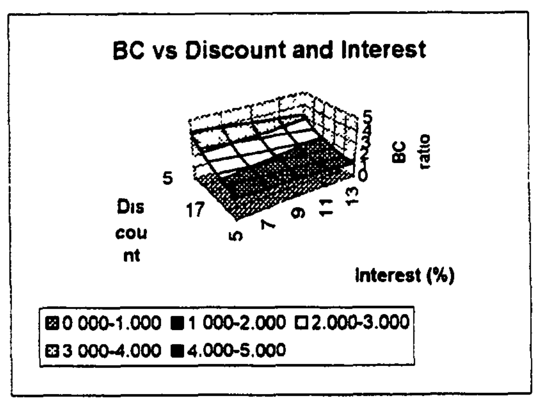
Case-9



Case-10



Case-11



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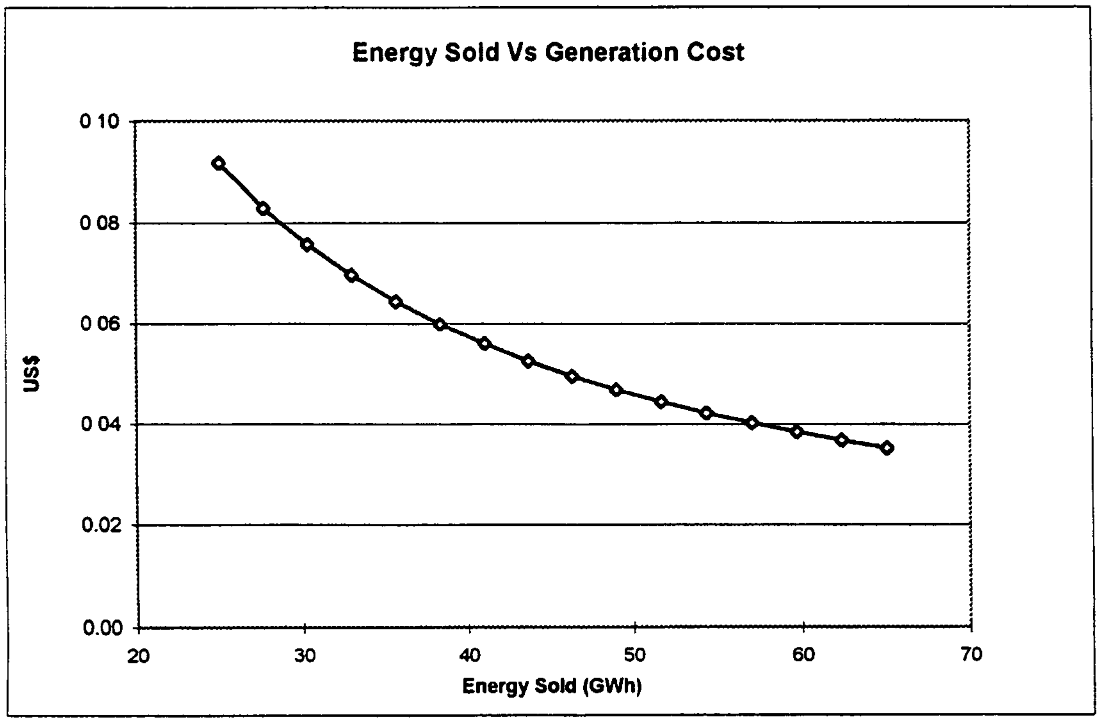
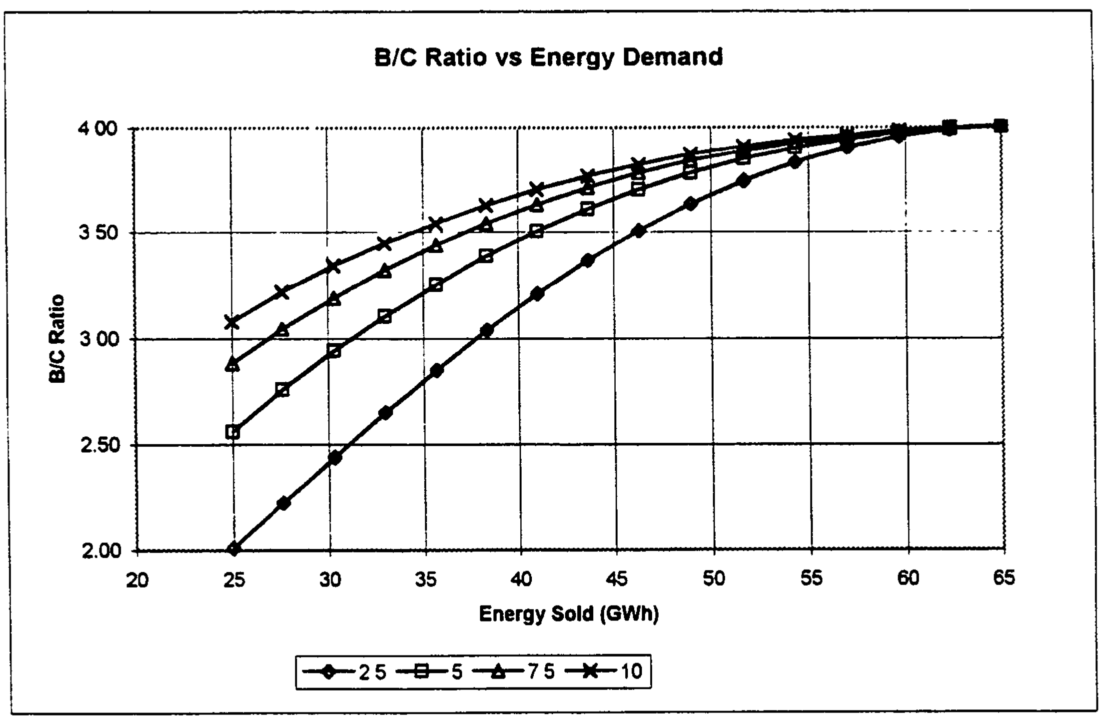
FINANCIAL SENSITIVITY ANALYSIS CASE 13 TO 14



