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Volume 2

ESMAP TECHNICAL PAPER

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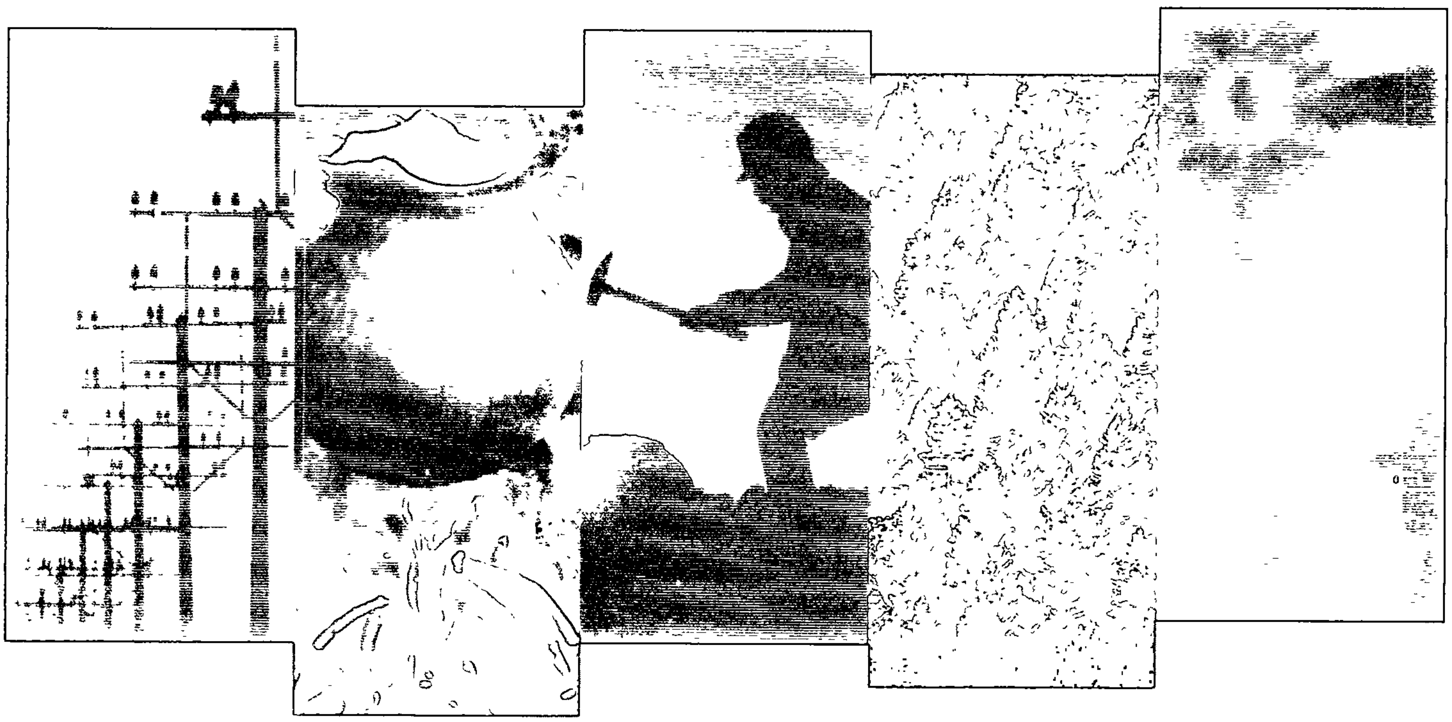
Tanzania —Mini Hydropower Development Case Studies on The Malagarasi, Muhuwesi, and Kikuletwa Rivers: Volume II — The Muhuwesi River



Energy

Sector

Management

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April 2002

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ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

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JOINT UNDP/ESMAP

TANZANIA
RUVUMA REGION

PRE-INVESTMENT REPORT
ON
MINI HYDROPOWER DEVELOPMENT

CASE STUDY ON
THE MUHUWESI RIVER

FINAL REPORT
MARCH 2000

PREPARED BY

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ESMAP Management"

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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 the 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 small hydropower projects (upto 10 MW). To effectively meet the load demand in the short term from these projects, the effort and time spent on the phases in a conventional approach to small / mini hydropower development such as planning, investigations and tendering should be reduced by simplified designs and layout so that implementation can commence quickly, and the construction period limited to one or two years.

The towns/regions referred to SECSD and the study methodology adapted come under two categories shown in figure 1-1. In the first category are the potential schemes in the region which have already been investigated to feasibility stage by TANESCO and other agencies, but were not implemented. These existing studies need to be updated 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. Due to these aspects, the projects provided only 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 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 formulated and 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.

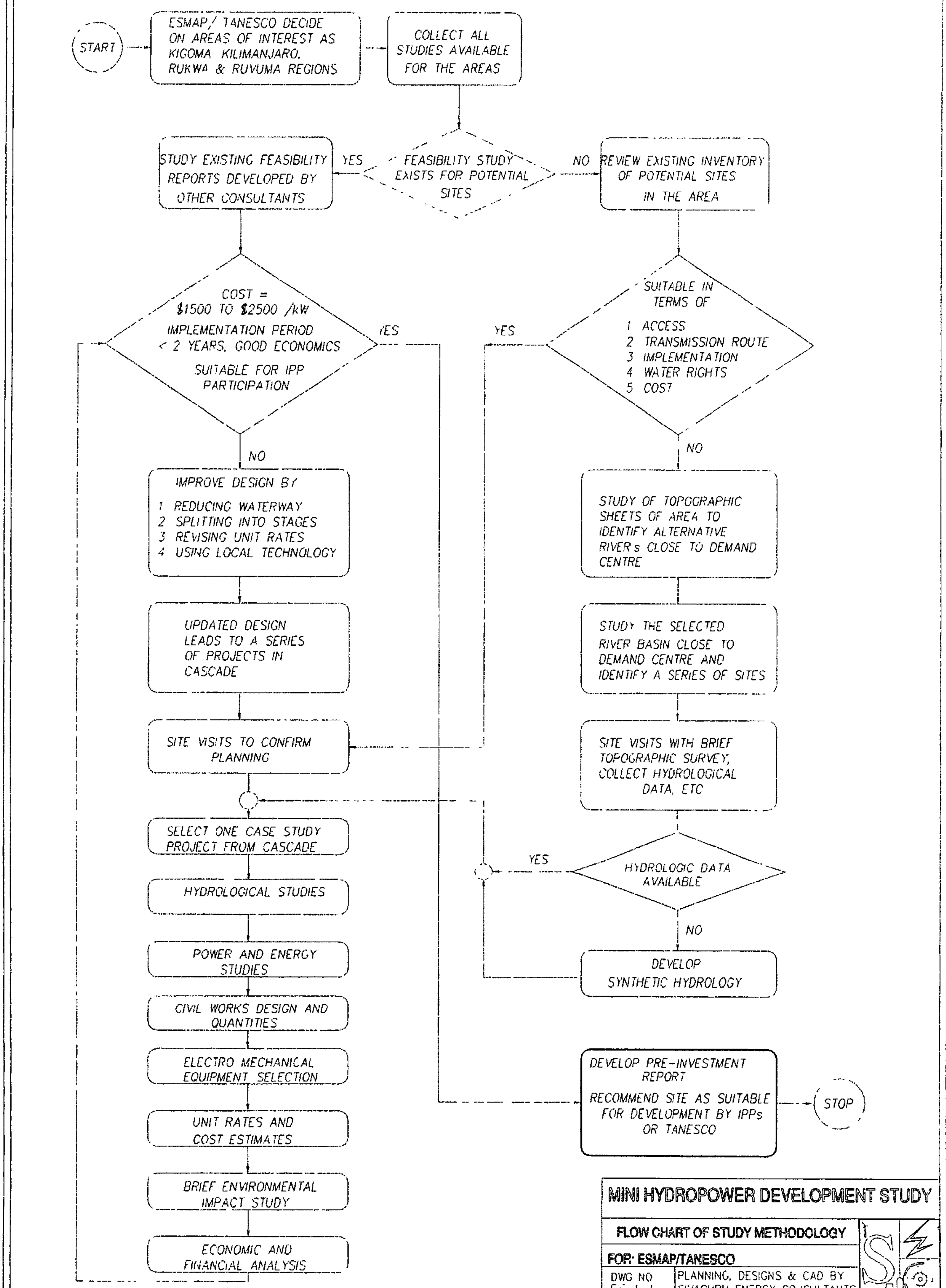
- Planning of power stations on a stream on isolated basis without doing planning of the entire stream or river basin.

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

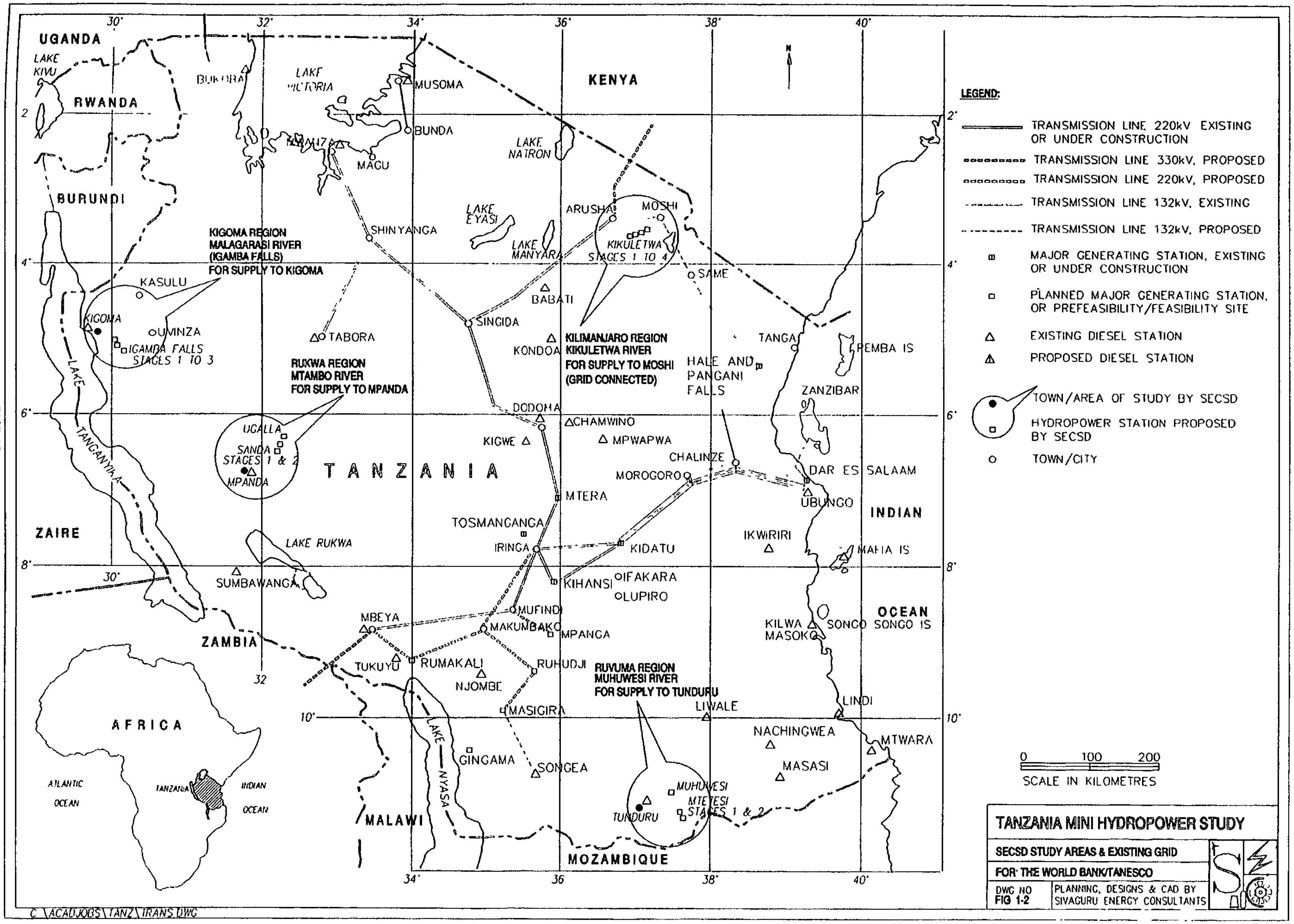
- Non availability of adequate observed river flow records with the result that potentially good streams have not been selected for development. In such cases synthetic hydrology has to be developed using elaborate models.

- 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, there are many sites which have been identified by various agencies on the basis of concentrated drops or steep gradients in the river bed. From the preliminary information available on these potential sites, it appears that these sites however are not close to the existing rural demand centers. Many such sites occur in reaches of streams where access is difficult or the drainage area is insignificant, with low and erratic flows, as a result of which power generation may not be reliable and has a large variance from year to year. Because of these factors, these sites call for substantial expenditure on access roads and transmission. Hence, instead of selecting sites to serve an area from the existing inventory, an alternative approach of thoroughly studying 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 concentrated head was undertaken. A series of such viable potential sites have been identified to meet the demand at an early date. They have been studied on toposheets



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
BUKOBA
LAKE VICTORIA
MUSOMA
BUNDA
MACU
KENYA
LAKE NATRON
ARUSHA
MOSHI
KIKULETWA STAGES 1 TO 4
SAME
LAKE EYASI
LAKE MANYARA
SHINYANGA
BABATI
SINGIDA
TABORA
KASULU
KIGOMA
UVINZA
IGAMBA FALLS STAGES 1 TO 3
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)
KONDOA
TANGA
PEMBA IS
HALE AND PANGANI FALLS
ZANZIBAR
DODOMA
CHAMWINO
MPWAPWA
KIGWE
UGALLA
SANDA STAGES 1 & 2
MPANDA
TANZANIA
LAKE TANGANYIKA
CHALINZE
MOROGORO
DAR ES SALAAM
UBUNGO
MTERA
TOSMANGANGA
IRINGA
KIDATU
IKWIRIRI
MAFIA IS
INDIAN OCEAN
ZAIRE
LAKE RUKWA
SUMBAWANGA
KIHANSI
IFAKARA
LUPIRO
MUFINDI
MBEYA
MAKUMBAKO
MPANGA
KILWA MASOKO
SONGO SONGO IS
ZAMBIA
TUKUYU
RUMAKALI
RUHUDJI
NJOMBE
RUVUMA REGION
MUHUWESI RIVER
FOR SUPPLY TO TUNDURU
LIWALE
LINDI
MASIGIRA
NACHINGWEA
MTWARA
LAKE NYASA
GINGAMA
SONGEA
MASASI
MUHUWESI
MTETESI STAGES 1 & 2
TUNDURU
MALAWI
MOZAMBIQUE
AFRICA
ATLANTIC OCEAN
TANZANIA
INDIAN OCEAN
30° 32° 34° 36° 38° 40°
2° 4° 6° 8° 10°
N
LEGEND:
TRANSMISSION LINE 220kV EXISTING OR UNDER CONSTRUCTION
TRANSMISSION LINE 330kV, PROPOSED
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
EXISTING DIESEL STATION
PROPOSED DIESEL STATION
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 SIVAGURU ENERGY CONSULTANTS
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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 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 small/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 and the existing diesel power stations. There are a total of fifteen isolated diesel stations generating about 56GWh per annum. There are also eleven diesel stations which are connected to the grid and which generate 431 GWh per annum (see table 1-1). Thus all these towns with isolated diesel power stations need to be supplied with mini hydropower which will give significant cost savings.

Both the approaches above result in a series of projects in a cascade. One representative project in each region, which is feasible at least cost and can meet the demand for the next few years has then been selected for the pre-investment study. It is felt that the remaining projects can also be further investigated on the same lines.

This report examines the layout details for the Kwitanda project on Muhuwesi river in the Tunduru district of Ruvuma region. The proposed project is a more economical alternative to the development of Sunda falls on Ruvuma river proposed earlier for electric supply to Tunduru town. 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.

It is interesting to note that some missions in the region have installed their own micro/mini hydro generating sets on perennial streams. One such installation is that at mission in Peramiho

The Ruvuma region is located in south western Tanzania on the eastern shores of Lake Nyasa. Songea is the regional capital. Tunduru is the only other major town in the region and is the district headquarters. The economy of the district is based predominantly on rainfed agriculture, cashewnuts production and gem stone mining. The region is not served by railway or scheduled flights. Road connections with other parts of the country are very 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 Mbeya having grid supply makes grid connection option very expensive. Even if the regional capital gets electricity from hydro through the proposed Nakatuta project on Ruvuma, it will not be feasible to transmit the power to Tunduru due to the distance of 285km from Songea. Thus an abundant source of cheap power has to be developed within the district if the pace of development and economic growth is to be accelerated. There are at present very few industries in the district which consume electric power for their production operations. If cheap electric power is made available, industries connected with agricultural products such as food processing and mining are likely to come up in the region. Such industries and entrepreneurs may also be interested in developing additional 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 also 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 Muhuwesi river will be to cater to the present and future electric power demands of the small scale industries, towns and villages in the Tunduru district which is situated in a remote area of the southern 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 Muhuwesi which has flowed to the Ruvuma 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 Muhuwesi 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 district for the next thirty years especially for places such as Tunduru, Ligoma, Namaskata, Kibwana, Msechela 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 district 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 plan and develop large generating stations on the Muhuwesi, Ruvuma and its tributaries which flow through this region.

The social consequences of electrification of households in Tunduru district 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 Tunduru district is likely to have considerable beneficial impacts.

The most important consideration for a developer of a 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 the method used in planning electric supply to an area from mini hydro whereby a new site near the town has been identified so that the cost of installed capacity has been reduced to make it attractive for rural electrification. 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 and 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 relevant project information that establishes the project's requirement so that it can be a basis for the project procurement and implementation.

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

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 Ruvuma region and Tunduru district 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 restricted load demand in Tunduru is about 500kW with annual energy demand of about 3 GWh. This may grow at rates anywhere between 2.5% to 6% per year. The villages in the vicinity will have a combined demand of about 250kW. Growth rates however may not exceed 3%. The comparison of energy use in the district from traditional non commercial fuels versus electricity is given below on the basis of 200,000 inhabitants and per capita consumption of 150kg oil equivalent per year with a heat value of 14000 heat units per pound and energy equivalent of 0.1818 hp-hour.

Box 1-1: Estimated Energy Balance for Tunduru District

Total Energy Consumption (kg oil eqv)	Energy Consumption (hp-hr)	Energy Consumption (kWh)	Electric Energy Consumption (kWh)	% Energy Consumed as Electricity
30,000,000	12,216,960	9,108,965	900,000	9.88

The above shows that use of electricity is very insignificant. Most of the energy used in rural areas 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 proposal at Sunda falls on Ruvuma river was reconnoitered and studied. This project is not recommended for implementation due to potential water rights issue with Mozambique and also unsatisfactory cost, access and transmission aspects. An alternative project using water from catchments within Tanzania and with easy access and shorter transmission is suggested which will reduce the implementation cost and make it suitable for IPP participation or implementation by TANESCO. Hence, a description of the original project layout as proposed by earlier consultant is given in chapter 3 and the new project proposed by SECSD is discussed in chapter 4. The original configurations had an unit investment cost of $3750 per kW and an energy cost of $0.107 per kWh all exclusive of IDC in 1982. As per the revised approach the unit investment cost will be about $2500 per kW inclusive of IDC and energy cost 6.0 US cents per kWh assuming market for the entire generated energy 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 about 1km downstream of the Muhuwesi bridge which is on the Tunduru Masasi main road. The Muhuwesi river at the bridge site enters a long gorge (Nawesa gorge) through which it flows for a distance of about 1.2km. The proposed power station is a further 2500 m downstream on the left bank. The topography of the intake dam site consists of steep rocky banks rising from the river course to elevation of about 430m. At the diversion site, the left bank of the river is vertical whereas the right bank rises more gently. The river is about 50m wide and the river gradient downstream of the proposed diversion site is moderate.

A reconnaissance level topographic survey has already been performed for the stretch of the river from the Muhuwesi bridge to the diversion site. This data is adequate for the suggested planning and further aerial mapping is not required as topographic sheets with contours are available for the project area and in fact the for the entire Ruvuma basin. At the time of implementation, topographic survey of the diversion weir and power house site could be performed. These aspects are discussed in chapter 5.

Section 5 Geology

The geology of the project area consists mainly of massive exposures of granite.

The bedrock is exposed in the river bed and banks for a considerable reach along the river and even upto the confluence of Muhuwesi with Ruvuma.

The 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 6.

Section 6 Hydrology

The Muhuwesi river has a total catchment of 9239 sqkm. The catchment has 7 precipitation stations. The locations are shown in figure 7-1. The annual rainfall variation within the catchment is insignificant. In the northern part of the catchment it is about 1100mm and reduces to about 1000mm near Tunduru. The mean annual rainfall over the catchment upto the diversion site by using the Thiessen polygon method with five rainfall stations is 1093 mm.

The river is also gauged at station 1Q4 along the axis of the Muhuwesi bridge which was probably established in 1968. But records are available from 1965. The catchment at the gauge site is 6521 sqkm. The station comprises staff gauges with observation of water level daily. The control consists of a rocky gorge of about 4 meters depth. The gauges have been reported to break frequently and there is no continuity in the data except in the year 1969. Subsequent to 1970 no data is available to date.

This gauging station is located about 1 km upstream of the proposed project site. Due to the discontinuous nature of the available data, four different sets of twenty year flow sequences for the period 1975 to 1995 have been built up by correlation of rainfall with runoff using different relationships. Out of these, one set has been selected which represents the expected flow conditions. These are discussed in chapter 7 on hydrology as well as in the annexure volumes A to F.

From the above rainfall runoff studies and the computed flows, the mean annual flow over the twenty years of completed flow records 1975-76 to 1994-95 is 193.9 cumecs. The mean annual flow varies from 118.2 cumecs in 1989-90 to 265 cumecs in 1978-79. Analysis of long term flow duration curve indicates that the mean annual flow is exceeded for 30% of time and the firm flow which hydrologists define as exceeded 90% of the time is 4 cumecs.

The flood magnitude is estimated to be 9000 cumecs for 1000 year return period which is selected for the design of the structures.

A more detailed treatment is given in chapter 7. Also discussed are climatology, flood studies and sedimentation.

Section 7 Power and Energy Studies

The proposed diversion site is located 1 km downstream of the gauge site 1Q4 at Muhuwesi bridge. As no stream joins the Muhuwesi in the reach from the gauge site upto the proposed intake dam, the computed flow at gauge site is taken to be the inflow at the diversion site.

The 1:50000 topographic survey maps have been used to work out the reservoir area and capacity curves by interpolation of contours to 2 m intervals which is given in figure 8-1.

The average annual continuous flow at the diversion weir site is 191 cum/sec.

The year in which the mean flow is close to this is 1986-87 with a mean flow of 184 cum/sec and a corresponding annual yield of 5803 MCM. Thus the year 1986-87 is a representative mean hydrologic year. Similarly the year with maximum yield is 1978-79 with a mean annual flow of 265 cum/sec and yield of 8358 MCM and the year with the least annual flow is 1989-90 with a flow of 119 cum/sec and yield of 3727 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 1000 kW. The detailed working tables are given in the Tables 8-1, 8-2 and 8-3.

From the results of the study, it has been decided that the power plant will have 2 units of 1000 kW each. Most of the years have flow equal to or greater than the average year in the spell 1975 to 1995, thus 14.5GWh is assured. In a wet year the energy output is 13.75 GWh and falls to 13 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 18m and efficiency of 90%. The most optimal installation is

2 x 1000 kW which gives 14.5 GWh per annum. There is scope for overload capacity and hence 2 x 1250 kW is also considered. These aspects are dealt with in detail in chapter 8 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 electrical variables such as power, energy etc are presented graphically. The major results of the simulation are given in Box 1-2. The dry weather flow volume in a wet year is less than that in an average year and installed capacity restricts use of monsoon flows in a wet year which is the reason for lesser energy in a wet year as compared to a mean year.

Box 1-2 Summary of Energy Outputs

Installed Capacity (kW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
2 x 1000	14.5	13.75	13.0

Section 8 Civil Works

The Muhuwesi hydropower project requires

- an access road
- a diversion weir to create head, store water and 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 from the power house 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 9 with the preliminary design and description of the various structures like diversion weir, intake structure, waterways, power house with tailrace and their outline drawings

Part I ***Access Road.***

The project is located very close to the Tunduru - Masasi main road. From this road, before the Muhuwesi bridge, a track leads to the diversion weir site. For access to the power house site a 3.5km access road is to be built on the left bank.

Part II ***Diversion Weir.***

This will be a composite dam with rockfill on the flanks and a centrally located concrete spillway section founded on the rock. It will be gated and the crest will be at 435m. The crest length of the diversion weir is about 180 m. The maximum height is about 10m. The elevation of the non overflow section is 442m. Aggregates for the concrete are available in the immediate vicinity and the concrete volume is not large hence will be very economical.

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

The intake structure is located on the left bank near the diversion structure. It is a concrete structure and admits water to an open trapezoidal power canal with FSL 439m. The maximum flow is 13.5 cumecs. The canal is about 2500m in length and conveys the water to a forebay. 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 1.7m diameter and length of about 160m each with separate intakes. 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 Muhuwesi river where the water level is 420m.

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 tubular Kaplan turbine generator units and all their auxiliaries. A separate service bay is not necessary. The units can be removed by use of mobile crane through a hatch in the roof. The Muhuwesi river is wide near the power house area and as a result, the high flood level is low and hence expensive flood protection structures are not 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 lined with local materials. The crest of the tailrace control weir will be such that at one unit discharge the water level is 420.35m.

Section 9 Electromechanical Equipment

The turbines with accessories and generator form the electro mechanical equipment. The power station will house two vertical shaft Kaplan turbines with tubular steel case and elbow draft tubes. The runner diameter will be 1080mm. The units are envisaged to be package type and will be supplied pre assembled and erected at site. The turbines will be coupled to synchronous three phase generators via a step up gearbox. The design flow through the turbines will be 6.75 cumecs each. The generators will be rated at 1250 kVA each. The turbine and generator sets are coupled by a 1:2 step up gearbox. The speed of the generator set is 1000 rpm. Outline of electromechanical equipment and specifications are given in chapter 10. 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 33 kV by outdoor transformers. The transmission scheme envisaged is to construct a 30 km 33kV single circuit line from the power station to Tunduru. These arrangements are discussed in chapter 11. 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 suppliers. The estimated quantities of various items of civil works are multiplied by the unit rates to give the cost. Further estimates have been made for transmission lines and allowances for contingencies and environmental considerations. These aspects are dealt with in chapter 12. In the present proposal the cost is reduced to US$4.82 million as compared to the estimated US$ 11.25 million in 1982 for Sunda falls. 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 1.6 GWh as well as full project potential of 14.5 GWh.

The economic value of energy produced ranged from US cents 15.01 for annual generation from diesel limited to 1.6GWh to US cents 13.54 for generation of 14.5 GWh. The following economic indicators were obtained for a discount rate of 12%.

Box 1-3: Benefit Cost ratios

	Demand = 6 GWh Growth = 2.5% p.a	Demand = 14.5 GWh Growth = 0% p.a
Base Case / No rise in fuel cost/	1.48	2.74
Base Case + 20% Cost / No rise in fuel cost	1.24	2.29
Base Case + 5% Inflation in fuel cost	2.33	4.02

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 1.00 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.

As the project may be financed on the basis of project financing or limited recourse, the financial analysis has been performed with such an 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's financial 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 13 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 geological conditions as sound rock is available for all civil structures. A construction schedule with the time frame required to implement each of the major project components is given. All these aspects are discussed in chapter 14.

Section 14 Environmental Considerations

The project area is located in an uninhabited area some 26km North East of Tunduru. The construction of the project will have minimal impact on the ecology and environment of the area. The only impact will be for the local people who are collecting gemstones from the river bed as they will have to move upstream or downstream.

The improved access to the area due to the 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 the diverted stretch of the river 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 15.

Section 16 Photo Documentation

Photographs of the project area showing the river is given which will be useful to the implementing agency are given together with reference material which was used.

Section 17 Annexures.

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

Annexure-A: Evaluation of Flow Records:

The available daily historic flow data observed at gauge site 1Q4 for the years 1965 to 1970 is presented. The data is then presented graphically as per the following charts and figures.

Available 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

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

Partial Flow duration curves for each month after assimilating all data for each month. Graphs are given with normal and log scales to enable reading of low flows.

Percentage exceedance of flows for each month

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

Annexure - B: Precipitation Data of Muhuwesi Basin

Available Precipitation data in the catchment along with graphical presentation is given for the important rainfall stations at Matemanga, Misechela, Muhuwesi, Nakapanya, Nalasi, Nampungu, Tunduru Agriculture and Tunduru Maji.

Annexure - C: Infilling missing precipitation records

The available precipitation records collected from the Department of Meteorology in Dar Es Salaam are discontinuous. The missing data was hence filled up for a twenty year period by correlation with adjacent stations. The completed records and the procedure are given in annexure C.

Annexure - D: Rainfall Runoff Models

Due to the discontinuous nature of runoff records, various types of correlation with rainfall have been attempted and four relationships obtained. These have been used to obtain four sets of mean monthly flows at the gauge site 1Q4. Duration curves and other graphs have been plotted and the models compared.

Annexure - E: Flood Studies

The expected maximum flood at the site 1Q4 has been derived by correlation of maximum flood with mean monthly discharge. The relationship shows a good correlation. This relationship has been used to derive maximum flood from the twenty year flow series. Flood frequency has then been fixed for various return periods.

Annexure - F: Morphological properties

The entire catchment of the Muhuwesi river has been studied and morphologic parameters have been derived for each of the sub basins. This is done so that similar studies in the adjacent basins can be carried out where data may be of better quality and flow relationships with morphologic parameters derived. These may be used to compare the flow sequences derived for the Muhuwesi river.

TABLE 1-1

UNITS kWh

ENERGY GENERATION BY DIESEL STATIONS IN YEAR 1997

A GRID DIESEL STATIONS													
STATIONS	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
DODOMA	455,210	1,014,230	422,100	258,960	170,170	989,350	1,448,880	1,617,370	2,408,310	1,183,140	2,208,170	483,250	12,659,140
MBEYA	542,700	428,100	518,100	270,200	312,900	740,700	1,884,600	1,657,800	3,015,500	2,300,200	2,795,200	662,500	15,128,500
MUSOMA	165,350	146,460	69,690	87,740	91,160	15,890	255,610	392,660	424,860	762,540	633,190	115,350	3,160,500
MWANZA	581,100	548,000	520,900	5,200	23,100	0	0	0	0	1,153,000	1,341,500	386,900	4,559,700
UBUNGO D	314,400	743,400	280,300	825,900	1,111,660	776,900	498,900	624,700	875,400	159,900	0	47,600	6,259,060
UBUNGO E	36,861,200	10,824,420	22,180,760	12,674,200	17,141,000	14,678,300	19,272,800	21,594,300	17,012,400	27,577,000	48,760,400	12,670,180	261,246,960
UBUNGO A	7,810,000	5,229,000	9,481,000	4,796,000	9,885,000	9,141,000	10,075,000	10,634,000	12,007,000	16,370,000	18,860,000	5,115,000	119,403,000
TUKUYU	0	0	0	0	0	0	0	0	0	0	0	0	0
TABORA	584,300	741,600	607,800	394,700	569,400	607,600	708,900	524,200	1,021,200	1,287,600	939,300	284,000	8,270,600
MPWAPWA	1,130	4,540	0	2,540	260	0	1,590	10,000	19,280	45,290	24,890	3,370	112,890
BUKOBA	0	15,860	18,670	24,690	21,650	180	11,070	2,890	27,320	12,500	7,480	6,960	149,270
GRID TOTAL	47,315,390	19,695,610	34,099,320	19,340,130	29,326,300	26,949,920	34,157,350	37,057,920	36,811,270	50,851,170	75,570,130	19,775,110	430,949,620
B ISOLATED THERMAL STATIONS													
IKWIRIRI	50,680	43,630	47,320	46,680	48,970	53,440	58,660	57,160	49,810	48,900	45,020	44,760	595,030
KIGOMA	811,640	791,960	835,800	865,850	850,630	861,600	947,560	885,040	853,780	673,020	717,590	832,050	9,926,520
K/MASOKO	56,980	47,450	63,700	58,750	37,090	49,620	50,330	62,690	72,380	69,690	59,600	85,620	713,900
KONDOA	161,527	144,211	166,030	161,794	176,639	157,379	171,448	185,047	176,392	174,364	173,396	134,865	1,983,092
LINDI	385,990	289,650	407,640	369,960	314,920	343,450	374,770	393,650	374,770	404,530	398,090	373,770	4,431,190
LIWALE	16,644	28,651	30,820	33,691	33,632	32,787	32,334	31,339	32,585	32,577	31,439	33,165	369,664
MASAI	797,760	573,890	493,250	511,030	522,670	539,870	588,120	626,980	696,570	592,540	627,500	699,005	7,269,185
MPANDA	166,310	163,900	173,250	184,220	187,520	176,250	200,300	224,980	208,740	223,250	144,750	214,750	2,268,220
MTWARA	522,584	598,912	644,194	658,964	522,444	453,004	514,356	710,584	591,492	549,864	693,872	660,870	7,121,140
NJOMBE	76,440	161,290	279,490	120,440	75,770	46,250	122,800	121,250	35,760	34,360	30,400	2,940	1,107,190
S/WANGA	596,620	571,570	577,750	567,700	558,860	547,000	630,220	627,220	570,020	544,690	404,220	626,170	6,822,040
SONGEA	598,600	627,540	789,790	668,021	710,530	682,890	710,290	767,930	686,650	785,370	858,100	775,140	8,660,851
TUNDURU	83,920	66,990	48,320	41,820	63,980	91,080	91,520	111,320	108,920	98,060	94,380	88,480	988,790
BABATI	198,580	174,300	194,680	193,270	194,840	187,820	204,000	203,360	194,230	194,170	185,570	156,780	2,281,600
MAFIA	140,380	123,930	127,040	111,360	112,060	106,960	108,190	127,120	126,270	96,680	121,480	128,650	1,430,120
ISO TOTAL	4,664,655	4,407,874	4,879,074	4,593,550	4,410,555	4,329,400	4,804,898	5,135,670	4,778,369	4,522,065	4,585,407	4,857,015	55,968,532
GRAND TOTAL	51,980,045	24,103,484	38,978,394	23,933,680	33,736,855	31,279,320	38,962,248	42,193,590	41,589,639	55,373,235	80,155,537	24,632,125	486,918,152

SOURCE TANESCO

Chapter 2 Overview of Ruvuma Region and Project Area

Section 1 General

The Ruvuma region is situated in the south western part of Tanzania, on the eastern shores of Lake Nyasa. Songea is the regional capital. Tunduru is the only other major town besides which there are many scattered villages. The region is bordered by Lake Nyasa on the west, Iringa and Morogoro regions on the north, Lindi region on the north east, Mtwara region on the east and by Mozambique on the south. A considerable portion of the region comprises moderate to dense forest. Map of the region is given in figure 2-1.

Section 2 Access

The regional capital is accessible by main road B4 from Makambako which is located on road A104 which links Iringa with Mbeya. Makambako is also on the Tanzania - Zambia railway (TAZARA) connecting Dar Es Salaam to Zambia via Mbeya. Songea is 300km from Makambako. Access to Tunduru from Songea is by road A19 going east to Masasi in Mtwara region. The distance is 285km and road conditions are very poor especially during rainy season. A number of airstrips are available throughout the region for small charter aircraft. The most convenient access is by use of small aircraft from Dar to Tunduru airstrip which takes three hours flying time.

Section 3 River Basins

The region can be described as an almost flat moderately dense forest land with the land sloping gently principally to the north and south with a ridge running through the center. The two access roads are on this ridge. The western most part of the region adjacent to the shores of Lake Nyasa is very hilly with peaks reaching 2000m and forms part of the Livingstone mountain range. A number of short rivers like Mbangala, Msangesi, Sasawara, Lukubule, Chingweru, Muhuwesi, Lukwika, Likonde etc with catchments upto 9000 sqkm drain the southern slopes of the region into the Ruvuma river which flows to the Indian Ocean and forms the southern boundary of the country with Mozambique. The northern slopes are drained by larger rivers such as Mbarangandu and Luwegu into the Rufiji. The mountainous area in the western part is drained directly into Lake Nyasa mainly by Rutukira and Ruhuhu basins. Most of the rivers seem to be swampy and hence provide good regulated flow in the dry season. Most of the region receives an annual rainfall of about 1000mm.

The Muhuwesi river originates in the central elevated ridge area of the region and flows in an easterly direction. It is joined by two major tributaries from the north one of which is Likuyu. It then turns to flow in an south easterly direction where it picks up two tributaries at a trijunction just near the Muhuwesi bridge called Masonya, and Nampungu. Further on it enters a Narrow gorge called Nawesa gorge for a short distance and continues to flow with gentle slope. It then enters a section with rapids where it is joined by the Mtetesi river. Just before it joins the Ruvuma river at an elevation of about 240m it receives its last tributary Ligoma on the right bank.

Section 4 Topography

The topography of the region consists of gently rolling hills. The Ruvuma river, shown in figure 2-1, occupies a large portion of the region. The basin stretches from Lake Nyasa on the west some 1000 km to Lindi on the east.

The western boundaries are marked by the highlands which extend discontinuously southward from Burundi, along the east coast of Lake Tanganyika to the area north of Lake Rukwa and then along the east coast of Lake Nyasa. These highlands reach elevations of more than 2,000 m. A number of small rivers drain these areas into lake Nyasa which is at an elevation of 472 m,

Section 5 Economy

The primary income of the inhabitants of the region is from rain fed agriculture. The major cash crop is cashewnuts and Tanzania is the worlds largest exporter. All other farming is mainly for subsistence. The crops cultivated include maize, beans, cassava, sweet potatoes and fruit. Livestock is limited

Fishing in Lake Nyasa is a very significant part of life for the people living on the shores of the Ruvuma region.

In recent times collection of gem stones from the Muhuwesi and other rivers seems to be a source of employment with the youth. These are then sold to middlemen who cut, polish and export the stones. Among the stones found in the Muhuwesi river are Tourmaline, Alexandrite, Garnets, Ruby, Emeralds, Sapphire etc. The mining of these stones leads to the erosion of the river banks and channels.

There are very few small scale industries in the region which may be attributed to the lack of proper infrastructure such as electricity and roads.

The gross per capita income in the Region may be near about the national average.

The region is rich in hydropower potential but transmission to the demand centres could be a major constraint in developing large generating plants. On Ruvuma many large power stations are also possible which would require participation from Mozambique.

Section 6 Climatic Conditions

The area is situated in the dry, hot heartland of Tanzania where ground elevation is about 430m. Average annual temperature variation is quite minimal, ranging from 20.C to 30.C Annual precipitation varies from about 1200mm near Lake Nyasa to about 1000mm near the project area. It then picks up as one moves towards the coast.

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 Ruvuma basin the ITCZ has very minimal effects. Less than 5 percent of annual total rainfall in the area 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 region, ranging from an average of 1,700 mm/year at Songea to almost 2,000 mm/year at Tunduru.

Section 7 Demography

The region is sparsely populated and exists to this day in its natural state. The Region has a population density of approximately 20 people/km2 and the annual growth rate is very uneven,

Section 8 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 Songea town. There are generators in Tunduru also with a capacity 2 x 350kW . The service area is limited to only the towns. The present load in Tunduru is about 300kW. Considerable costs are involved in running them as fuel is very expensive and has to be transported over a long distance which is very difficult in the monsoon. Frequent shut down of the generating station due to fuel shortage is not uncommon. 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. In Peramiho, there is a mission which operates its own mini hydro plant. The rest of the region is not electrified. 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.

Detailed studies on the potential electric power demand of the region were carried out in 1982 by SWECO. The study estimated that the demand in Tunduru would be about 1300kW by 1994. The energy demand was estimated to be about 10GWh. The study was based on the assumption that a 3000kW power plant would be commissioned at Sunda falls on the Ruvuma river in 1984. This project 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 2-1. This table is derived from studies in Kigoma. The demand in Kigoma was about 300kW in 1969 and rose to 680kW in 1979. This period was also one in which there was good economic growth in Tanzania. This gives a growth rate of about 7.1%.

