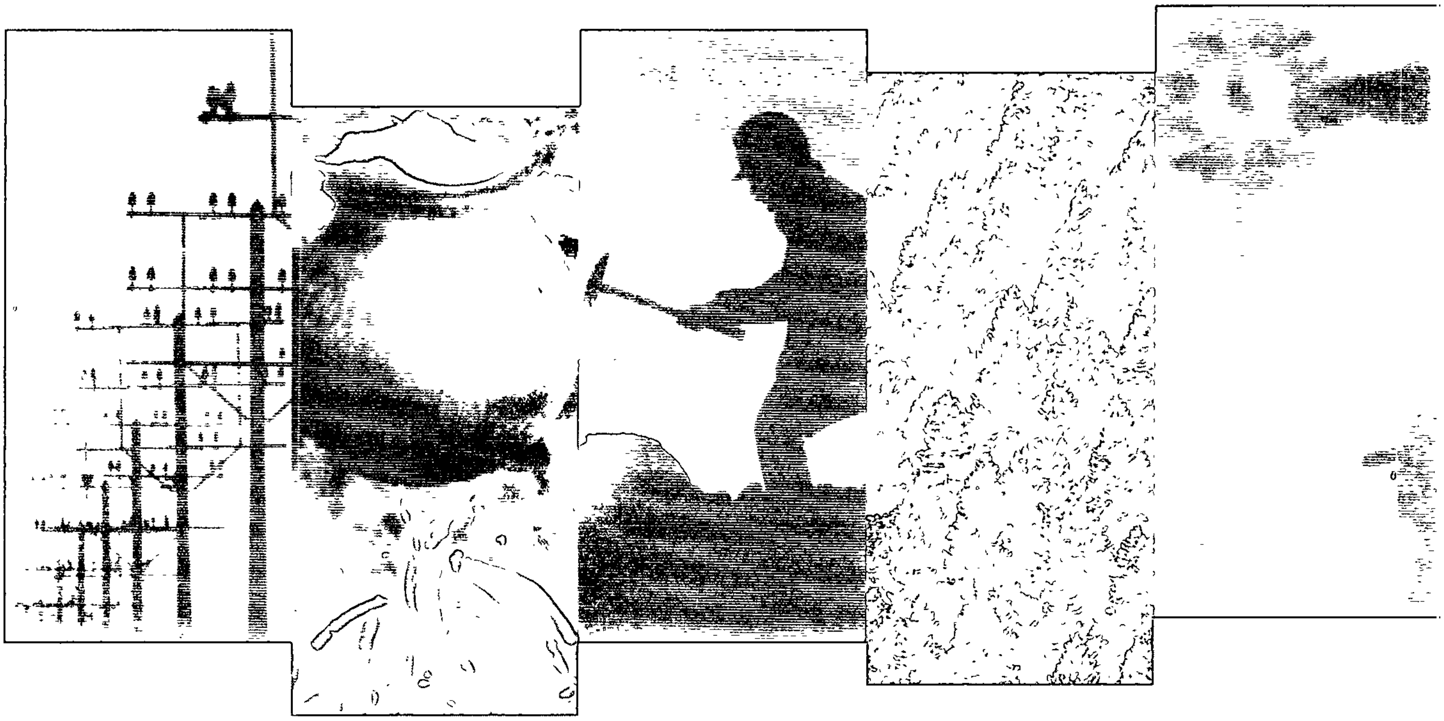
ESMAP TECHNICAL PAPER
024

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



Energy

Sector

Management

Assistance

Programme

April 2002

ESMAP

Papers in the ESMAP and EASEG Technical Series are discussion documents, not final project reports. They are subject to the same copyrights as other ESMAP publications.

JOINT UNDP / WORLD BANK

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance partnership sponsored by the UNDP, the World Bank and bi-lateral official donors. Established with the support of UNDP and bilateral official donors in 1983, ESMAP is managed by the World Bank. ESMAP's mission is to promote the role of energy in poverty reduction and economic growth in an environmentally responsible manner. Its work applies to low-income, emerging, and transition economies and contributes to the achievement of internationally agreed development goals. ESMAP interventions are knowledge products including free technical assistance, specific studies, advisory services, pilot projects, knowledge generation and dissemination, trainings, workshops and seminars, conferences and roundtables, and publications. ESMAP work is focused on three priority areas: access to modern energy for the poorest, the development of sustainable energy markets, and the promotion of environmentally sustainable energy practices.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (the ESMAP CG) composed of representatives of the UNDP and World Bank, other donors, and development experts from regions which benefit from ESMAP's assistance. The ESMAP CG is chaired by a World Bank Vice President, and advised by a Technical Advisory Group (TAG) of independent energy experts that reviews the Programme's strategic agenda, its work plan, and its achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank, and from the energy and development community at large, to conduct its activities under the guidance of the Manager of ESMAP.

FUNDING

ESMAP is a knowledge partnership supported by the World Bank, the UNDP and official donors from Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom. ESMAP has also enjoyed the support of private donors as well as in-kind support from a number of partners in the energy and development community.

FURTHER INFORMATION

For further information, a copy of the ESMAP Annual Report, or copies of project reports, etc., please visit the ESMAP website: **www.esmap.org**. ESMAP can be reached by email at **esmap@worldbank.org** or by mail at:

ESMAP
c/o Energy and Water
The World Bank
1818 H Street, NW
Washington, DC 20433
U.S.A.

JOINT UNDP/ESMAP

TANZANIA
KILIMANJARO REGION

PRE-INVESTMENT REPORT
ON
MINI HYDROPOWER DEVELOPMENT

CASE STUDY ON
THE KIKULETWA RIVER

FINAL REPORT
MARCH 2000

PREPARED BY

SECSD (P) LTD.

The International Bank for Reconstruction
and Development/THE WORLD BANK
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

Manufactured in the United States of America
First printing April 2002

ESMAP Reports are published to communicate the results of the ESMAP's work to the development community with the least possible delay. The typescript of the paper therefore has not been prepared in accordance with the procedures appropriate to formal documents. Some sources cited in this paper may be informal documents that are not readily available.

"ESMAP Values your Feedback

If you have found this report useful, or would like to provide comments on our reports and services, please log on to our website at **www.esmap.org** and leave your feedback. In this way we can better understand our audience's needs and improve the quality of our knowledge products. Thank you.

ESMAP Management"

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF BOXES

LIST OF PHOTOGRAPHS

Chapter 1 Executive Summary

Section 1 Introduction

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

The primary objective of the study is to look for economical and reliable alternatives for meeting the growing electric power demand in the Kilimanjaro, Kigoma, Rukwa and Ruvuma regions of Tanzania. These regions with the exception of Kilimanjaro are very remote and are not yet electrified by the national grid. The existing local grid supply in 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, implies that 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.

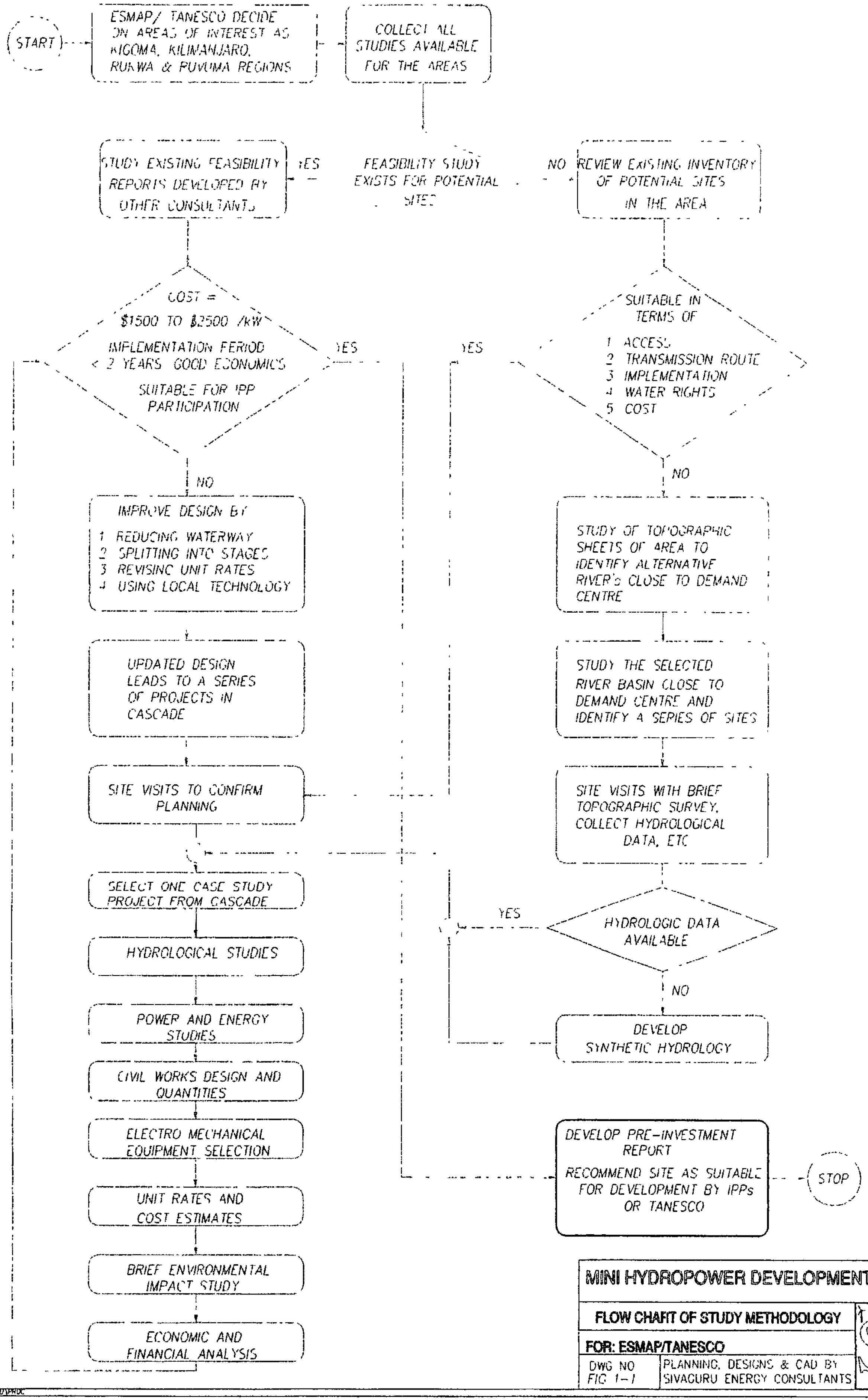
- Planning of power stations on a stream on isolated basis without doing planning of the entire stream or river basin.

- 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 exhaustively and reconnoitered well. Simultaneously, a total river basin development for

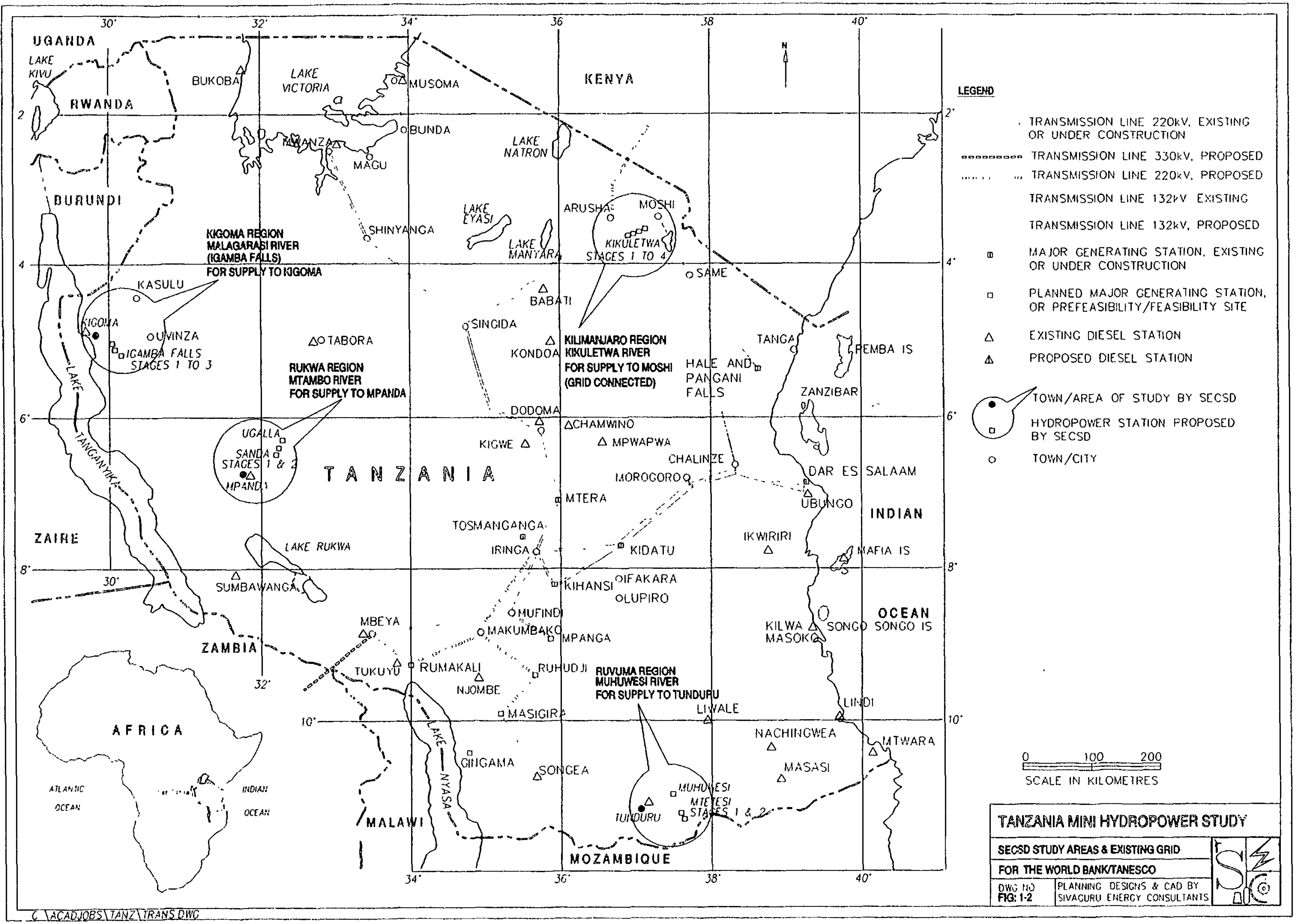


MINI HYDROPOWER DEVELOPMENT STUDY

FLOW CHART OF STUDY METHODOLOGY

FOR: ESMAP/TANESCO

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



TANZANIA MINI HYDROPOWER STUDY

SECSD STUDY AREAS & EXISTING GRID

FOR THE WORLD BANK/TANESCO

DWG NO **FIG: 1-2**

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

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

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

Many companies and industries in Tanzania have expressed interest in private sector participation in power. Some merits of this approach are

- the foreign exchange required can be met by equipment supplier's credit due to consortium formed between local companies and the supplier,
- Involvement of rural agencies and NGO's in management and administration,
- minimal cost overrun due to delays,
- efficient operation of the plant, adequate maintenance, committed project milestones and deadlines,
- the state utility is relieved of construction management and administration especially in distant and remote areas.

The main demerit faced by project's under private financing is the delay due to an understanding which needs to be reached between the many cooperating teams which may initially take a long time to achieve. Nevertheless, initiation of private sector involvement in power projects will set the stage for creating a legal framework that will attract lenders and investors. Tanzania's macro economic and political environment is stable, hence, with the current trend in promoting private sector involvement in many developing countries, it is necessary to initiate in Tanzania also, the involvement of the private sector initially in generation through small hydropower projects.

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

The Kilimanjaro region is one of the more developed regions in Tanzania with respect to infrastructure as compared to most of the other regions of the country. It is also served with good communications and is a very important tourist destination. There are also many industries in the vicinity of Arusha and Moshi which consume electric power for their production operations. As mentioned earlier, such industries have evinced keen interest in developing generation facilities using hydro resources and many companies are capable of financing the small hydro projects entirely or by forming consortia. Thus the region is suitable to demonstrate the participation of private sector in power generation. Participation may be started with the traditional BOOT approach which is the strategy adopted in many developing countries.

The most important consideration for a developer of a private power project is that the project is bankable or capable of being financed. The company which implements the project may be a newly established company which has no prior experience in hydropower or credit standing. This means that the project company will resort to non-recourse method as opposed to balance sheet financing used by state utilities. Investors in the project company will look towards the cash flow which the project will provide during operation as collateral. The project must also assure return on equity to participants. These constraints necessarily require that returns on investment must start accruing early, the rate of return must be sufficiently high, the returns must be stable which in turn depends on the hydrology of the selected river, load demand characteristics of the area, and the simultaneously tariff which the developer charges should be competitive. All of these imply that the project design should be simple, economical and easy to implement without cost overruns. In view of the foregoing discussion, this report effectively examines methods whereby the cost of installed capacity of a representative project in the Kilimanjaro region which was initially planned for development on conventional lines, has been reduced so as to make it attractive for private sector participation in its development. The main scope of this study has been to fix the basic project configuration which will not pose any delays and problems thereby making the project attractive to the private sector for development. This report will hence prove to be useful to potential developers as most of the preliminary project design and configuration have been fixed under this study to a sufficient detail. Thus it will be able to attract qualified developers who can quickly evaluate project needs and risks as they 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 to TANESCO.

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

Section 2 Project Area

A brief description of the project area with potential sites for hydropower development and the demand supply situation is given in chapter 2.

Section 3 Revised Planning

As previously mentioned, the original project configuration was modified to reduce the implementation cost and make it suitable for IPP participation. Hence, a description of the original project layout is given in chapter 3 and the revised layout as per SECSD is discussed in chapter 4. The original configuration had an unit investment cost of $4900 per kW and an energy cost of $0.072 per kWh even for a soft term loan financing in 1989 value. As per the revised approach the unit investment cost will be about $1291 per kW and energy cost $0.045 per kWh in 1999 value with project type loan from Financial Institutions. The project will hence be competitive and suitable for IPPs.

Section 4 Topographic Features and Surveys

The proposed intake dam is located about 3.5 km downstream of the existing Kikuletwa 1 power station and the proposed power station is a further 0.8km downstream. The topography of the intake dam site consists vast flat tableland. At the diversion site, both banks of the river are near vertical cliffs which rise high above the river bed with a maximum elevation of about 830m. The river has cut a deep V shaped valley and the river gradient downstream of the proposed diversion site is 1:50.

The detailed topographic survey on 1:5000 scale has already been performed for a considerable stretch of the river from the existing Kikuletwa 1 power station for a distance of nearly 10km downstream. This data is adequate for the revised planning and no further aerial mapping is required. 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 rocks of Kikuletwa project area are volcanic rocks. The rocks are thought to be mainly from the activity of the Kibo peak of Mt. Kilimanjaro. These lavas mainly consist of phoripory such as tranchyandesite, trachyte, phonolite and Lahar. The Lahar is reddish brown and well consolidated. The former consists of dark gray tuff breccia overlain with limestone. The Lahar is referred to as Tuff Breccia 1 and the phoripory is referred to as Tuff Breccia 2. The tuff Breccia 2 was subsequently subjected to the sedimentary action of limestone. During volcanic activity Tuff Breccia 1 flowed and settled over 2.

The reservoir will have a maximum depth near the diversion site of 20m The reservoir will be formed in an area composed chiefly of Tuff Breccia and limestone. Tests made on the permeability in the vicinity of the project, drilling performed earlier has revealed that the rock masses are fresh and hard and the permeability of the rock is 10^{-5} cm/sec. All structures will be located on Tuff Breccia 2.

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 Kilimanjaro region has more rainfall than most of the semi arid regions of Tanzania. The annual rainfall varies from 1800mm on higher slopes of Mt. Kilimanjaro to 500mm in the plains below. The river Kikuletwa is formed by several rivulets, the important ones being Usa, Sanya and Kware. The river basin is composed of the products of volcanic activity from the summits of Kilimanjaro and Meru. These volcanic rocks are highly permeable. Significant amount of rainfall enters the strata and emerges from springs in the area. There are light rains in the months November and December followed by heavy rains from March to May. The main runoff observation data which is available is that from site IDD-54 which is located about 300m downstream from the existing Kikuletwa 1 power station. The drainage area intercepted at this station is 2,220 sqkm. The flow at this station includes the runoff from the catchment of Kikuletwa contributed by Mount Meru, Kilimanjaro and the flow from the springs in the area. The measured flow is presented in Annexure-A. The average run off for the period 1969 to 1993 is 14.30 cumecs. A continuous period of ten years wherein data is not missing is taken to be representative of the hydrological cycle. This is the period 1968 to 1979. In this period are identified a set of extreme flow conditions which are least flow, maximum flow and mean flow. These are termed as dry, wet and mean hydrological years. The daily flow data for these years is presented as flow duration curves. From the curve it is seen that the Kikuletwa river has a base flow of 10 cumecs throughout the year. The shape of the curves are different for each type of hydrological year. A more detailed treatment is given in chapter 7. Also discussed are climatology, flood studies and sedimentation.

Section 7 Power and Energy Studies

The diversion site is located about 3km downstream of the gauge site IDD54. As no major stream or tributary joins Kikuletwa in this reach, the flow at gauge site is taken to be the inflow at the diversion site.

The 1:5000 topographic survey maps have been used to work out the reservoir area and capacity curves.

The average annual continuous flow at the diversion weir site is 14.31 cum/sec.

The year in which the mean flow is close to this is 1971 with a mean flow of 14.30 cum/sec and a corresponding annual yield of 451.11 MCM. Thus the year 1971 is a mean hydrologic year. Similarly the year with maximum yield is 1979 with a mean annual flow of 25.8 cum/sec and yield of 813.3 MCM and the year with the least annual flow is 1976 with a flow of 11.42 cum/sec and yield of 360 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 5.5 MW. The detailed working tables are given in the Tables 8-1, 8-2 and 8-3.

Box 1-1 Summary of Energy Outputs

Installed Capacity (MW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
1 x 4	36.0	81.9	55.9
1 x 6	54.1		
2 x 4	59.7		
2 x 5.5	65.1		
2 x 6	66.2		

From the results of the study, it has been decided that the power plant will have 2 units of 5.5 MW each. Most of the years have flow equal to or greater than the average year in the spell 1969 to 1979, thus 65GWh is assured. In a wet year the energy output rises to about 82 GWh and falls to 56 GWh in a dry year.

The computations were performed with a computer program which models all the main features of the power plant and accounts for all items such as 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 are plotted for head of 63m and efficiency of 90%. The most optimal installation is 2 x 5.5 MW which gives 65GWh per annum. There is scope for overload capacity and hence 2 x 6MW is also considered. These aspects are dealt with in detail in chapter 8 with the methodology used for predicting the power and energy output of the plant in each of the above hydrological years with variation of typical parameters such as reservoir levels, net heads, losses etc presented graphically.

Section 8 Civil Works

The Kikuletwa hydropower project requires

- Improvement to existing 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 conveys 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 and tailrace and their outline drawings

Part I **Access Road.**

There are existing roads to the project site, but not in good condition. Hence these roads will have to be upgraded. The access to the power house site will be from the left bank.

Part II **Diversion Weir.**

This will be a concrete structure founded on the rock. It will be ungated and the crest will be at 805m. The crest length of the diversion weir is about 40 m. The elevation of the non overflow section is 812.5m. An arch/gravity dam is considered as the abutments are sound rock. They could also be improved through rock anchors, guniting and or shotcreting. The selected site is very narrow and it is also suitable for an arch dam. This alternative will be very economical as concrete volume required is reduced to 30% of the gravity dam. However suitable treatment of the abutments are required.

Part III **Intake and Waterway.**

A cut and cover conduit of "D" section with 2.5m base width and 325m length will be provided. The maximum flow in the conduit is to be 20.0 cumecs. In view of the short length and the proximity of the reservoir, wave surges will not be a problem. A bifurcation is installed at the end. Two 1.5 m diameter steel penstocks are to be laid to convey the water to the power station located near bed level 740m.

Part IV Power House.

The power house will be of surface type. It is designed as a circular well. It will accommodate two vertical shaft Francis turbine generator units and all their auxiliaries. A service bay will be provided. The Kikuletwa river widens at bed level 740m. Hence the space available for construction of the power station in the gorge is adequate and access will not be difficult.

Part V Tailrace

The tailrace will be an open channel which joins the river bed. 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 740.0m.

Section 9 Electromechanical Equipment

The turbines with accessories and generators form the electro mechanical equipment. The power station will house two vertical shaft Francis turbines with steel spiral cases. The runner diameter will be 1000mm. The turbines will be coupled to synchronous three phase generators. The design flow through the turbines will be 10 cumecs each. The generators will be rated at 6.5 MVA each. The turbines and generator are direct coupled. The speed of the set is 600 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 33kV by outdoor transformers. The envisage transmission scheme is to construct a 14.5km 33kV line from the power station to the existing Kiyungi substation. 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 manufacturers. 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$12.3 million as compared to the estimated US$49 million in 1989. 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 will be connected to the existing grid which has shortfall in capacity and energy, all the energy produced can be readily utilized by existing consumers and hence revenues will not be limited by future demand growth patterns. The economic and financial analysis are hence identical as the value of the energy produced from the project should be fixed at the price of obtaining energy from the grid. It is also not necessary in this case to compare the project with an alternative diesel set to obtain the economic value of energy.

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

Based on this, the Benefit cost ratio of the project is found to be 5.76. 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. 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 will not exceed 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 on the southern slope of Mount Kilimanjaro which consists of vast gently undulating plains. On the left bank is Rundugai village where paddy and other crops are grown in patches. Apart from this, the main vegetation in the area consists of a sparse distribution of various thorny plants and other bushes. The right bank is less developed and is wild with a similar natural vegetation.

The construction of the Kikuletwa 3 power station will have no negative impact. As the diversion scheme is very short, the length of the river wherein flow will be reduced is less than one kilometer. Moreover there is no human settlement in this diverted stretch which may require water. The construction of the 20m high dam in the narrow gorge will confine the reservoir to the gorge and hence no farm, plantation, or house will be submerged. 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 as per the previous consultants report are wild pigs, deer and hyenas. The main components of the power plant are all located close together and construction activity is confined to a small area. The area in the immediate vicinity of the project is uninhabited and is wilderness. Consequently no land will need to be acquired by paying compensation. A simple walkway can be provided across the diversion weir for the local people to easily cross the river.

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 diversion weir site, lake spread, power house area 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 size IDD54 for the years 1967 to 1993 is presented. The data is then presented graphically as per the following charts and figures.

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

30 day Runoff depth and volume with mass runoff.

30 day average specific discharge.

Bar chart representation of runoff with logarithmic scale.

Annual Mass runoff.

30 day minimum observed flows for the period 1967 to 1993 with the maximum, minimum, mean, volume and runoff values for each month.

30 day maximum observed flows for the period 1967 to 1993 with the maximum, minimum, mean, volume and runoff values for each month.

30 day mean observed flows for the period 1967 to 1993 with the maximum, minimum, mean, volume and runoff values for each month.

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

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

Flood hydrographs for each year and the recession curve.

Annexure-B: Flood Studies

From the observed historic flow data, the expected maximum flow magnitude in a specified period (e.g instantaneous, 1 day, 3 day etc) for a specified recurrence interval (100 year, 1000 year) is calculated by various empirical, statistical and analytical. The results are used to fix the capacity of the spillway.

Annexure-C Low Flow Studies

From the observed historic flow data, the expected minimum flow magnitude in a specified period (e.g instantaneous, 1 day, 3 day etc) for a specified recurrence interval (100 year, 1000 year) is calculated. The results can be used to evaluate the minimum flow and hence dependable capacity of the power station.

Annexure-D Morphological Properties

This volume presents the morphological properties of the Kikuletwa river basin. It is mainly presented so that further hydrological studies can be prepared to extend and build up hydrology for the various streams in the region by use of these methods which are now gaining acceptance.

Chapter 2 Overview of Project Area

Section 1 *General*

The Kilimanjaro region is one of the most important regions in the United Republic of Tanzania. The region is spread along the southwest to southeast skirt of the 5895m high Mount Kilimanjaro which is permanently snowcapped. The region is bordered by Arusha region on the West, Tanga on the East and by Kenya in the north. Apart from Mount Kilimanjaro, Kilimanjaro National park in the north and Mkomazi Game Reserve in the south are important tourist attractions. Access to the region is possible by railway, road or air. Kilimanjaro International airport is located in the region and is important for tourism industry. The important load centers are Moshi town which is the regional capital and Arusha which is the capital of Arusha region and is about 80km west of Moshi. The area is well populated especially on the lower slopes of Mount Kilimanjaro and Mount Meru due to good climatic conditions. The map of the region is given in figure 2-1.

Section 2 *Demand Supply Situation*

Prior to 1987, the region was dependent for its electric supply on the Kikuletwa No.1, Nyumba ya Mungu and Old Pangani hydropower stations. A diesel plant was located in Arusha town which has now been retired from service. Due to many industries which have developed in the area and good economic growth, the load growth in the area was correspondingly rapid and hence to meet the demand, a 132 kV line was constructed from Same to Arusha via Moshi as shown in figure 1-2. The growing load demand was thus met by the Kidatu power station and the power had to be transmitted over a distance of 700km with consequent transmission loss and poor voltage regulation. With the rehabilitation of Hale (1987-88) and redevelopment of Pangani (1995) hydropower projects, the operating conditions were improved. A 220kV link has been established between Singida and Arusha with a connection planned to Kenya in the future. This will transmit power to the region from Mtera and Kihansi power stations which are distantly located in the heart of Tanzania.

Even though the average precipitation in this region is quite low, the area is drained by numerous streams and rivers which flow down the slopes of Mount Kilimanjaro and Mt Meru. These streams have the characteristic of stable flow throughout the year due to snow melt at the peaks, good precipitation at higher altitudes and the presence of many springs. One of the main rivers formed by joining of these streams is the Kikuletwa river which flows east at the foot of the Kilimanjaro and then south through a vast arid plain. After joining the Ruvu river, it is known as the Pangani and it empties into the Indian Ocean south of the town Tanga. The river basin has already been partly developed for hydropower and existing and planned generating plants on this river are given below in box 2-1.

Box 2-1 Existing and Planned Projects in the Basin.

Project	Capacity (kW)	Energy (GWh)	Remarks
Kikuletwa No.1	1160	Nil	Damaged in 1990.
Kikuletwa No.2	11000	67	Feasibility study by JICA in 1989.
Nyumba ya Munga	8000	48	Irrigation project.
Buiko	21000	-	Reconnaissance study completed
Mandera	21000	112	Feasibility Study completed
Hale	21000	143	Rehabilitated
Old Pangani	21000	-	Operates in years with surplus flow
New Pangani	66000	305	Completed in 1994.
Arusha Diesel	1500	Nil	Retired from service

The Pangani and Hale stations which are by far the most reliable supply options, are far from the Arusha and Moshi areas. It is estimated that the transmission loss entailed in supplying Arusha and Moshi is 6 to 7 MW with an energy loss of about 40 GWh per annum. This represents a significant loss in the system. Any hydropower station in close vicinity to these demand centers will considerably improve operating conditions.

The existing power and energy supply demand balance for the Arusha, Kilimanjaro and Tanga regions is given in tables 2-1 and 2-2. It can be seen that Kikuletwa river projects need to be implemented very soon as otherwise the region has to be supplied with power from the 132kV grid over a distance of 300km which entails losses. The 220kV connection with Singida also involves transmission from Mtera over a distance of nearly 500km.

TABLE 2 1
POWER DEMAND AND SUPPLY BALANCE FOR ARUSHA KILIMANJARO AND TANGA REGIONS

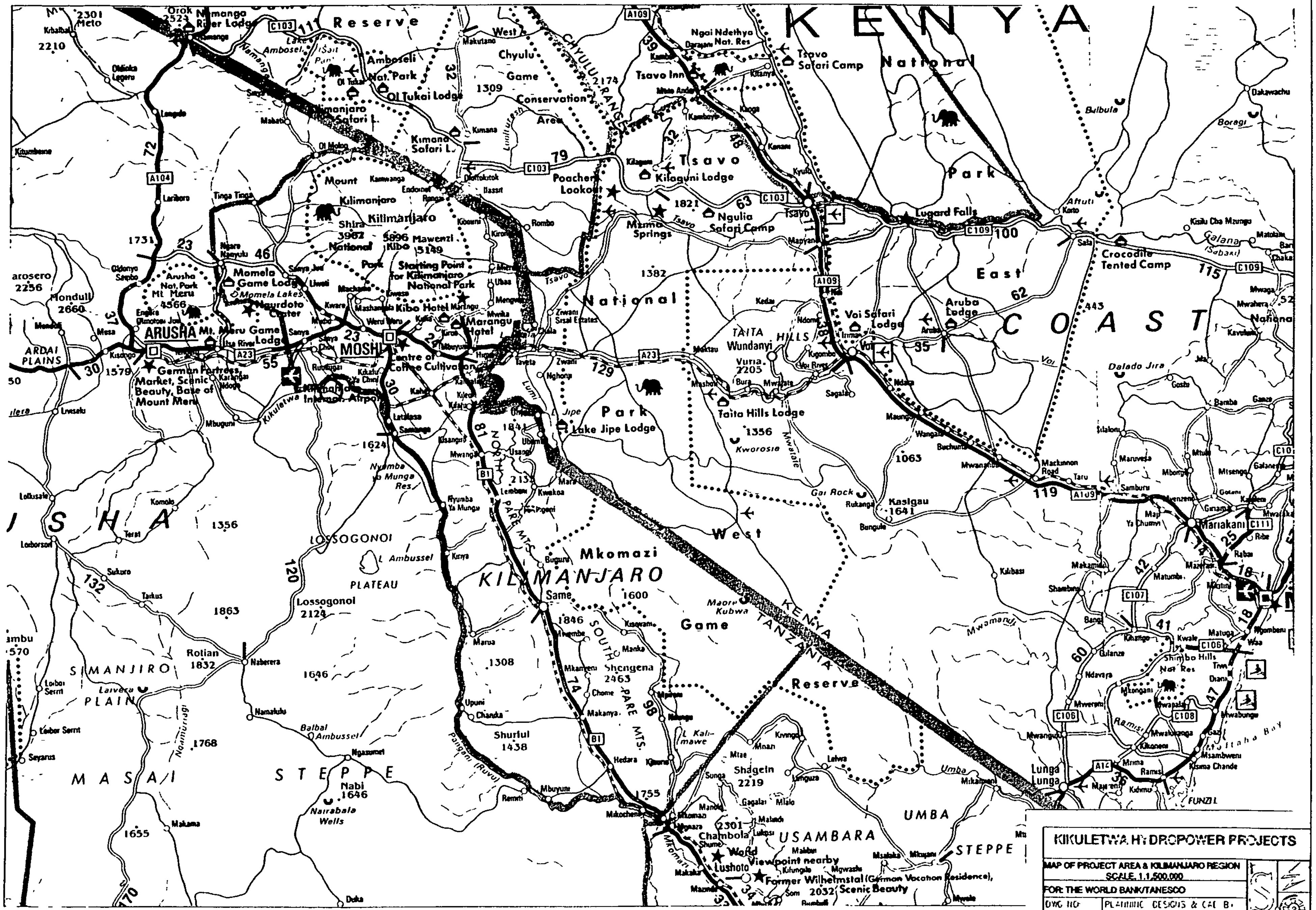
SL	ITEM	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	Maximum power demand (MW)																			
	Arusha	17 3	18 1	19 1	20 4	23 5	24 6	25 7	26 0	28 2	29 2	30 9	32 3	33 8	35 8	37 1	38 8	40 6	42 4	44 4
	Moshi	11 4	12 0	12 7	13 6	15 8	16 5	17 3	18 1	18 9	19 8	20 7	21 7	22 7	23 8	24 9	26 0	27 2	28 5	29 8
	Tanga	25 7	26 7	28 3	30 2	34 9	36 6	38 3	40 0	42 0	43 9	46 0	48 1	50 4	52 7	55 1	57 9	60 3	63 1	66 0
	Aggregated total	54 4	56 8	60 1	64 2	74 2	77 7	81 3	85 1	89 1	93 2	97 6	102 1	106 9	111 9	117 1	122 5	128 1	134 0	140 2
(A)	***Coincident peak load (MW)**	51 1	53 4	56 5	60 3	69 7	73 0	76 4	80 0	83 8	87 6	91 7	96 0	100 5	105 2	110 1	115 2	120 4	126 0	131 8
	Existing supply capability (MW)																			
	Arusha (Diesel)	3 4	3 4	3 4	3 4	3 4	3 4	3 4		-	-	-	-	-	-	-	-	-	-	-
	Kikuletwa No 1	0 5	0 5	0 5	0 5	-	-	-		-	-	-	-	-	-	-	-	-	-	-
	Nyumba Ya Mungu	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0	8 0
	Hale	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0	17 0
	Old Pangani Falls	17 5	17 5	17 5	17 5	17 5	-	-		-	-	-	-	-	-	-	-	-	-	-
	Pangani Falls Redevelopment	-	-	-	-	-	-	-	-	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0
(B)	**Existing total (MW)**	46 4	46 4	46 4	46 4	45 9	28 4	28 4	25 0	91 0	91 0	91 0	91 0	91 0	91 0	91 0	91 0	91 0	91 0	91 0
(C)	Balance (B) - (A)	-4 7	-7 0	-10 1	-13 9	-23 8	-44 6	-48 0	-55 0	7 2	3 4	-0 7	-5 0	-9 5	-14 2	-19 1	-24 2	-29 4	-35 0	-40 8
	Planned new projects (MW)																			
(D)	Mandera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21 0	21 0	21 0	21 0
(E)	Balance (C) + (D)	-4 7	-7 0	-10 1	-13 9	-23 8	-44 6	-48 0	-55 0	7 2	3 4	-0 7	-5 0	-9 5	-14 2	-19 1	-3 2	-8 4	-14 0	-19 8
	Proposed new projects (MW)																			
	Kikuletwa No 1 rehabilitation															2 0	2 0	2 0	2 0	2 0
	Kikuletwa Stage 2															11 0	11 0	11 0	11 0	11 0
	Kikuletwa Stage 3															2 0	2 0	2 0	2 0	2 0
	Kikuletwa Stage 4															2 0	2 0	2 0	2 0	2 0
(F)	**Total**	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	17 0	17 0	17 0	17 0	17 0
(G)	**Balance (E)+(F) (MW)**	-4 7	-7 0	-10 1	-13 9	-23 8	-44 6	-48 0	-55 0	7 2	3 4	-0 7	-5 0	-9 5	-14 2	-2 1	13 8	8 6	3 0	-2 8

Note * Calculated using a diversity factor of 0 94

TABLE 2 2
ENERGY DEMAND AND SUPPLY BALANCE FOR ARUSHA KILIMANJARO AND TANGA REGIONS

SL	ITEM	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	Energy consumption (GWh)																			
	Arusha	70 42	73 81	78 09	83 09	87 19	91 29	95 58	100 05	104 73	109 62	114 73	120 07	125 65	131 48	137 57	143 94	150 60	157 55	168 82
	Moshi	45 53	47 83	50 74	54 13	56 92	56 59	62 31	65 31	68 37	71 56	74 89	78 38	82 02	85 83	89 81	93 96	98 31	102 85	107 59
	Tanga	89 34	93 85	99 56	6 22	111 41	116 65	122 12	127 85	133 82	140 07	146 60	153 42	160 55	168 00	175 79	183 93	192 43	201 31	210 60
	Total Consumption	205 29	215 49	228 39	143 44	255 52	264 53	280 01	293 21	306 92	321 25	336 22	351 87	368 22	385 31	403 17	421 83	441 34	461 71	487 01
(A)	**Required energy generation***	301 90	316 90	335 87	359 00	375 76	390 43	411 88	431 19	451 35	472 43	494 44	517 46	541 50	566 63	592 90	620 34	649 03	678 99	716 19
	Existing supply capability (GWh)																			
	Arusha Diesel	4 75	4 75	4 75	4 75	4 75	4 75	4 75								-	-	-		-
	Kikuletwa No 1	3 50	3 50	3 50	3 50	-		-	-	-						-		-	-	-
	Nyumba Ya Mungu	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00	48 00
	Hale	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00	143 00
	Old Pangani Falls	110 00	110 00	110 00	110 00	110 00			-							-	-	-	-	-
	Pangani Falls Redevelopment									305 00	305 00	305 00	305 00	305 00	305 00	305 00	305 00	305 00	305 00	305 00
(B)	**Existing total (GWh)**	309 25	309 25	309 25	309 25	305 75	195 75	195 75	191 00	496 00	496 00	496 00	496 00	496 00	496 00	496 00	496 00	496 00	496 00	496 00
(C)	Balance (B) (A)	7 35	-7 65	-26 62	-48 75	70 01	-197 68	-216 13	-240 19	44 65	23 57	1 56	-21 46	45 50	-70 63	-96 90	-124 34	-153 03	-182 99	-220 19
	Planned new projects (GWh)																			
(D)	Mandera																112 00	112 00	112 00	112 00
(E)	Balance (C) + (D)	7 35	-7 65	-26 62	-48 75	-70 01	197 68	-216 13	-240 19	44 65	23 57	1 56	21 46	-45 50	-70 63	-96 90	-12 34	-41 03	-70 99	-108 19
	Proposed new projects (GWh)																			
	Kikuletwa No 1 Rehabilitation															11 82	11 82	11 82	11 82	11 82
	Kikuletwa Stage 2															11 82	11 82	11 82	11 82	11 82
	Kikuletwa Stage 3															65 00	65 00	65 00	65 00	65 00
	Kikuletwa Stage 4															11 82	11 82	11 82	11 82	11 82
(F)	**Total**	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	100 46	100 46	100 46	100 46	100 46
(G)	**Balance (E) + (F) (GWh)**	7 35	-7 65	-26 62	-48 75	-70 01	-197 68	-216 13	-240 19	44 65	23 57	1 56	-21 46	-45 50	-70 63	3 56	88 12	59 43	29 47	-7 73

Note * Energy loss factor of the above regions in 1986 is calculated to be 32% as shown below
This factor was used for this study



KIKULETWA HYDROPOWER PROJECTS

MAP OF PROJECT AREA & KILIMANJARO REGION
SCALE. 1:1,500,000

FOR: THE WORLD BANK/TANESCO

DWG NO:
FIG: 2-1

PLANNING DESIGNS & CAD BY
SUACURU ENERGY CONSULTANTS

c:\acad\proj\tanz\kil-map

Chapter 3 Review of Previous Proposals (JICA)

Section 1 General

In 1989, The Japan International Cooperation Agency (JICA) carried out a feasibility study on development of mini hydropower in the region. The study explored and ranked nine sites identified previously by TANESCO which are given in table 3-1. As can be seen from the table, the Benefit Cost ratio of the potential project's is very low and implementation is not worthwhile. The study finally recommended a rehabilitation of the Kikuletwa No. 1 station and the construction of a new power station called Kikuletwa No. 2 downstream of the existing Kikuletwa No. 1 power station. An outline of the Kikuletwa No. 2 project as proposed by JICA is given in figures 3-1 and 3-2.

