Somali Democratic Republic
Ministry of Agriculture

Mogambo Irrigation Project

Electrification of Pump Station

Final Report

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ACKNOWLEDGEMENTS

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SUMMARY

The study has shown that an extension of the power line from Kamsuuma to serve the Mogambo Irrigation Project is feasible.

The power would only be available for about 296 days per annum three years out of four.

The cost of the works including power lines, sub-stations, switchgear, transformers and converting one 231 kW and one 115 kW pump unit to electric motive power is SoSh 118 million (US$ 1.18 million).

The annual cost of operating the existing system including diesel fuel, maintenance and depreciation is: SoSh 13.49 million with fuel at SoSh 25 per litre. This would rise to SoSh 16.88 million if the fuel price were to rise to SoSh 35 per litre.

The annual cost of operation for the proposed new system including purchase of power from the Fanoole Project, diesel fuel (at times when Fanoole cannot provide power), maintenance and depreciation is: SoSh 8.58 million with diesel at SoSh 25 per litre and electric power charged at SoSh 3.0 per kWh. These figures would rise to SoSh 16.41 million with electric power charged at SoSh 10.0 per kWh and SoSh 23.12 million with electric power charged at SoSh 16.0 per kWh.

1. INTRODUCTION

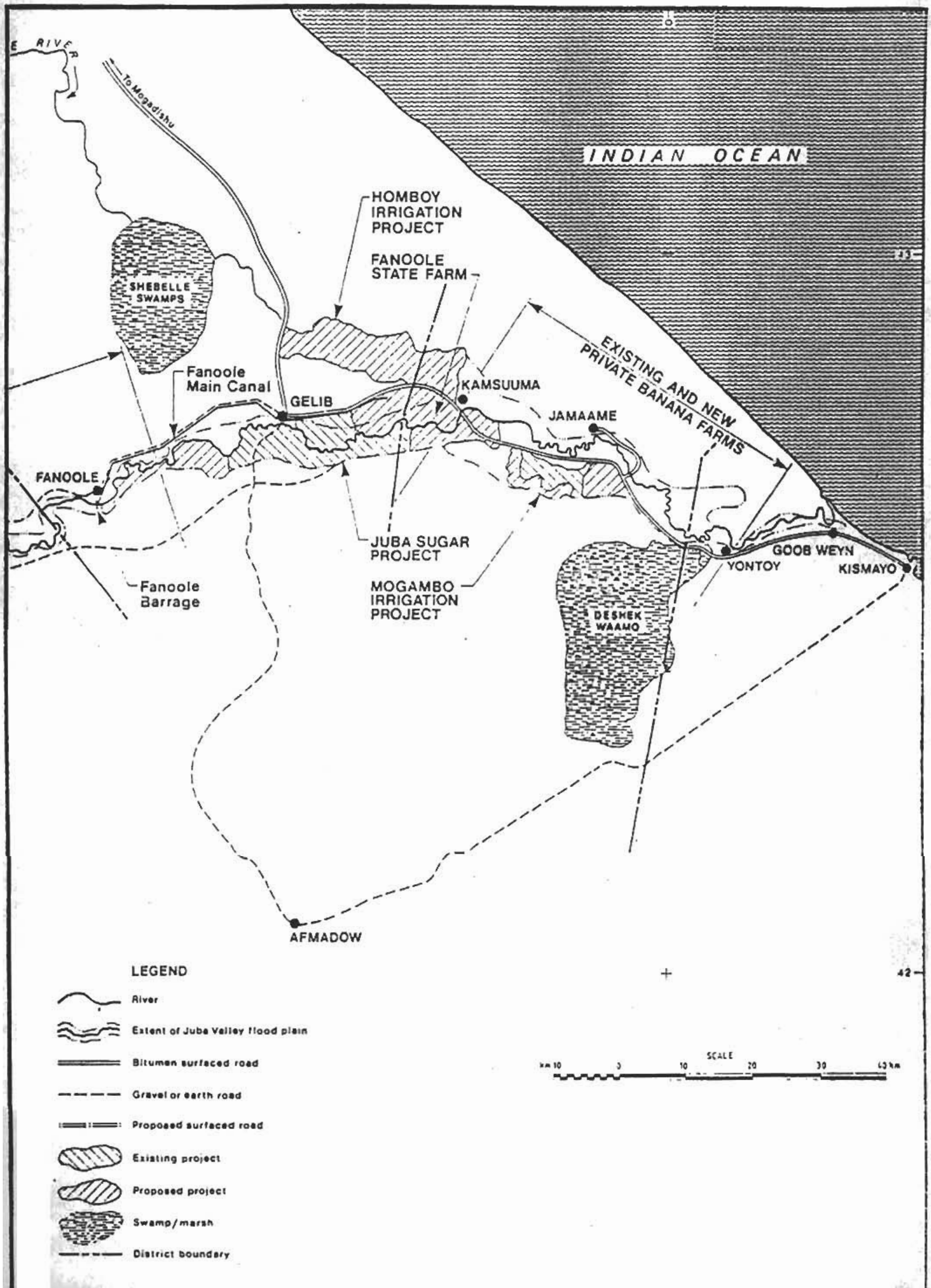
In a meeting in Mogambo on 10 February 1988, both Kreditanstalt fur Wiederaufbau (KfW) and Mogambo Irrigation Project (MIP) requested Sir. M. MacDonald & Partners Limited (MMP) to carry out a simple pre-feasibility study to evaluate the possibility of extending Fanoole hydropower supplies to serve Mogambo Irrigation Project.

A draft terms of reference for the study handed over to MMP on 13 February 1988 are presented as Appendix 1.

This study covers the current output and consumptions from the Fanoole hydropower station together with maximum production capacity and potential further users.

Figure 1.1 shows the general locations of various project sites.

Figure 1.1
Location Map



2. GENERAL DESCRIPTION OF MOGAMBO IRRIGATION PROJECT

2.1 Background

The project consists of some 2 000 ha of net irrigable area, completed in 1987, together with administration buildings and senior management housing. Currently work is in progress on construction of housing for middle management staff. The irrigation water requirements are met from a pump station located on the west bank of Juba river near the village of Bulo Yaag.

