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DEPARTMENT OF WATER AFFAIRS

SOUTH WEST AFRICA

PRELIMINARY RECONNAISSANCE REPORT

ON

IRRIGATION POSSIBILITIES ALONG THE OKAVANGO RIVER

IN THE KAVANGO

SECRETARY FOR WATER AFFAIRS
PRIVATE BAG 13193
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1. INTRODUCTION

This report has been prepared in response to a request by the Infrastructure Committee of the former Council of Ministers to prepare a short report on the feasibility of an irrigation scheme utilizing electrical power generated by a hydroelectric scheme on the Okavango River at Popa Falls.

This preliminary feasibility report has been based upon a desk study of available information and upon a number of simplifying assumptions. It is therefore important to appreciate the limitations of the report and to use it only as an indication of the feasibility of a particular scheme.

In order to evaluate the feasibility of utilizing hydroelectrically generated power for irrigation purposes a comparison must be made with other possible modes of providing power for irrigation. Two alternatives to hydroelectric power have been considered. These are diesel pumps located at each of the irrigation schemes and by using power supplied from the national grid.

The purpose of this preliminary feasibility study is to examine the various costs involved in developing a number of irrigation schemes along the Okavango River and the cost of providing electrical power to those irrigation schemes. This can be compared to the potential return that could be achieved by the sale of the produce from the irrigation schemes. In this way the economic viability of the irrigation schemes can be determined.

Although the report specifically studies the possibilities of irrigation in the Kavango this is not to say that the findings and results cannot be ... The Caprivi both east and west has also the

In compiling the report use has been made of previous reports which have a bearing on this study, for example in 1969 a report was prepared by the consulting firm Hydroconsults on the preliminary feasibility investigations of the Popa Falls hydro-power scheme.

Use has also been made of the 'Consolidated report on reconnaissance surveys of the soils of northern and central South West Africa in terms of their potential for irrigation', prepared by R F Loxton and Hunting in 1971. Details of irrigation schemes, crop yields and selling prices have been supplied by the First National Development Corporation based upon their irrigation project at Shadikongoro in eastern Kavango. Furthermore the reports ''n Raamwerk vir Ontwikkeling van Kavango' by Professor D Page prepared in 1980 was studied and should be read in conjunction with this report. This is also one of the reasons why the emphasis has been placed upon the Kavango since similar information on the Caprivi is not at this stage available.

This report has been prepared for the information of the Secretary for Water Affairs in order that the Infrastructure Committee of the Administrator-General may be informed as to the feasibility of developing irrigation schemes along the Okavango River, the magnitude of the capital costs involved, time scale and the expected return on investment.

Many factors such as the economic climate, exchange rates, commercial and trade trends, markets, transport costs, export possibilities and the political situation will have a profound influence on the assumptions made, albeit not always so easily defined as to be taken into account in a report of this nature.

organisations to carry out studies into all the various aspects which are also involved in the development process and on which they have better authority and a more detailed knowledge. There is also a need to establish, on a National scale, the priorities with regard to development strategy and the role to be played by the various sectors of the economy. Depending upon how important a role agriculture including irrigation is to play in the strategy, the approach to the economic analysis of the feasibility of agricultural projects may be influenced. In the absence of a national strategy such factors cannot be accounted for at this stage.

Finally, this report deals with irrigation on a very large scale, this being a requirement for some of the proposals in this report. It must therefore be emphasised that comparisons should be made with other possible projects in the country such as irrigation along the Orange River or the development of the irrigable lands close to the Cunene River. This must be done before any significant decisions can be taken effecting the economic development of the country and the expenditure of capital funds.

Todaro, in his book "Economic Development in the Third World", stresses the importance of the development in the rural sector and quotes two authorities as follows:

"It is in the agricultural sector that the battle for long term economic development will be won or lost."

Gunnar Myrdal

The importance of irrigation development in the Kavango, which is discussed in this report in a pure economic context, should also be seen in a regional socio-economic development context.

Whilst it is not the primary purpose to discuss in detail general development policies to be considered and applied, the interactive nature of any development exercise makes some brief references necessary.

2. GEOGRAPHICAL DETAILS

2.1 LOCATION

The Kavango is situated in the north-eastern part of South West Africa and is 41 700 km^2 in extent. In the north, over a distance of 430 kilometres, the Okavango River forms the international boundary with Angola. In the east the territory shares common borders with Botswana and West Caprivi. The Popa Falls is located on the Okavango River where it forms the border with West Caprivi.

The areas of land recommended for irrigation are located along the Okavango River on the river terraces. Refer to ANNEXURE 1 for more details.

2.2 TOPOGRAPHY

The perennial Okavango River is the dominant physical feature of the predominantly flat country which lies at an average elevation of 1 100 metres. The river flows through a broad flood valley that is annually inundated by the floods and, as a result, provides good grazing during the

2.3 CLIMATE

The climate of the Kavango is subtropical with an average rainfall of 610 mm per annum. On average it rains for between 50 and 60 days per year with over 90% falling between October and March. There are more than five months of the year where the monthly rainfall can be expected to exceed 50 mm. Although the average rainfall is 610 mm this can vary by as much as 25% from one year to another.

The mean maximum summer temperature is 34°C and the mean minimum winter temperature is 6°C. The absolute maximum and minimum temperatures recorded have been 40,8°C, in October and-4,2°C in July, respectively, measured at Rundu. The average minimum temperatures are somewhat higher to the west of Rundu, approximately 9°C.

The Kavango receives an average of 8 hours sunshine per day.

Gross evaporation in the region is less than 2 600 mm per year.

The prevailing wind direction is north easterly to easterly, with an average velocity of between 10 and 20 km/hour.

2.4 VEGETATION

The vegetation of the Kavango is classified as Kalahari woodland, which is characterised by fine stands of dolf wood, Rhodesian teak, wild lilac, Mangetti and Acacia negrescens along the river banks and Makalani palms occurring particularly along the Omiramba

2.6 LAND USE

The people of the Kavango are to a large extent bound to the river as a result of their form of subsistence. The people practise dryland cropping mainly with mahongo on the narrow strip of fertile soil along the river, graze their cattle on the flood plains and also fish the river extensively.

Horticulture is the primary economic activity whilst animal husbandry has begun to play an increasing role in the economic existence of the people. Fishing is also another important economic activity.

Away from the river, land is utilized for hunting and gathering of wild foods.