Case - 13



Case - 14

Chapter 15 Implementation Aspects

Section 1 General

The successful implementation of the project depends on close coordination between the various teams involved in the design, construction etc. Some aspects of the implementation are discussed below.

Section 2 Supply of Materials and Equipment

The construction of the power station and the related transmission facilities will require the hauling in of materials and construction equipment, electro-mechanical equipment (turbines, generators etc) and hydraulic equipment (gates etc).

The longest and heaviest construction items are assumed to be the following

Heaviest Article	Longest Article
Prior to construction -Breaker about 25 tons During construction - Generator rotor segments	Travelling crane about 8m

It is expected, that mechanical and electrical equipment shall be furnished in major items as follows :

1. Penstocks, Gates and Trashracks
2. Turbines, Governors, Cranes and Hoists
3. Auxiliary Mechanical Equipment
4. Generators
5. Transformers
6. Major Electrical Equipment
7. Equipment for 66 kV Switchyard .
8. General Materials

These principal items may be furnished on special contracts. The items involved will be procured from three major sources

1. Imported Heavy Articles. This will consist of construction machinery not available in Tanzania, the electro mechanical equipment and major electrical

equipment. All of these will be landed at the Dar Es Salaam harbour. Railway can be conveniently used for transport from the port to the Lugufu railway station which is very near with intermediate storage if necessary.

2. Imported Light Articles. These articles which would consist of any sensitive equipment will be flown to Kigoma Airport and subsequently transported by road directly to site.

3. Domestically procured Materials: All equipment and materials which are locally available will be procured at Dar or other cities and transported suitably to the site.

Section 3 Organisation

The nature of the Malagarasi Project is such that it is to divide into major project features, executed if need be as follows under separate contracts, taking due consideration of local contractors and facilities which exist in Tanzania:

1. Access Roads
2. Housing and Facilities at the Site
3. River Diversion, Care of the River and Unwatering
4. Diversion Weir
5. Power Station
6. 66kV Switchyard
7. Transmission Line 66 kV
8. Receiving substation in Kigoma

Section 4 Construction Schedule

There is a rainy season in the months of December to May and a dry season from June to November. Consequently, it is necessary to adapt the sequence of construction operations to these climatic conditions. The greatest advantage possible should be taken of the dry season, particularly the months of September to November for the operations in the main river.

In order to shorten the time taken for the construction, it is necessary to accomplish, even during the rainy season, individual types of operations, such as rock quarrying, concrete work, and equipment installation.

It is necessary to take into account that during the rainy season the average construction output is reduced.

The entire construction of the hydroelectric project, according to the tentative schedule is estimated to take two years. To achieve this a highly mechanized approach to construction is contemplated.