The power requirements for the administration buildings and housing area are met from two 200 kW diesel driven generators, one of which is on standby. The power requirements of the middle management housing area currently under construction will also be met by this existing installation. The pumps at the main pump station are driven by two 231 kW and one 115 kW diesel engines.

2.2 Location

The project takes its name from the village of Mogambo which is located on the west bank of the Juba river, approximately 70 km by road from the coastal town of Kismayo.

The project boundary to the east is formed by existing banana plantations adjacent to the river. To the north is the Trans-Juba Livestock Project and the southern end of the Juba Sugar Project area. The western boundary of the project is formed by a series of interconnecting old river channels on the edge of a marine plain. The project headquarters, housing, and the main irrigation pump station are some 12.5 km south of Kamsuuma by road.

3. GENERAL DESCRIPTION OF FANOOLE STATE FARM PROJECT

3.1 Background

Fanoole State Farm is located on the left bank of the Juba river just south of Gelib. It is supplied by gravity from the Fanoole barrage by a 50 km long main canal. The present irrigable area is about 1 600 ha. Fanoole is run as a state farm, under the Ministry of Agriculture with technical assistance provided by the Chinese Government.

The project's power requirements for approximately eight months of the year are met from a small hydro-electric power generating station at Fanoole barrage. Steps are being taken to improve the availability of power from the hydropower station during periods of low river flows.

In the absence of any power from the hydropower station, the electricity demand is met from 3 x 540 kW standby diesel generators located at Gelib.

4. POWER AVAILABILITY FROM FANOOLE AND PRESENT USAGE

4.1 Hydroelectric Power

Fanoole Project area obtains most of its electric power from Fanoole barrage sited on Juba river 37 km north of Gelib. A hydro power station is constructed at the site of the barrage on the left bank of the river. There are two Austrian manufactured turbines each capable of generating 2 300 kW. The turbines have operated without major problems since installation. At present no power is usually generated during the months of January, February and March due to low river levels and for a month in September/October due to high river levels. The turbines can only be operated when the difference in river level upstream and downstream of the turbine house is a minimum of 3.0 m and a maximum of 6.0 m. At present no power is generated when the downstream water level is below 25.30 metres above sea level, National Somali Survey datum. With the assistance provided by the Chinese Government, the Fanoole Project is currently in process of placing large precast concrete caissons at the downstream end of the turbine house outlet channel. The effect of this work will be to form a pool to maintain minimum downstream river levels in the turbine house outlet channel of 25.50 m. Thus the availability of power from the river during the months of January, February and March should be improved as from 1989. Generation, however, will still depend on the incoming flows. For approximately one month during September/October, the high flow in the river means that the difference in river level between upstream and downstream of the power house is less than 3.0 m and as a result no power can be generated.

The minimum river flow required for power generation is and will remain at 15 m^3/s. For full generation a flow of 58.5 m^3/s is required.

4.2 Juba River Low Flows

The der floods normally end in November and the Juba river flows gradually recede throughout the jilaal season until the following April or May, when the gu flood waters from the Ethiopian catchment arrive.

Unfortunately, little reliable river flow data is available for points in the lower Juba valley. Since 1978 the Juba Sugar Project has conscientiously recorded water levels upstream of its intake at Mareerey. These records approximate to the flow passing through the Fanoole barrage. With a small amount of infilling, daily discharges are available for all the jilaal seasons from 1977/78 to 1985/86 except for 1984/85. Comparisons with concurrent records at Lugh suggest that the sample of data at Mareerey is representative of jilaal flows. Lugh has therefore been used to quantify low flows in the lower Juba.

Table 4.1 shows the 10-day mean discharges during the jilaal seasons for the infilled and extended hydrological data.

Daily data were used to determine the number of consecutive days for which river flows remained less than or equal to 5, 10 and 20 m^3/s during the eight jilaal seasons. The results are presented in Table 4.2.

It can be seen from Table 4.1 that there are large variations in river discharges during the jilaal season from year to year. In three of the years shown there would have been no interruption of power supplies due to insufficient flows. In other years the flow is below the minimum requirement of 15 m^3/s for up to 90 days. On average it can be expected that electricity generation will be impossible for 41 days each jilaal season.

Table 4.2, which has been derived from the same data, shows a similar pattern. In an average year the flows can be expected to remain below 20 m^3/s for a continuous period of 52 days.

As noted in Section 4.1 the work presently being carried out to maintain minimum downstream water levels at the barrage will not have any effect on the minimum flow requirements.

4.3 Standby Generation at Gelib

The existing turbine generation at Fanoole is supplemented by standby diesel generation in Gelib. The installation comprises 3 x 540 kW generator sets with one of the sets at anytime designated as standby. These diesel sets are connected into the Fanoole/Gelib/Kamsuuma distribution system (see Section 4.5), and are intended for use during the periods when the river flows make hydroelectric generation impossible.

4.4 Present Power Usage

Discussions with Senior Management Staff at the Fanoole Project have indicated that the normal demand for electricity from the existing distribution system is approximately 500 kW. This increases to 800 kW when the Fanoole rice mill is operating. The town of Gelib and the village of Kamsuuma do not at present have any significant industrial or agricultural connections to the distribution system. Consumption for lighting and small machinery in these two centres is therefore only a small proportion of the totals quoted above.

4.5 Existing Distribution System

At present the distribution system comprises 35 kilo Volt (kV) and 11 kV transmission lines with associated substations. See Figure 4.1.

The 35 kV line commences at the barrage and runs parallel to Fanoole main canal to Gelib. Here a sub-station is located and connections to the standby generation sets are described in Section 4.3.