Three sets of demand studies have been carried out. The first assumes supply to Tunduru with the present load of 350 kW with a low growth scenario of 3%p.a. The next is a medium growth scenario with load of 600kW with 250kW from surrounding villages and a 5% annual growth rate. The last is a high growth scenario with 500kW load in Tunduru and 250kW from surrounding villages. The growth rate is 7%. The energy demands are calculated for each of the growth rates with a load factor of 60%.

The predicted demand is plotted yearwise and an exponential curve is fitted by method of least squares. Similar curve has been fitted for the energy demand.

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

The projections show that with a medium growth scenario the demand will be about 2000kW in 2020 with required energy of 8.37GWh. In case of a high growth scenario, the demand will be 5350kW in 2020 with energy requirement of 13GWh.

The proposed mini hydro project on Muhuwesi has a capacity of 2000kW and energy generation of 14.5GWh per year. Thus it will be able to serve the district for the low and medium growth cases. In the case of high growth scenario, additional capacity has to be provided in 2010.

Generation data as obtained from TANESCo's diesel power station at Tunduru is given in tables 2-2 to 2-4. Table 2-2 gives the daily maximum alternator output in kW recorded during the year 1997. The maximum demand recorded was 330kW on January 20th. The minimum demand was 130kW recorded on April 20^{th}. The mean load is about 260kW. A plot of maximum, minimum and mean demand for each month is given below the table as also the daily load for the months having the minimum and maximum load.

Table 2-3 gives the daily energy generation. The maximum energy generated in a day was 4350kWh on September 13th The minimum energy generated was 160kWh on Dec 6th due to outage on the sets. The mean energy generated in a day is 2857kWh. The total annual energy demand is 982,660kWh.

Table 2-4 gives the operational status of the diesel power station. It gives the number of hours for which the station was generating power each day along with the constraints on operation such as fuel shortages, breakdown in equipment, outages, scheduled maintenance etc.

Below the table are given the maximum, minimum and mean number of hours for which the station generated each month and also the number of days in each month when supply was available for 24 hours.

The available unit and station capacities in each month are indicated below that. The unit which is in service is indicated by SE and that in standby is indicated by SB. Units which are out of service due to preventive and scheduled or forced outage is indicated by R.

The load factor of the plant is indicated for each month as also is the unit load factor.

Finally, the number of days in each month when the units were out of service due to fuel shortage, outage or repair is indicated.

Below this is given the above data in graphical form. The first figure indicates the maximum, minimum and mean running hours as pillar charts.

The second graph gives the days of diservice in each month due to either fuel shortage, repair or outage.

The last graph gives the available capacity in each month from either unit as well as that from the station.

A load duration curve is then plotted ignoring the days on which operating constraints were incurred. The curve is shown in figure 2-2 and has a base load of about 150kW.

Based on the above data, the following conclusions can be drawn.

- Continuity in supply is frequently hampered due to Fuel shortage. In the year 1997 there were seventy days when fuel was in short supply that is 20% of the time. Examination of the table indicates that supply was disrupted in February, March, April and May. This may be attributed to the monsoon which renders the roads impassable to tankers from Songea or from Masasi.

- The number of days for which supply was available 24 hours is only 47 days in a year. This is again due to shutting down of units either to conserve fuel or because the load demand is smaller than the minimum output of the units. Hence the consumers cannot be assured of continuity in supply.

- The units are operated in rotation due to preventive maintenance required. A look at the available station capacity for each month shows that full capacity of 600kW was available only during January, February, March, August and September. In the remaining months, one of the units was under repair. Thus the net capacity available is that from only one unit of 300kW. It should be further noted that even in February and March fuel constraint limits the capacity to only one unit. Thus in conclusion only 300kW dependable capacity seems to be available.

- The present maximum load is about 330kW. This is the output of one machine. Due to reliability constraints as discussed above, further growth in load hence cannot be met due to insufficient installed capacity.

- The present energy demand of about 1GWh is a restricted demand. The maximum recorded daily energy consumption of 4350kWh gives an annual demand of 1.58GWh and a load factor of 60.1%.

- The load duration curve indicates a base load of about 150kW, load exceeded 80% of time of about 250kW and that exceeded 40% of time to be 260kW.

- From the above, the economic price per kWh is derived in chapter on economic and financial analysis as 15 US cents per kWh. Given that the average tariff charged by TANESCo is about 7 US cents per kWh, the station is not generating any profit and so expansion and supply are in a sense subsidized.

- From the above it is seen that TANESCo is facing difficulty in operating the diesel station and should hence have an alternative and economical reliable source of power from hydro so that it is able to expand its service area in Tunduru district and make profit from its operations.

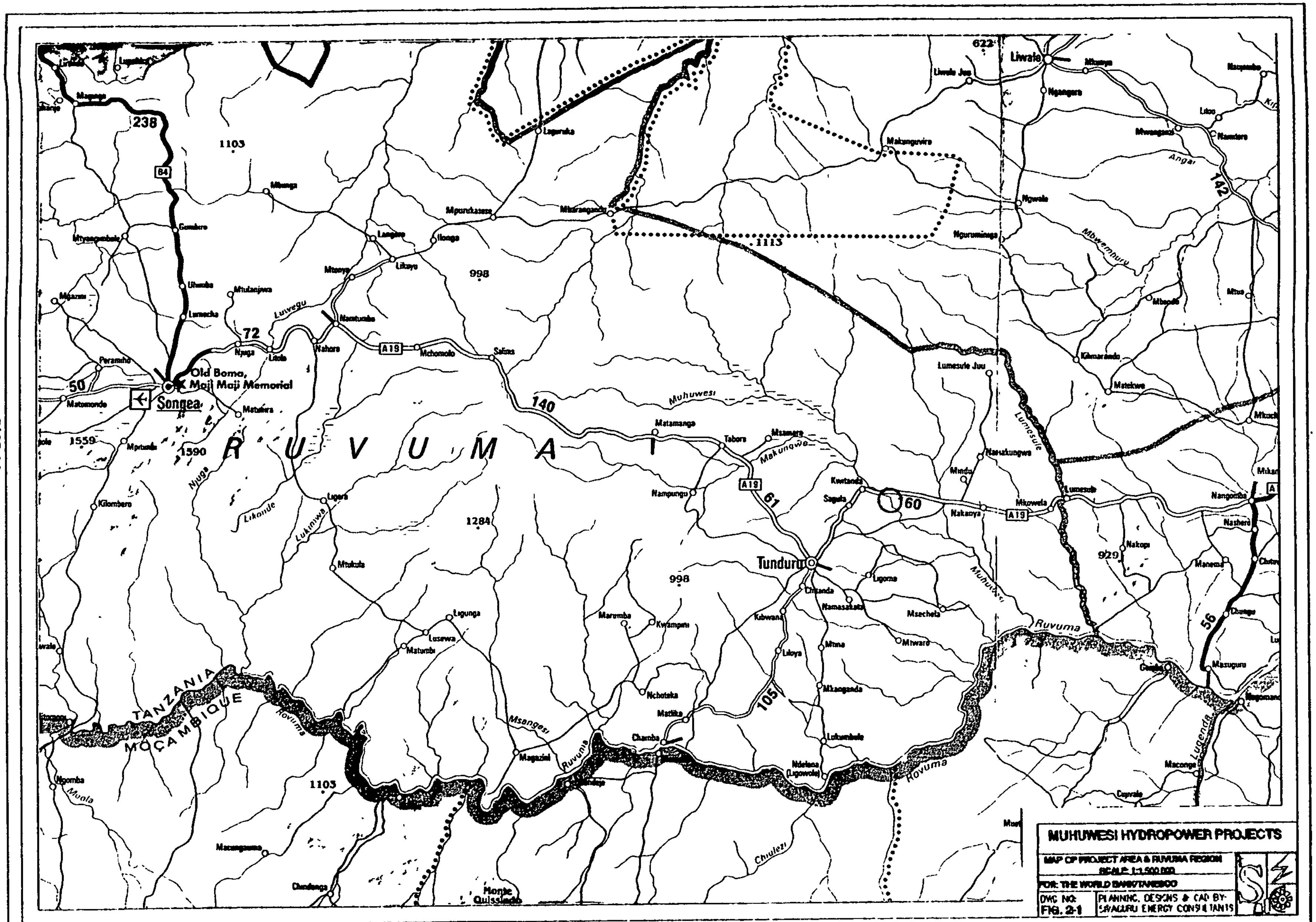

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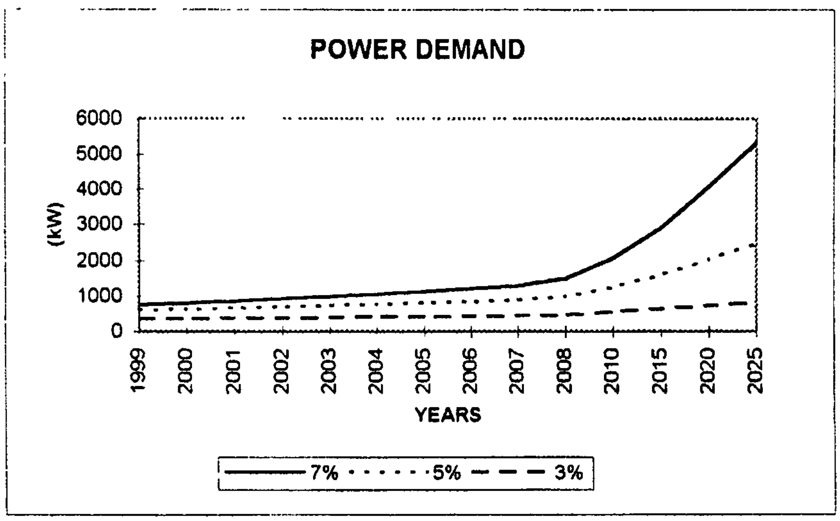
TABLE 2-1
POWER AND ENERGY DEMAND FORECAST

SL	YEAR	POWER DEMAND (kW) HIGH 7%	MEDIUM 5%	LOW 3%	ENERGY DEMAND (GWh) HIGH 7%	MEDIUM 5%	LOW 3%
1	1999	750	600	350	3.94	3 15	1.84
2	2000	803	630	361	4.22	3 31	1 89
3	2001	859	662	371	4.51	3 48	1 95
4	2002	919	695	382	4 83	3 65	2 01
5	2003	983	729	394	5.17	3 83	2.07
6	2004	1052	766	406	5 53	4 02	2.13
7	2005	1126	804	418	5 92	4 23	2.20
8	2006	1204	844	430	6 33	4 44	2 26
9	2007	1289	886	443	6.77	4.66	2.33
11	2008	1475	977	470	7 75	5 14	2 47
16	2010	2069	1247	545	10.88	6.56	2.87
21	2015	2902	1592	632	15 25	8 37	3.32
26	2020	4071	2032	733	21.39	10.68	3.85
30	2025	5336	2470	825	28 04	12.98	4.34



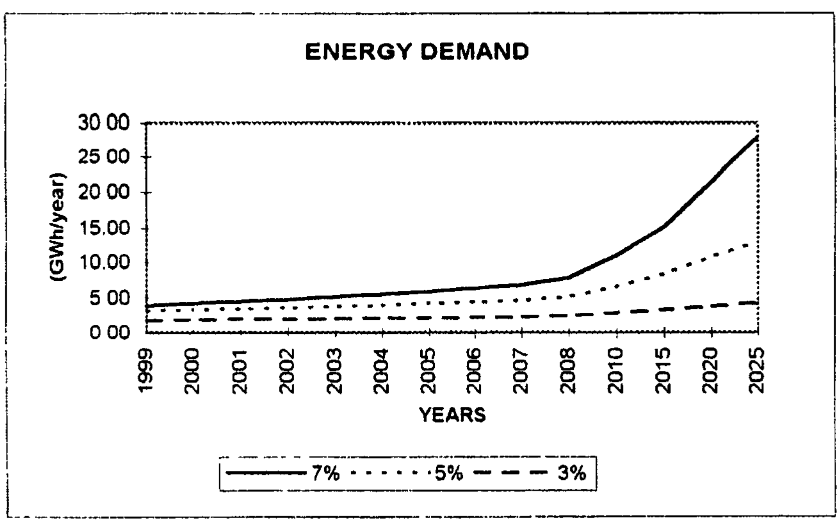
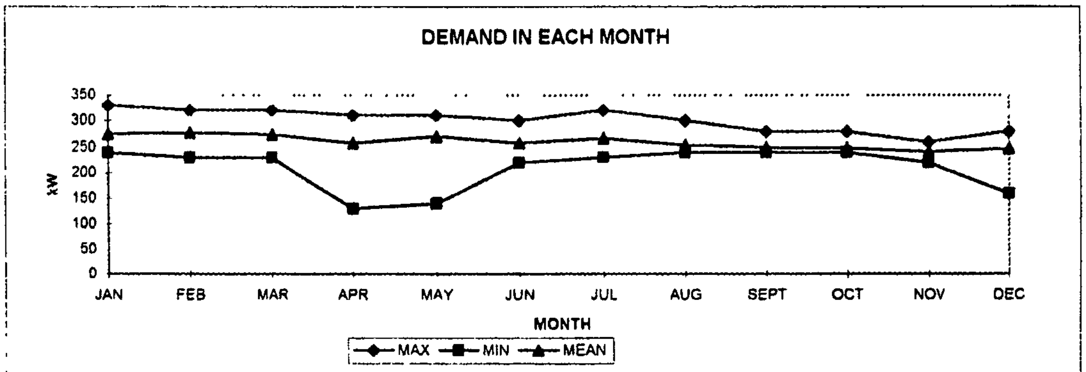


TABLE 2-2
DAILY DEMAND AT TUNDURU POWER DIESEL STATION

YEAR 1997
UNITS kW

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1	260	270	280	240	NIL	240	260	260	250	280	260	240	
2	300	280	270	300	NIL	250	260	250	240	250	250	230	
3	240	NIL	260	260	NIL	260	240	240	250	240	220	230	
4	240	NIL	300	250	140	260	270	300	250	240	250	220	
5	270	NIL	320	260	NIL	260	320	260	240	240	240	230	
6	270	NIL	300	260	NIL	250	290	240	250	250	240	160	
7	260	240	320	300	NIL	280	280	260	250	240	240	260	
8	270	250	250	280	NIL	240	240	250	240	240	240	260	
9	280	230	300	300	NIL	250	260	260	240	260	240	230	
10	260	230	NIL	280	280	260	250	260	250	250	240	240	
11	270	240	NIL	260	260	240	300	260	280	260	260	240	
12	270	290	NIL	270	240	230	250	240	240	240	230	240	
13	260	300	NIL	290	260	230	280	260	240	240	240	240	
14	260	290	NIL	NIL	290	230	290	270	240	240	220	240	
15	260	300	260	NIL	240	240	300	250	260	240	240	260	
16	270	300	260	NIL	300	250	260	270	260	250	250	260	
17	260	300	260	280	280	270	280	260	250	250	240	270	
18	300	290	280	220	280	280	300	260	260	240	240	250	
19	260	320	280	260	290	280	300	260	240	260	240	260	
20	330	310	300	310	250	300	280	260	250	260	260	260	
21	250	310	260	260	300	280	260	250	260	260	240	270	
22	260	260	300	270	310	220	280	250	240	260	230	260	
23	250	270	280	260	310	240	230	240	250	240	240	260	
24	250	260	300	260	310	260	260	250	260	260	240	240	
25	260	300	280	260	280	280	240	240	250	250	240	230	
26	320	270	270	240	250	260	240	240	260	240	260	240	
27	320	290	240	260	300	300	240	250	260	250	240	280	
28	290	270	NIL	260	240	240	240	240	240	240	220	270	
29	320		230	130	270	300	250	240	250	240	240	260	
30	320		230	150	260	270	270	260	240	240	240	250	
31	310		230		280		260	250		240		280	
DAYS	31	24	25	27	23	30	31	31	30	31	30	31	344
MAX	330 00	320 00	320 00	310 00	310 00	300 00	320 00	300 00	280 00	280 00	260 00	280 00	330 00
MIN	240 00	230 00	230 00	130 00	140 00	220 00	230 00	240 00	240 00	240 00	220 00	160 00	130 00
MEAN	275 48	277 92	274 40	258 15	270 43	258 33	267 10	254 19	249 67	248 06	241 00	247 10	259 42

NIL INDICATES PLANT OUTAGE OR FUEL SHORTAGE



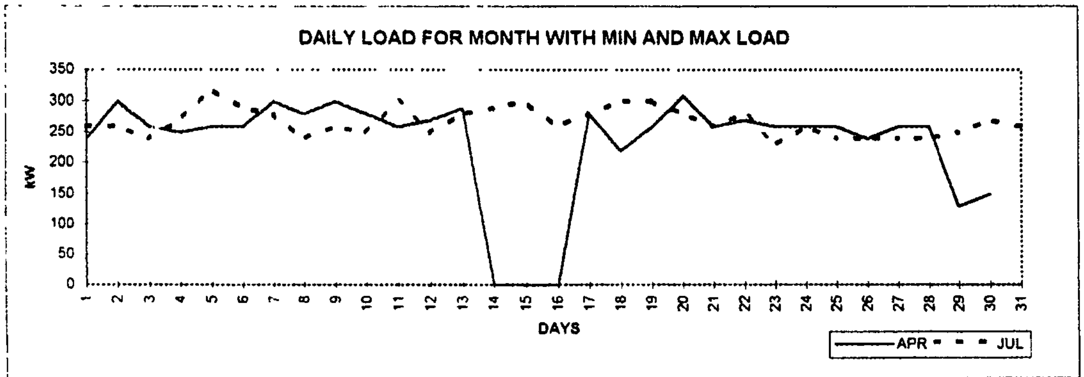
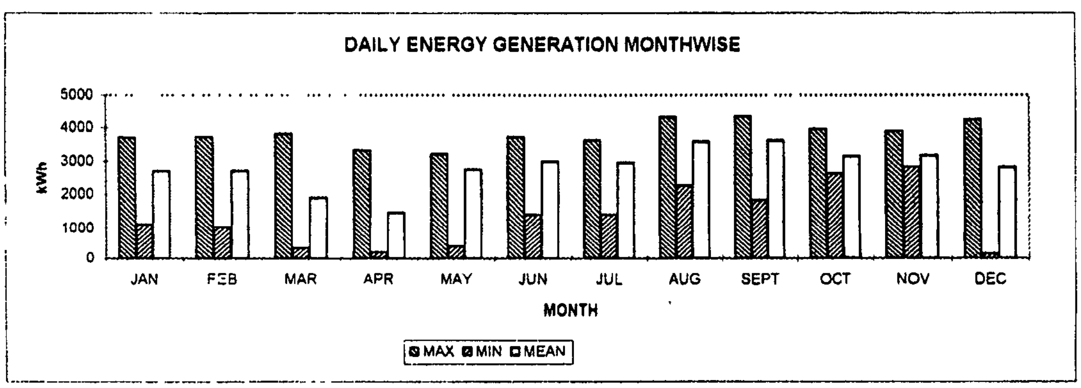


TABLE 2-3
DAILY ENERGY GENERATION AT TUNDURU DIESEL POWER STATION

YEAR 1997
UNITS kWh

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1	3530	1180	3260	1890	NIL	3050	1510	2270	3520	2800	3680	2790	
2	2990	1040	3280	3100	NIL	2970	2980	2890	3510	2970	3530	2930	
3	2900	NIL	1330	1140	NIL	2850	3270	3230	3450	3210	3900	2790	
4	2990	NIL	1340	1340	400	2940	3460	3240	3270	3560	2840	2880	
5	2940	NIL	1360	1190	NIL	2960	3450	3390	1850	3350	3010	2680	
6	2900	NIL	1300	1180	NIL	3000	3360	3580	3750	3000	2830	160	
7	2830	2160	1400	1210	NIL	2900	3360	4150	3720	2930	3180	1820	
8	2950	2830	340	1190	NIL	2930	3400	4120	3510	2970	3430	3390	
9	3030	3240	1080	1430	NIL	2810	3220	4250	3830	2640	3450	3520	
10	3020	3450	NIL	1210	1680	2840	3530	4330	4070	3800	3480	2580	
11	3060	2730	NIL	1080	2970	1520	3260	3990	4080	3970	3190	3110	
12	3580	3080	NIL	1130	2780	1430	3310	4140	4080	3650	2910	3050	
13	3710	3020	NIL	1160	2700	1840	3400	3650	4350	3080	2880	2910	
14	2980	3010	NIL	NIL	3000	3210	3560	3520	3870	3370	3010	2980	
15	3030	3200	3820	NIL	2700	3370	2460	3780	3160	3250	3370	2770	
16	3010	3150	3100	NIL	2970	3410	1660	3590	3730	2910	3370	2800	
17	1740	3060	2900	1580	2910	3390	2550	3260	3550	3180	3020	2750	
18	2880	3110	3070	3340	2870	3360	1490	3560	3310	3540	2930	2510	
19	3090	1130	2970	2640	2890	3460	1440	3520	3820	3420	2960	2900	
20	2800	1320	2770	2960	2990	3400	1560	3270	3570	2730	2980	2810	
21	3010	1860	2720	1140	2700	3510	3330	3090	4100	3150	2990	2760	
22	2870	2990	1010	1190	2560	3140	3420	3690	3350	2850	3530	2870	
23	2960	3080	1160	1470	2770	3360	3090	3390	3220	2820	3360	2810	
24	2940	3050	1020	1420	3020	3370	3400	3510	3590	3160	3060	3360	
25	2860	3140	540	1140	2780	3280	3620	3530	4040	3370	2940	3430	
26	3040	3210	1140	1060	3020	3370	3140	3620	3990	3440	2940	3460	
27	1200	3400	1160	1610	3090	3430	3360	3470	4100	3040	2900	2710	
28	1130	3720	NIL	1630	3140	3720	3560	3650	3960	2910	2980	2990	
29	1310		440	210	3030	3170	3450	3820	2930	2930	3380	3060	
30	1320		2400	670	3070	1750	2290	3970	3630	2950	3350	1850	
31	1320		2670		3230		2550	3750		3200		4250	
DAYS	31	24	25	27	23	30	31	31	30	31	30	31	344
MAX	3710	3720	3820	3340	3230	3720	3620	4330	4350	3970	3900	4250	4350
MIN	1130	1040	340	210	400	1430	1440	2270	1850	2640	2830	160	160
MEAN	2707	2715	1903	1493	2751	2991	2950	3585	3630	3166	3179	2828	2857
TOTAL	83920	65160	47580	40310	63270	89740	91440	111120	108910	98150	95380	87680	
CUMUL	83920	149080	196660	236970	300240	389980	481420	592540	701450	799600	894980	982660	

NIL INDICATES PLANT OUTAGE OR FUEL SHORTAGE



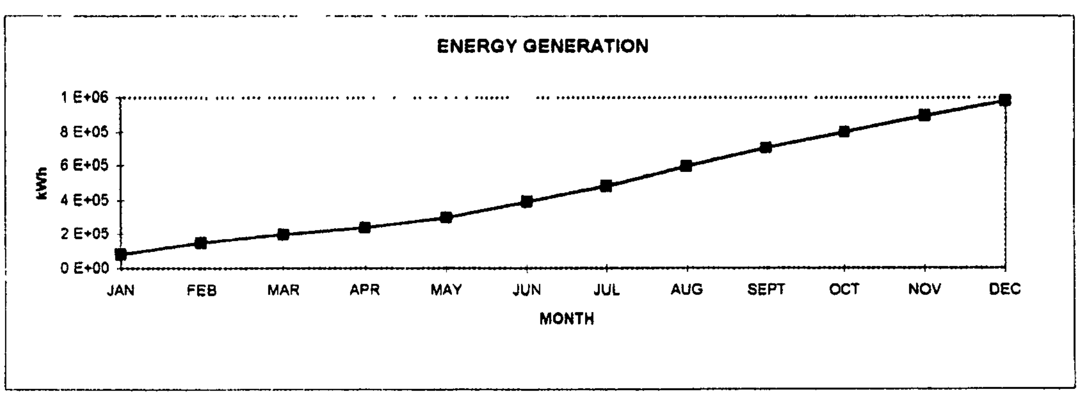


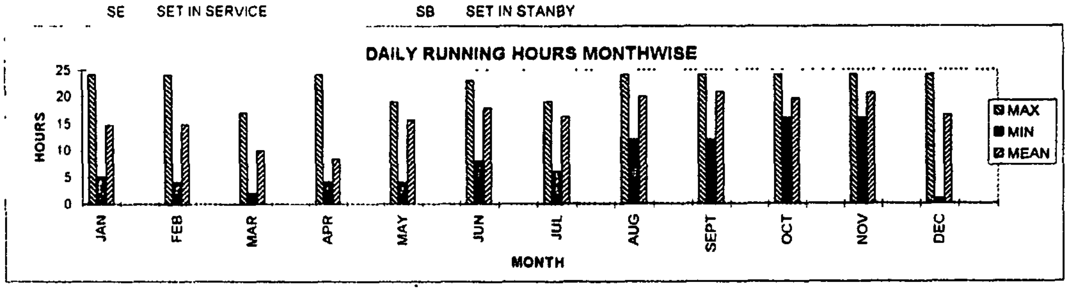
TABLE . 2-4

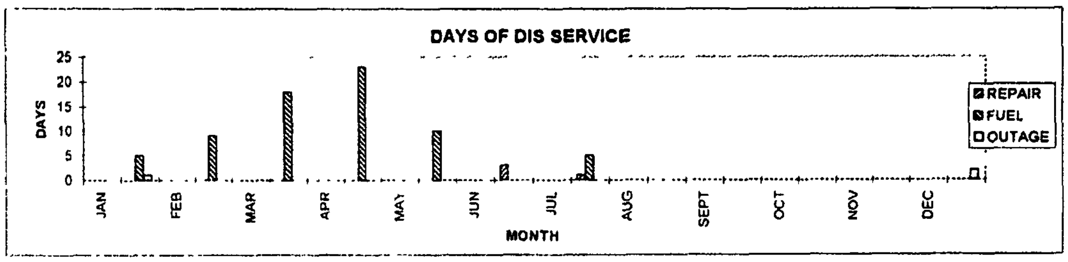
DAILY RUNNING HOURS OF TUNDURU DIESEL POWER STATION

DAY	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC		ANNUAL
1	24		5	FS	17		16		NIL	FS	20		7	R	15		18		21		24		18		
2	16		4	FS	17		11		NIL	FS	19		11		12		18		18		24		18		
3	11		NIL	FS	15		12		NIL	FS	19		19		21		18		18		19		18		
4	16		NIL	FS	5	FS	7	FS	4	FS	19		19		20		18		24		16		18		
5	16		NIL	FS	5	FS	5	FS	NIL	FS	19		19		19		21		24		18		19		
6	16		NIL	FS	5	FS	5	FS	NIL	FS	19		19		19		12		18		16		1	OU	
7	16		10		5	FS	5	FS	NIL	FS	19		19		24		24		18		19		7	OU	
8	16		16		5	FS	5	FS	NIL	FS	19		19		24		18		18		24		23		
9	16		24		5	FS	6	FS	NIL	FS	17		19		23		24		18		24		24		
10	16		24		5	FS	5	FS	6	FS	19		19		24		24		20		24		15		
11	16		16		NIL	FS	5	FS	17		8	R	18		24		23		24		24		18		
12	24		16		NIL	FS	5	FS	17		10	R	19		24		24		24		19		18		
13	24		16		NIL	FS	5	FS	17		10	R	19		19		24		18		18		18		
14	16		16		NIL	FS	NIL	FS	17		18		19		18		24		18		20		18		
15	16		18		14		NIL	FS	17		19		15		20		18		18		24		16		
16	16		16		16		NIL	FS	17		19		12	FS	19		18		17		24		15		
17	7	OU	16		16		8	FS	19		19		13	FS	21		18		20		18		15		
18	16		16		16		24		17		19		6	FS	19		18		24		18		15		
19	16		13	FS	16		16		17		19		6	FS	19		24		24		18		15		
20	14		5	FS	14		16		17		19		8	FS	18		24		17		18		15		
21	16		6	FS	14		13		14		19		14		16		24		16		20		15		
22	16		16		13		5	FS	14		19		19		20		18		16		23		15		
23	16		16		5	FS	7	FS	16		19		19		18		18		17		24		15		
24	16		16		5	FS	7	FS	17		19		19		21		18		19		18		20		
25	16		16		2	FS	5	FS	17		19		19		19		24		23		18		24		
26	16		16		5	FS	9	FS	17		19		19		19		24		24		18		24		
27	13	FS	17		5	FS	7	FS	17		19		19		19		24		18		18		15		
28	5	FS	24		NIL	FS	7	FS	17		23		19		22		24		18		20		15		
29	5	FS			3	FS	4	FS	17		17		19		21		16		18		24		15		
30	5	FS			12		5	FS	17		15		17		24		21		18		24		15		
31	5	FS			17				17				17		18				19				15		
DAYS	31		24		26		27		23		30		31		31		30		31		30		31		345
24 HOURS	3		3		0		1		0		0		0		6		13		7		11		3		47
MAX	24		24		17		24		19		23		19		24		24		24		24		24		24
MIN	5		4		2		4		4		8		6		12		12		16		16		1		1
MEAN	14 74		14 83		9 88		8 33		15 74		17 90		16 29		19 97		20 70		19 58		20 53		16 52		16 45
AVAILABLE CAPACITY																									
UNIT-1	300	SB	300	SE	300	SE	270	SE	270	SB	NIL	R	NIL	R	300	SB	320	SE	320	SE	320	SE	320	SE	
UNIT-2	300	SE	300	SB	300	SB	NIL	R	320	SE	320	SE	320	SE	320	SE	300	SB	NIL	R	NIL	R	NIL	R	
STATION	600		600		600		270		590		320		320		620		620		320		320		320		
GEN UNITS	83920		65160		47580		40310		63270		89740		91440		111120		108910		98150		95380		87680		
LOAD FACTOR																									
PLANT	19 1%		14 8%		10 8%		9 2%		14 4%		20 4%		20 8%		25 3%		24 8%		22 3%		21 7%		20 0%		
RUNNING	19 1%		14 8%		10 8%		20 4%		14 6%		38 3%		39 0%		24 5%		24 0%		41 9%		40 7%		37 4%		
DAYS OF DISSERVICE																									
FUEL		5		9		18		23		10		0		5		0		0		0		0		0	70
OUTAGE		1		0		0		0		0		0		0		0		0		0		0		2	3
REPAIR		0		0		0		0		0		3		1		0		0		0		0		0	4

FS FUEL SHORTAGE — OU OUTAGE OR BREAKDOWN — R REPAIRS

SE SET IN SERVICE — SB SET IN STANBY





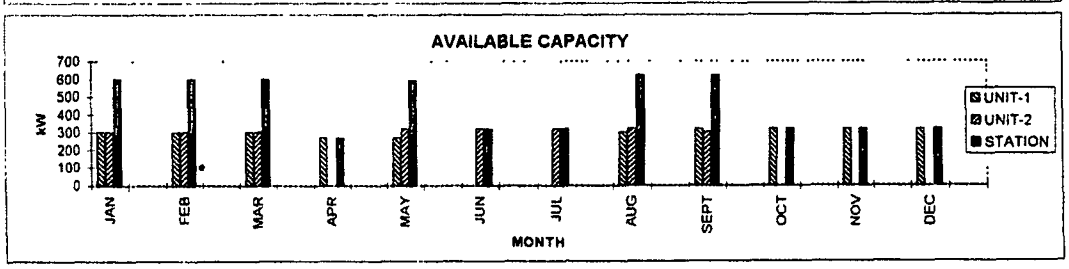
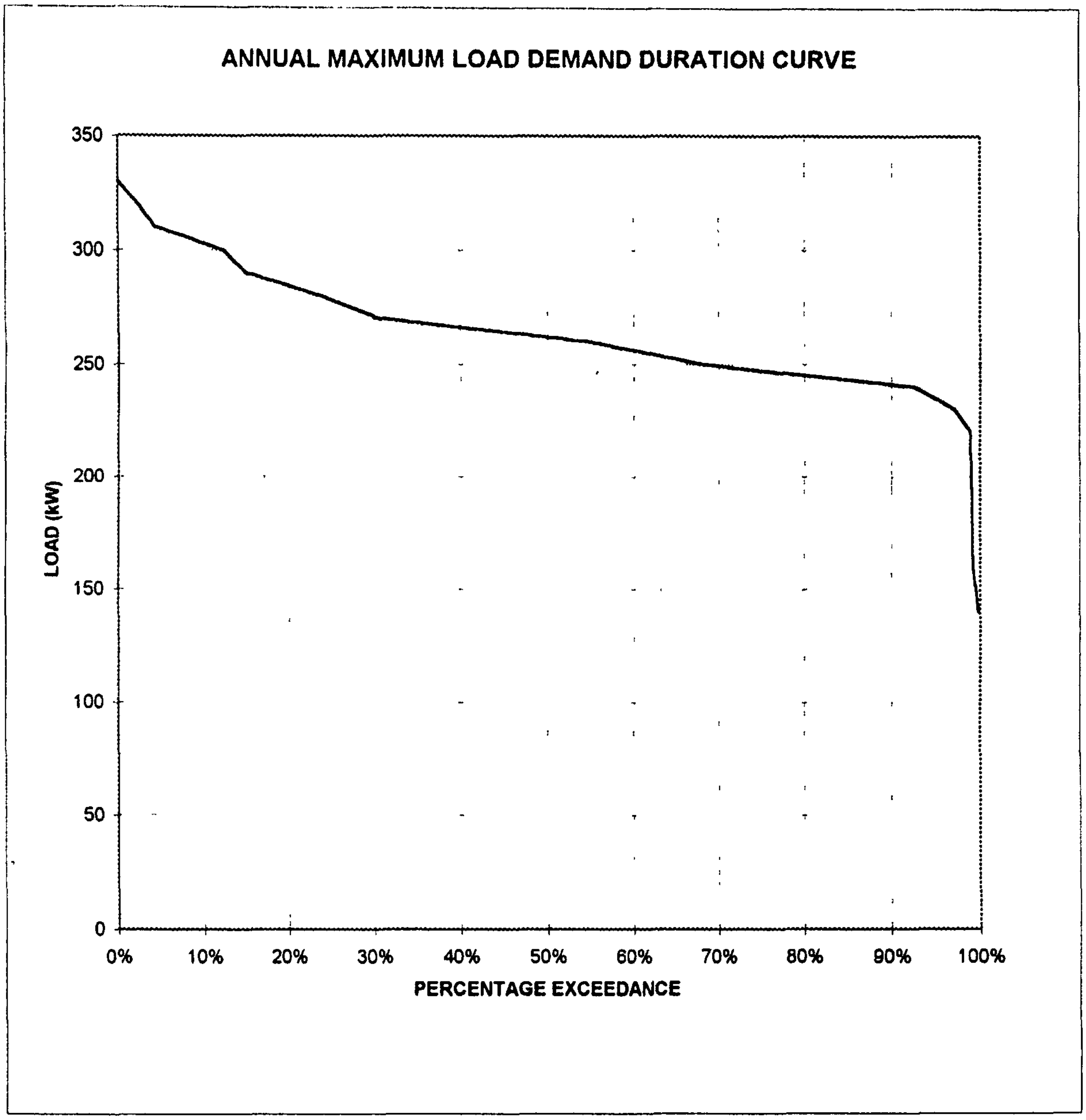


FIGURE 2-2
ANNUAL LOAD DURATION CURVE FOR TUNDURU POWER STATION



SOURCE DATA: TANESCO

Chapter 3 Review of Previous Proposals (SWECO)

Section 1 Alternatives

During 1981-82 SWECO carried out a pre feasibility study on development of mini hydropower in the region. The study explored the possibilities of hydropower development for supply to Songea and Tunduru. As this report concentrates on Tunduru, only the proposals put forth for Tunduru are discussed.

The two options studied for supply to Tunduru were Ruvuma at Sunda falls and Muhuwesi at Nawesa gorge. The description of the schemes are given below.

Section 2 Sunda Falls

Sunda falls are located on the Ruvuma river which is the border between Tanzania and Mozambique in an uninhabited area about 65km south east of Tunduru. The catchment area at the site is about 62,700 sqkm of which about half lies in Mozambique. The river is very wide at the site and the flow occurs in many channels with large islands in the middle. These islands are probably subject to flooding during the high water periods. The flow in the dry season is said to be confined to mainly one channel where it cascades down a 13.5m high drop.

The study proposed two alternatives as follows. The salient features of the development are given below. It was forecast that alternative 1 will meet the demand of Tunduru for 15 to 20 years with 7 to 8 percent annual growth rate whereas the second option would meet the demand for 10 years. The main features are summarized below.

Box 3-1: Alternatives for Sunda falls by SWECO

	PLANT FLOW (cum/s)	HEAD (m)	CAPACITY (kW)	ENERGY (GWh)	EXPECTED GENERATION (GWh)
1	26	13.5	2 x 1500	25	10
2	14	13.5	2 x 770	13	7

1. The proposed Sunda falls power plant will be located on the Tanzanian side of the river.

2. The access road from Tunduru which is in very poor condition for some stretches ends about 1km from the site. New road of about 1km will have to be built which will be about 4.5m width.

3. The power station will be connected to the river banks by an earth and rockfill dam with a crest level 294m. The dam will have an impervious core, consisting of laterite which is protected from erosion by a layer of rockfill on the crest and the sloping faces. Between the rockfill and core are transition zones of coarse material and sand.

4. All materials for the rockfill dams are available in the vicinity.

5. The diversion structure will consist of 4 small overflow concrete weirs which will be constructed, two on the Mozambique side and two on the Tanzanian side. The weirs will be about 1 to 2m in height. Plan and section of the diversion weir is shown in figure 3-1.

6. The mean firm flow at the site (62,700 sqkm) is estimated from the records of station 1Q7 located on Ruvuma at Muhiga which is 375km upstream and where the catchment is 4900 sqkm. The flow duration curve at the site is deduced in proportion to the catchment increase over that at Muhiga.

7. Based on the above, the firm flow at Sunda was estimated to be 24 to 26 cumecs.

8. The flood at the Muhiga site for 1000 years return period was estimated to be 960 cumecs. It was then deduced that as catchment at Sunda falls is about 13 times larger, the flood magnitude cannot be estimated proportionately but must be based on further studies.

9. The geological investigations were brief and concluded that the rocks in the area belonged to the Usagavan system of Archean age. The rocks in this class occur mainly as marble, quartzite and various schists and gneisses. The rocks in the Sunda falls area seemed to be gneissic and the outcrops along the river were sound.

10. A headrace canal with a length of 280m and a width of 9 meters will be excavated in rock. An intake structure equipped with closure arrangements and stop logs is provided.

11. The headrace canal leads to the power house which is located close to the left bank. The substructure of the power house will be founded on the rock. The substructure consists of deep shafts at the base of which the turbines are located. The running speed of the turbines is 350 rpm. Runner diameter is 1.5m.

12. The superstructure is made up of concrete elements and houses the gearbox and generators. The turbine generator sets are coupled by long shafts with intermediate guide bearings. The step up gearbox ratio is 1:2.14. The generators sets are air cooled and run at 750rpm. The generator voltage is 400V.

13. Water after generation is conveyed back to the river by a deep tailrace canal which is about 300m in length and has a bottom width of 9 meters. It is excavated mostly in rock.

14. The transmission system consists of a 33kV step up transformer at the power station and a 65km long 33kV transmission line to Tunduru. At Tunduru a substation will be built with feeder lines to various loads.

15. The construction of the plant was estimated to take two and half years.

16. The cost estimate of the plant was worked out which included civil works comprising direct costs and contractors indirect costs, mechanical and electrical works comprising equipment costs, freight, insurance, bonds, erection, transmission and substation, contingencies, engineering and supervision. The estimate was made for both the alternatives. It is presented in table 3-1.

17. 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 from about 1GWh to the full output of the plant. For the purposes of economic analysis this variable increase was converted to average constant demand as shown in

shown in Box 3-2. Thus all the capacity of the plant would not be used for 20 years in case of alternative 1 and 10 years in case of alternative 2 with the result that revenue from sales would be restricted till the demand grows.

Box 3-2: Average energy sale from plant

PERIOD	ALT-1 (GWh)	ALT-2 (GWh)
40 years	18	11
10 years	7	6
average	10	7

A summary of the cost estimate taken from table 3-1 is given in box 3-3 below with the breakup of foreign and local components. The cost of generation is derived in box 3-4.