The following are the maximum rates of progress adopted for the estimation of the construction period.

Box 15-1 :Construction Rate

Item	Units	Rate
Access Road	km/day	0.5
Open Excavation with power shovels	m^3/day	50
Rock Excavation	m^3/day	50
Rock Excavation in River	m^3/day	30
Concrete Placement	m^3/day	20
Reinforced concrete	m^3/day	10
Shotcrete	m^3/day	10
Backfill	m^3/day	50
Transmission	km/day	0.25

The sequence of construction of the hydroelectric project is divided into the following items

Part I Preliminaries

It is assumed that either TANESCO will implement the project or it will be implemented by IPP. In the former case, the implementation will involve the issue of a bid document and evaluation of tenders. In the case of IPP participation, a formal structured RFP will be issued to which various IPPs will respond. In either case, about 12 months will have to be set aside for various negotiations and contractual arrangements to be finalized, final feasibility report preparation which may be required by various lending institutions, additional field investigations etc. The time frame which these are expected to take is given in the preliminaries heading of the implementation schedule in table 15-1. The actual contract for Civil works and Electro mechanical equipment is assumed to be issued by the project company twelve months after the decision to go ahead with the project is taken.

Part II **Preliminary Works**

This consists of the construction of access road, clearing the construction and the camp sites, excavation and grading of the areas around the site. The required camps can be constructed alongside the access road. Also included will be any temporary roads required for working the quarries or borrow areas. The erection of the bridge to cross the river is also included in the access.

The area to be occupied by the principal structures, such as the dam, the power plant, the spillway and the appurtenances to be constructed, together with the surfaces of all borrow areas, shall be cleared of all vegetation the material being used as construction wood or sold.

The construction material for the dam from sources other than from the excavations required for the construction, shall be taken from quarries/borrow pits. These shall be selected so as to lie as close to the point of utilisation as possible, in accordance with the results of the second phase of the survey.

A concrete batching plant of about 50 cubic meters per day capacity will be installed at the site

Adequate electric power will be required for the construction of the project. It is estimated at about 500kW. The best method to obtain this power is from a truck mounted diesel generator in the vicinity of the site.

Both stationary and portable air compressors will be used. Power can be obtained from the distribution system which will be setup to convey construction power to various points at site.

Water for construction can be pumped from the Malagarasi river and stored in tanks prior to utilisation. Potable water may have to be brought by tankers from Kigoma.

Part III Diversion Weir

The river flow in the dry season is confined to one or two channels with river bed rock exposed considerably at other sections. When preliminary works have been completed, a diversion channel near the left bank taking advantage of the bend in the river in the left bank shall be excavated from a point about 200m upstream of the dam axis to just downstream of the dam so that the diversion weir area is rendered dry by a cofferdam built just downstream of the entrance to the channel. The diversion channel will be used for bypassing the minimum flow occurring in the months of September to November from the central portion of the river so as to enable excavation.

Immediately after diversion, the main dam area shall be de- watered and there shall be initiated, excavation for the foundation of the dam near the center of the river. Rockfill can be placed in the central portion upto an elevation of 862m.

The excavation near the flanks can be taken up after this and made ready for placement of rockfill. At the end of the first dry season three segments of the diversion weir, one on each flank and one in the central portion will be completed with two gaps for passage of the monsoon flows.

During the monsoon construction activity will be diverted to the power canal, forebay and power house areas.

In the second dry season, the river flow is again passed in the diversion channel and the two gaps in the diversion weir are closed and the weir is completed upto 865m. The concrete slab on the upstream face is also done simultaneously. At the end of the second dry season, the diversion weir will be completed. Thus it will take about 12 - 14 months for the completion.

A total of 11370 cum of rockfill is required. The entire excavation for the diversion weir can be completed in the first dry season. In the second dry season, rockfill placement can be completed.

All materials for the foundations, in accordance with the first phase of the investigation, are first classified as follows :

Rock excavations include all solid rock that cannot be removed either by large power shovels or loosened by rippers without blasting.

Standard excavations include all the materials outside those included in the rock excavations, that is, earth, gravel, loose or shattered rock fragments and all other materials that can be removed by the excavating machinery without blasting.

Excavations in the river bed include all materials other than rock, to be excavated from the natural river bed.

Excavations by means of blasting shall be performed only to a limited extension.