From Gelib the 35 kV line runs alongside the main road towards Kismayo until 1.5 km north of the village of Sheikh Abdi Muddi, 9 km north of Kamsuuma. At this point there is a 35/11 kV substation. The 35 kV line is carried on steel towers with spans of 300 metres. From the substation an 11 kV line extends to Kamsuuma. This line is carried on single wooden or metal poles set 50 m apart. There is an 11/0.4 kV step down transformer at Kamsuuma to provide local low voltage power supplies.

TABLE 4.1

Mareerey: 10-Day Mean Discharges During Jilaal Season

	December			January			February			March			April		
	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	21-28	1-10	11-20	21-31	1-10	11-20	21-30
1977/78	-	506	263	151	94	69	40	39	33	40	228	178	154	195	142
1978/79	305	217	124	98	70	55	66	84	60	66	44	45	137	132	135
1979/80	68	47	33	27	20	17	12	9	8	6	4	3	0	2	4
1980/81	45	31	19	12	8	5	3	2	2	0	0	164	526	519	617
1981/82	95	70	49	36	28	23	19	17	13	10	9	10	11	36	208
1982/83	259	266	188	171	93	66	75	59	62	43	38	22	22	22	58
1983/84	325	176	114	82	63	47	36	27	21	16	14	13	6	8	22
1985/86	108	65	49	33	24	16	11	9	7	6	5	5	10	85	222
Mean	172	172	105	76	50	37	33	31	26	23	43	55	108	125	176

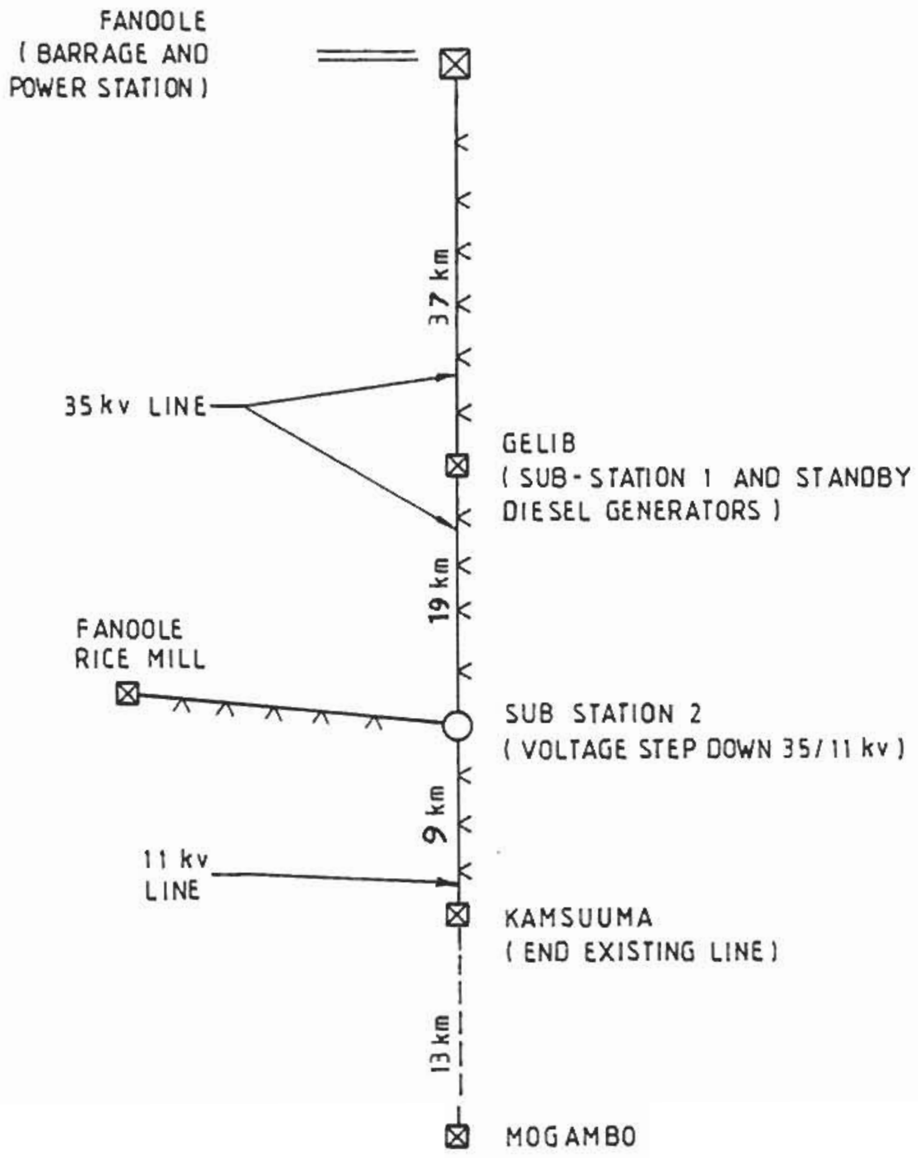
TABLE 4.2

Mareerey Jilaal Flows: Longest Periods (days) For Which Flow ≤ Q

	$Q(m^3/s)$					
Season	5	10	20	30	40	50
1977/78	0	0	0	0	21	28
1978/79	0	0	0	0	5	10
1979/80	53	78	113	131	147	152
1980/81	59	76	91	98	109	112
1981/82	0	25	75	93	102	112
1982/83	0	0	3	35	37	41
1983/84	2	19	55	78	86	115
1985/86	28	60	80	100	104	110

Figure 4.1

Existing Distribution System



5. REQUIREMENTS OF JUBA SUGAR PROJECT

5.1 Power Lines for Juba Sugar Project

In discussions with senior members of the Juba Sugar Project (JSP).it transpired that they had done some brief studies on the possibility of utilising Fanoole electric supply for the benefit of JSP. However they said that it was not viable for the JSP to use Fanoole electricity in terms of costs unless a supply could be guaranteed year round which would require the construction of additional diesel generating units at Gelib. This the Fanoole Project Authorities had been unable to promise.

JSP is self-sufficient for power needs during the months when Fanoole hydropower station is operating. Power being supplied by generators powered by steam obtained from burning the bagasse from the factory. During sugar factory closure, JSP have diesel generators on stand by.