Section 2 JICA Project Features

The main project features of the proposed project were

1. A concrete dam of 13m height and 105m crest length on the Kikuletwa river which creates a regulating pond of 209,000 m^3. The high water level is 817m. The dam is to be located about 2.2 km downstream of the existing Kikuletwa No. 1 power station.

2. An intake structure which admits water to a 2250m long headrace culvert built on the left bank.

3. The headrace culvert is followed by a 1050m long open canal which conveys water to a forebay.

4. From the forebay, a surface penstock of 2.6m diameter descends on the steep banks of the Kikuletwa river to the power house located adjacent to the river. The length of the penstock is 835m.

5. The total length of waterway works out to be about 5 km.

6. The total gross head available is 86.1m and the available net head for the power station was 78.20m, with FSL of 817m and TWL of 730.9m. The maximum flow was fixed at 17.90 cumecs.

7. The power house would consist of two vertical shaft Francis turbines coupled to synchronous generators rated at 5800 kVA.

8 The generated power was to be transmitted by a 33kV double circuit transmission line between Kikuletwa 2 and the Kiyungi substation. The length is 14km.

9. The implementation cost in 1989 was USD 49.4 million and the period required for construction is 48 months. The estimated cost of the installed capacity was $4,490 per kW. The cost components of the project are given in Box 3-1.

10. The annual energy output from the scheme was predicted to be 67.8 GWh. At 10% annual costs the cost of energy would be 7.28 cents per kWh.

11. The Benefit Cost ratio of the project was calculated to be 1.174 as compared to alternative thermal generation using a discount factor of 10%.

Box 3-1: Implementation Cost of JICA's proposal

Work Item	Local MUS$	Foreign MUS$	Total MUS$
Preparatory Works			
Access Road	0.915	2.135	3.050
Camps	0.800	3.200	4.000
Miscellaneous	0.350	1.050	1.400
Civil Works			
Dam and Intake	0.220	1.252	1.472
Headrace	1 768	9.848	11.616
Head Tank	0.110	0.710	0.820
Penstock	0.216	1.401	1.617
Power House	0.240	1.576	1.816
Miscellaneous	0.200	0.800	1.000
Hydraulic Equipment	0.143	2.362	2.505
Electro-mechanical Equipment	1 073	9.657	10.730
Transmission	0.160	0 640	0.800
Administration and Engg	0 620	3 463	4.083
Contingency	0 682	3 809	4.491
Grand Total	7.497	41.903	49.400

The expected disbursement schedule of the funds during the construction period is given in box 3-2.

Box 3-2: Funds Disbursement schedule

Year-1	Year-2	Year-3	Year-4
28.70%	31.24%	25.06%	15.0%

The study calculated the economic benefit of the project as the present worth obtained by discounting all costs of an equivalent diesel station minus that of the proposed hydro. The result is given in Box 3-3.

Box 3-3: Economics of JICA's proposal

PRESENT WORTH	KIKULETWA 2	DIESEL POWER PLANT
Investment	32 112	9.259
Operation and Maintenance	5.136	3.452
Fuel Cost		25.708
Lubricating Oil Cost		5.321
Total Cost	37.248	43.741

Thus Surplus Benefit obtained by implementing hydro over thermal was shown to be 6.493 M USD. Hence the Benefit Cost was calculated to be 1.174.

The economic values of the benefit cost ratio for different installed capacities are given in box 3-4.

Box 3-4 Variation of B/C versus capacity

Capacity (kW)	12700	11000	9300	8500
Energy (GWh)	67.30	67.09	64.50	63.29
B/C	1.150	1.174	1.153	1.148

The financial analysis of the project studied two major sources of funds for implementation. The first was a Government based soft loan from a cooperating country and the second being a Commercial project loan from an International

Financial Institution. The following are the conditions assumed for each of the two financing options.

- Foreign Government Loan with an Interest Rate of 1.5% p.a, repayment period of 30 years with a ten year grace period.
- International Financial Institution Project Loan with an Interest Rate of 7.64% p.a, repayment period of 15 years with a five year grace period.

For the above cases, the rate of return was computed as shown in box 3-5.

Box 3-5: Financing Alternatives and Rate of Return

Item	Foreign Government Loan	International Financial Institution
Initial Investment	49.400	49.400
Interest During Construction	1 636	8.335
Total	51.036	57.735
Depreciation Cost	1.020	1.154
Net Income	57 404	27.041
Rate of Return	5 58%	2.22%

The project was however not implemented. The primary reason was probably inability to secure the requisite funds. The economic and financial analysis also appear to be far from satisfactory. In fact the feasibility study itself recommended implementation of the project with the help of a soft term government to government loan from a cooperating country. With the conventional funding from an International Financial Institution, the cash flow during the loan period was shown to be negative. Also the corresponding rates of return were very low. The following are extracts from the report.

Page 13-5:
"Hydro power plant construction requires a large investment, while the turn-over ratio of the total assets is low. It is therefore desirable that construction be financed at a low interest rate and with a long repayment period..."

Page 13-7 a)
"For the case of the foreign government loan, the cash balances for both projects (Kikuletwa No.1 and 2) will be favorable every year from commissioning...."

Page 13-7 b)
"In the case of the International financial institution project loan, the cash balances for both projects will show deficits every year throughout the repayment period...."

Page 13-7 c)
"The project is financially justifiable based on the equalizing discount rates and on the rates of return. However, the financial burden will be very large if the required funds are financed by loans from International Financial Institutions. It is recommended that the project be financed by a government to government based soft term loan from a cooperating country."

Section 3 SECSD Observations

The above discussion clearly rules out implementation by TANESCO, the participation of IPPs and even funding from World Bank. Another point to be noted is that the Benefit Cost ratio compared to an alternative diesel station is only 1.174 thereby favoring the thermal alternative.

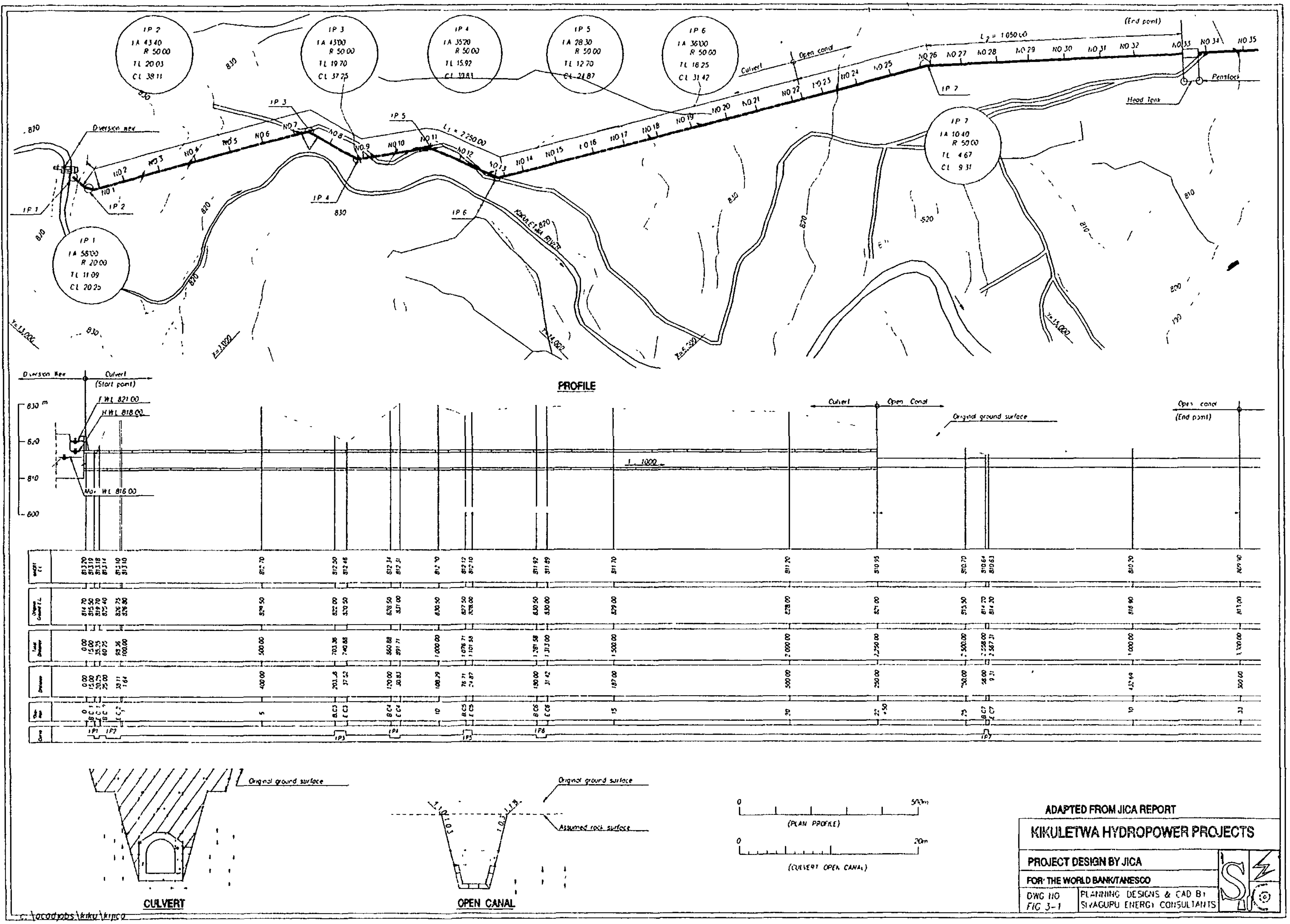
A study of the cost components in Box 3-1 shows that the cost of water conductor system (Head race, Head tank, Penstock) is US$ 14.053 M or 28.5% of the total cost, The cost of Administration, Engineering and Contingencies is US$ 8.5M, and expenditures on Access, Camps and Miscellaneous is US$ 8.45 M. Thus a total of about US$31 M or 62% of the cost is spent on items which can be considerably reduced if design is simplified so that project execution period is reduced.

In updating the above feasibility study, 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 chapter four and elaborated further in the remainder of this report.

TABLE: 3-1
SUITABLE SMALL HYDROPOWER SITES IN THE KILIMANJARO REGION

SL	PARTICULARS	UNIT	Kikuletwa No 1 Rehabilitation	Kikuletwa No 2	Himo No 1 Rehablitation	Himo No 2	Bombo Rehabilitation	Hingilili	Ndungu	Hindi	Gulutu
1	Name of river		Kikuletwa	Kikuletwa	Himo	Himo	Hinigilili	Hingilili	Yongoma	Sesseni	Sesseni
2	Catchment area	sqkm	2,200	2,280	174	183	1 8	53 5	57	181 3	190
3	Annual inflow	MCM	410	421	52	54 6	0 56	28 3	30 1	64 3	67.4
4.	H W.L	m	830.47	818 00	1,025 5*	885 00	1470 00	900 00	1071 00	690 00	600 00
5	Headrace length	km		3.20	1 00	1 60	0 40	0 40	0 90	1 80	1 00
6	Penstock length	m	20.00	834 50	82 00	200 00	400 00	1600 00	1100 00	120 00	220.00
7	T W L	m	817.40	730.90	954 20	837 00	1380.00	585 00	532 00	617 00	545 00
8	Gross head	m	13.07	87.10	71.20	48 00	90 00	315.00	539 00	73 00	55 00
9.	Effective head	m	12.70	78.20	67 60	43 70	84 50	299.00	512.00	67 00	51.20
10.	Max discharges	m3/s	15.40	17.90	0.43	0.43	0 09	0 80	1 00	0 96	1 00
11.	Firm discharge	m3/s	10.53	17.90	0.13	0 14	-	0.12	0.15	1.24	0 25
12.	Type of turbine		S-Type Tubular	Francis	Cross Flow	Cross Flow	Cross Flow	Pelton	Pelton	Francis	Francis
13.	Installed capacity	kW	1,500	11,000	220	140	50	1,830	3,940	480	380
14.	Frim capacity	kW	1,055	11,000	66	43	0	270	575	120	96
15.	Annual Energy	GWh	10.53	67.09	1.49	1 02	0.06	10.00	21.50	3 60	2.90
16.	Transmission line length	km	-	9.00	1.00	1.50	0.50	1.00	13.50	17.00	12.00
17.	Total project cost	MUS$	7.20	49.40	1.07	3.71	0.44	9.56	16.29	7.29	5.11
18.	Energy Cost	US$/kWh	0.68	0.73	0.69	2.43	7.08		0.73	1.83	1.61
19.	Benefit / cost ratio		1.27	1.17	1.08	0.21	-	0.70	0.87	0.34	0.39
20.	EIRR	%	13.30	12.30	11.30	less than 0.1		6.63	8.52	0.96	1.97

Note : * High water level at head tank.



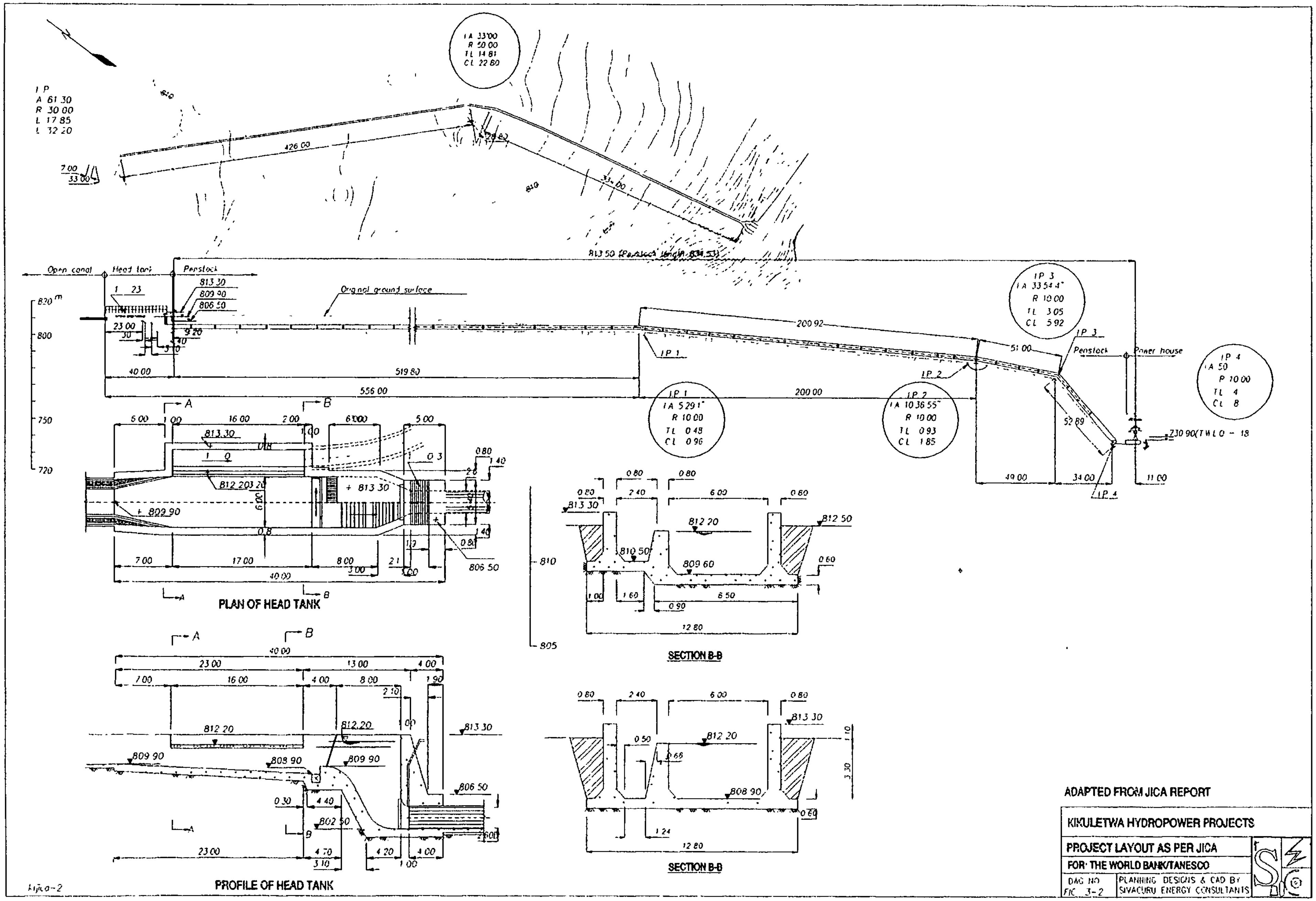
ADAPTED FROM JICA REPORT

KIKULETWA HYDROPOWER PROJECTS

PROJECT DESIGN BY JICA

FOR: THE WORLD BANK/TANESCO

DWG NO FIG 3-1	PLANNING DESIGNS & CAD BY SIVAGUPU ENERGY CONSULTANTS



PLAN OF HEAD TANK

SECTION B-B

PROFILE OF HEAD TANK

SECTION B-B

kijica-2

ADAPTED FROM JICA REPORT

KIKULETWA HYDROPOWER PROJECTS

PROJECT LAYOUT AS PER JICA

FOR: THE WORLD BANK/TANESCO

DWG NO FIG. 3-2

PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

Chapter 4 Revised Layout of the Project (SECSD)

Section 1 *General*

The feasibility study by JICA was exhaustive and led to the assimilation and analysis of important and useful topographic, geological and hydrological data which was useful for the present study. The main topographic data is the aerial photography of the project area and ground surveying by TANESCO from which were constructed maps in 1:5000 scale of the Kikuletwa river from the existing stage-1 diversion weir for a stretch of six kilometers downstream.

Section 2 *Revised Layout*

Part I Planning

The above topographic information was studied in detail by SECSD and relevant topographic data extracted from this map is given in figures 4-1, 4-2, 4-3 and 4-4. From the topographic data is plotted the longitudinal profile of the river from bed level 810m to 730m in figure 4-6.

From the figures it is seen that downstream of the Kikuletwa 1 power station the river forms six bends (first, third and sixth which have a large radii and wherein the river has a relatively gentle gradient) and (second, fourth and fifth which are of smaller radii width but wherein the river has a steep gradient).

From the profile it is seen that a fall in bed level of 50m from bed elevation 790m to 740m is advantageously concentrated in the short fifth loop of the river. Further the river at bed level 790m which is at the head of the rapids is flowing in a very deep gorge. A 15m high diversion structure at this point will give an extra head of 15m converting the third and fourth loops to a storage.

JICA planned the development of a total gross head of 85m available from all the above loops in a single stage development by construction of a 13m high dam at the beginning of the second loop, bypassing the 50m rapids in the fifth loop and 22m provided by the natural gradient of the river occurring in the long stretch of the river with the third, fourth and sixth loops with a total water conductor of about 5000m.

In the present proposal, considerable savings in civil works is achieved by relocating the dam site to just upstream of the third bend in which there are 50m rapids (790m to 750m). The dam length gets reduced considerably due to topography of the site and height required is only 15m. By foregoing the 22m drop due to balance natural gradient which occurs in a long stretch of the river, considerable savings in water conductor length results. To get the original capacity of 11000kW, it is necessary to increase the discharge to 20 cumecs from 17.9 cumecs which does not increase the cost as the length of the waterway is very short.

With the above planning, the following cascade configuration is planned for the stretch of the river from the existing Kikuletwa No. 1 power station upto bed level 730m taking into account the planning for the stage 3 project as discussed above.

Box 4-1: Proposed Cascade Development of Kikuletwa

SL	PROJECT	FSL (m)	TWL (m)	Q (cum/s)	H (m)	Power (kW)	Energy (GWh/yr)
1	STAGE-1	830	817	20	13	2 x 1000	11.80
2	STAGE-2	817	805	20	12	2 x 1000	11.80
3	STAGE-3	805	740	20	65	2 x 5500	65.00
4	STAGE-4	740	728	20	12	2 x 1000	11.80
TOTAL						17,000	100.40

Brief description of the stages in the cascade is given below. The main feature is that all reaches of the river with mild slope are used for storage and head is obtained by bypassing steep reaches and constructing small diversion structures.

STAGE-1: This involves rehabilitation of the existing diversion structure, canals, and forebay. It is proposed to have a new power house with pre-assembled vertical Kaplan units with multiple asynchronous generators and cylindrical sluices. Cross section of power house is given in figure 4-1. The asynchronous machines are preferred due to lower cost and their reactive power demand can be met by stage 3.

STAGE-2: This project retains the site already investigated by JICA and the lake will extend upto the existing old power station. The diversion weir gives a head of

5m and additional head of 7m is obtained by a short waterway of 230m length. Electromechanical equipment and features will be similar to stage 1.

STAGE-3: This is the most important project and the largest of all stages. Its capacity and energy output are equal to that of the JICA proposal with the civil works quantities reduced considerably.

STAGE-4: This project is a dam based development at the power house site proposed by JICA. Head is obtained entirely due to the construction of the diversion weir. Electromechanical equipment and features are similar to stage 2.

The above planning results in the standardized design of three power stations (stages 1, 2 and 4) 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 3 project is the largest and also reasonably sized, the present volume is devoted to the development of pre-investment report on this project. Similar studies for the other three schemes can easily be repeated by other organizations on lines similar to that adopted by SECSD in other similar projects of Tanzania.

The above planning is illustrated on the available detailed topographic survey sheets with features such as the diversion weir site, power canal/conduit and power house. The projects are also illustrated on the 1:50000 topographic sheet available from Survey Department which is reproduced in figure 4-5. Finally the projects are also illustrated on figure 4-6 which shows the longitudinal profile of the Kikuletwa river.

The benefits derived from the stage 3 project over the previous layout are

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

2. The installed capacity of 11000kW for stage 3 is equal to that of the JICA proposal wherein a total head of 85m was utilized in a single stage development. In the present proposal, with a waterway restricted to about 400m length and head of 65m, no sacrifice is made with respect to capacity and energy. In fact an additional capacity of 4MW is available in the same

stretch of the river as two additional projects have been planned and can be executed independently. These additional projects also have very short waterway. Thus stage 3 project alone is equivalent to the original proposal and hence can be compared directly.

3. Implementation cost is US$12.3 million as compared to US$49 million in 1989. Thus cost is reduced to nearly 25%.

4. A reservoir with more storage and hence better peaking capacity. The volume is increased to 273000 m^3.

5. Better transient operating conditions.

6. As the penstock is short and is located on a relatively milder slope, separate penstocks can be installed and they can be buried. This avoids bifurcation upstream of power house.

7. As the peak load in the Kilimanjaro region is rising rapidly, an alternative design is to make use of the increased storage available and increase the installed capacity of the Kikuletwa No.3 power station. The design of the waterway for peaking purpose is not a problem as the length is very short.

8. The remaining stages can be constructed very economically as package type electromechanical equipment can be procured and erected very quickly in view of the smaller installed capacity. Further induction generators can be used thereby saving on cost.

With the above revised planning, hydrology, power studies and costing were performed. Important features of the project are 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 5.5MW. (Vertical Shaft Francis turbines)
Average Net Head	64.0m
Power Station Discharge	20 cubic metres per second.
Mean Annual Energy	65.0 GWh.
Total Construction Cost	12.3 M USD (exclusive of IDC)
Construction Period	2 years

Financial Analysis @ US 7 cents/kWh

	IPP financing (I = 10%, n = 7 years)	Soft Term Loan (I = 3%, n = 30 years)
IDC (MUSD)	1.907	0.559
Cost per kW (USD)	1291	1169
Financial Benefit Cost	5.76	7.49
Cost/kWh (1st year)	4.50 US cents	1.60 US cents

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

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

Part II Topography

The present layout is based on 1 in 5,000 and 1:50000 topographic sheets and several reconnaissance visits to the dam site and project area. Additional detailed topographic mapping and surveying would be conducted later if required and incorporated in the final design drawings. The project is situated in a reach where the river flows in a bend in a deep gorge 3 km downstream of the confluence of the river Kware with Kikuletwa. The site controls a catchment area of 2,280km^2

which for the most part is heavily inhabited with small scale irrigation and plantations of Sisal etc. The river in this reach is considerably steep and the river banks are nearly vertical. There is scattered vegetation along the banks of the river. Some small trees are observed growing from the crevices in the rock faces forming the bank. The river bed is also similarly rocky. Many suitable sites are available in this reach. The site selected is such that access is easy. Abundant sources of construction material are available in the vicinity.

Part III **Access**

The left bank of project area is criss-crossed by numerous tracks and paths. The selected site is situated approximately in the south east direction from the village Rundugai, The site is accessible by an infrequently used road along the left bank of Kikuletwa from Moshi which passes 50m from the site. Moshi is the regional capital and is accessible by air, train and road. The power house site is readily accessible from the left bank.

Alternate access is also possible via the village Rundugai which is located at a distance of about 11 km from Moshi on the existing Dar-Moshi-Arusha railway. From Rundugai, the existing dirt road will be converted as the access road to lead directly to the diversion weir site.

The Kikuletwa river for a stretch of 20km is very difficult to cross rendering the right bank virtually uninhabited. Thus the creation of the lake will enable easy access to these areas by boats.

Part IV **Civil Structures**

For the diversion structure a concrete gravity cum arch dam is considered. It will have the feature of passing surplus flood water over the crest.

The concrete portion of the diversion weir dam will be about 20 m in height, about 40 m in length and will be ungated. The features are shown in figure 9-1.

The power house will be surface type located about 0.8 km downstream of the diversion weir along the river course. Its tailrace will be led into the Kikuletwa river downstream of the power house. The installed capacity will be 2 x 5.5 MW. The maximum design flow for the power station has been fixed at 20 m^3/s

Part V Generation, Transmission and Utilisation

With regard to the magnitude of discharge, change in head and the general layout, two units of vertical shaft Francis turbines coupled with generators (2 x 5.5 MW) are considered.

The generators would be designed for operation with the power factor cos phi = 0.85. With this, sufficient wattless output for load compensation and for tension regulation in this section of the 132 kV grid will be ensured if required. The stability of the transmission line of 132 KV will then be considerably improved. Hence in the case of construction of the Kikuletwa water power development the installation of reactive compensation in future in the area may not be required.

The two generators will be connected to individual 3 phase step up power transformer. The outlet line will be provided only with circuit breaker, lightning arresting device and disconnecting switch. A 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 11,000 kW, the Kikuletwa power station will exceed the immediate demand for electricity in the vicinity. Its output however is partly sufficient for the neighboring towns of Arusha and Moshi, and other small places. which are electrified by national grid. The power station will thus need to be connected to the grid, so that surplus generated electricity is transmitted to the existing load centers till such a time that the demand in the vicinity develops. The power will be therefore transmitted to the existing receiving sub-station at Kiyungi which will be modified suitably. Having regard to the natural and uniform regulated river flow of the Kikuletwa river and therefore to its guaranteed output, this power station will be able to cover part of the electricity supply 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 with the existing main grid section by means of a 14 km 33kV double circuit transmission line which goes from the switchyard to the Kiyungi substation.

With the supply of electricity to Moshi and surrounding areas etc from the Kikuletwa power station, the transmission loss in the grid from Hale to Moshi will be reduced considerably. This reduction of the mentioned loss will be about 17.5 million kWh per annum against a continuous power demand of 8 MW per annum and a 10% loss in the transmission from Hale to the load. With the present tariff for electricity in the region the saving is about $ 550,000 at 8 cents per kWh. These savings could be used to finance the rehabilitation of the small ruined Kikuletwa No.1 power station.

Part VI **Environmental Impact**

The maximum reservoir elevation was determined in relation to the morphology of the flooded area, the elevation of the tablelands on the banks and last but not least in relation to the tail water level of the existing Kikuletwa No.1 power station. 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 provision has been made for any affected item in table 12-1 on mitigation costs. The created pondage at Kikuletwa is of relatively small volume and will partly regulate the flows for the other proposed downstream projects which have been planned till the confluence with Myumba ya Munga.

Part VII **Costing & Economics**

It is estimated that the total construction cost of the scheme will be US$ 12.3M without accounting for IDC which is 1.907 MUS$. The Benefit Cost ratio is 5.76 and the net cost of energy is about 4.5 US cents per kWh in the first year of operation (all figures are inclusive of IDC). Further details are given in table 13-1.

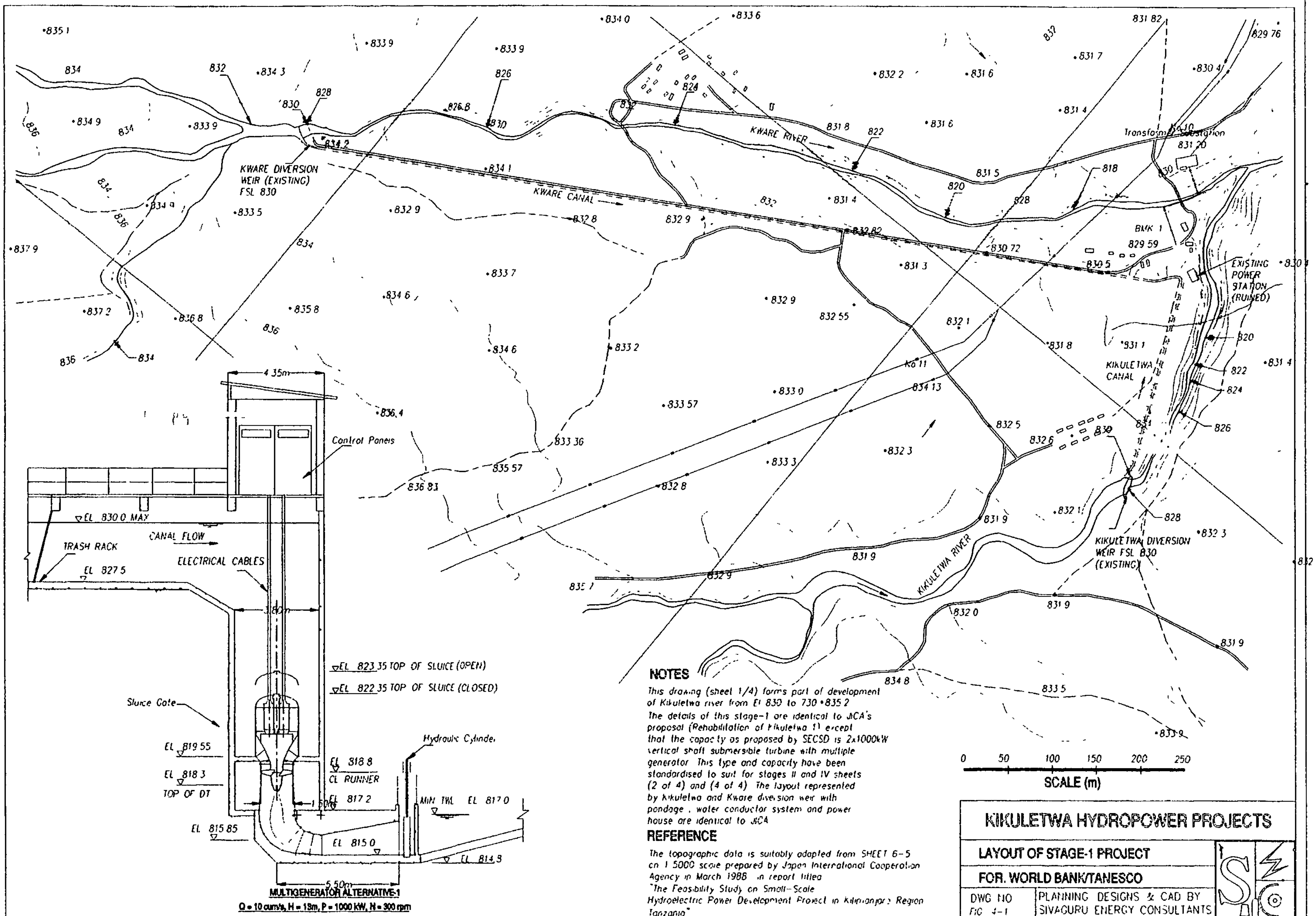
Table 4-1
MAIN FEATURES OF KIKULETWA STAGE-3 HYDRO ELECTRIC PROJECT

	Project Particulars	Description
1	**General**	
a	Type of Project	Run of River Type Hydro Electric Generating Station
b	Location	On Kikuletwa River downstream of existing power house in Kilimanjaro region About 14km from Moshi
c	Installed Capacity	11000 kW
d	Catchment Area	2220 sqkm
e	No of Units	2 units
f	Annual Energy Output	65 GWh (average year), 82 (wet year), 56 (dry year)
g	Plant Load Factor	67 45% (average year), 85 1%(wet year), 58 5%(dry)
2	**Diversion Weir**	
a	Non Overflow Section	
i	Type	Concrete diversion weir
ii	River Bed Level	790m
iii	Full Supply Level	805m
iv	Minimum Drawdown Level	802 5m
v	Gross Storage Capacity	273,000 cubic meters
vi	Length	40m
vii	Maximum Height	22 5m
b	Overflow section	
i	Type	Concrete Over flow Ogee weir
ii	Crest Level	805m
iii	Gates	None
iv	Size of Gates	-
v	No of Gates	-
3	**Waterway**	
i	Type	D section Cut and Cover conduit
ii	Width	2 5m
iii	Maximum Discharge	20 cumecs
iv	Length	325m
v	Penstocks	Steel Penstock laid on ground with supports
vi	Diameter	1 5m, 10mm thickness
vii	Length	50m
4	**Power House**	
i	Type	Surface Well type
ii	Diameter	9 5m
iii	Maximum Height	16m
iv	Floors	Three
5	**Electromechanical Equipment**	
a	Turbine	Vertical Shaft Francis turbine with elbow draft tube
i	Rated Head	62m
ii	Rated Discharge	10 cumecs
iii	Minimum Net Head	60 14m
iv	Maximum Net Head	64.12m
v	Speed	600 rpm
vi	Governor	Electronic Digital Governing system
vii	Runner Diameter (approx)	1000 mm
viii	Inlet Valves	Servo operated disc type
b	Generators	3 phase AC 50Hz
i	Type	Synchronous
ii	Poles	10
iii	Speed	600 rpm
iv	Rating	6.6 kV, 6.5 MVA, 0.85 pf
v	Exciter	Static excitation system

TABLE 4-1 Contd

MAIN FEATURES OF KIKULETWA STAGE-3 HYDRO ELECTRIC PROJECT

6	**Electrical Equipment**	
a	Transformer	2 Nos (Ultimate)
b	Rating	6 6 / 33 kV, 6 5 MVA
c	Switchyard	Double bus arrangement with SF6 breakers
d	Transmission Line	33 kV line from station to Kiyungi Substation approximately 14km length if existing 33kv line close to the Project area is not serviceable.
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 (2 units of 6.5 MW)**	
a	Civil Works Cost	US$ 4 026M
b	Electromechanical and Allied works	US$ 6 216 M
c	Transmission	US$ 0 420 M
d	Construction Cost	US$ 10 662M
e	Engg, Administration, Environment & Contingencies	US$ 1 637M
f	Construction Period	24 months
g	Interest During Construction @10% interest rate	US$ 1 907 M
h	Total Implementation Cost	US$ 12 30M
i	Cost per kW installed without IDC	US$ 1118
j	Annual Debt Service for 7 year Project loan	US$ 2 918M
k	Annual Operation and Maintenance	US$ 0 129M
l	Depreciation	US$ 0 075M
m	Total Annual Costs	US$ 1 736M
n	Annual Energy Output	65 GWh
o	Grid Wheeling charges	NIL
p	Banking charges	NIL
q	Water Royalty	NIL
r	Net Energy for sale	65 GWh
s	First year Generation Cost per kWh	US 4 8 cents
t	Life cycle Generation cost per kWh	US 1 1 cents
u	Economic Life	30 years
v	Ratio of Life Cycle Benefits/ Life Cycle Costs	5 764
x	Cost per kW installed with IDC	US$ 1291