Box 3-3: Summary of Implementation Cost

	Alternative-1	Alternative-2
Foreign Component (MUSD)	8.662	7.325
Local Component (MUSD)	2.588	1.800
Total (MUSD)	11.250	9.125
Investment Cost/kW (USD)	3750	5925
Investment Cost/kWh (USD)	1.125	1.303

Box 3-4: Annual Costs in MUSD and Energy Cost

	ALT-1				ALT-2		
Discount Rate	2%	6%	10%		2%	6%	10%
Foreign Component							
Capital	0.3025	0.5675	0.8837		0.2575	0.4825	0.7362
Operation & Maintenance	0.1125	0.1125	0.1125		0.0937	0.0937	0.0937
Total	0.4150	0.6775	0.9962		0.3512	0.5762	0.8299
Local Component							
Capital	0.0875	0.1675	0.2625		0.0612	0.1175	0.1837
Operation & Maintenance	0.0562	0.0562	0.0562		0.0437	0.0437	0.0437
Total	0.1437	0.2237	0.3187		0.1049	0.1612	0.2274
Foreign + Local	0 5587	0.9012	1.3149		0.4561	0.7374	1.0573
Energy Cost (US cents)	5.587	9.012	13.149		6.515	10.534	15.104

The study calculated the economic benefit of the project by comparison with an alternative diesel set which would have to be installed instead of the proposed hydropower station. The following parameters were presented.

Box 3-5: Cost parameters of Diesel set

DESCRIPTION	UNITS	ALTERNATIVE-1	ALTERNATIVE-2
Investment Cost	USD/kW	1250	1250
Economic Life	years	25	25
Fuel Cost	USc/kWh	27.50	27.50
O & M Cost	USc/kWh	0.625	0.625
Installed Capacity	kW	3000	1540
Energy Output @ 75% lf	GWh/year	19.71	10.118

The recurring unit annual costs on the capital were worked out for different discount rates as in box 3-6 below.

Box 3-6: Recurring unit fixed annual energy costs

Discount Rate	UNIT	2%	6%	10%
Annuity	USD/kW			
Capital Cost	USc/kWh	0.975	1.487	2.093
Fuel Cost	USc/kWh	27.500	27.500	27.500
O& M Cost	USc/kWh	0.625	0.625	0.625
Total Cost/kWh	USc/kWh	29.100	29.612	30.218

Finally, the benefit cost ratio defined as cost of energy from hydro to that from diesel is derived as given in box 3-7 below.

Box 3-7: Benefit Cost Ratio

DISCOUNT RATE	ALT-1 2%	ALT-1 6%	ALT-1 10%	ALT-2 2%	ALT-2 6%	ALT-2 10%
Hydropower Energy	5.587	9.012	13.149	6.515	10.534	15.104
Diesel Energy	29.100	29.612	30.218	29.100	29.612	30.218
Difference	23.513	20.600	17.069	22.585	19.078	15.114
Benefit Cost	5.208	3.286	2.298	4.466	2.811	2.000

Based on the above the Economic internal rate of return was calculated to be 28.5% for alternative 1 and 24.0% for alternative 2.

Section 3 Muhuwesi

The other proposal briefly studied was the Muhuwesi at Nawesa gorge. The flow was estimated to be about 2 cumecs and a head of 22m was contemplated by construction of a 25m high dam. The installed capacity was proposed to be 1700kW with a firm capacity of 1300kW from a 220 million cubic meter reservoir. The annual energy was estimated to be 12GWh. The site is 26km from Tunduru and is easily accessible as it is on the Masasi - Tunduru main road which the Muhuwesi crosses. The project was not recommended as it would be less economic due to the 25m dam even if the shorter transmission line is considered.

Section 4 SECSD Observations

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

1. The project is to be built on an international river with Mozambique having more than half of the rights over the water. Further the scheme involves structures on the Mozambique side of the river. These require discussions between both governments and possibly a cooperative agreement between the two countries

2. It is not known whether similar studies have been done by Mozambique to implement Sunda falls to supply small towns in Mozambique. If this is the case, then the power produced will have to be shared and the dependable capacity available for Tunduru will be reduced.

3. The Sunda falls site was visited by SECSD team. The access is very difficult and in some cases steep slopes have to be negotiated apart from crossing a number of streams. However, in the cost estimates only 0.9km has been shown against access roads. It is hence necessary to include in the estimates the cost of bridges, considerable distance of new roads etc which would affect the cost estimates.

4. The minimum flow at Sunda falls has been estimated to be 22 cumecs based on proportionate increase in catchment over Muhiga. As the river is very wide,

for nearly 375 km, the dry season flow is spread over a wide area and evaporative losses would be considerable and hence the dependable flow needs to be verified by establishing gauge site near the project site

5. The transmission distance is considerable and the cost of transmission is more. It is also felt that significant recurrent costs will be incurred in maintenance of access road and transmission.

6. The contemplated diversion structures to plug the channels of the river are very small and subject to over topping by floods of considerable magnitude in the monsoons. Further it is not certain whether they will be able to withstand the huge floods expected at this location.

7. The quantities presented in the civil works estimate are considerable. For example over 50, 000 cubic meters excavation for the headrace and tailrace canals and 7000 cubic meters for the power house. Another 14,000 cubic meters of earthwork is involved for the diversion weir. Due to the above quantities, the project cost ranges from $3750 per kW for a 3000kW plant to $ 5925 per kW for a 1540kW plant. The above suggests that if the installed capacity is increased, the unit cost may come down. This has not been studied in the report.

8. In spite of the natural head, the quantities of civil works are considerable. For a lesser quantum of the above civil works quantities, it is possible to have an alternative project nearer to Tunduru and within Tanzania to give same power and energy.

9. The power house with the long shafts etc can be substituted with submersible generators with cylindrical gates as shown in figure 3-2.

10. Considerable power is likely to be lost in transmission and capacitors would be required in Tunduru to contain the voltage drop.

11. 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

12. The energy cost of 10 to 15 cents assuming 10GWh average energy for discount rates from 6% to 10% is high. TANESCo will have to sell the power at a loss as average tariff is about 7 cents per kWh. If the present demand of 1GWh is to be served in Tunduru then energy cost will be very high and debt repayment will be difficult. Thus the financial benefit cost and financial rate of return is low.

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.

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 and energy will be economically produced. 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.

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. The project should be such that water rights are entirely vested with Tanzania so that the project can be constructed easily and quickly. Even with the demand less than the potential of the project that is rising from a base market demand of 6 GWh, 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 cost of cement and transport are expensive.

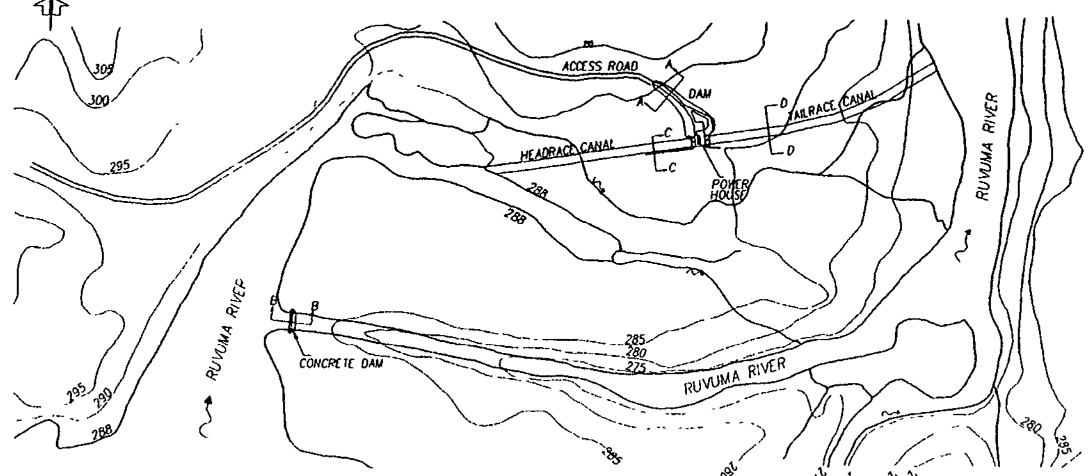
6. Simulation of the operation of the power station for low, high and mean runoff years with all relevant features such as monthly power, energy, water levels, hydraulic losses etc should be given.

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 reduced.

8. The site on Muhuwesi river has been summarily rejected without establishing hydrology or the power potential. In contrast, the site is readily accessible and has good potential. The flow is confined to a single channel making it easy to construct the project. Transmission distance is one third that for Sunda falls and the terrain is flat with good access making maintenance easy. It is necessary to study the Muhuwesi site further.

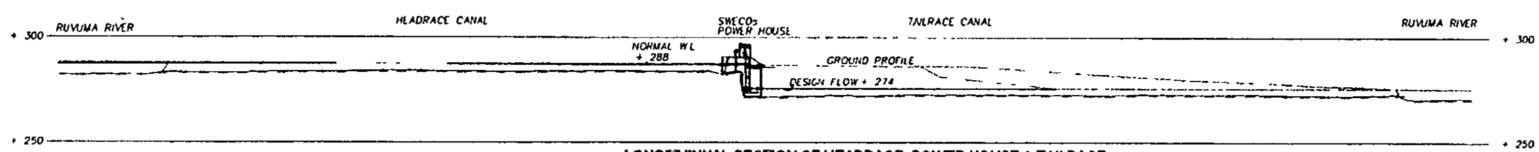
9. If the criteria as per the SWECO report is natural drop, similar drops are also available on Muhuwesi which is closer to Tunduru and whose catchment is also entirely in Tanzania. For lesser civil works quantities than those estimated for Sunda falls, these drops can be exploited for hydropower.

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 four and elaborated further in the remainder of this report.

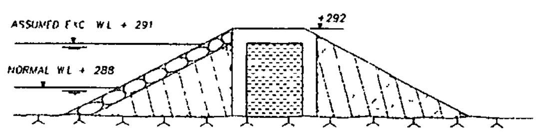


RUVUMA RIVER AND SUNDA FALLS PROJECT LAYOUT (PLAN)

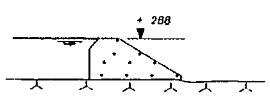
LAYOUT WITH ACCESS AND TRANSMISSION



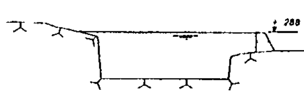
LONGITUDINAL SECTION OF HEADRACE, POWER HOUSE & TAILRACE



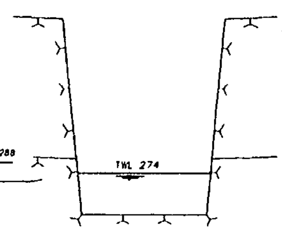
SECTION A–A MAIN DAM



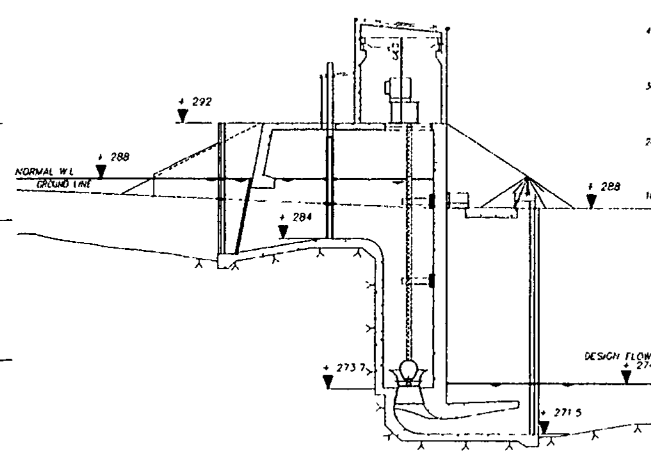
SECTION B–B CONCRETE DAM



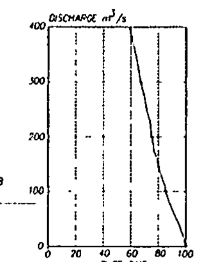
SECTION C–C HEADRACE CANAL



SECTION D–D TAILRACE CANAL



CROSS SECTION OF POWER HOUSE



DURATION CURVE FOR RUVUMA RIVER AT SUNDA FALLS

NOTES:

This drawing is a computerized plot of the layout of Sunda Falls Hydropower Project designed by SWECO (1982) to supply electricity to Tunduru town. The Sunda falls is on Ruvuma river which forms the border between Tanzania and Mozambique

The proposal involves constructing four small concrete diversion weirs to divert a part of the flows of the Ruvuma towards the Tanzanian side where the power station is located

The power station will have two units with 13 cumecs discharge each at head of 13.5m and capacity 2 x 1500kW with annual energy of 10GWh

A headrace canal with FSL 288 in dry season which will get submerged in the wet season with FSL 291 is proposed. The turbine will be located in a deep shaft. The generator will be located above ground level connected via a gearbox to the turbine by a long shaft. A deep tailrace channel is also to be excavated.

The overall cost of the project is in excess of TZS 30.000/kW (1982)

The power house excavation is as per SWECO's proposal. It may be possible to excavate the power house as a vertical shaft and provide a tail conduit either tunnel or as a cut and cover conduit

RUVUMA HYDROPOWER PROJECT	
SUNDA FALLS LAYOUT (SWECO)	
FOR IBRD/TANESCO	
DWG NO: FIG 3-1	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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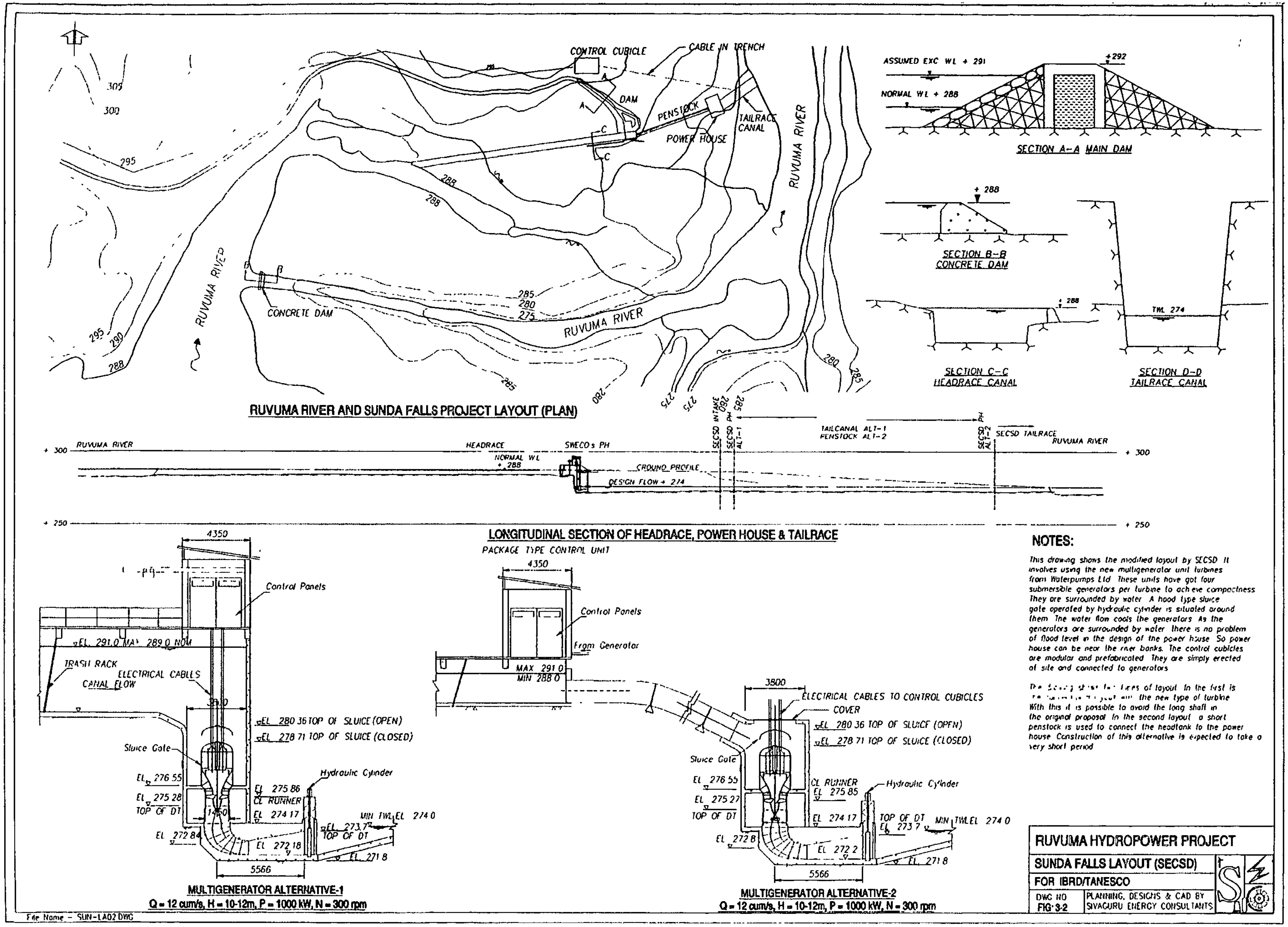


CONTROL CUBICLE
CABLE IN TRENCH
DAM
PENSTOCK
POWER HOUSE
TAILRACE CANAL
RUVUMA RIVER
CONCRETE DAM
RUVUMA RIVER AND SUNDA FALLS PROJECT LAYOUT (PLAN)
ASSUMED EXC WL + 291
NORMAL WL + 288
+292
SECTION A–A MAIN DAM
+ 288
SECTION B–B CONCRETE DAM
TWL 274
SECTION C–C HEADRACE CANAL
SECTION D–D TAILRACE CANAL
HEADRACE
SWECO's PH
NORMAL WL + 288
GROUND PROFILE
DESIGN FLOW + 274
SECSD INTAKE
SECSD PH ALT-1
TAILCANAL ALT-1
PENSTOCK ALT-2
SECSD PH ALT-2
SECSD TAILRACE
LONGITUDINAL SECTION OF HEADRACE, POWER HOUSE & TAILRACE
PACKAGE TYPE CONTROL UNIT
Control Panels
From Generator
TRASH RACK
ELECTRICAL CABLES
CANAL FLOW
EL 291.0 MAX 289.0 NOM
MAX 291.0
MIN 288.0
EL 280 36 TOP OF SLUICE (OPEN)
EL 278 71 TOP OF SLUICE (CLOSED)
Sluice Gate
Hydraulic Cylinder
CL RUNNER
TOP OF DT
MIN TWL EL 274 0
ELECTRICAL CABLES TO CONTROL CUBICLES
COVER
MULTIGENERATOR ALTERNATIVE-1
Q = 12 cum/s, H = 10-12m, P = 1000 kW, N = 300 rpm
MULTIGENERATOR ALTERNATIVE-2
Q = 12 cum/s, H = 10-12m, P = 1000 kW, N = 300 rpm
NOTES:
This drawing shows the modified layout by SECSD It involves using the new multigenerator unit turbines from Waterpumps Ltd These units have got four submersible generators per turbine to achieve compactness They are surrounded by water A hood type sluice gate operated by hydraulic cylinder is situated around them The water flow cools the generators As the generators are surrounded by water there is no problem of flood level in the design of the power house So power house can be near the river banks. The control cubicles are modular and prefabricated They are simply erected at site and connected to generators
In the first is ... the new type of turbine With this it is possible to avoid the long shaft in the original proposal In the second layout a short penstock is used to connect the headtank to the power house Construction of this alternative is expected to take a very short period
RUVUMA HYDROPOWER PROJECT
SUNDA FALLS LAYOUT (SECSD)
FOR IBRD/TANESCO
DWG NO FIG 3-2
PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS
File Name – SUN-LA02.DWG

TABLE. 3-1
QUANTITY AND COST ESTIMATE FOR SUNDA FALLS BY SWECO

		Unit	Unit Rates		Quantity		Costs	
			TZS	USD	Alt-1	Alt-2	Alt-1 USD	Alt-2 USD
1	CIVIL WORKS							
a	Temporary works and overheads	lumpsum			1		1,000,000	750,000
b	Access Road	km	1,000,000	125,000	1		125,000	125,000
c	Dam							
i	Soft Rock Excavation	m3	150	18.75	2000	2000	37,500	37,500
ii	Hard Rock Excavation	m3	400	50.00	2000	2000	100,000	100,000
iii	Earthfill	m3	200	25.00	2000	2000	50,000	50,000
iv	Rockfill	m3	300	37.50	8000	8000	300,000	300,000
v	Miscellaneous	lumpsum					87,500	87,500
	Total						575,000	575,000
d	Head Race Canal							
i	Soft rock excavation	m3	150	18.75	2000	1178	37,500	22,088
ii	Hard Rock Excavation	m3	400	50.00	12000	7068	600,000	353,400
iii	Miscellaneous	lumpsum					62,500	37,000
							700,000	412,488
e	Intake and power house							
	Soft Rock Excavation	m3	150	18 75	2000	1710	37,500	32,063
	Hard Rock Excavation	m3	400	50.00	3000	2565	150,000	128,250
	Concrete	m3	3300	412.50	2000	1710	825,000	705,375
	Formwork	m3	750	93 75	3500	2990	328,125	280,313
	Reinforcement	t	16000	2000.00	80	68.4	160,000	136,800
	Super Structure	lumpsum					87,500	74,800
	Miscellaneous	lumpsum					311,875	267,500
	Total						1,900,000	1,625,100
f	Tailrace canal							
i	Soft rock Excavation	m3	150	18.75	6000	3600	112,500	67,500
ii	Hard Rock Excavation	m3	400	50.00	30000	18000	1,500,000	900,000
iii	Miscellaneous	lumpsum					137,500	82,500
iv	Total						1,750,000	1,050,000
	TOTAL CIVIL WORKS						6,050,000	4,537,588
2	MECHANICAL WORKS							
a	Intake gates, trash racks, stoplogs & cranes	lumpsum					325,000	212,500
b	Turbines, gearboxes & cooling equipment	lumpsum					762,500	687,500
	TOTAL						1,087,500	900,000
3	ELECTRICAL WORKS							
a	Generators	lumpsum					387,500	350,000
b	Transformer/ other electrical equipment	lumpsum					325,000	287,500
c	Transmission and substation	km					1,237,500	1,212,500
	TOTAL						1,950,000	1,850,000
	TOTAL ELECTROMECHANICAL WORKS						3,037,500	2,750,000
4	ENGINEERING (10% of Civil and E&M)						912,500	875,000
5	PHYSICAL CONTINGENCIES (15% Civil, 10% E&M)						1,250,000	962,500
6	*TOTAL IMPLEMENTATION COST*						11,250,000	9,125,088
	COST PER kW INSTALLED						3,750	5,925

NOTES: 1USD = 8TZS IN JANUARY 1982

Chapter 4 Revised Proposals for Tunduru District (SECSD)

Section 1 General

The report by SWECO is of preliminary nature and more investigations need to be carried out and studies based on further data assimilated on topographic, geological and hydrological aspects will be necessary before a decision on Sunda falls can be made. In the present approach an alternative set of three sites have been identified which are more feasible and should be taken up for supply to Tunduru. The main topographic data used is the maps of 1:50000 scale of the Muhuwesi and Ruvuma basin

Section 2 Revised Layout

Part I Planning

The above topographic information was studied in detail by SECSD and suitable sites for hydropower identified initially on the basis of these maps. The maps were digitized and longitudinal sections of the Ruvuma and Muhuwesi river and its tributaries were prepared. These are shown in figure 4-1 and 4-2. Figure 4-1 shows the profile of the Ruvuma river with all the tributaries which join from the Tanzanian side. The locations of Sunda falls and the Muhuwesi confluence have been depicted therein.

The profile of Muhuwesi and its tributaries is shown in figure 4-2.

Three sites suitable for hydropower development have been identified and are shown in the longitudinal profile of the river. A description of each stage is given below.

<u>STAGE-1 PROJECT:</u>

This stage involves the construction of a diversion weir with FSL 439m about 1km downstream of the Muhuwesi road bridge. The site is about 90km upstream from the confluence of Muhuwesi with Ruvuma river. The Muhuwesi river in this stretch flows in a narrow channel flanked on both sides by high rocky banks which in some places are steep vertical cliffs. The concrete diversion weir will be about 10m in height and about 40m in length and will have gates to pass flood water in the wet season and maintain the FSL at 439m in dry season. A power station can be constructed at the toe of the diversion weir to get a head of about 9.5m and power of 1000kW. To increase the power in the dry season, it is necessary to have a power canal on the left bank for a distance of about 2500m. This increases the power output and the project is still economical because the excavation will be mainly in soil and soft rock and the quantities are lower than that for the two canals envisaged for Sunda falls. The project also has the advantage of providing good storage as the banks of the river suddenly widen upstream of the road bridge providing considerable storage with a relatively small dam. The proposed increase in water level will not affect the bridge. An additional bridge can also be had over the new diversion weir at little extra cost. The project features are shown in figure 4-3.

STAGE-II PROJECT

The stage II project involves exploiting a natural drop in the Muhuwesi river which occurs in the vicinity of the confluence of Mtetesi with Muhuwesi. The site is about 44km upstream from the confluence of Muhuwesi with Ruvuma. The river bed is very rocky for a distance of 6km in this stretch and the river drops by 40m from an elevation of 340m to 300m in 6km which gives a gradient of 1:150. The first stage involves construction of a diversion weir with FSL of 345m and a height of 5m about 1km upstream of the confluence of Mtetesi. A power canal of 2000m length designed for 13.5 cumecs conveys the water to a power house to be located on the right bank with tailwater level of 322.5m. The total gross head is 22.5m of which 17.5m is a natural drop. The power house will have a capacity of 2 x 1250kW. The project features are shown in figure 4-4.

STAGE-III PROJECT

The stage III project involves exploiting a natural drop in the Muhuwesi river which occurs about 40km upstream from the confluence of Muhuwesi with Ruvuma. This stage involves construction of a diversion weir with FSL 322.5m of about 12.5m height. Water is conveyed by a 1100m long canal to a power house located on the right bank with tailwater level 300m. The flow in the canal is 13.5 cumecs. Out of a total head of 22.5m, 10m is natural drop and 12.5 m is from the diversion structure. The diversion weir will have a central spillway with rockfill flanks which will be economical. The installed capacity of this stage will be 2 x 1250kW. The project features are shown in figure 4-4.

CASCADE FEATURES

The total installed capacity of the cascade is thus 7000kW. Initially, only single units can be developed starting with stage 1. This will be able to meet the immediate load demand of Tunduru. 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 7000kW, it is feasible to increase the size of waterways or build additional parallel ones to have increased discharge as they are surface canals and are very short to give increased installed capacity.

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 1 project is readily accessible and is nearest to Tunduru, it is recommended for implementation and 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 4-1: Proposed Cascade Development of Muhuwesi

Location	PROJECT	FSL (m)	TWL (m)	Q (cum/s)	H (m)	Power (kW)	Energy (GWh)
Muhuwesi	Stage-1	439.0	420.0	13.5	19.0	2 x 1000	14.5
Mtetesi	Stage-2	345.0	322.5	13.5	22.5	2 x 1250	20.0
Mtetesi	Stage-3	322.5	300.0	13.5	22.5	2 x 1250	20.0
TOTAL						7,000	54.5

With the above revised planning, hydrology, power studies and costing were performed. Important features of the project is given in Box 4-2. Full details are given in table 4-1.

Box 4-2 Project at a glance

Main Features

Type of Project	Hydro electric run of river type	
Installed Capacity	2 x 1000kW. (Vertical Shaft Tubular Kaplan turbines)	
Average Net Head	17.0m	
Power Station Discharge	13.5 cubic metres per second.	
Mean Annual Energy	14.5 GWh	
Construction Cost	4.83 M USD (exclusive of IDC)	
Construction Period	2 years	

Financial analysis @ US 7 cents/kWh

	IPP financing (I = 10%, n = 10 years)	Soft Term Loan (I = 3%, n = 30 years)
IDC	0.748 MUSD	0.219 MUSD
Cost per kW	2788 USD	2523 USD
Financial Benefit Cost	2.08	3.563
Cost/kWh (1st year)	6.79 US cents	2.80 US cents

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 1:50000 topographic sheets and several reconnaissance visits to the dam site and project area. Preliminary surveying was conducted during the field visit. Additional topographic mapping and surveying could be conducted later during execution of the project and incorporated in the final design drawings. The project is situated in a reach about 1 km downstream from the Muhuwesi bridge. The site controls a catchment area of 6,520km^2 which for the most part is very sparsely inhabited and is a moderately spaced woodland. The river in this reach is considerably rocky and the river banks are high. There is vegetation along the banks of the river. 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 eastern side of the Muhuwesi River, approximately 20 km North North East of Tunduru town. The coordinates of the site are approximately latitude 10^{0}51'30"S and longitude 37^{0}28'30"E

Both riverbanks of the diversion weir can be reached with a 4WD vehicle by a motorable track, about 1 km long, branching off from the Tunduru-Masasi road before and after the Muhuwesi bridge near the village Kwitanda. The distance along the road and track from Tunduru town to the river at the project site is altogether approximately 26 km to the diversion weir and 30km to the power house site.

The proposed access to the diversion site will be by a new road to be built branching off from the main road 1km before reaching Muhuwesi bridge from Tunduru as shown in figure 4-3, and the route of the new access road will be so as to follow the existing track directly to the river. The proposed access road to the power house will be a branch from the main road after crossing Muhuwesi bridge. The road runs due south for about 1.25km before turning south east and will follow the proposed power canal. Road construction along the proposed alignment is expected to be straight-forward. Sufficient quantity of construction materials area available along the route.

As part of the access road, suitable strengthening of the Muhuwesi bridge and repairs may be involved, though the bridge has withstood over topping by floods during previous years as per local enquiry.

Part IV **Civil Structures**

For the diversion structure a concrete dam with rockfill flanks is considered. It will have the feature of passing surplus flood water over its crest and will be gated.

The spillway portion of the diversion weir dam will be about 30 m in length, about 10 m in height and will be gated. The features are shown in figure 9-2. The water will be diverted into a canal with FSL 439 which leads to a forebay with FSL 438m.

Water is conveyed to the power house by penstocks. The power house will be surface type located about 2500m downstream of the diversion weir along the river course. Its tailrace will be led into the Muhuwesi river in the immediate vicinity of the power house. The installed capacity will be 2 x 1000 kW. The maximum design flow for the power station has been fixed at 13.5 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 tubular Kaplan turbines coupled with generators (2 x 1250 kVA) 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 33 kV grid will be ensured if required.

The two generators will be connected to a single 3 phase step up power transformer. The outlet line will be provided only with circuit breaker, lightning arresting device and disconnecting switch. A 33 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 2,000 kW, the Muhuwesi stage-1 power station will exceed the present demand for electricity in the district. Its output is more than adequate for the towns of Tunduru and other small places. The power station will thus need be connected to a new district grid, so that generated electricity is transmitted to the existing load centers. Having regard to the natural and uniform regulated river flow of the Muhuwesi river and therefore to its guaranteed output, this power station will be able to reliably and economically provide electricity supply to the district 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 Tunduru with a new 30km 33kV single circuit transmission line which goes from the switchyard to the new Tunduru substation.

With the supply of electricity to Tunduru and the surrounding areas from the Muhuwesi power station, the load on the diesel generators at Tunduru 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 150,000 USD 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 and the existing Muhuwesi bridge. 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 12-1 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**

The comparison of the cost components between the earlier SWECO proposal on Ruvuma at Sunda falls and the SECSD proposal on Muhuwesi is given in box 4-3. It is seen that the Sunda falls project becomes expensive due to the cost components associated with the Temporary works, power house, tailrace, transmission, engineering and contingencies amounting to a total of USD 8.049M.

In the SECSD project, the total cost of these components is reduced significantly to only USD 1.319M.

It is estimated that the total construction cost of the scheme will be US$ 4.828M without accounting for IDC which is 0.76 MUS$ for financing at 10% interest and 10 years loan period. The economic Benefit Cost ratio to the national economy is

4.09 at 12% discount rate by valuing the energy at 13.74 US cents per kWh. The financial benefit cost to the developer is 2.08 and the net cost of energy is about 6.8 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 13.

Box 4-3: Comparision of Specific costs

ITEM	SWECO ESTIMATE USD	SECSD ESTIMATE USD	SWECO SPECIFIC COST USD/kW	SECSD SPECIFIC COST USD/kW
Temporary works	1,000,000	75,000	333	37.50
Access roads	125,000	50,000	43	25.00
Dam	575,000	1,485,000	193	742.50
Head Race	700,000	769,000	233	384.50
Power House	1,900,000	67,500	633	33.75
Tailrace	1,750,000	94,665	583	47.33
E & M equipment	1,800,000	1,088,000	600	544.00
Transmission	1,237,500	450,000	412	225.00
Engineering & Admn	912,500	326,344	304	163.17
Contingencies	1,250,000	381,856	416	190.91
Environmental Impacts	-	40,795	0	20.39
TOTAL	11,250,000	4,828,000	3750	2414

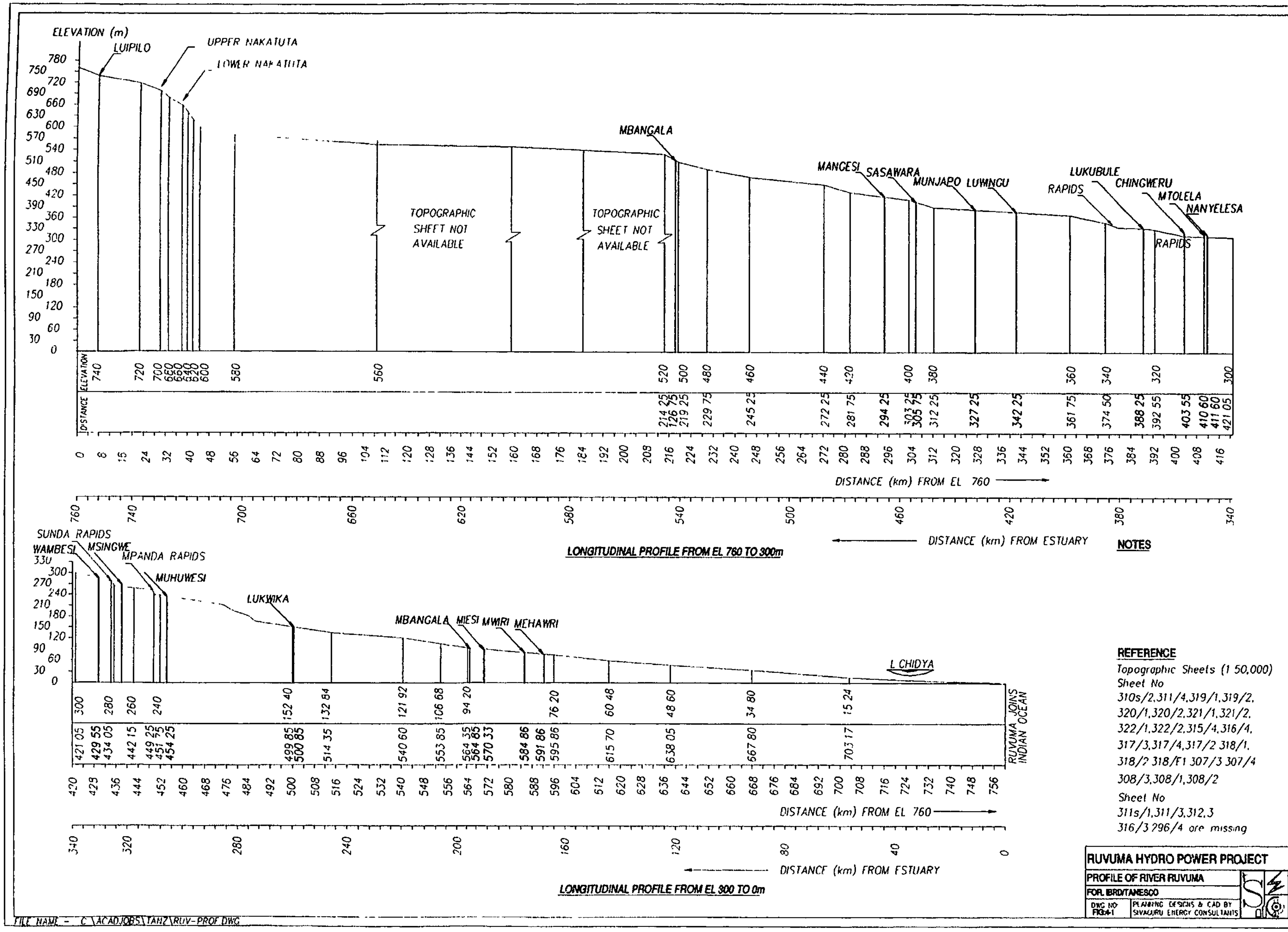
Table:4-1
MAIN FEATURES OF MUHUWESI STAGE-1 HYDRO ELECTRIC PROJECT

	Project Particulars	Description
1	**General**	
a	Type of Project	Run of River Type Hydro Electric generating project
b	Location	on Muhuwesi River near Muhuwesi bridge in Tunduru district of Ruvuma region about 26km east of Tunduru on Tunduru-Masasi road
c	Installed Capacity	2000kW
d	Catchment Area	6521 sqkm
e	No of Units	2 units
f	Annual Energy Output	14 5 GWh (mean year), 13.75 (wet year), 13 (dry year)
g	Plant Load Factor	83.1% (average year), 78 48%(wet year), 74.2%(dry)
2	**Diversion Weir**	
a	Non Overflow Section	
i	Type	Rockfill or Rubble Masonry
ii	River Bed Level	432m
iii	Full Supply Level	439m
iv	Minimum Drawdown Level	437m
v	Gross Storage Capacity	6,080,000 cubic meters
vi	Length	120m
vii	Maximum Height	10m
viii	Crest Width	1.5m
b	Overflow section	
i	Type	Concrete weir with crest gates
ii	Crest Level	435m
iii	Gates	Taintor gates
iv	Size of Gates	4m x 4m
v	No of Gates	6
vi	Length	35m
3	**Waterway**	
i	Type	Trapezoidal power canal
ii	Bed Width/ Top Width	0 75m/ 5m
iii	Side Slope	1:1.75
iv	Gradient	1:2500
v	Maximum Discharge	13.5 cumecs
vi	Length	2500m
vii	Penstocks	Steel Penstock laid on ground with supports
viii	Diameter	1.7m
ix	Length	140m
4	**Power House**	
i	Type	Surface Type with superstructure
ii	Length	9m
iii	Width	5m
iv	Floors	Two
5	**Electromechanical Equipment**	
a	Turbine	Vertical Shaft elbow Tubular Kaplan turbine.
i	Rated Head	16m
ii	Rated Discharge	6.75 cumecs
iii	Minimum Net Head	14.67m
iv	Maximum Net Head	17.59m
v	Speed	500 rpm
vi	Governor	Electronic Digital Governing system
vii	Runner Diameter (approx)	1080mm
viii	Inlet Valves	Servo operated butterfly valve
b	Generators	3 phase AC 50Hz
i	Type	Synchronous
ii	Poles	6
iii	Speed	1000 rpm
iv	Rating	6 6 kV, 1250 kVA, 0 85 pf
v	Exciter	Static excitation system