6. POWER REQUIREMENTS FOR MOGAMBO PROJECT

6.1 Existing Electricity Supply

Mogambo Irrigation Project has two diesel driven generators each rated at 200 kW one of these is on standby. At present they serve the administration buildings and senior staff housing area. By early 1989, these generators will also have to service middle management housing currently under construction. The current fuel consumption to run the diesel engines is 152 000 l/year which will go up to 197 000 l/year when power is also required for the new housing area.

6.2 Main Irrigation Pump Station

The irrigation water needs of the project are met by pumping water from the Juba river. The pump station is sited about 0.5 km east of the staff housing area. At present there are two full duty pumps each capable of delivering 2.2 m^3/s and one half duty pump capable of delivering 1.1 m^3/s. They are powered by diesel engines rated at 231 kW and 115 kW for 2.2 and 1.1 m^3/s pumps respectively.

The fuel consumption for running the pump station is about 142 000 l/year.

6.3 Modified Power Requirements

In discussions with senior staff of MIP, they indicated that should the power supply from Fanoole hydropower station prove to be viable then they would prefer to:

(a) Link in existing power supply line with the proposed supply line from Fanoole.

(b) Convert one full duty pump from diesel powered drive unit to electric motor drive unit.

(c) Install an additional half duty pump with electric motor drive unit.

The above system would give flexibility to utilise fully Fanoole electric power supply when available and also have diesel driven pumps either on standby or as boosters to water requirements.

7. ELECTRICTY SUPPLY TO MOGAMBO FROM FANOOLE DISTRIBUTION SYSTEM

7.1 Mogambo Requirements

Assuming that at peak periods, MIP ran one electrically driven 2.2 m^3/s and one electrically driven 1.1 m^3/s pump, then the power requirement would be 346 kW, in addition, the power requirement for the housing area would be 190 kW. Therefore the MIP peak requirement would be 536 kW. One should add another 10% to the above figures to allow for additional demand which would be generated by local users.

Therefore the total peak power requirement would be 590 kW or 700 kilovolt amps (kVA).

The anticipated total future loading on the distribution system is therefore the existing 800 kW plus the forecast 590 kW, giving a total of 1 390 kW (say).

The 1 390 kW load can readily be supplied by the existing generators at the Fanoole barrage but could not be supplied by two generators at Gelib when river flows are such as to prevent hydroelectric generation.

7.2 Extension of System

The actual increase in system load by 700 kVA, 590 kW represents only a small load on the high voltage distribution systems under consideration, i.e., at 11 kV the current drawn will be 36 amps, at 35 kV the current will only be 11 amps.

There are two possible ways of extending the existing system, i.e. extension at the 11 kV level and extension at the 35 kV level, both of which are considered further below.

7.2.1 11 kV Extension from Kamsuuma to Mogambo

As described in Section 4.5, the existing 35 kV distribution from Fanoole includes two 35/11 kV substations. Substation Nr 1 located in the Gelib area and substation Nr 2 located approximately 9 km north of Kamsuuma which is supplied by an 11 kV line from substation Nr 2. Option Nr 1 therefore is to extend the Kamsuuma line to Mogambo, a distance of approximately 13 km, giving an effective total of line route length from the substation to Mogambo of 22 km.

The option of an 11 kV line to Mogambo appears technically inferior to a 35 kV line due to the distances over which the power is carried, which will lead to oversizing of the line conductors to limit the line voltage drop to acceptable levels at Mogambo. This will lead to the increase in strength of supporting structures and/or reducing span lengths. Any further future extensions of the line must also be considered, e.g. supplies to Jamama or beyond and proceeding with an 11 kV system extension to Mogambo would make any future extensions more problematic and probably uneconomical. (Energy losses in the line will also be higher in the 11 kV option). Therefore the 11 kV extension option is not deemed advisable and is not considered further.

7.2.2 35 kV Extension from Substation Nr 2 to Mogambo

The 35 kV system currently extends to substation Nr 2 which is approximately 22 km from Mogambo. The overall 35 kV system route length between the Fanoole barrage and substation Nr 2 is 56 km, i.e., 37 km from the barrage to substation Nr 1 and 19 km from substation Nr 1 to substation Nr 2. The size of conductor is reported to be AC 120, which is unfamiliar terminology. However, unless this is one of the smallest conductor sizes having a comparatively high resistance, it is unlikely that there will be any problem in extending the 35 kV system from an electrical viewpoint with both load carrying capacity and voltage drops in the line conductors being within acceptable limits.

7.3 Provision of Additional Generating Capacity

To meet the new power demands caused by the extension of the system to Mogambo, additional generating capacity will be required when the only power is the supply from the Gelib diesel generators. The estimated shortfall is (590 - 280) kW = 310 kW. This shortfall could be met by utilisation of the existing generators at Mogambo, i.e., two sets each of 200 kW rated output power. To minimise operational and maintenance problems it would be possible for these sets to be transferred to Gelib to run adjacent to the existing diesel gensets. Suitable switchgear, cabling and step-up transformer would be needed with suitable modifications to the existing synchronising control circuitry. This, along with the resulting loss of control over the standby power at Mogambo, means that it would probably be more advisable to retain the existing generators at Mogambo.

7.4 Distribution of Power Supplies at Mogambo

The power supply to the area will provide electricity for the housing and office complex plus the pumping station pumpsets, with one full duty 231 kW pumpset remaining diesel driven. The most economical method of distributing power around the housing and office complex will be to utilise the existing switchgear and overhead lines as far as possible.