NOTES

This drawing (sheet 1/4) forms part of development of Kikuletwa river from El 830 to 730 •835 2

The details of this stage-1 are identical to JICA's proposal (Rehabilitation of Kikuletwa 1) except that the capacity as proposed by SECSD is 2x1000kW vertical shaft submersible turbine with multiple generator This type and capacity have been standardised to suit for stages II and IV sheets (2 of 4) and (4 of 4) The layout represented by Kikuletwa and Kware diversion weir with pondage , water conductor system and power house are identical to JICA

REFERENCE

The topographic data is suitably adapted from SHEET 6-5 on 1 5000 scale prepared by Japan International Cooperation Agency in March 1988 in report titled "The Feasibility Study on Small-Scale Hydroelectric Power Development Project in Kilimanjaro Region Tanzania"

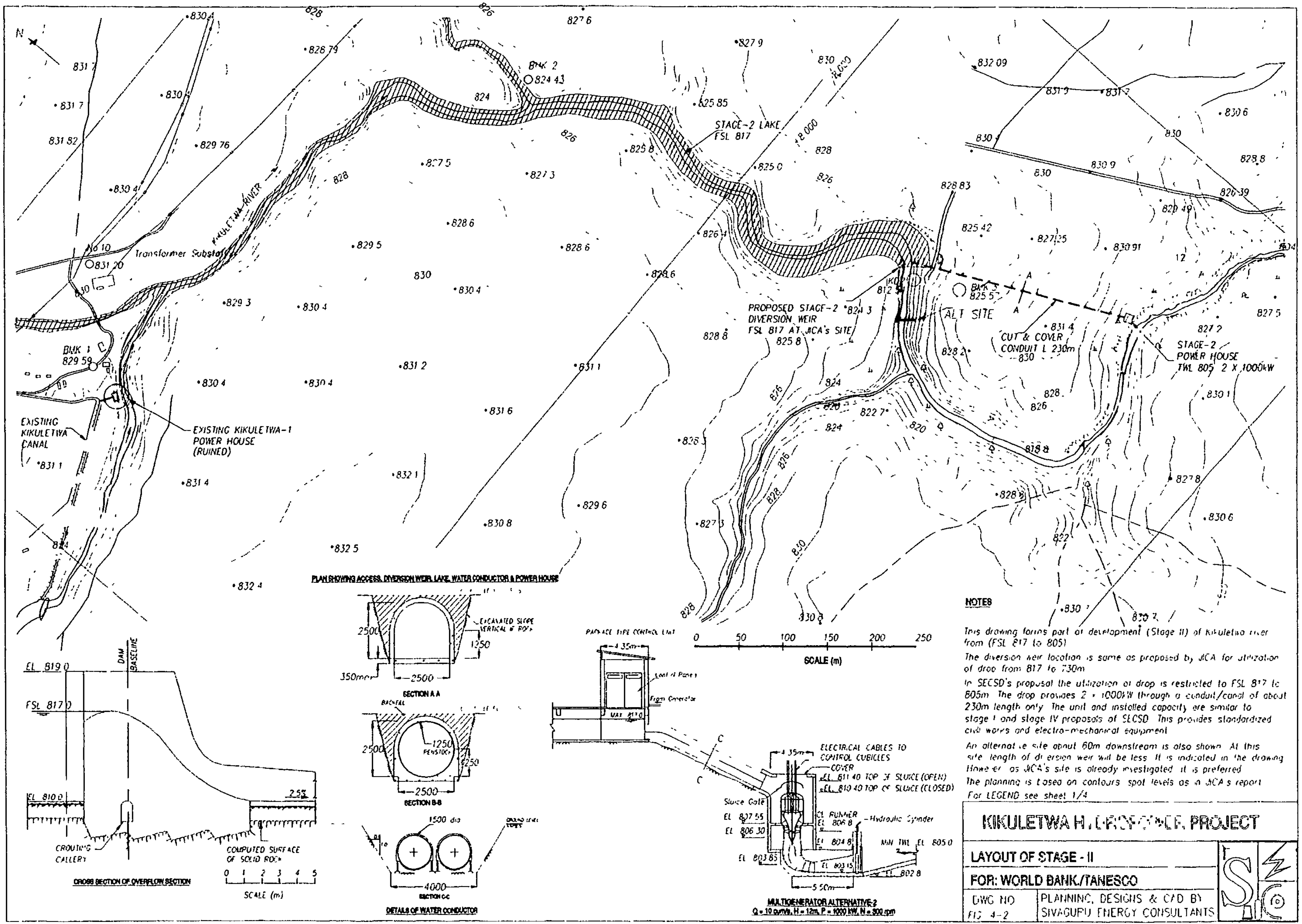
KIKULETWA HYDROPOWER PROJECTS

LAYOUT OF STAGE-1 PROJECT

FOR. WORLD BANK/TANESCO

DWG NO FIG 4-1	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

C \ACADJOBS\KIKU\STAGE-A



PLAN SHOWING ACCESS, DIVERSION WEIR, LAKE, WATER CONDUCTOR & POWER HOUSE

CROSS SECTION OF OVERFLOW SECTION

SECTION A A

SECTION B-B

SECTION C-C

DETAILS OF WATER CONDUCTOR

MULTIGENERATOR ALTERNATIVE-2
Q = 10 cum/s, H = 12m, P = 1000 kW, N = 300 rpm

NOTES

This drawing forms part of development (Stage II) of Kikuletwa river from (FSL 817 to 805)

The diversion weir location is same as proposed by JICA for utilization of drop from 817 to 730m

In SECSD's proposal the utilization of drop is restricted to FSL 817 to 805m The drop provides 2 × 1000kW through a conduit/canal of about 230m length only The unit and installed capacity are similar to stage I and stage IV proposals of SECSD This provides standardized civil works and electro-mechanical equipment

An alternative site about 60m downstream is also shown At this site length of diversion weir will be less It is indicated in the drawing However as JICA's site is already investigated it is preferred

The planning is based on contours spot levels as in JICA's report

For LEGEND see sheet 1/4

KIKULETWA HYDROPOWER PROJECT

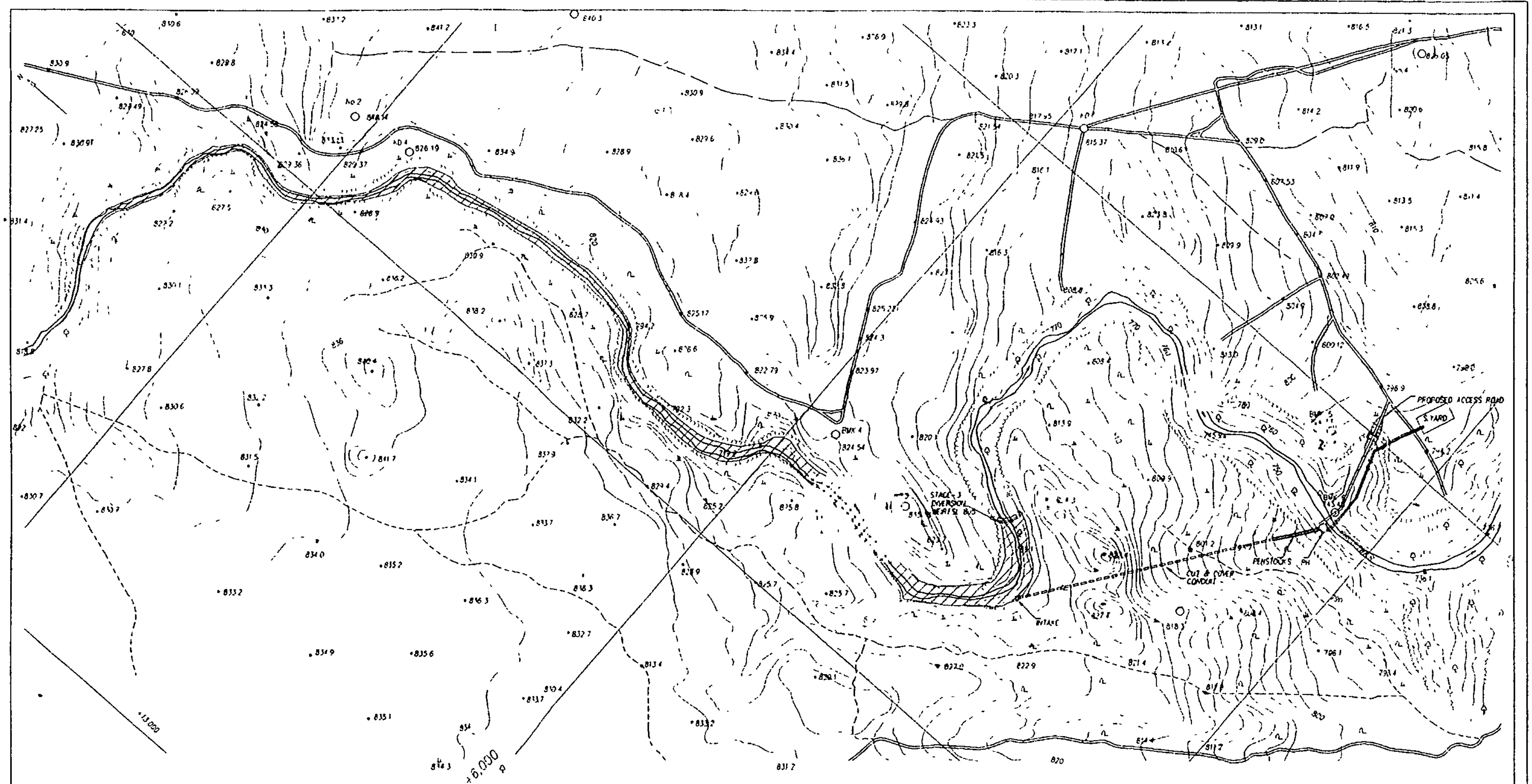
LAYOUT OF STAGE - II

FOR: WORLD BANK/TANESCO

DWG NO
FIG 4-2

PLANNING, DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

C:\ACADJOBS\KIKU\STAGE-B.DWG



PLAN OF RIVER WITH DIVERSION WEIR, WATER CONDUCTOR SYSTEM AND POWER HOUSE

NOTES

THIS DRAWING SHOWS STAGE III OF THE FOUR STAGE DEVELOPMENT OF KIKULETWA RIVER FORMULATED BY SECSD. THIS STAGE HAS THE FOLLOWING FEATURES

1. ARCH DAM FSL 805
2. WATER CONDUCTOR SYSTEM ABOUT 400m LENGTH
3. POWER HOUSE WITH TAILRACE

LEGEND

═══	FORMED ROADS
----	TRACKS
~42	CONTOUR WITH ELEVATION
•825.7	SPOT HEIGHT
' '	CLIFFS
	STEEP SLOPES
⌒	SCATTERED TREES
♀	FOREST
⊥	SCRUB
○ BMK 6 743.48	BENCHMARK
○ HD6	DRILL HOLE
○ No 2	TRAVERSE POINT
	DIVERSION WEIR
▨	LAKE OF PONDAGE
▽	INTAKE STRUCTURE
▭▭▭▭▭	CUT & COVER CONDUIT

REFERENCE

This drawing is based on SHEET 6-5 on 1:5000 scale prepared by Japan International Cooperation Agency in March 1959 from report titled "The Feasibility Study on Small-Scale Hydroelectric Power Development Project in Kilimanjaro Region Tanzania"

0 50 100 150 200 250

SCALE (m)

KIKULETWA HYDROPOWER PROJECT
(STAGE-III)

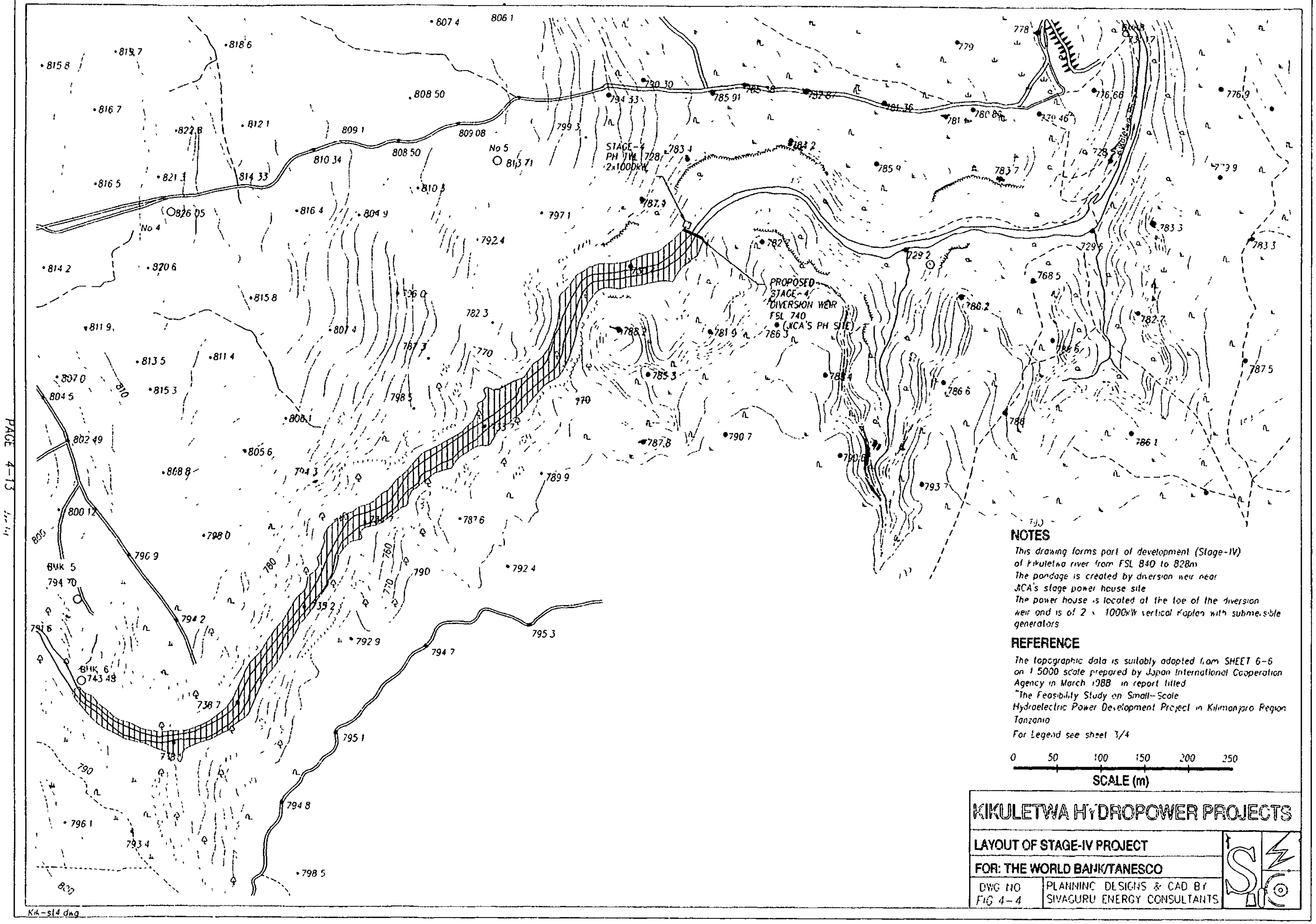
LAYOUT DETAILS

FOR. WORLD BANK/TANESCO

DWG NO
FIG 4-3

PLANNING DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

C:\ACAD\OBS\KU\STAGE_C1.DWG



NOTES

This drawing forms part of development (Stage-IV) of Kikuletwa river from FSL 840 to 828m

The pondage is created by diversion weir near JICA's stage power house site

The power house is located at the toe of the diversion weir and is of 2 x 1000kW vertical Kaplan with submersible generators

REFERENCE

The topographic data is suitably adopted from SHEET 6-6 on 1 5000 scale prepared by Japan International Cooperation Agency in March 1988 in report titled "The Feasibility Study on Small-Scale Hydroelectric Power Development Project in Kilimanjaro Region Tanzania

For Legend see sheet 3/4

KIKULETWA HYDROPOWER PROJECTS

LAYOUT OF STAGE-IV PROJECT

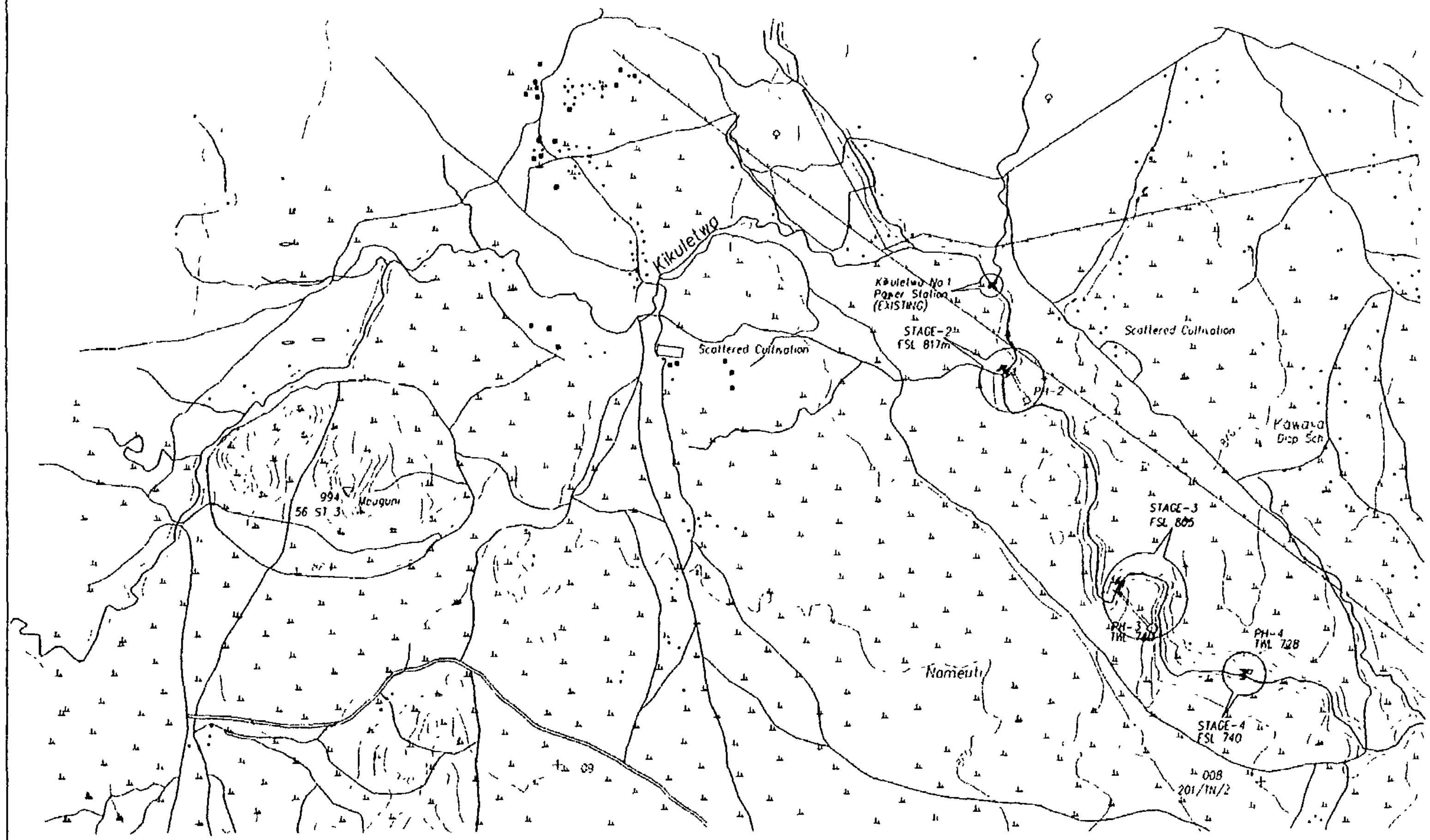
FOR: THE WORLD BANK/TANESCO

DWG NO
FIG 4-4

PLANNING DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

Kik-st4.dwg

This drawing shows the modified proposal by SECSD obtained by splitting the Kikuletwa No 2 scheme of JICA into two stages called Kikuletwa No 2 and No 3



PLAN SHOWING KIKULETWA STAGES 1 TO 4

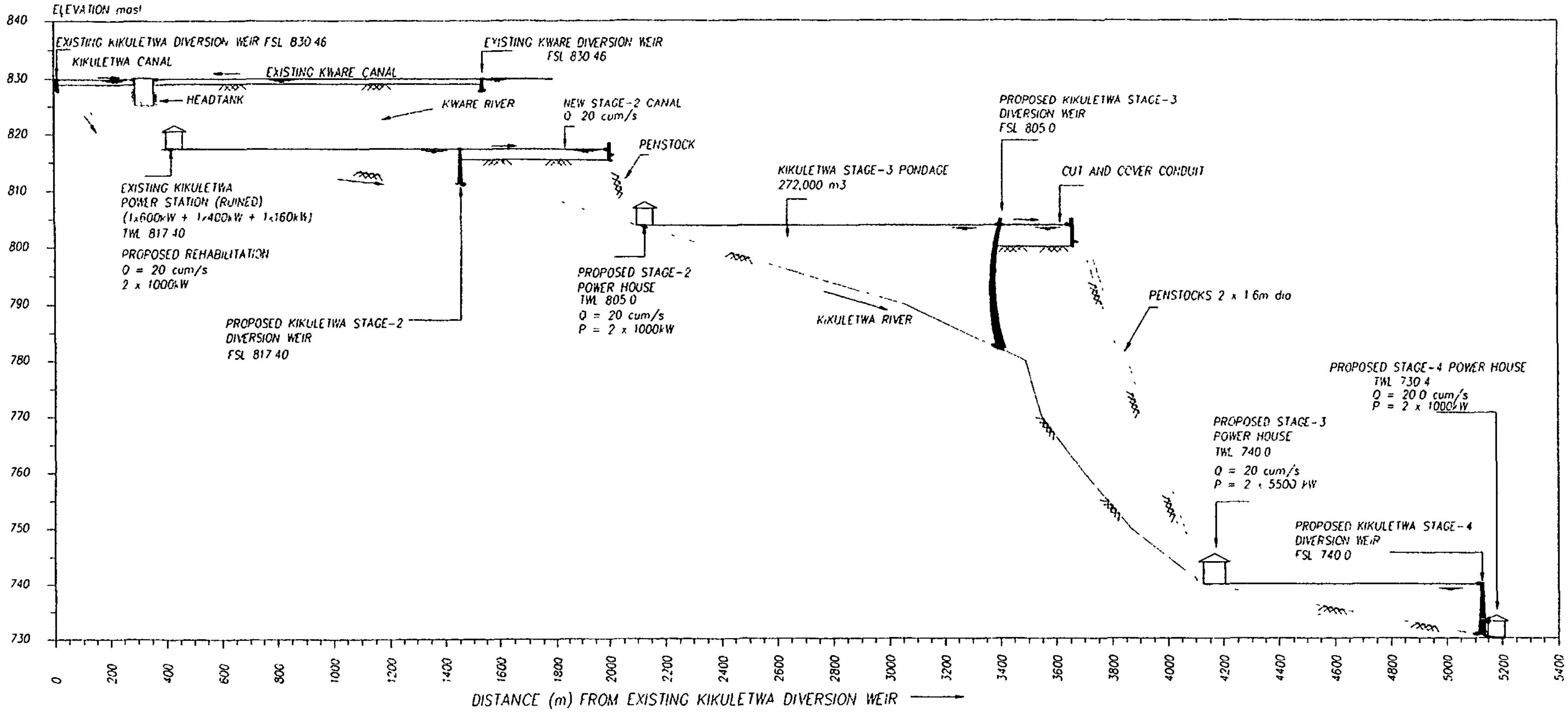
	FSL (m)	TWL (m)	H (m)	Q (m 3/s)	P (kW)	HEADRACE (m)	PENSTOCK (m)	ENERGY (GWh/yr)
STAGE-1 (REHAB)	830 46	817 0	13 0	20 0	2 x 1000	370+1676	1 5ø/20m	11 80
STAGE-2	817 0	805 0	12 0	20 0	2 x 1000	230	1 5ø/20m	11 80
STAGE-3	805 0	740 0	65 0	20 0	2 x 5500	325	1 5ø/20m	65 0
STAGE-4	740 0	728 0	12 0	20 0	2 x 1000	-	-	11 80

0 0 5 1 0 1 5 2 0 2 5
SCALE (km)

REFERENCE
SURVEY OF TANZANIA TOPOGRAPHIC MAPS
1 50000 SCALE

KIKULETWA HYDROPOWER PROJECTS
LOCATION MAP (STAGES 1 TO 4)
FOR THE WORLD BANK/TANESCO
DWG NO Fig 4-5
PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

C_\ACADJOBS\TANZ\SANYA



LONGITUDINAL PROFILE OF KIKULETWA RIVER SHOWING PROPOSED CASCADE DEVELOPMENT

KIKULETWA RIVER HYDROPOWER PROJECTS
(STAGES 1 TO 4)

PROFILE WITH CASCADE FEATURES

FOR: THE WORLD BANK/TANESCO

DWG NO
FIG 4-6

PLANNING, DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

kik-15 dwg

Chapter 5 Topographic Features and Surveys

Section 1 *Topography*

The Kikuletwa sites are located in the Mount Kilimanjaro area. The project area is located on a vast plain, which has an elevation of 700 to 800 m, at the south-southwest foot of the 5895m high Mount Kilimanjaro. The sites are approximately 45 km from the peak.

The rivers Himo, Karanga, Weru Weru and Kware , the sources of which are near the summit, flow down the southern slope of the mountain in a fan-like pattern. These streams ultimately drain into the Kikuletwa River south of the city of Moshi. The Kikuletwa River, after passing the Nyumba Ya Munga Reservoir, becomes the Pangani River which empties into the Indian Ocean south of Tanga.

Mt. Meru (El,4,566 m) is located about 70 km west of Mount Kilimanjaro, and also has a fan-like pattern of streams flowing down its slope. One of these streams is the main tributary of the upstream portion of the Kikuletwa River.

The proposed projects on Kikuletwa are located in the vicinity of the confluence of the Kware River, flowing from Mt. Kilimanjaro and the Kikuletwa River, flowing from Mt. Meru.

The main topographic feature of the project area is the deep valley which the Kikuletwa river has cut and the rather steep slope of the river bed. At some places the depth of the valley is over 30m with nearly vertical sides. On both banks the terrain is almost flat tableland of elevation of about 800m.

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 56/3 titled Sanya Chini. An extract of the relevant area of interest is given in figure 4-5.

The stretch of the Kikuletwa river was photographed from the air, extensively surveyed and mapped by JICA in 1989 as per details below.

Box 5-1: Extent of Survey and Mapping by JICA

SL	ITEM	SCALE	QUANTITY
1	Aerial Photography	1:20000 longitudinal 1:8000 transverse	300 sqkm
2	Flight Courses		9
3	Longitudinal Mapping	1:1000	30 sqkm
4	Transverse Mapping	1:1000	9 km
5	Topographic Maps	1:5000	
6	Topographic Surveys of Kikuletwa I and 2	1:500	182500 sqm

The 1:20000 aerial photographs were used to prepare the 1:5000 topographic maps for an area of approximately 300 sqkm.

1:8000 aerial photographs were used to prepare the 1:scale longitudinal and transverse profiles
Ground surveying was used to prepare the 1:500 topographic maps for the main structure sites of the originally envisaged Kikuletwa No. 1 and 2 schemes.

Section 3 *Results*

All the revised project features proposed by SECSD are within the limits of the survey information available in the JICA report. Hence for the new layout no additional surveying is required to be done. Requisite information has been extracted from the available sheets and is presented in figures 4-1 to 4-6. Additional information inferred from the above include the following which are presented in the relevant sections of this 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 a diversion weir upto 20m height. Also the formation of the proposed impoundment will not give rise to any major slips or settlements in the bed or banks of the reservoir.

Section 2 *Regional Geology*

The area is chiefly composed of the volcanic products of Mount Kilimanjaro. The origin of these volcanic rocks is thought to be between 13 to 15 million years so that Kilimanjaro's volcanic activity might have started between the Miocene and Pliocene eras. The frequency of activity gradually decreased from Pleistocene to the Holocene eras. Present day activity is limited to local eruption.

The past activity can be divided into three stages which formed the three peaks with Shira being the first and Kibo the most recent. The composition of the lavas is given below.

Box 6-1: Composition of volcanic products

STAGES	COMPOSITION OF VOLCANIC PRODUCTS
Shira	Lava with pyroclastic rocks
Mawenzi	volcanic products such as basaltic lava, tuff breccia and agglomerate
Kibo	volcanic rocks or porphyry such as trachyandesite trachyte, phonolite, and rhomb porphyry in addition to a deposit known as Lahar.

The proposed project sites are located in the area of the Kibo volcanic product distribution. The volcanic products are of the Rhomb Porphyry Group partially overlayed with Lahar.

Section 3 *Engineering Geology*

Part I General

The results of the JICA team's aerial photo interpretation, detailed geological field surveys, and core drillings indicate that the geology of the Kikuletwa Project Area may be summarized as follows:

- The sub-area upstream of the proposed site for the Kikuletwa No. 2 intake dam. This area includes Kikuletwa No.1 project area.

- The sub-area from the proposed site for the intake dam to the proposed powerhouse site for JICA's Kikuletwa No. 2 (SECSD stage 4).

- The sub-area downstream of the proposed site for the JICA's Kikuletwa No. 2 powerhouse (SECSD stage 4).

The topographical differences within the project area are considered to be due to the geologies which formed them. The geologies concerned are those of the Kibo "Rhomb porphyry Group" and of the "Lahar" The former within the project area, consists of dark grey tuff breccia, with part of the top layer containing limestone. The "Lahar" is itself of reddish brown color; the "Lahar" studied in the surface reconnaissance and core drilling, however, had a high degree of consolidation, and presented the appearance of tuff breccia. This consolidated Lahar contains numerous blocks, which appear to be phonolite characterized by mega-phonocrysts.

The Rhomb Porphyry Group will be referred to Tuff Breccia (2); and the geology containing Lahar will be referred to as Tuff Breccia (1).

Part II Origins and Stratigraphies

It is thought that Tuff Breccia (2) was accumulated in the volcanic activity of Mt. Kilimanjaro and was subsequently subjected in part to the sedimentary environment of limestone. Tuff Breccia (1) is considered to be a secondary deposit of volcanic products and is thought to have covered Tuff Breccia (2) in the form of filling valley topography when flowing down the slopes. In the project area studied, the thickness of Tuff Breccia (2) is greatest in the vicinity of the midpoint of the headrace planned by JICA for Kikuletwa No. 2 which is very near the modified stage 2 project site where it is estimated to exceed 50 m.

Part III Hydrogeological Conditions

Springs which flow into the Kikuletwa River are located about 2 Km upstream of the existing TANESCO Hydropower Station, in an area of Tuff Breccia (2) distribution. The volume of spring water is comparatively stable throughout the year This, together with the fact that the existence of confined water has been recognized in Tuff Breccia (2) through core drilling investigations at the Kikuletwa No.2 intake dam site, downstream of the spring location, make it seem quite likely that some part of the Tuff Breccia (2) layer is in aquifer.

Talus deposits and alluvium are present as unconsolidated deposits overlying the basement rocks. These deposits are either distributed over small areas, or are thinly and widely distributed.

No prominent fault structures, landslides or slope failures have been recognized in the project area.

The intake dam and the powerhouse site for the Kikuletwa stage 3 Hydropower project are located approximately 3 km approximately 3.8 km, respectively, downstream of the existing TANESCO power station.

The topography from the r stage 3 intake dam site (including the regulating reservoir area) to the powerhouse site is that of a gently sloped tableland, of elevation from 800 to 840 m. The section from the intake dam site to the powerhouse site excluding the reservoir area shows a predominance of small mounds on the table- land.

The Kikuletwa River flows down the tableland from the commencement of the reservoir, from the stage 2 intake dam site toward the stage 3 powerhouse site, gradually descending to form a "V" shaped valley and meandering slightly. The average river bed gradient in the regulating reservoir area (including the intake dam site) is 1/500. The gradient between the intake dam and powerhouse site is 1/50.

Part IV Geology of Regulating Reservoir

The regulating reservoir and intake dam site are composed of Tuff Breccia (1), Tuff Breccia (2) and limestone. The Tuff Breccia (1) thinly over-lies the Tuff Breccia (2) almost horizontally, with limestone interbedded at the boundary between the two. The limestone lens is limited to the vicinity of the intake dam site.

All of the bedrocks are generally hard, and except for Tuff Breccia (1) at the surface layer of the right bank of the intake dam, the permeability coefficients are

10^{-4} to 10^{-5} cm/sec. The groundwater level at the tail end of the reservoir is EL. 813 m, approximately 2 m above the water surface on both banks of the Kikuletwa River.

Unconsolidated deposits, consisting of talus deposits and alluvium overlie the basement rocks. These deposits, however, are extremely thin.

Part V Geology at Diversion site

The important drill holes for the stage 3 project are KD-4 which is in the regulating reservoir area, KD-5 which is very near the diversion wier site and KD-6 which is downstream of the diversion site. The geology at the diversion site is assumed to be close to that met with in KD-5. The drill hole showed the material to be Tuff Breccia with phonolite and good values of RQD.

The geology along the headrace route of JICA is Tuff Breccia (1) overlain at parts by very thin talus deposits of not more than 1 m. It is assumed that the same conditions are met with on the opposite bank of the river also. So far as ascertained in core drilling, the Tuff Breccia (1) is well-consolidated and hard to a depth of 20 m from the ground surface. Blocks thought to be phonolite, which exist in large numbers in the bedrock, are very hard, and their hardness differs from that of the fine material surrounding them.

For all drill holes, permeability coefficients at depths over 10 m from the ground surface were found to be 10^{-5} cm/sec or less. The groundwater level is highest near the midpoint of the proposed headrace, which it is about the same as or lower than headrace elevation in the vicinities of the intake dam located upstream, and the head tank, located downstream.

Part VI Geological Engineering Assessment

It is expected that excavated high slopes will be formed at the proposed headrace because of topographical features of the route. The properties of the Tuff Breccia (1) indicate that the cut slopes will be stable. As the headrace route runs through a gently-sloped tableland, there is little risk that of debris and loose soil from the surrounding ground surface will slide into the canal.

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

Section 4 *Construction Materials*

A thorough investigation of source of construction materials has been done by JICA. The main results are given below. The locations of the sources are given in figure 6-2.

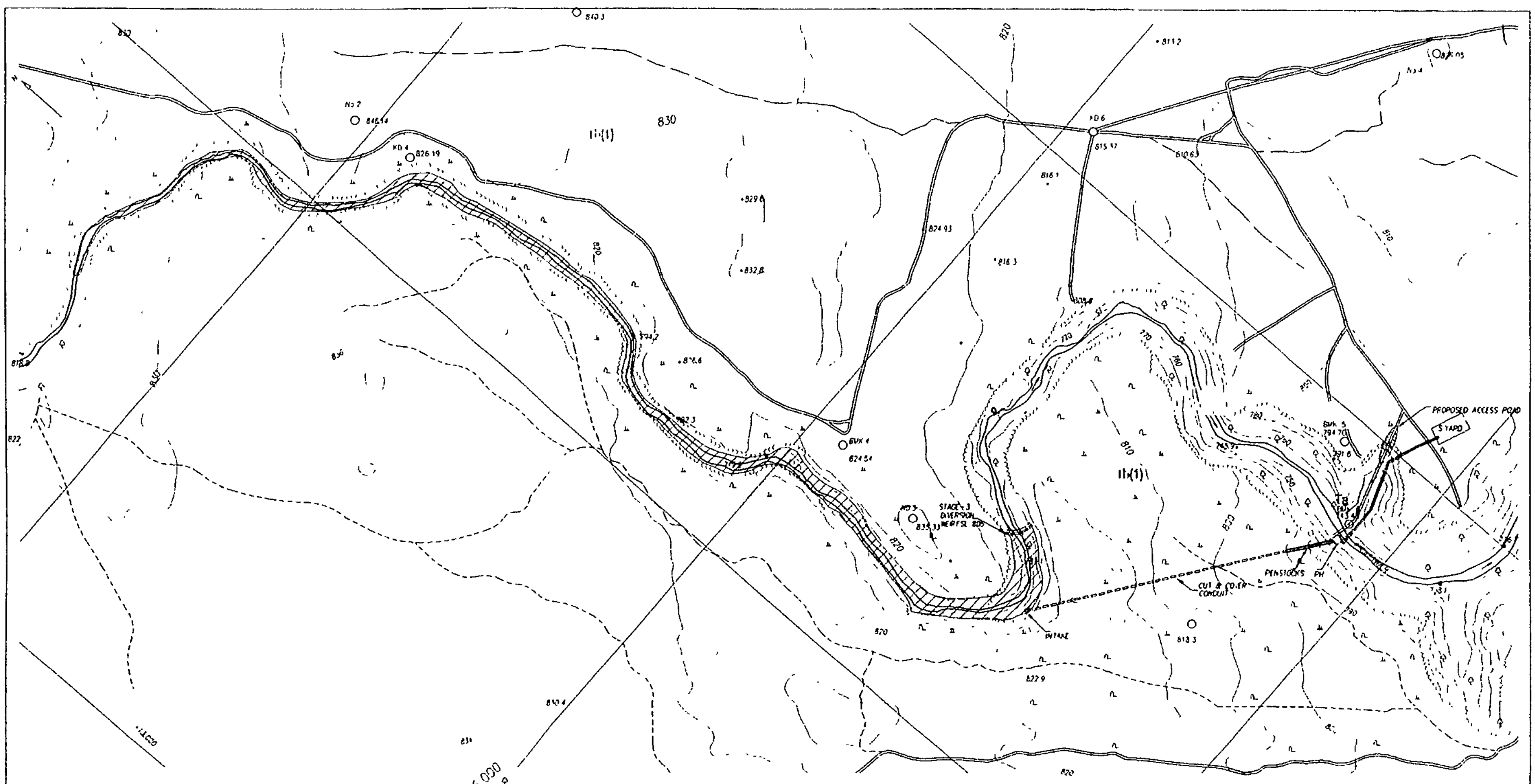
Box 6-2: Sources of Construction Material

SITE	LOCATION	MATERIAL	QUANTITY	REMARKS
KITETO	7 km SE of stage-1	Medium to coarse grained sand of crystalline schist and gneiss of pre cambrian sedimentary origin from tributary of Kikuletwa	10,000 cum	
NYM	90km SE of stage-1	medium to coarse grained sand of pre cambnan schist and gneiss of pre cambrian sedimentary origin	100,000 cum	
HAI	15km North of stage-1	basaltic rocks from volcanic products		Existing crusher produces in sizes from 0.25 to above 1 inch
R KARANGA	12km NE of stage-1	sand gravel orginating from basaltic rocks of volcanic activity		
TPC	3km South of R Karanga site	Volcanic alkaline basalt	Fairly large	5m over burden is to be removed

The test results are summarized in box 6-3.