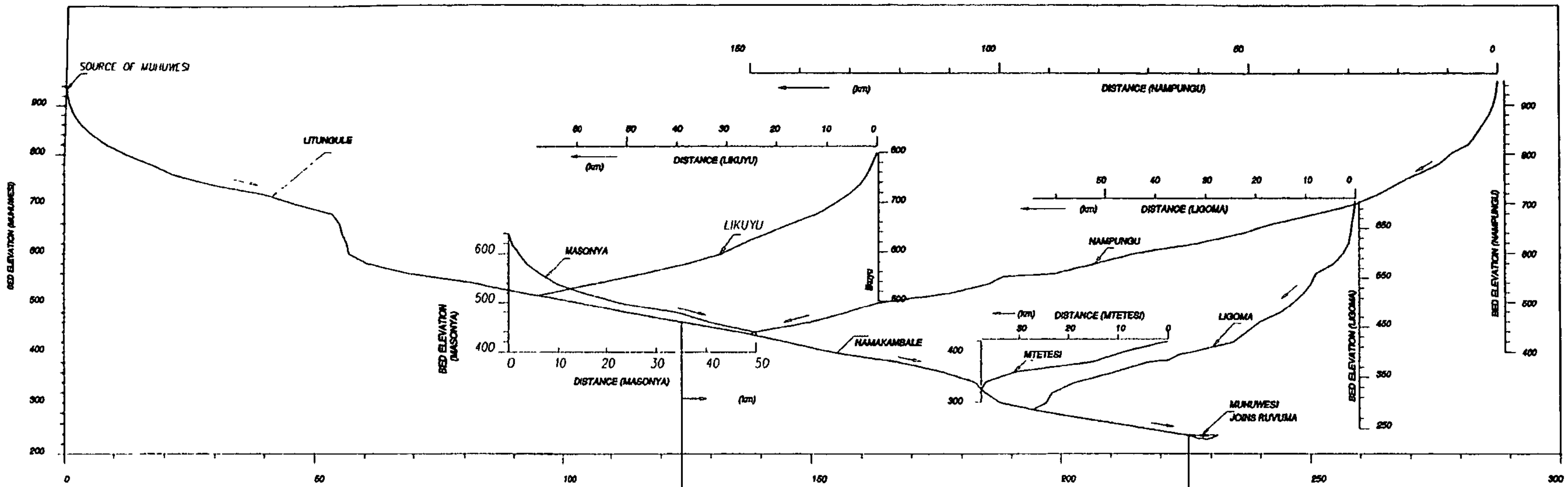
TABLE. 4-1 Contd

MAIN FEATURES OF MUHUWESI STAGE-1 HYDRO ELECTRIC PROJECT

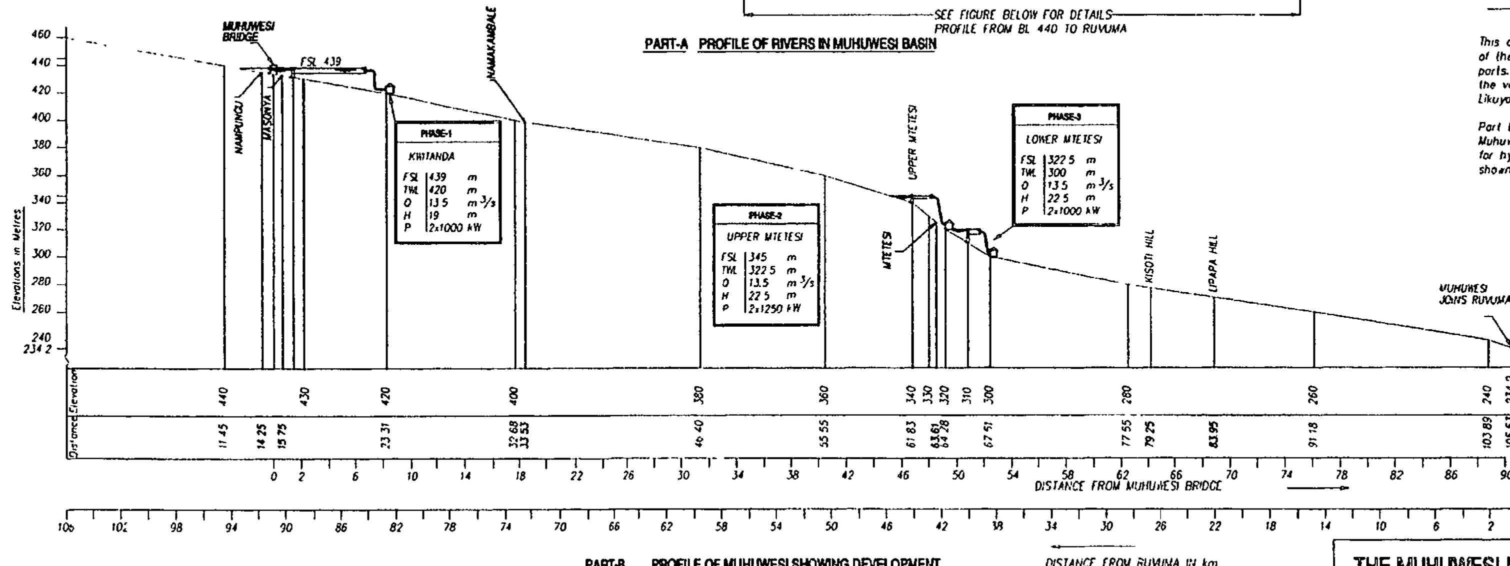
6	Electrical Equipment	
a	Transformer	1 Nos
b	Rating	6 6 / 33 kV, 2 5 MVA
c	Switchyard	Double bus arrangement with air breakers
d	Transmission Line	33 kV line from station to new Tunduru Substation approximately 30km length
7	Environmental Impacts	No significant impact and lake will be confined to river 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$ 2 541M
b	Electromechanical and Allied works	US$ 1 088 M
c	Transmission	US$ 0.450 M
d	Direct Construction Cost	US$ 4 079M
e	Engg, Administration, Environment & Contingencies	US$ 0 748M
f	Construction Period	24 months
g	Total Implementation Cost	US$ 4 827M
h	Interest During Construction @10% interest rate	US$ 0 748 M
i	Total Project Capital Cost	US$ 5 575M
j	Cost per kW installed without IDC	US$ 2414
k	Annual Debt Service (10 year Project loan @10%)	US$ 0 908M
l	Annual Operation and Maintenance	US$ 0 048M
m	Depreciation	US$ 0 029M
n	Total Annual Costs	US$ 0 985M
o	Maximum possible Energy generation	14 5 GWh
p	Grid Wheeling charges	NIL
q	Banking charges	NIL
r	Water Royalty	NIL
s	Net Energy for sale	14 5 GWh
t	First year Generation Cost per kWh for 14.5GWh	US 6.8 cents
u	Life cycle Generation cost per kWh	US 1 4 cents
v	Economic Life	30 years
w	Sale price of energy	US 7 cents escalating at 5% p a
x	Ratio of Life Cycle Benefits/ Life Cycle Costs	2 08 (calculated with energy price of US 7cents per kWh at 12% discount rate
y	Cost per kW installed with IDC	US$ 2785



ELEVATION (m)
LUIPILO
UPPER NAKATUTA
LOWER NAKATUTA
MBANGALA
TOPOGRAPHIC SHEET NOT AVAILABLE
TOPOGRAPHIC SHEET NOT AVAILABLE
MANGESI
SASAWARA
MUNJAPO
LUWNGU
LUKUBULE
RAPIDS
CHINGWERU
MTOLELA
NANYELESA
RAPIDS
ELEVATION
DISTANCE
DISTANCE (km) FROM EL 760
DISTANCE (km) FROM ESTUARY
LONGITUDINAL PROFILE FROM EL 760 TO 300m
SUNDA RAPIDS
WAMBESI
MSINGWE
MPANDA RAPIDS
MUHUWESI
LUKWIKA
MBANGALA
MIESI
MWIRI
MEHAWRI
L CHIDYA
RUVUMA JOINS INDIAN OCEAN
DISTANCE (km) FROM EL 760
DISTANCE (km) FROM ESTUARY
LONGITUDINAL PROFILE FROM EL 300 TO 0m
NOTES
REFERENCE
Topographic Sheets (1 50,000)
Sheet No
310s/2,311/4,319/1,319/2,
320/1,320/2,321/1,321/2,
322/1,322/2,315/4,316/4,
317/3,317/4,317/2 318/1,
318/2 318/F1 307/3 307/4
308/3,308/1,308/2
Sheet No
311s/1,311/3,312,3
316/3 296/4 are missing
RUVUMA HYDRO POWER PROJECT
PROFILE OF RIVER RUVUMA
FOR. IBRD/TANESCO
DWG NO FIG4-1
PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS
FILE NAME - C \ACADJOBS\TANZ\RUV-PROF DWG



PART-A PROFILE OF RIVERS IN MUHUWESI BASIN



PART-B PROFILE OF MUHUWESI SHOWING DEVELOPMENT

This drawing shows the longitudinal section of the rivers of the Muhuwesi Basin in two parts. Part A shows the Muhuwesi river and the various major tributories Nampungu, Likuyu Mtetsi Masonya and Ligoma

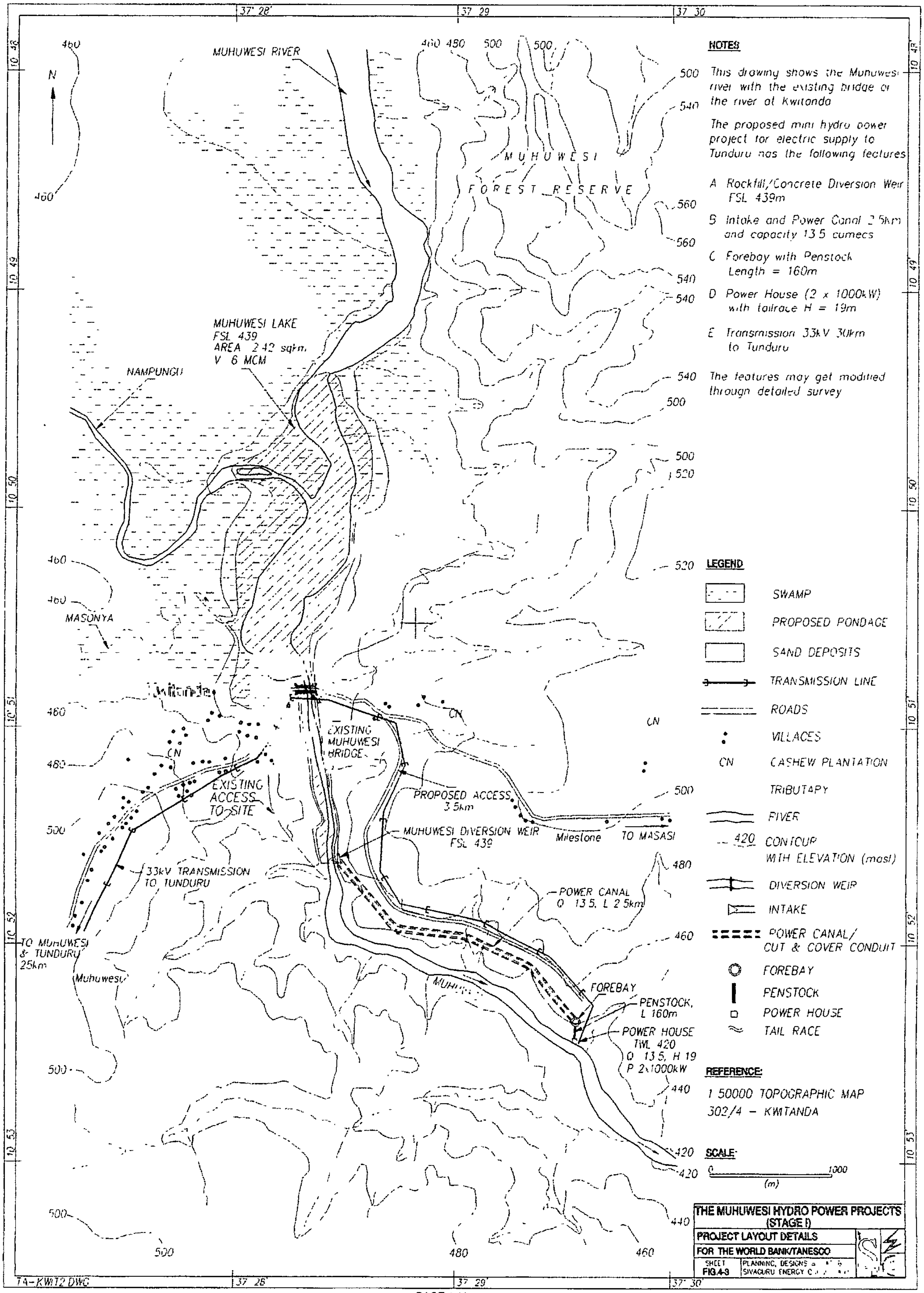
Part B shows the stretch of the main stem Muhuwesi which is proposed to be developed for hydropower. The proposed projects are shown on the longitudinal section

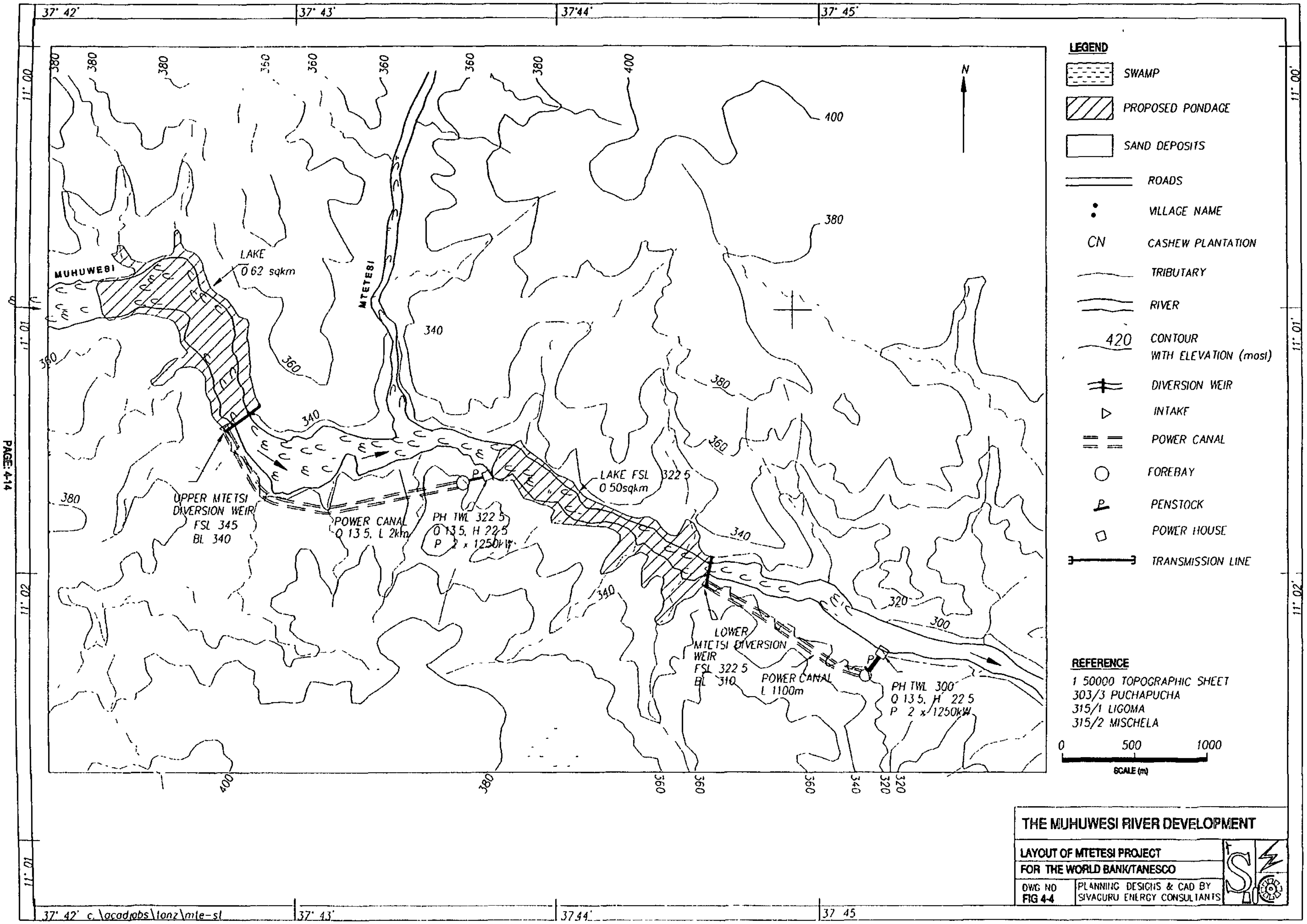
REFERENCE
1 50000 Topographic Maps

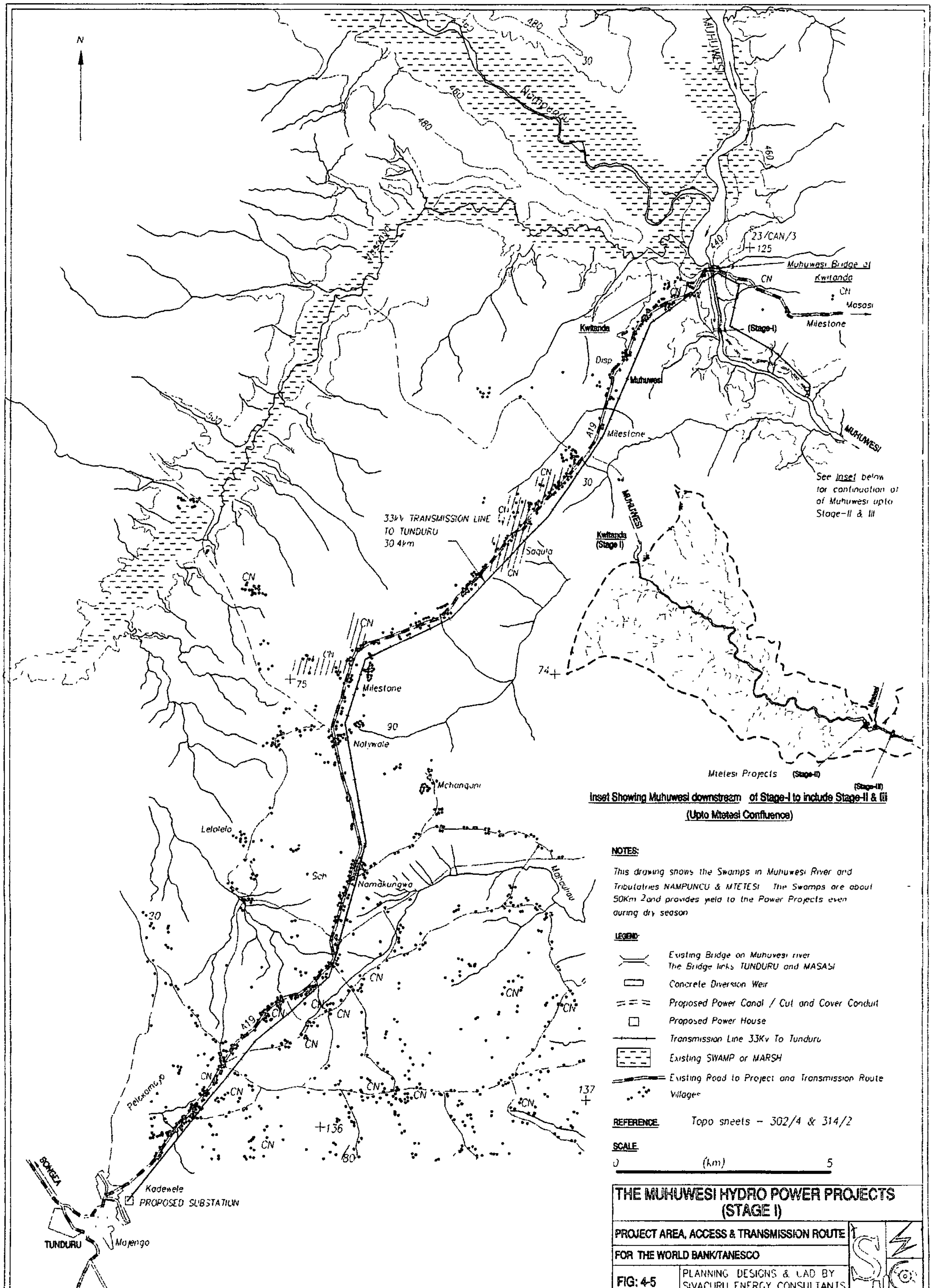
289/4 MBARANG ANDU RIVER
290/3 KIPOJORA NORTH
290/4 NAMBALAPI RIVER WEST
291/3 NAMBALAPI RIVER
301/1 MPELEMBE WEST
301/2 MPELEMBE
301/3 KIHOWERA
301/4 MTUNGWE RIVER
302/1 KIPOJORA
302/2 MUHUWESI RIVER
302/3 NAMPUNGU
302/4 KWITANDA
303/1 PUCHAPUCHA NORTH
303/3 PUCHAPUCHA
303/4 NAKAPANYA
315/1 LIGOMA
315/2 MSECHELA
315/4 MSINEJEWE RIVER

THE MUHUWESI RIVER DEVELOPMENT	
LONGITUDINAL SECTION OF MUHUWESI RIVER	
FOR: THE WORLD BANK / TANESCO	
DWG NO FIG 4-2	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

C \ACADJOBS\MUH-LSC DWG


37° 28'
37° 29'
37° 30'
10° 48'
10° 49'
10° 50'
10° 51'
10° 52'
10° 53'
N
MUHUWESI RIVER
MUHUWESI FOREST RESERVE
MUHUWESI LAKE
FSL 439
AREA 2.42 sqkm.
V 6 MCM
NAMPUNGU
MASONYA
Kwitanda
EXISTING MUHUWESI BRIDGE
EXISTING ACCESS TO SITE
PROPOSED ACCESS 3.5km
MUHUWESI DIVERSION WEIR FSL 439
Milestone
TO MASASI
33kV TRANSMISSION TO TUNDURU
TO MUHUWESI & TUNDURU 25km
Muhuwesi
POWER CANAL Q 13.5, L 2.5km
FOREBAY
PENSTOCK, L 160m
POWER HOUSE
TWL 420
Q 13.5, H 19
P 2x1000kW
CN
NOTES
This drawing shows the Muhuwesi river with the existing bridge on the river at Kwitanda
The proposed mini hydro power project for electric supply to Tunduru has the following features
A Rockfill/Concrete Diversion Weir FSL 439m
B Intake and Power Canal 2.5km and capacity 13.5 cumecs
C Forebay with Penstock Length = 160m
D Power House (2 x 1000kW) with tailrace H = 19m
E Transmission 33kV 30km to Tunduru
The features may get modified through detailed survey
LEGEND
SWAMP
PROPOSED PONDAGE
SAND DEPOSITS
TRANSMISSION LINE
ROADS
VILLAGES
CN CASHEW PLANTATION
TRIBUTARY
RIVER
420 CONTOUR WITH ELEVATION (masl)
DIVERSION WEIR
INTAKE
POWER CANAL/ CUT & COVER CONDUIT
FOREBAY
PENSTOCK
POWER HOUSE
TAIL RACE
REFERENCE:
1:50000 TOPOGRAPHIC MAP
302/4 - KWITANDA
SCALE:
0 1000
(m)
THE MUHUWESI HYDRO POWER PROJECTS (STAGE I)
PROJECT LAYOUT DETAILS
FOR THE WORLD BANK/TANESCO
SHEET FIG.4-3
T4-KWIT2.DWG


THE MUHUWESI RIVER DEVELOPMENT
LAYOUT OF MTETESI PROJECT
FOR THE WORLD BANK/TANESCO
DWG NO
FIG 4-4
PLANNING DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS
LEGEND
SWAMP
PROPOSED PONDAGE
SAND DEPOSITS
ROADS
VILLAGE NAME
CN
CASHEW PLANTATION
TRIBUTARY
RIVER
420
CONTOUR
WITH ELEVATION (mosl)
DIVERSION WEIR
INTAKE
POWER CANAL
FOREBAY
PENSTOCK
POWER HOUSE
TRANSMISSION LINE
REFERENCE
1 50000 TOPOGRAPHIC SHEET
303/3 PUCHAPUCHA
315/1 LIGOMA
315/2 MISCHELA
0
500
1000
SCALE (m)
N
MUHUWEBI
MTETESI
LAKE
0 62 sqkm
UPPER MTETSI
DIVERSION WEIR
FSL 345
BL 340
POWER CANAL
Q 13 5, L 2km
PH TWL 322 5
Q 13 5, H 22 5
P 2 x 1250kW
LAKE FSL 322 5
0 50sqkm
LOWER
MTETSI DIVERSION
WEIR
FSL 322 5
BL 310
POWER CANAL
L 1100m
PH TWL 300
Q 13 5, H 22 5
P 2 x 1250kW
37° 42'
37° 43'
37°44'
37° 45'
11° 00'
11° 01'
11° 02'
c.\acadjobs\tanz\mte-sl


N
MUHUWESI
Nampungu
Mtetesi
23/CAN/3
125
Muhuwesi Bridge at Kwitanda
CN
Masasi
Milestone
(Stage-I)
Kwitanda
Disp
Muhuwesi
Milestone
A19
See Inset below for continuation of of Muhuwesi upto Stage-II & III
33kV TRANSMISSION LINE TO TUNDURU 30.4km
Kwitanda (Stage I)
Saquta
75
74
Milestone
Nalywale
Mchonguni
Mtetesi Projects
(Stage-II)
(Stage-III)
Inset Showing Muhuwesi downstream of Stage-I to include Stage-II & III
(Upto Mtetesi Confluence)
Lelolelo
Sch
Namakungwa
NOTES:
This drawing shows the Swamps in Muhuwesi River and Tributaries NAMPUNCU & MTETESI. The Swamps are about 50Km 2and provides yield to the Power Projects even during dry season
LEGEND:
Existing Bridge on Muhuwesi river The Bridge links TUNDURU and MASASI
Concrete Diversion Weir
Proposed Power Canal / Cut and Cover Conduit
Proposed Power House
Transmission Line 33Kv To Tunduru
Existing SWAMP or MARSH
Existing Road to Project and Transmission Route
Villages
REFERENCE: Topo sheets - 302/4 & 314/2
SCALE
0 (km) 5
137
136
Kadewele
PROPOSED SUBSTATION
SONGEA
TUNDURU
Majengo
THE MUHUWESI HYDRO POWER PROJECTS (STAGE I)
PROJECT AREA, ACCESS & TRANSMISSION ROUTE
FOR THE WORLD BANK/TANESCO
FIG: 4-5
PLANNING DESIGNS & CAD BY SIVACURU ENERGY CONSULTANTS

Chapter 5 Topographic Features and Surveys

Section 1 Topography

The proposed mini hydropower development is to be located in the Ruvuma Region, approximately 25 km from Tunduru. In this area the Muhuwesi River flows due south at an elevation of about 430m above sea level.

Near the project area, the river has cut a deep and narrow gorge through the bedrock of 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 gradually with a mean gradient of 1:250 .

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 302/4. An extract of the relevant area of interest is given in figure 4-3.

A preliminary survey was conducted at the bridge site, and along the river to the diversion site and finally a cross section of the diversion site was taken. From this data additional maps have been prepared with contours at 2m intervals which are given in the chapter on Civil works.

There were no existing triangulation points with UTM-coordinates close to the mapping area and the sheets are therefore in a local coordinate and elevation system with the benchmark at Muhuwesi bridge fixed at 440m

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.

Part I Further Investigations

If the full feasibility study has to be prepared, before taking up construction, the following detailed ground survey is considered necessary. As the project area involved is about 3 to 5 sqkm and the project has been proved viable, the survey could be done during construction.

- Benchmark available in Tunduru has to be transferred to the diversion weir site and along canal alignment and power house site
- From the aerial photography and control points, maps of 1:5000 scale of the project area has to be prepared
- Block levelling at 2m grid intervals to be conducted 100m upstream and downstream of the diversion weir, power house
- Ground profile along the power canal and penstock alignment
- River cross section at diversion weir site
- Establish pondage area by locating outline of 439m contour.
- Access road and construction camp survey

Part II Mapping and Profiling

The following maps should be compiled:

- Mapsheet Index of EDM Traverses: scale 1:10 000, contour interval 5 m, 1 sheet,
- Intake area: scale 1:200, 1 sheet
- Power Station area: scale 1:500.
- Site Map: scale 1:10 000, 1 sheet, map no. M13.

Section 3 Results

The purpose of the above survey will be to confirm and establish the results obtained in this study. The said survey will not substantially affect the cost estimates or designs presented for the project in this report. All the required surveys can be carried out in one working season of about three months

For the development of this pre investment report, the above requirements have been constructed using computer model from available topographic information and is presented in the various drawings in the chapter on civil works. Additional information inferred from the above include the following, which are presented in various sections of the report.

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 6 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 Engineering Geology

The proposed access route from Tunduru does not require a bridge for crossing the river to approach the power house and canal.

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 proposed concrete/rockfill dam.

The bedrock exposed at the diversion site is suitable for the contemplated diversion structure. The intake is situated in the massive rock exposures of the left bank.

From the intake to the forebay, the canal alignment follows more or less along the contour lines at elevation 840m. The total length of the headrace canal is approximately 2500m. Bedrock is exposed at some places 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.

The power house is very small and no problems with bearing capacity are expected.

Section 3 Construction Materials

A thorough investigation of source of construction materials needs to be done at the feasibility stage.

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.

The most competent bedrock exposed consists of the beds of granite exposed.

During construction, additional investigations such as geological and geotechnical survey, test pit excavations and sampling could be undertaken.

Chapter 7 Hydrology

Section 1 Drainage Network

The Ruvuma is the principal river draining most of the region. It originates near Songea and flows south for a considerable distance towards the Mozambique border where it turns east and flows towards the Indian Ocean. For this entire length, it forms the boundary between Mozambique and Tanzania. On its journey, it is joined by numerous short rivers from Tanzania draining the Ruvuma and Mtwara regions. One such river is the Muhuwesi which has its source in the central elevated area of Ruvuma region at an elevation of about 940m. This highland area is drained radially by many streams and is the source of most of the rivers draining the Ruvuma region. Apart from Muhuwesi, the other rivers which originate here are Mbarangandu which flows north and is a tributary to Rufiji and many smaller rivers such as Lukwika, Msangesi, Sasawara, which are other tributaries to the Ruvuma.

From its source the Muhuwesi river runs principally east for about 130 km in which it receives two large tributaries from the north, one of which is the Likuyu. The river then turns south east and forms a trijunction with Masonya and Nampungu rivers the latter of which is a large tributary with its source close to that of Muhuwesi. On its onward journey to Ruvuma it runs in principally the same south east direction and crosses the Tunduru Masasi main road after which it picks up its final tributary Mtetesi coming from Lindi region and joins Ruvuma downstream of Mpanda rapids. The main stem of the river is in all 225km in length and has a total catchment area of 9521km2. Most of the catchment is natural forest land and exists to this day in its present state. 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 7-1 titled meteorological stations in the basin.

Section 2 River Flow Data

There are a number of river gauging stations in the western part of Ruvuma region on various rivers. However, there are very few gauge sites on the tributaries of Ruvuma in central and eastern part of Ruvuma region and data is inadequate.

Box 7-1: River Gauging stations in Ruvuma Region

CODE	STATION	RIVER	AREA (sqkm)	Q (cum/s)	Q spec (cum/s /sqkm)	Runoff (mm)	Record	Comp years
1RB14	MBINGA	LUAITA	55	-	-	-	1975-77	0
1RA1	NANGOMBO	LUEKEI	253	4.1	16.2	507	1985-94	5
1RB10	MWINAMAJI BR	MWINAMAJI	506	5.2	10.3	326	1976-78	1
1RB6	NAMBUNJU	MNGAKA	839	7.6	9.1	284	1976-93	9
1RB11	HANGA BR	HANGA	1399	19.7	14.1	444	1975-80	2
1RB7B	NGOJANGOJA	LUMECHA	1469	14.1	9.6	302	1977-81	1
1Q10	LIGOWONGA	LIKONDE	1494	9.7	6.5	204	1971-75	1
1RB2	MASIGIRA	RUHUHU	1940	40.6	20.9	660	1971-93	14
1Q7	MAHINGA	RUVUMA	3414	47.2	13.8	435	1971-84	7
1RB5	RUTUKIRA BR	RUTUKIRA	5622	46.4	8.3	260	1975-92	5
1Q7	MUHUWESI BR	MUHUWESI	6521	-	-	-	1976-69	1
MEAN			1881	21.62	12.08	380		

The most useful records for establishing flows accurately are that of station 1Q4 which is located at Muhuwesi bridge about 1km upstream of the proposed diversion site. The station was established in 1968 and comprises of staff gauges with a range of 0 to 10m. The station operated for a brief period from 1965 to 1969 and hence the available records are for a very short period. Frequent breaking of the staff gauges is said to have occurred and hence the data is discontinuous. The available data is presented in annexure volume A. The gauge site should be immediately revived and if possible painted on the rock outcrop or bridge piers and extended upto the top of railings as the bridge has been over topped.

As the discharge required for the proposed power station is very small compared to the wet season flows, it is important to establish the dry season flows as precisely as possible to assist in co-ordinated operation with the Tunduru diesel set and later with downstream stations in the cascade.

One method would be to derive probable flows of Muhuwesi by using the data available for other rivers in the region. Hence, the long term mean flow of various rivers in the region is given in Box 7-2. The rivers have been ranked according to the catchment area. The monthly mean flows as above have been converted to specific discharges in litres/sec contributed by each sqkm of catchment and given in Box 7-3. The mean specific discharge is given in the last row.

Box 7-2: Monthly mean discharge of rivers in Ruvuma region

SL	RIVER	CODE	AREA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1	LUAITA	LUA1	55	8.34	8.19	8.09	2.34	0.67	0.61	0.54	0.62	0.60	0.65	4.02	8.18
2	LUEKEI	1RA1	253	7.24	4.27	3.42	2.86	2.43	2.16	2.02	1.87	3.21	5.03	6.61	7.81
3	MWINAMAJI	1RB10	544	6 06	4.24	4.09	3.96	3.82	3.68	3.54	3.63	5.36	4.98	7.49	12.14
4	MNGAKA	1RB6	839	12.60	9.14	7.47	6.52	5.73	4.83	4.19	4.49	5.89	8.67	8.90	12.39
5	HANGA	1RB11	1400	51 82	21.35	10 01	10.97	8 79	5 46	3.79	4.36	14.25	24.84	36 45	45.64
6	LIKONDE	1Q10	1422	19.78	11.04	7.90	5.73	4.63	4.25	3.39	3.44	7.66	13.59	15.24	20.14
7	LUMECHNA	1RB7B	1440	32.93	15.01	10.68	9.08	8.20	7.12	5.91	6.01	8.34	11.82	21.35	33.24
8	RUHUHU	1RB2	1940	71.38	51.30	38.31	34.08	30.63	26.35	22.43	23.08	32.99	45.12	49.84	62.81
9	RUVUMA	1Q7	3414	90.70	61.12	48.31	38.70	32.56	25.73	22.08	21.53	33.56	55.46	54.80	82.03
10	RUTUKIRA	1RB5	5622	90.68	46.88	35.21	30.97	27.84	20.10	17.23	20.03	42.55	59.30	75.03	93.17

Box 7-3: Mean specific discharge of rivers in Ruvuma region in litres/sec/sqkm

SL	RIVER	CODE	AREA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
1	LUAITA	LUA1	55	151 6	148.9	147.1	42.55	12.18	11.09	9.82	11.27	10.91	11.82	73.09	148.7
2	LUEKEI	1RA1	253	28 62	16 88	13.52	11.30	9 60	8 54	7.98	7.39	12.69	19.88	26.13	30.87
3	MWINMAJI	1RB10	544	11.14	7.79	7.52	7.28	7.02	6.76	6.51	6.67	9.85	9.15	13.77	22.32
4	MNGAKA	1RB6	839	15.02	10.89	8.90	7.77	6.83	5.76	4.99	5.35	7.02	10.33	10.61	14 77
5	HANGA	1RB11	1400	37.01	15.25	7.15	7.84	6.28	3.91	2.71	3.11	10.18	17.74	26.04	32 60
6	LIKONDE	1Q10	1422	13.91	7.76	5.56	4.03	3.26	2.99	2.38	2.42	5.39	9.56	10.72	14.16
7	LUMECHNA	1RB7B	1440	22.87	10.42	7.42	6.31	5.69	4.94	4.10	4.17	5.79	8.21	14.83	23.08
8	RUHUHU	1RB2	1940	36.79	26.44	19.75	17.57	15.79	13.58	11.56	11.90	17.01	23.26	25.69	32.38
9	RUVUMA	1Q7	3414	26.57	17.90	14 15	11.34	9.54	7.54	6.47	6.31	9.83	16.24	16.05	24.03
10	RUTUKIRA	1RB5	5622	16 13	8.34	6.26	5 51	4.95	3.58	3.06	3.56	7.57	10.55	13.35	16 57
	MEAN			23.12	13.52	10.02	8.77	7.66	6.40	5.53	5.65	9.48	13.88	17 46	23.42

The mean monthly discharges for each catchment have also been converted to runoff depths in mm and expressed in Box 7-4. The mean runoff depth for the region in each month has been indicated in the last row. It should be noted that all the above rivers are located at a higher elevation of about 1000masl and the precipitation is also higher in these catchments than that in Muhuwesi basin. Precipitation generally varies reaching 2500 mm in the hilly areas in between Songea and Mbinga to 2000mm in the areas south of Njombe to about 1500mm near Mbamba bay and 1200mm near Songea. Hence the runoff observed in the rivers is a function of precipitation and none of the rivers except Rutukira can be said to have similar features as Muhuwesi in terms of drainage area and precipitation. Hence transfer of hydrology from these basins to Muhuwesi should be exercised with due care. The mean flow of Muhuwesi worked out by transferring the mean specific yield of Rutukira is presented below in Box 7-5.

Box 7-4: Mean monthly runoff depth in mm of rivers in Ruvuma region

SL	RIVER	CODE	AREA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
8	LUAITA	LUA1	55	399 6	392 4	387.6	112.1	32.10	29.23	25.87	29.71	28.75	31.14	192.6	391.9	2053.1
1	LUEKEI	1RA1	253	75 41	44.48	35 62	29.79	25.31	22.50	21.04	19.48	33.43	52.39	68.85	81.35	509.65
6	MWINAMAJI	1RB10	544	29.36	20.54	19.81	19.18	18.50	17.83	17.15	17.58	25.96	24.12	36.28	58.81	305.13
4	MNGAKA	1RB6	839	39.58	28.71	23.46	20.48	18.00	15.17	13.16	14.10	18.50	27.23	27.95	38.92	286.25
7	HANGA	1RB11	1400	87.54	40 19	18.84	20 65	16.55	10.31	7.13	8.21	26.82	46.76	68.61	85.91	447.51
10	LIKONDE	1Q10	1422	36 66	20.46	14.64	10.62	8.58	7.88	6.28	6.37	14.20	25.18	28.24	37.32	216 43
5	LUMECHNA	1RB7B	1440	60.26	27 47	19 54	16.62	15.01	13.03	10.82	11.00	15.26	21.63	39.07	60.83	310 53
2	RUHUHU	1RB2	1940	96.96	69.68	52.04	46.29	41.61	35.79	30.47	31.35	44.81	61.29	67.70	85.32	663.31
9	RUVUMA	1Q7	3414	70.01	47.18	37.29	29.87	26.13	19.86	17.04	16.62	25.90	42.81	42.30	63.32	437.33
3	RUTUKIRA	1RB5	5622	42.50	21.97	16.50	14.52	13.05	9.42	8.08	9.39	19.84	27.80	35.17	43.67	262.02
		MEAN		60.92	35.63	26.42	23.11	20.19	16.87	14.57	14.90	24.98	36.58	46.02	61.72	381.91

Box 7-5: Derived mean flow of Muhuwesi in cumecs

SL	REF	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	MEAN
1	MEAN	150 75	88 17	65 37	57.19	49.97	41 74	36.06	36.87	61.82	90.52	113 88	152.72	78.75
2	RUTUKIRA	105 18	54 38	40.84	35.92	32.29	23.31	19.99	23.23	49.35	68.78	87.03	108.07	54.03
	MEAN	127.96	71 27	53 11	46 56	41.13	32.52	28.02	30.05	55.59	79.65	100.45	130.39	66.39

The rivers in the western part of Ruvuma region have good baseflow in the dry season with Rutukira having a flow of 25 cum/s for a catchment of 5622 sqkm and Ruvuma having a flow of 20 cum/s for a catchment of 3414 sqkm in the month of September which is the driest month.

The flow in the Muhuwesi is however not this much in the dry season especially in the months of July to October. Hence the transfer of hydrology from adjacent basins is not suitable for estimating the dry weather flow of Muhuwesi which is important for establishing the firm power.

Hence an alternative method of correlating the available rainfall records with the few discharge observations which are available has been carried out. The detailed procedure adopted is given in annexure volumes A, B, C, D and E. Here we give an overview of the method adopted and the principal results obtained.

The method was to collect available precipitation records of the Muhuwesi catchment and perform a rainfall runoff correlation with the available discharge records of station 1Q4 arranged in four sets. For this the equivalent precipitation upto 1Q4 was computed by Thiessen polygon method. The following were the Thiessen weights obtained and the equivalent precipitation in the catchment is found to be 1093mm. The historic rainfall data is presented in annexure B. The historic rainfall data had missing values and and the incomplete data was first filled in by correlation. The detailed procedure is given in annexure C.