3. SOCIO-ECONOMIC FACTORS

3.1 POPULATION

According to the 1981 Census there were a total of 105 690 people in the Kavango Census District of whom 12 307 resided at Rundu. The remaining 93 383 persons are mainly concentrated in a 3 kilometre wide strip of land along the river bank in small villages and settlements. The vast majority of the total population is therefore rural.

3.2 DEVELOPMENT

Rundu is the main town and centre of development for the Kavango region, it is also the administrative centre of the region. Apart from Rundu there are also a number of other small villages and settlements, mostly situated along

Generally speaking the main lines of communication therefore run either from north east to south west or from east to west.

Further details of the development of the Kavango can be found in ''n Raamwerk vir Ontwikkeling van Kavango'.

4. AGRICULTURAL DEVELOPMENT

4.1 DRYLAND CROPPING

Dryland cropping is extensively practised in the Kavango along the river terraces and some of the Omiramba. It takes the form of subsistence agriculture aimed primarily at supporting the needs of the local village population. Production of a surplus is not a consideration or an objective of the local population.

4.2 STOCKFARMING

The Kavango peoples are not primarily pastoralists but they do own an appreciable number of head of cattle. As yet no attempt has been made to develop cattle farms or put stock rearing on a commercial basis.

4.3 IRRIGATION

Irrigation agriculture has not been practised by the local population, however, there are a number of irrigation schemes in operation along the Okavango River. These schemes are either administered and run by the Administration for Kavango's Department of Agriculture or by the First

TABLE 1A: DETAILS OF ENCK IRRIGATION PROJECTS

SCHEME NAME	IRRIGATED AREA (Ha)	IRRIGATED CROPS	TYPE OF IRRIGATION	AREA OF DRYLAND CROPPING (Ha)	DRYLAND CROPS	DATE OF PROJECT STARTING
MUSESE	180	Ground nuts Wheat	Centre pivot (3 x 60 ha)	430	maize casava	1976
MAGUNI	22,5	Citrusfruit ~~Mangoes~~ Vegetables	Lateral line flood			1980
NAJANGO	46,2	Avocados Citrusfruit Litchies Mangos	micro= sprinkler			1981
SHADIKONGORO	160 331	Cotton Maize	portable lateral line sprinkler	180	cotton maize	1975
SHITEMO	65 65 65	Maize Ground nuts Potatoes	Centre pivot (3 x 65 ha)	500	cotton	1977
UVUNGU-VUNGU	10 60	Vegatables Fodder	sprinkler	80	maize	1974

(1) Experimental crop

(2) Vegetables are grown for the plot owners own consumption.

IRRIGATION EQUIPMENT		PLANTS		CAPITAL REDEMPTION		TRANSPORT		DIVERSE		LIVESTOCK		TOTAL	
SUB TOTAL	UNIT	SUB TOTAL	UNIT	SUB TOTAL	UNIT	SUB TOTAL	UNIT	SUB TOTAL	UNIT	SUB TOTAL	UNIT	CAPITAL (R x 1 000)	UNIT (R/ha)
416	2 311					28		46	256			1 065	5 221
64	2 844	4	178	22								102	3 555
151	3 258	11	238	13								188	3 787
368	736					32		45	90			1 188	2 414
424	2 174					40		57	292			1 427	5 799
160	1 514					10				57	950	602	6 742

The Department of Agriculture of the Administration for Kavango's has a small agricultural college established at Mashari which has been set up to train the local population in basic agricultural skills. The number of people trained per year is between 5 and 10. In addition the Department also participates in the Shitembo scheme with ENOK. There are also plans to start a further small irrigation scheme of 12 hectares at Nkurenkuru.

4.4 AGRICULTURAL DEVELOPMENT POTENTIAL

The ground potential of the Kavango with respect to agricultural development has been investigated on two occasions by two different bodies. In 1970 R F Loxton, Hunting and Associates prepared a 'Consolidated report on reconnaissance surveys of the soils of northern and central South West Africa in terms of their potential for irrigation'. In 1977 a more detailed report on the potential of the Kavango soils was prepared by the University of the Orange Free State.

The 1970 report stated that much of the land constituting the terraces of the Okavango River had been classed as 'recommended' for irrigation use. Furthermore it went on to say that in view of the adjoining abundant water source and low pumping lift, the soils had a high potential for early irrigation development. The report noted that topographically the terraces are ideally suited to irrigation. It was concluded in the report that some 30 000 hectares out of the total area of river terraces would be suitable for development along the river terraces.

According to the 1977 report the Okavango River terraces in the Kavango amount to a total area of 75 000 hectares. Of this total, 900 hectares was land for irrigation. This total amount of land has been adopted in this report as the maximum area of land that can be considered as being available for the development of irrigation schemes.

Should it be decided to go ahead with the development of agricultural projects in the Kavango, soil surveys carried out at a detailed level will be a prerequisite at those sites where development is envisaged. This will then clarify the position with regards to the amount of land its suitability for irrigation and the type of irrigation.

4.5 WATER REQUIREMENTS FOR IRRIGATION

It is necessary to determine what the requirement is for water for irrigation for two principle reasons. Firstly to determine how much water must be supplied and when to ensure good crop yields, as this might have an important impact on the river regime. Secondly it is also required to determine the pump sizes, power requirements and energy costs which would be incurred.

The starting point must be how much water is required for ensuring good crop yields under irrigation, which is generally known as the crop consumptive use. This will vary with climate, crop, length of growing season and a number of other factors. It is usually a subject which requires much more detailed attention from agricultural experts. In order to overcome this difficulty several text books have been consulted. Information has been extracted from these books on research into and data gathered on the consumptive use of water by crops under arid conditions, carried out in the USA. It is felt that these conditions can be applied to SWA. Two crops have ... typical consumptive uses namely cotton and maize. and

Sout West Africa. Furthermore there are limited facilities for milling and cold storage of the produce available which could, to an extent, even out the effect of flucuations in market demand.

Therefore whilst it is appreciated that double cropping would lead to a greater profit than a single crop system, only a single crop has been assumed. Double cropping would also increase the demand for water. It will be shown that even with single cropping irrigation can be economically feasible and it is the comparison of the different modes of powering a scheme and its effect on the economic viability that is being investigated. It is not so important under these circumstances whether single or double cropping is assumed as long as the assumptions are consistent throughout.

Without going into too great detail, the consumptive water use of plants varies with the plant development, and in general follows a skew distribution, see ANNEXURE 3. For an economic water usage the amount of water applied should closely follow the consumptive plant use. Added to this must be an amount which allows for evapotranspiration. The efficiency of the method of irrigation used must also be taken into account.