Box 6-3: Tests on construction material

	SPECIFIC GRAVITY	ABSORPTION	ABRASION	SOUNDNESS	ORGANIC IMPURITY	CRUSHING	ALKALI REACTIVITY
KITETO	2.60 to 2 73	10 7 to 14.2% FINE		6.4 to 14 1	LIGHT YELLOW		WITHIN LIMITS
NYM	2.71			5.2	LIGHT YELLOW		WITHIN LIMITS
HAI	2.54 to 2.57	1.9 to 2.8% FOR COARSE	22.3 to 24.8	2.3 to 3.2	DARK BROWN	22%	HIGH for size < 5mm
R. KARANGA	2.43 to 2.46	15 2 to 24.1FOR MIXED	25.2 to 27.2	4.6 to 7.2 2.7 to 3.0 coarse	DARK BROWN	15%	HIGH for size < 5mm
TPC	2.52				DARK BROWN		HIGH for size < 5mm



GEOLOGICAL PLAN OF PROJECT AREA

LEGEND

NEOGENE-PLEISTOCENE-HOLOCENE

- Tt — TALUS DEPOSIT
- Tt(1) — TUFF BRECCIA (1) (PHONOLITE BLOCK RICH)
- Lm — LIMESTONE
- Tt(2) — TUFF BRECCIA (2) (RHOMB PORPHYRY BLOCK RICH)

- ═══ FORMED ROADS
- - - - TRACKS
- CONTOUR WITH ELEVATION
- SPOT HEIGHT
- CLIFFS
- STEEP SLOPES
- SCATTERED TREES
- FOREST
- SCRUB
- ○ BMK 6 743.48 — BENCHMARK
- ○ KD 6 — DRILL HOLE
- ○ No 2 — TRAVERSE POINT
- DIVERSION WEIR
- ▨ LAKE OR PONDAGE
- INTAKE STRUCTURE
- ▭▭▭▭▭ CUT & COVER CONDUIT

NOTES

THIS DRAWING SHOWS STAGE III OF THE FOUR STAGE DEVELOPMENT OF KIKULETWA RIVER FORMULATED BY SECSD. THIS STAGE HAS THE FOLLOWING FEATURES

1. ARCH DAM FSL 805
2. WATER CONDUCTOR SYSTEM ABOUT 430m LENGTH
3. POWER HOUSE WITH TAILRACE

REFERENCE

This drawing is based on SHEET 6-5 on 1 5000 scale prepared by Japan International Cooperation Agency in March 1988 from report titled "The Feasibility Study on Small-Scale Hydroelectric Power Development Project in Kilimanjaro Region Tanzania"

0 50 100 150 200 250

SCALE (m)

KIKULETWA HYDROPOWER PROJECT
(STAGE-III)

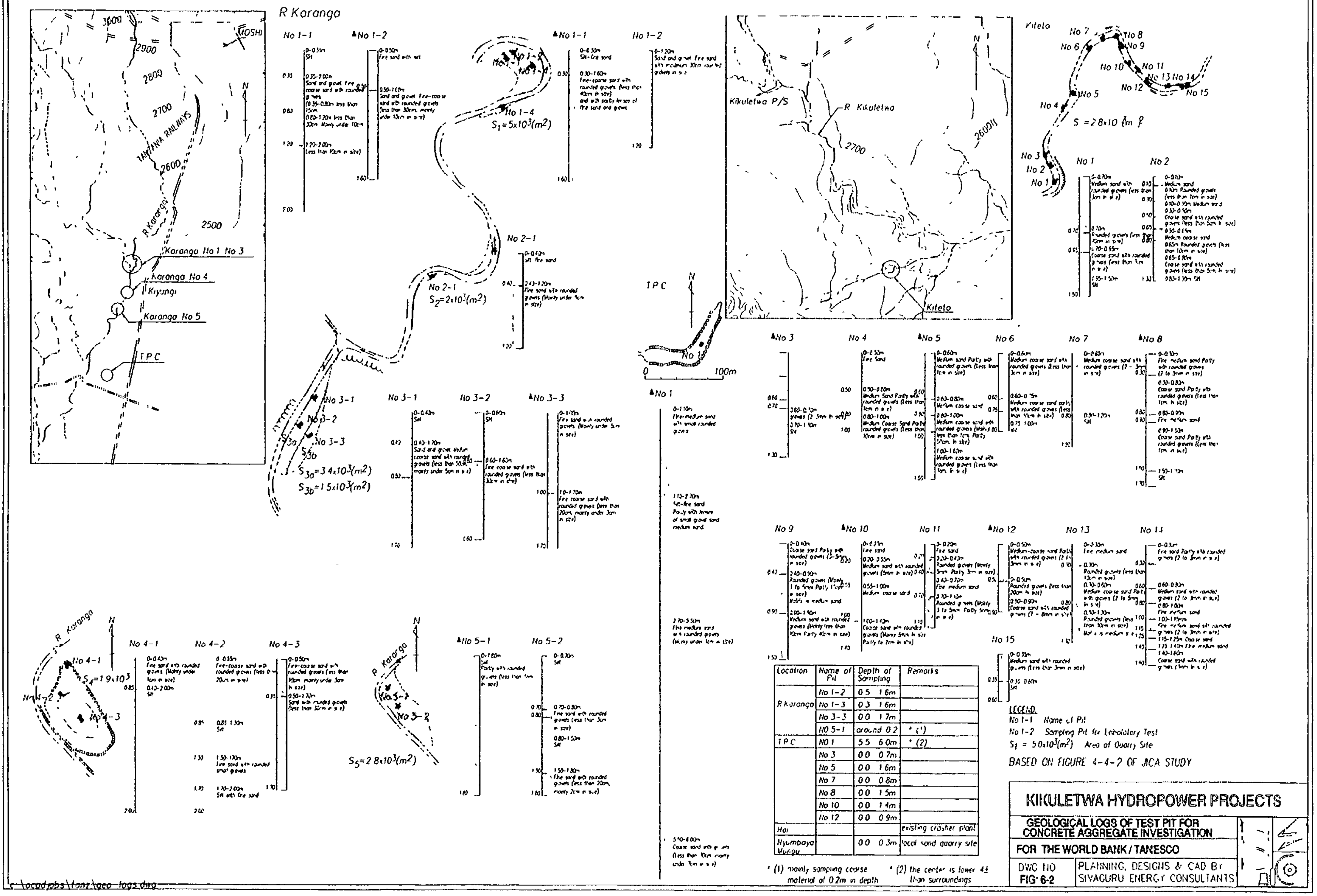
GEOLOGICAL PLAN OF PROJECT AREA

FOR: WORLD BANK/TANESCO

DWG NO
FIG 6-1

PLANNING DESIGNS & CAD BY
SIVACURU ENERGY CONSULTANTS

C:\ACAD\JOBS\KIKU\STAGE-C1.DWG



Location	Name of Pit	Depth of Sampling	Remarks
R Karanga	No 1-2	0.5 1.6m	
	No 1-3	0.3 1.6m	
	No 3-3	0.0 1.7m	
	NO 5-1	around 0.2	* (1)
TPC	NO 1	5.5 6.0m	* (2)
	No 3	0.0 0.7m	
	No 5	0.0 1.6m	
	No 7	0.0 0.8m	
	No 8	0.0 1.5m	
	No 10	0.0 1.4m	
	No 12	0.0 0.9m	
Hai			existing crusher plant
Nyumbaya Mungu		0.0 0.3m	local sand quarry site

* (1) mainly sampling coarse material of 0.2m in depth

* (2) the center is lower 4± than surroundings

LEGEND

No 1-1 Name of Pit

No 1-2 Sampling Pit for Labolatory Test

$S_1 = 5.0x10^3(m^2)$ Area of Quarry Site

BASED ON FIGURE 4-4-2 OF JICA STUDY

KIKULETWA HYDROPOWER PROJECTS

GEOLOGICAL LOGS OF TEST PIT FOR CONCRETE AGGREGATE INVESTIGATION

FOR THE WORLD BANK / TANESCO

DWG NO
FIG 6-2

PLANNING, DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

c:\locadjobs\tanz\geo_logs.dwg

Chapter 7 Hydrology

Section 1 *Drainage Network*

The catchment area of the Kikuletwa river is drained by a large number of streams and rivers which form a close and dense network at the higher elevations but are sparse in the plains. The river is formed from three major tributaries Kware and Sanya running down the south slope of Mount Kilimanjaro and Usa running down the southern slope of Mount Meru. The drainage network and hydro-meteorological stations in the catchment are illustrated in figure 7-1 titled Hydro-meteorological stations in the basin. The map was constructed by using the following topographic sheets of 1:50000 scale.

Box 7-1: Topographic Sheets for Drainage Map

SL	SHEET No.	NAME
1	55/1	OLDONYO SAMBU
2	55/2	NGARE NANYURI
3	55/3	ARUSHA
4	55/4	USA RIVER
5	56/1	WEST HAI
6	56/2	KILIMANJARO
7	56/3	SANYA CHINI
8	56/4	MOSHI
9	71/2	MBUGUNI
10	72/1	LOSSOITO
11	72/2	ARUSHA CHINI

The drainage area is fan shaped. The figure shows the drainage network for the main stem of the Kikuletwa river till it joins the Ruvu river and then flows into Myumba ya Munga reservoir. From here the river is known as Pangani and it flows southwards for a considerable distance through an arid plain and then turns east and empties into the Indian Ocean. The sub networks for the three major tributaries the Kware, Sanya and the Usa have been shown. The drawing also shows the rainfall stations in and around the catchment with altitude and the various river gauging stations with their identification numbers. The catchment area is covered with the porous products of volcanic activity from Kilimanjaro. A significant portion of the rainfall is thus absorbed and reappears as springs in the area such as Rundugai and Chemka. Locations of some of the important springs are also shown in the drawing.

Section 2 *River Flow Data*

Observations of runoff for the major streams and rivers of the region is done by Water Resources office at Moshi. From the point of view of the hydropower studies for the proposed site, the most important flow data is that obtained from gauging station IDD-54 which is located about 300m downstream of the existing TANESCO Kikuletwa 1 power station. The data was collected from Ministry of Water in Dar-Es-Salam. The daily observed data with analysis of the data is given in the separate volume annexure A.

Section 3 *Observations*

The catchment area at the gauge site is 2220 km^2. From the measured flow data, the average run off is found to be 14.35 cum/s corresponding to a runoff depth of 204 mm. The average precipitation over the catchment is 800mm giving a run off coefficient of 25%. The observed records include the runoff from water sheds of Mount Meru and Kilimanjaro, and the Rundugai and Chemka springs. In addition the runoff from Kware and Kikuletwa together with the amount of water which was being diverted for power generation by Kikuletwa 1 power station and released back is included in the measurements. Duration curves based on the above data have been prepared and are presented in the annexure volume. The following important observations can be made.

- The river has a constant base flow.
- The ratio between 95 day discharge and 355 day discharge is small.
- The annual range of fluctuation in discharge is small.
- The pattern of flow is ideally suited for production of hydropower.

Section 4 *Yield at Kikuletwa site*

The proposed diversion site is located a little downstream of the gauge site. The catchment area at the proposed diversion site is 2280 sqkm representing an increase of only 2%. No major stream or tributary joins the Kikuletwa between the gauge site and the proposed diversion site nor is there any abstraction of water in this reach. Hence the yield at the diversion site is taken to be equal to the measured flow. The error involved in the assumption will be less than 0.1%.

Analysis of the flow data by duration curve gives the exceedance values given in box 7-2 which are partly reproduced from table 8-1 of annexure A.

Box 7-2: Percentage Exceedance of Flows

%	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
10	15.23	14.32	16 71	30.46	29 76	20.17	15.55	13.75	15.71	13.31	14.51	16.58
20	12 94	13.02	13 39	23 51	22.98	17.59	13.89	12.35	12.12	12.14	12.91	12.94
40	12.16	12 14	12.43	18 35	20.27	14.12	12.73	11.79	11.68	11.64	12.18	12.12
60	11 56	11.61	11 65	12.86	15.77	12.63	11.75	11.45	11.44	11.50	11.57	11.67
80	11 34	11.35	11.37	11.67	13.24	11.57	11.42	11.22	11.19	11.24	11.25	11.43
100	6.08	9.29	7.32	10.26	11.22	8.94	4.00	9.12	7.34	9.20	9.20	8.97

From the above, it is seen that the months April and May have the highest flow. The discharge exceeded 40% of the time in these months is 18.35 and 20.27 cumecs respectively.

Section 5 *Flood Studies*

The maximum daily discharge recorded at the IDD54 gauging station for each year is given in annexure A.

Study of precipitation records at Arusha (No. 933-633) and Kikuletwa (No. 933-769), where data collection is comparatively sufficient, shows that precipitation was extreme in the years 1963, 1968, and 1978 - a cycle, at both sites, first of 5 years and then of 10 years. Yearly variations in river runoffs for the Kikuletwa River flowing from Mt. Meru and Mr. Kilimanjaro, has shown that the high water years were 1968 and 1974 - a cycle of 6 years.

It is said that a large flood occurs in the Kilimanjaro Region about once every 10 years. According to the above records, the cycle for medium-scale floods is approximately 5 years, while large-scale floods have a return period of close to 10 years.

The largest flood remembered by personnel at the existing TANESCO power station occurred in May 1978. On the basis of high water marks and river cross section, the flood water level is estimated to have been EL. 820.80 m, and the flood discharge estimated to be approximately 200 m^3/sec.

The probable flood discharges, as estimated by fitting various probability distributions are given in annexure B, based on the daily maximum discharge record for the 16-year period. The main results are given in box 7-3.

Box 7-3 Flood Estimates

RETURN INTERVAL	FOSTER TYPE -1	FOSTER TYPE -3	HAZEN'S	PEARSON	LOG PEARSON	GUMBEL
1.01	15.8	11 1	6.7	5.0	15.8	
1.05	16.8	14 6	12.9	11.6	19.9	7.0
20	59.2	58.2	58.6	84.5	90.1	94.2
100	113.8	116.5	119.2	110.9	136.6	129.2
1000	139 1	158 0	168.8	145.1	225.1	178.7
10000	155 5	196 6	223 7	174.2	351.0	228.0

The May 1978 flood discharge observed at the existing TANESCO power station, mentioned in the preceding section, is estimated to have been from a flood with a magnitude corresponding to a 1000-year return period. For the design of the spillways a discharge of 200 cumecs is fixed. For the construction, a design of 100 cumecs is fixed corresponding to 20 year flood. Both are based on Log-Pearson distribution.

Section 6 *Climatology*

Temperature, humidity, evaporation, and sunshine hours are recorded at the Moshi (EL. 854 m) and Same (EL. 872 m) observatories in the Kilimanjaro Region, and compiled at the Directorate of Meteorology in Dar es Salaam.

Part I **Temperature**

As is to be expected in a tropical country, temperatures are high, with little variation from year to year. February is the hottest month with a mean temperature of 33.1°C. August is the most pleasant month with a mean temperature of 15.4°C.

Part II **Rainfall**

The Kilimanjaro Region, which borders Kenya and is situated approximately 450 km northwest of Dar es Salaam, enjoys considerably more rainfall than the semi-arid regions which make up most of the country.

At the higher elevations on the slopes of Mt. Kilimanjaro's, annual precipitation exceeds 1,800 mm. On the higher areas of Mt. Pare , annual precipitation exceeds 1,000 mm. Precipitation decreases at lower elevations, however, and low-lying areas receive less than 500 mm of precipitation each year. Figure 7-2 shows an isohyetal map of the area.

This region generally has two rainy seasons. A heavy rainy season from March to May, and light rainy season in November and December.

Part III **Humidity**

The region is characterized by mild or moderate temperatures and very low relative humidities of about 40 to 60 percent.

Part IV **Evaporation**

Evaporation is fairly substantial even in the rainy season (with a value of about 300 mm in March). The mean monthly evaporation rates is given in Box 7-4.

Box 7-4: Monthly Evaporation in mm

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
EVAP	276.2	281.1	305.8	184.7	126.4	108.2	126.4	136.2	171.2	114.5	213.4	244.7	2290.8

Section 7 *River Water Quality*

Water samples were collected from the Kikuletwa and other rivers by JICA. Analysis carried out at the Soil & Water Laboratory in Maji Ubungo showed that water in the rivers flowing down Mt. Kilimanjaro is alkaline, with pH values slightly higher than 7.

No abnormal physical or chemical properties were recognized in any of the samples analyzed.

The suspended loads and discharges of the Kikuletwa, Weru-weru, and Pangani rivers, are given in box 7-5.

Box 7-5: Water Quality

River	Station	Area (km^2)	Discharge (m^3/s)	Suspended Load
Kikuletwa	IDD-1	3840	14.8 to 90.1	9 to 164
Weru-Weru	IDD-5A	146	6.2 to 60.6	19 to 698
Pangani	ID-8	9037	16.8 to 96.9	21 to 133

Using the discharge - suspended load relationship for the Weru-weru River, for which the suspended load is comparatively high, the following suspended load and discharge are found for 1970 by JICA team, for the year of average runoff condition at gauging station No. 1DD-54 on the Kikuletwa River.

River	Station	Suspended Load	Discharge
Kikuletwa	IDD-54	28	7.65
		300	30.97

Based only on the above data, the total suspended load is calculated to be approximately 24,505 m^3, against a total annual flow volume of approximately 41.1 million m^3. This corresponds to 11.04 cu.m per square kilometer annually.

The Kikuletwa River, for the 72 km stretch from Msitu Wa Mbogo near Arusha to its confluence with the Karanga River, may be considered to be a transitional area. The average river gradient in this stretch is approximately 1:300. The suspended load, instead of being deposited in this transitional area, is carried down and deposited in to the plan area, or else is carried further down, to the Nyumba ya Mungu Reservoir.

Section 8 *Sedimentation*

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 7-6: Normal scouring velocities.

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

In the case of the Kikuletwa 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 Kikuletwa reservoir. However, the matter will have to be watched in future, especially the silt load volume. Changes of the river channel and its bottom have to checked. 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 Nyumba ya Munga reservoir which is downstream.

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 Kikuletwa site results in the following estimate :

q_S = 0.501 x (151,000/22,20) $^{0.569}$ = 5.53 cum/sqkm/yr

Q_S = qs x Catchment area = 5.53 x 22,20 = 12,273 cu.m/yr

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

Cr = Reservoir volume/Average annual inflow
= 151,000/452x10^6 = 0.000334

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 x12,273 = 62 Cubic meters

Over a period of 40 years, total sediment volume = 2480 cubic meters or about 2% of the gross storage of the reservoir. However due to the operation of the gates, regular flushing of the deposits near the diversion structure will occur and the actual trap efficiency will be much lower.

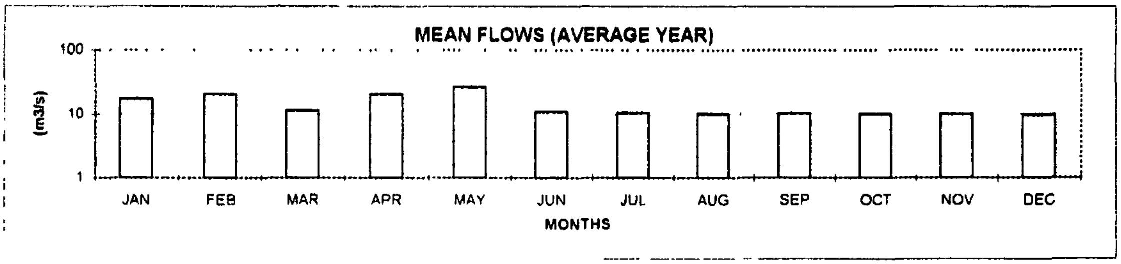
SITE 1DD54
STREAM KIKULETWA
BASIN KIKULETWA

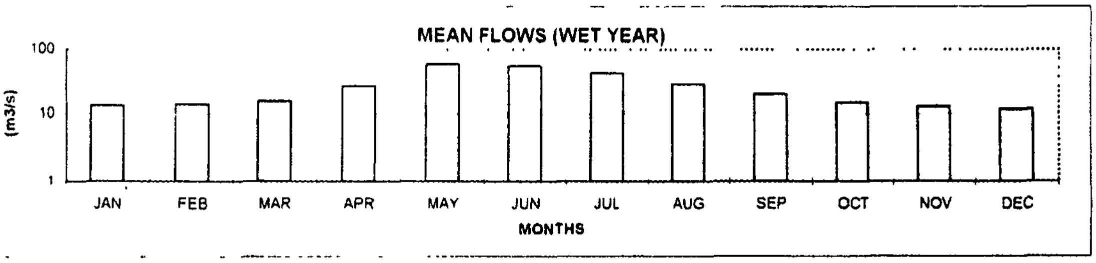
TABLE 7-1
OBSERVED FLOW AT SITE 1DD54

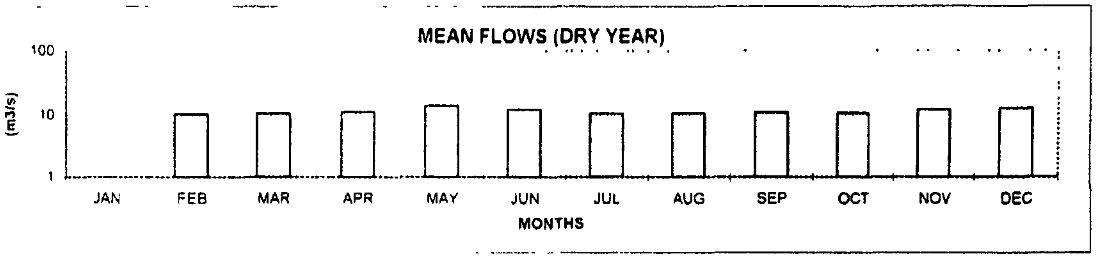
UNITS m^3/s
CATCHMENT 2,220 km^2

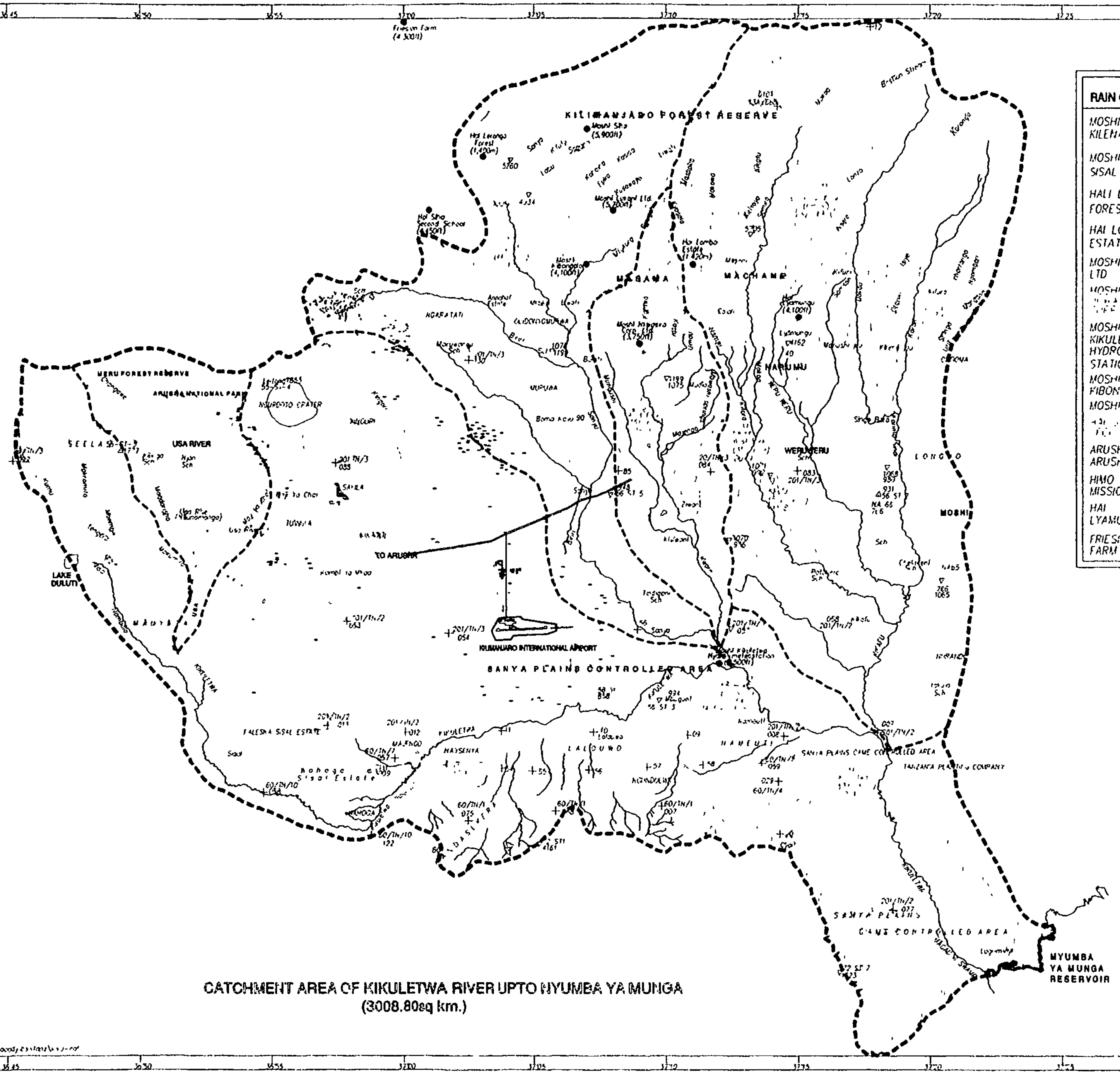
DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL MEAN	YIELD (MCM)
1967	N A	10 37	10 53	10 98	13 79	12 20	10 60	10 66	10 81	10 66	11 94	12 33	11 36	327 8
1968	11 44	11 76	13 85	24 25	24 32	25 52	14 82	12 61	11 26	11 43	14 43	17 54	15 80	483 1
1969	12 16	13 42	13 21	12 56	13 89	12 37	11 72	11 91	11 91	11 33	12 23	12 11	12 39	390 8
1970	12 59	12 50	12 95	19 63	19 31	12 65	11 53	11 29	10 60	11 44	10 57	11 20	13 02	410 7
1971	17 49	20 86	11 48	20 59	26 65	10 92	10 39	9 95	10 23	9 96	9 91	9 37	13 89	434 5
1972	10 61	10 16	13 27	16 04	19 01	14 92	11 95	11 17	12 22	12 49	13 21	12 31	13 12	414 8
1973	12 46	12 42	11 69	14 44	18 77	12 25	12 44	11 84	11 58	11 40	11 39	11 49	12 69	400 1
1974	12 22	13 06	11 49	33 78	15 57	11 83	11 68	11 29	11 49	11 60	11 18	11 43	13 86	437 0
1975	11 20	11 30	11 09	12 47	14 13	12 95	11 48	11 32	11 49	11 38	11 14	11 41	11 78	371 5
1976	11 23	11 42	11 48	11 76	11 63	11 29	11 41	11 36	11 37	11 28	11 36	11 33	11 41	360 8
1977	11 39	14 20	11 82	17 68	13 61	12 29	11 54	12 23	12 29	12 69	13 57	12 78	12 99	409 5
1978	12 54	13 13	14 14	19 82	21 68	17 33	13 95	19 34	22 94	17 37	16 34	15 62	17 03	536 9
1979	13 08	13 52	15 20	25 81	58 90	55 24	41 91	27 72	19 29	14 64	12 69	11 72	25 88	816 3
1980	11 39	11 59	11 98	11 90	24 33	N A	13 91	11 75	11 24	11 27	11 74	11 94	13 02	378 0
1981	11 50	11 80	11 77	13 55	16 95	12 77	11 51	11 50	11 56	11 53	11 43	11 44	12 28	387 2
1982	11 21	11 24	11 44	13 91	15 29	13 00	11 74	N A	N A	12 06	14 86	16 69	13 26	331 0
1983	11 78	11 46	11 35	11 55	16 39	15 06	11 48	11 42	11 45	11 63	11 42	N A	12 28	354 3
1984	11 43	N A	11 65	12 42	15 95	12 22	12 29	11 52	13 80	12 20	N A	N A	12 68	268 4
1985	11 78	12 13	22 46	27 51	22 86	19 54	16 14	12 64	11 95	11 84	12 29	15 56	16 41	517 5
1986	19 97	13 64	11 97	22 07	33 32	20 24	13 82	12 12	11 74	11 54	12 29	12 28	16 27	513 0
1987														
1988	12 19	14 16	16 71	18 16	14 00	13 10	12 85	11 96	11 44	11 46	12 71	12 40	13 42	424 4
1989														
1990	12 37	12 84	N A	31 62	21 78	18 34	15 25	N A	12 85	12 19	16 62	26 69	18 08	473 4
1991	25 37	23 62	20 40	N A	N A	17 27	14 62	12 13	N A	N A	11 81	12 15	17 11	359 3
1992	11 71	11 63	11 44	28 57	21 07	18 67	13 72	N A	N A	N A	N A	N A	16 67	306 8
MEAN													14 45	421 1
YEARS	23	23	23	23	23	23	24	21	21	22	22	21	269	
MAX	25 37	23 62	22 46	33 78	58 90	55 24	41 91	27 72	22 94	17 37	16 62	26 69	58 90	
MIN	10 61	10 16	10 53	10 98	11 63	10 92	10 39	9 95	10 23	9 96	9 91	9 37	9 37	
MEAN	13 00	13 14	13 19	18 74	20 57	16 61	13 86	12 75	12 55	11 97	12 50	13 32	14 35	
VOLUME	34 83	31 79	35 32	48 58	55 10	43 05	37 13	34 15	32 52	32 07	32 41	35 69	452 64	
RUNOFF	15 69	14 32	15 91	21 88	24 82	19 39	16 73	15 38	14 65	14 44	14 60	16 07	203 89	

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


MEAN FLOWS (AVERAGE YEAR)


MEAN FLOWS (WET YEAR)


MEAN FLOWS (DRY YEAR)



CATCHMENT AREA OF KIKULETWA RIVER UPTO NYUMBA YA MUNGA
(3008.80sq km.)

RAIN GAUGE	CODE
MOSHI(HIMO) KILEMA-CHINI	933-745
MOSHI HIMO SISAL ESTATE	933-731
HALI LERONGO FOREST	933-7134
HAI LOMBO ESTATE	933-7135
MOSHI LUKANI LTD	933-7119
MOSHI [illegible]	933-7136
MOSHI KIKULETWA HYDRO-METEO STATION	933-769
MOSHI KIBONGOTO	933-778
MOSHI SIHA	933-7118
[illegible] SCHOOL	933-7142
ARUSH ARUSH AIR-PORT	933-633
HIMO ROMBO MISSION SCHOOL	933-706
HAI LYAMUNGU	933-721
FRIESIAN FARM	933-747

RIVER	CODE
RUVU 3,370km^2	IDC-2A
RAU 270km^2	IDC- 3A
MUE 280km^2	IDC-6
HIMO 264km^2	IDB-11A MOSHI-TANGA RD BRIDGE
KIKULETWA 3 880km^2	IDD-1
WERU-WERU 68km^2	IDD-6A
KIKULETWA 2 20km^2	IDD-54 TANESCO P/STATION
KIKAFU (50sq mile)	IDD-8
KWARE WEST FORK (35s mile)	IDD-9
KWARE WEST FORK (16s mile)	IDD-10
SANYA JUU (44s mile)	IDD-13

LEGEND

River	
Tributaries & Sub-tributaries	
Trigonometrical Station Secondary	▽ Ground Station
Trigonometrical Station Other	● Ground Station
Air Photo Principal Point with Film No	+ 010 201/TH/7
Rainfall station	●
Gauging station	

REFERENCE

Topo-Sheet No 72/2 56/4,56/2,72/1,71/2
55/4 56/1 55/2,56/3

0 10
SCALE (km)