Box 7-6: Thiessen weights upto station 1Q4

STATION	AREA	WEIGHT
MATEMANGA	3472.1	0.533
MUHUWESI	1688.4	0.259
NALASI	368.5	0.057
NAMPUNGU	798.6	0.122
TUNDURU	192.0	0.029
TOTAL	6519.7	1.000

Due to the scanty nature of runoff data, correlation study was grouped by collecting equivalent rainfall runoff data into the following groups, 1968, 1969, Combined and January and the following regression equations were obtained.

Box 7-7: Rainfall Runoff Regression equations

MODEL	1968	1969	Combined	January
Coefficient	1 210	0.042	1.712	2.286
Constant	-30.270	1.930	-180.31	-355.47
	0.974	0.982	0.854	0.978

Using the above equations and the precipitation records for 1975 to 1995, the runoff depth was computed and four sets of runoff obtained. The above equations are applied only for the months November to March.

For computing the flow in the dry weather, the flow obtained in March is decremented according to the equation $Q = 3e^{-1.0818x}$ where x is the index of the month represented by x = 1 for March and so on. Thus the dry weather flow is obtained.

The four sets of runoff depths for the years 1975 to 1995 is converted to continuous discharge and presented in annexure volume D. The percentage exceedance values obtained from each of the four models are given in box below.

Box 7-8: Comparision of Exceedance values of Flow by various models

	MODEL			
EXCEEDANCE	JAN	1968	COMBINED	1969
0%	2605.15	1769.47	2163.67	68.20
5%	736.05	780.06	763.83	37.09
10%	506.98	656.93	592.27	31.19
15%	422.92	610.78	527.60	29.23
20%	311.51	509.32	417.25	27.48
25%	185.08	364.49	314.09	25.93
30%	141.57	261.50	185.03	22.79
35%	92 48	193.08	118.38	18.60
40%	42.17	104.86	64.38	15.47
45%	29.53	64.23	35.01	12.06
50%	21.76	31.89	24.07	8.86
55%	16.99	22.71	18.31	4.87
60%	11.77	17.34	14.50	3.46
65%	9.34	10.28	9.76	1.62
70%	7.08	7.83	7.85	1.06
75%	5.35	6.61	6.29	0.48
80%	4.15	5.89	5.42	0.36
85%	3.30	5.20	4.79	0.31
90%	2.74	3.94	3.97	0.26
95%	2.12	2.76	3.04	0.18
100%	0.57	0.75	0.38	0.05

From the above, it is seen that the exceedance values are almost identical for the 1968, January and combined model. For 1969 which was a dry year, the runoff values are very low. From the above, the discharge series obtained by use of combined model has been adopted for the hydrology of site 1Q4. The results obtained for dry weather flow in months August, September and October matched visual estimation of flow at site 1Q4. Hence the derived hydrology is considered to be of sufficient accuracy to estimate power generation at the Muhuwesi site and will not give an error as compared to using runoff data of adjacent basins directly in proportion to catchment and rainfall.

From the point of view of the power and energy studies for the proposed site, the most important flow data is that obtained as above from the regression study. As no major stream or tributary joins the Muhuwesi downstream of the gauge site upto the proposed diversion weir site no further modification is required to reflect the flow conditions at the site.

Section 3 Observations

From the synthesized flow data, the average annual run off is found to be 193.9 cum/s corresponding to a runoff depth of 927mm. This corresponds to a runoff coefficient of 84.5%. This high value indicates that most of the precipitation becomes overland flow and hence flood magnitude is expected to be high. This is also the reason why baseflow in Muhuwesi is lower as compared to the rivers in the western part of the Ruvuma region. 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 without need for considerable storage.

Section 4 Yield at Diversion site

Analysis of the flow data by flow duration curve gives the exceedance values shown in Box 7-8 which are partly reproduced from table 8-1 of annexure A.

From the above the month of February has the peak flow. Minimum flow occurs in the month of October. The minimum recorded flow is 0.38 cumecs in October 1989. The firm flow which is defined as the flow that is exceeded 90% of the time is 3.97 cumecs.

Section 5 Flood Studies

As the flow records are incomplete peak flow measurements are also missing. The procedure adapted to estimate floods have been to correlate monthly mean flow with the peak flow and establish a relationship. The procedure adapted is given in annexure E. The relationship is found to be $F = 2.0377Q + 165.33$.

This relationship is then used with the computed mean records to derive a set of peak flows.

Various frequency distributions are fitted and the following results were obtained.

Box 7-9: Flood magnitude by various methods

RETURN PERIOD	FOSTER TYPE-1	FOSTER TYPE-III	HAZEN	PEARSON TYPE-III	LOG PEARSON	GUMBEL
1	1131	1000	748	504	967	194
20	3938	3846	3878	3738	3874	4129
100	5228	5284	5520	4823	5679	5556
1000	6558	7337	8306	6235	9082	7574

The flood discharge recorded on 3/2/68 measuring 4545 cumecs can be hence described as a 100 year return flood as per the log Pearson distribution.

For the design of the overflow section a discharge of 9000 cumecs is fixed corresponding to a 1000 year return period. For the project construction a design of 4000 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 region where significant rainfall occurs.

The meteorological observations in the region are carried out at Songea airfield, Mahanje mission and Mbinga mission. The basic climatic factors recorded at the meteorological station include temperature, relative humidity, wind velocity, sunshine duration, solar radiation, evaporation and rainfall.

Part I **Temperature**

The mean annual air temperature 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. In Songea the annual variation is from 16°C to 26°C although extremes of 4°C and 35°C have been recorded.

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 Ruvuma region. For example, west of Songea town on the western slopes of the mountains bordering lake Nyasa, the annual rainfall is close to 2000 mm. This heavy rainfall, the highest measured in the Region, is caused by orographic lifting of air masses. Along the coast of the lake, 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 catchment rainfall calculated by applying Thiessen weights is given in figure 7-1. The mean rainfall is 1100 mm.

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.

Part IV **Sunshine**

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 annual bright sunshine hours is more than eight.

Part V **Radiation**

Radiation intensity is high in September when the sun's rays strike the ground vertically and the sky is clear. Mean total radiation on a horizontal surface varies from 400 to 500 calories per square cm per day.

Part VI **Evaporation**

The annual open surface evaporation is about 1280mm and evapotranspiration is aoubt 1400mm per annum. The above are based on the Sogea area. In Tunduru due to the dry climate it is expected to be much higher at about 1700mm per year.

Box 7-10: Monthly Evaporation in mm

PLACE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
SONGEA	113	52	112	113	109	83	92	115	117	139	123	111	1279
MBAMBA BAY	111	111	129	116	87	27	115	128	134	165	146	148	1417
TUNDURU	131	127	140	128	135	138	161	167	173	161	126	121	1708

Section 7 Sedimentation

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

Sediment data is available at station1Q7 (Ruvuma at Mahinga) which shows suspended concentration to be 1.45 mg/l and a maximum value of 17.79 mg/l. The ratio between suspended sediment load in tons per day and the discharge Q in cumecs has been developed by MAJI Ubungo and is given by

$$S = 0.056Q^{1.55}$$

Based on this for a discharge of 191 cumecs, S = 70,158 tons/year.

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 7-11: 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 Muhuwesi 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 Muhuwesi.

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 Muhuwesi site results in the following estimate :

$$q_s = 0.501 \times (6{,}000{,}000/6{,}521)^{0.569} = 24.36 \text{ cum/sqkm/yr}$$

$$Q_s = qs \times \text{Catchment area} = 24.36 \times 6{,}521 = 158{,}699 \text{ cu.m/yr}$$

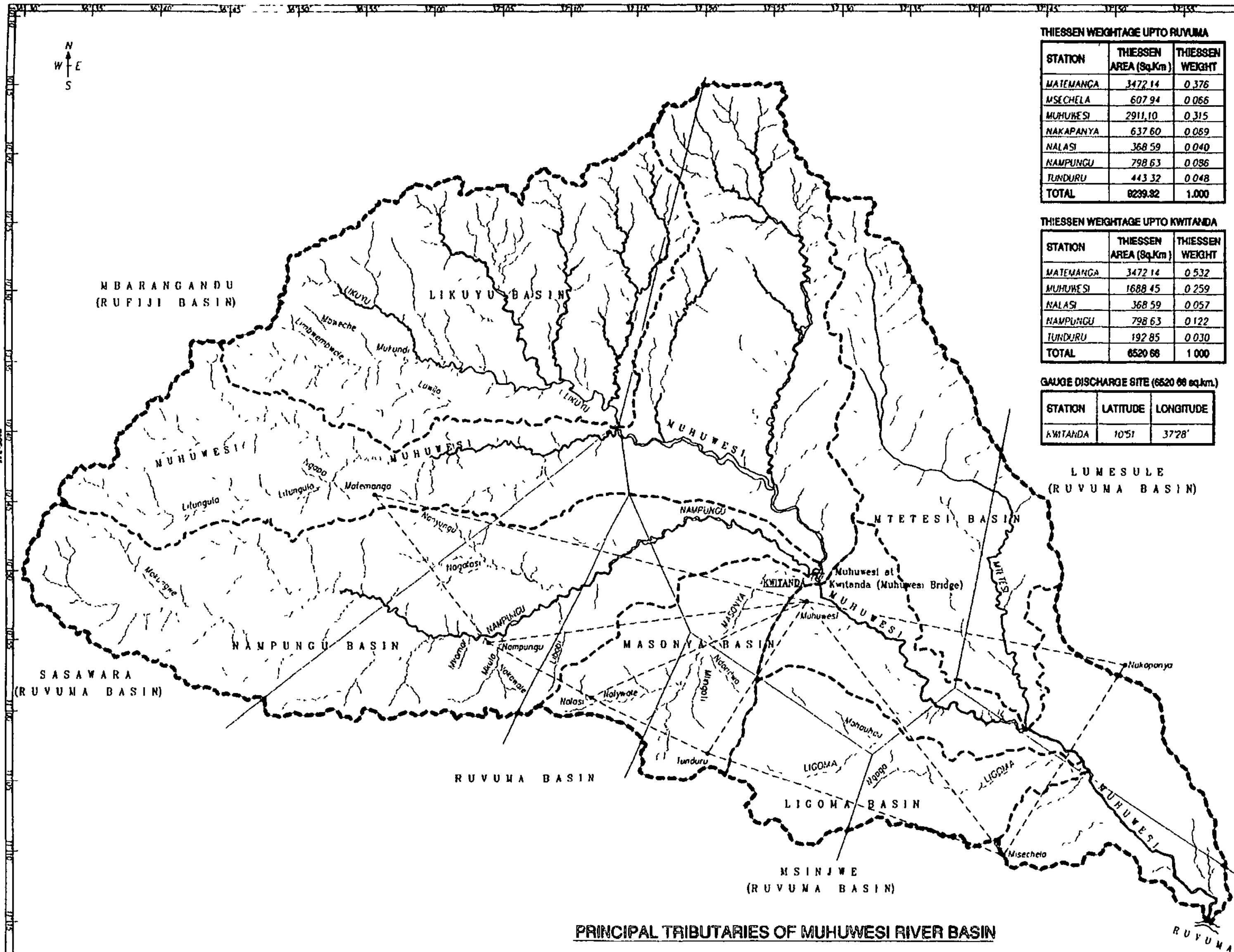
Most of this suspended load will be carried along the restricted width of the pondage and over the weir crest. For working out the deposition in the reservoir, the capacity inflow ratio may be computed.

Cr = Reservoir volume/Average annual inflow
= $6{,}000{,}000/6045\times10^6$ = 0.000992

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 158,699 = 795 Cubic meters

Over a period of 40 years, total sediment volume = 31,740 cubic meters or about 0.5% of the gross storage of the reservoir. Hence there will be no problem with respect to siltation.



PRINCIPAL TRIBUTARIES OF MUHUWESI RIVER BASIN

THIESSEN WEIGHTAGE UPTO RUVUMA

STATION	THIESSEN AREA (Sq.Km)	THIESSEN WEIGHT
MATEMANGA	3472 14	0 376
MSECHELA	607 94	0 066
MUHUWESI	2911,10	0 315
NAKAPANYA	637 60	0 069
NALASI	368 59	0 040
NAMPUNGU	798 63	0 086
TUNDURU	443 32	0 048
TOTAL	9239.32	1.000

THIESSEN WEIGHTAGE UPTO KWITANDA

STATION	THIESSEN AREA (Sq.Km)	THIESSEN WEIGHT
MATEMANGA	3472 14	0 532
MUHUWESI	1688 45	0 259
NALASI	368 59	0 057
NAMPUNGU	798 63	0 122
TUNDURU	192 85	0 030
TOTAL	6520 66	1 000

GAUGE DISCHARGE SITE (6520 66 sq.km.)

STATION	LATITUDE	LONGITUDE
KWITANDA	10'51	37'28'

MUHUWESI RIVER BASIN (9239.31 Sq.Km.)

SUB BASINS	AREA (Sq.Km.)
MASONYA	539 88
LIGOMA	616 60
MTETESI	1068 02
LIKUYU	1638 64
NAMPUNGU	2001 43
MUHUWESI	3374 74
TOTAL	9239 31

MUHUWESI R BASIN UPTO KWITANDA (6520.67Sq.Km.)

SUB BASINS	AREA (Sq.Km.)
MASONYA	539 88
LIKUYU	1638 64
NAMPUNGU	2001 43
MUHUWESI	2340 72
TOTAL	6520 67

LEGEND

- River
- Tributaries & Sub-Tribuatries
- Basin Boundary
- Sub-Basin Boundary
- Basin & Sub-Basin Name — LIGOMA BASIN
- Rain Gauging Station — •Matemanga
- Thiessen Line
- Thiessen Area

REFERENCE: 1 50 000 TOPOSHEETS

SHEET NO	NAME
289/4	MBARANG ANDU RIVER
290/3	KIPOJORA NORTH
290/4	NAMBALAPI RIVER WEST
291/3	NAMBALAPI RIVER
301/1	MPELEMBE WEST
301/2	MPELEMBE
301/3	KIHOWERA
301/4	MTUNGWE RIVER
302/1	KIPOJORA
302/2	MUHUWESI RIVER
302/3	NAMPUNGU
302/4	KWITANDA
303/1	PUCHAPUCHA NORTH
303/3	PUCHAPUCHA
303/4	NAKAPANYA
315/1	LIGOMA
315/2	MSECHELA
315/4	MSINEJEWE RIVEP

SCALE

0km 5 10 15 20km

MUHUWESI RIVER HYDRO POWER DEVELOPMENT

RIVER BASIN WITH THIESSEN POLYGONS

FOR: THE WORLD BANK / TANESCO

DWG NO: FIG:7 1

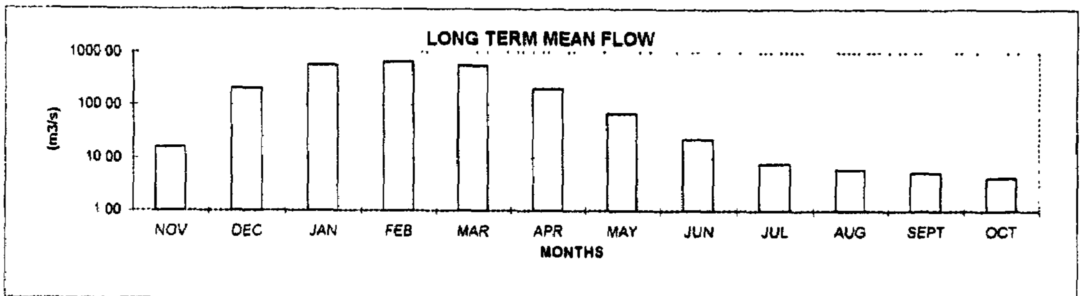
PLANNING DESIGNS & CAD BY SONAGURU ENERGY CONSULTANTS

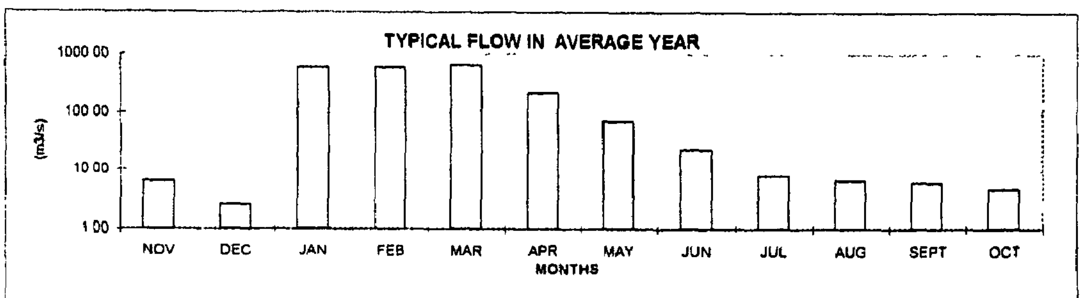
TABLE 7-1
COMPUTED DISCHARGE AT MUHUWESI USING COMBINED MODEL

UNITS m³/s

YEAR	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	ANNUAL MEAN	YIELD (MCM)
1975-76	5 76	2 30	546 77	184 49	488 18	164 03	54 68	18 06	5 86	4 88	4 39	3 42	123 57	3896 8
1976-77	1 38	0 63	1027 34	890 89	299 34	99 78	32 96	10 69	8 91	8 02	6 24	5 35	199 31	6285 4
1977-78	6 16	2 46	593 06	595 97	656 92	220 72	73 57	24 31	7 88	6 57	5 91	4 60	183 18	5776 7
1978-79	26 55	378 78	1434 18	728 05	402 49	135 24	45 08	14 89	4 83	4 02	3 62	2 82	265 05	8358 5
1979-80	12 25	393 02	1842 02	736 81	93 64	31 46	10 49	3 46	1 12	0 94	0 84	0 66	260 56	8217 0
1980-81	3 78	1 51	194 40	2163 67	439 90	147 81	49 27	16 28	5 28	4 40	3 96	3 08	252 78	7971 6
1981-82	13 93	466 92	327 14	322 47	423 33	142 24	47 41	15 66	5 08	4 23	3 81	2 96	147 93	4665 2
1982-83	28 95	11 58	209 71	640 90	558 68	187 72	62 57	20 67	6 70	5 59	5 03	3 91	145 17	4578 0
1983-84	20 76	500 17	597 83	709 64	532 49	178 92	59 64	19 70	6 39	5 32	4 79	3 73	219 95	6936 3
1984-85	17 48	549 98	33 71	693 54	816 60	274 38	91 46	30 21	9 80	8 17	7 35	5 72	211 53	6670 9
1985-86	23 99	250 64	534 26	452 12	893 44	300 19	100 06	33 06	10 72	8 93	8 04	6 25	218 48	6889 9
1986-87	17 35	568 88	154 17	575 67	585 61	196 76	65 59	21 87	7 03	5 86	5 27	4 10	184 00	5802 5
1987-88	12 49	78 92	347 93	326 66	440 95	440 95	148 16	49 39	16.32	5 29	4 41	3 97	156 29	4928 7
1988-89	21 13	17 53	1165 74	468 29	54 73	18 39	6 13	2 02	0 66	0 55	0 49	0 38	146 17	4609 6
1989-90	5 20	2 08	164 56	534 34	451 79	151 80	50 60	16 72	5 42	4 52	4 07	3 16	116 19	3664 1
1990-91	27 59	79 74	661 37	510 99	958 31	321 99	107 33	35 46	11 50	9 58	8 62	6 71	228 27	7198 6
1991-92	19 77	554 04	186 16	774 54	260 25	86 75	28 66	9 29	7 75	6 97	5 42	4 65	162.02	5109 5
1992-93	14 59	5 84	345 56	578 03	1076 57	361 73	120 58	39 83	12 92	10 77	9 69	7 54	215 30	6789 8
1993-94	21 89	3 04	456 04	584 77	1011 31	339 80	113 27	37 42	12 14	10 11	9 10	7 08	217 16	6848 5
1994-95	20 42	298 60	749 81	679 51	630 90	211 98	70 66	23.34	7 57	6 31	5 68	4 42	225 77	7119 8
YEARS	20	20	20	20	20	20	20	20	20	20	20	20	20	20
MAX	28 95	568 88	1842 02	2163 67	1076 57	440 95	148 16	49 39	16 32	10 77	9 69	7 54	265 05	8358 51
MIN	1 58	0 63	33 71	184 49	54 73	18 39	6 13	2 02	0 66	0 55	0 49	0 38	116 19	3664 12
MEAN	16 08	208 33	578 59	657 47	553 77	200 63	66 91	22 11	7 69	6 05	5 34	4 22	193 93	6115 67
VOLUME	43 07	540 00	1549 69	1760 96	1435 37	537 37	173 43	59 21	20 61	14 64	14 29	11 31	6115 87	6115 67
RUNOFF	6 61	82 82	237 69	270 10	220 16	82 42	26 60	9 08	3 16	2 25	2 19	1 74	938 05	938 05

1978-79 WET 1989-90 DRY 1986-87 MEAN





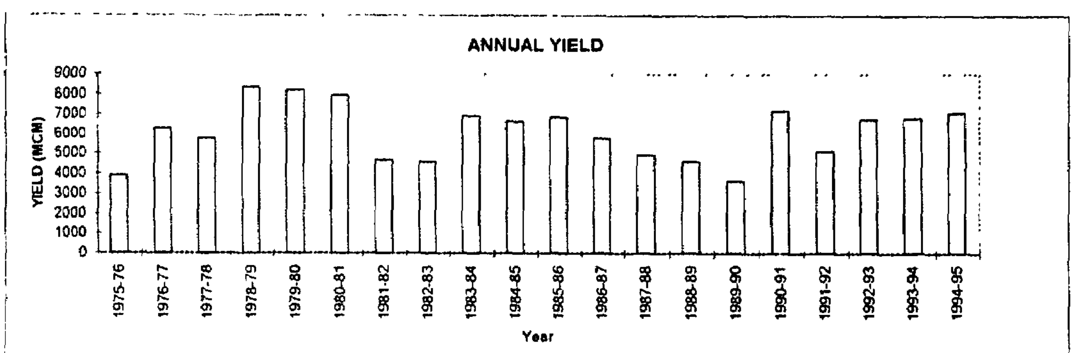
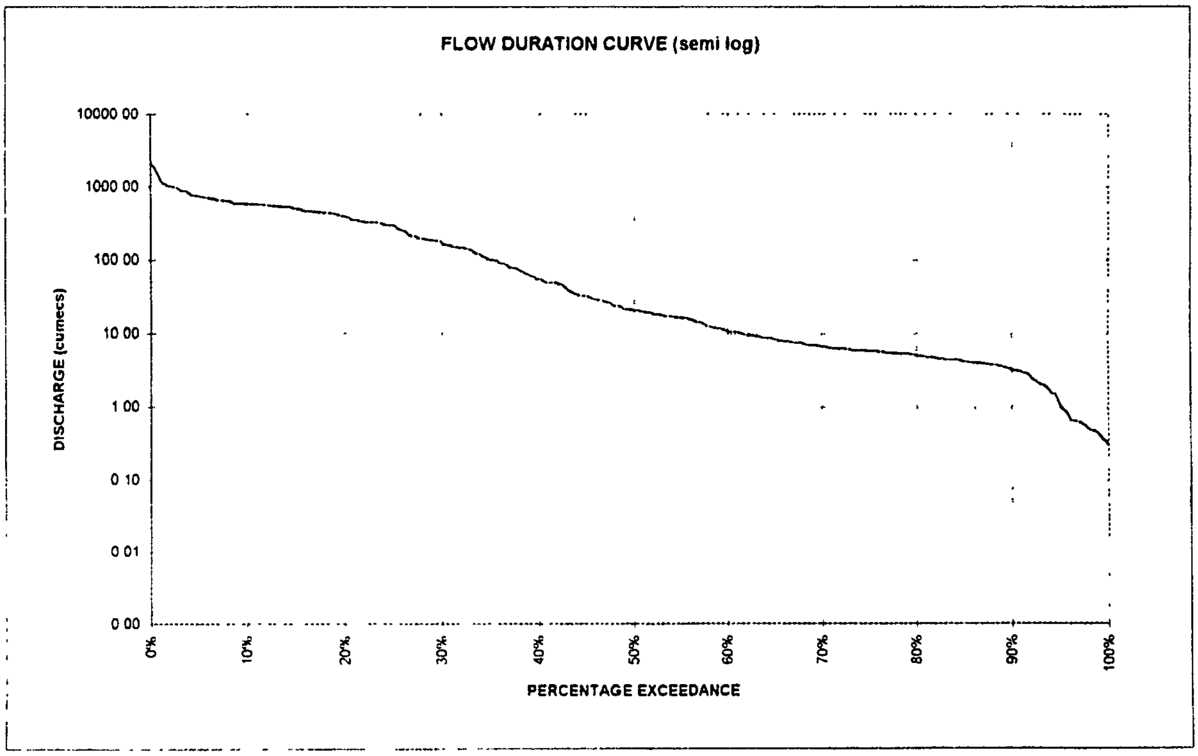
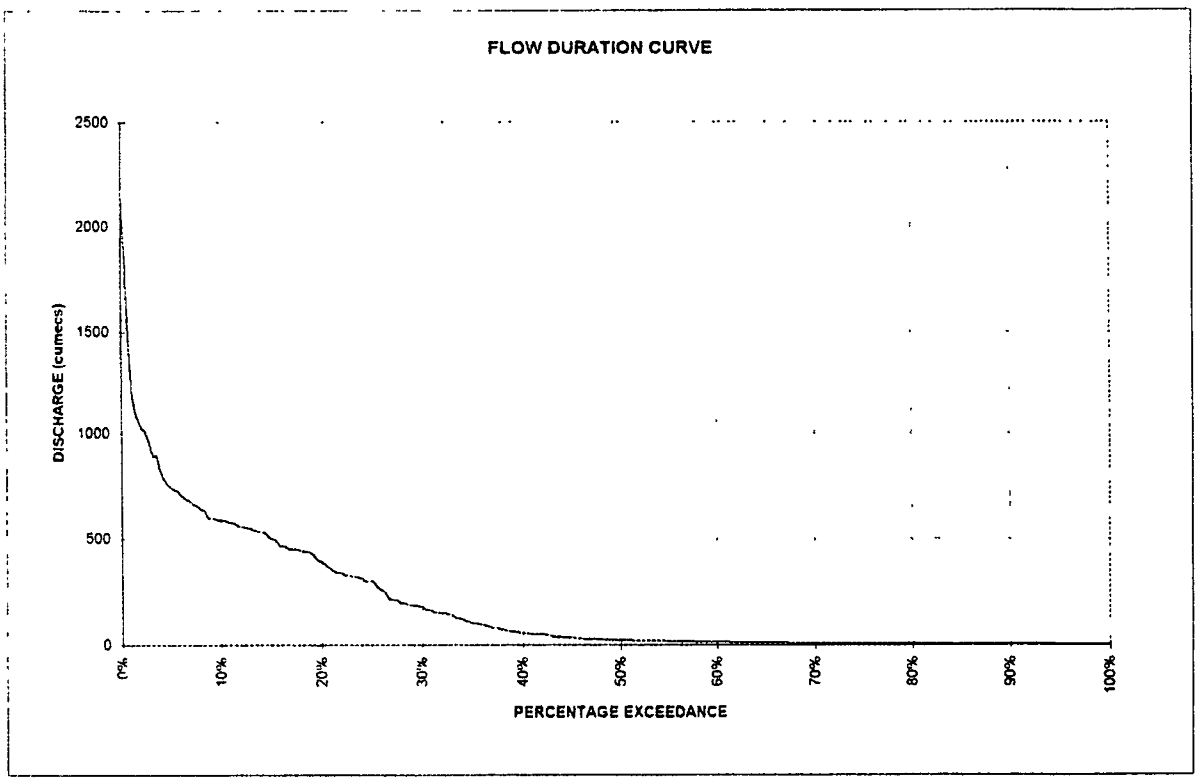


FIGURE 7-2
FLOW DURATION CURVE AT MUHUWESI USING COMBINED MODEL





Chapter 8 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 1:50000 aerial topographic maps which are existing. The contours on the map were digitized and the contours were further interpolated to contour intervals of 2m 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 8-1.

Section 3 Methodology

The methodology adapted in deriving the inflow sequence at the proposed diversion site has been dealt with in chapter 7. 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 a twenty 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 twenty 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 1995. The average yield of Muhuwesi for this period at the proposed site is 193.9 cumecs with a yield of 6116 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 1978-79 with a mean annual flow of 265 cumecs and a yield of 8358.5 MCM, the year with minimum yield was 1989-90 with a mean annual flow of 118.2 cumecs yield of 3726.6 MCM. The year in which the yield was closest to the twenty year mean with monthly distribution of runoff corresponding to the average of the twenty years is 1986-87 with a mean annual flow of 184 cumecs and yield of 5802.5 MCM. Thus 1986-87 is an average year, 1978-79 is a wet year, and 1989-90 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 twenty-year period 1975 to1995.

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 500kW. 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 2000kW and the power station will consist of two units. (2 x 1000kW). As a drawdown of about 3m is permitted, considering the fairly uniform head which will be obtained during the year, vertical shaft tubular 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 1986-87 with an installed capacity of 2 x 1000kW.

2. Operation of the power station in a typical wet year 1978-79 with an installed capacity of 2 x 1000kW.

3. Operation of the power station in a typical dry year 1989-90 with an installed capacity of 2 x 1000kW.

Section 6 Results

Detailed performance and operating tables are presented in tables 8-1, 8-2 and 8-3 for the average, wet and dry years respectively. 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 rack, 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 8-1 Summary of Energy Outputs

Installed Capacity (kW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
2 x 1000	14.56	13.75	13.00

The annual energy production in an average year is about 14.5 GWh. The annual inflow volume and utilization for generation in the various years is given below in Box 8-2.

Box 8-2: Water Utilization for generation

YEAR	Average	Wet	Dry
Inflow (MCM)	5744	8314	3644
Utilization (MCM)	343	342	311
Percent Utilization	5.97	3.89	8.53

The plant load factor in each year is given in Box 8-3.

Box 8-3: Plant Load Factor

YEAR	Average	Wet	Dry
Plant Load Factor	83.10	78.48	74.20

Further from the tables 8-1 to 8-3, it is seen that in an average year, 2000 kW can be generated continuously for the months November to June. In July, the power output drops to 1100kW and in October to 750kW.

In a dry year, 2000 kW can be generated continuously from November to June. During the month July generation drops to 900 kW, and falls to a minimum of 420 kW in October.

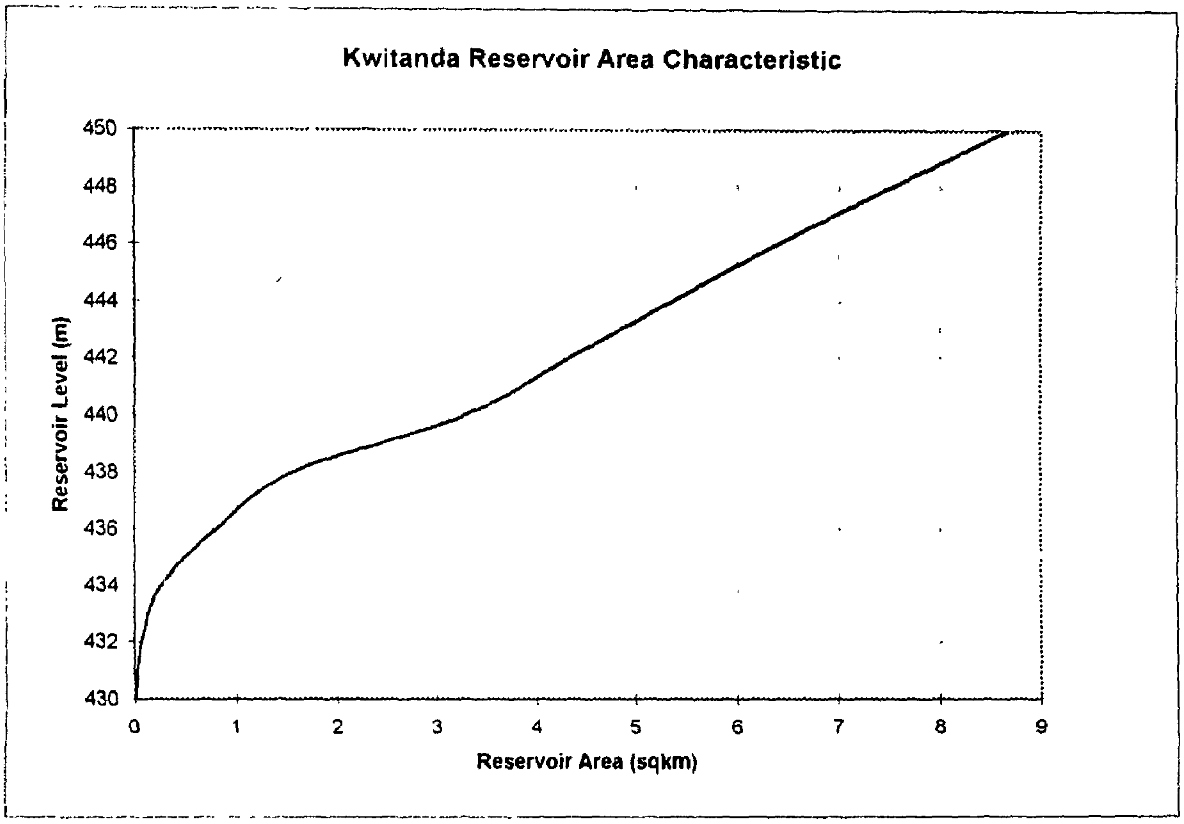
A tubular Kaplan turbine can operate satisfactorily down to about 40% of its rated power by adjusting the wicket gates and runner blades. Hence if 420kW corresponds to 40% capacity, the turbine rating is 1000 kW. Hence unit capacity is fixed at 1000kW. This also enables the unit to operate at the minimum demand of about 450kW satisfactorily.

As initially, the power plant will be the only generating plant operating into the Tunduru grid system and because during the initial years load may be only about 500kW, 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 July to November when load develops to more than 1000kW. At this time, 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 2000kW, 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:8-1
KWITANDA RESERVOIR AREA AND CAPACITY CHARACTERISTICS



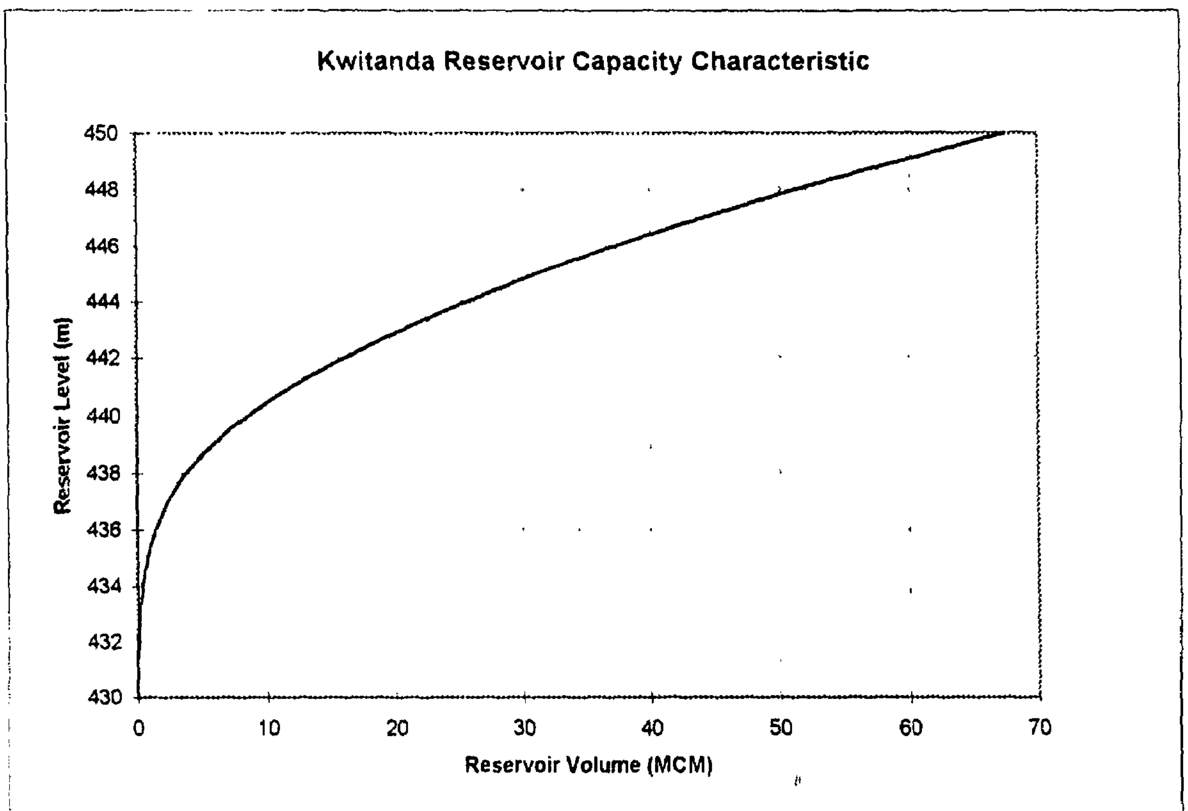
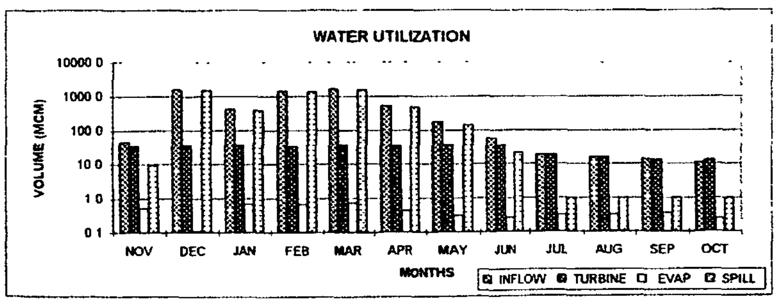
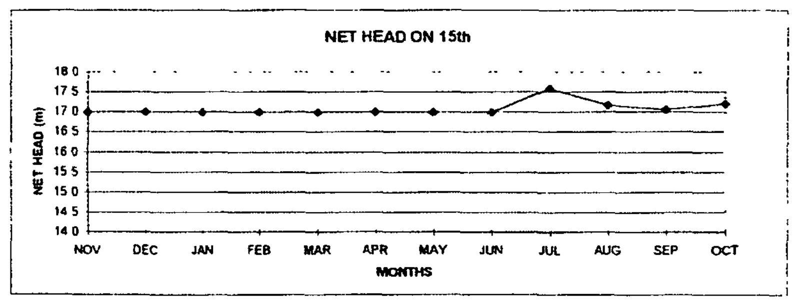
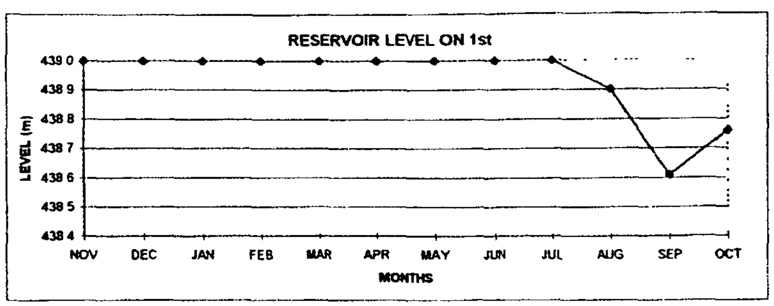


TABLE 8-1
KWITANDA PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL AVERAGE YEAR FOR 2 x 1 MW (1986-87)