It is presumed that all suitable materials from the excavation required will be used in the construction of embankments, riprap, cofferdam blankets or fill material. Excavated materials which will be found unsuitable or will not be required for further construction shall be dumped in dumping areas shown in the final drawings. These disposal areas shall be arranged so as to have a neat appearance.

Part IV Waterway

The waterway requires excavation of about 10500 cum. It is estimated to take about 6 to 8 months. Concrete of about 1000 cum is required. Concrete placement shall continue in parallel with excavation. The entire construction is spread over 6 months which is the first dry and wet season. The forebay requires an excavation of 3000 cum and 1000 cum of concrete. The canal and forebay works can be done irrespective of the season. The penstocks in view of short length can be erected when the canal works are nearing completion.

Part V Power House

Immediately after the preparatory works are finished, there shall be erected around the power house site a temporary cofferdam built upto elevation of 840 m. The main river shall continue to flow in its original channel undisturbed. Simultaneously with the construction of the cofferdam, the excavation of power house shall be carried out. The surfaces of all rock foundations, upon or against which concrete is to be placed, shall be conditioned so as to promote good bond between the rock and the concrete and to provide adequate and satisfactory foundations.

The construction of the power house shall go undisturbed irrespective of the season. In three months the entire excavation is completed and the placing of the draft tube and welding of the structural components shall begin which will be the first items delivered by the equipment supplier. The entire concreting of the substructure shall take about 2 months.

Subsequently, it will be possible to start intense work on the superstructure of the power house. In the course of the first stage of construction, concrete shall be placed up to a minimum level of 840m for the power house.

At the time when the main works of the machine hall with have been finished, the assembly of the main crane and then the installation of the turbine runners, generators and the accessory equipment shall be started.

The power house will be finished in about 14 months.

Part VI Tailrace

The tailrace involves relatively low excavation and concrete. It shall be initiated when power house excavations are complete. Concreting is expected to take about 4 months.

Part VII Switchyard

Another structure, the completion of which influences the commissioning of the power plant, is the switchyard. The earthwork shall be initiated while the excavations in the bedrock for the power house are in progress, in order to make possible the completion of the subsequent civil engineering part and electrical equipment installation at the time of the completion, that is, within the 18 months following the start of the work.

Part VIII Transmission

The transmission works can be done independent of the other works. It is estimated that it will take a total of about twelve months to complete the work.

Part IX Final Works

At about the time when the project is nearing completion there shall be initiated an intensive clean up operation which shall clear all waste materials and restore the site to its original conditions taking into consideration replacing any lost vegetation etc in the vicinity of the site.

The commissioning of the power plant depends on the successful completion of all the civil and electrical works. The attainment of the minimum water level is not a problem as the storage provided is small.

Based on the economical rates at which construction activities can be progressed for a project of this scale a preliminary project construction schedule has been drawn up and is presented in table 15-1. The construction period will not exceed two years. The construction sequence is not rigid and can be changed suitably to adapt to the contractor's requirement.

TABLE 15-1
IMPLEMENTATION SCHEDULE

			QTY	UNIT
		SEASON W WET, D DRY		
1		PRELIMINARIES		
	a	RFP PREPARATION BID EVALUATION		
	b	FURTHER FIELD INVESTIGATIONS		
	c	FULL FEASIBILITY REPORT		
	d	LICENSING & OTHER CLEARANCES		
	e	POWER PURCHASE AGREEMENTS		
	f	FINANCING PACKAGE		
	g	DETAILED ENGINEERING STUDIES		
	h	CIVIL WORKS CONTRACT AWARDED		
	i	ELECTRO-MECH EQUIP ORDERED		
	j	DESIGN MANUFACTURE OF TURBINES AND GENERATORS AND AUXILIARIES		
	k	SUPPLY OF MAIN EQUIPMENT		
2		PRELIMINARY CIVIL WORKS		
	a	Access Roads	24	km
	b	Bridge		
	c	Construction site preparation		
	d	Construction power water supply etc		
	e	Housing and Colonies		
3		DIVERSION WEIR		
	a	Site Preparation & river Diversion		
	b	Excavation	8000	cum
	c	Rockfill/Cement Mortar Masonry	15000	cum
	d	Concreting	4000	cum
	e	Impoundment		
5		WATER CONDUCTOR		
	a	Preliminaries		
	b	Excavation	13000	cum
	c	Concreting	2000	cum
	d	Backfilling	1000	cum
	e	Penstocks		
6		POWER HOUSE		
	a	Site Preparation		cum
	b	Excavations	800	cum
	c	Electromechanical Equipment		
	d	Concreting	1600	cum
	e	Super structure		
	f	Other Electrical Works		
7		TAILRACE		
	a	Excavation	200	cum
	b	Concreting and finishing	315	cum
8		SWITCHYARD		
	a	Preliminary Works		
	b	Construction		
	c	Equipment		
9		TRANSMISSION	100	km
	a	Preliminaries		
	b	Tower Erection		
	c	Stringing of conductors		
	d	Substation in Kigoma		
10		FINAL WORKS		
	a	Testing of plant		
	b	Clean up and other miscellaneous works		
	c	Commissioning		
	d	Commercial Operation Starts		
11		TIME		MONTH