ANNEXURE 3 also shows the theoretical demand curve used to estimate water demand - it also allows for evaporation losses but not irrigation efficiency and any distribution losses. The peak daily demand, as determined from the literature corresponds very closely with local experience of peak daily crop water demand. Local practice appears to be to apply a constant daily amount of water which corresponds to the peak daily crop demand. ? In view of the foregoing discussion this is obviously a wasteful practice and is not adopted in this report.

When designing the irrigation system, it must be capable of supplying the peak day crop water demand. However in calculating the total quantity of water to be supplied through the growing season, from abstraction from the river, then due cognizance of the contribution of rainfall should be taken. The mean annual rainfall of the Kavango region is 550 mm, this can vary from year to year by up to 25%. Therefore a minimum rainfall of 414 mm can be expected in most years. The daily variation in rainfall is likely to be much greater than the annual variation.

It would be reasonable to take account of the contribution that rainfall can make to the crop water demand, however the variability and erratic nature of rainfall must also be allowed for. Therefore it is proposed that in the long term a contribution of 75% of the minimum rainfall of 414 mm can be assumed, i.e 300 mm. This is important in determining the amount of water to be extracted from the Okavango River and in turn the cost of pumping from the river. The irrigation equipment should however be designed in such a way that it can supply the full peak crop water demand without a contribution from rainfall.

Therefore the quantity of water to be abstracted from the Okavango River would be;

Total depth of water required - rainfall contribution = 750-300

= Nett depth of water required = 450 mm per growing season of six months.

Nett average depth of water to be supplied by abstraction = 450/0.7

= 650 mm per growing season of six months.

and texture of the soils investigated. In general the soils do not hve high water retaining properties and this does not favour flood irrigation as it could lead to soil leaching.

Hence the total water requirement for the 30 000 hectares would be;

30 000 x 100 x 100 x 0,65 = 195 Mm^3 per growing season.

5. POWER REQUIREMENTS AND POWER SOURCE

5.1 ASSUMPTIONS

In order to estimate the power requirements of possible irrigation projects along the Okavango River a number of a assumptions must be made in order to provide a basis for the estimation. The assumptions made are at this stage educated guesses given the uncertainties involved.

However, an indication can be given as to what the power requirements might be, an estimate which can be refined at a later date on the basis of further information and a knowledge of the type of scheme envisaged.

Sprinkler irrigation has been assumed for reasons given in the previous section. By making this assuptions an upper limit on the power requirements will be arrived at as sprinkler systems generally have a greater power requirement than any other form of irrigation system.

A second point is that the capital investment required is also greater for a sprinkler irrigation system than for others, notably flood irrigation, under most normal circumstances.

In order to minimise peak energy demand and required power capacity a 20 hour irrigation cycle has been adopted. This would leave four hours per day for maintenance during the period of peak water demand from the crops. At other times the irrigation cycle time can be decreased and hence the crop water demand matched by the delivery.

A seventy metre pumping head has been assumed in calculations, comprising of 25 metres static head and 45 metres friction head. The average height of the river terrace on which irrigable soils were located is 25 metres above river level. A friction head of 45 metres is an estimation of the friction losses in pipelines and irrigation equipment plus the pressure requirements for the sprinklers that has been made from pumping data obtained from the Shadikongoro irrigation scheme.

5.2 POWER REQUIREMENTS

The power required apart from depending upon the above assumptions, will also depend upon the type of pump motive power unit adopted. Typically diesel driven pump sets are less efficient in terms of energy conversion than electrically driven pump sets.

In this report the pump unit efficiency has been taken as 70% irrespective of type of motive power unit used. When using a diesel motor an efficiency of 60% is used giving an overall efficiency of 42%, whilst adopting an 80% efficiency for an electric driven motor, giving an overall efficiency of 56%. This is an important aspect as the size of pump set required for any given flow and pumping height will depend upon the overall efficiency of the pump set. In turn this will effect the running cost such as energy cost and

5.2.1 INSTALLED POWER REQUIREMENTS

Peak flow is determined as follows assuming a 20 hour cycle.

$$\text{per hectare} = \frac{11,5 \text{ mm} \times 100 \text{ m} \times 100 \text{ m}}{20 \text{ hours} \times 3600 \text{ s}}$$

$$= 1,6 \ \ell/\text{s/ha}$$

Installed kilowatts required

$$= \frac{QH}{n \times 0,102}$$

where Q = peak flow; $1,6 \times 10 \ \ m^3/s$

H = total pumping head; 70 m

n = overall efficiency (n = 0,42 diesel power and n = 0,56 for electric power)

. For diesel pumpsets the required installed kilowatt capacity would be 2,61 kW/ha, and for electric pumpsets 1,95 kW/ha.

5.2.2 ENERGY REQUIREMENTS

Determine the number of working hours per growing season from the net quantity of water to be applied per hectare.

5.2.3 SUMMARY

PUMP SET	INSTALLED POWER	ENERGY CONSUMPTION
DIESEL	2,61 kW/ha	2 950 kWh/ha
ELECTRIC	1,95 kW/ha	2 200 kWh/ha

5.3 POWER SOURCE

As has already been mentioned three possible sources of power to irrigation schemes along the river have been proposed; diesel powered pumps as required at each irrigation scheme, power from the National Grid and power from a hydro-electric scheme at Popa Falls. In the case of the last two mentioned power sources much infrastructure development would be required, such as upgrading of roads and the development of a power distribution system. Some of the aspects of each of the proposed power sources are discussed below.

5.3.1 DIESEL PUMPS

It is envisaged that this type of scheme would consist of diesel powered pumps to extract the water from the river and to provide the motive power for the irrigation system, whether sprinkler or boom. In addition, electrical power would also be required and would be provided by a small diesel powered generating set.

There are several advantages to using diesel pumps and locally generated power. Principally the initial investment is

5.3.2 NATIONAL ELECTRICITY GRID

Construction of the Rundu-Grootfontein pumping main will require the up=grading of the existing 132 kV powerline which runs to Rundu, in order to provide sufficient power for the booster pump stations. It would therefore be feasible when upgrading to include provision for supplying power to irrigation schemes, along the Okavango. In order to provide power to the irrigation schemes a high tension powerline would have to be constructed along the Okavango, running east and west from Rundu. This could be either a 132 kV or 220 kV powerline, a substation would be required at Rundu.

At each irrigation scheme a step-down transformer substation would be required to convert the supply from 132 kV or 220 kV down to 11 kV which can be used on site. From the substation the power would be distributed to the electrically driven pumps and other equipment.