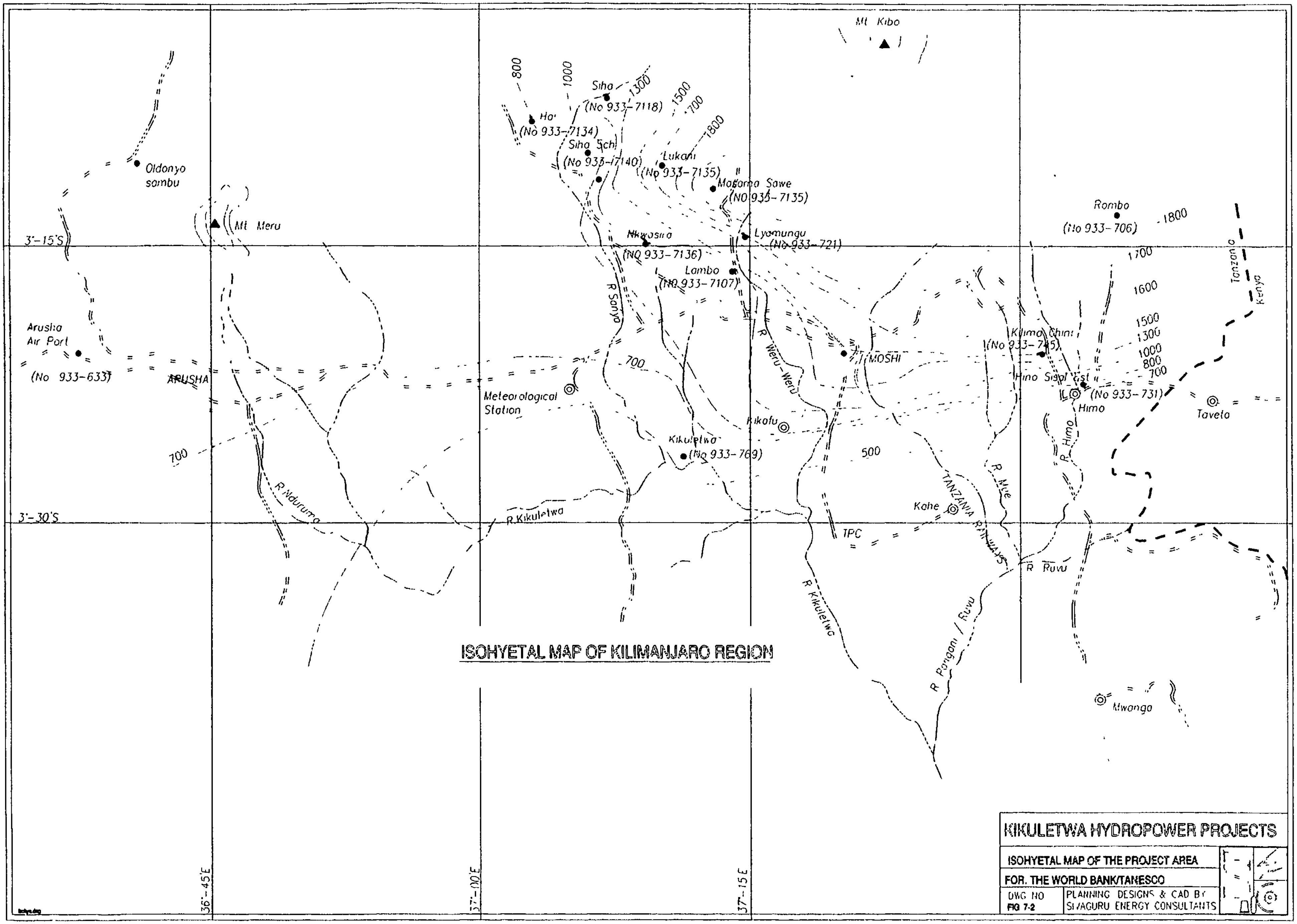
THE KIKULETWA HYDROPOWER PROJECT

HYDROMETEOROLOGICAL STATIONS

FOR: WORLD BANK/TANESCO

DWG NO
Fig 7-1

PLANNING, DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS



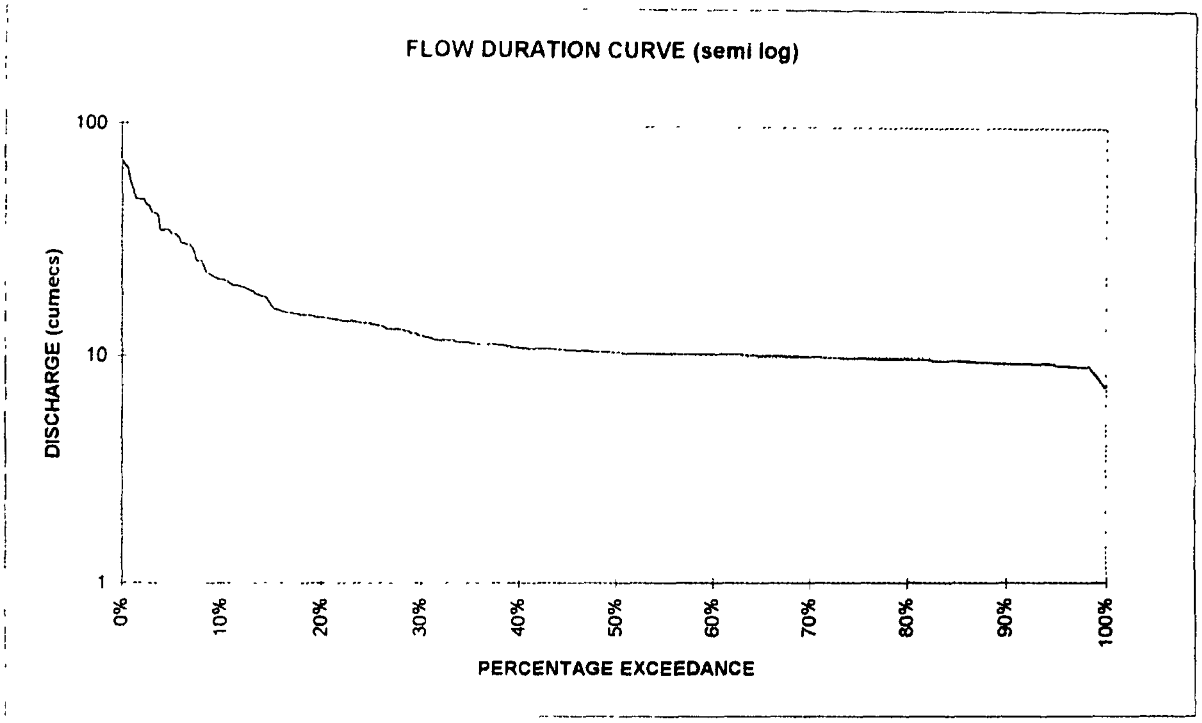
KIKULETWA HYDROPOWER PROJECTS

ISOHYETAL MAP OF THE PROJECT AREA

FOR. THE WORLD BANK/TANESCO

DWG NO FIG 7-2	PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

FIGURE . 7-3
FLOW DURATION CURVE IN AVERAGE YEAR



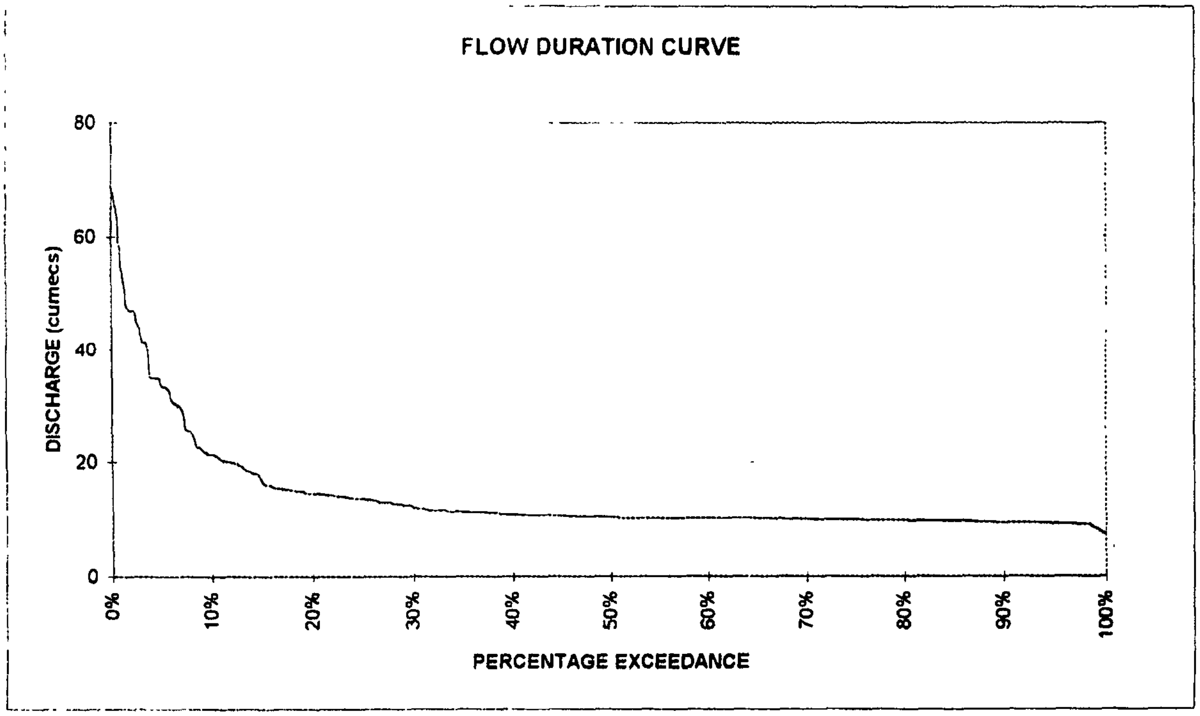
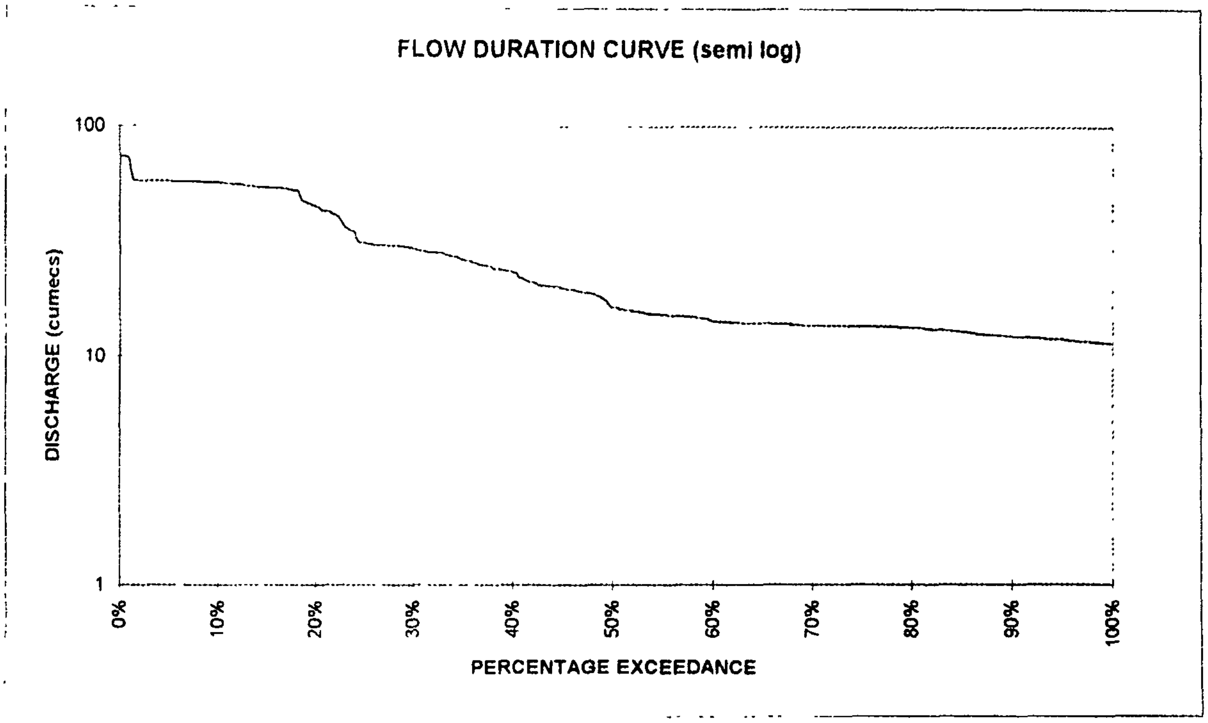
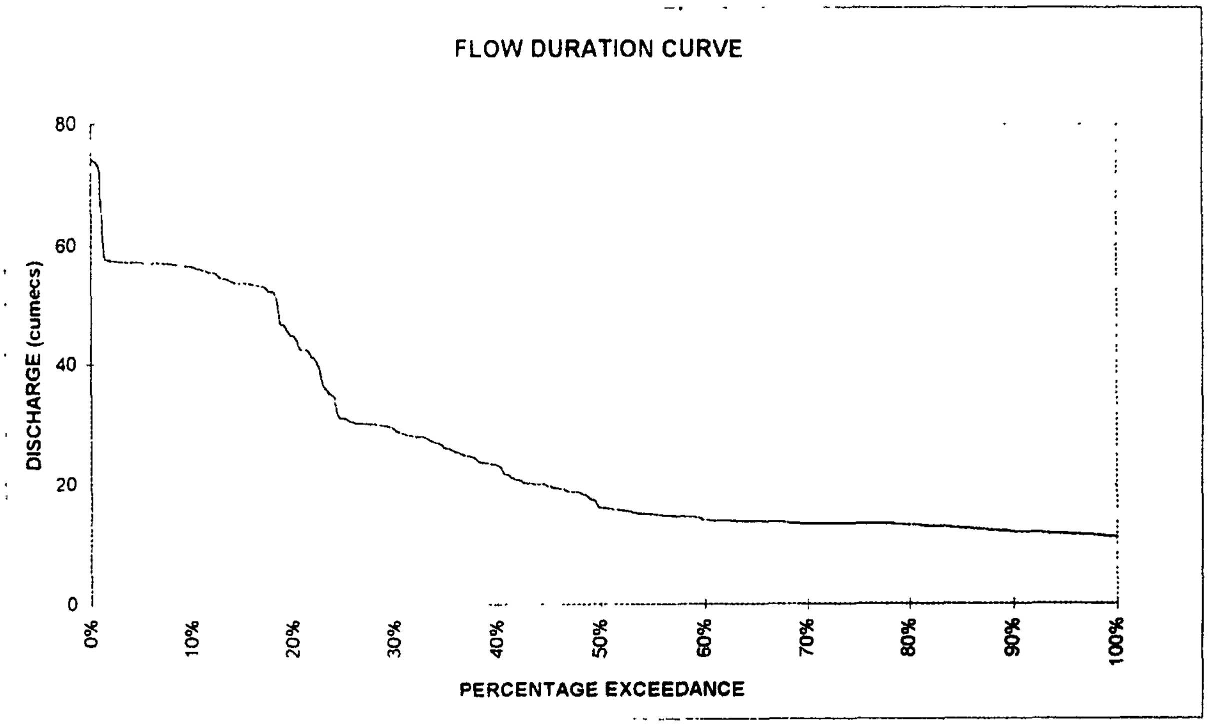


FIGURE · 7-4
FLOW DURATION CURVE IN A WET YEAR

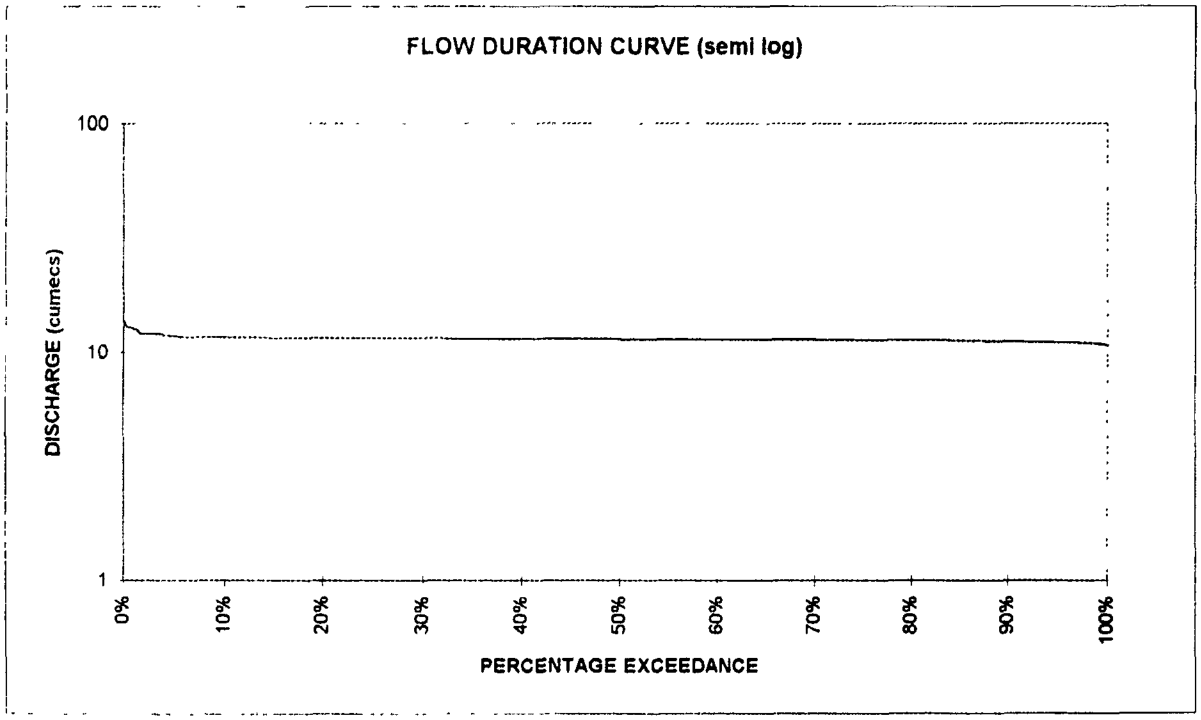


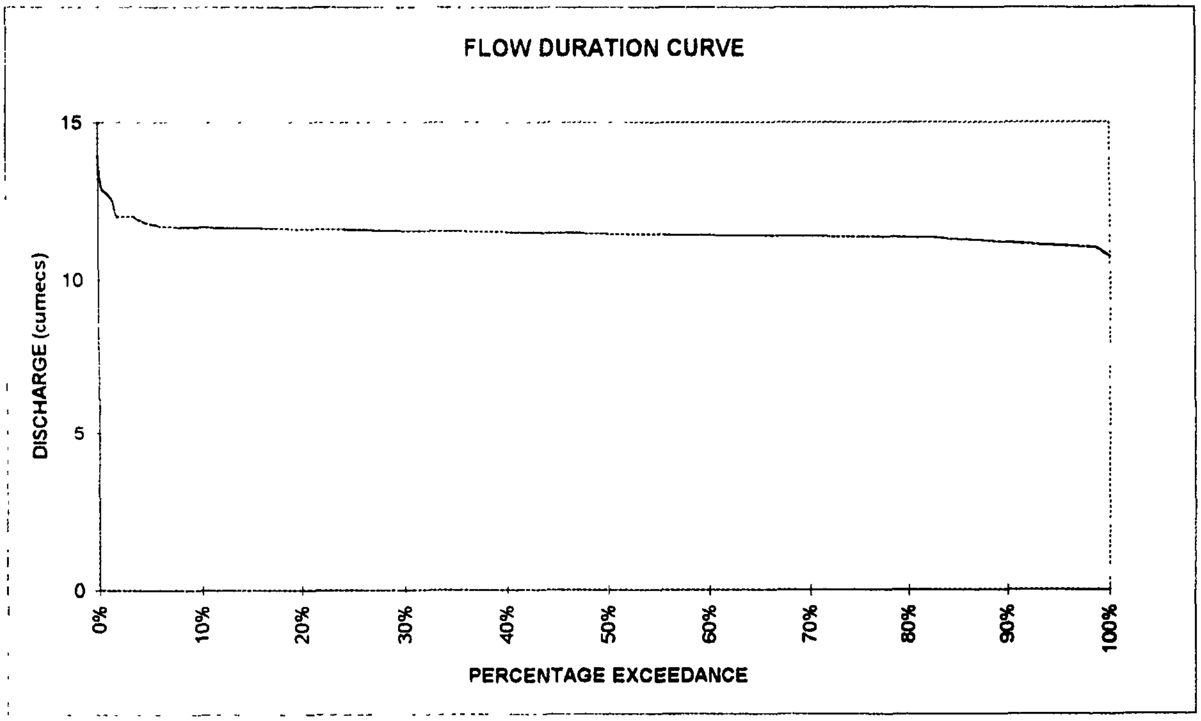


SITE IDD54
STREAM KIKULETWA
BASIN KIKULETWA

FIGURE 7-5
FLOW DURATION CURVE IN A DRY YEAR

YEAR 1976





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 1:5000 aerial topographic maps which are existing. The contours on the map were digitised and the contours were further interpolated to contour intervals of 1m by use of a Digital Terrain modelling software. The area enclosed by each contour at the diversion weir site was calculated. The incremental storage between any two levels h_1 and h_2 is given by the following cone formula.

$A = A_1 + A_2 + \sqrt{(A_1A_2)}$ where A_1 and A_2 are area in m^2 at elevation h_1 and h_2 respectively.
$\Delta V = A (h_1 - h_2)/3$ cubic meters.
$V = \Sigma\Delta V$ cubic meters.

The area/capacity characteristics are given in figure 8-1.

Section 3 *Methodology*

The methodology adapted for deriving the inflow sequence at the Kikuletwa dam 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 with no missing data is taken to be representative of the hydrological conditions which are likely to recur during the lifetime of the project. This representative period is the hydrological years 1970 to 1979. The average yield of Kikuletwa for this period at the proposed site is 14.61 cumecs with a yield of 451.1 MCM. A set of extreme conditions in the above period were identified to carry out the power and energy studies.

The year with maximum yield was 1979 with a yield of 814 MCM and the year with minimum yield was 1976 with a yield of 359.8 MCM. The year in which the yield was closest to the mean with monthly distribution of runoff corresponding to the average of the ten years is 1971 with a yield of 450.9 MCM. Thus 1971 is an average year, 1979 is a wet year, and 1976 is a dry year. In any actual year, the energy output from the plant would be between the extreme values as determined from the above.

Thus the evaluation was carried out according to the series of daily average discharges available for the 10-year period 1970 to1979.

The installed capacity and the choice of the number of units was fixed so as to minimize the spill in an average year as well as to use some of the extra flows available in a wet year. 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 11MW and the power station will consist of two units. (2 x 5.5MW). As a drawdown of about 3 to 4m is permitted, considering the fairly uniform head which will be obtained during the year, vertical shaft Francis 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 or pondages are 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 Kikuletwa power station in a typical average year 1971 with an installed capacity of 2 x 5.5MW.

2. Operation of the Kikuletwa power station in a typical wet year 1979 with an installed capacity of 2 x 5.5MW.

3. Operation of the Kikuletwa power station in a typical dry year 1976 with an installed capacity of 2 x 5.5MW.

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 rake, draft tube etc but does not include the losses in the turbine.

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

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

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

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

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

house for various auxiliaries. Then the losses in the power transformer and bus is subtracted to give the net power available.

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

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

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

Section 7 *Conclusions*

The results of the studies are summarized below.

Box 8-1 Summary of Energy Outputs

Installed Capacity (MW)	Mean Year (GWh)	Wet Year (GWh)	Dry Year (GWh)
1 x 4.0	36.0	82.0	55.9
1 x 6.0	54.1		
2 x 4.0	59.7		
2 x 5.5	65.0		
2 x 6.0	66.2		

The annual energy production in an average year is about 65 GWh. The annual inflow volume and utilization for generation for each year is given below in Box 8-2.

Box 8-2: Water Utilization for generation

Year	Wet Year	Average Year	Dry Year
Inflow (MCM)	816.3	448.9	359.7
Utilization (MCM)	526.1	414.4	359.7
Percent Utilization	64.45	92.31	100.00

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

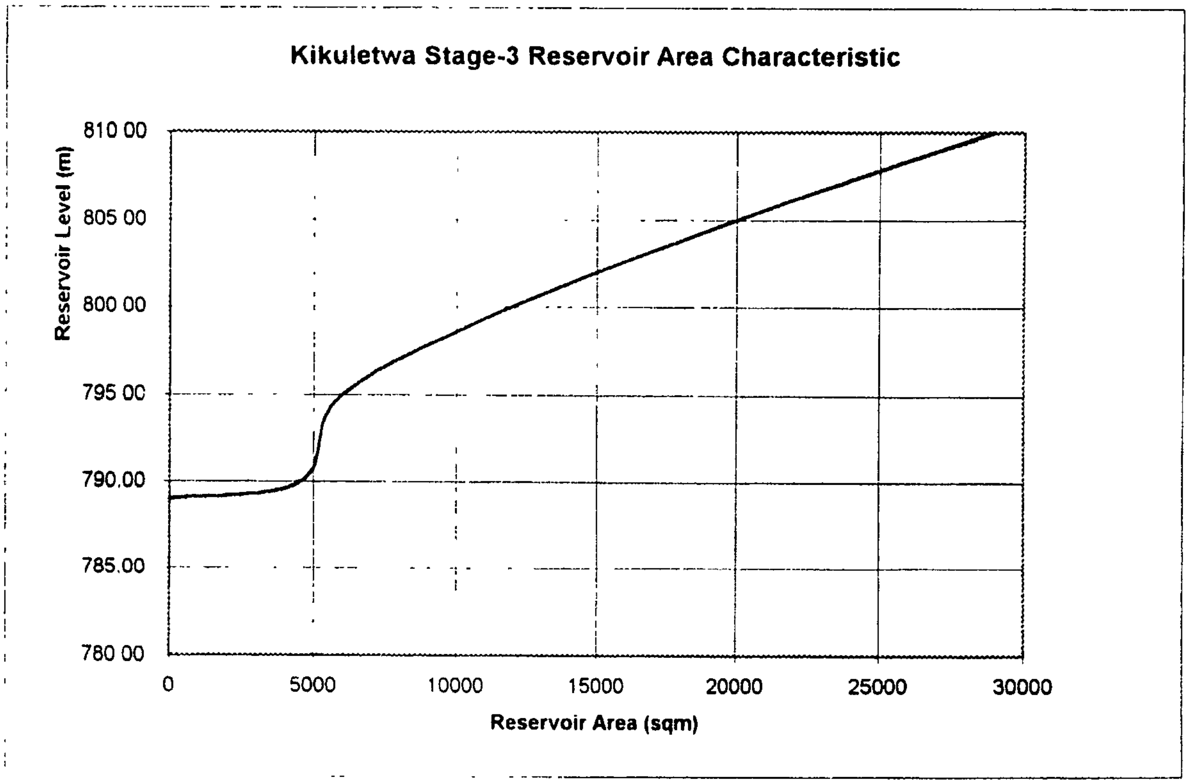
Box 8-3: Plant Load Factor

Year	Average	Wet	Dry
Plant Load Factor	67.45	85.10	58.50

Further from the tables 8-1 to 8-3, it is seen that in an average year, 11,000 kW can be generated continuously in the months February to May. In the other months one unit can be on full load.

As initially, the power plant will be the only generating plant operating near Moshi into the existing grid it is anticipated that the power station will give peaking facility and voltage support. Also surplus energy can be utilized in neighboring areas easily.

FIGURE 8-1
RESERVOIR AREA AND CAPACITY CURVES



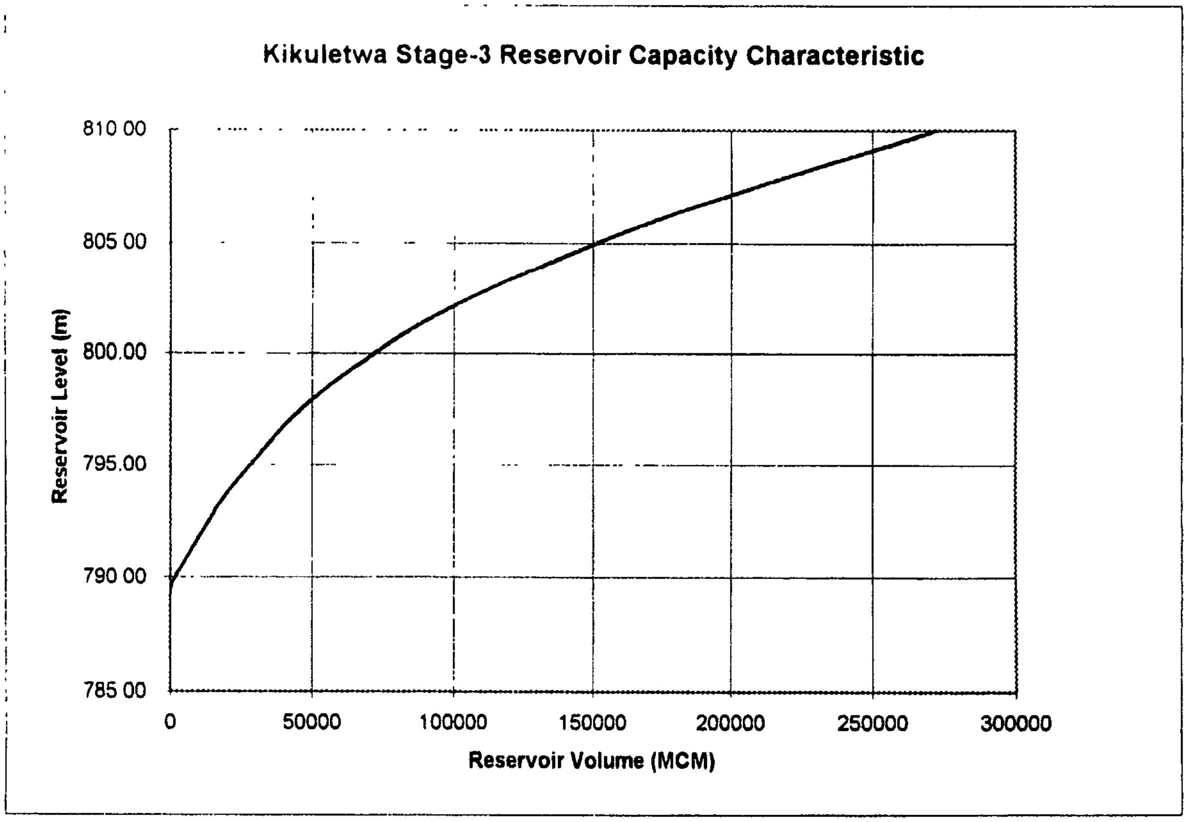
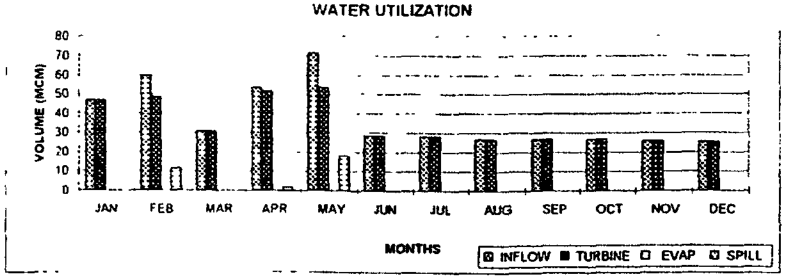
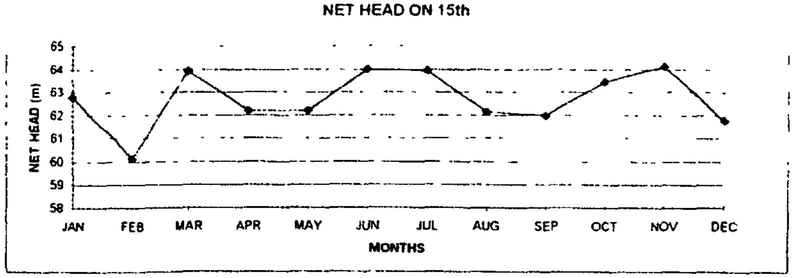
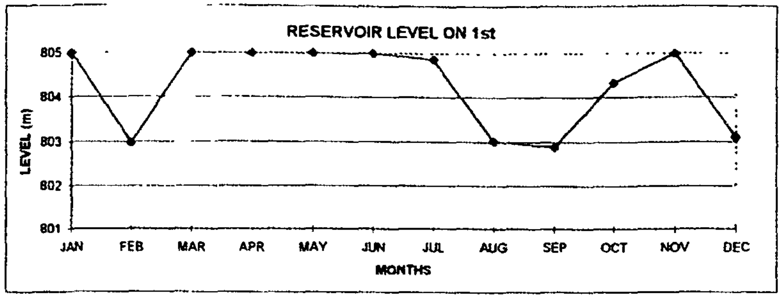


TABLE 8 1
KIKULETWA STAGE-3 PROJECT
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL AVERAGE YEAR FOR 2 x 5 5MW (1971)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM	MAND RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	0 15	805 00	46 85	46 87	0 02	0 01	0 00	0 00	0 12	802 96	0 00	0 00	0 03	17 50	24 00	2	64 59	1 82	62 77	60 14	62 77	740 41	9 63	7 16
FEB	0 12	802 96	59 75	48 38	0 02	0 00	0 00	0 00	0 15	805 00	11 33	670 09	0 03	20 00	24 00	2	62 51	2 36	60 14	63 90	60 14	740 45	11 10	7 46
MAR	0 15	805 00	30 75	30 72	0 02	0 01	0 00	0 00	0 15	805 00	0 02	744 00	0 00	11 47	24 00	2	64 69	0 79	63 90	62 19	63 90	740 31	6 47	4 82
APR	0 15	805 00	53 37	51 84	0 02	0 00	0 00	0 00	0 15	805 00	1 53	720 00	0 00	20 00	24 00	2	64 55	2 36	62 19	62 19	62 19	740 45	11 13	8 02
MAY	0 15	805 00	71 38	53 57	0 02	0 00	0 00	0 00	0 15	805 00	17 81	744 00	0 00	20 00	24 00	2	64 55	2 36	62 19	63 98	62 19	740 45	11 29	8 40
JUN	0 15	805 00	28 30	28 30	0 02	0 00	0 00	0 00	0 15	804 86	0 00	0 00	0 00	10 92	24 00	2	64 70	0 72	63 98	63 92	63 98	740 30	6 25	4 50
JUL	0 15	804 86	27 83	27 86	0 02	0 00	0 00	0 00	0 12	803 01	0 00	0 00	0 03	10 40	24 00	2	64 57	0 65	63 92	62 13	63 92	740 29	5 87	4 37
AUG	0 12	803 01	26 65	26 65	0 02	0 00	0 00	0 00	0 12	802 87	0 00	0 00	0 00	9 95	24 00	2	62 73	0 60	62 13	61 95	62 13	740 28	5 53	4 11
SEP	0 12	802 87	26 52	26 49	0 02	0 00	0 00	0 00	0 14	804 33	0 00	0 00	0 02	10 22	24 00	2	62 58	0 63	61 95	63 45	61 95	740 29	5 74	4 11
OCT	0 14	804 33	26 68	26 65	0 02	0 00	0 00	0 00	0 15	805 00	0 01	421 89	0 01	9 95	24 00	2	64 04	0 60	63 45	64 12	63 45	740 28	5 68	4 23
NOV	0 15	805 00	25 69	25 71	0 02	0 00	0 00	0 00	0 12	803 09	0 00	0 00	0 03	9 92	24 00	2	64 72	0 59	64 12	61 77	64 12	740 28	5 59	4 02
DEC	0 12	803 09	25 10	25 10	0 02	0 00	0 00	0 00	0 12	803 05	0 00	0 00	0 00	9 37	24 00	1	62 87	1 05	61 77	63 05	61 77	740 27	5 23	3 89
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	MEAN	(MEAN)	(MEAN)	(TOTAL)
		804 25	448 86	418 14	0 02	0 04	0 00	0 00		804 10	30 70	3299 98	0 03	13 31	8760 00		63 92	1 21	62 71	62 73	62 71	740 34	7 46	65 11







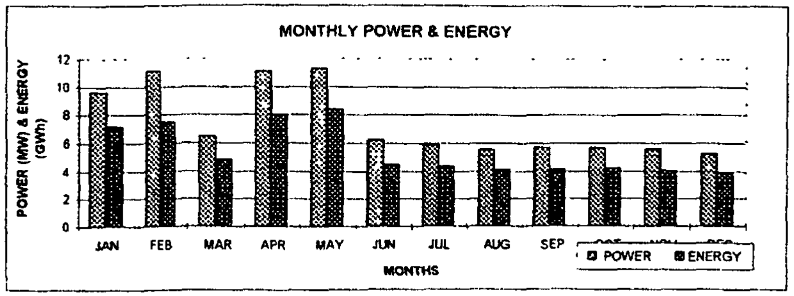
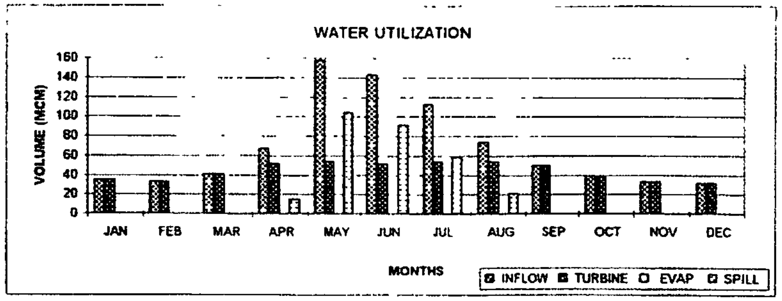


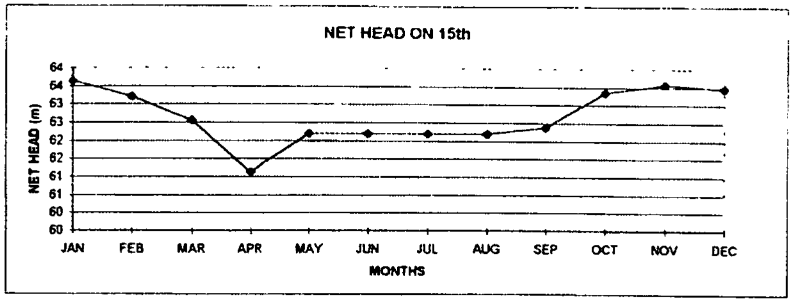
TABLE 8-2

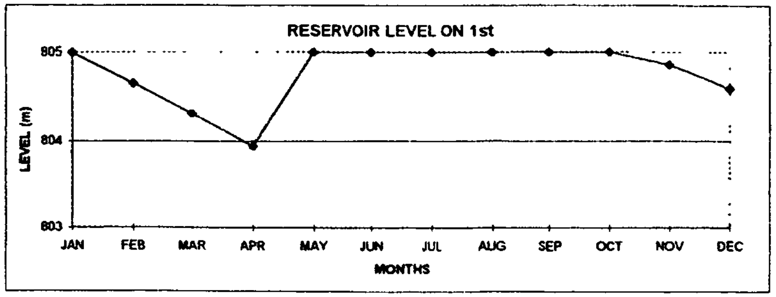
KIKULETWA STAGE-3 PROJECT

MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL WET YEAR FOR 2 x 5 5MW (1979)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM	MAND RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	0 15	805 00	35 03	35 01	0 02	0 01	0 00	0 00	0 15	804 65	0 00	0 00	-0 01	13 08	24 00	2	64 66	1 02	63 64	63 21	63 64	740 34	7 43	5 52
FEB	0 15	804 65	32 71	32 71	0 02	0 01	0 00	0 00	0 14	804 31	0 00	0 00	-0 01	13 52	24 00	2	64 30	1 09	63 21	62 55	63 21	740 35	7 61	5 11
MAR	0 14	804 31	40 71	40 71	0 02	0 01	0 00	0 00	0 13	803 94	0 00	0 00	-0 01	15 20	24 00	2	63 93	1 38	62 55	61 13	62 55	740 38	8 41	6 26
APR	0 13	803 94	66 90	51 84	0 02	0 00	0 00	0 00	0 15	805 00	15 04	719 20	0 02	20 00	24 00	2	63 49	2 36	61 13	62 19	61 13	740 45	11 04	7 95
MAY	0 15	805 00	157 76	53 57	0 02	0 00	0 00	0 00	0 15	805 00	104 19	744 00	0 00	20 00	24 00	2	64 55	2 36	62 19	62 19	62 19	740 45	11 13	8 28
JUN	0 15	805 00	143 18	51 84	0 02	0 00	0 00	0 00	0 15	805 00	91 34	720 00	0 00	20 00	24 00	2	64 55	2 36	62 19	62 19	62 19	740 45	11 13	8 02
JUL	0 15	805 00	112 25	53 57	0 02	0 00	0 00	0 00	0 15	805 00	58 68	744 00	0 00	20 00	24 00	2	64 55	2 36	62 19	62 19	62 19	740 45	11 13	8 28
AUG	0 15	805 00	74 25	53 57	0 02	0 00	0 00	0 00	0 15	805 00	20 67	744 00	0 00	20 00	24 00	2	64 55	2 36	62 19	62 38	62 19	740 45	11 15	8 30
SEP	0 15	805 00	50 00	49 77	0 02	0 00	0 00	0 00	0 15	805 00	0 23	720 00	0 00	19 20	24 00	2	64 56	2 18	62 38	63 35	62 38	740 44	10 80	7 78
OCT	0 15	805 00	39 21	39 21	0 02	0 00	0 00	0 00	0 15	804 86	0 00	0 00	0 00	14 64	24 00	2	64 63	1 28	63 35	63 56	63 35	740 37	8 32	6 19
NOV	0 15	804 86	32 89	32 89	0 02	0 00	0 00	0 00	0 14	804 59	0 00	0 00	0 00	12 69	24 00	2	64 52	0 97	63 56	63 45	63 56	740 33	7 21	5 19
DEC	0 14	804 59	31 39	31 39	0 02	0 00	0 00	0 00	0 14	804 53	0 00	0 00	0 00	11 72	24 00	2	64 27	0 83	63 45	64 53	63 45	740 32	6 71	4 99
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		804 78	816 28	526 10	0 02	0 04	0 00	0 00		804 74	290 15	4391 20	-0 01	16 67	8760 00		64 38	1 71	62 67	62 74	62 67	740 40	9 34	81 88







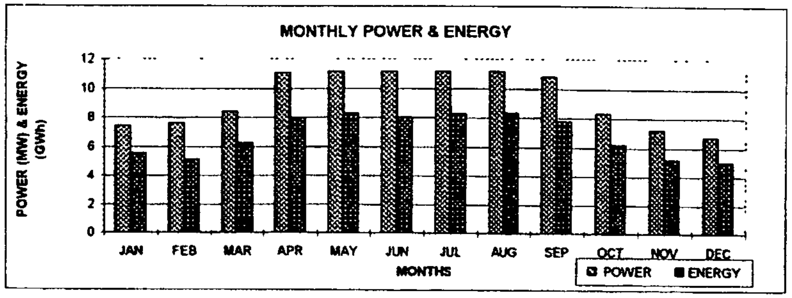
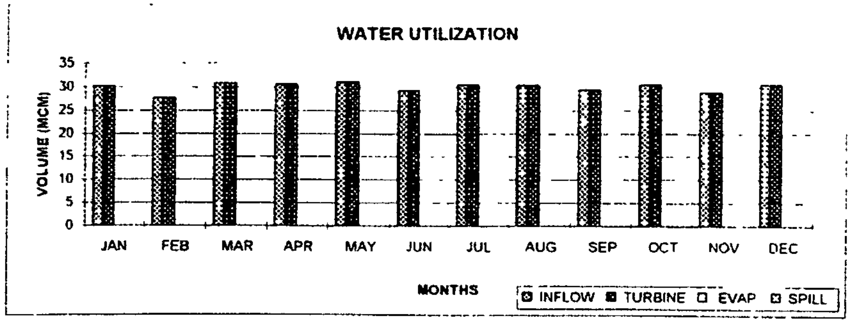


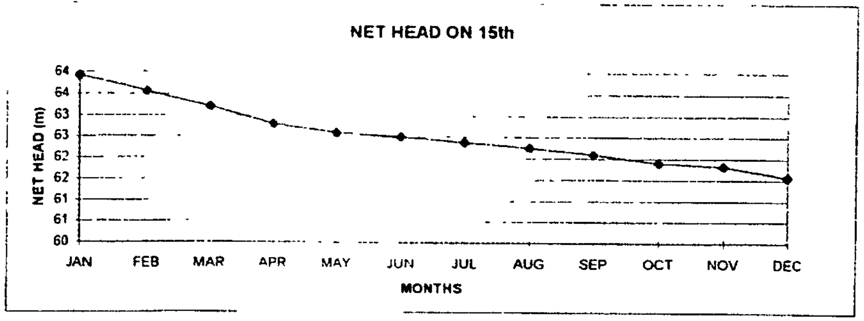
TABLE 8-3

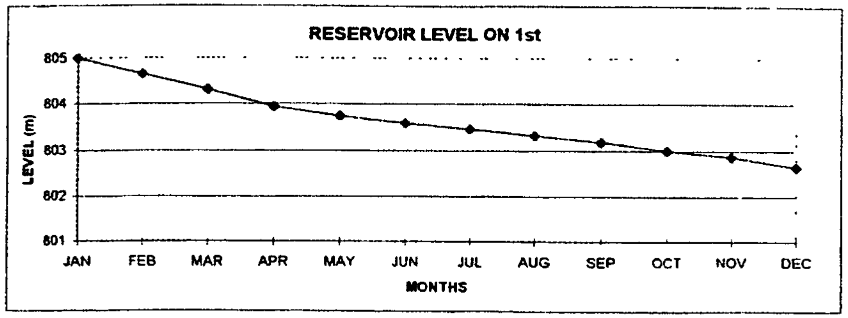
KIKULETWA STAGE 3 PROJECT

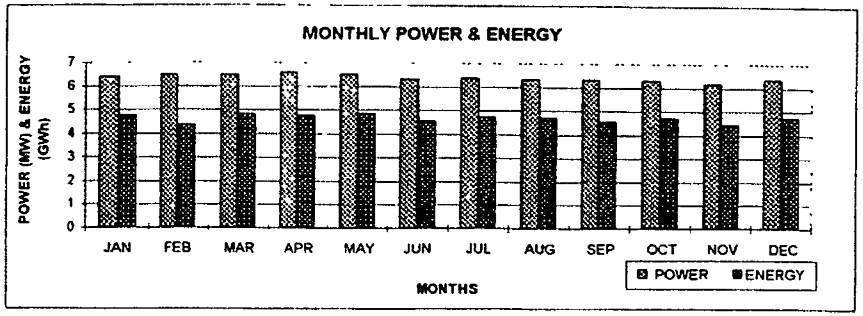
MONTHLY SUMMARY OF OPTIMIZED DAILY POWER STUDY IN A TYPICAL DRY YEAR FOR 2 x 5.5MW (1976)

MONTH	START VOLUME (M CUM)	START LEVEL (m)	INFLOW VOLUME (M CUM)	TURBINE VOLUME (M CUM)	LAKE SURFACE AREA (SQ KM)	EVAP VOLUME (M CUM)	IRR RELEASE (M CUM)	MANC RELEASE (M CUM)	FINISH STORAGE (M CUM)	FINISH LEVEL (m)	SPILL VOLUME (M CUM)	SPILL HOURS	CHANGE IN STORAGE (MCM)	AVERAGE STATION DISCH (cum/s)	HOURS RUN PER DAY	UNITS RUN	AVERAGE GROSS HEAD (m)	AVERAGE LOSS (m)	START NET HEAD (m)	FINISH NET HEAD (m)	AVERAGE NET HEAD (m)	AVERAGE TWL (m)	AVERAGE POWER (MW)	ENERGY (GWh)
JAN	0.15	805.00	30.08	30.08	0.02	0.01	0.00	0.00	0.15	804.65	0.00	0.00	0.01	11.23	24.00	2	64.69	0.76	63.93	63.56	63.93	740.31	6.41	4.77
FEB	0.15	804.65	27.63	27.63	0.02	0.01	0.00	0.00	0.14	804.31	0.00	0.00	0.01	11.42	24.00	2	64.34	0.78	63.56	63.20	63.56	740.31	6.48	4.35
MAR	0.14	804.31	30.75	30.75	0.02	[illegible]	0.00	0.00	0.13	803.94	0.00	0.00	-0.01	11.48	24.00	2	63.99	0.79	63.20	62.79	63.20	740.31	6.47	4.82
APR	0.13	803.94	30.48	30.48	0.02	[illegible]	0.00	0.00	0.13	803.73	0.00	0.00	0.00	11.76	24.00	2	63.62	0.83	62.79	62.60	62.79	740.32	6.60	4.75
MAY	0.13	803.73	31.15	31.15	0.02	[illegible]	0.00	0.00	0.13	803.58	0.00	0.00	0.00	11.63	24.00	2	63.41	0.81	62.60	62.51	62.60	740.31	6.51	4.85
JUN	0.13	803.58	29.26	29.26	0.02	[illegible]	0.00	0.00	0.13	803.46	0.00	0.00	0.00	11.29	24.00	2	63.28	0.77	62.51	62.37	62.51	740.31	6.31	4.54
JUL	0.13	803.46	30.56	30.56	0.02	[illegible]	0.00	0.00	0.12	803.32	0.00	0.00	0.00	11.41	24.00	2	63.15	0.78	62.37	62.24	62.37	740.31	6.36	4.73
AUG	0.12	803.32	30.43	30.43	0.02	[illegible]	0.00	0.00	0.12	803.17	0.00	0.00	0.00	11.36	24.00	2	63.01	0.78	62.24	62.09	62.24	740.31	6.32	4.70
SEP	0.12	803.17	29.47	29.47	0.02	[illegible]	0.00	0.00	0.12	802.99	0.00	0.00	0.00	11.37	24.00	2	62.56	0.78	62.09	61.90	62.09	740.31	6.31	4.54
OCT	0.12	802.99	30.48	30.48	0.02	[illegible]	0.00	0.00	0.12	802.87	0.00	0.00	0.00	11.38	24.00	2	62.68	0.78	61.90	61.82	61.90	740.31	6.30	4.69
NOV	0.12	802.87	28.87	28.87	0.02	0.00	0.00	0.00	0.11	802.64	0.00	0.00	0.00	11.14	24.00	2	62.56	0.75	61.82	61.55	61.82	740.31	6.15	4.43
DEC	0.11	802.64	30.56	30.56	0.02	[illegible]	0.00	0.00	0.11	802.60	0.00	0.00	0.00	11.41	24.00	2	62.33	0.78	61.55	62.60	61.55	740.31	6.34	4.72
		(MEAN)	(TOTAL)	(TOTAL)	(MEAN)	(TOTAL)	(TOTAL)	(TOTAL)		(MEAN)	(TOTAL)	(TOTAL)	NET STORAGE	(MEAN)	(TOTAL)		(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(MEAN)	(TOTAL)
		803.64	359.72	359.72	0.02	0.14	0.00	0.00		803.44	0.00	0.00	0.04	11.41	8760.00		63.33	0.78	62.55	62.43	62.55	740.31	6.38	55.89









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 and overflow sections.
4 Construction of the intake structure for the waterway.
5 Construction of waterway comprising cut and cover conduit and penstock.
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. Fortunately the site is located such that the works required will be limited to improvement of an existing 8km stretch. Other works involved are the improvement of existing second class road which is to be made suitable for transport of the machinery, especially through provision of some small culverts across streams. Therefore, it will not be necessary to seek permission to develop new roads. The access road will be used to transport all the equipment required to construct the project. The road is proposed to be 7.20m wide with shoulders 1m wide. The proposed elevation of the access road is at EL 830m so as to be above the elevation of the high flood expected downstream of the diversion site. Two main branches are provided, one leading to the top of the dam which is at 812m and the other descending to the power house machine hall level which is at 740m. The power house access road requires some grading of the left bank of the river so as to have a gradient suitable for descent of vehicles. A simple bridge has to be provided to cross the river to the right bank where the power house is located.