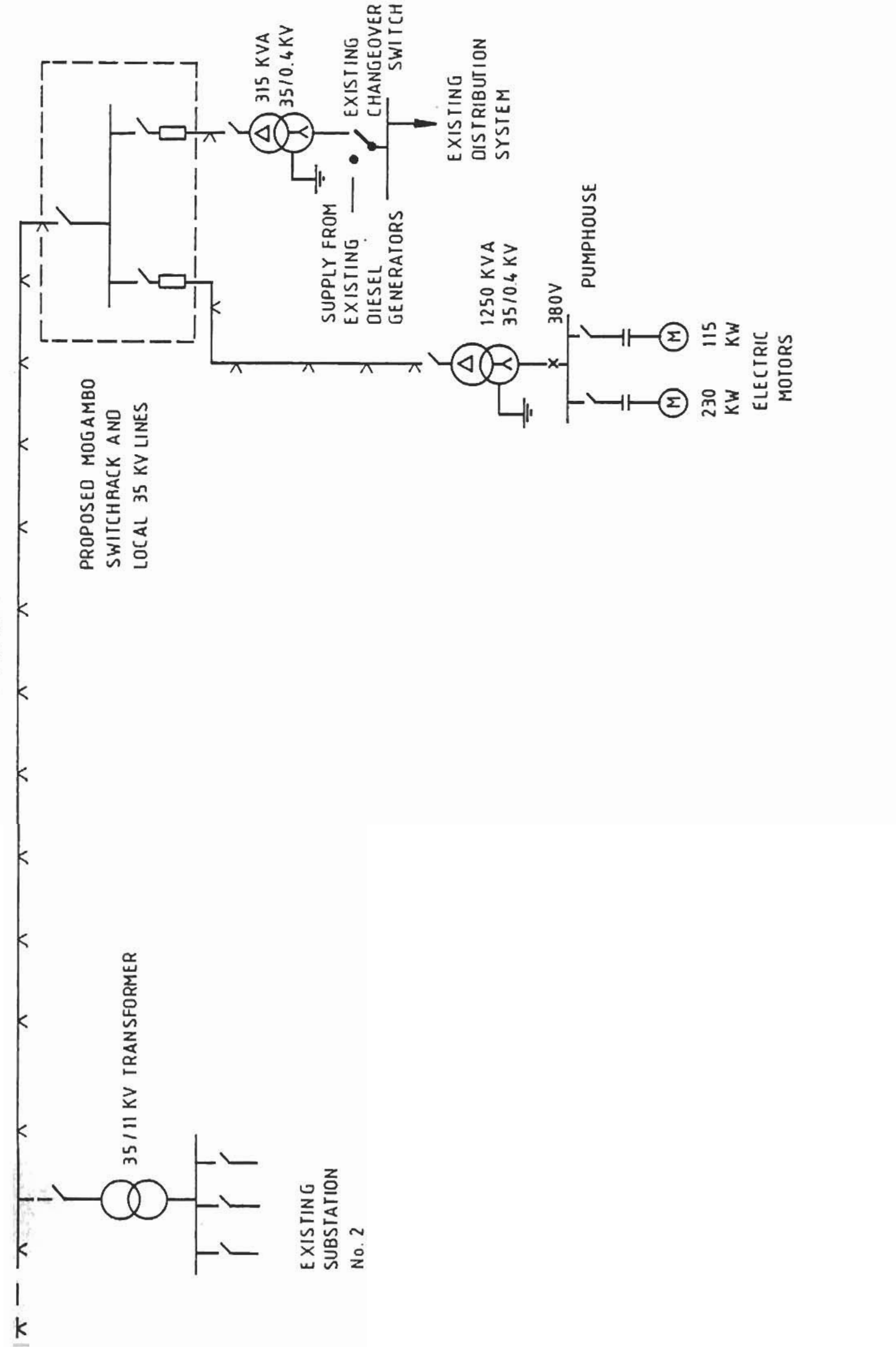
The pumping station does not at present have a power supply and it is recommended that pump motors have a simple starting arrangement, i.e., star-delta starting to minimise operating and maintenance problems. Due to current surges associated with induction motor starting leading to excessive voltage drops, it is recommended that the step-down transformer is located adjacent to the pumping station.

The transformer must be rated so as to limit the voltage drop associated with the current surges during starting of the pump motors. It is estimated the transformer rating will not exceed 1 250 kVA the voltage ratio being 35/0.4 kV. The provision of the power supply to the pumping station will necessitate the installation of associated low voltage switchgear, cabling, motors and lighting and small power items.

The above distribution arrangement will require the provision of a 35 kV three bay substation at Mogambo comprising a minimum of 1 Nr incoming supply isolator and 2 Nr fused feeders (refer single line diagram, Figure 7.1).