Provision of power in this way could also be co-ordinated with a regional development plan. The provision of a powerline would have a big impact upon the infrastructure of the region and could possibly provide the impetus for further development of the region.

Against this must be counted the high initial cost and the vulnerability of the distribution line to sabotage.

5.3.3 HYDROELECTRIC POWER

Construction of a lowhead run-of-the-river power generator scheme at the site of the Popa Falls has been proposed and preliminary feasibility studies

Provision of a dam at the Popa Falls to enable the generation of power would be the most costly option in terms of capital considered here. For not only would it necessitate the construction of the power distribution network, as would be the case with provision of power from the National Grid, it would also entail the construction of a dam and its associated generating equipment. The cost of such equipment is at this stage subject to many uncertainties and therefore conservative assumptions have been made.

In evaluating the feasibility of a dam at the Popa Falls a number of policy matters must be resolved. For example the dam could be built for the purpose of supplying power into the national grid, under such circumstances the grid would have to be extended to incorporate the additional power supply point. It would then be the proximity of the irrigation schemes to the grid which would make the provision of electrical power an attractive proposition. The cost of energy to an irrigation scheme would then be no different whether it was supplied from Popa Falls or another source as this would all be part of the national grid. On the other hand the Popa Falls scheme could still be developed as part of the national grid but would sell power to the irrigation schemes at say the breakeven cost. In other words at a price which would cover capital repayments, operational and maintenance costs, assuming all the power produce would be sold.

Alternatively the power generation scheme would be viewed as part of the irrigation scheme. In which case any surplus energy could be sold to other consumers almost as if it were an agricultural product. This would generate an additional income for the irrigation project taken as a whole. A prerequisite in this case would be for the whole 30 000 hectares to be developed, whilst if the previous approach were to be used then the whole

5.3.3.1 CHARACTERISTICS OF A HYDROPOWER SCHEME

The scheme, described in the Hydroconsults report, which has been adopted in this report as a basis for costing purposes, is detailed as scheme 4. The main characteristics of the scheme are given below in TABLE 2. The position of the dam favoured in the report would be on the continuous rock barrier which forms the falls themselves. A central concrete spillway, 700 metres long, was envisaged. The power house together with a scour outlet would be located at the edge of the right bank and could be flanked by a short earth embankment. Closure of the left flank would involve a long embankment of the order of 1 500 metres.

TABLE 2: POPA FALLS HYDRO-POWER SCHEME CHARACTERISTICS

DESCRIPTION		QUANTITY
Full Storage Level	MSL	1 014,5
Gross Storage	Mm^3	170
Usable Storage	Mm^3	85
Design Flow	m^3/s	177
Gross Head	m	16,0
Effective Head	m	14,7
Average Power	MW	21,7
Installed Capacity	MW	43,4
Firm Energy	GWh/a	190

6. FINANCIAL ASPECTS

6.1 GENERAL

The following financial aspects have been considered in determining the economics of the irrigation scheme as a whole. The capital cost of establishing and equiping a typical irrigation project has been determined from information supplied by the First National Development Corporation and the Agricultural Engineering Division in Pretoria. The running costs of a typical scheme have been taken from information supplied by the First National Development Corporation on their Shadikongoro project. The Corporation also supplied informaton on crop yields and generated income from the sale of produce.

The cost of pumping water from the river has been considered separately from the development and running costs.

6.2 ENONOMICS OF IRRIGATION EXCLUDING PUMPING

The following costings have assumed that the individual irrigation schemes will be 500 hectares in extent. The present Shadikongoro scheme is 480 hectares. Furthermore the larger the scheme the more economical it is to use sprinkler and overhead spray irrigation equipment such as pivot booms, up to a certain point. Therefore 500 hectares has been assumed.

It is accepted that by choosing a 500 hectare unit it must be that such a scheme is run along the lines of a company venture and will in turn require a high level of managerial skill. Whether this is the type of scheme best suited to local conditions is a question which will

TABLE 3: DEVELOPMENT COSTS

ITEM	PURCHASE PRICE (R/ha)	MAINTENANCE %	USEFUL LIFE Years
IRRIGATION EQUIPMENT (incl: piping, sprinklers, booms, but not pumps)	2 000	4,0	20
BUSH CLEARING	750		

Given a 500 hectare scheme and assuming the current Treasury Interest Rate of 12% the annual costs would be;

Annual Repayment on Irrigation Equipment R134 000 or R268/ha
Annual Maintenance of Irrigation Equipment R 40 000 or R80/ha

6.2.2 WORKING OVERHEAD

Working overheads is taken to mean the provision of those items which are necessary to keep the scheme running and in production. This includes such items as fertilizer, weed killers, labour etc. These costs will to a certain extent be dependant upon the type of crop grown. However the costs given have been taken from returns from Shadikongoro and therefore can be taken as being representative of the working costs of irrigation schemes. TABLE 4 gives details of the annual working overhead costs.

TABLE 4: WORKING OVER HEADS

The cost of providing the necessary farming equipment could be calculated from a figure of R1 225 per hectare, with maintenance on the equipment taken as 7%. On the other hand ENOK have provided a detailed cost breakdown of the type of equipment required for growing cotton and mealies, the number of hours usage and associated costs. This analysis has been used and an average cost per hectare derived, and is given in Appendix A.

The equipment costs, which includes maintenance costs, repayment costs and fuel costs, are R189,02/ha for cotton and R235,40/ha for mealies. This gives an average equipment cost of R212,36/ha/annum.

6.2.3 GENERATED INCOME

The crops that can be considered suitable for growth under irrigation include maize, mahango, ground nuts and cotton. The majority of the land would be given over to the cultivation of these crops. To a lesser extent, vegetables and fruit could also be grown. At this stage only the above mentioned crops have been considered, these are shown in TABLE 5 along with information supplied by ENOK on typical yields obtained under irrigation by schemes in the Kavango, the farmers, selling price and estimated income. Note these are the farmers selling prices and therefore do not include such costs as milling and marketing.

TABLE 5: GENERATED INCOME

CROP	YIELD Tonnes/ha	SELLING PRICE (R/tonne 1983)	GROSS INCOME (R/ha)

Other crops could also be considered for example tobacco, sugercane rice and sunflower, but have not been included in this feasibility study. The reason for this is that they are not at present grown commercially in the region and therefore there is no information available on them. They may however merit further study. A gross income of R2355 per hectare will be adopted in this report for the purposes of evaluating the economic viability of the various methods of pumping water and the power source. This is the average gross income from cotton and maize as these are the most likely crops to be grown on a large scale. It also ties in with information available on the production costs.