	2000											
MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
UNIT	1	2	3	4	5	6	7	8	9	10	11	12
SEASON	W	W	W	W	W	D	D	D	D	D	D	D
TIME												

	2001											
MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
UNIT	1	2	3	4	5	6	7	8	9	10	11	12
SEASON	W	W	W	W	W	D	D	D	D	D	D	D
TIME	1	2	3	4	5	6	7	8	9	10	11	12

	2002											
MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
UNIT	1	2	3	4	5	6	7	8	9	10	11	12
SEASON	W	W	W	W	W	D	D	D	D	D	D	DEC
TIME	13	14	15	16	17	18	19	20	21	22	23	24

Chapter 16 Conclusions and Recommendations

1. The Malagarasi river is perennial has a good flow throughout the year. This is advantageous and obviates need for providing storage. This also implies that the river can give dependable capacity and hence can attract industrial customers for the generated power.

2. A feasibility study was conducted in 1983 by Norconsult on hydropower generation for the stretch of the river known as Igamba falls.

3. The feasibility study by Norconsult recommended a diversion type development with an installed capacity of 7.6MW (2 x 3.8MW) and (3 x 3.8MW ultimate) and an energy output of 67GWh per year with a long waterway of about 4 km total length consisting of (590m headrace canal, 3200m headrace tunnel, 87m long surge shaft, 205m long penstock and 350m tailrace canal) to obtain a gross head of 62m and net head of 55m. All project features are to be on the left bank. Implementation cost was about $3925 per kW in 1983 without IDC.

4. The project has however not been implemented.

5. The demand in the main load centre Kigoma has yet to develop to the full potential of 8MW. Hence, market for power will be about 4MW with energy requirement of about 25GWh. Growth rate may be about 2.5% p.a.

6. As per the updated economic cost of energy, the benefit cost ratio for discount factor of 12% was calculated to be 1.24 for conditions given as above.

7. The financial benefit cost for the developer is less than one unless funding is obtained on soft term basis. Energy production costs are also very high.

8. It is necessary to improve, the above project configuration, if the project is to be used to economically electrify the region. As per SECSD revised planning, the implementation cost and time required for construction can be reduced significantly by taking advantage of the concentrated falls in the river course to

have a series of small power stations. This leads to a reduction in length of the waterway to less than 500m for a total head of 25m.

9. The present modified proposal has an installed capacity equivalent to the original capacity of 8MW, and gives equivalent amount of energy (65 GWh) with a very short water conductor system. Further the head on the plant is 25m as compared to 62m gross and 55m net head in the Norconsult proposal. This balance head of 37 m can be utilized by building two additional power stations which can give additional capacity and energy.

10. The present study proposes a cascade development consisting in all of 5 small hydro power stations aggregating to 40MW capacity with energy of 326 GWh. This will hence be sufficient for the region in the years to come.

11. Due to the revised planning, the construction cost of the first scheme is US$ 11.25M and IDC is US$ 1.75M.

12. The unit implementation cost will be reduced to $1625 per kW. The cost of energy from the project will be US cents 3.53 per kWh (9.5 cents considering restricted demand of 25GWh with low growth of 2.5%p.a) even with very stringent financing conditions.

13. The economic benefit cost ratio based on an economic price of 19 US cents per kWh (from alternative diesel set) shows the benefit cost ratio to be 5.45 (even for low initial demand).

14. The present average tariff charge by TANESCo in the area is about 7 US cents per kWh.

15. The financial benefit cost for the developer based on conventional funding at 10% interest with payback period of 10 years, 12% discount rate, a tariff of 7 US cents per kWh escalating at 5% p.a and demand of 25 GWh with 5% growth is 4.00. Hence developers will be interested as the project provides profit.