Figure 7.1

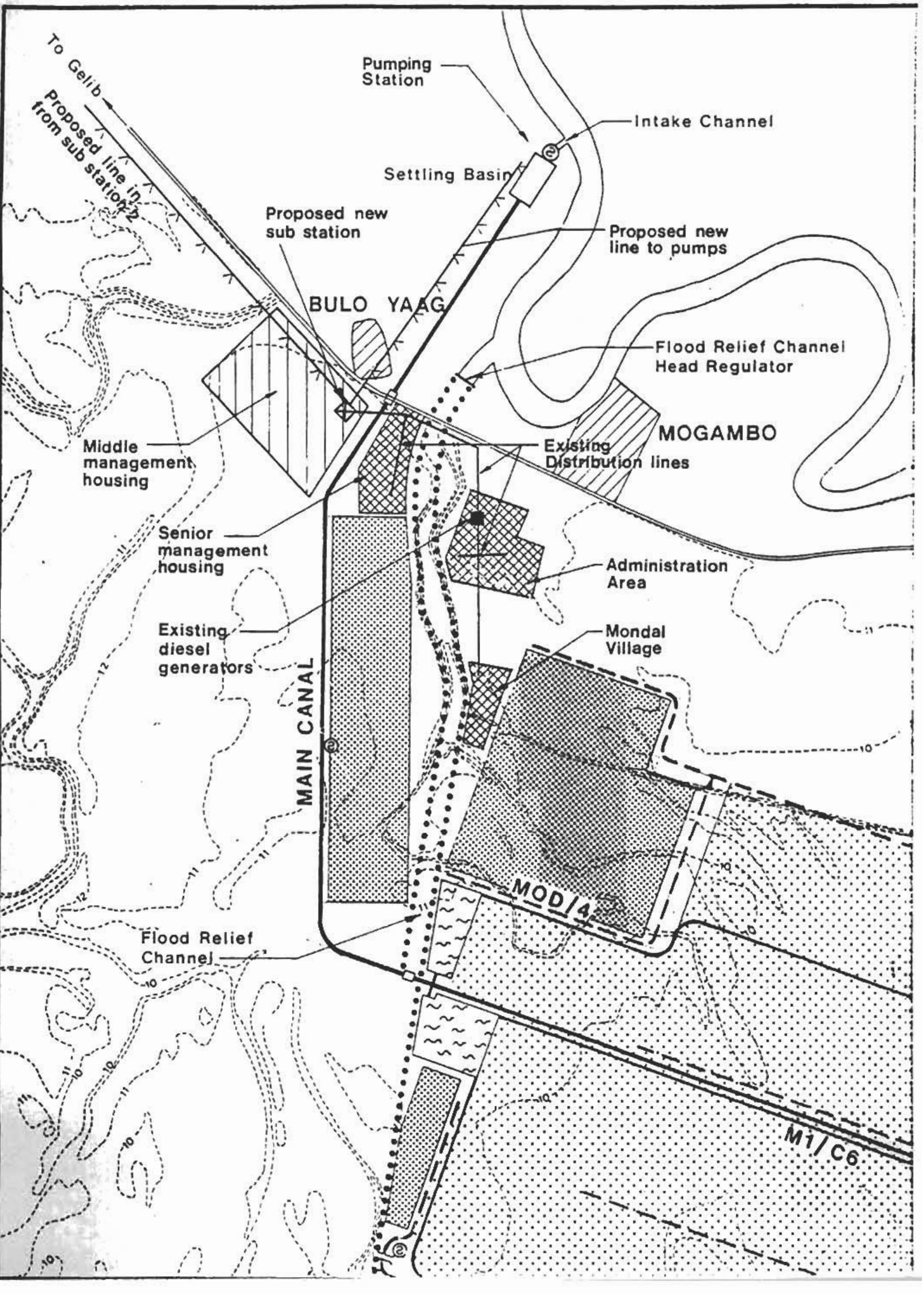
Extention of 35KV O/H Line to Mogambo and Local Distribution



The transformer providing power to the housing and office complex will feed into the exising 800 A changeover switch associated with diesel gensets and subsequent distribution would be at 380 V and 3.3 kV around the area as at present. It is estimated the transformer rating will not exceed 315 kVA, the voltage ratio being 35/0.4 kV.

Figure 7.2

Layout at Mogambo Project Headquarters



8. ECONOMIC ANALYSIS

8.1 Introduction

Section 7 describes the preferred technical solution to provide satisfactory power supplies at Mogambo. Summarised this is as follows:

(a) Provision of 23 km of 35 V overhead line running between substation Nr 2 and Mogambo supported on steel towers.

(b) Provision of a 35 kV, 3 bay substation at Mogambo and 35 kV overhead distribution to local step-down transformers.

(c) 1 Nr 1250 kVA 35/0.4 kV transformer, low voltage switch-gear, motors, cabling, lighting and small power items as required for the pumping station.

(d) 1 Nr 315 kVA 35/0.4 kV transformer and cabling to supply power to the housing and administration and workshop complexes.

The probable costs involved in providing items (a) to (d) above are discussed in the following section, primarily to enable an economic analysis to be undertaken to provide justification or otherwise for the project as discussed later.

The exchange rate used throughout is US$ 1 = SoSh 100.

8.2 Capital Costs

The works required are itemised in Appendix 2. Notes on the works are given below:

8.2.1 Supply Line

The requirement is for 23 km of line from the existing substation Nr 2 to Mogambo. The unit rate is derived from the Homboy Area report by Sir M. MacDonald & Partners July 1987. The foreign exchange content for this item is estimated as 75%.

8.2.2 35 kV Switchrack Type Substation

This is the substation to be located at Mogambo. The foreign exchange content for this item is estimated as 85%.

8.2.3 Electrical Distribution at Mogambo Including Pump Station Modifications

This item includes for all necessary works to distribute the power at Mogambo and includes for the modification of one of the main duty irrigation pumps to electric drive.

Also included in the cost for purchasing and installing is an additional electric powered half duty pump set.

The foreign exchange content for this item is estimated as 85%.

8.2.4 Contractor's Overheads

This item includes for all charges in relation to the Contractor's overhead costs in carrying out the necessary works.

These costs will be 100% in foreign exchange.

8.2.5 Consultancy Fees

Included in this item are all charges relating to the Consultant's duties in the administration and supervision of the works.

These costs will be 100% in foreign exchange.

8.2.6 Summary of Costs

The total sum from Appendix 2 is SoSh 102.5 million.

To this should be added an allowance of say 15% for contingencies giving an overall total of SoSh 118 million.

This cost estimate is for extending the hydro-electric power supply system to Mogambo and associated distribution as defined in Section 7.

The local currency portion of the SoSh 118 million total would be approximately 17%.

8.3 Annual Recurring Costs

8.3.1 Existing System - Local Diesel Generation

The annual recurring costs for the existing system installed at Mogambo comprise:

(i) diesel fuel costs for generating sets plus the main pump station drive units.

(ii) maintenance costs for both generating and pump stations.

(iii) depreciation to cover replacement of items after their useful life.

It should be noted that although the current diesel price is 25 SoSh/l this is very low in world terms and can be expected to rise to around 35 SoSh/l in the near future. Fuel consumptions are as set out in Section 6 of this report, with the generator sets assumed to be supplying the new middle management housing area as well as the existing installations.

The annual diesel fuel costs are estimated to be as indicated in Table 8.1 below:

TABLE 8.1

Existing System - Annual Cost of Diesel Fuel (SoSh '000)

Fuel for:	Fuel costed at: SoSh 25 per litre	SoSh 35 per litre
2 Nr 200 kW generating sets	4 925	6 895
2 Nr 231 kW irrigation pump sets 1 Nr 115 kW irrigation pump sets	3 550	4 970
Total	8 475	11 865

When reviewing the annual depreciation requirements only the pump drive units and generating sets should be considered.