6.3 FINANCIAL ANALYSIS OF IRRIGATION BY DIESEL PUMPS

In order to determine the economics of irrigation using diesel pumps, suppliers of engineering equipment were approached to give cost estimates of pump sets. The following information was received: purchase cost R420 per kilowatt for diesel pump sets, having a working life of 20 000 hours. Refering to an annual number of working hours as calculated in paragraph 5.2.2 this would mean the pump sets would last approximately 15 years before needing to be replaced. Maintenance was estimated at 4% of the purchase price.

The cost of establishing a scheme will include the construction of pump houses, accommodation and office building and access roads.

The cost of energy for diesel pump sets is taken as 17 c/kWh as recently calculated by the Planning Division in conjunction with Mechanical/Electrical Water Schemes Division. This is the direct marginal cost of fuel only and does not include such ...

TABLE 6: CAPITAL COST ESTIMATE FOR 500 HECTARE UNIT IRRIGATED BY DIESEL PUMPS

ITEM	COST (Rands)
Bush Clearing	375 000
Access Roads	50 000
Pump Houses	20 000
Buildings (houses, sheds, silos etc)	400 000
Irrigation Equipment	1 000 000
Diesel Pumpsets	548 000
TOTAL	2 393 000

The total cost for establishing a 500 hectare irrigation scheme has been estimated as R 2 393 000 or R4786/ha.

6.3.2 ECONOMIC ANALYSIS

The economic analysis takes into consideration the annual costs of a scheme and the income generated. This is shown in TABLE 7.

TABLE 7: ECONOMIC ANALYSIS OF 500 HECTARE UNIT IRRIGATED BY DIESEL PUMPS

ITEM	ANNUAL COSTS (Rand)
CAPITAL WORKS	
Civil Works (incl. roads and buildings (redemption life 45 years)	57 000
Irrigation Equipment (redemption life 20 years)	134 000
Diesel Pump Sets (redemption life 15 years)	80 000
SUBTOTAL CAPITAL WORKS	271 000
MAINTENANCE	
Civil Works (1% of capital value)	5 000
Irrigation Equipment (4% of capital value)	40 000
Diesel Pump Sets (4% of capital value)	22 000
SUBTOTAL MAINTENANCE	67 000
OPERATION	
Salaries	60 000
Variable Energy Cost	251 000
Working Overheads (See TABLE 4)	379 000
Farming Equipment	106 000
SUBTOTAL OPERATION	796 000
SUBTOTAL EXPENDITURE	1 134 000
ANNUAL INCOME	1 177 500
ANNUAL PROFIT	[illegible]

6.4 FINANCIAL ANALYSIS OF IRRIGATION BY ELECTRIC PUMPS, ELECTRICITY SUPPLIED FROM NATIONAL GRID

The establishing of schemes supplied with electricity from the National Grid will entail the provision of a power line to Rundu with sufficient capacity to supply the proposed Rundu-Grootfontein pumping main and the irrigation projects.

There is already an existing SWAWEK powerline to Rundu, since the upgrading of the line to supply the Eastern National Water Carrier is in any case required no cost arising from this should be debited to the scheme. A power distribution line along the Okavango River must be seen as part of the development of infrastructure in the region, which will be partly paid for by the sale of electricity to consumers in the area. Therefore it does not seem reasonable to debit the full cost of the provision of a powerline against the irrigation schemes. The cost of providing the powerline is R10 per metre to which it is proposed that the irrigation projects contribute R5 per metre towards the cost of the 360 kilometres of powerlines, which it is estimated will be required.

The current SWAWEK charge for energy of 2,85c/kWh will be assumed with regard to the demand charge, the requirement for power will follow very closely the growing season and constitutes only six months of the year assuming single cropping. Therefore it seems fair to make the demand change applicable only to half the year, this will amount to R63 per installed kW.

The purchase cost of electrical pumps as quoted by various suppliers is R205 per kilowatt, maintenance is estimated by these suppliers as 2% of the purchase price with a working life

TABLE 8: CAPITAL COST FOR 500 HECTARE UNIT IRRIGATION BY ELECTRICAL PUMPS

ITEM	COST (RAND)
Bush Clearing	375 000
Access Roads	50 000
Pump Houses	20 000
Buildings	400 000
Irrigation Equipment	1 000 000
Electrical Pump Sets	200 000
Electricity Substation	200 000
TOTAL	2 245 000

The total cost of establishing a 500 hectare irrigation scheme has been estimated as R2 245 000 or R4 490/ha. The cost of providing the power distribution network, at R5/m over 360 kilometres as discussed on the previous page, is estimated at R 1 800 000, which if the whole 30 000 hectares were to be developed would be equivalent to R60/ha. This does imply that the whole irrigible area must be developed to make the scheme viable.

6.4.2 ECONOMIC ANALYSIS

TABLE 9: ECONOMIC ANALYSIS OF 500 HECTARE UNIT IRRIGATED BY ELECTRICAL PUMPS

ITEM	ANNUAL COSTS (Rand)
CAPITAL WORKS	
Civil Works (incl. roads and buildings (redemption life 45 years)	57 000
Power Distribution, R60/ha recovered over 20 years at 12% interest	4 000
Irrigation Equipment (redemption life 20 years)	134 000
Electrical Pump Sets (redemption life 15 years)	29 000
Substation (redemption life 15 years)	29 000
SUBTOTAL CAPITAL WORKS	253 000
MAINTENANCE	
Civil Works (1% of capital value)	5 000
Irrigation Equipment (4% of capital value)	40 000
Electrical Pump Sets (4% of capital value)	8 000
Substation (4% of capital value)	2 000
SUBTOTAL MAINTENANCE	55 000
OPERATION	
Salaries	60 000
Energy: Fixed Charges R63/installed kW/year	61 000
Variable Charge 2,85c/kWh	31 000
Working Overheads	379 000
Farming Equipment	106 000
SUBTOTAL OPERATION	637 000
SUBTOTAL EXPENDITURE	945 000

6.5 FINANCIAL ANALYSIS OF IRRIGATION BY ELECTRICAL PUMPS, ELECTRICITY SUPPLIED FROM A HYDRO POWER SCHEME AT POPA FALLS

The characteristics of a hydro electric power schemes at Popa Falls have been outlined above. SWAWEK were approached with a view to obtaining more detailed and up-to-date information on the costs of such a project. However SWAWEK were of the opinion that they were not in a position to be of assistance at this stage. Therefore the costing given in the 1969 report on Popa Falls has been brought up to present values by making use of the Consumer Price Index. Since 1970 the Consumer Price Index has increased by 329% over the last 14 years.