16. From the view point of the present state of power supply in the Region, it is more desirable to implement a series of such small hydropower project close

to the demand centre. The Stage 2 will be able to meet all of the capacity and energy demand of the town of Kigoma and other small towns.

17. The electric power produced at the stage 2 power station will be supplied to the new Regional grid and this will improve the electric supply demand and supply situations.

18. In order to expedite the implementation of this project, the layout is such that, the times required for the detailed designs, financing and construction are kept to their practical minimum. It will be possible to commence commissioning of the stage 2 project in late 2002. The project expenditure and size is such that it is suitable for being financed by many local companies who can become IPPs.

19. The construction of the reservoir will not result in the loss of valuable agricultural or grazing land. The lake will not inundate a populated valley necessitating the displacement of population. Therefore the cost of moving the inhabitants and of replacing the farm will not affect the total cost estimates.

20. The construction of dam and reservoir will not interfere with fishing rights. As far as fish and wildlife are concerned the creation of the reservoir can only enhance the value of the area.

21. During construction and later during operation of the project sufficient quantities of water will be released to the downstream bed of the river. The operation of the hydro power station will not lead to a reduction in the downstream flow pattern. On the contrary, the construction of the cascade will ensure the regulation of flows to some degree.

22. The principal structures will be the diversion weir, intake structure, short waterway, powerhouse above ground and tailrace. No underground structures will be involved.

23. The power house will have two units of 4MW Kaplan turbines and produce 65.0 GWh of energy in an average year. The plant capacity factor is 91.2%.

24. The geological conditions for the various proposed structures are sound and have ample bearing capacity for all the structures.

25. The Kigoma region is very distant from Tabora which has grid supply. Extension of grid supply to Kigoma will be uneconomical due to the small demand. Hence the proposed Malagarasi cascade is ideally suited for meeting the demand of the region.

26. On the basis of the above, it is recommended that the stage 2 project be taken up for implementation soon, so as to provide rapid electrification in the region.