Section 3 *Preliminary Design*

Part I Diversion Weir

The diversion weir is a concrete gravity cum arch structure 20m in height and curved in plan. Considering that the diversion site is very narrow about 25m wide at the base and about 40m wide at the crest, an arch type of design is considered to reduce the amount of concrete. Centrally situated is an uncontrolled overfall ski jump spillway. There is a weir of suitable shape at the top of the dam. The average inflow at the intake dam site described in the section on hydrology exceeds the 20 m^3/sec maximum power discharge for about 40 days in an average year. The surplus water will be discharged downstream by the ungated 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. Near the base of the dam are two outlet conduits each controlled by a high pressure hydraulically operated slide valve.

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

If the design water level is normal high water level then
$h_f = h_w + h_e + h_a$
but if the design water level is design flood water level
$h_f = h_w$
The larger of the two values above is to be adopted,
where,
h_f : addition to required water level (m)
h_e : wave height due to earthquake (m)
h_w : wave height due to wind (m)
h_a : addition depending on existence or non-existence of spillway (0.5 m)

a) Wave Height due to Earthquake

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

where,

k : horizontal seismic coefficient (0.15).

r : period of seismic wave (1 sec).

H_o : water depth of regulating pond from normal high water level (15 m)

Substituting

$h_e = 1/2 \times ((0.15 \times 1)/\pi) \times \sqrt{(9.8 \times 15)}$

$= 0.289$m

b) Wave Height due to Wind

$H_w = 0.0086 \ V^{1\ 1} \ F^{0.45}$

where,

F is the fetch (= 50 m)

V is the 10-minute average wind speed (30 m/sec)

H_w : $0.0086 \times 30^{1.1} \times 50^{0.45} = 2.108$m

Height of Non-overflow Section

Where design water level is normal high water level

$h_f = h_w + h_e + h_a$

$h_f = 2.108 + 0.289 + 0.5 = 2.897$m

Elevation of non-overflow section = 805 + 2.89 = 807.89m.

The elevation of the top of non-overflow section is fixed at 812.5m due to approach considerations. The features of the diversion weir are given in figure 9-1.

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 conduit. The structure is founded on the hard rocks which form the banks of the river. The flow should be controlled in such a manner that air should be prevented from entering into the conduit. There is provided a trash rack structure to prevent any debris from entering the conduit. Admission is controlled by means of a slide gate operated by a hoist. The design of the structure is conventional.

Part III **Power Conduit**

The power conduit consists of a D section cut and cover section as shown in figure 9-2. The overburden to be removed is very small except for a short stretch where the ground level is about 822m. The width of the conduit is 2.5m and most of the excavation is soft rock. The total length is about 325m. The conduit is made up of reinforced concrete in a trench which is excavated and backfilled after construction. At the end is embedded a 2.5 to 1.5 m dia steel bifurcation from which two penstocks covey the water to the power house. The hydraulic loss was estimated with the Manning's formula with L=325m, A = 5.579 m^2 , P = 8.926m, v = 3.58m/s, n = 0.015. The loss at maximum flow is 1.75m.

Part IV **Penstock**

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 the penstock is about 50m. Loss was estimated by the Scobey's formula with K = 0.34, v = 5.65 m/s, D = 1.5m. The loss at maximum flow is 0.755m. Thus total loss in the waterway is 2.505m without taking into account losses in intake. The features of the waterway are shown in figure 9-2.

Part V **Power House**

The power station building is to be situated in the valley in which the Kikuletwa river flows about 1 km downstream of the diversion weir and intake structure. The power station building consists of a cylindrical tower built inside a circular excavation in the slope of the right bank of the river. The cylindrical structure is 9.5m in diameter. Alongside this on the upstream side is another shaft which houses the terminal section of the penstocks and bend. The entire power station equipment is contained within this structure which is divided into three floors housing the various equipment. The access into the structure is from EL 743. The bottom of the tower is founded in sound bedrock. The plan of the power station at various elevations is shown in figure 9-3.

The bottom structure of the power plant (from the foundations up to the turbine floor level) is formed of mass concrete founded on solid rock. The top structure is formed by a 12 m high cylindrical reinforced concrete shell. This shell which also forms the peripheral walls will be dimensioned so as to resist the water pressure if the downstream water level rises to an elevation + 740m. On the downstream wall is provided a hoist for operating the draft tube outlet gates by means of a crane.

The power plant consists of the machine hall, service bay, substructures, control room and space to house all auxiliaries. The access to the power plant is from a branch of the main access road going along the left bank of the river and descending to the river at a point near the power house from 820m to 745m. Final access to the power house is by means of a bridge across the river. The bridge leads to the approach area which is at elevation of 743.70. 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 shaft is by a 2.5m wide gate from the western side. The whole structure due to its design is capable of withstanding the 1000 year high flood level as seen from figure 9-4. Additional protection from flooding of the power plant up to a flood level of 1000 years occurrence is possible by propping the entrance gate and sealing its joints so as to make it watertight.

The bottom most floor level which is at EL 737m is the turbine floor. The spiral casings of the two turbines are installed such that they are symmetrical in plan about the longitudinal center line. Also accessible from this floor are the main inlet valves by means of a stairway leading down to the valve pit, the bottom of which is at EL 735.3m. This pit also houses the valve servomotors. Located centrally between the two units is a sump pit to collect all waste water and pumps which pump it to a level above the tailwater. This floor also houses the pressure oil and cooling system and the wicket gate servomotors. To enable lifting of equipment from this floor there is provided in the centre a column which houses the lift shaft as well supports a circular crane beam on which runs an overhead crane such that its path describes an entire circle. Thus items may be picked up from any floor and delivered to the unloading bay situated at EL 743.70m

The generator is supported on a concrete generator barrel which also houses the shaft and the coupling. Access is possible into the barrel from the turbine floor for inspection of the guide vane apparatus. The top of the generators is at the machine hall floor which is at EL. 740.20. The piers of the draft tube extend upto this level.

Iron gratings which can be removed are provided to remove the inlet valves from this floor thereby avoiding waste of space. Alongside the machine hall is located the control room which is below the unloading bay. This arrangement will provide a clear view of the machine hall and the service bay. The wall facing the machine hall will be fully glazed.

Above this level is the unloading bay and entrance gate which are at EL 743.70m The floor has been extended such that it becomes rectangular thereby increasing the area available. Stairs are provided on the periphery for descending down to the machine hall.

The roof of the power house is made of reinforced cement concrete slab at EL748.40m. It has a provision for the lift room as well as space for the two power transformers from which the line goes to the 33kV switchyard located adjacent to the approach road on the left bank. A standby diesel set and air conditioning equipment is also installed on the roof. All the above features are shown in the plan of the power house at different elevations in figure 9-3.

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

The elevation of the centre line of the turbine runner will be 736 m, a value determined in consideration of the normal tailrace water level (EL. 740.0 m) and the draft head. The cross section of the power house is shown in figure 9-4.

Part VI Tailrace

The draft tubes are shut off by 4 vertical-lift gates placed in position by a 3-t hoist traversed along the flood platform at an elevation of +741m. The draft tube outlets can be closed by means of four stop logs measuring about 2m x 2m.

A open tailrace channel of trapezoidal section with 1:2 slope will be excavated along the right bank. It will be about 13 m wide at the top and about 20 m in length. It will be lined. It is expected that most of the excavation involved will be soft rock excavation. A service road is provided on both sides. A berm is provided 0.6m above the normal water level of 740.00m.

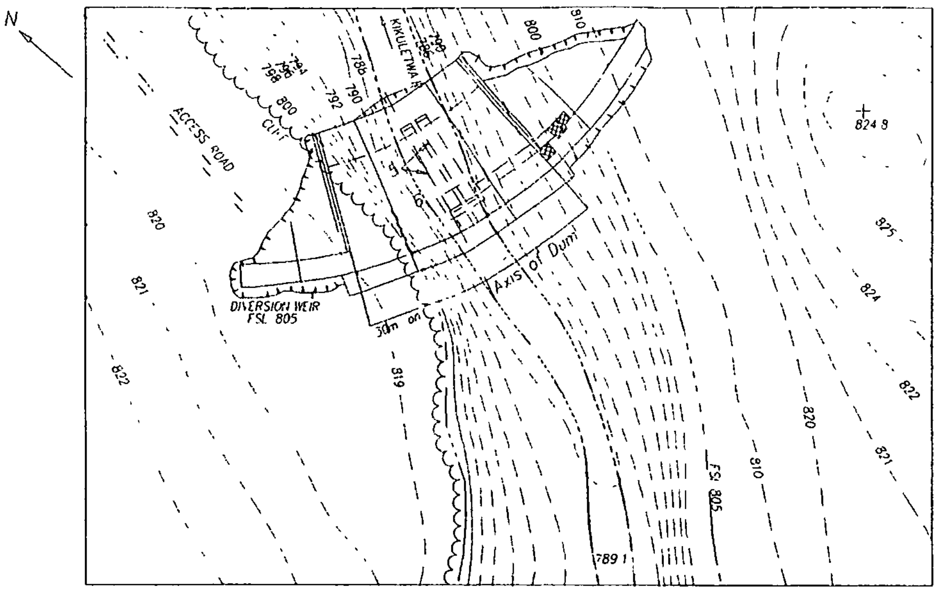
Part VII **Reservoir and Bank Erosion**

The Kikuletwa reservoir submerges about 20,000 m^2 at FSL 805m and extends for 1500m with a maximum width of about 40m. It is appropriate to consider the reservoir as a small lake contained in a narrow and deep gorge. Due to steep gradient of the river bed, the flow in the form of rapids has probably scoured the river bed and hence the flow is in a deep gorge of 25 to 50m depth. Bank erosion has not been noticed except at only one place on the left bank (photograph). The upstream lake (stage II) will absorb the floods which is limited to 200 m^3/s (1 in 1000 year frequency). The lake is also formed in fairly a flat reach of the river bed. Hence the flow velocity in the lake gets reduced due to increased waterway width at FSL thus eliminating the chances of bank erosion. The surface water level is almost steady at the weir crest (805m) and fluctuates within 3 m during spill in February to May of a wet year only. There is negligible scope for water seeping into the bank with return flow to induce slides/slips. Hence it could be concluded that erosion of the river bank in the lake spread area will not occur. Moreover, the annual precipitation in the project area is hardly 800 to 1000mm for sheet or bank erosion. This is also confirmed from the following field investigations by JICA.

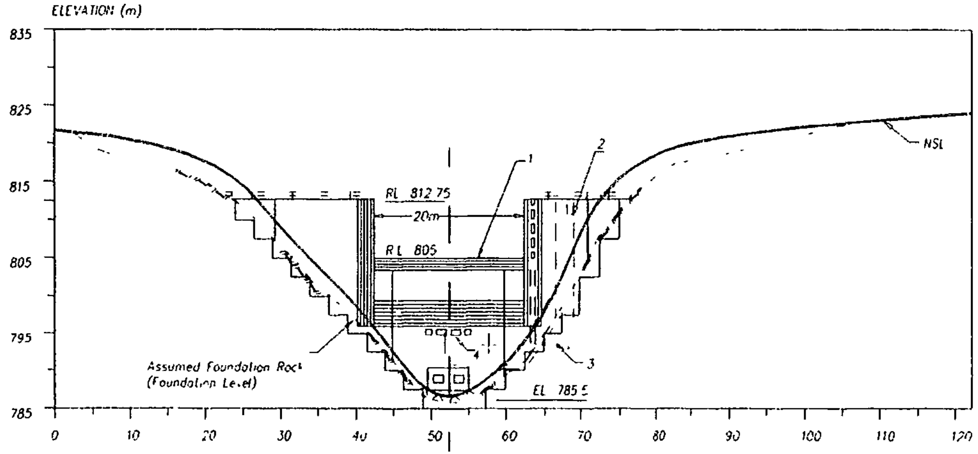
Drill hole data at the diversion weir site, intake, water conductor system, head tank, penstock and power house (appendix III-1), (b) Physical and chemical water analysis (appendix II-7), (c) Record of permeability test in drill holes (appendix III-2) and (d) Record of water levels in drill holes (appendix III-3). The conclusions drawn from the results of the above investigations are

- There is fresh rock at various depths along the left bank (4 to 5km) with core recovery percentage upto 99% in the head pond and penstock area of JICA's proposal. This area forms SECSD's proposal (stage III).
- Negligible suspended/dissolved material in water confirming nil erosion.
- Low permeability of the order of 9.34×10^{-6} to 1×10^{-3} cm/s along the left bank in the reach from diversion weir to power house (about 5km).

The above reasoning coupled with the presence of Tuff Breccia all along the river banks/project area confirms that bank erosion or sloughing is very unlikely. Hence stability of the river banks in the lake area is assured. However, suitable bank protection in the form of pitching or Gabion mesh anchored and strengthened by Guniting or shotcreting at required places could be considered at the time of execution of the project.

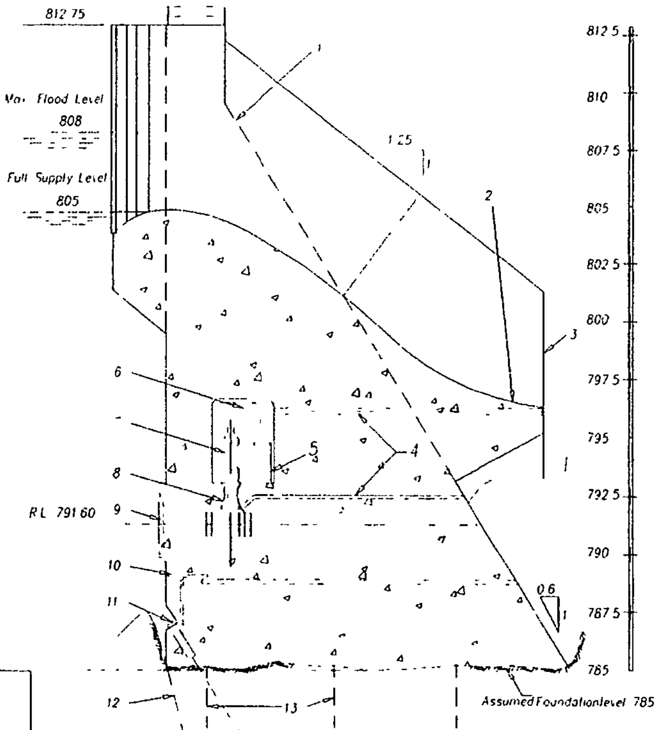


PLAN OF DIVERSION WEIR



UPSTREAM ELEVATION

1 Spillway crest 2 Service shaft 3 Access gallery, 4 Gate chamber, 5 Outlets 6 Spillway training Wall

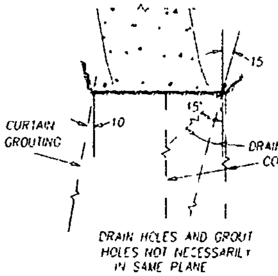


SECTION THROUGH OUTLET CONDUIT

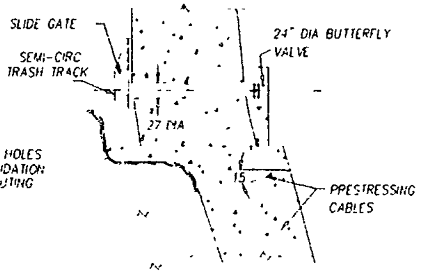
1 Abutment Section 2 Ski-jump spillway bucket, 3 Spillway training wall, 4 Air vents
5 Valve control cabinet 6 Valve chamber 7 Hydraulic hoist 8 Slide valve 9 Stoplog guide, 10 Foundation drainage piping 11 Foundation drainage hole drilled from upstream face and afterwards capped 12 Curtain grout holes, 13 Blanket grout holes

NOTES

This drawing shows Arch cum Gravity Concrete Dam for Kikuletwa River (Stage-III) The hard rock level in the River Bed and Banks is assumed and the Layout is for estimate purposes only



TYPICAL SECTION SHOWING GROUTING AND DRAINAGE HOLES



SECTION THROUGH RIPARIAN OUTLET

KIKULETWA HYDRO POWER PROJECT
(STAGE-III)

GRAVITY CUM ARCH DAM-DETAILS

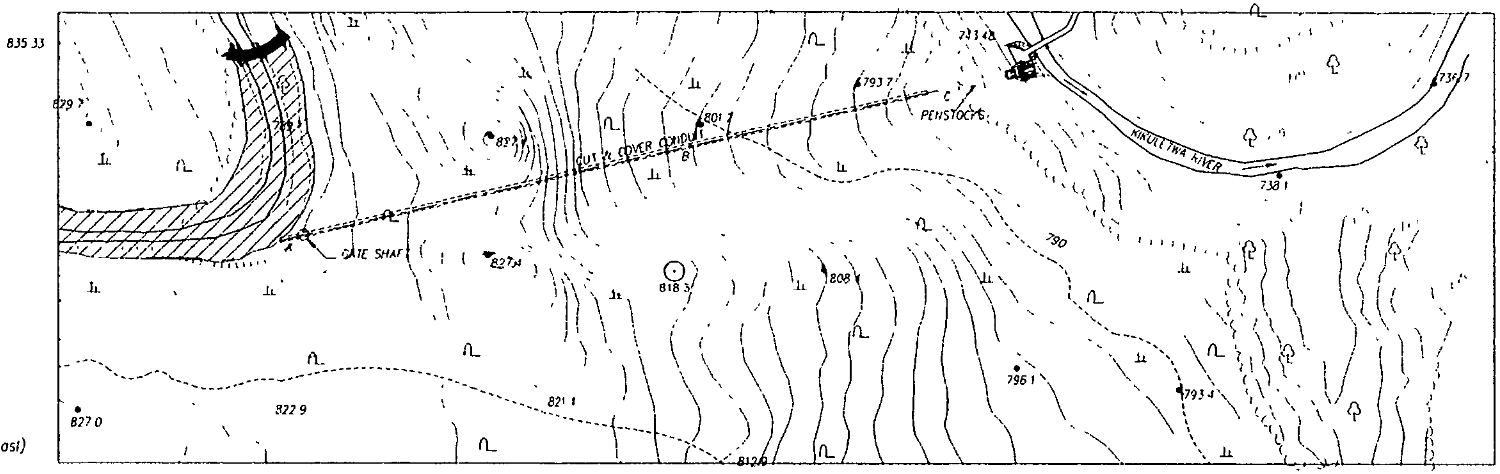
FOR: THE WORLD BANK/TANESCO

DWG NO FIG 9-1	PLANNING, DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

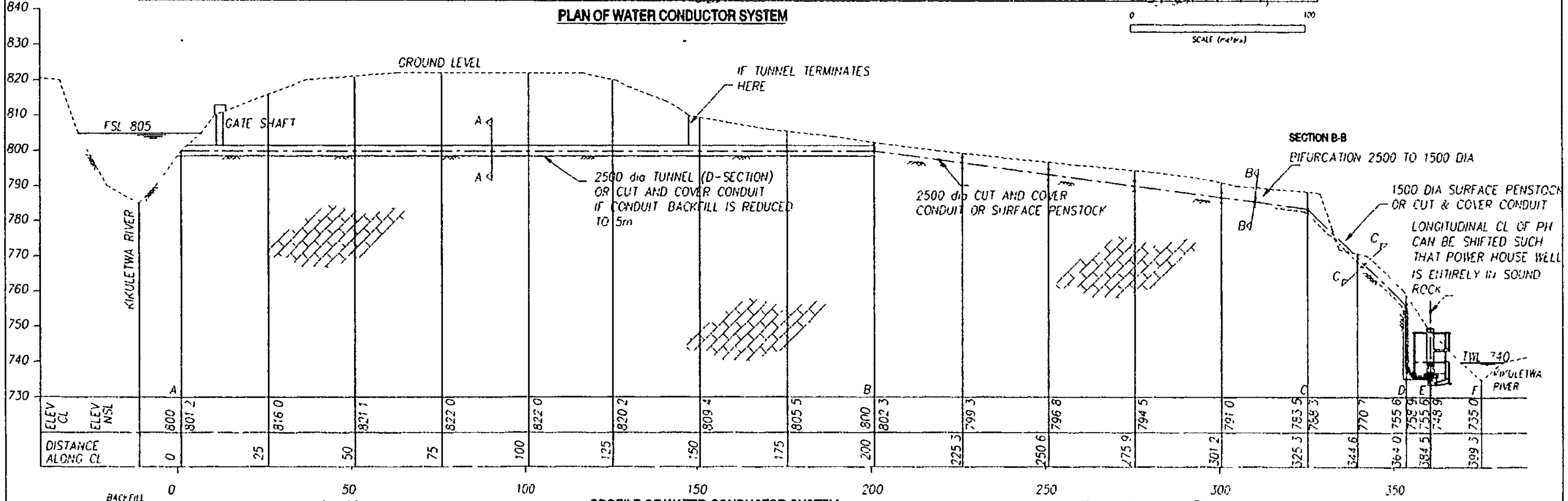
kik-3dw dwg

NOTES

THIS DRAWING IS TO BE USED FOR ESTIMATE PURPOSES



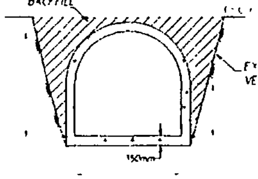
PLAN OF WATER CONDUCTOR SYSTEM



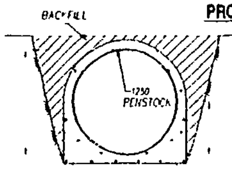
PROFILE OF WATER CONDUCTOR SYSTEM

PLAN DISTANCE ALONG WATERWAY FROM INTAKE STRUCTURE

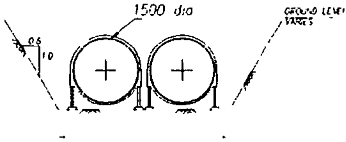
0 SCALE(m) 50



SECTION A-A



SECTION B-B



SECTION C-C

KIKULETWA HYDROPOWER PROJECTS
(STAGE-III)

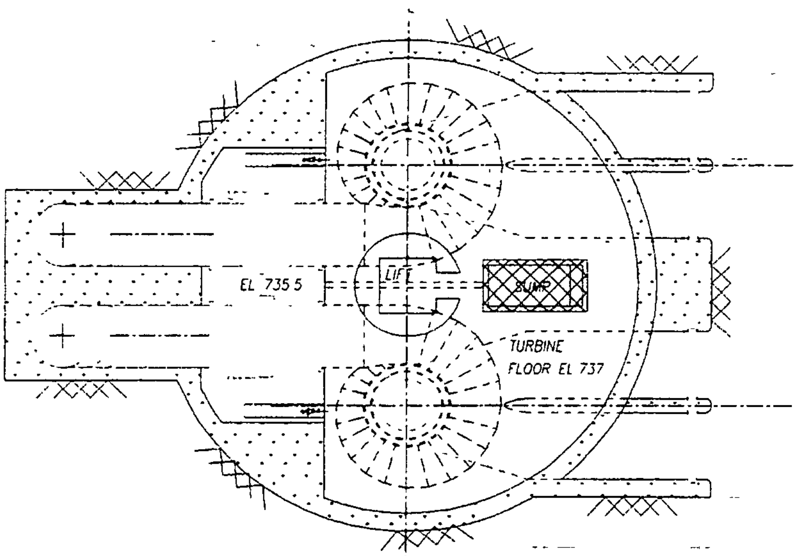
PLAN & PROFILE OF WATERWAY

FOR. THE WORLD BANK/TANESCO

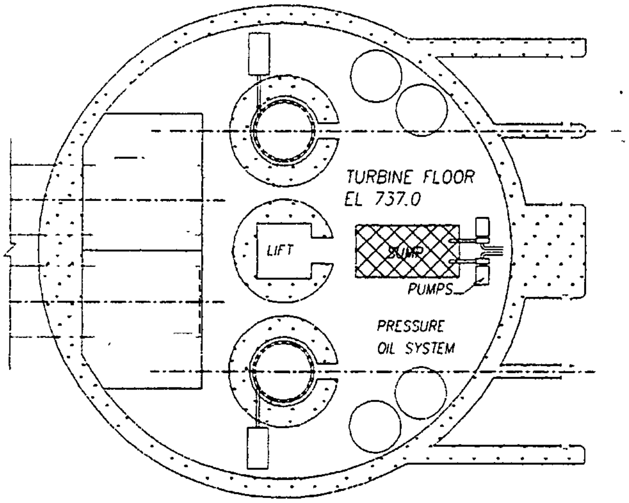
DWG NO FIG 9-2

PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

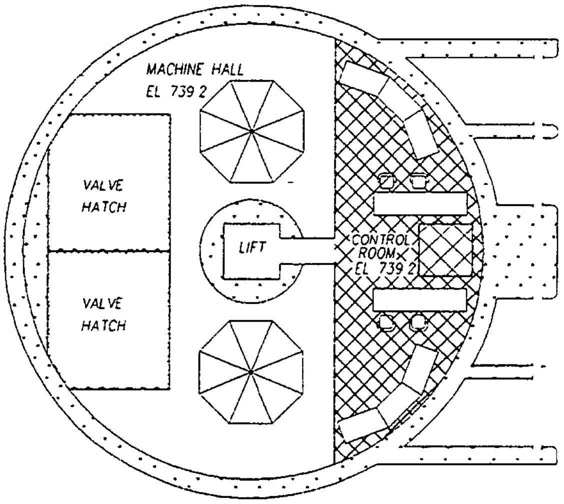
kik-wc3.dwg



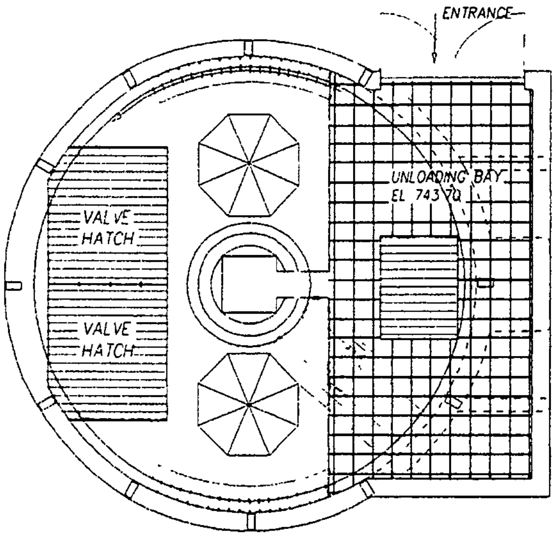
PLAN AT A-A (TURBINE FLOOR EL 737.0)



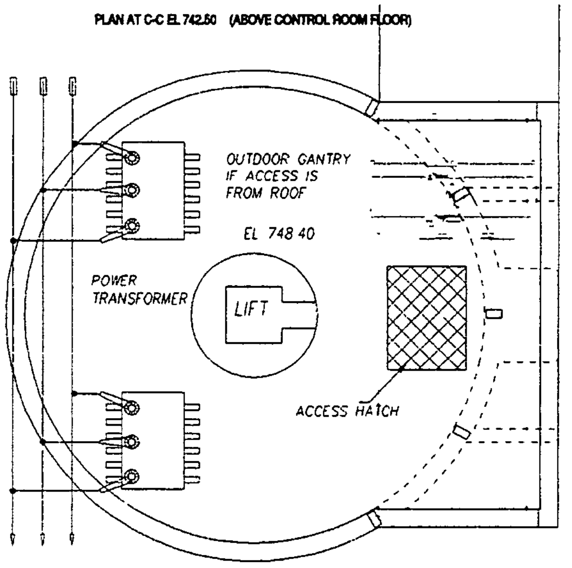
PLAN AT B-B EL 736.50 (ABOVE TURBINE FLOOR)



PLAN AT C-C EL 742.50 (ABOVE CONTROL ROOM FLOOR)



PLAN AT D-D EL 747.50 (ABOVE SERVICE AREA)



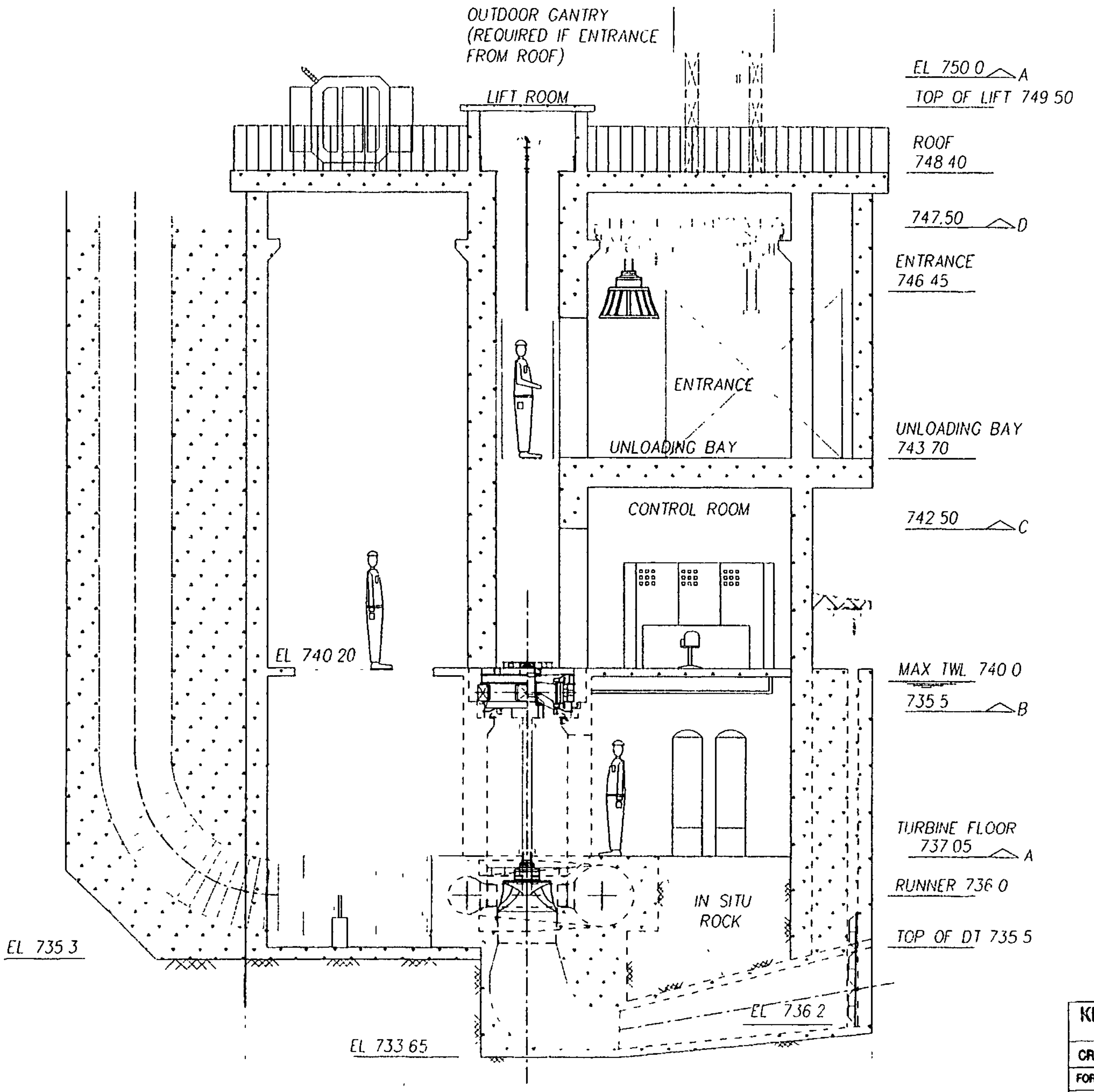
PLAN AT E-E 750.0 (ABOVE ROOF)

0 5
SCALE (meters)
ALL DIMENSIONS IN mm
ALL ELEVATIONS IN masl

DRAWING TO BE USED FOR ESTIMATE ONLY

KIKULETWA HYDROPOWER PROJECTS
(STAGE-III)
PLAN OF POWER HOUSE AT DIFFERENT ELEVATIONS
FOR: THE WORLD BANK/TANESCO
DWG NO FIG 9-3
PLANNING DESIGNS & CAD BY SIVAGURU ENERGY CONSULTANTS

kik-shpl dwg



NOTES

This drawing shows the cross section of well type power house
The drawing may be used for estimate purposes only

0 5
SCALE (meters)
ALL DIMENSIONS IN mm
ALL ELEVATIONS IN masl

KIKULETWA HYDROPOWER PROJECTS (STAGE-III)

CROSS SECTION OF POWER HOUSE

FOR THE WORLD BANK/TANESCO

DWG NO
FIG 9-4

PLANNING DESIGNS & CAD BY
SIVAGURU ENERGY CONSULTANTS

kik-shxs.dwg

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, and control of the bottom outlet gates of the diversion weir. The electromechanical equipment of the power plant was selected based upon the results of the power and energy studies. The preliminary dimensioning was carried out with a set of equations as well as database of turbine data obtained from various manufacturers. The equipment outline based on these dimensions are shown in figure 10-1.

Section 2 *Turbine*

Part I **Dimensions**

On the basis of detailed hydrological studies it has been decided that the power plant will consist of two units of 5.5 MW each so that maximum energy can be produced. The maximum net head for the plant at full load is about 64.1m. The minimum operating head will be about 60.15m. 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 Francis type hydraulic turbine is considered. The adoption of this type is advantageous from the operational point of view with the small variation of the head and discharge as compared to the types with adjustable runner blades, as high orders of efficiency are achieved, regardless of service conditions at much lesser cost.

Safe design is made with respect to cavitation resistance of the runner blades, this undesirable effect is prevented 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 4m below the minimum tailwater level.