A useful life of 8 years for the diesel engines is assumed which is considered realistic.

For the present study the maintenance costs including spares, lubricants and oil have been taken to be equal to the depreciation.

Hence depreciation (12.5%) plus maintenance (12.5%) gives a total for this item of 25%.

TABLE 8.2

Existing System - Capital (1988) and Annual Depreciation and Maintenance Costs (SoSh '000)

	Costs	
Item	Capital	Annual depreciation and maintenance
2 Nr 200 kW generator motors	7 500	1 875.0
2 Nr 231 kW pump motors	9 260	2 315.0
1 Nr 115 kW pump motor	3 290	822.5
Total	20 050	5 012.5

8.3.2 Hydro-electric System with Diesel Standby

The recurring costs of the proposed system outlined in Section 7 comprise:

(a) Electricity Unit Charges

Charges to the made by Fanoole Project per unit of electricity supplied by Mogambo.

This is a most difficult parameter to predict. During discussions with the Fanoole authorities in March 1988 it was stated that the charge for hydro-electricity supplied was SoSh 3.0 per kilowatt-hour (kWh) but likely to rise to SoSh 4.0 or even SoSh 4.5 in the near future. In further discussions in April 1988 a figure of SoSh 10.0 per kWh was mooted as being necessary to meet Fanoole's costs.

The 1985 report on Rural Electrification in Lower Juba by Dr M. Bogouslavski at the Somali Ministry of Agriculture stated that for Fanoole hydro-electric power 'the break-even consumer price under the most optimistic assumptions must be above SoSh 16.0 per kWh in order to cover all costs (depreciation and operation)'. The report goes on to state that the presently paid consumer price at Gelib (1985) was SoSh 8.0 per kWh.

Clearly any economic appraisal of the viability of extending hydro-electric power to Mogambo is entirely dependent on what price is assumed per unit of electricity, and this in turn depends on whether the Ministry of Agriculture continues to charge a rate which is clearly heavily subsidised, or decides to make the Fanoole system self financing.

It is inappropriate in a study of this type to predict what rates will be fixed for the provision of electricity from the Fanoole hydro-electric plant. However, to test the sensitivity of the effect of various unit rates we can consider three - SoSh 3.0; SoSh 10.0 and SoSh 16.0 per kWh.

Assuming that 1 litre of diesel fuel used for electric generation or for pumping is equivalent to 3.5 kWh of electricity then, using the fuel consumptions quoted in Section 6 the equivalent electric use and costs are given in Table 8.3 with the three unit rates for the electric power.

TABLE 8.3

Electric Power Used and Cost to Mogambo Project

Item	Electric power ('000 kWh)	Cost to Mogambo project (SoSh '000)		
		SoSh 3.0 per kWh	SoSh 10 per kWh	SoSh 16 per kWh
Housing and administration areas	650.1	1 950.3	6 501.0	10 401.6
1 Nr 231 kW pump set 1 Nr 115 kW pump set	468.6	1 405.8	4 686.0	7 497.6
Total	1 118.7	3 356.1	11 187.0	17 899.2

(b) Diesel Fuel

As predicted in Section 4 there will be an average 70 days per year when the river levels will preclude the generation of hydro-electric power. During these periods the Mogambo project will have to resort to its existing diesel generating sets to supply the housing and office areas and to the standby diesel powered pumps for irrigation purposes.

Estimated costs are given in Table 8.4. The consumption of fuel for the generating sets has been calculated on a basis of 70/365 of the annual total used in Section 8.3.1. For the pumpsets a further factor of 50% has been applied to the fuel consumptions since the periods when the river flow is too low to allow hydro-electric power generation will generally coincide with low river levels at Mogambo which will preclude pumping at that time at the project.

TABLE 8.4

Standby Diesel Costs (SoSh '000)

Plant item	Diesel fuel costed at Sosh 25 per litre	Diesel fuel costed at SoSh 35 per litre
2 x 200 kW generator sets	944.5	1 322.5
1 x 231 kW irrigation pumpset 1 x 115 kW irrigation pumpset	340.4	476.6
Total	1 284.9	1 799.1

(c) Depreciation and Maintenance

The diesel drive units of the pump and generator sets will still be required from time to time. Since they will only be used for standby generation their useful life is estimated to be at least 12 years. Maintenance costs including for spare parts and lubricants can be taken as 50% of the depreciation.

TABLE 8.5

Using Fanoole Power - Standby Motors Annual Depreciation and Maintenance Costs (SoSh '000)

Plant item	Annual cost
2 x 200 kW generator motor	937.50
1 x 231 kW pump motor	578.75
1 x 115 kW pump motor	411.25
Total	1 927.50

For the electric pump drive units assume a useful life of 20 years for the motors and maintenance costs to be the same as depreciation. Table 8.6 gives the 1988 capital costs and those for annual depreciation and maintenance.

TABLE 8.6

Electric System - Capital (1988) and Annual Depreciation and Maintenance Cost (SoSh '000)

Plant item	Capital cost	Annual cost
1 x 231 kW pump motor	1 400	140
1 x 115 kW pump motor	700	70
Total	2 100	210

Section 8.2 shows the capital costs of linking a 35 kV extension to the existing system, including power lines, transformers, switchgear etc. Assuming a useful life of 40 years we then have for Items 1, 2 and 3 of Section 8.2 the annual depreciation and maintenance costs given in Table 8.7. This assumes that maintenance will be 10% of depreciation costs.

TABLE 8.7

Distribution System - Capital (1988) and Annual Depreciation and Maintenance Costs (SoSh '000)

Item	Capital cost	Annual cost
Supply line	51 750	1 421.8
Substation at Mogambo	3 000	82.5
Distribution at Mogambo	10 650	292.9
Total	65 400	1 797.2

Note : Capital cost for distribution at Mogambo excludes the cost of motors already considered in Table 8.5.