Reference to TABLE 1 will show that the installed capacity of a Hydropower scheme would be 43,4 MW, with a required capacity of 1,95 kW/ha a total of 22 000 ha could be irrigated. This must be taken into consideration when calculating costs.

6.5.1 CAPITAL COST ESTIMATE

The capital cost estimate for establishing a 500 hectare irrigation project which uses electrical powered pumps has already been given in TABLE 8.

The capital cost of constructing a hydro power scheme at Popa Falls with an installed generating capacity of 43,4 MW is given in TABLE 10.

TABLE 10: COST ESTIMATE OF HYDRO POWER SCHEME AT POPA FALLS

ITEM	COST (Rand)

This does not include the cost of replacing mechanical and electrical equipment every 15 years.

6.5.2 UNIT COST OF POWER

In order to estimate the unit cost of power from the proposed Popa Falls scheme it has been assumed that the scheme has a life of 45 years and that the full generating capacity will be utilised over the period.

The annual cost incurred in generating power are given in TABLE 11.

TABLE 11: ANNUAL COSTS OF GENERATING POWER FROM POPA FALLS

ITEM	ANNUAL COST (Rand)
CAPITAL WORKS	
Dam	3 885 000
Power House	285 000
Plant	1 269 000
Plant Replacement	1 332 000
Switch Yard and Transformers	241 000
SUBTOTAL CAPITAL WORKS	7 012 000
MAINTENANCE	
Dam	80 000
Power House	6 000
Plant	420 000
SUBTOTAL MAINTENANCE	506 000
OPERATION	

The annual costs are estimated to be R7 678 000. The annual amount of power generated is 190 GWh/a and it is assumed that all this is sold. Therefore the unit cost of energy is:

= R7 678 000/190 GWh

= 4,04 c/kWh say 4 c/kWh

Which does not include the cost of transmission.

This would be the cost of supplying power to the irrigation consumers, the surplus energy not required for irrigation would be fed into the National Grid at Rundu.

The capital cost of power distribution can be calculated in the following manner

Length of power line	264 km
Cost per metre	R5/m
Capital cost	R1 320 000
Number of hectares supplied	22 000 ha
Unit cost is therefore	R60/ha

6.5.3 ECONOMIC ALANYSIS

The economic analysis of a 500 hectare irrigation unit is shown in TABLE 12. This differs from TABLE 9 in that cost of energy is calculated in a different manner, using a variable energy cost of 4 c/kWh.

TABLE 12: ECONOMIC ANALYSIS OF A 500 HECTARE UNIT IRRIGATED BY ELECTRICAL PUMPS

ITEM	ANNUAL COST (Rand)
CAPITAL WORKS	
Civil Works	57 000
Power Distribution @ R60/ha (recovered over 20 years at 12% interest)	4 000
Irrigation Equipment (redemption life 20 years)	134 000
Electrical Pump Sets (redemption life 15 years)	29 000
Substation (redemption life 15 years)	296 000
SUBTOTAL CAPITAL WORKS	253 000
MAINTENANCE	
Civil Works (1% of capital value)	5 000
Irrigation Equipment (4% of capital value)	40 000
Electrical Pump Sets (4% of capital value)	8 000
Substation (4% of capital value)	20 000
SUBTOTAL MAINTENANCE	55 000
OPERATION	
Salaries	60 000
Variable energy cost @ 4 c/kWh	44 000
Working Overheads	379 000
Farming Equipment	106 000
SUBTOTAL OPERATIONS	589 000
SUBTOTAL EXPENDITURE	897 000
ANNUAL INCOME	

The sale of surplus energy at 4 c/kWh would generate an income of R5 664 000, this has been calculated as follows:

190 GWh/a a (generated energy) - 48,4 GWh/a (Irrigation Energy)
= 141,6 GWh/a Surplus Energy for sale
= 141,6 GWh/a x R0,04/kWh
= R5 664 000

The economic analysis of a 500 hectare unit using electrical power supplies from a generating scheme at Popa Falls indicates a profit of R280 500 or R561/ha. The benefit cost ratio is 1.31.

6.6 FINANCIAL SUMMARY

The results of the preliminary economic analysis of the three types of scheme considered in this report are given in TABLE 13. As stated previously this analysis has been based upon one crop per year.

TABLE 13: FINANCIAL SUMMARY (COST x R1 000)

DESCRIPTION	CAPITAL COST	ANNUAL EXPEN= DITURE	ANNUAL INCOME	ANNUAL PROFIT	BENEFIT COST RATIO
1. DIESEL SCHEMES					
500 Ha unit	2 393	1 134	1 177,5	+ 43,5	
30 000 Ha	143 580	68 040	70 650	2 610	1.03
TOTAL DEVELOPMENT COST	143 580				
2. NATIONAL GRID					

The capital investments required for the two schemes utilising electrical power are lower than that required for the schemes using diesel pumpsets. The development costs for schemes utilizing hydropower as indicated here would be marginally higher than for schemes using power from the national grid.

The big difference between diesel and electric power can be ascribed wholly to the cost difference between pump sets. The marginal difference between the two electric schemes arises from the smaller land area that can be developed when power comes from a hydropower scheme. It should be explained that the hydro power scheme can supply energy on a year round basis but that the demand for energy of the irrigation schemes is limited to the growing season. Therefore energy generated outside the growing season can be sold.

It would be possible to develop a number of irrigation schemes based upon diesil powered pump sets and, at a later stage, convert them to electrically driven pump sets as the electrical supply network was extended. However this would make no difference to the capital cost or the profitability of a scheme as the initial high investment in diesil powered pumps would still be necessary. Only after a period of time when these pump sets could be written off and a change made to electrically driven pump sets would the profitability increase. Yet it may still be considered worth while to do this for practical reasons such as scarcity of funds precluding the initiation of the total development or, in order to establish the viability of such ventures before committing capital funds.

In view of the marginal cost differences it may be worth considering the utilization of power from the national grid as a first step with a hydropower

If it is assumed that a farmer would be given a plot of 5 hectares, then the income generated through that plot must be more than the income he and his family would derive from practising subsistance farming. It has been estimated by ENOK that the equivalent income to be derived from subsistance farming is between R400 and R500 per family per annum. Therefore for there to be any incentive for a Kavango to participate in the scheme his income per hectare must be substantially more than R110 per annum. The last two mentioned schemes would be able to meet this criteria as they promise a return per hectare of four times that amount.