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)
NOV	6 08	439 00	44 97	34 99	2 42	0 52	0 00	0 00	6 08	439 00	9 46	720 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 48
DEC	6 08	439 00	1523 69	36 16	2 42	0 11	0 00	0 00	6 08	439 00	1487 42	744 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 53
JAN	6 08	439 00	412 93	36 16	2 42	0 67	0 00	0 00	6 08	439 00	376 10	744 00	0 00	13 50	24 00	2	18 65	1 66	15 99	16 99	16 99	420 35	2 05	1 53
FEB	6 08	439 00	1392 66	32 66	2 42	0 68	0 00	0 00	6 08	439 00	1359 32	672 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 38
MAR	6 08	439 00	1568 50	36 16	2 42	0 74	0 00	0 00	6 08	439 00	1531 60	744 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 53
APR	6 08	439 00	510 00	34 99	2 42	0 45	0 00	0 00	6 08	439 00	474 56	720 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 48
MAY	6 08	439 00	175 68	36 16	2 42	0 31	0 00	0 00	6 08	439 00	139 21	744 00	0 00	13 50	24 00	2	18 65	1 66	16 99	16 99	16 99	420 35	2 05	1 53
JUN	6 08	439 00	56 17	34 99	2 42	0 26	0 00	0 00	6 08	439 00	20 91	720 00	0 00	13 50	24 00	2	18 65	1 66	16 99	17 59	16 99	420 35	2 09	1 50
JUL	6 08	439 00	18 83	18 75	2 42	0 31	0 00	0 00	5 86	438 90	0 00	0 00	-0 23	7 00	24 00	2	18 78	1 19	17 59	17 17	17 59	420 22	1 09	0 81
AUG	5 86	438 90	15 70	16 07	2 34	0 32	0 00	0 00	5 16	438 61	0 00	0 00	-0 69	6 00	24 00	1	18 70	1 53	17 17	17 06	17 17	420 20	0 92	0 68
SEP	5 16	438 61	13 66	12 96	2 09	0 36	0 00	0 00	5 51	438 76	0 00	0 00	0 34	5 00	24 00	1	18 43	1 37	17 06	17 20	17 06	420 18	0 77	0 55
OCT	5 51	438 76	10 98	13 39	2 21	0 25	0 00	0 00	2 84	437 25	0 00	0 00	-2 66	5 00	24 00	1	18 58	1 37	17 20	16 25	17 20	420 18	0 75	0 56
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		438 94	5743 76	343 44	2 37	4 96	0 00	0 00		438 79	5398 60	5808 00	-3 24	10 92	8760 00		18 64	1 56	17 08	17 02	17 08	420 30	1 67	14 56







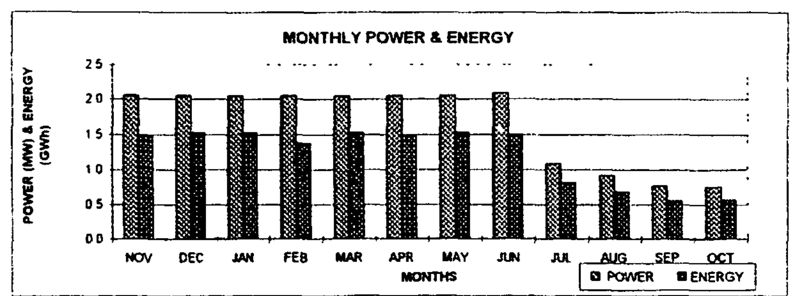
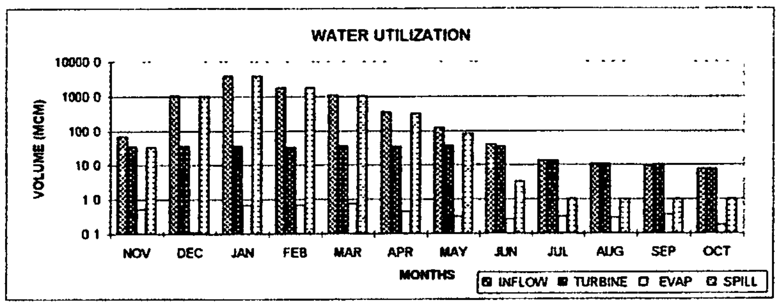
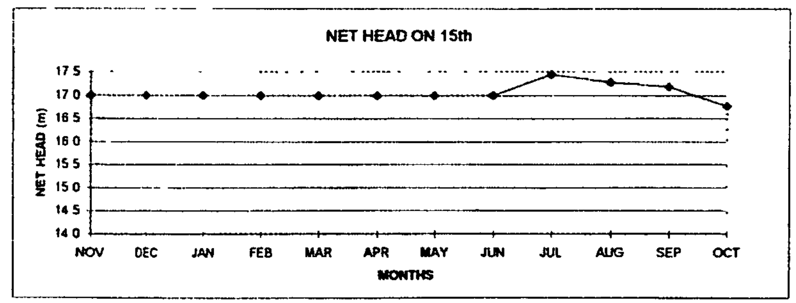
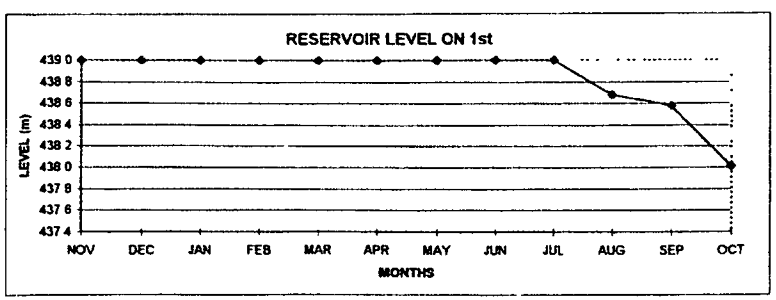


TABLE 8-2
KWITANDA PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL WET YEAR FOR 2 x 1 MW (1978-79)

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)
NOV	6.08	439.00	68.82	34.99	2.42	0.52	0.00	0.00	6.08	439.00	33.31	720.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.48
DEC	6.08	439.00	1014.52	36.16	2.42	0.11	0.00	0.00	6.08	439.00	978.26	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
JAN	6.08	439.00	3841.31	36.16	2.42	0.67	0.00	0.00	6.08	439.00	3804.48	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
FEB	6.08	439.00	1761.30	32.66	2.42	0.68	0.00	0.00	6.08	439.00	1727.96	672.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.38
MAR	6.08	439.00	1078.03	36.16	2.42	0.74	0.00	0.00	6.08	439.00	1041.13	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
APR	6.08	439.00	350.54	34.99	2.42	0.45	0.00	0.00	6.08	439.00	315.10	720.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.48
MAY	6.08	439.00	120.74	36.16	2.42	0.31	0.00	0.00	6.08	439.00	84.28	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
JUN	6.08	439.00	38.59	34.99	2.42	0.26	0.00	0.00	6.08	439.00	3.34	720.00	0.00	13.50	24.00	2	18.65	1.66	16.99	17.45	16.99	420.35	2.08	1.50
JUL	6.08	439.00	12.94	13.39	2.42	0.31	0.00	0.00	5.32	438.68	0.00	0.00	-0.76	5.00	24.00	1	18.82	1.37	17.45	17.28	17.45	420.18	0.78	0.58
AUG	5.32	438.68	10.77	10.71	2.14	0.29	0.00	0.00	5.08	438.58	0.00	0.00	-0.24	4.00	24.00	1	18.52	1.24	17.28	17.18	17.28	420.15	0.62	0.46
SEP	5.08	438.58	9.38	10.37	2.06	0.35	0.00	0.00	3.74	438.01	0.00	0.00	-1.34	4.00	24.00	1	18.42	1.24	17.18	16.77	17.18	420.15	0.61	0.44
OCT	3.74	438.01	7.55	7.55	1.57	0.18	0.00	0.00	3.57	437.87	0.00	0.00	-0.18	2.82	24.00	1	17.89	1.13	16.77	16.87	16.77	420.12	0.42	0.32
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		438.86	8314.50	324.30	2.30	4.86	0.00	0.00		438.76	7987.86	5808.00	-2.52	10.32	8760.00		18.57	1.52	17.05	17.04	17.05	420.28	1.57	13.74







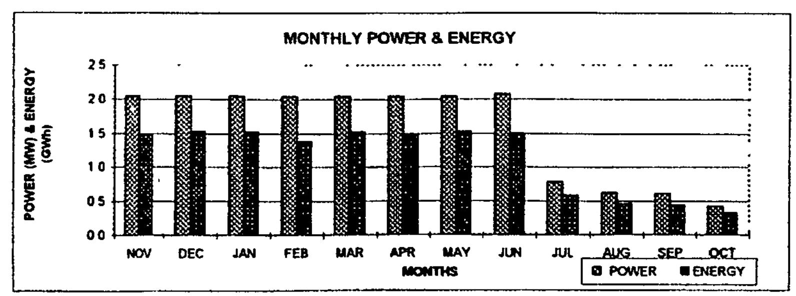
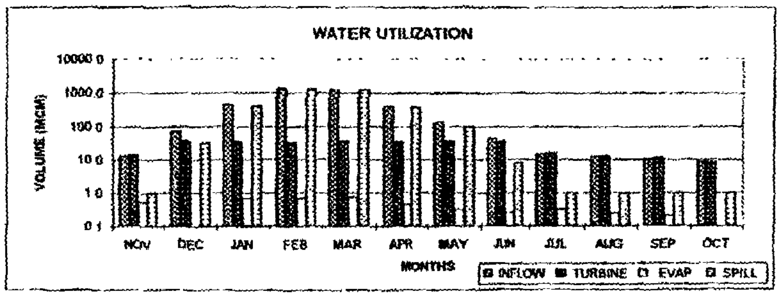
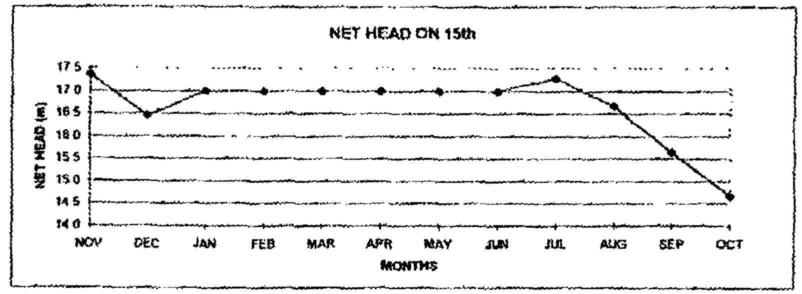
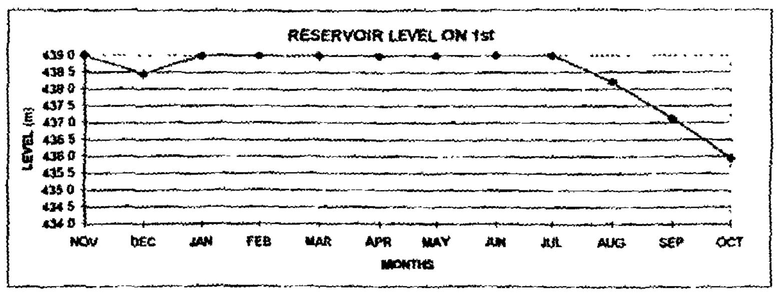


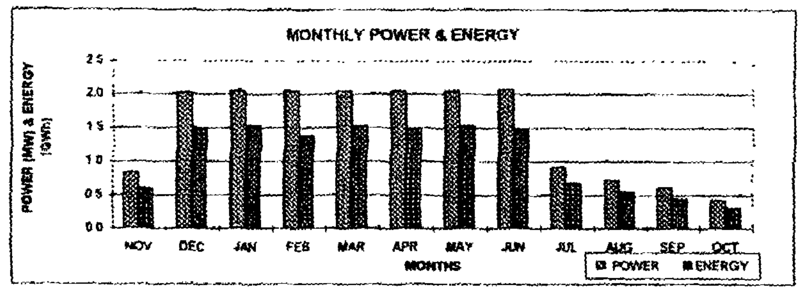
TABLE 8-3
KWITANDA PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL DRY YEAR FOR 2 x 1 MW (1989-90)

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)
NOV	6.08	439.00	13.48	14.26	2.42	0.52	0.00	0.00	4.79	438.45	0.00	0.00	-1.29	5.50	24.00	1	18.81	1.45	17.36	16.45	17.36	420.19	0.83	0.60
DEC	4.79	438.45	69.29	36.16	1.95	0.09	0.00	0.00	6.08	439.00	31.75	714.86	1.29	13.50	24.00	2	18.11	1.66	16.45	16.99	16.45	420.35	2.02	1.50
JAN	6.08	439.00	440.76	36.16	2.42	0.67	0.00	0.00	6.08	439.00	403.93	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
FEB	6.08	439.00	1292.68	32.66	2.42	0.68	0.00	0.00	6.08	439.00	1259.34	672.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.38
MAR	6.08	439.00	1210.07	36.16	2.42	0.74	0.00	0.00	6.08	439.00	1173.18	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
APR	6.08	439.00	393.47	34.99	2.42	0.45	0.00	0.00	6.08	439.00	358.03	720.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.48
MAY	6.08	439.00	135.53	36.16	2.42	0.31	0.00	0.00	6.08	439.00	99.06	744.00	0.00	13.50	24.00	2	18.65	1.66	16.99	16.99	16.99	420.35	2.05	1.53
JUN	6.08	439.00	43.34	34.99	2.42	0.26	0.00	0.00	6.08	439.00	8.08	720.00	0.00	13.50	24.00	2	18.65	1.66	16.99	17.27	16.99	420.35	2.07	1.49
JUL	6.08	439.00	14.52	16.07	2.42	0.31	0.00	0.00	4.22	438.21	0.00	0.00	-1.86	6.00	24.00	1	18.80	1.53	17.27	16.86	17.27	420.20	0.91	0.68
AUG	4.22	438.21	12.11	13.39	1.74	0.24	0.00	0.00	2.70	437.12	0.00	0.00	-1.52	5.00	24.00	1	18.04	1.37	16.66	15.65	16.66	420.18	0.72	0.54
SEP	2.70	437.12	10.55	11.66	1.23	0.21	0.00	0.00	1.37	435.96	0.00	0.00	-1.32	4.50	24.00	1	16.96	1.31	15.65	14.67	15.65	420.17	0.61	0.44
OCT	1.37	435.96	8.46	8.46	0.75	0.09	0.00	0.00	1.28	435.78	0.00	0.00	-0.09	3.16	24.00	1	15.82	1.16	14.67	14.78	14.67	420.13	0.42	0.31
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		438.48	3644.24	311.12	2.09	4.55	0.00	0.00		438.71	3333.37	5058.86	-4.80	9.89	8760.00		18.20	1.54	16.67	16.45	15.67	420.28	1.49	13.00









Chapter 9 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 4.50m wide with shoulders 1m wide. During the project construction, it is not necessary to surface the road. The total length of roads involved is about 5km. Its elevation is generally at about 440m from which it descends to 420m near the power house site.

Section 3 Preliminary Design

Part I Diversion Weir

The diversion weir comprises a overflow and non overflow section. The overlfow section is a concrete gravity structure 10m in height and is provided with 6 openings with piers to accommodate crest gates. Considering that the diversion site is about 35m wide at the base and about 150m wide at the crest, rockfill flanks are preferred especially on the right flank to reduce the volume of concrete. The overflow section is centrally situated with a crest of suitable shape. The average inflow at the intake dam site described in the section on hydrology exceeds the 13.5 m^3/sec maximum power discharge for about 120 days in an average year. The surplus water will be discharged downstream by the spillway. Before placement of concrete the foundations and abutment should be consolidated by low pressure grouting through suitable holes. After completion a line of holes should be drilled partly from gallery in the dam and partly from the heel thereby forming a grout curtain to minimize leakage and uplift pressures.

The flanks can be either of rockfill or dry laid rubble masonry structure and will be about 7.5 m in height. Considering that the crest length is about 150m, this type of design is considered to reduce the amount of concrete and make use of materials available in the immediate vicinity. 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 site with spillway and rockfill flanks is given in figure 9-2.

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. The rockfill section is capable of being overtopped though such a situation will not arise in the present case due to provision of separate spillway.

Rockfill Type

The second type is a rockfill dam. Floods can be passed over the crest but such a situation will not arise due to provision of spillway. 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 is provided on the upstream face.

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 canal consists of a trapezoidal section excavated on the left bank as shown in the drawing. The overburden to be removed is very small. The bed width of the canal is 0.75 m with a side slope of 1:1.75 as most of the excavation is soft rock. The width at the top is 5m. The total length is about 2500m. The alignment proceeds on the left bank of the river. The lining is made up of concrete slabs or shotcrete. The bed slope provided is 1:2500. Thus water level at the forebay is 438.0m. This is sufficient to convey the maximum power discharge of 13.5 cumecs. Manning's formula was used in fixing the dimensions with n = 0.011. The velocity of flow obtained is 1.41 m/s. The details are shown in figure 9-3. The loss of head is 1m.

Part IV **Forebay and Penstock**

The forebay is a rectangular structure excavated in the ground. It measures about 10m x 20m. 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 1.5m 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 125m. Loss was estimated by the Scobey's formula with K = 0.34, v = 3.83 m/s, D = 1.6m. The loss at maximum flow is 0.9 m. Thus total loss is about 2.0 in the water condcutor. The cross section of penstock and the longitudinal profile are shown in figure 9-3.

Part V **Power House**

The power station building is to be situated adjacent to the river channel about 2500m downstream of the diversion weir and intake structure. The mean ground elevation near the power house is about 423m so as to be above the level of the 1000 year flood.

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 4.8m x 9m x 4.5 m high framework filled with brickwork or precast panels and provided with a simple roof.

The power plant consists of the machine hall, with space to house equipment, controls and all auxiliaries. The unit spacing is 4m. 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 1.5 m wide gate at the eastern end of the power house. This whole area along with the approach area is above the 1000 year high flood level as seen from figure 9-4 which shows the plan of the power house.

The main sub structure of the power plant has a length of 7 m and a width of 8m. The turbine floor is at elevation 419.8m. The area of the floor directly above the turbine and valve is provided with removable steel covers with openings through which the generator and gearbox project into the machine hall. In the machine hall is provided a winding stairway by which access can be had to the butterfly valve and runner chambers. The power house will have an overhead travelling crane of about 1t capacity and a simple roof made of trusswork.

On the downstream side is provided piers over the draft tube with a slab 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 423.35 m to isolate the power house from the 1000 year flood.

At the lowest elevation of the sub structure which is at 417m, is the sump pit 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 420.0m, a value determined in consideration of the normal tailrace water level (EL. 420.35 m) and the draft head. The longitudinal and cross section of the power house is shown in figures 9-5 and 9-6.

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.

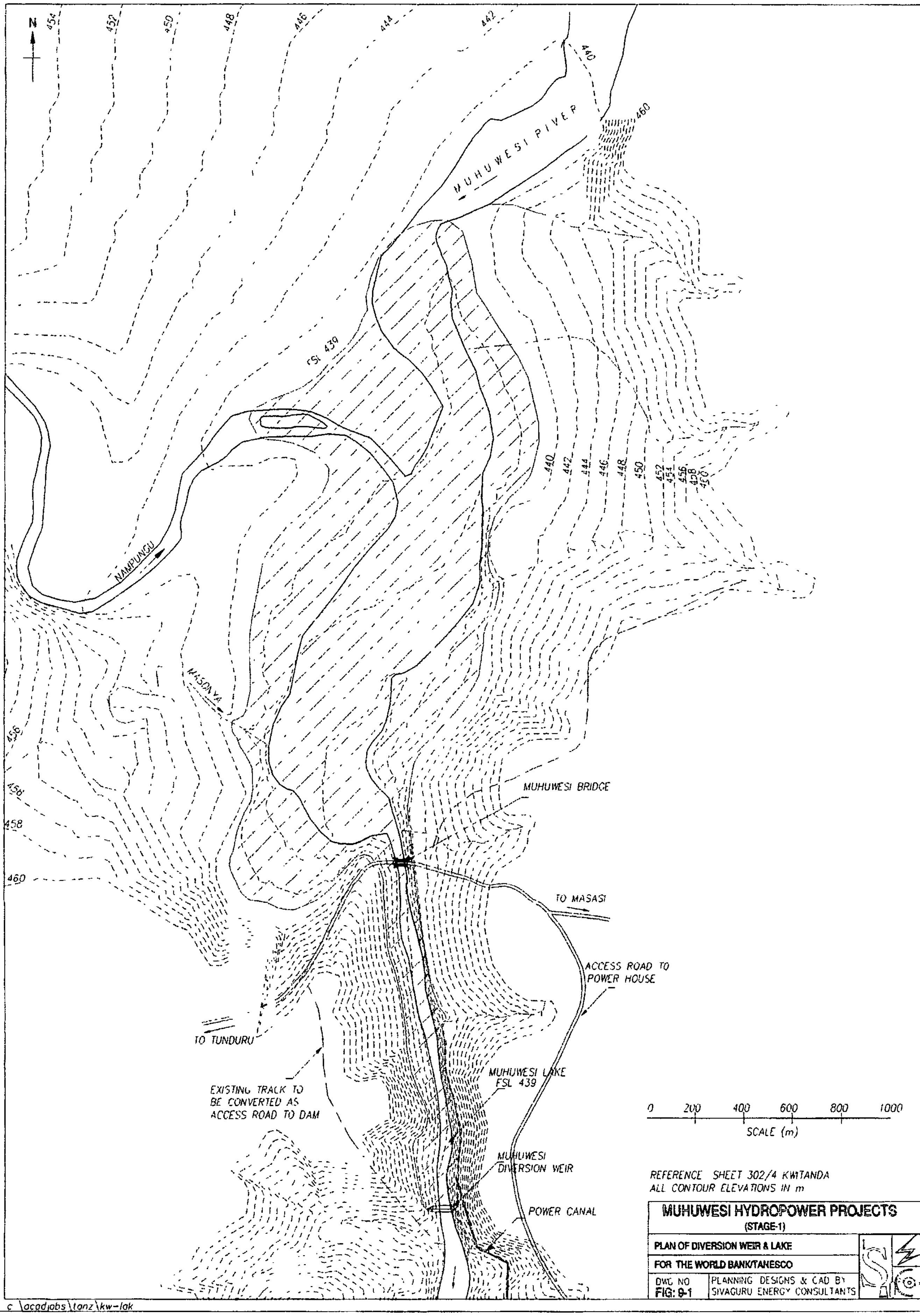
Part VI **Tailrace**

A open tailrace channel of trapezoidal section with 1:2 slope will be excavated on the left bank. It will be about 6.75 m wide at the bottom. Maximum top width will be near the power house which is about 18m. The total length is about 30 . It will be lined. It is expected that most of the excavation involved will be soft rock excavation.

The draft tubes are shut off by 2 vertical-lift gates placed in position by a 3-t hoist traversed along the flood platform at an elevation of +423.35m. The draft tube outlets can be closed by means of four stop logs measuring about 1.5m 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.



REFERENCE SHEET 302/4 KWITANDA
ALL CONTOUR ELEVATIONS IN m

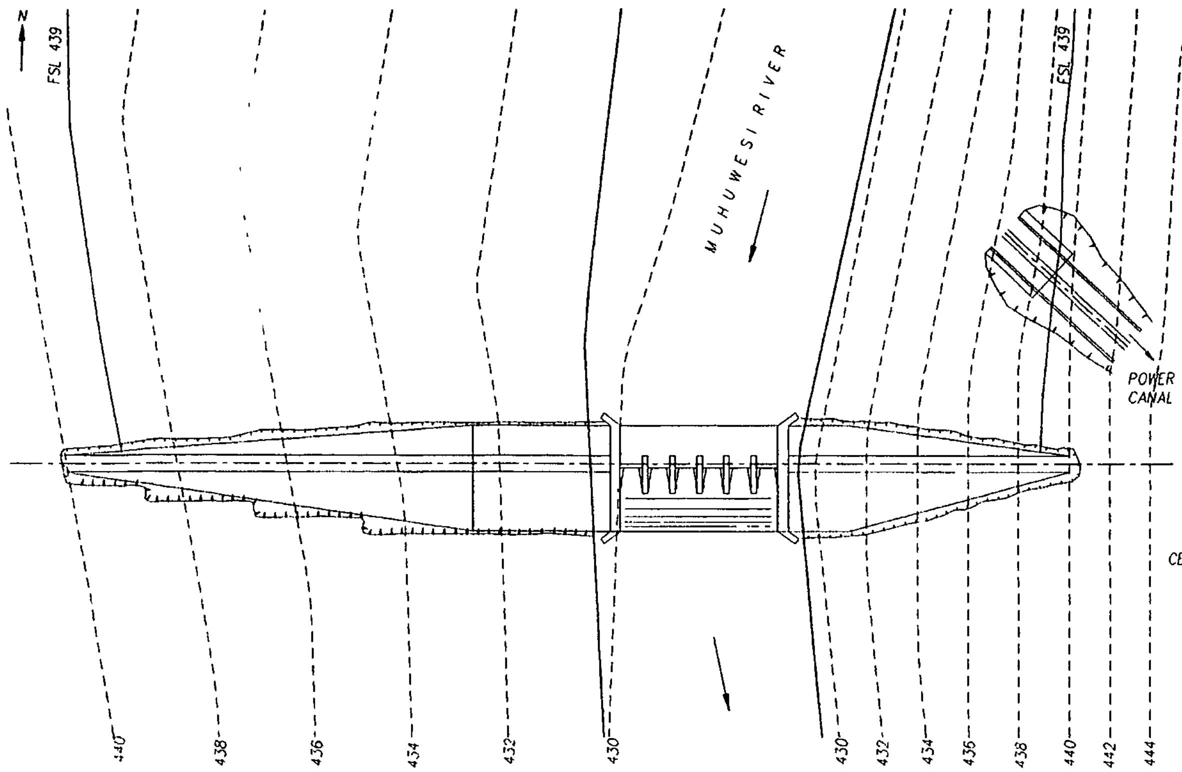
MUHUWESI HYDROPOWER PROJECTS
(STAGE-1)

PLAN OF DIVERSION WEIR & LAKE

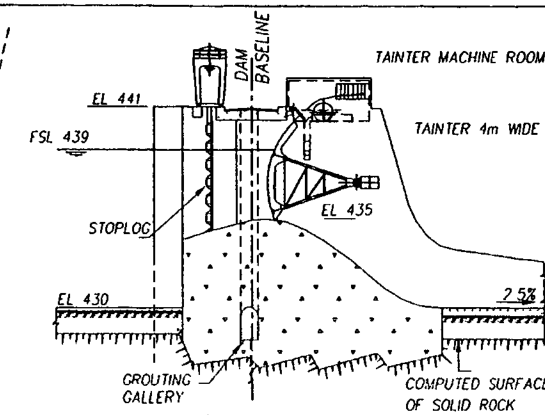
FOR THE WORLD BANK/TANESCO

DWG NO FIG: 9-1

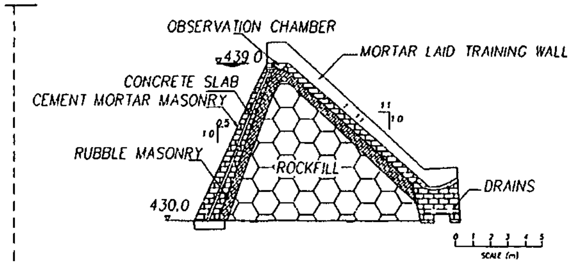
PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS



PLAN OF DIVERSION WEIR

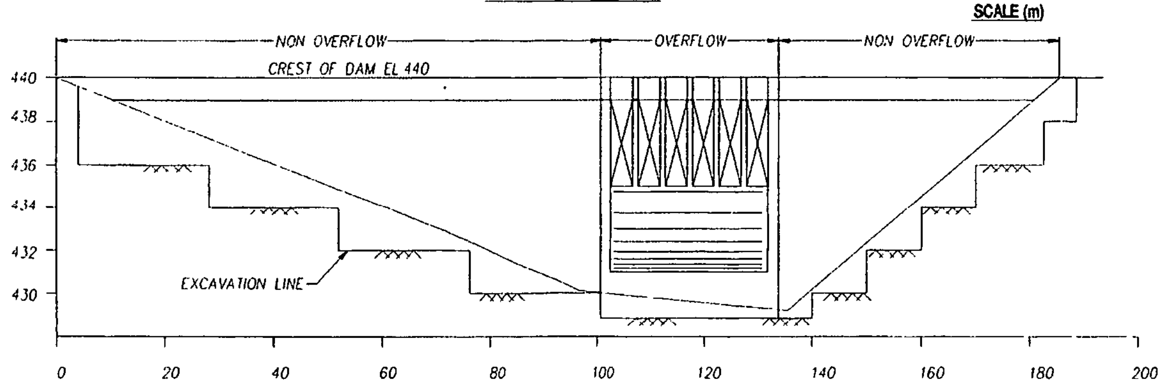


CROSS SECTION OF OVERFLOW SECTION



CROSS SECTION OF ROCKFILL DAM

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

MUHUWESI HYDROPOWER PROJECTS (STAGE - 1)	
DIVERSION WEIR PLAN & SECTIONS	
FOR: THE WORLD BANK/TANESCO	
DWG NO FIG 9-2	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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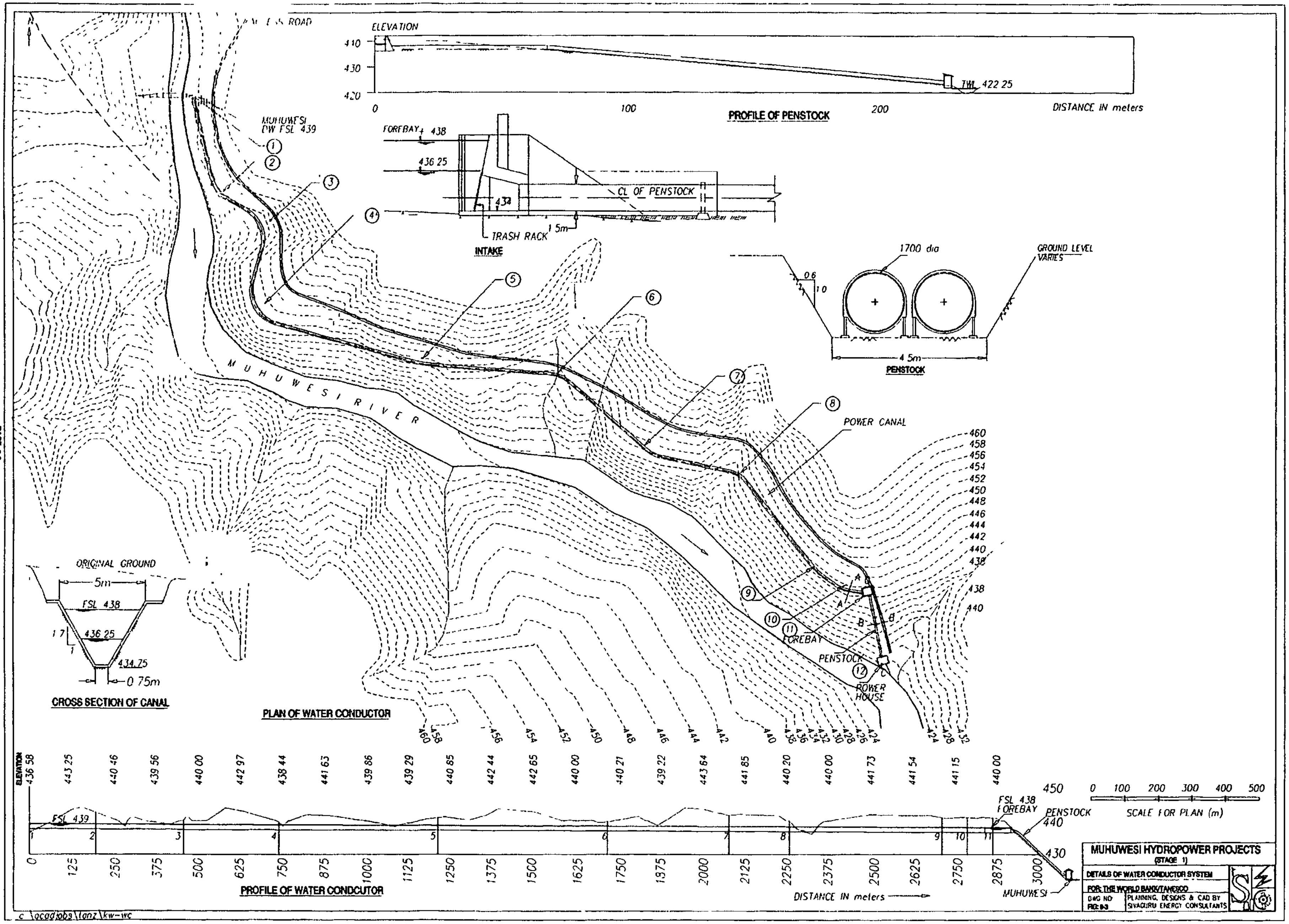
ELEVATION
410
430
420
0
100
200
TWL 422 25
PROFILE OF PENSTOCK
DISTANCE IN meters
MUHUWESI
DW FSL 439
FOREBAY 438
436 25
CL OF PENSTOCK
434
1 5m
TRASH RACK
INTAKE
1700 dia
GROUND LEVEL VARIES
0 6
1 0
4 5m
PENSTOCK
M U H U W E S I R I V E R
POWER CANAL
FOREBAY
PENSTOCK
POWER HOUSE
ORIGINAL GROUND
5m
FSL 438
436 25
434 75
0 75m
CROSS SECTION OF CANAL
PLAN OF WATER CONDUCTOR
FSL 439
FSL 438
FOREBAY
PENSTOCK
MUHUWESI
450
440
430
0 100 200 300 400 500
SCALE FOR PLAN (m)
PROFILE OF WATER CONDCUTOR
DISTANCE IN meters
MUHUWESI HYDROPOWER PROJECTS
(STAGE 1)
DETAILS OF WATER CONDUCTOR SYSTEM
FOR: THE WORLD BANK/TANESCO
PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS
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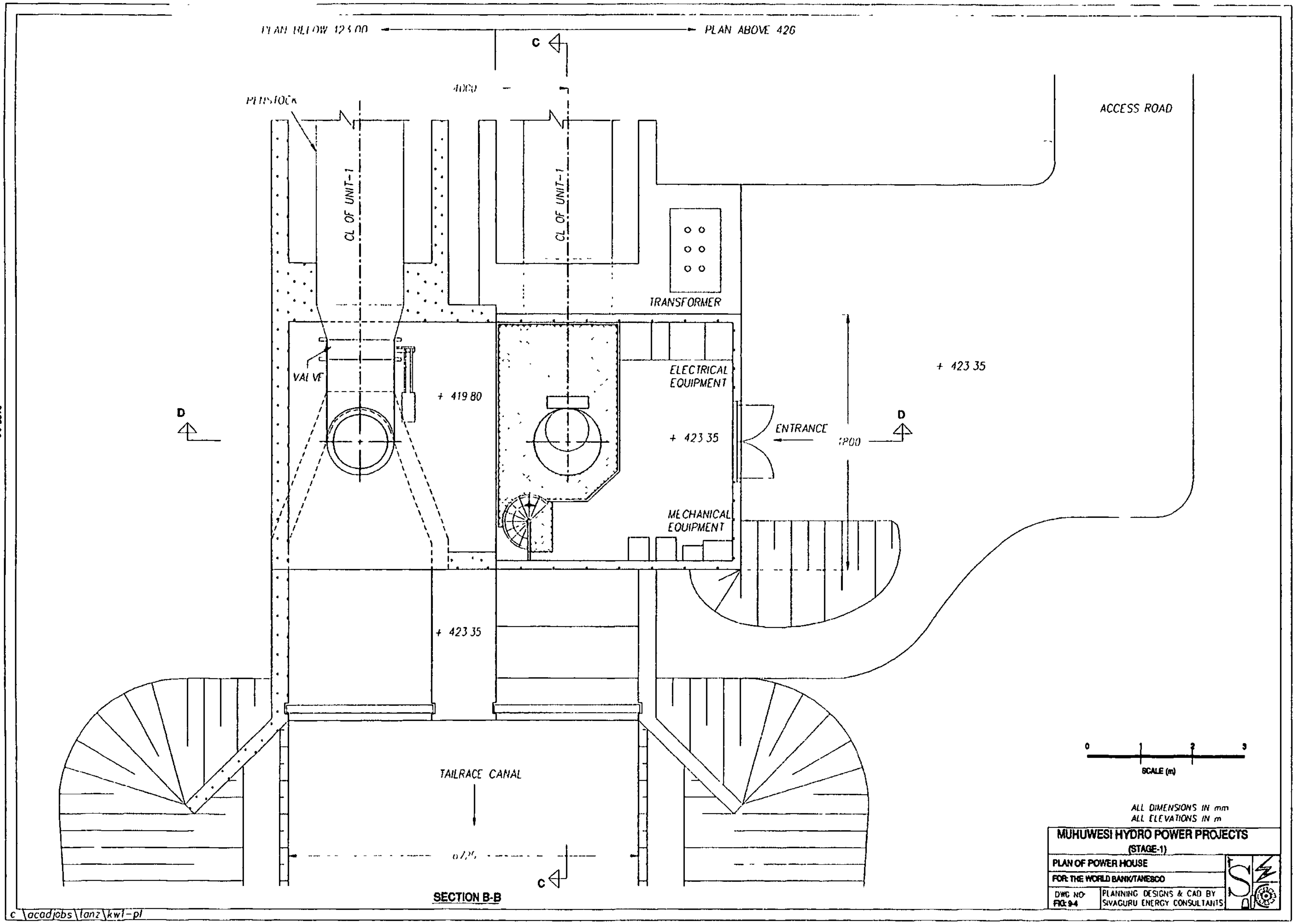
PLAN BELOW 423.00
PLAN ABOVE 426
PENSTOCK
CL OF UNIT-1
CL OF UNIT-1
ACCESS ROAD
TRANSFORMER
VALVE
+ 419.80
ELECTRICAL EQUIPMENT
+ 423.35
ENTRANCE
MECHANICAL EQUIPMENT
+ 423.35
+ 423.35
TAILRACE CANAL
SECTION B-B
C
C
D
D
SCALE (m)
ALL DIMENSIONS IN mm
ALL ELEVATIONS IN m
MUHUWESI HYDRO POWER PROJECTS
(STAGE-1)
PLAN OF POWER HOUSE
FOR: THE WORLD BANK/TANESCO
DWG NO: FIG: 9-4
PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS
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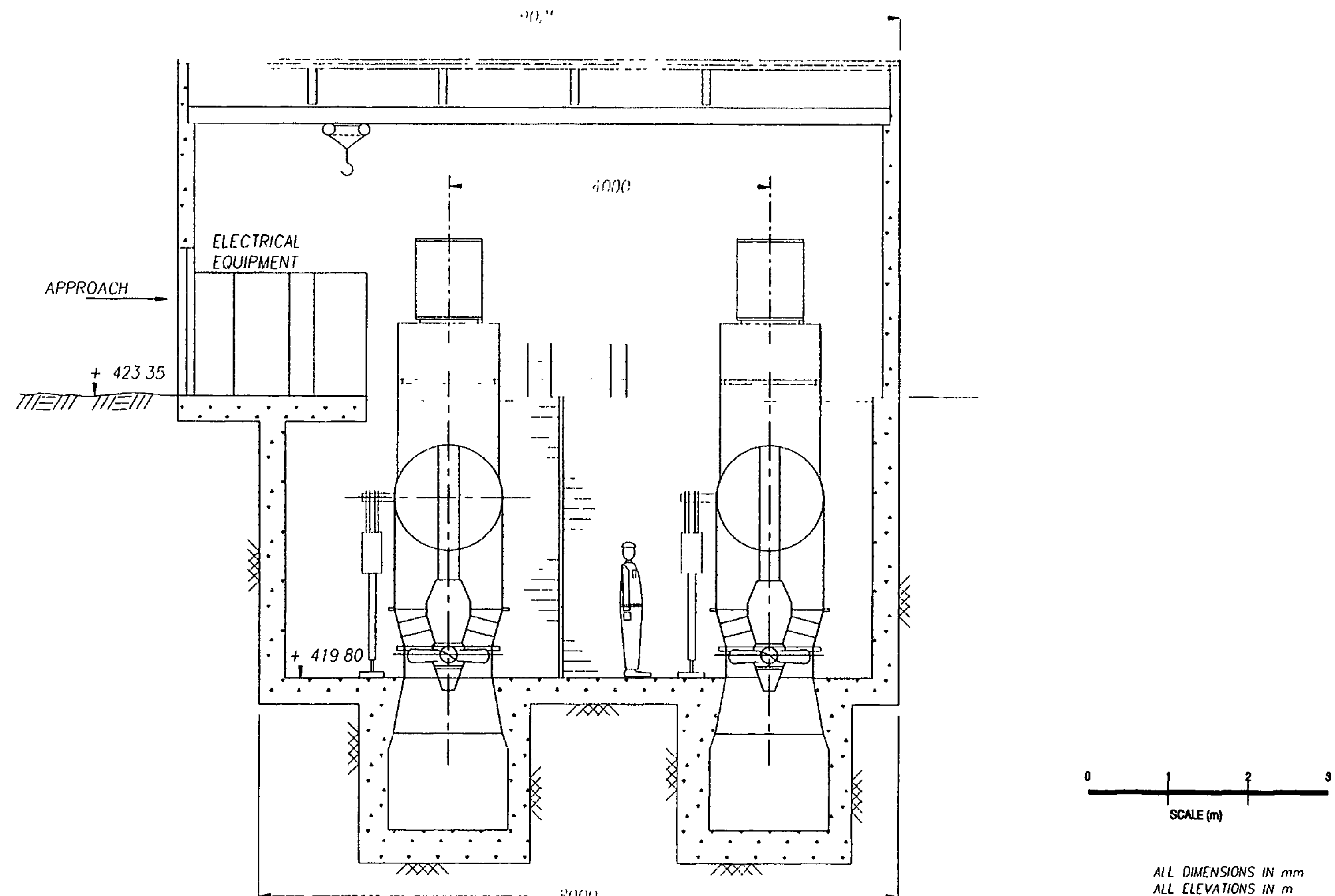

SECTION D-D

ALL DIMENSIONS IN mm
ALL ELEVATIONS IN m

MUHUWESI HYDRO POWER PROJECTS (STAGE-1)	
L-SECTION OF POWER HOUSE	
FOR THE WORLD BANK/TANESCO	
DWG NO FIG.9-5	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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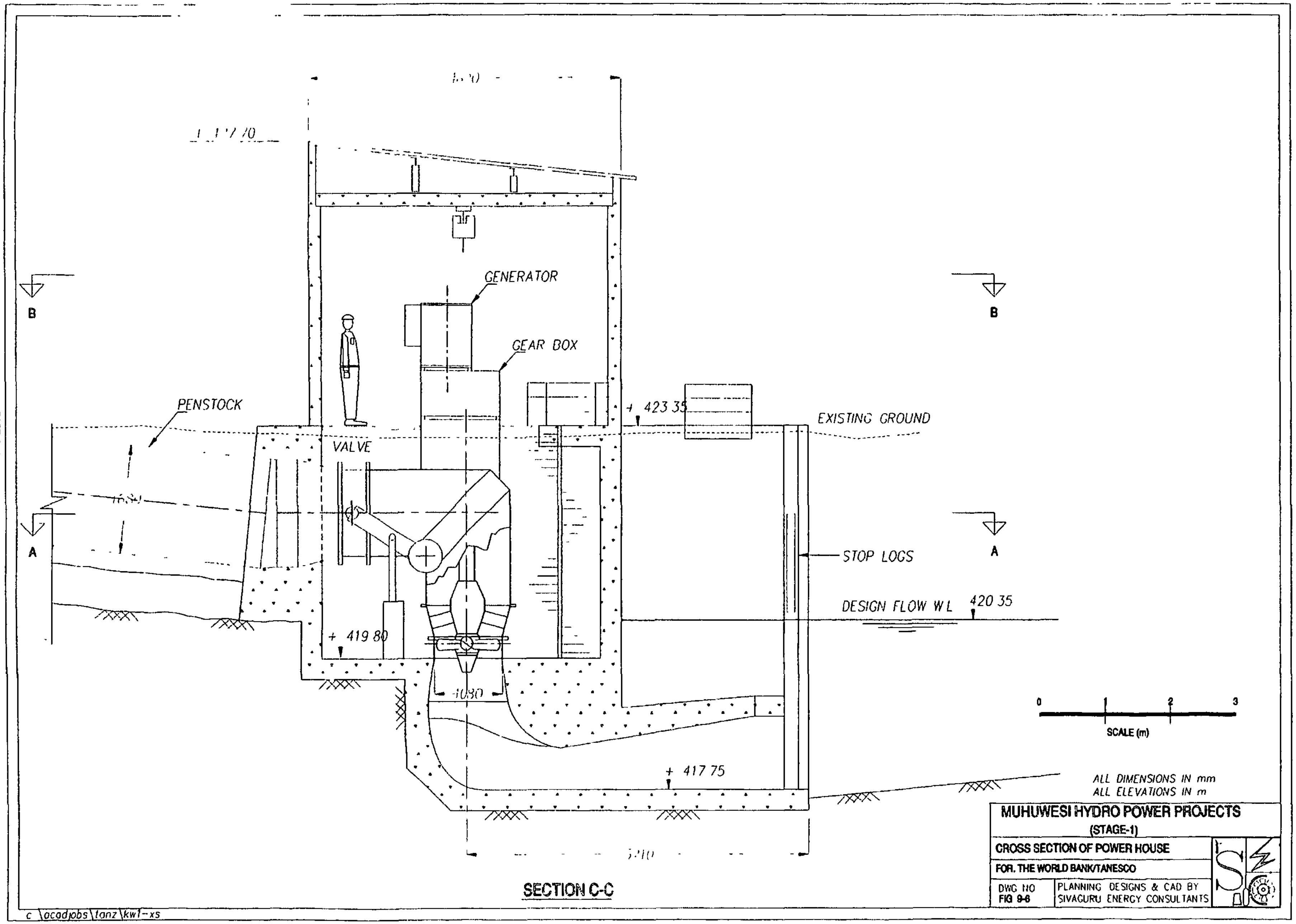

GENERATOR
GEAR BOX
PENSTOCK
VALVE
+ 423 35
EXISTING GROUND
B
B
A
A
STOP LOGS
DESIGN FLOW W L
420 35
+ 419 80
+ 417 75
0
1
2
3
SCALE (m)
ALL DIMENSIONS IN mm
ALL ELEVATIONS IN m
SECTION C-C
MUHUWESI HYDRO POWER PROJECTS
(STAGE-1)
CROSS SECTION OF POWER HOUSE
FOR. THE WORLD BANK/TANESCO
DWG NO
FIG 9-6
PLANNING DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS
c \acadjobs\tanz\kw1-xs

Chapter 10 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.