8.4 Cost Comparisons

8.4.1 Existing System

The annual costs are given in Table 8.8.

TABLE 8.8

Summary Existing System - Annual Cost (SoSh '000)

Item	Cost with diesel costing SoSh 25 per litre	SoSh 35 per litre
Diesel fuel	8 475.0	11 865.0
Depreciation and maintenance	5 012.5	5 012.5
Total	13 487.5	16 877.5

8.4.2 Tie with Fanoole Hydro-electric Supply

The capital cost of the works to accomplish the tie with the existing electricity supply is estimated as SoSh 118 million with a foreign exchange component in order of 85%, that is SoSh 100 million.

The annual costs are shown in Table 8.9.

TABLE 8.9

Summary Using Fanoole Power - Annual Cost (SoSh '000)

Item	Cost with electric power charged at SoSh 3.0 per kWh	SoSh 10.0 per kWh	SoSh 16.0 per kWh
Purchase of electric power	3 356.1	11 187.0	17 899.2
Diesel costs at:			
SoSh 25 per litre	(1 284.9)	(1 284.9)	(1 284.9)
SoSh 35 per litre	1 799.1	1 799.1	1 799.1
(i) Diesel motors	1 927.5	1 927.5	1 927.5
(ii) Electric motors	210.0	210.0	210.0
(iii) New distribution system	1 797.2	1 797.2	1 797.2
Total			
With diesel at:			
SoSh 25 per litre	8 575.7	16 406.6	23 118.8
SoSh 35 per litre	9 089.9	16 920.8	23 633.0

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 General

It has been shown that there is excess capacity generated by the Fanoole hydroelectric station which could be utilised at the Mogambo Project. Hydrological data indicate that this supply would be available for 295 days in the average year.

During periods when the hydroelectric turbines were not operational the standby diesel sets at Gelib would not have enough spare capacity to supply Mogambo. Therefore the generating station at Mogambo would need to remain available as a standby. One 231 kW diesel engine driven pump and one 115 kW diesel driven pump would need to be retained at the pump station for use when power was not available.

The report does not address the possibility of extension of the 35 kV line to supply future loads other than at the Mogambo Project as defined elsewhere.

9.2 Costs

An estimate of capital costs indicates a cost of SoSh 118 million for the required works. Of this sum approximately 83% will be required in foreign exchange.

Calculations carried out show that the annual recurring costs are very sensitive to the price paid for diesel fuel and per kilowatt-hour of electricity purchased from Fanoole. As noted in Section 8, the current local price is SoSh 25 per kWh but this is low by world prices. Similarly the cost per kWh of power is at present charged at SoSh 3 but the Fanoole officials indicate this could be increased to SoSh 10.

Section 8 considers the costs at various prices for the power and the diesel fuel. This study shows that the annual cost for the existing system is SoSh 13.49 million and SoSh 16.88 million with the fuel costs at SoSh 25 and SoSh 35 per litre respectively. The annual cost for the system with the Fanoole tie is SoSh 16.41 million and SoSh 16.92 million with the power at SoSh 10.0 per kWh and fuel at SoSh 25 and SoSh 35 per litre respectively.

9.3 Recommendations

If the electrification is to proceed then the optimum solution would be as set out in Section 6.3. That is, to retain the existing Mogambo diesel generators as standby, to install an additional half duty electrically driven pumpset, and to convert one of the existing full duty pumps to electric drive.

The recommended method for linking Mogambo with the existing distribution system is to extend the 35 kV line from substation 2 for 22 km to Mogambo, and provide a new substation at Mogambo with step-down transformers, switchgear and motors etc.

Prior to the implementation it is proposed that a detailed design be prepared by a consultant to confirm the recommendations contained in this report, which was prepared with the inputs of the mechanical and electrical engineering staff of the Consultant being confined to the Cambridge Office. Obviously, at design stage it will be necessary for an on site inspection of the existing electrical installation to be carried out by a qualified electrical engineer to report on the condition and where any changes may be necessary to ensure compatibility of equipment, etc. and to confirm feasibility of the extension.

APPENDIX 1

TERMS OF REFERENCE FOR STUDY FOR MOGAMBO PUMP STATION ELECTRIFICATION

1. Assess availability of hydro generation - month wise - in an average and a dry year.

2. Assess the power requirements of the Fanoole Region (existing network).

3. Assess the programmed requirement at Juba Sugar Project.

4. Assess the electricity available for Mogambo (MIP).

5. Propose the technical solution for transfer of electricity from Fanoole via Gelib and Kamsuuma to Mogambo.

6. Propose the technical solution for the future pumping stations.

7. Cost estimates for the different solutions.

8. Economic evaluations.

APPENDIX 2

CAPITAL WORKS REQUIRED FOR ELECTRIFICATION OF MOGAMBO

Number	Item Description	Unit	Quantity	Rate	Amount 000 SoSh
1.	Supply Line				
1.1	35 kV line with metal towers	km	23	2 250	51 750
2.	35 kV Switchrack Type Substation				
2.1	Incoming isolator	Nr	1	)	
2.2	Vertical disconnect switches	Nr	2	)	3 000
2.3	Expulsion type fuses and supporting structure	Set	2	)	
2.4	Line accessories and conductors	Set	1	)	
3.	Electrical Distribution at Mogambo and Pumphouse Modifications				
3.1	35 kV line with metal towers	km	1	2 250	2 250
3.2	Transformers, switchgear, cables, motors, pumphouse lighting and small power items	Set	1	10 500	10 500
3.3	Additional half duty pump	Nr	1	16 050	16 050
4.	Contractors' Overheads				
4.1	Detailed design costs, administration, project management costs	Sum		10 000	10 000
4.2	Site supervision	Sum		5 000	5 000
5.	Consultancy Fees				
5.1	Design (outline), issue of tender documents, tender evaluation, design review/approval and site supervision (one month)	Sum		4 000	4 000
	TOTAL				102 500