An important difference between the diesel powered schemes and the electrically powered schemes is this, that in order to make the electrical schemes work and show a profit, there must be a committment to implement the scheme as a whole. In other words both of the electrical schemes rely on economies of scale for their viability. If a committment to the whole project cannot be made then the costs will be bourne by fewer users and consequently the profitability will decrease. On the other hand with diesil powered schemes it is not necessary to develop all of the 30 000 hectares, much smaller tracts of land can be developed without affecting profitability. This means that the diesil schemes would be much more flexible from many points of view.

The results given in this report relate to a direct economic analysis and serve as a basis of comparison of the three alternatives proposed. However this is not the only basis upon which the projects could be analysed. In development project economics a variety of other factors can be brought into play, factors such as shadow prices, development objectives, factor price distortion etc. These can be taken into account in order to evaluate the type of scheme chosen maximises the return on the investment made. On the direct economic analysis made here the Benefit-Cost ratio is highest for the hydropower option and lowest for the diesel option.

7. RELATED MATTERS

7.1 INTERNATIONAL AGREEMENT FOR WATER USE

The Okavango River is an international river since it passes through more than one state. Therefore the use of the water, whether consumptive as in the case of irrigation or non consumptive use, will be subject to international agreement. The rules generally applicable under these circumstances are known as the Helsinki Rules, prepared by the International Law Association in 1966. The Rules state that each State within the drainage basin is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin. This does not mean that each co-basin State will receive an identical share in the uses of the waters, the key word is "beneficial" which is interpreted as meaning economically or socially valuable. Establishment of a usage will entitle any co-basin State to a considerable degree of protection of that usage in the face of proposed development by other basin States as long as the factors justifying its continued existance are not out-weighed by factors showing the desirability of its modification or termination.

There does exist an agreement, signed in 1964 between Portugal and South Africa, where general rules for the development of rivers of common interest were set out. The relevance and applicability of this agreement should be the Okavango Swamp in order to preserve the water levels and ecology of the swamp. In this respect it will probably be the total volume of inflow into the Okavango Swamps that will be of importance. This matter is discussed further under section 7.5.2.

The consumptive use of water by irrigation schemes along the Okavango River will have to be the subject of trilateral agreement between Botswana, Angola and South West Africa. Whether or not this agreement should be a necessary precondition for development is a point which needs careful consideration. Agreement could be reached retrospectively after implementation, under which circumstances, the prior establishment of beneficial consumptive use would place South West Africa in a very strong position. However such a course of action, if carried out under the present political circumstances, would generate a great deal of criticism internationally.

7.2 INFRASTRUCTURE DEVELOPMENT

There can be little doubt that the development of irrigation schemes along the Okavango River would provide a tremendous boost to the economic and infrastructural development of the region. This would be especially so if electrical power were to be used, for under these circumstances it would be feasible to also supply electricity for domestic and other purposes.

Irrigation schemes would provide employment opportunities in the region and would in turn increase the disposable income. This would inevitably give rise to a demand for more consumers services, such as textiles, furniture, stationary, chemists, general dealers, etc. ie the Tertiary Sector of the economy. It would also be possible to develop industries for processing the raw agricultural produce, say for example milling and

Improved infrastructure would aid the development of tourism in the region. It has been pointed out that the development of the Popa Falls and the Caprivi as major tourist attractions could be considered. This would imply that a hydroscheme at Popa Falls should not be developed and it has been shown here that use of the national Grid for power would still be an attractive and economic proposition. It is felt that an important part of any future work into the viability of such schemes should be an Economic Impact Assessment Study. This can be understood to encompass such aspects as the effect of the development of irrigation schemes on stimulating other sectors of the local and national economy, the possible employment opportunities created, the manpower skills required. These in turn will necessitate that the State provide additional services in the region, such as roads, schools, clinics etc. The scope of this report precludes an in-depth analysis of all these aspects but they can be mentioned as being necessary for the next stage of investigation.

7.3 FOOD PRODUCTION

In this report attention has been focused upon only two crops, cotton and maize, however due consideration can be given to other products. South West Africa is very heavily dependent upon imported food stuffs, a situation which must be to the general detriment of the country. Therefore whilst the feasibility and economic viability of irrigation schemes has been demonstrated, it is proposed that any development of agronomy should make a significant contribution to the food production and requirements of the country as a whole. This means that the range of foodstuffs to be grown should be expanded beyond those given here with a view to market substitution of imported foodstuffs. This needs careful consideration for although there is a need the local

It has been assumed that a primary aim would be food import substitution for the country as a whole. On the other hand it could be decided that, in order to earn foriegn exchange, "cash crops" such as coffee, should be grown. Experience in developing economies over the past five years has shown this to be a hazardous path to follow, Kenya and Tanzania are examples of the failure of this type of policy.

The contribution that produce from irrigation schemes could make to freeing the country as a whole from a dependence upon imported food stuffs needs to be given closer attention. This in turm would influence the type of crops to be grown.

7.4 TYPE OF MANAGEMENT

Despite the economic feasibility analyses presented in this report the success or failure of such projects will be largely determined by the manner in which such projects are managed. This also goes hand-in-hand with the question of objectives, in other words is one of the objectives to get the local people to operate and run such schemes. Alternatively such schemes can be run by a quasi-government agency which merely employs labour.

A mode of management which has been suggested is that a scheme should consist of a number of plot holders who work their land in order to provide themselves and their families with a cash income. The plot holders would have access to a central organisation which would provide not only professional advice and training but also those items of equipment which the individual farmer could not reasonably be expected to own. It would also act as agent for selling of farm produce.

As an alternative to the above a kibbutz type cooperative approach could be adopted whereby those participating would be paid a salary. The scheme would then own all the equipment, and be responsible for running the scheme and selling its produce. The local Kavango people would provide the labour and be expected to run the scheme on a co-operative basis and share in the profits.

A third alternative would be for the State to initially provide incentives for private enterprise companies to become involved and run such ventures. It is proposed that consideration should be given to a mix of the above options in order to cater for the varying degrees of skills and iniative available among the local population. For it may be that there would be a reasonable number of people who have the necessary skills to participate in a kibbutz type system. There will be many fewer who would be able to participate in a moshav type system as this would require a greater amount of skill. So too would the number of people who could participate in a company venture or even set up their own company, be limited. In this latter case the salary must be more than the present family subsistence income.

The management aspect is one of the most important to the success of the whole irrigation scheme concept and does require the most careful consideration. It must be studied in-depth using as far as possible case studies of similar schemes in order to arrive at sound recommendations.