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 1000 kW each so that maximum energy can be produced. The maximum net head for the plant at full load is about 17.6m. The minimum operating head will be about 16.25m. 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, a vertical tubular Kaplan type hydraulic turbine is considered, with fixed wicket gates and adjustable runner blades. The adoption of this type is advantageous from the small size of the plant and operational point of view with the variation of discharge and the requirement to adjust power output according to the load demand. As compared to the types with fixed runner blades, higher order of efficiency is achieved. The distinct feature is the absence of the spiral case, with the runner being located in a tubular steel water passage. This gives rise to considerable reduction in the size of the equipment and power house. Another advantage is that the units are usually supplied assembled as a package so that installation is simplified at site. The equipment is pre designed in a range of standardized sizes so that they have the following advantages.

- The design cost is spread over multiple units and hence equipment is cheaper
- Economies of scale are obtained in manufacture
- Utilizes commercially available components
- Simplifies feasibility studies

- Time required for supply of equipment is usually very short.
- Simplifies engineering and construction.
- Simplifies equipment selection by customers
- Equipment Peformance is known prior to manufacture

Rigorous attention should be paid to cavitation resistance 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 0.5m 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 conveys 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 condition 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
$n_s' = 2334/\sqrt{h_d} = 2334/\sqrt{17} = 566.09$ rpm (typical values for Kaplan units)

A trial specific speed of 566 rpm was fixed.

Trial speed $n' = n_s' \times H^{5/4} / \sqrt{P}$
where P is in metric horsepower. A turbine output of 1000kW corresponds to 1322 mhp

where H = 17 m, P = 1322 mhp

So n' = 537.4 rpm

Nearest synchronous speed = 500 or 375 rpm

for poles = 12 or 16

Standardized Tubular turbines usually have a gearbox to step up speed and have a higher running speed for generator. Step up ratios upto 2.5 are used. Generator speeds are usually 750 or 1000 rpm. For turbine speed of 500 rpm, generator speed of 1000 rpm can be obtained with a 1:2 step up gearbox.

Thus Design Specific speed = $n_s = (n \times \sqrt{P})/H^{5/4}$
$= 526.65$rpm

Discharge coefficient $\phi = 0.0233 n_s^{2/3}$
$= 1.5515$

Diameter $= 84.47\phi\sqrt{H}/n = 1.080$ m.

Based upon the operating conditions which are to be met it has been decided that the turbine will have a runner of 1080mm diameter. The standard recommendation by the manufacturer was the same unit.

Thoma's Cavitation coefficient

$\sigma = n_s^{1.64}/50,324 = 0.577$

The elevation of the power house area = 420m

Atmospheric pressure H_a = 9.847m of water at elevation 420m.
Mean temperature of river water = 25°C
Vapour pressure H_v = 0.324 m of water

Barometric pressure $H_b = H_a - H_v$ = 9.847 - 0.324 = 9.523 m of water.
H_{cr} = critical head = 17.0 m
σ_P = (plant sigma) = 0.58 (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) = $H_b - \sigma_P H_{cr}$ = -0.35m

Now average minimum tailwater level = 420.0m from power study.

Elevation of turbine runner = TWL +Hs = 419.65m.

The elevation is fixed at 419.65m.

Part II **Specifications**

The tubular housing of the turbine is made up of steel plates. The casing is stress relieved with internal ribs. An access hatch or inspection porthole is provided.

The guide vanes are of fabricated steel with radial vanes which support the guide bearing located within a water tight housing. The turbine throat ring is a fabricated steel extension of the vaned intake and both are provided with necessary anchorage for embedding . Lubricating oil supply and drain pipes for guide bearing are part of the vanes which are shaped for optimum hydraulic performance.

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 lower part of the turbine shaft where it extends through the vaned intake is of a special design to accommodate a water lubricated bearing within the standard vaned intake. The necessary strainers, flow indicator and piping to the water lubricated bearing are included. An adequate supply of clean water is required.

The turbines are fitted with a runner having four blades, of cast steel 13 % Chromium, 4 % Nickel. The runner is of adjustable blade type with steel hub and blades. The adjustable blade operating mechanism consists of steel levers attached to the blade trunnions. The levers are connected by steel links to the crosshead which interlocks all the blades at the same angle. It is positioned by the blade operating rod which extends through the turbine shaft to a hydraulic blade positioner located on the outboard side of either the speed increaser or generator.

The runner hub linkage and blade trunnions are supported on bronze bushings which are lubricated by oil from within the hub.

The hydraulic blade positioner consists of a pivot mounted on hydraulic cylinder and a double lever on a rigid support. The cylinder is controlled by either a speed frequency governor, load controller, or a head water level sensing control. The latter automatically adjust the runner blade angle to provide appropriate turbine discharges and power outputs to properly maintain the headwater level within a pre established adjustable control range. Any of these control devices may be provided with remote indication and/or remote override controls in addition to local manual controls.

The turbine shaft is of tubular design for optimal torsional and lateral stiffness. The shaft is fabricated from seamless mechanical tubing with steel flanges. A stainless steel sleeve is provided at the packing box.

A shaft extension is provided from the runner hub into the upstream bearing and another extension is used in conjunction with the outboard combination guide bearing and thrust bearing if the unit is direct connected.

The upstream turbine bearing, as well as the main guide and thrust bearing where necessary are of self aligning spherical or tapered roller type. These bearings carry all mechanical and hydraulic loads imposed by the turbine. They can compensate for mis alignment upto 1.5 degrees, have a minimum L-10 life of 100,000 hours and are oil bath lubricated.

The draft tube is of high energy recovery, elbow type fabricated from plate steel. Stiffening ribs are provided to minimize distortion and vibration. The top portion is removable (bolted) for access and or removal of the runner and shaft. The shaft packing box with an adjustable gland is mounted on the draft tube elbow and uses conventional woven square packing.

The speed increaser will be located between the main turbine shaft and generator to provide a suitable step up ratio from the design turbine speed to the generator speed. The speed increaser will contain the upper guide and thrust bearing which will have a minimum L-10 life of 100,000 hours. The housing will be of steel construction reinforced in high load areas. All shafts will comply with limits set by various standards for shaft stresses, finishes and tolerances.

The gears and bearings are lubricated by the same lubricant. An adequate supply of oil for initial filling of the speed increaser is provided. A sight gauge is provided on the housing. An oil pump is provided to circulate the oil wherever splash lubrication is not suitable.

The speed increaser will have a hollow bored low speed shaft to accommodate the blade positioning rod. A bell crank lever arrangement will be provided to adapt the standard blade positioners to the vertical blade control rod position.

An integral oil cooling system is provided when necessary. If cooling water is required, provisions will be made for attachment to the purchaser's supply.

Efficiencies of approximately 98.5% are obtained in the single reduction units. A rigid coupling is provided for connecting the turbine shaft to the low speed shaft of the speed increaser. A flexible coupling is provided to connect the generator to thehigh speed side of the speed increaser. This type of coupling accommodates small amounts of lateral and angular misalignment.

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 alteration 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 quick 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 for reactive power of the 33 kV system.

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 turbine housing.

The generator is synchronous type. A speed increaser is incorporated in order to take advantage of the lower cost of a higher speed generator. Hence, the generator combination guide and thrust bearing is replaced by the speed increaser which itself has the necessary shaft support bearings and thrust capability.

The stator yoke is of welded box type construction fabricated from steel plates and steel members. The stator core laminations are die punched from thin, specially rolled pre coated electrical sheet steel. The stator windings are of the double layer lap type with Class B insulation are better.

The rotor spider is of steel construction. To facilitate synchronization starting with the turbine, a connected damper winding is provided consisting of several round copper bars in each pole head. The design is adequate to withstand runaway speed.

Generator cooling air is taken in by the shaft fans from the generator room, from each side of the stator. Rated generator capacity is based on cooling air into the generator not exceeding 40 degrees C.

For most units, a brushless exciter is used and is mounted on the outboard end of the generator frame. A static voltage regulator is included to control the voltage of the synchronous generator by varying the current supplied to the exciter. A static excitation system will be used when brushless exciters are not available.

Section 4 Transformer

Both the units will work into a single power transformers. The power transformer will be three phase step up 6.6kV/33kV rated at 2.5 MVA. It will be installed outdoors. 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 cable will connect the generator to the transformer. 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 cylinder hoist.

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

An intake closure device to provide tight shut off of the water passageways while the unit is shutdown is provided. In addition, it must be able to provide for emergency shutdown in event of loss of load or any other malfunction. For some applications, it may be used for throttling the flow to provide a reduced net head on the turbine during start up. The intake closure device and its operating mechanism must therefore be carefully selected and designed to meet the necessary operating conditions.

Butterfly valves located in the power house as shown are envisaged. Hydraulic operators are generally recommended since with a stored energy system they can provide reliable emergency closure upon loss of power. Dual speed opening and closing valves can be provided. A common pressure system provides energy to operate both the valve and adjustable turbine blades. The valve operator is sized to assure closure against turbine runaway speed discharge.

Generally, rubber seals are recommended along with stainless steel seating surfaces and self lubricated trunnion bearings. Standard commercial products are used whenever available and suitable.

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 has also a separate lubricating system 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 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. 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. An oil pressure system is provided for the blade positioner and intake closure device. The system consists of a motor driven pump complete with pressure switches, accumulators, oil reservoir, control valves and necessary check, throttle and shut-off valves. The system operates at a nominal pressure range of 6Mpa to 7Mpa (900 to 1000 psi). The components are heavy duty, industrial grade. The initial oil supply for the pressure system is included.

8. **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.**

TABLE 10-1
SPECIFICATIONS OF ELECTROMECHANICAL EQUIPMENT

	EQUIPMENT PARAMETER	DESCRIPTION
	Turbine	
	Type	Tubular Kaplan type with adjustable blades, vertical installation
	Number of Units	Two units
	Maximum Gross Head	18 80 meters
	Maximum Net Head	17 60 meters
	Minimum Net Head	14 67 meters
	Design Head	17 00 meters
	Rated Head	17 00 meters
	Rated Discharge	13 5 cubic meters per second
	Turbine Rating	1000 kW nominal
	Overload	5%
	Runner Diameter	1080 mm
	Speed	500 revolutions per minute
	Specific Speed	526 65 revolutions per minute
	Auxiliaries	Hydraulically operated blade servomotors
	Governor	
	Type	Electronic - Digital Type
	Gearbox	
		1 2 step up oil immersed
	Inlet Valves	
	Type	Butterfly valves
	Size	1680mm
	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	1250 kVA
	Voltage	6 6kV (final choice left to manufacturer)
	Power Factor	0 85
	Speed	1000 rpm
	Poles	10
	Cooling	Air cooled
	Coupling	Flange coupling through gearbox
	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	2 5 MVA
	Number of Units	One unit
	HV Terminal	33kV bushing with CT built in

Chapter 11 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 1250 kVA coupled to tubular Kaplan turbines. One 2.5-MVA, 6.6/33 kV power transformer is located outside. General features of the electrical works are given in table 11-2.

Section 2 Generator

Part I Description

The generator is mounted on the speed increasor. 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 in the control cabinet.

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 also working 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 to prevent a faulty operation of this relay in case of an outside short circuit, 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 to protect against an overload of the generator and signal a dangerous current overload of the generator,

5. Field ground relay signals the 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).

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 33kV 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 33 kV side,

3. Oil pressure relay (Bucholtz protection), which acts when gases form 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 in the second switches the 33 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 11-1 titled Control, Protection and Metering strategy. The main step up power transformers are connected between the 6.6kV bus and the 33kV bus. It is differentially protected with the other usual protection arrangements.

A terminal box is provided which encloses the leads, current transformers, surge capacitors and lightning arrestors. The generator is provided with stator temperature protection installed in the stator winding with leads brought out to the terminals. Also bearing temperature protection is included with a temperature detector located close to the bearing surface of each bearing. Each temperature detector is connected to an indicator with alarm terminals. A neutral grounding resistor is provided and is of the stainless steel edge wound type mounted in a personnel safe enclosure. A current transformer is provided for ground fault current indications.

Control and monitoring cubicles are designed and built to relevant standards. Mounted on the front are protective relays, control switches, indicators and monitoring devices. Inside are relays, terminals, motor starter and control circuit breakers. The completed panels are factory inspected and tested, and a standard simulation test is performed on the system before shipment.

The outdoor accessory equipment includes a switchgear cubicle with horizontal draw out metal clad switchgear. This contains an air circuit breaker, capacitor trip device, potential transformers, current transformers, control power transformers and necessary fuses, switches, indicators, heaters, receptacles and key interlocks A three phase power transformer is included to provide step up from the generator voltage to the transmission voltage and is throat connected to the switchgear cubicle. The high voltage side is either throat connected to the load switch cubicle, or is provided with suitable bushings for connection by others. The transformer is oil to air cooled and may have forced air provisions. The load switch cubicle encloses a load break disconnect switch, protective fuses and lightning arresters, terminals for utility connection and space for utility furnished metering equipment. The cubicle includes front doors and key interlocks.

There is no separate control room and the equipment is situated in the machine hall 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.

For providing emergency station service consumption, a 5 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 33 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 Muhuwesi water power plant with permanent attendance for the following reasons :

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

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 shuts down the machine set. 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 Muhuwesi 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 for the 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 system for remote control 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 in drawing 11-1. This is in accordance with current practice and gives a complete survey of the immediate condition of the electric equipment.

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

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 or cable and to decrease the necessary ground work to the smallest possible extent.

The power inlet to the 33 kV switchyard is by a short cable. The switchyard is located as shown in the drawings showing the various project features The schematic of the switchyard is shown in figure 11-1. The single bus arrangement is preferred so as to be simple. 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 Tunduru substation. Further enlargement is not envisaged .

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.

From the power plant the route follows the power house access road upto the main road where it crosses the Muhuwesi and is situated on the left hand side till it reaches Tunduru.

The main consumers of the power produced by the Muhuwesi facility are Tunduru town and surrounding villages as also villages on the route of the line. The route is shown in figure 4-5. In addition to the main load centres, the chosen routes will simplify the future electrification of villages.

The total length of the transmission lines in this system is approximately 30 km and 33kV is selected even though 11kV 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 Muhuwesi to Tunduru is made up of relatively dense forest with minor areas of 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.

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 11-2. The towers can be either of steel or wood poles. The performance of the line was evaluated for transmission of entire 2000kW to Tunduru for both 11kV and 33kV. The 11kV option requires capacitors at Tunduru to avoid an excessive voltage drop apart from requiring large conductors. As 33kV voltage exists in Tanzania, it is preferred to have 33kV single circuit towers. Creosote treated wooden poles are recommended.

The conductors are proposed to have an area of about 35 sqmm. Average span is about 300ft

The conductor size is such that total generation of 2000kW can be transmitted to Tunduru with maximum voltage drop not exceeding 10%. The performance of the main line Muhuwesi - Tunduru for 2000kW total load at power factor of 0.85 lagging is given in table 11-1. The line parameters and other features are indicated.

It is seen that for a load in Tunduru of 2000kW at 0.85 pf lagging, the sending end voltage is 1.073 pu or in other words the voltage drop is 7.32%. The transmission efficiency is 80.8%. For loads upto 1000kW the voltage drop is only 3.66% with 90% efficiency. Performance at other loads is indicated in Box 11-1.

Box 11-1: Power Loss and Voltage drop in Transmission Line

Generation (kW)	Loss (kW)	Power factor (lag)	Voltage Drop (%)	Efficiency (%)
250	7.20	0.85	0.915	97.118
500	28.05	0.85	1.829	94.390
750	61.35	0.85	2.745	91.820
1000	106.10	0.85	3.660	89.390
1500	226.80	0.85	5.491	84.880
2000	383.00	0.85	7.322	80.818

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

A Substation in Tunduru is necessary to step down the voltage and distribute power. The single line diagrams for the substations are shown in figure 11-2 .

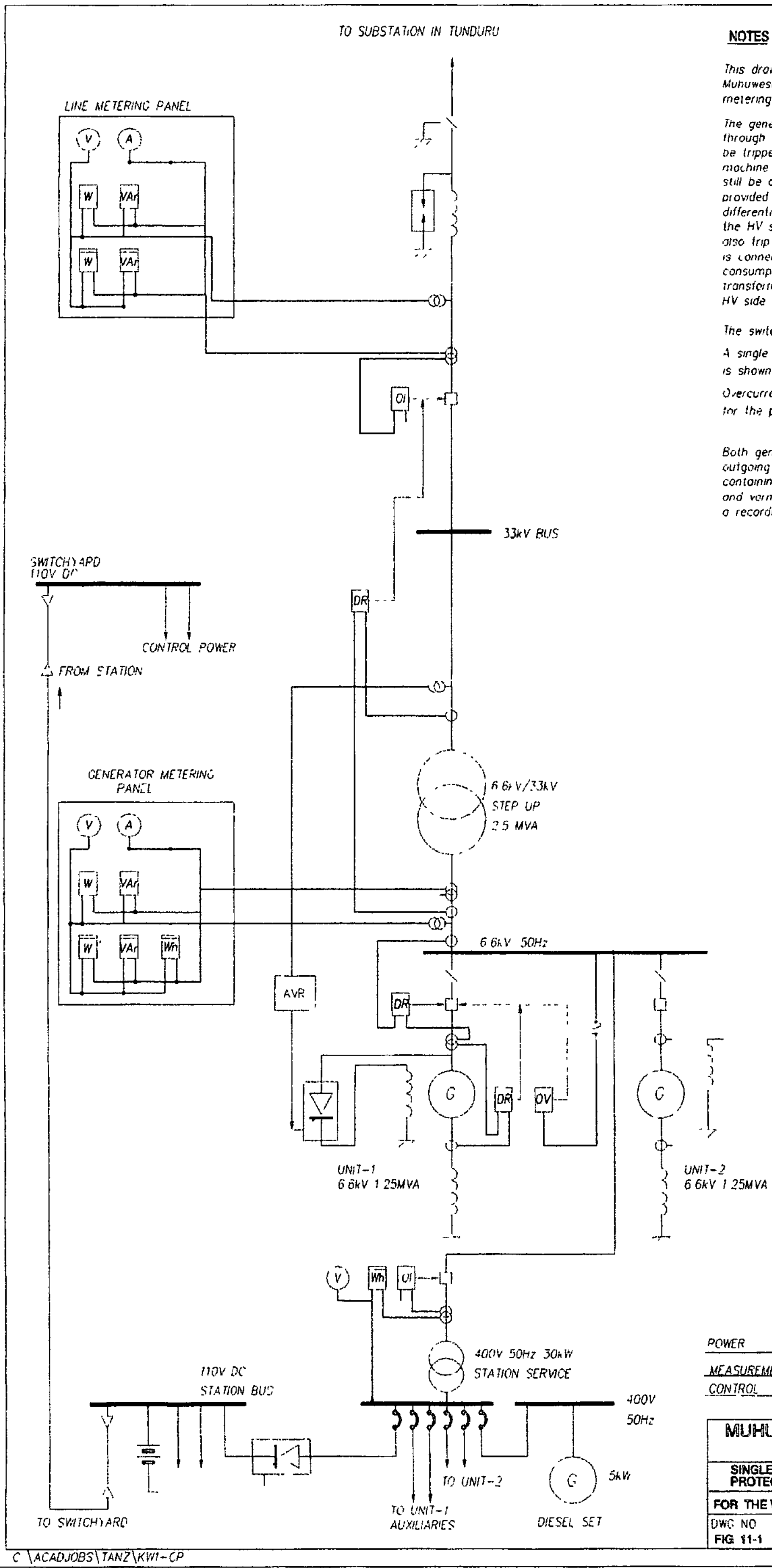
The substation is proposed to be of the open type, with necessary buildings. The transformers and switchgear will be outdoors.

Box 11-2: Features of Substations

SUB STATION	TRANSFORMER RATIO (kV)	CAPACITY (MVA)	OUTGOING BAYS
TUNDURU	33/11/0.4	2	4

Circuit breakers with protective relays will be beneficial both in reducing the number of outages and in protecting the system. Therefore, circuit breakers at the 33 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 rural 11kV lines which may be installed from Tunduru for service to villages beyond and surrounding Tunduru. 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 Muhuwesi 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

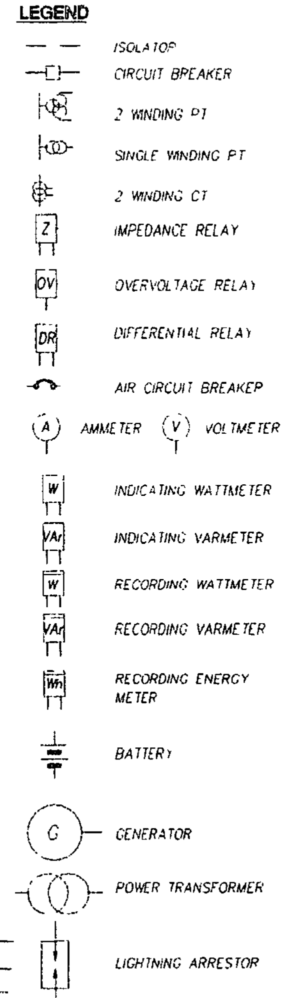
The switchyard will have on a single bus

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

Overcurrent 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



MUHUWESI HYDROPOWER PROJECTS STAGE-I

SINGLE LINE DIAGRAM WITH CONTROL, PROTECTION & MONITORING SCHEME

FOR THE WORLD BANK/TANESCO

DWG NO **FIG 11-1**	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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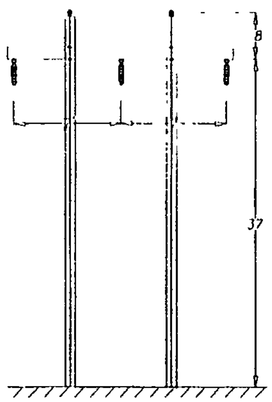
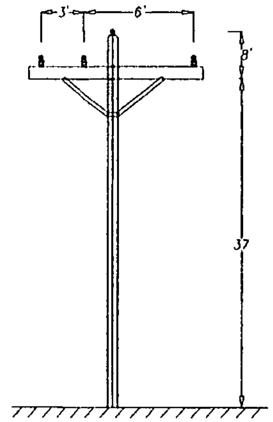
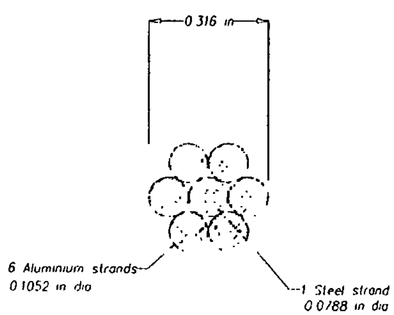


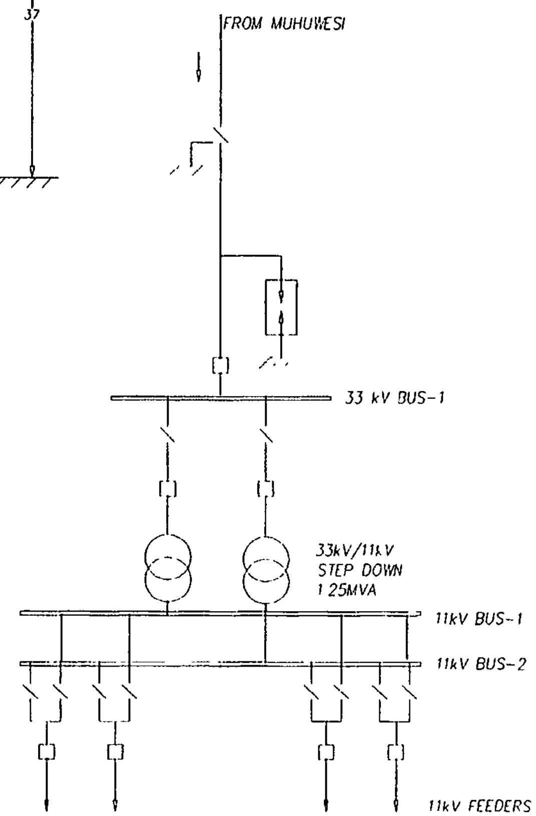
33kV WOOD POLE
AVERAGE SPAN - 300 FT



33kV WOOD POLE
AVERAGE SPAN - 300 FT



CONDUCTOR CROSS SECTION
MUHUWESI-TUNDURU LINE



SINGLE LINE DIAGRAM OF TUNDURU SUBSTATION

MUHUWESI HYDROPOWER PROJECTS STAGE-1	
TRANSMISSION LINE DETAILS	
FOR THE WORLD BANK/TANESCO	
DWG NO FIG 11 2	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

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TABLE 11-1

PARAMETERS OF TRANSMISSION LINE AND PERFORMANCE CALCULATION

	Parameters		
	Line Voltage	kV	33
	Frequency	Hz	50
	Electrical system		Single Circuit 3 phase 3 wire
	Base MVA	MVA	2
	Receiving End power	kW	2000
	Receiving End power factor		0 85
	Line Length	miles	18 75
	Conductor Code Word		
	Aluminium Conductor cross section area	cmils	66370
	Resistance per mile of Conductor	Ohms	1 660
	Inductive Reactance per mile of Conductor at 1ft	Ohms	0 554
	Capactive Reactance per mile of Conductor at 1ft	Mohms	0 154
	Equivalent Spacing of conductors	ft	7
	Inductive Reactance per mile at equivalent spacing	Ohms	0 1967
	Capactive Reactance per mile at equivalent spacing	Mohms	0.0693
	Current Carrying capacity @ 50 deg C temp rise	Amps	180
	Aluminium strands	No	6
	Strand dia	in	0.105
	Steel strands	No	1
	Strand dia	in	0 105
	Ultimate strength	lbs	2790
	Weight of conductor per mile	lbs	484
	Outside diameter	in	0 316
	Insulators	Type	Pin Type
	Support		Wooden poles with steel cross arms
	Base Impedance	Ohms	544 5000
	Base Current	A	34.9909
	Line Resistance	Ohms	31.1250
	Line Inductive Reactance	Ohms	14.0764
	Line Capactive Reactance	Mohms	4 1903
	Line Resistance in per unit	per unit	0.0572
	Line Inductive Reactance in per unit	per unit	0.0259
	Line Capactive Reactance in per unit	per unit	7695.6315
	Line Impedance in per unit		5 71625344352617E-002+2 58518878689848E-002i
	Receiving End Voltage	per unit	1
	Receiving End Current	A	41.1658
	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	1.1765
	Receiving End Current Phasor	per unit	0.85-0.526782687642637i
	Receiving End Current	per unit	1-0 619744338403102i
	Series Drop	per unit	7.31840955790969E-002-9.574269216041E-003i
	Sending Voltage	per unit	1.0731840955791-9.574269216041E-003i
	Sending Voltage Magnitude	per unit	1.0732
	Regulation	percent	7 3227
	Loss	per unit	0.2374
	Loss	MW	0.4747
	Efficiency of Transmission Line	percent	80.8177

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TABLE 11-2
ELECTRICAL WORKS SPECIFICATIONS

	Equipment Category	Units	
1	**Generator output**		
	Type		Insulated Copper Cables
	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 behind power house
	Voltage	kV	33
	Design		As per TANESCO guidelines
	Type of Arrangement		Single Bus bar
	Incoming Lines		Two incoming cables from Power Station
	Outgoing Lines		One outgoing line to the Tunduru Substation
	Circuit breaker type		Vaccum circuit breakers/air blast/oil as suitable
	No of Circuit breakers		1
	Isolators		Motorized post mounted rotary double break type
	No of isolators		1
	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		Wound 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 5 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		Overcurrent protection
8	**Transmission**		
	Voltage	kV	33
	Type		Single circuit towers
	Final Receiving Station		Tunduru Substation with two transformers and four 11kV feeders
	Length	km	30
	Conductors		34 sqmm ACSR

Chapter 12 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 each component of the project and aggregated unit prices applied to the main categories of works and equipment to give the direct construction cost.

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 12-1: 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. To the Implementation cost is to be added the interest during construction which depends on the source of the funds to give the project cost. This is dealt with in the chapter on Economic and financial analysis.

Section 2 Civil Works

The cost estimate for the civil works is confined to the major items of work involved in the diversion weir, waterway, 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 quantities and the aggregated unit prices for deriving the cost estimates are presented in table 12-1

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 tubular 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 tubular Kaplan type turbine rated at 1000 kW at 17m speed 500 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.
- Gearbox - 2 units of gearbox complete with lubricating oil and matched with the speed of turbine and generator.
- Generator - 2 units of synchronous generators rated 1250 kVA, 6.6kV, 50 Hz, cos phi 0.85, 1000 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 12-1. 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,
- Power Transformer
- Station service transformer, Emergency lighting, illumination and black start power,
- UPS and Battery system
- Fire fighting equipment

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, spillway gates, inlet valves and draft tube 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. Spillway crest gates with operating mechanisms
2. Inlet Valves with operating mechanism.
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.
Inlet valves - Lumpsum

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 33kV.

Section 7 Transmission

The costing includes the transmission lines and equipment for connection to the existing substations or new substations. The total transmission is about 30 km. It should be noted that cables/conductors are manufactured in Tanzania and hence costs will be lower than if imported.

Section 8 Miscellaneous and Contingencies

The cost of construction as calculated by applying unit cost estimates to the calculated quantities of the works identified for the main components of the project should be increased by a contingency allowance of 12% of the civil works and 5% of the hydro-electric equipment costs. 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 an amount equal to 1% of construction cost has been provided for environmental impacts.

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 12-1. The implementation cost 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 12-1
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	10,000	5	50,000	50,000	
b	**Bridge Improvements**	lumpsum	50 000		50,000	50,000	
c	**Construction Camp**	lumpsum	25,000		25,000	25,000	
d	**Diversion Weir Preliminaries**						
i	River Diversion	lumpsum	50,000	1	50,000		
ii	Site Clearing and Grading	m2	3	500	1,500	51,500	
e	**Diversion Weir**						
i	Soft Rock Excavation	m3	8	500	4,000		
ii	Rock Excavation	m3	13	500	6,500		
iii	Rockfill	m3	20	3200	64,000		
iv	Rubble Masonry	m3	25	650	16,250		
v	Cement Mortar Masonry	m3	30	1000	30,000		
vi	Cement Concrete Slab	m3	300	150	45,000		
vii	RCC Bucket	m3	384	100	38,400		
viii	Backfill	m3	8	250	2,000		
ix	Grouting	m	300	300	90,000	296,150	
f	**Spillway**						
i	Rock Excavation	m3	13	1500	19,500		
ii	Mass Concrete	m3	200	3220	644,000		
iii	Reinforced Concrete	m3	384	1000	384,000		
iv	Grouting	m	300	300	90,000		
						1,137,500	
	Total Cost of Diversion Weir						**1,485,150**
g	**Intake & Water Conductor**						
i	Land Clearing and Preparation	m2	3	21500	64,500		
ii	Soil Excavation	m3	4	71500	286,000		
iv	Cement Concrete	m3	200	1530	306,000		
vi	Penstocks etc inclusive of fabrication	t	5,000	10	50,000	706,500	
h	**Forebay**						
i	Land Clearing and Preparation	m2	3	300	900		
ii	Soft Rock Excavation	m3	8	2957	23,656		
iii	Backfill	m3	8	500	4,000		
iv	Concrete	m3	200	175	35,000	62,656	
	Total Cost of Water Conductor						**769,156**
i	**Power House**						
i	Soil Excavation	m3	4	50	200		
ii	Soft Rock Excavation	m3	8	225	1,800		
iii	Hard Rock Excavation	m3	13	225	2,925		
iv	Mass Concrete	m3	300	80	24,000		
v	Reinforced Concrete	m3	384	100	38,400	67,325	
j	**Tailrace**						
i	Soil and Soft Rock Excavation	m3	8	1000	8,000		
ii	Rock Excavation	m3	13	0	0		
iii	Concrete	m3	200	174	34,825		
iv	Reinforced Concrete	m3	384	135	51,840	94 665	
	TOTAL CIVIL WORKS COST						**2,641,296**
2	**ELECTROMECHANICAL EQUIPMENT**						
a	Turbine & Generator	kW	450	2000	900,000		
b	Auxiliaries	kW	25	2000	50,000		
c	Inlet Valves	lumpsum	25,000	2	50,000		
d	Draft Tube Outlet Gates	m2	800	10	8,000		
e	Spillway Radial gates	m2	800	100	80,000		
f	Transmission & Substation	km	15,000	30	450,000	1,538,000	
	TOTAL ELECTROMECHANICAL COST						**1,538,000**
3	**TOTAL CONSTRUCTION COST**						**4,079,296**
4	**OTHER COSTS**						
a	Engineering	percent	5		203,965		203,965
b	Administration	percent	3		122,379		122,379
5	**CONTIGENCIES**						
a	Civil Works	percent	12		304,956		304,956
b	Electromechanical & Others	percent	5		76,900		76,900
6	**ENVIRONMENTAL IMPACT COST**	percent	1		40,793		40 793
7	**TOTAL IMPLEMENTATION COST**						**4,828,288**
8	**COST PER kW INSTALLED**	USD			**2,414**		

Chapter 13 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 from the sale of energy which it generates. For comparing this with the costs incurred and deriving the economic benefit cost ratio, 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 streams 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 2000 kW located in Tunduru. 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. Diesel cost is calculated based on 1187liters = 1ton.

Box 13-1: Calculation of Economic Value of Energy from Hydropower

	Unit	Diesel	Diesel	Hydro	Hydro
Net Annual Energy	GWh	1.6	14.5	1.6	14.5
Cost of Installed capacity	USD/kW	1100	1100	2425	2425
Maintenance + Outage	% p.a	8+6 = 14	8+6 =14	nil	nil
Installed Capacity	kW	350	2000	2000	2000
Capital Cost	MUSD	0.385	2.200	4.85	4.85
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	1.684	15.26	1.6	14.5
Annual Debt Service	USD	62639	357940	789000	789000
Annual fixed O & M Cost	USD	19250	110000	48500	48500
Annual variable O & M Cost	USD	9600	87000	nil	nil
Fuel Cost	USD	128000	1220800	nil	nil
Total Annual Costs	USD	219489	1775740	837500	837500
Cost/kWh	US cents	13.71	12.24	52.40	5.77
Cost/kWh including CO_2 cost	US cents	15.01	13.54	52.40	5.77

The implementation cost of the hydro project is US$ 4.88 million for 2000KW 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$ 0.788 million. Total cost is then obtained by adding the two amounts which is USD 5.576 M.

Similarly the total annual costs of the diesel plant are calculated as shown in Box 13-1. 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 1.6 GWh, then the cost of generation from diesel set is 15.01 US cents/kWh. In case the diesel set produces 14.5GWh which is the energy from the hydro, then the generation cost from diesel comes down to 13.54 cents/kWh. For any intermediate conditions the average is computed which is 14.27 cents/kWh. Based on this and initially without applying discounting, the following first year benefits can be calculated.