Chapter 17 Photographs, References, Acronyms

Photo 17-1: View of Malagarasi Falls

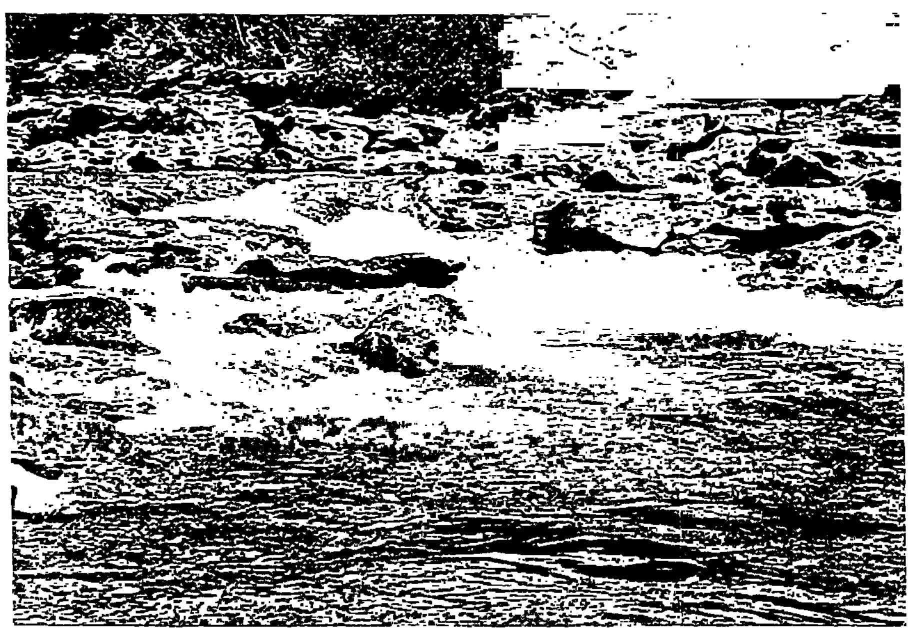


Photo 17-2: View of rapids on Malagarasi River

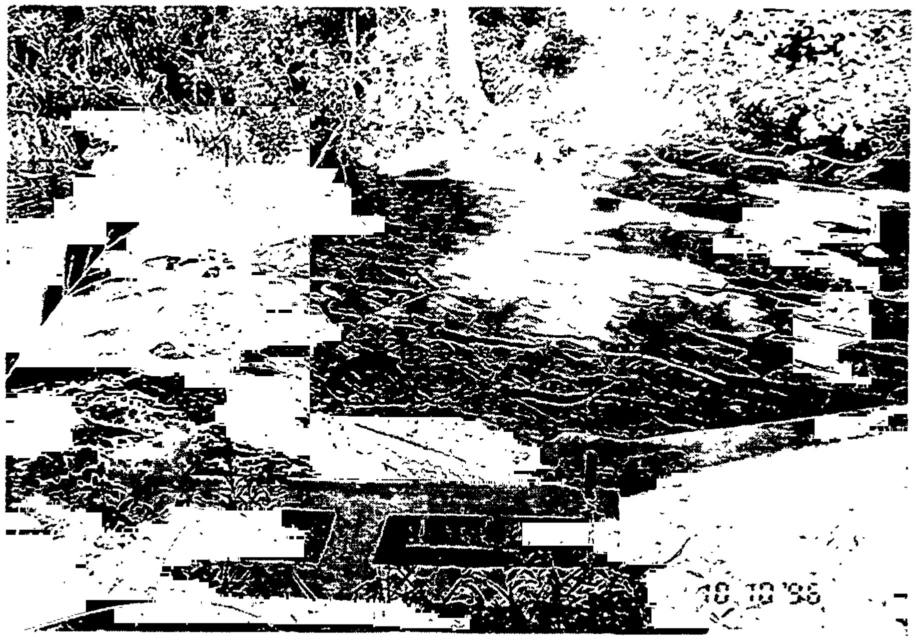


Photo 17-3: View of diversion structure on small stream near Kigoma

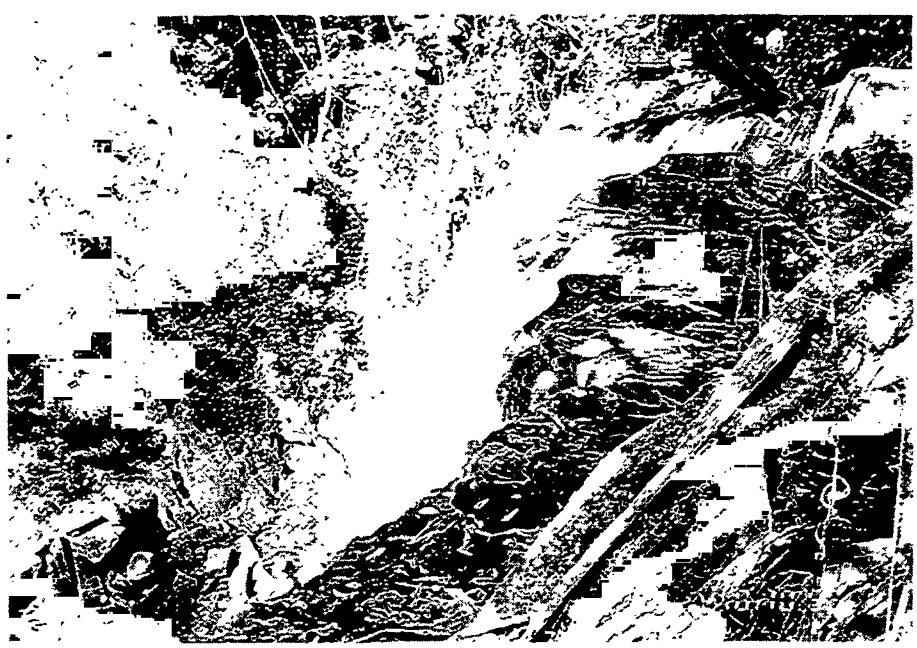


Photo 17-4: View of falls on small stream developed for micro hydro

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Section 2 Abbreviations

Institutions

TWB	The World Bank
ESMAP	Energy Sector Management Assistance Programme
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees
GOT	Government of The Republic of Tanzania
TANESCO	Tanzania Electric Supply Company
SECSD	Sivaguru Energy Consultants & Software Developers
IFI	International Financial Institutions
IPP	Independent Power Producer
BOOT	Build Own Operate and Transfer