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 conditions and shows no irregularities whatever. The draft tube profile shown in the drawing is as per current practice. The operation of the turbine will be smooth and quiet, without oscillations that would adversely affect the electric power output of the generator.

The dimensions of the turbine were calculated from 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
$n_s' = 2334/\sqrt{h_d} = 2334/\sqrt{64} = 291.75$ rpm (typical values for Francis units)

A trial specific speed of 291.75 rpm was fixed.

Trial speed $n' = n_s' \times H^{5/4} / \sqrt{P}$
where P is in metric horsepower. A turbine output of 5500kW corresponds to 7275 mhp

where H = 64 m, P = 7275 mhp

So n' = 614.4 rpm

Nearest synchronous speed = 600, 750 rpm

for poles = 10 or 8

The 600 rpm running speed was selected.

Thus Design Specific speed = $n_s = (n \times \sqrt{P})/H^{5/4}$
$= 282.71$ rpm

Discharge coefficient $\phi = 0.0211 n_s^{2/3}$
$= 0.9261$

Diameter $= 84.47\phi\sqrt{H}/n = 1.043$m.

Based upon the operating conditions which are to be met it has been decided that the turbine will have a runner of 1000mm diameter

The other parameters are estimated as follows.

$W_{runner} = 607D_{max}^{2.75}$ kg = 607 kg
$W_{turbine} = 15175D_{max}^{2.33}$ kg = 15.1t

Shaft diameter = $(70P_d/n)$ in = 7.15in = 180mm approx
Flange diameter = 1.75 x 180 = 320mm
Flange thickness = 0.20 x Flange diameter = 65mm

Thoma's Cavitation coefficient

$\sigma = n_s^{1.64}/50,324 = 0.208$

The elevation of the power house area = 740m

Atmospheric pressure H_a = 9.476m of water at elevation 740m.
Mean temperature of river water = 25°C
Vapour pressure H_v = 0.324 m of water

Barometric pressure $H_b = H_a - H_v$ = 9.476 - 0.324 = 9.152 m of water.
H_{cr} = critical head = 64 m
σ_P = (plant sigma) = 0.20 (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) = $H_b - \sigma_P H_{cr}$ = -4.15m

Now average minimum tailwater level = 740.40m from power study.

Elevation of turbine runner = TWL +Hs = 736.25m.

The elevation is fixed at 736m

Part II **Specifications**

The runner consists of crown made of mild steel which incorporates the coupling face and a stainless steel assembly forming the flow passages. The crown and skirt are separate castings made of 18/8 Nickel Chromium steel. The crown and skirt are machined over the flow surfaces and the vanes are separately ground to the box templates. The entire stainless steel assembly is stress relieved. The assembly is then fixed to the mild steel crown by high tensile bolts and after final machining the stainless steel sealing rings are shrunk fit.

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

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

The shaft is made of forged steel with integrally forged flanges on both sides for coupling with the runner and the generator rotor.

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

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

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

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

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

Part III Control

The generating unit will be equipped with an automatic control enabling start up or shut-down through depression of a single push button. This automatic control also permits a shut-down of the set in case of any breakdown which might call for such an immediate shut-down. 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 alterations 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 quickly operating emergency gates on the intake, the regulating mechanism is fitted with an additional safety air chamber which might replace the emergency gates.

Section 3 *Generator*

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

The generator shall be designed by taking into consideration the voltage conditions of the system to which the power plant will be connected, all estimated power station consumption and their average power factors. On the basis of these, the proposed generator power factor is cos $\gamma = 0.85$. This generator power factor also corresponds to the demand on compensation of the 132 kV system in a given place, at the same time. The generator will duly secure a supply of the required compensation capacity.

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

The generator will be of the three phase synchronous type running at 600 rpm. Each will be direct driven by the turbine. As the speed of the units is high, the umbrella type of installation will be unsatisfactory due to vibration. Hence the suspended type of arrangement is contemplated. The thrust bearing will be located on the generator stator on cross brackets. One guide bearing will be located below the generator. and also supported on cross brackets. Further specifications are given in the table 10-1 on electromechanical equipment. The actual dimensioning of the generator will be done by the manufacturer in consultation with the turbine manufacturer. The preliminary dimension obtained here and used for the sizing of the power house are based on empirical formulae.

Section 4 *Transformer*

Both the units will work into unit power transformers. The power transformer will be three phase step up 6.6kV/33kV rated at 6.5MVA. It will be installed outdoors on the roof of the power house. Under the transformers a sump will be provided to trap the oil which might leak out of the transformers. The HV bushing will have the CT built in. A short 33kV aerial line will connect the transformer to the switchyard.

The transformer will be oil immersed and cooled by air. A surge arresting device will be provided at the transformer to protect the transformer.

Section 5 *Intake Equipment*

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

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 designed 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 its heat and remove it, by way of the water discharged to the stream bed. Heat transfer is accomplished by contact of the cooling water in the pipes with the oil coming from the bearings, this direct contact between the two elements being produced in coolers.

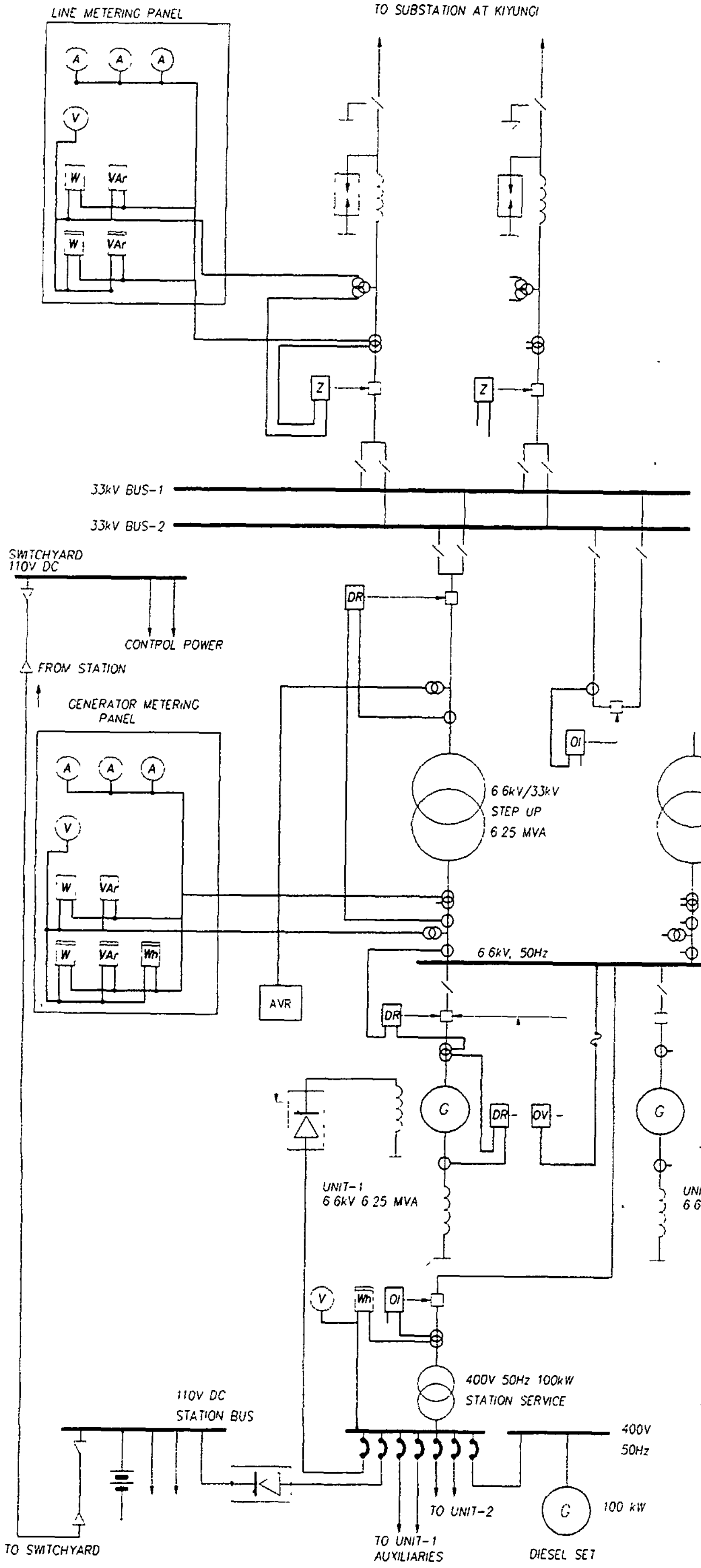
3. The cooling water should be free from any sort of contamination. In our case it is obtained straight from the penstock, since the existing pressure is sufficient to ensure an ample flow volume for cooling. Prior to being put to this use, the water is passed through water filters.

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

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

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

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



NOTES

This drawing shows the single line diagram of the Kikuletwa 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 grid supply exists The transformer is differential protected with a circuit breaker on the HV side A temperature and pressure relay can also trip this breaker The station service transformer is connected to the generator terminals Station consumption can be metered with an energy meter This transformer is protected by an over current relay on the HV side

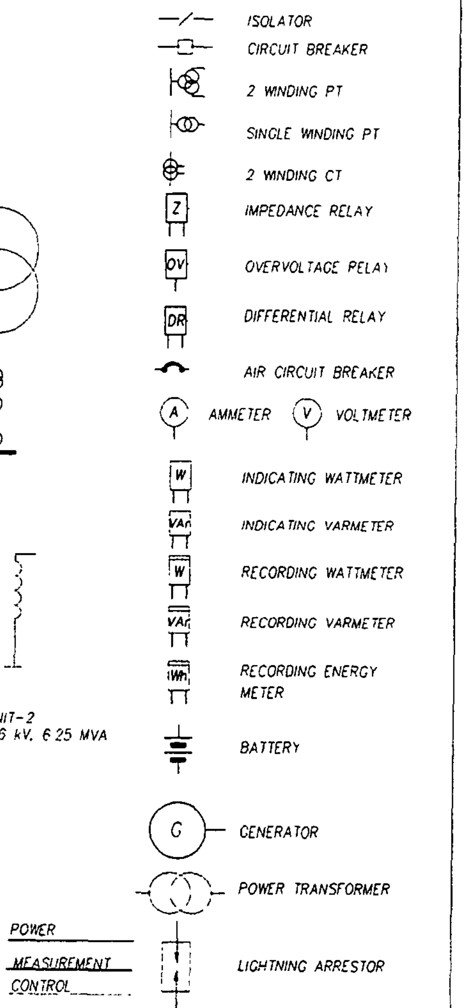
The switchyard will be of the double bus type but the generator circuit is provided with a bypass isolator with provision to service the transformer circuit breaker Thus one of the buses can act as a transfer bus

A double circuit line to the receiving station at Kiyungi is shown

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

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

LEGEND



KIKULETWA HYDROPOWER PROJECTS
STAGE-III

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

C \ACADJOBS\GHANA\OBU\OB-CP

TABLE 10-1
SPECIFICATIONS OF ELECTROMECHANICAL EQUIPMENT

	EQUIPMENT PARAMETER	DESCRIPTION
	Turbine	
	Type	Francis type vertical installation
	Number of Units	Two units
	Maximum Gross Head	67.0 meters
	Maximum Net Head	64.14 meters
	Minimum Net Head	60.14 meters
	Design Head	64.0 meters
	Rated Head	62.0 meters
	Rated Discharge	10 cubic meters per second
	Turbine Rating	5500 kW nominal
	Overload	5% continuous
	Runner Diameter	1000 mm
	Speed	600 revolutions per minute
	Specific Speed	282.71 revolutions per minute
	Auxiliaries	Hydraulically operated servomotors
	Governor	
	Type	Electronic - Digital Type
	Inlet Gates	
	Type	Butterfly or disc
	Size	1000mm
	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	6.25 MVA
	Voltage	6.6kV (final choice left to manufacturer)
	Power Factor	0.85
	Speed	600 rpm
	Poles	10
	Cooling	Water cooled
	Coupling	Flange coupling
	Number of Units	Two units
	Excitation	
	Type	Brushless Exciter (as recommended by supplier of alternator)
	Power Transformer	
	Type	Three phase
	Cooling	Oil immersed and cooled by air.
	Rating	6.25 MVA
	Number of Units	Two units
	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 6.25 MVA coupled to Francis turbines. Two 6.5-MVA, 6.6/33 kV transformers are located on the roof. General features of the electrical works are given in table 11-1.

Section 2 *Generator*

Part I Description

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

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

Part II Protection

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

1. Differential relay, common also for the block transformer and 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,

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 6.25 MVA coupled to Francis turbines. Two 6.5-MVA, 6.6/33 kV transformers are located on the roof. General features of the electrical works are given in table 11-1.

Section 2 *Generator*

Part I **Description**

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

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

Part II **Protection**

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

1. Differential relay, common also for the block transformer and 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, occurs 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 proportionate to the protected 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 lighting arresting device. The remaining instruments of the outlets, particularly the switch and the disconnecting switches, are installed in side the 33 kV switchyard.

Part II Protection

The transformer will be protected by

1. Differential relay (F1),

2. Instantaneous over current relay which is considered as a back-up protection for the differential relay. It is completed by an interlocking under voltage relay. The instantaneous over current relay is connected to the current transformers on the 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 in the first of which it only signals and on 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.

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

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

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

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

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

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

For an emergency coverage of station service consumption a 100 kVA diesel electric set is installed on the roof. For provision of D. C. voltage an alkaline storage battery 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 solution 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 Kikuletwa 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 need continuous maintenance,
b) In view of the size of the installed capacity and location.

On the other hand the 33 kV switchyard by its proximity to the power plant by its method of operation and by its relative simplicity will operate without permanent attendance and by remote control from the power station control room.

For these reasons the control of the power plant and the 33 kV switchyard will be centralised in the control room of the water power plant where all control, signalling, measuring apparatus and instruments necessary for the operation control of the power plant as well as of the switchyard will be installed.

According to current practice, the operation and 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 shut down. The generating unit is provided with control devices which in the case of 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 Kikuletwa water 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 future.

The extent of the measuring and recording of electric values may also be seen on drawing 11-1. This is in accordance with current practice and gives a complete survey of the immediate condition of the electric equipment for use of the local operation control.

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

Electric machines, the switchyard and the transmission line will be protected by electric protection relays which will assure the safe switching off of the outlet the moment any kind of trouble occurs and thus reduce the extent of possible damage to a minimum. The operation of protection relays will at the same time be signalled visually as well as audibly in the power plant control room. The extent of the protection is dealt with under each category of equipment. The overall strategy is given in figure 11-1.

Section 5 *Switchyard*

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

The power inlet to the 33 kV switchyard is by a short overhead transmission line. The outgoing conductors are anchored to the machine hall building. The switchyard is located as shown in the drawings showing the various project features. The switchyard is designed for 33kV operation. The schematic of the switchyard is shown in figure 11-1. The double bus arrangement is preferred with a coupling arrangement between the two buses to enable changeover on load from one bus to another. The control power will be supplied by means of a cable from the power station. The entire switchyard will be fenced off and the fencing adequately earthed. Facility is provided to monitor the line flows. The design of the switchyard will have to be done in accordance with rules and regulations of TANESCO . In view of the proximity of the switchyard to the power plant it is recommended that the switchyard be remote controlled from the power plant.

This switchyard will in the final construction contain two inlet lines from the power plant and one outlet field to Kiyungi substation. Further enlargement is not envisaged till stage 1,II and IV projects are taken up.

The service consumption of the 33 kV switchyard is fed by a 400 V voltage from the power plant by cables. The auxiliary electric equipment is located in an one-storey building of minimum size. There are a L.T. panel, auxiliary panel for protecting devices, a D.C. equipment, a compressor station and accessories for the compressed-air control of switching devices of E.H.T.

The switchyard operation is by remote control from the power plant control room. The emergency local control of the 33 kV equipment will be possible from outdoor control boxes located in each switchyard field.

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

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

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

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

Section 6 *Transmission*

Part I Description

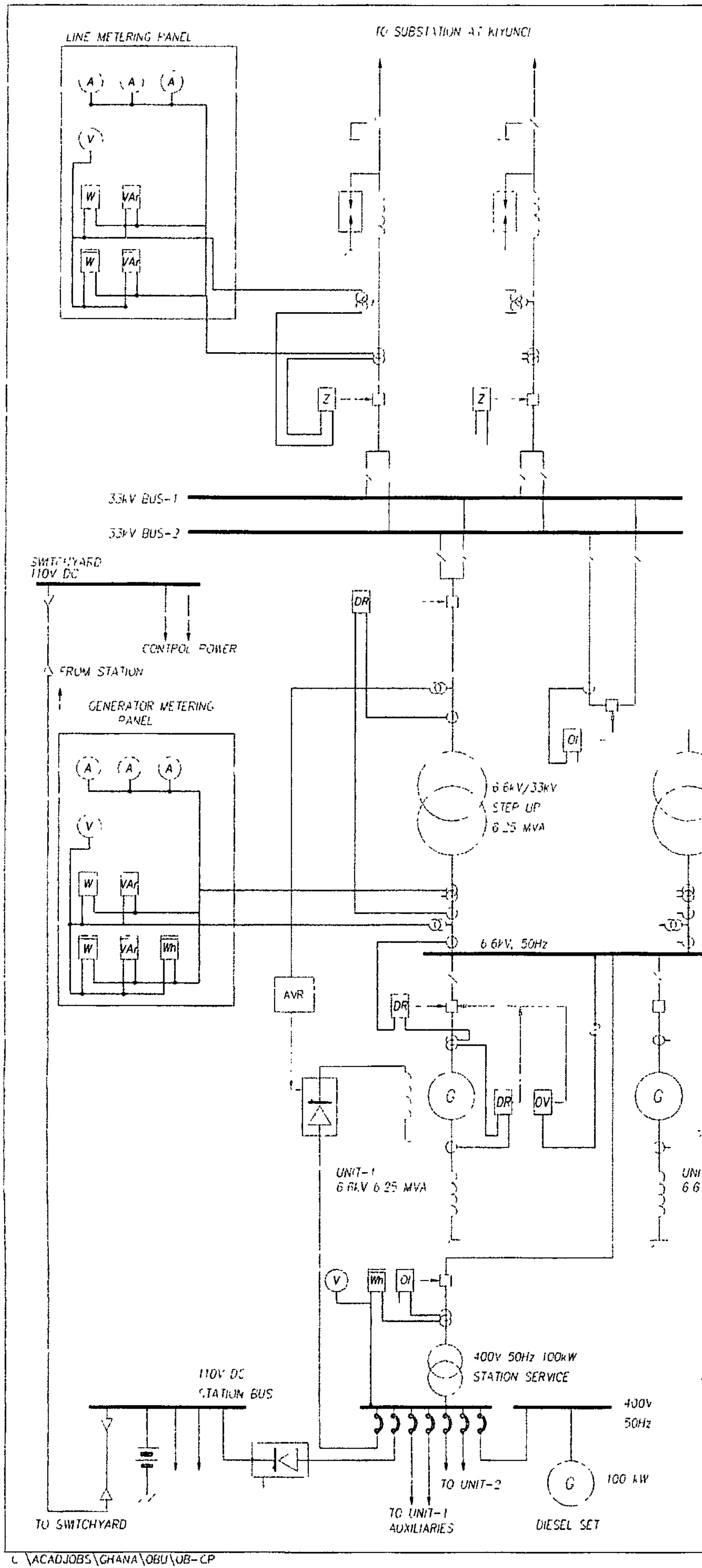
The 33kV line starts from the switchyard The rough route was fixed on the basis of maps as well as field reconnaissance. For most of the length of 14 km, the route follows the existing old line from Kikuletwa No. 1 station. The towers will be built of wood poles. In the design of the line due consideration has to be given to relability. Hence a double circuit line is preferred. Also in determining the size of the conductor, provision is made for transmitting the power from stages 1, 2 and 4 of the cascade through the same switchyard as that of stage 3. With the above in mind, the performance of the line as well as parameters are given in table 11-1. Earthing conductor will be provided at the top for protection against atmospheric disturbances.

Part II Protection of the Line

With regard to the short line sections the protection by distance relaying is sufficient for all line troubles. It is not necessary to supplement it by another back-up protection.

Section 7 *Grid Interconnection*

It is recommended that the Kikuletwa power station be connected to the grid in the vicinity for maximum operational benefit. Also it is considered beneficial to connect all the plants of the cascade to the grid. Several alternatives were considered for the network connection of the plant with the grid. It appears that the best way to accomplish this is to connect to the receiving substation at Kiygungi to which power from all the upstream and downstream projects will be transmitted.



NOTES

This drawing shows the single line diagram of the Kikuletwa 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 grid supply exists The transformer is differential protected with a circuit breaker on the HV side A temperature and pressure relay can also trip this breaker The station service transformer is connected to the generator terminals Station consumption can be metered with an energy meter This transformer is protected by an over current relay on the HV side

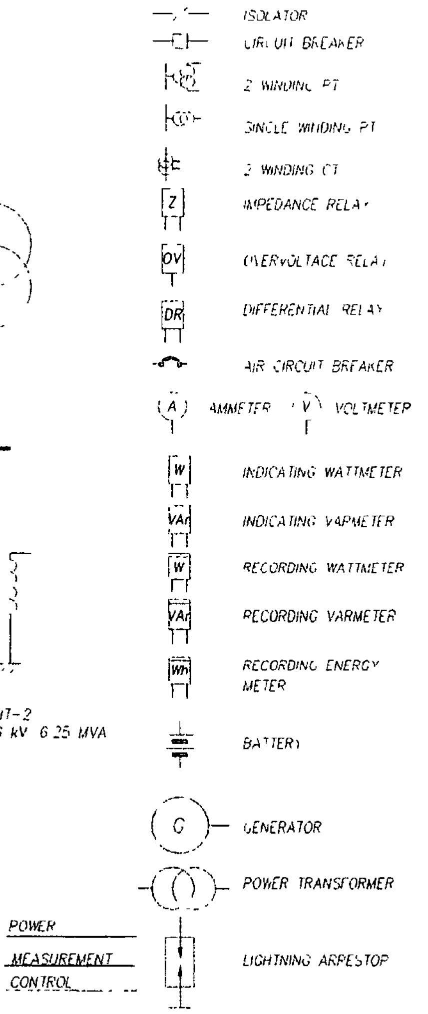
The switchyard will be of the double bus type but the generator circuit is provided with a bypass isolator with provision to service the transformer circuit breaker Thus one of the buses can act as a transfer bus

A double circuit line to the receiving station at Kiyungi is shown

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

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

LEGEND



KIKULETWA HYDROPOWER PROJECTS
STAGE-III

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

C \ACADJOBS\GHANA\OBU\OB-CP

TABLE 11-1

PARAMETERS OF TRANSMISSION LINE AND PERFORMANCE CALCULATION

	Parameters		
	Line Voltage	kV	33
	Frequency	Hz	50
	Electrical system		Double Circuit 3 phase 3 wire
	Base MVA	MVA	10
	Receiving End power	kW	5500
	Receiving End power factor		0.85
	Line Length	miles	8.75
	Conductor Code Word		
	Conductor cross section area	cmils	266800
	Resistance per mile of Conductor	Ohms	0.567
	Inductive Reactance per mile of Conductor at 1ft	Ohms	0.484
	Capactive Reactance per mile of Conductor at 1ft	Mohms	0.134
	Equivalent Spacing of conductors	ft	5.55
	Inductive Reactance per mile at equivalent spacing	Ohms	0.173271406
	Capactive Reactance per mile of Conductor at 1ft	Mohms	0.061017139
	Current Carrying capacity 50 deg C temp of cond	Amps	340
	Aluminium strands	No	6
	Strand dia	in	0.188
	Steel strands	No	1
	Strand dia	in	0.188
	Ultimate strength	lbs	8420
	Weight of conductor per mile	lbs	1542
	Outside diameter	in	0.563
	Insulators	Type	Pin Type
	Support		Steel towers typical illustration shown in drawing with double circuit vertical arrangement
	Base Impedance	Ohms	108.9000
	Base Current	A	174.9546
	Line Resistance	Ohms	4.9613
	Line Inductive Reactance	Ohms	5.7511
	Line Capactive Reactance	Mohms	1.7029
	Line Resistance in per unit	per unit	0.0456
	Line Inductive Reactance in per unit	per unit	0.0528
	Line Capactive Reactance in per unit	per unit	15637.2816
	Line Impedance in per unit		4.55578512396694E-002+5.28110634216794E-002i
	Receiving End Voltage	per unit	1
	Receiving End Current	A	113.2059
	Receiving End Current Vector Re	per unit	0.8500
	Receiving End Current Vector Im	per unit	-0.5268
	Receiving End Current Mag in pu	per unit	0.6471
	Receiving End Current Phasor	per unit	0.85-0.526782687642637i
	Receiving End Current	per unit	0.55-0.340859386121706i
	Series Drop	per unit	4.30579648401663E-002+1.3517263675346E-002i
	Sending Voltage	per unit	1.04305796484017+1.3517263675346E-002i
	Sending Voltage Magnitude	per unit	1.0431
	Regulation	percent	4.3146
	Loss	per unit	0.0572
	Loss	MW	0.5722
	Efficiency of Transmission Line	percent	90.5763
			Provision made in conductor for further 6MW from stages 1, 3 and 4

TABLE 11-2
ELECTRICAL WORKS SPECIFICATIONS

	Equipment Category	Units		
1	**Bus Bars**			
	Type		Copper bus bars in bus ducts	
	Voltage	kV	6 6kV	
	Current per phase	A	1150	
	Protection		Differentially protected	
2	**Generator Circuit breaker**			
	Type		None	
	Rating	MVA	To be selected in design stage	
	No of breakers		2	
3	**Switchyard**			
	Location		External and located about 100m from power house	
	Voltage	kV	33	
	Design		As per TANESCO guidelines	
	Type of Arrangement		Double bus bar type	
	Incoming Lines		Two incoming lines from Power Station	
	Outgoing Lines		One outgoing line to the Kiyungi Substation	
	Circuit breaker type		Vaccum circuit breakers	
	No of Circuit breakers		4	
	Isolators		Motorized post mounted rotary double break type	
	No of isolators		8	
	Earthing Switch		Earthing blade integral with isolators	
	Lightning Arrestors		Post type mouted on insulator post	
	Current transformers		Post type mouted on insulator post	
	Potential transformers		Capacitive type	
	Control power	V	110 V DC supplied from power station by cable	
4	**Earthing**			
	Generator		Neutral solidly earthed	
	Station & Switchyard		Grid mat with suitable connections to all electrical equipment and metal parts	
5	**Unit Auxiliaries**			
	Auxiliaries Supply	V	400 V 50 Hz ac	
	Auxiliaries source		6 6kV/400V step down from generator terminals	
	Type of scheme		Single station service transformer	
	Type of distribution		LT distribution panel with individual circuit breakers	
	Metering		Voltage kWh and current	
6	**Emergency Equipment**			
	Battery		110V sealed maintenance free battery system	
	Charging system		Electronic controlled charging	
	Lighting	V	110 V DC supplied from batteries in battery room	
	Black start		Diesel Electric set 100 kVA mounted outside station	
7	**Protection**			
	Turbine		Overspeed, Bearing temperatures, Oil temperatures	
	Generators		Loss of excitation, Negative sequence, stator faults Overspeed, Field short circuit	
	Transformer		Differential protection, Bucholz, tank grounding	
	Transmission		Distance protection	
8	**Transmission**			
	Voltage	kV	33	
	Type		Double circuit towers	
	Final Receiving Station		Kiyungi substation for interconnecting with grid	
	Length	km	14	
	Conductors		106 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 the project and aggregated unit prices applied to the main categories of works and equipment.

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

Box 12-1 Components of Implementation Cost

Item	Amount
CIVIL WORKS	A
Miscellaneous and contingencies 10 %	0.10 A
TOTAL CIVIL WORKS	1.10 A
EQUIPMENT	B
Miscellaneous and contingencies 5 %	0.05 B
TOTAL DIRECT CONSTRUCTION COST	***D = 1.10 A + 1.05 B***
OTHER COSTS	
Engineering (Investigations, Detailed Design and Construction Supervision) 5%	0.05 D
Administration 3%	0.03 D
TOTAL OTHER COSTS	O = 0.08 D
TOTAL CONSTRUCTION COST	C = D + O
ENVIRONMENTAL IMPACT MITIGATION	E
TOTAL IMPLEMENTATION COST	T = C + E

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

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

Section 2 *Civil Works*

The cost estimate for the civil works is confined to the major items of work involved in the diversion weir, 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 aggregated unit prices for the cost estimates are presented hereafter 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's for the same type of equipment (2 or 3 units, of turbines of the Francis 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 Francis type turbine rated at 5.5 MW at 64 m speed 750 rpm complete with runner of 13%Cr & 4%Ni, main shaft, main shaft seal, guide bearing, wicket gate mechanism, gate operating ring, discharge ring, draft tube, oil supply head, oil piping, drainage and dewatering system, instruments and devices and complete set of platforms, ladders and stairs, drawings showing details of foundation requirements, embedding of supports and anchors in first and second stage of concrete.
- Generator - 2 units of synchronous generators rated 6.5 MVA, 6.6kV, 50 Hz, cos phi 0.85, 750 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, bus bars and ducts.
- Overhead crane,
- Control Panels
- Protection system
- Ventilation, cooling and air conditioning
- Synchronising equipment,
- Station service transformer, Emergency lighting, illumination and black start power,
- UPS and Battery system
- Fire fighting

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

Section 5 *Hydro-mechanical Equipment*

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

1. Bottom outlets with operating mechanisms
2. Inlet Valves.
3. Draft tube gates

The unit costs used for the equipment cost estimates include manufacturing prices, transportation and installation costs.

Gates etc. - $800 per sq.m.

Section 6 *Switchyard*

The costing includes the cost of land, land clearing, fencing, earthing, lighting, fire fighting, Main power transformer, Auxiliary transformer, switchgear and all other equipment required for the proper and reliable operation. The swithchyard is 33kV.

Section 7 *Transmission*

The costing includes the transmission lines and equipment for connection to the existing substations or new substations. The cost of connection to the Kiyungi substation includes the cost of new transmission lines and new line bays to be added to the existing substations for the connection . The total transmission is about 14 km

Section 8 *Miscellaneous and Contingencies*

The cost of construction is calculated by applying unit cost estimates to the calculated quantities of the works identified as the main components of the project. The total cost resulting from these calculations should be increased by a contingency allowance of 10% for the civil works, 5% for the hydro-electric equipment. These contingency allowances represent the miscellaneous expenses that have not been listed in the table on quantities and implementation and that which might not have been identified properly, especially when the topographical and geological conditions of the site, as well as the design of the works, have not reached the level of precision of later stages.

Section 9 *Engineering and Administration*

A provision of 5% of the total direct construction costs has been considered for engineering services until the end of construction. This amount includes further topographical survey, geological and geo-technical investigations, feasibility and detailed design studies, environmental impact assessment and resettlement program, supervision of construction etc.

The cost of administration of the project by the Owner was estimated to be 3 % of direct construction costs.

Section 10 *Environmental Mitigation*

Further detailed topographic surveys are necessary to accurately assess the environmental impact. Prima facie it is evident from site visits that no significant impact will occur. At this stage a lumpsum amount of US$50,000 has been provided for environmental impact cost.

The percentage of the environmental costs for project will not exceed 1% of the total implementation cost.

Section 11 *Total Implementation Cost*

The total implementation cost as determined with the item wise break up is given in table 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 Improvements**	km	20,000	10	200,000	200,000	
b	**Construction Camp**	lumpsum	50,000		50,000	50,000	
c	Diversion Weir Preliminaries						
i	River Diversion	lumpsum	50,000	1	50,000		
ii	Site Clearing and Grading	m2	3	564	1,691	51,691	
d	Diversion Weir Non Overflow Section						
i	Soft Rock Excavation	m3	8	865	6,920		
ii	Rock Excavation	m3	13	736	9,568		
iii	Mass Concrete	m3	300	1355	406,500		
iv	Backfill	m3	16	250	4,000		
v	Grouting & Drainage	m	300	100	30,000	456,988	
e	Spillway						
i	Soft Rock Excavation	m3	8	497	3,976		
ii	Hard Rock Excavation	m3	13	428	5,564		
iii	Mass Concrete	m3	300	6250	1,875,000		
iv	Reinforced Concrete	m3	384	500	192,000		
v	Grouting & Drainage	m	300	100	30,000	2,106,540	
	Total Cost of Diversion Weir						2,615,219
f	Intake & Water Conductor						
i	Land Clearing and Preparation	m2	3	4050	12,150		
ii	Soft Rock Excavation	m3	8	11700	93,600		
iii	Backfill	m3	8	4270	34,160		
iv	Reinforced Concrete	m3	384	1114	427,776		
v	Mass Concrete	m3	210	200	42,000		
vi	Penstocks etc inclusive of fabrication	t	5,000	55 00	275,000	884,686	
g	Power House						
i	Soil Excavation	m3	4	200	800		
ii	Soft Rock Excavation	m3	8	100	800		
iii	Hard Rock Excavation	m3	13	1205	15,665		
iv	Mass Concrete	m3	210	100	21,000		
v	Reinforced Concrete	m3	384	350	134,400	172,665	
h	Tailrace						
1	Soil and Soft Rock Excavation	m3	8	1965	15,720		
ii	Rock Excavation	m3	13	0	0		
iii	Concrete	m3	210	174	36,566		
iv	Reinforced Concrete	m3	384	135	51,840	104,126	
	TOTAL CIVIL WORKS COST						4,026,696
2	ELECTROMECHANICAL EQUIPMENT						
a	Turbine & Generator	kW	500	11000	5,500,000		
b	Auxiliaries	kW	50	11000	550,000		
c	Inlet Gates	lumpsum	75,000	2	150,000		
d	Bottom Outlets	m2	800	20	16,000		
e	Connection to National Grid	km	30,000	14	420,000	6,636,000	
	TOTAL ELECTROMECHANICAL COST						6,636,000
3	TOTAL CONSTRUCTION COST						10,662,696
4	OTHER COSTS						
a	Engineering	percent	5		533,135		533,135
b	Administration	percent	3		319,881		319,881
5	CONTIGENCIES						
a	Civil Works	percent	10		402,670		402,670
b	Electromechanical & Others	percent	5		331,800		331,800
6	ENVIRONMENTAL IMPACT COST	lumpsum			50,000		50,000
7	TOTAL IMPLEMENTATION COST						12,300,182
8	COST PER kW INSTALLED	USD			1,118		

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. Usually for small hydro projects, 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.

In the present case the area is already served with grid supply, and hence the price of the least cost option is that of obtaining energy from the grid. Thus economic value of the energy is fixed at present average tariff in the area.

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. If the project is built to serve an area without existing grid supply, the energy which can be sold will gradually increase every year from a low base year demand. Hence the market demand will influence the financial analysis. This demand growth pattern 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 *Assumptions*

The main difference between the economic and financial analysis is the price of energy in each case In the first case it is usually fixed as the cost of producing and equivalent amount of energy from an alternative source and in the second case it is the price at which energy is sold. In the present case under study, both are equal to the average tariff prevalent in the area as the area is served by the grid. Hence the economic and financial analysis are identical.

In the financial analysis, the consumer's load and demand growth will not influence the revenue stream as the project will be grid connected and all the energy which is produced can be utilized by existing consumers who are connected to the grid This may give rise to conserving water at large storage dams for use in dry season. The assumptions in the analysis are given below.

The Implementation cost of the project is US$ 12.3 million for 2 units of 5500KW which has been worked out in the statement on quantities and Implementation cost. Based on the 24 month construction period, the IDC is US$ 1.907 million. 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 7 years (typical values from International Financial Institutions for loans to project developers). Based on this the capital recovery factor is about 20.54%. The economic life of the project is taken as 30 years.

The purchase price for electricity in the base year is taken as US$ 0.07 per kWh. An inflationary factor of 5% has been included in the calculations for the purchase price of electricity as well as the Operations and Maintenance costs. The annual operation and maintenance costs are taken as a lumpsum of 1% of the capital cost of the project.

For the financial analysis, the discount factor has also been taken as 6%. Thus all future receipts and payments are discounted to obtain their present worth. All receipts and payments are assumed to be made at end of year.

Based on the above, a computer program was used to perform the analyses and the results are presented in the table 7-1. The table brings out the debt service, depreciation, operation and maintenance and revenue flow as well as the discounted flows.

Section 3 *Methodology*

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

$C = 12.3$ 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 7 equal payments. Hence the annual payment in the nth year is

$L_n = P\, i(1 + i)^n/((1 + i)^n - 1)$ \$ for $1 <= n <= 7$.
$L_n = 0$ \$ for $n > 7$ (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

$E = 65{,}000{,}000$ kWh (8)

The base price for electricity in the first year is T cents/kWh The escalation rate for the electricity price (e) = 5%

Thus $e = 0.05$ (9)
In any year n after commercial operation starts, annual revenue

$R_n = ET(1 + e)^n$ \$ (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

$OM_n = 0.01C(1 + e)^n$ \$ (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

$c = (OM + D + P)/30E$ (20)

The cost of generation in the first year is given by
$L_1 + D_1 + OM_1/65,000,000$ \$/kWh.

For each year the cash flow is computed as

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

which when positive indicates net inflow and when negative indicates net outflow of funds.

Section 4 *Results*

The analyses shows that the Benefit Cost ratio of the project is 5.76. The average cost of energy based on the total life cycle costs divided by the energy produced over the life cycle in today's worth is 1.11 US cents per kWh and the cost of energy produced in the first year is 4.5 US cents per kWh.

If the project is financed by soft term loans (interest rate 3%, payback 30 years) as obtained by governments, and which is probably the basis on which the economic and financial analyses of other proposed hydropower projects in Tanzania are calculated , then the economics of the project are BCC = 7.49 and cost of energy 1.60 US cents/kWh.

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.

From these additional parameters can be computed as follows

Total present worth of all operating costs is given in column 9
Total present worth of all

Section 5 *Sensitivity Analysis*

Since some of the conditions assumed for the 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 and 13-2.

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
- Low price for electricity sold which is US 7 cents/kWh escalating at 5% p.a.

Box 13-1: Cases for Sensitivity Analysis

CASE	PARAMETER	COST	LOAN PERIOD	INTEREST	PURCHASE PRICE	DISCOUNT RATE
1	B/C RATIO	12.30	7	5% to 10%	0.07	6%
2	ENERGY COST	12.30	7	5% to 10%	0.07	6%
3	B/C RATIO	12 30	7	10%	0.05 to 0.10	6%
4	ENERGY COST	12 30	5 to 20	10%	0.07	6%
5	ENERGY COST	10-20	7	10%	0.07	6%
6	B/C RATIO	10-20	7	10%	0 07	6%
7	B/C RATIO	12 30	7	10%	0.07	5% to 20%
8	NPV	12 30	7	10%	0.07	5% to 30%
9	LIFE CYCLE ENERGY COST	12 30	7	10%	0.07	5% to 30%
10	BENEFITS AND COSTS	12.30	7	10%	0.07	5% to 30%
11	NPV	12.30	7	5% to 15%	0.07	5% to 30%
12	B/C RATIO	12.30	10	5% to 15%	0.07	10% to 30%

Following observations can be made on each of the cases above.