Box 13-2: Economic Feasibility without considering lifetime costs/benefits

Economic Price of Energy	US cents/kWh	13.54	14.27	15.01
Energy from Hydro	GWh	14.5	10.0	1.6
Value of Benefits	MUSD	1.963	1.427	0.240
Costs	MUSD	0.837	0.837	0.837
B/C ratio		2.345	1.708	0.286

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 cost streams. 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 3 GWh in the first year and rises at a low growth rate of 2% p.a. The following are the base case conditions

Cost = 4.88MUSD, IDC = 0.78 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 13-3: Economic Analysis with Sensitivity

Case	Condition	Base Demand	Demand Growth	B/C Ratio	NPV (MUSD)	EIRR (%)
1	Base / Discount 8%	3.0 GWh	0.0%	1.166	1.219	10.50
2	Base / Discount 10%	3.0 GWh	2.5%	1.383	2.524	15.00
3	Base / Discount 12%	3.0 GWh	2.5%	1 204	1.219	15.00
4	Base / Cost + 20%	9.0 GWh	2.5%	2.851	13.22	> 40
5	Base / Inflation 0%	9 0 GWh	5.0%	2.715	9.87	> 40
6	Base / Inflation 0%	9.0 GWh	0.0%	1.789	4.54	> 40
7	Base / Inflation 2.5%	9.0 GWh	5.0%	3.490	14.53	> 40
8	Base / Discount 12%	9.0 GWh	0.0%	2.143	6.67	> 40
9	Base / Cost + 20%	14.5GWh	0.0%	3.347	16.78	> 40
10	Base/ Discount 12%	14.5GWh	0.0%	4.018	17.97	> 40

From the above, the benefit cost ratio is very satisfactory for all the above test conditions. Of particular interest is case 1 where the demand does not increase from the initial 3GWh per year for a discount rate of 8%. The Benefit cost ratio for this case is 1.166. Case 6 is when the initial demand of 9GWh does not grow nor is there a price rise in diesel cost. Finally case 10 is for maximum energy production from the project shows the benefit cost ratio to be 4.018.

Section 3 Financial Analysis

The financial analysis is indicated in table 13-1 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 13-1. 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

$C = 4.828$ 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 = 14,500,000 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 = 6,000,0000 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 = 15.01 US cents for economic analysis with demand = 1.6GWh
T = 13.54 US cents for economic analysis with demand = 14.5 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

$$F_n = R_n - L_n - D_n - OM_n \qquad (21)$$

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 13-1. The results for the cases are presented in figures 13-1,13-2 and 13-3.

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 part of maximum energy produced with different growth rates in demand.
- Low price for electricity sold which is US 7 cents/kWh escalating at 5% p.a.

Box 13-4: Cases for Financial Sensitivity Analysis

CASE	PARAMETER	COST	LOAN PERIOD	INTEREST	PURCHASE PRICE	DISCOUNT RATE
1	B/C RATIO	4.82	10	5% to 15%	0.07	12%
2	ENERGY COST	4.82	10	5% to 15%	0.07	12%
3	B/C RATIO	4.82	10	10%	0.05 to 0.10	12%
4	ENERGY COST	4.82	5 to 10	10%	0.07	12%
5	ENERGY COST	4-8	10	10%	0.07	12%
6	B/C RATIO	4-8	10	10%	0.07	12%
7	B/C RATIO	4.82	10	10%	0.07	10% to 30%
8	NPV	4.82	10	10%	0.07	10% to 30%
9	LIFE CYCLE ENERGY COST	4.82	10	10%	0.07	10% to 30%
10	BENEFITS AND COSTS	4.82	10	10%	0.07	10% to 30%
11	NPV	4.82	10	5% to 15%	0.07	10% to 30%
12	B/C RATIO	4.82	10	5% to 15%	0.07	10% to 30%
13	ENERGY COST vs ENERGY	4.82	10	10%	0.07	12%
14	B/C RATIO vs ENERGY & GROWTH	4.82	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 9 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 10.5 cents
5. Case-5: Even if the capital cost increases by 50%, energy cost does not exceed 10 cents
6. Case-6: Even if the capital cost increases by 50% benefit cost ratio is 1.25

7. Case-7: Even for a high discount rate of 20%, the benefit cost ratio exceeds 1.5
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 discount rate more than 20%. 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 6.79 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 financial B/C ratio of 1 can be achieved with a sale of 5GWh per year with low growth rate of 2.5%.

Summarizing the project is highly feasible from economic and financial terms and has higher merits than a diesel station. Hence construction of the project as an alternative to the existing diesel is recommended.

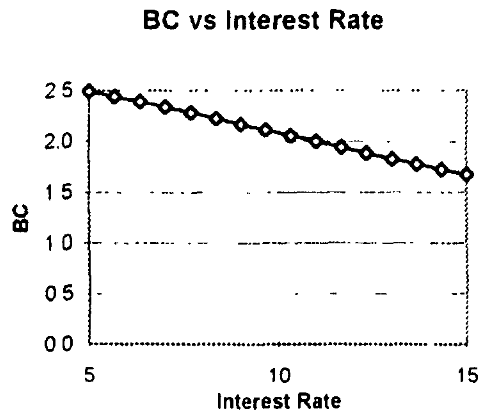
TABLE 13-1
ECONOMIC AND FINANCIAL ANALYSES

Capital Cost	4.828	M US$	Maximur	14 5	GWh
Interest Rate	10	percent			
Payback Period	10	years			
CRR	0.1627				
Discount rate	12	percent			
Base year Demand	14.500	GWh			
Base Price of Energy	0.07	$/kWh			
Inflation Rate	5	percent			
O&M	1	percent			
IDC	0.748	M US$			
IDC + Capital Cost	5 576	M US$			
Economic Life	30	years			
Demand Growth	0	percent			

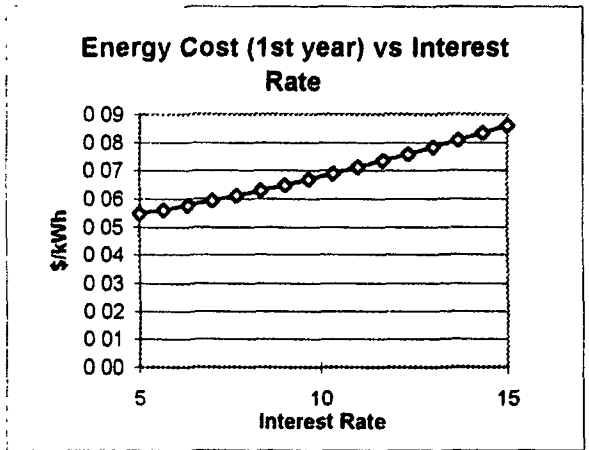
Years	% CC	Investment M US$ 1	Sigma inv	IDC M US$ 2	Debt Service M US$ 3	Depre-ciation M US$ 4	O & M M US$ 5	Energy Sold GWh	Gen Cost $/kWh	REVENUE M US$ 6	NET INCOME M US$ 7	PWF 8	PRESENT WORTH RUNNING COSTS M US$ 9	PRESENT WORTH ENERGY COST $/kWh	PRESENT WORTH REVENUE M US$ 10	PRESENT WORTH CASH FLOW M US$ 11
-2	50	2 414	2.414	0 241												
-1	50	2.414	4 828	0 507												
											(6)-(3+4+5)		(8)x(3+4+5)		(8)x(6)	(10)-(9)
1		0 000			0 908	0 029	0 048	14.500	0 068	1 015	0.030	0.893	0.880	0.061	0.906	0.027
2		0 000			0 908	0 029	0.051	14.500	0 068	1 066	0.078	0.797	0 787	0.054	0 850	0.062
3		0 000			0 908	0 029	0 053	14 500	0.068	1 119	0.129	0.712	0.705	0.049	0 797	0.092
4		0 000			0 908	0 029	0 056	14 500	0 068	1 175	0.182	0.636	0.631	0 044	0.747	0 116
5		0 000			0 908	0 029	0 059	14 500	0 069	1 234	0 238	0 567	0 565	0 039	0 700	0 135
6		0 000			0 908	0 029	0.062	14.500	0 069	1.295	0 297	0 507	0 506	0 035	0 656	0 150
7		0 000			0 908	0 029	0 065	14 500	0 069	1.360	0.359	0.452	0 453	0 031	0 615	0.162
8		0 000			0 908	0 029	0 068	14 500	0.069	1.428	0.423	0 404	0 406	0 028	0 577	0 171
9		0 000			0 908	0 029	0.071	14 500	0.070	1.500	0.491	0 361	0.364	0.025	0 541	0 177
10		0.000			0 908	0.029	0 075	14.500	0.070	1.575	0 563	0 322	0 326	0 022	0 507	0 181
11		0 000			0.000	0 029	0 079	14.500	0 007	1 653	1.545	0.287	0.031	0.002	0 475	0 444
12		0.000			0 000	0 029	0.083	14.500	0.008	1.736	1.624	0.257	0.029	0.002	0.446	0.417
13		0 000			0 000	0 029	0 087	14 500	0.008	1.823	1.707	0.229	0.027	0.002	0 418	0.391
14		0 000			0 000	0.029	0 091	14 500	0.008	1 914	1 794	0.205	0.025	0.002	0.392	0 367
15		0 000			0 000	0 029	0 096	14 500	0.009	2.010	1.885	0.183	0.023	0.002	0 367	0.344
16		0.000			0.000	0 029	0 100	14 500	0 009	2 110	1 980	0.163	0.021	0.001	0 344	0 323
17		0.000			0 000	0.029	0 105	14 500	0 009	2.216	2.081	0.146	0 020	0.001	0 323	0.303
18		0.000			0 000	0 029	0 111	14 500	0.010	2 326	2 186	0 130	0.018	0 001	0 303	0 284
19		0 000			0.000	0.029	0.116	14 500	0.010	2.443	2.297	0.116	0 017	0.001	0 284	0.267
20		0 000			0 000	0 029	0 122	14 500	0.010	2.565	2 414	0.104	0.016	0.001	0.266	0 250
21		0.000			0.000	0 029	0 128	14 500	0.011	2 693	2 536	0 093	0.015	0.001	0.249	0 235
22		0 000			0 000	0 029	0 135	14 500	0 011	2 828	2 664	0 083	0 014	0.001	0.234	0 220
23		0 000			0 000	0 029	0 141	14 500	0.012	2 969	2 799	0 074	0 013	0 001	0.219	0 206
24		0 000			0 000	0 029	0 148	14 500	0.012	3.118	2.940	0.066	0.012	0 001	0 205	0.194
25		0 000			0 000	0 029	0 156	14.500	0.013	3.273	3.088	0.059	0.011	0.001	0.193	0.182
26		0 000			0 000	0 029	0.163	14 500	0 013	3 437	3 244	0.053	0.010	0.001	0.181	0.170
27		0 000			0 000	0 029	0 172	14 500	0.014	3.609	3 408	0 047	0 009	0 001	0.169	0 160
28		0 000			0 000	0.029	0 180	14 500	0 014	3.789	3.580	0 042	0.009	0 001	0 159	0 150
29		0 000			0.000	0 029	0 189	14.500	0 015	3 979	3 760	0 037	0.008	0.001	0.149	0 141
30		0 000			0 000	0 029	0 199	14.500	0 016	4 178	3 950	0.033	0.008	0 001	0.139	0 132
									MEAN					MEAN		
TOTAL		4 828		0.748	9.075	0.881	3.208	435	0 030	67.435	54.272		5.954	0.014	12.408	6 454

PW of Total Life Cycle Benefits	12.408	M US$	
PW of Total LCC (OM+Cap+IDC+De	5.954	M US$	
Benefit Cost Ratio	2.084		
Average Cost of Energy	0 014	$/kWh	Computed over lifetime energy
Net Present Value	6 454	M US$	

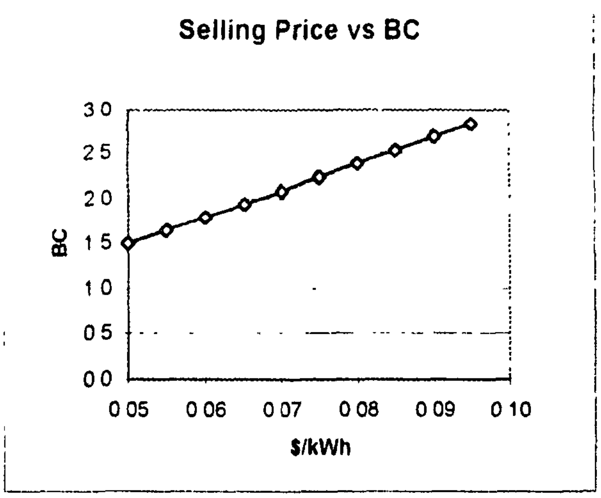
FIGURE 13-1
FINANCIAL SENSITIVITY ANALYSES CASES 1 to 6



Case-1



Case-2



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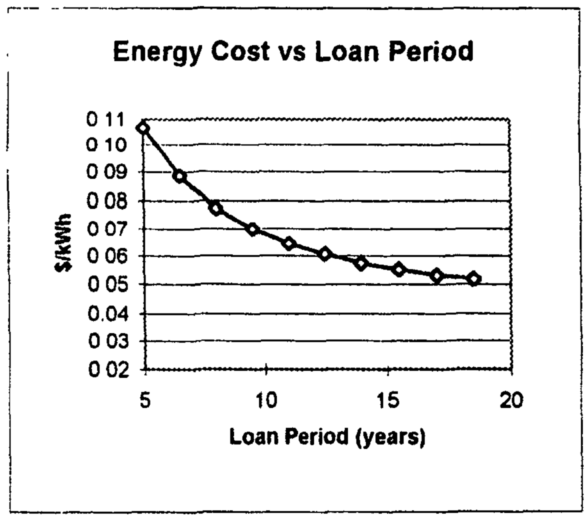

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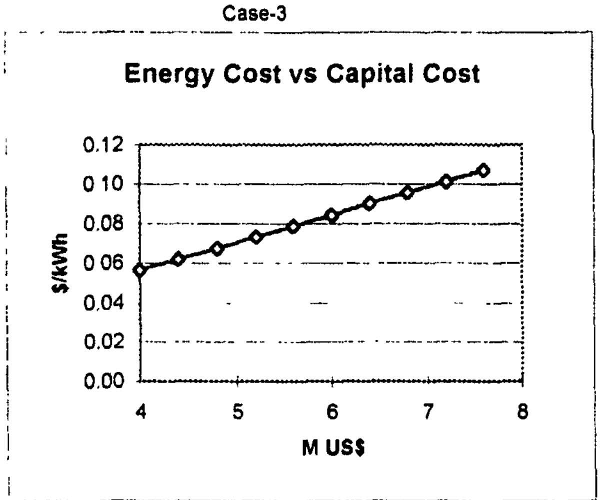

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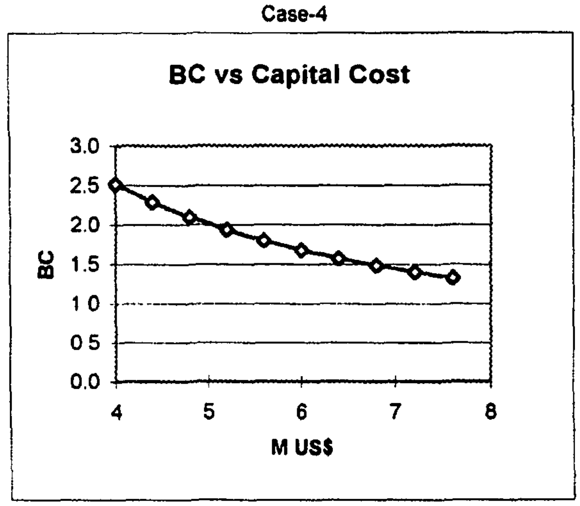

Case-6

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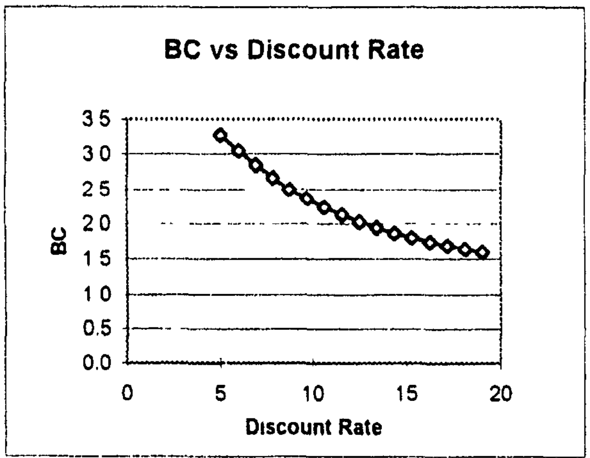
FINANCIAL SENSITIVITY ANALYSIS CASES 7 to 12



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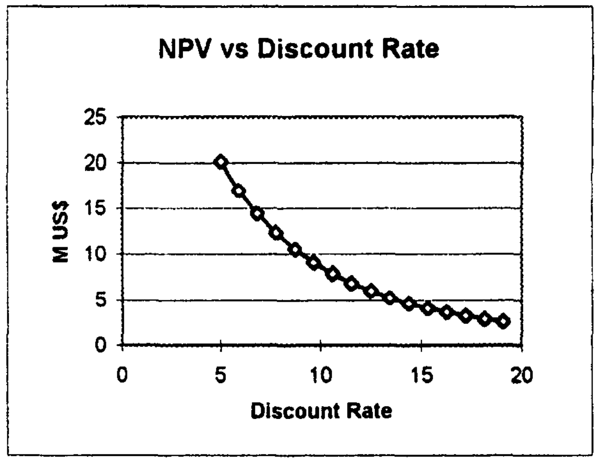
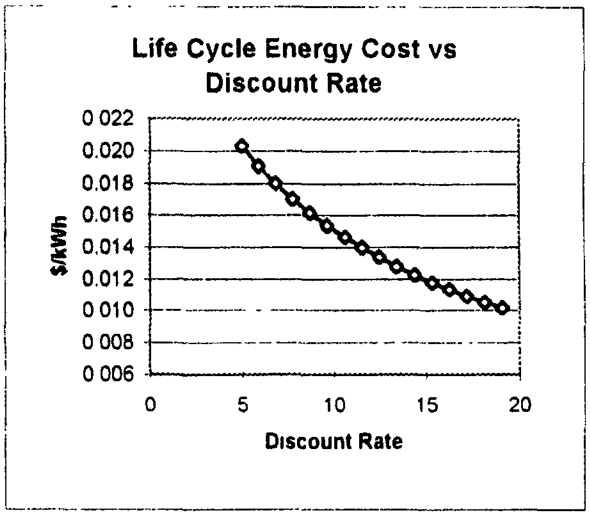
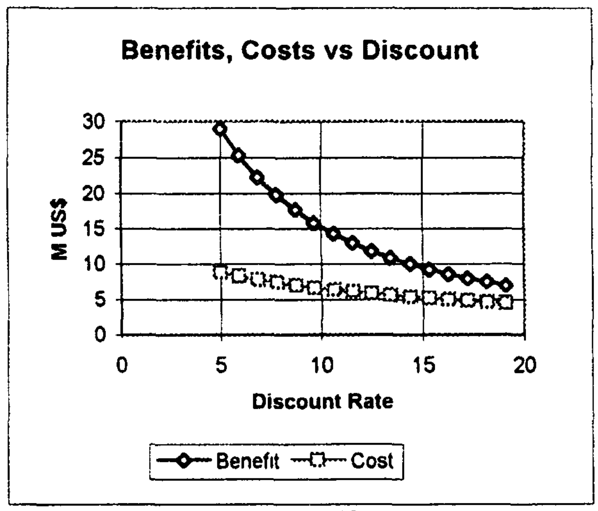


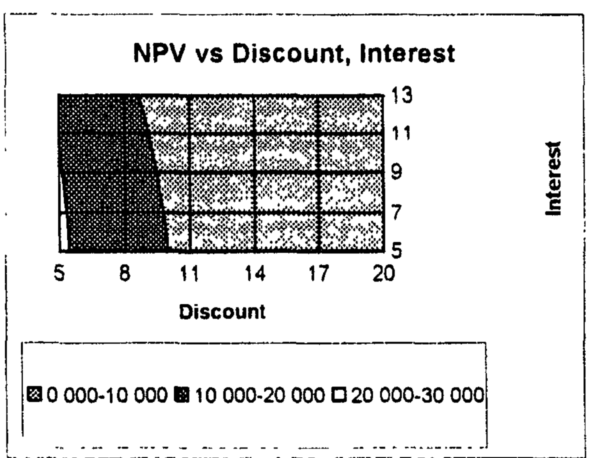
Case-8



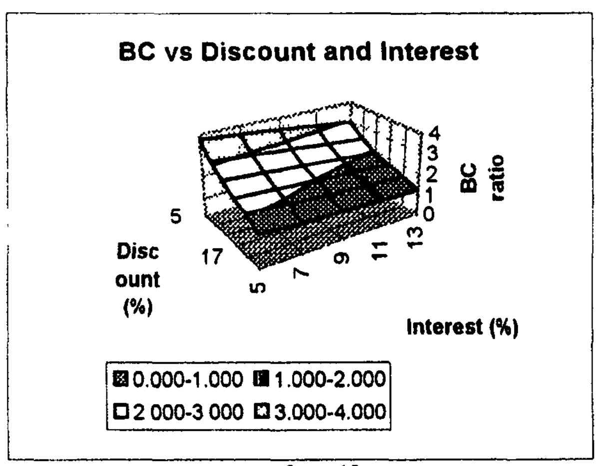
Case-9



Case-10



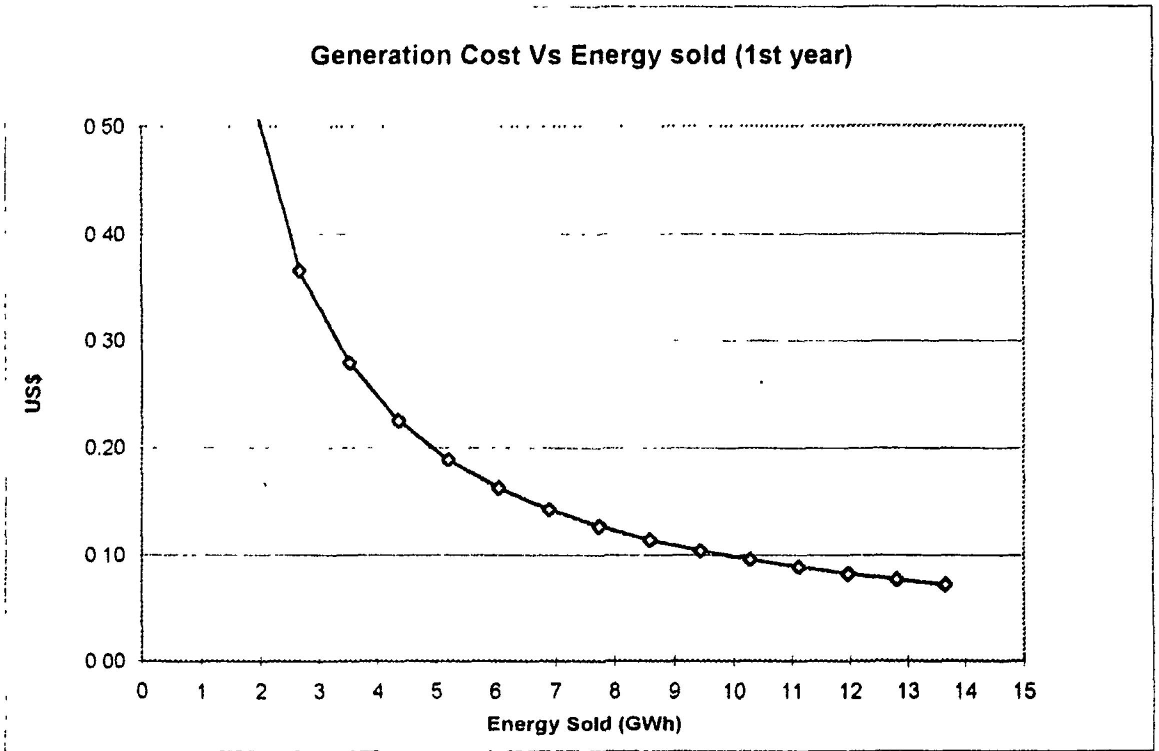
Case-11



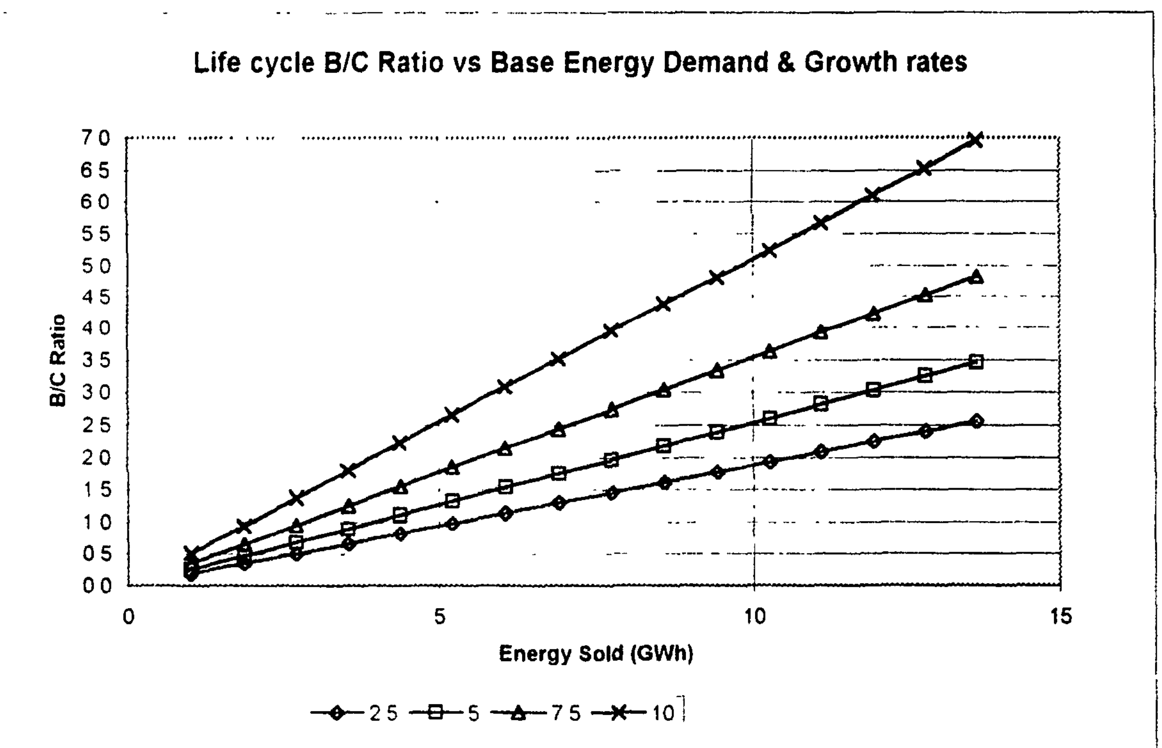
Case-12

FIGURE 14-3

FINANCIAL SENSITIVITY ANALYSIS CASE 13 TO 14



Case - 13



Case - 14

Chapter 14 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 - Pre assembled turbine generator unit	Penstock lengths about 6m.

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 33 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 Makumbako railway station and then by road to Songea with intermediate storage if necessary. From here road transport to Tunduru is the only alternative

2. Imported Light Articles. These articles which would consist of any sensitive equipment will be flown to Songea airfield 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 Muhuwesi Project is such that it is logical 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. 33kV Switchyard
7. Transmission Line 33 kV
8. Receiving substation in Tunduru

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 14-1:Construction Rate

Item	Units	Rate
Access Road	km/day	0.5
Open Excavation with power shovels	m^3/day	150
Rock Excavation	m^3/day	50
Rock Excavation in River	m^3/day	30
Concrete Placement	m^3/day	20
Reinforced concreting	m^3/day	10
Shotcrete	m^3/day	10
Rockfill placement	m^3/day	15
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 14-1. 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. Suitable strengthening of the existing bridge is also included in the access works.

The area to be occupied by the principal structures, such as the dam, the power plant, the spillway, the canal 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 required 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 250kW. 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 Muhuwesi river and stored in tanks prior to utilisation. Potable water may have to be brought by tankers from Tunduru.

Part III Diversion Weir

The river flow in the dry season is confined to the central part of the river channel with river bed rock exposed considerably at other sections. When preliminary works have been completed, a diversion channel near the right bank can be created using sand bags or other suitable method, so that the diversion weir area is rendered dry. 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 for the spillway.

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. Concrete can be placed in the central portion upto an elevation of 432m.

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 the two flanks of the diversion weir, and the central concrete portion upto 432m will be completed. The monsoon flows will then be passed over the concrete weir.

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 portions of the concrete overflow portion and the weir completed upto 435m and the piers are taken up. The concrete slab on the upstream and downstream is also done simultaneously. At the end of the second dry season, the diversion weir will be completed. Thus it will take about 18 months for the completion.

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 75000 cum. It is estimated to take about 15 months. Concrete of about 1500 cum is required. Concrete placement shall continue in parallel with excavation. The forebay requires an excavation of 3000 cum and 200 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 423 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 423m 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 generator equipment and the accessory equipment shall be started.

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 and Substation**

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. The local Tanesco office will be able to carry out most of the works involved.

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 14-1. 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 14-1
IMPLEMENTATION SCHEDULE

No.		Activity	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	5	km
	b	Bridge Improvements		
	c	Construction site preparation		
	d	Construction power water supply etc		
	e	Housing and Colonies		
3		DIVERSION WEIR		
	a	Site Preparation & river Diversion		
	b	Excavation	2500	cum
	c	Rockfill/Cement Mortar Masonry	15000	cum
	d	Mass Concreting of spillway	4000	cum
	e	Reinforced concrete for Spillway piers	1000	cum
	f	Grouting		m
	g	Fixing Crest gates		
	h	Impoundment		
5		WATER CONDUCTOR		
	a	Preliminaries & Land clearing	21800	sqm
	b	Excavation	75000	cum
	c	Concreting	1650	cum
	d	Backfilling	500	cum
	e	Penstocks	10	t
6		POWER HOUSE		
	a	Site Preparation	300	sqm
	b	Excavations	500	cum
	c	Electromechanical Equipment		
	d	Concreting	180	cum
	e	Super structure		
	f	Other Electrical Works		
7		TAILRACE		
	a	Excavation	1000	cum
	b	Concreting and finishing	300	cum
8		SWITCHYARD		
	a	Preliminary Works		
	b	Construction		
	c	Equipment		
9		TRANSMISSION	30	km
	a	Preliminaries		
	b	Tower Erection		
	c	Stringing of conductors		
	d	Substation in Tunduru		
10		FINAL WORKS		
	a	Testing of plant		
	b	Clean up and other miscellaneous works		
	c	Commissioning		
	d	Commercial Operation Starts		
11		TIME		MONTH

Year	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2000	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 (MONTH)												
2001	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 (MONTH)	1	2	3	4	5	6	7	8	9	10	11	12
2002	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 (MONTH)	13	14	15	16	17	18	19	20	21	22	23	24

Chapter 15 Conclusions and Recommendations

1. The Tunduru district is rather remote from the rest of Ruvuma region and development needs to be accelerated by provision of an economical and reliable source of electricity.

2. A preliminary study was conducted in 1982 by SWECO on development of Sunda falls for hydropower on the Ruvuma river as it is perennial and has a good flow throughout the year.

3. The study showed that in spite of the natural head, the project cost would be US$11.25 with significantly large quantities of excavation and civil works.

4. The study by SWECO recommended a diversion type development with an installed capacity of 3000 kW (2 x 1500kW) an energy output of 23GWh per year. Head for the plant is 13.5m and discharge is 26 cumecs. Implementation cost was about $3750 per kW in 1982 without IDC.

5. The project has however not been implemented. It is situated on an international river and requires approval by Mozambique and possibly may involve structures on the Mozambique side as also sharing of the electricity which is generated. The transmission distance to Tunduru is 65km and with the present demand of only about 500kW it is likely to be expensive. Considerable investment on improving the existing access roads for 20 to 30km are required.

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 reduce costs if mini hydro projects are to be used to economically electrify the area. This will enable government to use its own funds in developing projects which will provide returns on investment.

9. Hence an alternative site on Muhuwesi river which is 26km from Tunduru and is situated on the main road to Masasi is suggested for development. Three sites have been proposed for implementation in stages. The first stage is called Kwitanda and is recommended for development to supply Tunduru.

10. The demand in the main load centre Tunduru has yet to develop to the full potential of 2000kW. Hence, market for power will be about 500kW with energy requirement of about 3GWh. Growth rate may be about 2.5% p.a.

11. The present study proposes a cascade development consisting in all of 3 small hydro power stations aggregating to 7000kW capacity with energy of 52 GWh. This will hence be sufficient for the region in the years to come.

12. Due to the revised planning, the construction cost of the first scheme is US$ 4.828M and IDC is US$ 0.786M.

13. The unit implementation cost will be reduced to $2420 per kW. The cost of energy from the project will be US cents 6.8 per kWh even with very stringent financing conditions.

14. The economic benefit cost ratio based on an economic price of 14.5 US cents per kWh (from alternative diesel set) shows the benefit cost ratio to be 2.32 (even for low initial demand).

15. The present average tariff charge by TANESCo in the area is about 7 US cents per kWh.

16. 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 14.5 GWh with 5% growth is 2.71. Hence developers will be interested as the project provides profit.

17. From the view point of the present state of power supply in the district, it is more desirable to implement a series of such small hydropower project close to the demand centre. The Stage 1 will be able to meet all of the capacity and energy demand of the town of Tunduru and other small villages.

18. The electric power produced at the stage 1 power station will be supplied to the new district grid and this will improve the electric supply demand and supply situations.

19. 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 1 project in late 2002. The project expenditure and size is such that it is suitable for being financed by local government to economically electrify the district.

20. 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.

21. 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.

22. 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.

23. The principal structures will be the diversion weir, intake structure, short waterway, powerhouse above ground and tailrace. No underground structures will be involved.

24. The power house will have two units of 1000kW tubular Kaplan turbines and produce 14.5 GWh of energy in an average year. The plant capacity factor is 82.75%.

25. The geological conditions for the various proposed structures are sound and have ample bearing capacity for all the structures.

26. The Tunduru district is very distant from Mbeya which has grid supply. It is also distant from Songea where hydropower supply is being planned. Hence extension of grid supply to Tunduru from either location will be uneconomical due to the small demand. Hence the proposed Muhuwesi cascade is ideally suited for meeting the demand of the district.

27. On the basis of the above, it is recommended that the stage 1 project be taken up for implementation soon, so as to provide rapid electrification in the area.

Chapter 16 Photographs, References, Acronyms

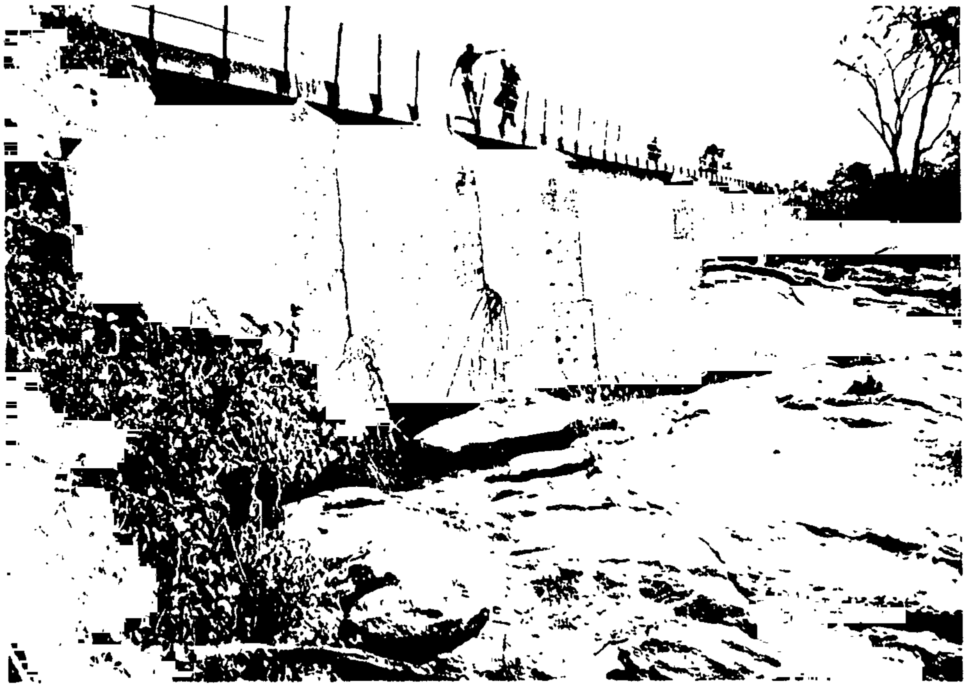


Photo 16-1: View of Muhuwesi bridge and gauge site 1Q4

(note the deep river channel)

Photo 16-2: Downstream view of Muhuwesi river from bridge

(note the significant flow even in the month of September)

Photo 16-3: Upstream view of Muhuwesi from bridge

(note the wide area available for storage)

◄ **Photo 16-4**: View of the diversion weir site

(note the rock which forms the banks and narrow river channel)

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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

Joint UNDP/World Bank

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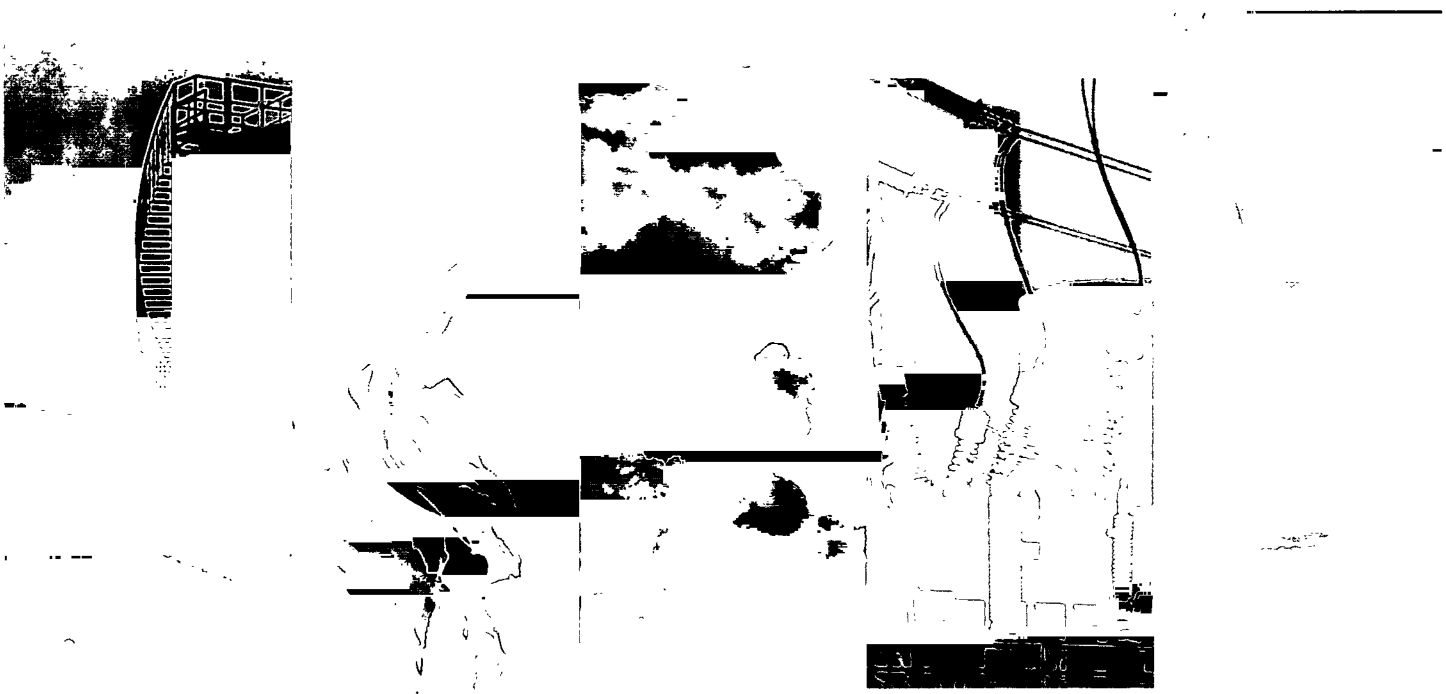

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