Electrical

W	Watt
kW	kilowatt = 1000Watts
MW	Megawatt = $1x10^6$ Watts
Wh	Watthour
kWh	kilo Watt hour = 1000 Wh
GWh	Giga Watthours = $1x\ 10^6$ kWh
V	Volt
kV	kilovolt = 1000 Volts
VA	Volt Ampere
kVA	kilo Volt Ampere = 1000 VA
MVA	Megavolt ampere = $1x10^6$ VA
A	Ampere
kA	kiloampere = 1000 ampere
pu	per unit
LT	Low Tension
HT	High Tension
AC	Alternating current
DC	Direct current
pf	Power Factor

Hz	Hertz
rpm	Revolutions per minute
rps	Revolutions per second
cmils	circular mils

Hydraulic

cum	cubic meter
m3	cubic meter
m3/s	cubic meters per second
cumecs	cubic meters per second
MCM	Million Cubic meters = $1x10^6$ cum
FSL	Full Supply Level
H	Water head in m
TWL	Tail water level
masl	meters above sea level
EL	Elevation

Measurements

sqkm	square kilometers
ha	hectare = 0.01 sqkm
m	meter
km	kilometre = 1000m
in	inches
ft	feet = 12 inches
'	feet
mm	millimeter
lbs	pounds
kg	kilogram = 2.21 lbs
t	tonne = 1000 kg
F	Farenheit
C	Celsius
PJ	Petajoules
1 joule	1 watt/s

Financial

USD	United States dollar
TSh	Tanzania Shillings
IDC	Interest during construction
O&M	Operation and Maintenance
PWF	Present Worth Factor
BC	Benefit Cost ratio
NPV	Net Present Value
M	million

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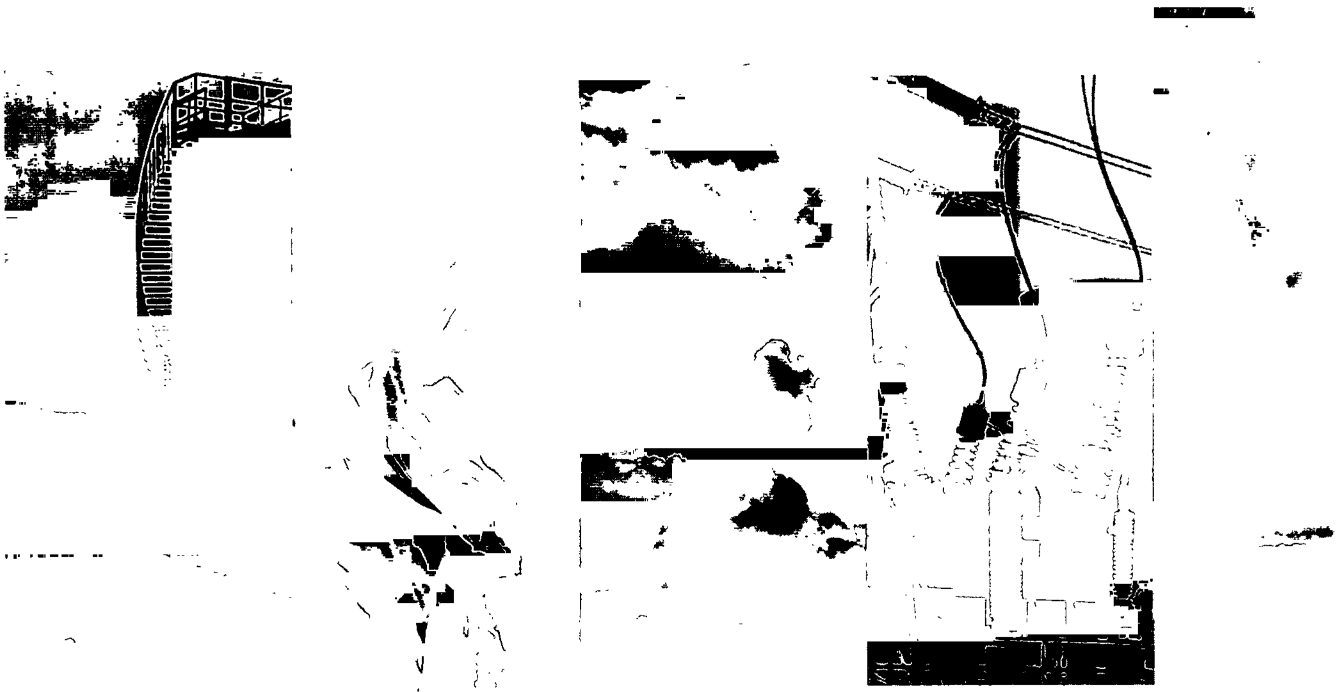

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