1. Case-1: Even for a high financing rate of 10% the project benefit cost ratio does not fall below 5.75
2. Case-2: Even for a high financing rate of 10%, the energy cost in the first year does not exceed 4.8 US cents per kWh.

3. Case-3. Even if the purchase price per kWh falls to 5 cents, the benefit cost ratio is 4.0.
4. Case-4: Even for a short loan payback period of 5 years, the first year energy cost is only 6.0 US cents per kWh.
5. Case-5: Even if the capital cost increases by 50%, energy cost does not exceed 7 US cents per kWh.
6. Case-6: Even if the capital cost increases by 50% benefit cost ratio is 4.0
7. Case-7: Even for a high discount rate of 20%, the benefit cost ratio exceeds 2.0
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 0.6 US cents per kWh
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.

Summarizing the project is highly feasible from economic and financial terms. Hence construction of the project as an alternative to support the existing grid is recommended.

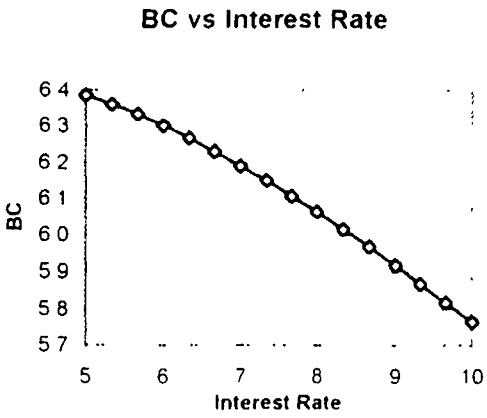
TABLE 13-1
ECONOMIC AND FINANCIAL ANALYSES

Capital Cost	12 300	M US$
Interest Rate	10	percent
Payback Period	7	years
CRR	0 2054	
Discount rate	6	percent
Net Annual Energy	65 000	GWh
Base Price of Energy	0 07	$/kWh
Inflation Rate	5	percent
O&M	1	percent
IDC	1 907	M US$
IDC + Capital Cost	14 207	M US$
Economic Life	30	years

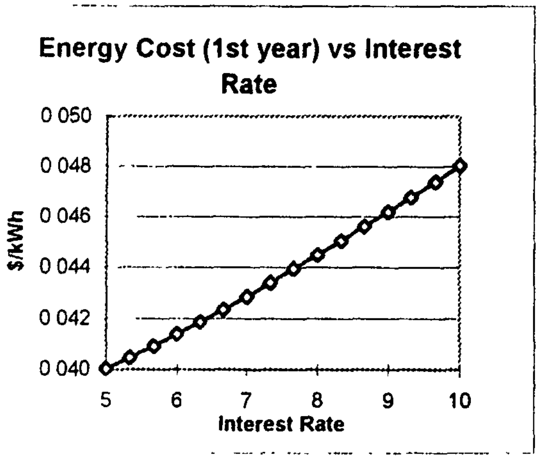
												PRESENT WORTH			
Years	% CC	Investment M US$ 1	Sigma inv	IDC M US$ 2	Debt Service M US$ 3	Depreciation M US$ 4	O & M M US$ 5	Energy Cost $/kWh	REVENUE M US$ 6	NET INCOME M US$ 7	PWF 8	RUNNING COSTS M US$ 9	ENERGY COST $/kWh	REVENUE M US$ 10	CASH FLOW M US$ 11
-2	50	6 150	6 150	0 615											
-1	50	6 150	12 300	1 292											
										(6)-(3+4+5)		(8)x(3+4+5)		(8)x(6)	(10)-(9)
1		0 000			2 918	0 075	0 129	0 048	4 778	1 655	0 943	2 945	0 045	4 507	1 562
2		0 000			2 918	0 075	0 136	0 048	5 016	1.888	0 890	2 784	0 043	4 465	1 680
3		0 000			2 918	0 075	0 142	0 048	5 267	2 132	0 840	2 632	0 040	4 422	1 790
4		0 000			2 918	0 075	0 150	0 048	5 531	2.388	0 792	2 489	0 038	4 381	1 892
5		0 000			2.918	0 075	0 157	0 048	5 807	2 657	0 747	2 354	0 036	4.339	1 986
6		0 000			2 918	0 075	0 165	0 049	6 097	2 940	0 705	2.226	0 034	4 298	2 072
7		0 000			2 918	0 075	0 173	0 049	6 402	3 236	0 665	2 106	0 032	4 258	2 152
8		0 000			0 000	0 075	0 182	0 004	6 722	6 466	0 627	0.161	0 002	4 218	4 057
9		0 000			0 000	0 075	0 191	0 004	7 059	6 793	0.592	0 157	0 002	4 178	4 021
10		0 000			0 000	0 075	0 200	0 004	7 411	7 136	0 558	0 154	0 002	4 139	3 985
11		0 000			0 000	0 075	0 210	0 004	7 782	7 497	0 527	0 150	0.002	4.099	3.949
12		0 000			0 000	0 075	0 221	0 005	8 171	7 875	0 497	0.147	0 002	4 061	3 914
13		0 000			0 000	0 075	0 232	0 005	8 580	8 273	0 469	0.144	0 002	4.022	3 879
14		0 000			0 000	0 075	0 244	0 005	9.009	8.690	0.442	0 141	0 002	3.985	3 844
15		0 000			0 000	0 075	0 256	0 005	9 459	9 129	0 417	0 138	0 002	3 947	3 809
16		0 000			0 000	0 075	0 268	0 005	9 932	9 589	0 394	0 135	0 002	3 910	3 775
17		0 000			0 000	0 075	0 282	0 005	10 429	10 072	0 371	0 132	0 002	3 873	3 740
18		0 000			0 000	0 075	0 296	0 006	10 950	10 579	0 350	0 130	0 002	3 836	3 706
19		0 000			0 000	0 075	0 311	0 006	11 498	11 112	0 331	0 127	0 002	3 800	3 673
20		0 000			0 000	0 075	0 326	0 006	12 073	11 671	0.312	0.125	0.002	3.764	3 639
21		0 000			0 000	0 075	0 343	0 006	12.676	12.259	0.294	0.123	0.002	3.729	3 606
22		0 000			0 000	0 075	0 360	0.007	13.310	12 875	0 278	0 121	0 002	3 694	3 573
23		0 000			0 000	0 075	0 378	0 007	13 975	13.523	0.262	0.118	0 002	3.659	3 540
24		0 000			0 000	0 075	0 397	0 007	14 674	14.203	0 247	0 116	0 002	3.624	3.508
25		0 000			0 000	0 075	0 417	0 008	15.408	14 917	0 233	0 114	0 002	3 590	3 476
26		0 000			0 000	0 075	0 437	0.008	16 178	15.666	0.220	0.113	0.002	3.556	3 444
27		0 000			0 000	0 075	0 459	0.008	16 987	16 453	0.207	0.111	0 002	3.523	3 412
28		0 000			0 000	0 075	0 482	0 009	17.837	17 280	0 196	0.109	0.002	3 489	3 380
29		0 000			0 000	0 075	0 506	0 009	18 728	18.147	0 185	0.107	0.002	3 456	3 349
30		0 000			0 000	0 075	0 532	0 009	19 665	19 058	0 174	0.106	0.002	3.424	3 318
								MEAN					MEAN		
TOTAL		12 300		1 907	20 427	2 243	8 581	0 016	317 412	286.161		20 516	0.011	118.246	97 730

PW of Total Life Cycle Benefits	118 246	M US$	
PW of Total LCC (OM+Cap+IDC+E	20 516	M US$	
Benefit Cost Ratio	5 764		
Average Cost of Energy	0 011	$/kWh	Computed over lifetime energy
Net Present Value	97 730	M US$	

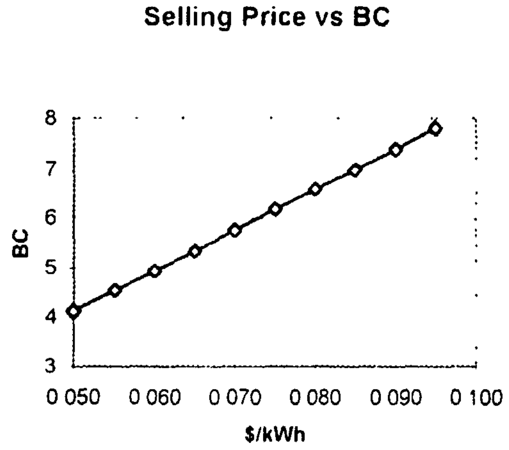
FIGURE 13-1
SENSITIVITY ANALYSES CASES 1 to 6



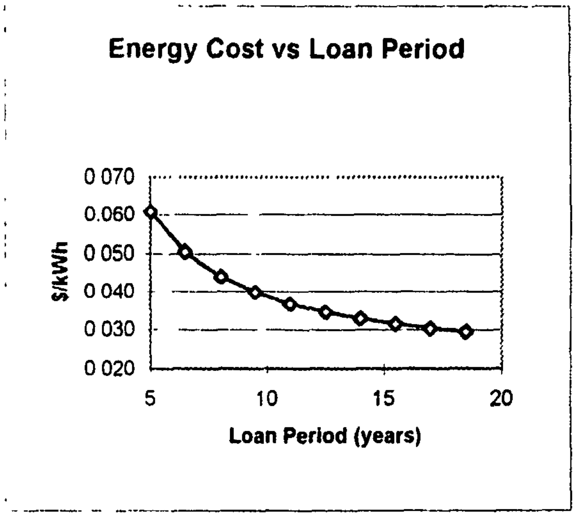
Case-1



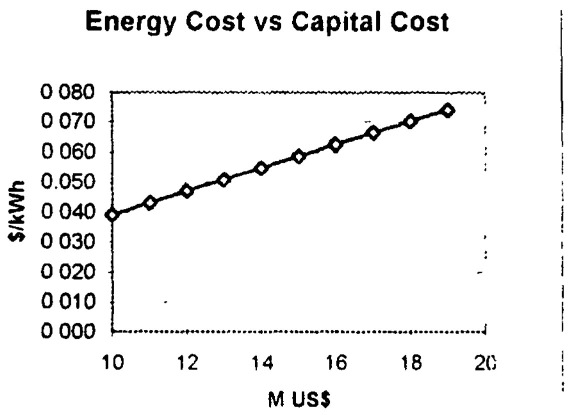
Case-2



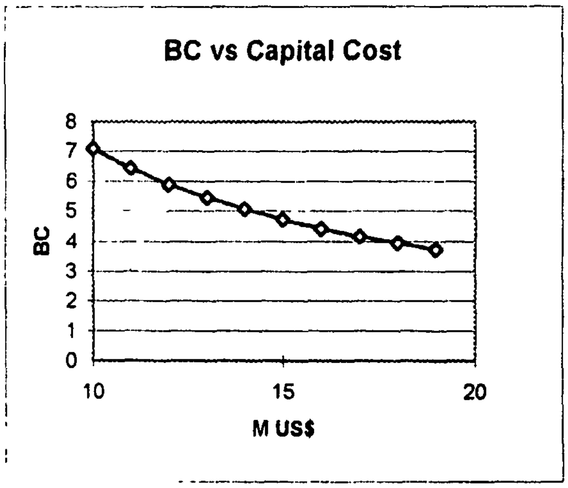
Case-3



Case-4



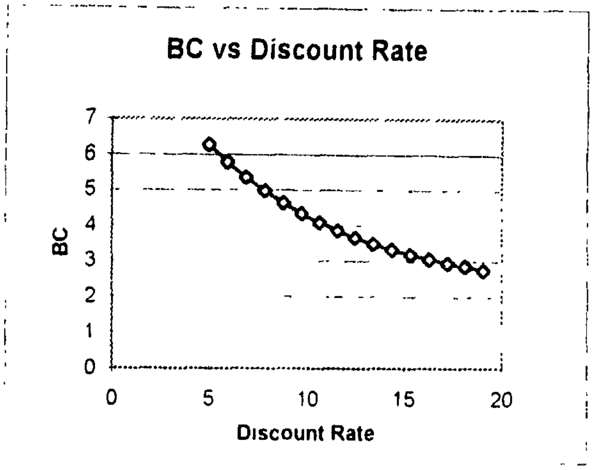
Case-5



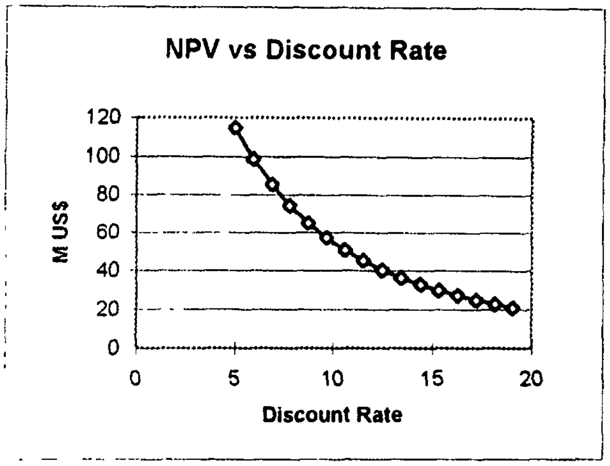
Case-6

FIGURE 13-2

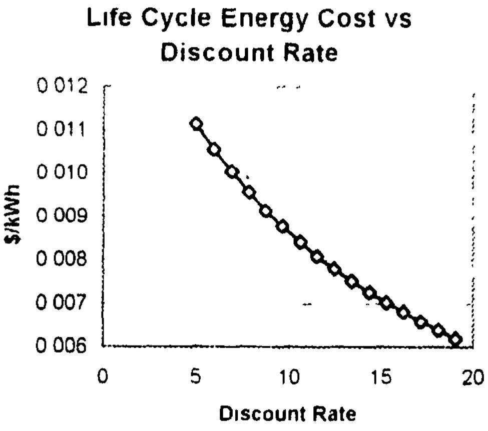
SENSITIVITY ANALYSIS CASES 7 to 12



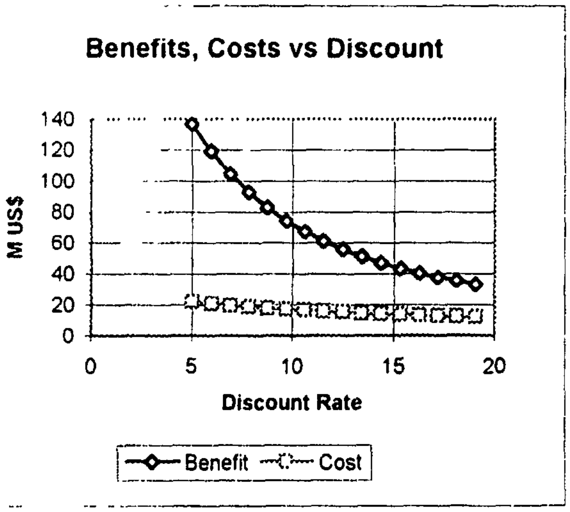
Case-7



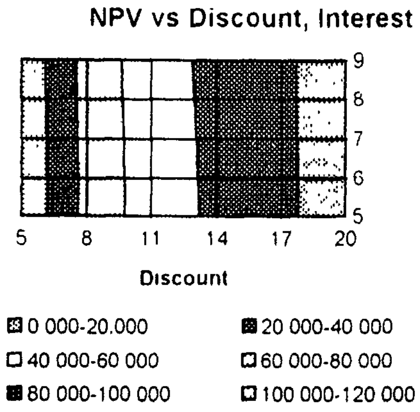
Case-8



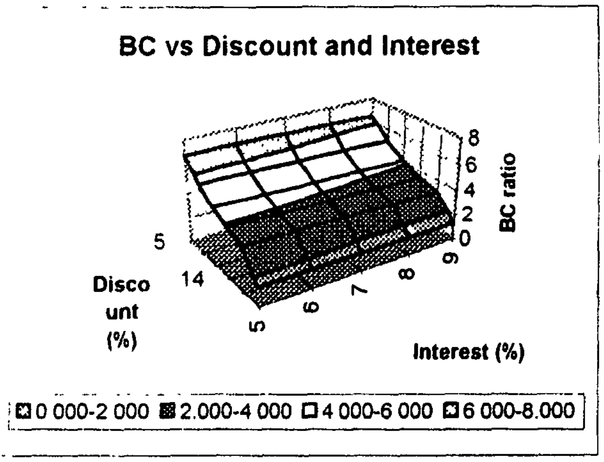
Case-9



Case-10



Case-11



Case-12

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 in which the construction team would be interested are discussed below.

Section 2 *Supply of Materials and Equipment*

The construction of the power station and the related transmission facilities will require the hauling in of materials and construction equipment, electro-mechanical equipment (turbines, generators etc) and hydraulic equipment (gates etc).

The longest and heaviest construction items are assumed to be the following

Heaviest_Article	Longest_Article
Prior to construction -Breaker about 25 tons During construction - Generator rotor segments	Travelling crane about 8m

It is expected, that mechanical and electrical equipment shall be furnished in major items as follows :

1. Penstocks, Gates and Trashracks
2. Turbines, Governors, Cranes and Hoists
3. Auxiliary Mechanical Equipment
4. Spillway Gates
5. Generators
6. Transformers
7. Major Electrical Equipment
8. Equipment for 33 kV Switchyard .
9. 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, the electro mechanical equipment etc. All of these will be landed at the Dar Es Salaam harbour. Trucks and trailers or railway can be conveniently used for transport from the port to the site or from port to Rundugai railway station which is very near with intermediate storage if necessary.

2. Imported Light Articles These articles which would consist of any sensitive equipment will be flown to Kilimanjaro International Airport which is very near and subsequently transported by road directly to site.

3 Domestically procured Materials: All equipment and materials which are locally available will be procured at Arusha or Dar or other cities and transported to the site.

Section 3 *Organisation*

The nature of the Kikuletwa Project is such that it is logical that it will be divided into major project features, perhaps separate contracts, if need be as follows taking due consideration of local contractors and facilities which exist in Tanzania:

1. Housing and Facilities of the Site
2. River Diversion, Care of the River and Unwatering
3. Dams
4. Spillways
5. Power Station
6. 33kV Switchyard
7. Tailwater Channel
8. Access Roads
9. Transmission Line 33 kV
10. Receiving bay at substation in Kiyungi

Section 4 *Construction Schedule*

There is a rainy season in the months of November, December and heavy rains from March to May. Consequently, it is necessary to adapt the sequence of constructional operations to these climatic conditions. The greatest advantage possible should be taken of the dry seasons, particularly in the months of June to October for the operations in the main river.

In order to shorten the time taken by the construction, it is necessary to accomplish, even during the rainy season, individual types of operations, such as rock quarrying, concrete work, grouting operations performed outside the foundation pit, and 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 Roads	km/day	0.20
Open Excavation with power shovels	m^3/day	50
Rock Excavation	m^3/day	25
Dam Excavation	m^3/day	20
Concrete placing	m^3/day	20
Reinforced Concrete	m^3/day	15
Shotcrete	m^3/day	10
Backfill	m^3/day	50
Transmission works	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 either case, the implementation will involve the issue of a bid documents and evaluation of tenders. In the case of IPP participation, a formal structured RFP will be issued to which various IPPs will respond. Based on this 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, construction site and the camps and clearing, excavation and grading of site. The required camps can be constructed alongside the access road as well as on road from the dam to the switchyard Also included will be any temporary roads required for working the quarries or borrow areas

The area to be occupied by the principal structures, such as the dam, the power plant, the spillway and the appurtenances to be constructed, together with the surfaces of all borrow areas, shall be cleared of all vegetation the material being used as industrial wood or burned.

The construction materials earmarked for the sections of the dam and proceeding from other sources than from the excavation required for the construction, shall be taken borrow pits designated in the final drawings. The pits 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.

According to the results of the first-stage surveys, occurrence of landslides is not likely. Nevertheless, the estimates include sufficient contingencies for this case

A concrete batching plant of about 50 cubic meters per day capacity will be installed at 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 Kikuletwa river and stored in tanks prior to utilisation. Potable water may have to be brought by tankers from Moshi.

Adequate electric power will be required for the construction of the project. It is estimated at about 1000kW. The best method to obtain this power is from a truck mounted diesel generator in the vicinity of the site. Alternatively, the existing transmission line at Kikuletwa 1 to the national grid should be operated at 33kV with step down facility to obtain the construction power

Part III **Diversion Weir**

When preliminary works have been completed, a diversion tunnel near the diversion site taking advantage of the bend in the river in the left bank shall be excavated so that the diversion weir area is rendered dry. After the construction, the diversion tunnel shall be plugged with concrete. The diversion tunnel being rather small it shall be completed upon which the main river shall be diverted by closing the river channel both upstream and downstream of the dam baseline so that the minimum flow occurring in the months of Jun to October be admitted to the diversion channel and passed safely downstream. Immediately after diversion, the main dam area shall be de- watered and there shall be initiated, excavation for the foundation of the dam.

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.

Concrete placement for the spillway and non overflow sections shall be done continuously. A total of about 2000 cum of excavation and 8000 cum of concrete is required. The entire diversion weir can be completed in about nine months.

Part IV **Waterway**

The waterway requires excavation of about 16500 cum. It is estimated to take about 6 to 8 months Reinforced concrete of about 1300 cum is required. Concrete placement shall continue in parallel with excavation. The entire construction is spread over 14 months. The penstocks in view of short length can be erected when the conduit 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 742 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 740m for the power house, At the time when the main works of the machine hall with have been finished, the assembly of the main crane and then the installation of the turbine runners, generators and the accessory equipment shall be started.

The power house will be finished in about 17 months.

Part VI **Tailrace**

The tailrace involves relatively low excavation and concrete. It shall be initiated when power house excavations are complete. Concreting is expected to take about 4 months.

Part VII **Switchyard**

Another structure, the completion of which influences the commissioning of the power plant, is the switchyard. The earthwork shall be initiated while the excavations in the bedrock on the right river bank for the power house are in progress, in order to make possible the completion of the subsequent civil engineering part and electrical equipment installation at the time of the completion, that is, within the 18 months following the start of the work.

Part VIII **Transmission**

The transmission works can be done independent of the other works. It is estimated that it will take a total of about six months to complete the work.

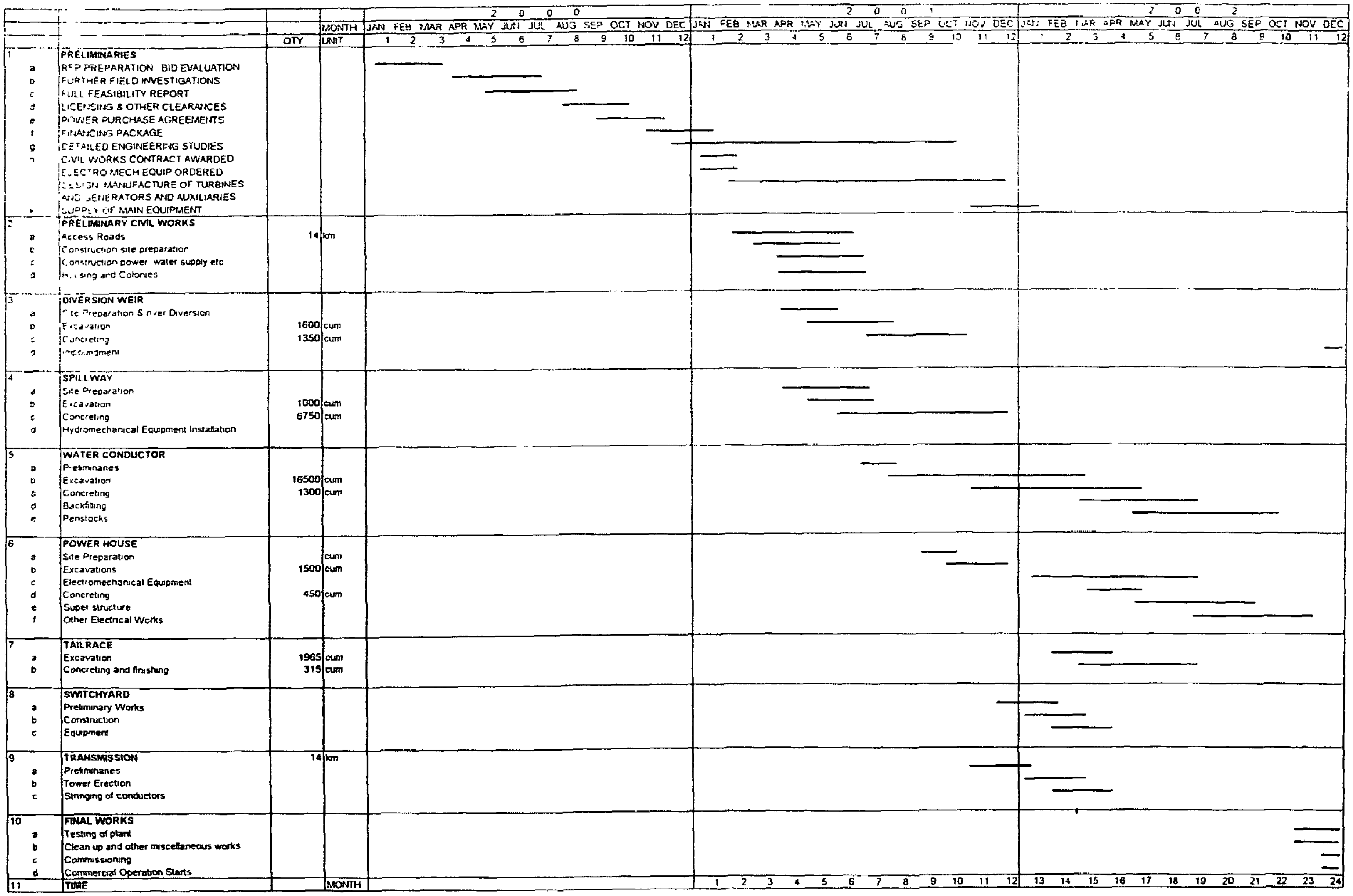
Part IX **Final Works**

At about the time when the project is nearing completion there shall be initiated an intensive clean up operation which shall clear all waste materials and restore the site to its original conditions taking into consideration replacing any lost vegetation etc in the vicinity of the site.

The commissioning of the power plant depends on the successful completion of all the civil and electrical works. The attainment of the minimum water level is not a problem as the storage provided is small.

Based on the economical rates at which construction activities can be progressed for a project of this scale a preliminary project construction schedule has been drawn up and is presented in table 14-1. The construction period will not exceed a two years.

TABLE 14-1
IMPLEMENTATION SCHEDULE



				MONTH
			QTY	UNIT
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		
		ELECTRO MECH EQUIP ORDERED		
		DESIGN MANUFACTURE OF TURBINES AND GENERATORS AND AUXILIARIES		
	k	SUPPLY OF MAIN EQUIPMENT		
2		**PRELIMINARY CIVIL WORKS**		
	a	Access Roads	14	km
	b	Construction site preparation		
	c	Construction power water supply etc		
	d	Housing and Colonies		
3		**DIVERSION WEIR**		
	a	Site Preparation & river Diversion		
	b	Excavation	1600	cum
	c	Concreting	1350	cum
	d	Impoundment		
4		**SPILLWAY**		
	a	Site Preparation		
	b	Excavation	1000	cum
	c	Concreting	6750	cum
	d	Hydromechanical Equipment Installation		
5		**WATER CONDUCTOR**		
	a	Preliminaries		
	b	Excavation	16500	cum
	c	Concreting	1300	cum
	d	Backfilling		
	e	Penstocks		
6		**POWER HOUSE**		
	a	Site Preparation		cum
	b	Excavations	1500	cum
	c	Electromechanical Equipment		
	d	Concreting	450	cum
	e	Super structure		
	f	Other Electrical Works		
7		**TAILRACE**		
	a	Excavation	1965	cum
	b	Concreting and finishing	315	cum
8		**SWITCHYARD**		
	a	Preliminary Works		
	b	Construction		
	c	Equipment		
9		**TRANSMISSION**	14	km
	a	Preliminaries		
	b	Tower Erection		
	c	Stringing of conductors		
10		**FINAL WORKS**		
	a	Testing of plant		
	b	Clean up and other miscellaneous works		
	c	Commissioning		
	d	Commercial Operation Starts		
11		TIME		MONTH

Chapter 15 Conclusions and Recommendations

1. The Kikuletwa river has a stable flow throughout the year. This is advantageous and obviates need for providing storage. This also implies that the river can give dependable capacity and hence can attract industrial customers for the generated power.

2. A feasibility study was conducted in 1989 by JICA on hydropower generation from the stretch of the river downstream of the existing Kikuletwa 1 power station.

3. The feasibility study by JICA recommended a diversion type development with an installed capacity of 11MW (2 x 5.5MW) and an energy output of 68GWh per year. A long waterway of about 4.2 km total length (2250m headrace culvert, 1050 open canal and 835m penstock) was proposed to obtain a gross head of about 85m. All project features were planned to be on the left bank. The Implementation cost was estimated to be about $4920 per kW in 1989.

4. To obtain satisfactory cash flow and financial analysis, JICA recommended implementation of the project by securing a soft term loan from a co-operating country. The project has however not been implemented till date probably due to inability to secure funding under the desired terms.

5. As per the revised planning suggested by SECSD, the implementation cost and time required for construction can be reduced significantly by taking advantage of loops in the river course. This is achieved by splitting the development into stages which results in a reduction in length of the waterway to less than 400m for development of a head of 65m for the largest stage.

6. In the present modified proposal with an installed capacity equivalent to the original capacity fixed by JICA of 11MW, 65 GWh of energy is generated with a very short water conductor system. Further the head on the plant is 65m as compared to 85m gross and 78.2m net head in the JICA proposal. This balance head of 13.2 m and loss of 6.8m in JICA proposal is utilized by two small power stations which can give additional capacity and energy.

7. From the view point of the present state of power supply in the Region, it is more desirable to implement a medium hydropower project close to the demand centre The Kikuletwa Stage 3 will be able to meet most of the energy demand of the town of Moshi.

8. The principal structures will be the diversion weir, intake structure, short waterway, powerhouse above ground and tailrace.

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

10. Comparison studies of alternative plans indicates that the optimum development capacity is 11000kW.

11. The power house will have two Francis turbines of 5.5MW each and produce 65.0 GWh of energy in an average year. The plant capacity factor is 67.45%.

12. The total construction cost is estimated to be US$12.30M and IDC US$ 1.90M.

13. Due to the revised planning, implementation cost will be reduced to $1110 per kW. The cost of energy from the project will be US cents 4.5 per kWh even with very stringent financing conditions.

14. The results of the economic evaluation show that the project is economically feasible.

15. The financial rates of return based on discount factor of 6% indicates that the project is financially sound.

16. The electric power produced at the Kikuletwa stage 3 power station will be supplied to the Regional grid and this will improve the electric supply demand and supply situations.

17. 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 Kikuletwa stage 3 project in late 2002. The project expenditure and size is such that it is suitable of being financed by many local companies who can become IPPs.

18. The Kiyungi and Njiro substations are at the end of the 132kV transmission system. The voltage drop is therefore great. The Kikuletwa-2 power station will give ample voltage support and increase the stability of this line thereby improving operating conditions in other parts of the system.

19. The construction of the reservoir will not result in the loss of valuable agricultural or grazing land. The lake will not inundate a populated valley necessitating the displacement of the population. Therefore the cost of moving the inhabitants and of replacing the farm will not affect the total cost estimates.

20. The value of land and property in the area of the project, which is not in direct physical interference, will not be adversely affected by the construction of engineering works

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 flow. On the contrary, the operation of the reservoir will ensure the regulation of flows to some degree.

Chapter 16 Photographs, References, Abbreviations

Photo 16-1: View of Diversion weir site from downstream

Photo 16-2: View of Power House site

Section 1 Rerferences

1 Feasibility Study on Small Scale Hydroelectric Power Development in Kilimanjaro Region by Japan International Cooperation Agency Jan 1989 Vol-1

2 Feasibility Study on Small Scale Hydroelectric Power Development in Kilimanjaro Region by Japan International Cooperation Agency Jan 1989 Vol-2

3. Survey of Tanzania Topographic sheets on 1:50000 scale - 55/1, 55/2, 55/3, 55/4, 56/1, 56/2, 56/3, 56/4, 71/2, 72/1, 72/2.

4. India - Mini Hydro Development on Irrigation Dams and Canal Drops Pre Investment Study Volume - 1, Main Report, Report No. 139A/91. Joint UNDP/ESMAP study 1991.

5. India - Mini Hydro Development on Irrigation Dams and Canal Drops Pre Investment Study Volume - 2, Technical Supplement, Report No. 139B/91. Joint UNDP/ESMAP study 1991.

6 India - Mini Hydro Development on Irrigation Dams and Canal Drops Pre Investment Study Volume - 3, Cost Estimates, Report No. 139C/91. Joint UNDP/ESMAP study 1991

7. Submission and Evaluation of Proposals for Private Power Generation Projects in Developing Countries - The World Bank, IEN Occassional Paper No.2 April 1994.

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
JICA	Japan International Cooperation Agency
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 = 1×10^6 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

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
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF TECHNICAL PAPER SERIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Kenya	Field Performance Evaluation of Amorphous Silicon (a-Si) Photovoltaic Systems in Kenya: Methods and Measurement in Support of a Sustainable Commercial Solar Energy Industry	08/00	005/00
	The Kenya Portable Battery Pack Experience Test Marketing an Alternative for Low-Income Rural Household Electrification	05/01	012/01
Senegal	Regional Conference on the Phase-Out of Leaded Gasoline in Sub-Saharan Africa	03/02	022/02
Swaziland	Solar Electrification Program 2001—2010. Phase 1: 2001—2002 (Solar Energy in the Pilot Area)	12/01	019/01
Tanzania	Mini Hydropower Development Case Studies on the Malagarasi, Muhuwesi, and Kikuletwa Rivers Volumes I, II, and III	04/02	024/02
Uganda	Report on the Uganda Power Sector Reform and Regulation Strategy Workshop	08/00	004/00
	WEST AFRICA (AFR)		
	LPG Market Development	12/01	017/01
	EAST ASIA AND PACIFIC (EAP)		
China	Assessing Markets for Renewable Energy in Rural Areas of Northwestern China	08/00	003/00
	Technology Assessment of Clean Coal Technologies for China Volume I—Electric Power Production	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume II—Environmental and Energy Efficiency Improvements for Non-power Uses of Coal	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume III—Environmental Compliance in the Energy Sector. Methodological Approach and Least-Cost Strategies	12/01	011/01
Thailand	DSM in Thailand· A Case Study	10/00	008/00
	Development of a Regional Power Market in the Greater Mekong Sub-Region (GMS)	12/01	015/01
Vietnam	Options for Renewable Energy in Vietnam	07/00	001/00
	Renewable Energy Action Plan	03/02	021/02
	SOUTH ASIA (SAS)		
Bangladesh	Workshop on Bangladesh Power Sector Reform	12/01	018/01

Region/Country	*Activity/Report Title*	*Date*	*Number*
	LATIN AMERICA AND THE CARIBBEAN (LAC)		
	Regional Electricity Markets Interconnections — Phase I		
	Identification of Issues for the Development of Regional Power Markets in South America	12/01	016/01
	Population, Energy and Environment Program (PEA)		
	Comparative Analysis on the Distribution of Oil Rents (English and Spanish)	02/02	020/02
	Estudio Comparativo sobre la Distribución de la Renta Petrolera		
	Estudio de Casos: Bolivia, Colombia, Ecuador y Peru	03/02	023/02
	GLOBAL		
	Impact of Power Sector Reform on the Poor: A Review of Issues and the Literature	07/00	002/00
	Best Practices for Sustainable Development of Micro Hydro Power in Developing Countries	08/00	006/00
	Mini-Grid Design Manual	09/00	007/00
	Photovoltaic Applications in Rural Areas of the Developing World	11/00	009/00
	Subsidies and Sustainable Rural Energy Services: Can we Create Incentives Without Distorting Markets?	12/00	010/00
	Sustainable Woodfuel Supplies from the Dry Tropical Woodlands	06/01	013/01
	Key Factors for Private Sector Investment in Power Distribution	08/01	014/01

4/8/02

The World Bank

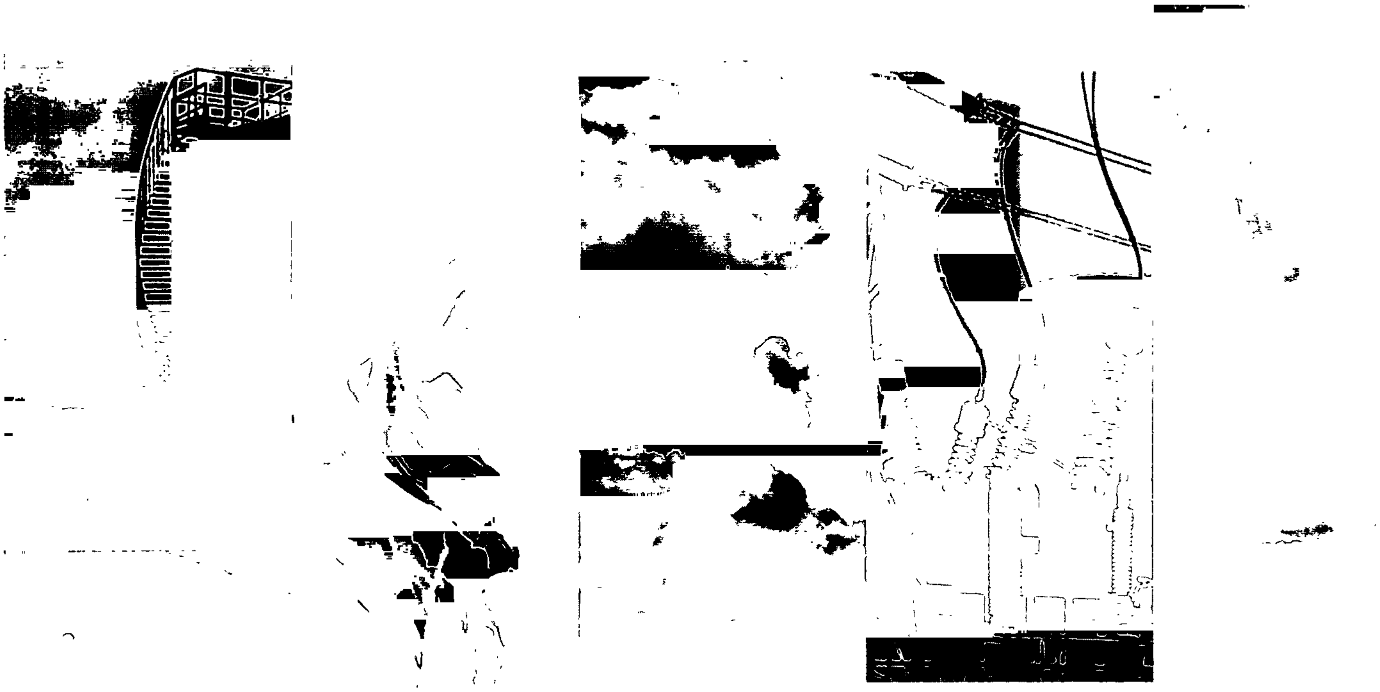
1818 H Street, NW

Washington, DC 20433 USA

Tel 1 202 458.2321 Fax 1.202 522 3018

Internet www esmap org

Email: esmap@worldbank org



A joint UNDP/World Bank Programme