7.5 HYDROLOGY

Up to this point in the report it has been implicitly assumed that sufficient water will be available for consumptive use on irrigation. This assumption

7.5.1 EFFECT OF A DAM ON THE OKAVANGO RIVER

A dam built on the Okavango River for power generation would serve to increase and utilise the available head and to a certain extent would regulate flow in the river, by creating a storage basin behind the dam. The storage basin created would not be of a great enough capacity to provide proper flow regulation. In essence though a dam would constitute a run-of-the-river scheme, and not water storage. Therefore a dam itself would have little effect upon the river hydrology, a certain amount of flow regulation would occur but because of the limited size of any storage basin behind the dam the ability to regulate would be limited. To all intents and purposes, given the level of detail of this report, it can be said that a dam would have little to no effect upon the river hydrology.

7.5.2 EFFECT OF ABSTRACTION FROM THE RIVER

The Hydrology Division have carried out a minimum flow analysis for the Okavango River for two river reaches indicated by the Planning Division. This can be compared with the expected monthly abstractions along the river in order to gauge whether or not the abstraction will have a significant effect on river flows.

From a proposed pattern of monthly water requirements given in APPENDIX B and the location of irrigible land, a cumulative monthly abstraction pattern along the Okavango River was derived. When the river geography is considered it can be seen that in simple terms the river can be divided into two reaches. One reach upstream of the Cuito-Okavango River confluence and the other reach downstream of the confluence. The TABLE below summarises the

ABSTRACTION FROM THE OKAVANGO RIVER

CE	DOWNSTREAM OF THE CUITO-OKAVANGO CONFLUENCE (AT BAGANI)								
ERIODS	ABSTRACTION		FLOW RETURN PERIODS (YRS)						
1:50 (m^3/s)	FLOW (m^3/s)	VOLUME Mm^3	1:5 YRS FLOW	1:5 YRS VOLUME (Mm^3)	1:25 YRS FLOW	1:25 YRS VOLUME (Mm^3)	1:50 YRS FLOW	1:50 YRS VOLUME (Mm^3)
14,8	4,82	12,9	144	352	125	308	122	297
16,3	4,86	12,6	137	328	120	281	115	270
25,5	17,03	45,6	154	427	139	380	136	372
59,0	24,31	65,1	196	575	154	495	146	481
46,0	24,46	53,8	259	711	202	596	192	577
			335	1029	248	793	230	673
			395	1155	296	870	275	807
			322	1030	254	808	241	758
			240	718	200	508	193	556
			201	578	171	511	166	499
			174	500	155	442	152	428
			146	411	133	378	130	372
		195		7 814		6 450		6 090

It should be noted that the above abstraction figures do not include a provision of 3 m^3/s abstraction arising from the ENWC intake works at Rundu. This is a peak capacity, the average abstraction would be lower than this for a long period of time.

An inspection of the figures in TABLE 14 demonstrates that sufficient water will be available from the river to meet irrigation requirements. However upstream of the Cuito-Okavango confluence abstraction will account for a significant percentage of the flow, up to 47% in the case of the November one in fifty year minimum expected flow. Even on the one in five year minimum expected flows the abstraction would amount to 35% of the total flow. Downstream of the confluence, abstraction is considered to have very little effect upon the flow or flow volume of the river due to a consistently high base flow contribution from the Cuito River.

On the other hand the total abstraction of 195 Mm^3 for irrigation of 300 000 hectares represents a very small percentage of the total flow volume passing Bagani. It will be the total volume of water entering the Okavango Swamps that will, in all probability, be of interest to the Botswana Government. The total amount of 195 Mm^3 represent only 3% of the total volume of a 1:50 year low flow season. Addition of abstraction for the Eastern National Water Carrier, at 3 m^3/s on a year round basis, would increase this percentage to 5%. Indeed the variation in flow volumes from year to year will be much greater than the volume abstracted. Therefore it is concluded that abstraction of water for irrigation and the Eastern National Water Carrier will have a minimal effect on the volume of water entering the Okavango Swamps and the water levels of the Swamps. By implication there should also be a minimal impact upon the ecology and wild life of the area.

circumstances it can be seen that although some irrigation could be allowed certainly not all the potential land upstream of the Cuito-Okavango confluence could be developed. This conclusion gives added impetus to the search for irrigible land in, say, West Caprivi, where abstraction of water for agriculture has less effect on the river hydrology.

8. SUMMARY

The background to the proposal that the land along the banks of the Okavango River be brought under irrigation has been outlined and the possible methods of achieving this have been discussed. An economic feasibility study has been made of the three possible types of schemes; irrigation by diesel pumps, irrigation by electrical pumps using either power from the National Grid or generated by a hydro power scheme at the Popa Falls on the Okavango River. The size of the project assumed for this reconnaissance report is that 30 000 hectares would eventually be irrigated. This notion has an important bearing upon this report for only by embarking at this scale can certain economies of scale be achieved and thereby making the project more economically feasible.

The economic study has indicated that the maximum nett generated income would be derived from the implementation of irrigation schemes supplied with electrical power. The figures indicate power from the National Grid would lead to a greater overall pofit although nett generated income per hectare is greater for a hydro power scheme. The difference arising from the smaller land area to be developed due to generating capacity restrictions that come into operation on the hydro power project. It must also be added that even diesel run schemes have been shown to be capable of being run at a profit, although in this latter case the nett generated income will be very sensitive to crop yields per hectare achieved and crop selling prices.

Other aspects which it was considered would have a bearing and an influence on such a project have been briefly mentioned. Although they have been briefly mentioned their importance should not be underestimated, a full and proper discussion of them falls outside the scope of this report. The need to fully investigate and evaluate these aspects such as; International Agreement, effect upon infrastructural development, the impact and effect upon food production and, management, marketing and the socio economic impact of such a project, must be stressed.

The preliminary hydrological investigation given as an input to this report has served to indicate that taking into consideration the monthly minimum flows, it does not appear feasible to develop all the potentially irrigible land upstream of the Okavango-Cuito River confluence. Downstream of this point it is not expected that abstraction will have any significant effect on the river hydrology.

In conclusion it can be said that the development of irrigation schemes along the Okavango River would be a project having a great deal of merit, which has been shown in this report to be a financially economic proposition. There do remain a number of aspects which must be properly appraised before such a project could go ahead. These are outside the scope and expertise of the Department of Water Affairs. It is suggested that a special development body be set up charged with the full investigation of this matter of setting up irrigation schemes. Such a body should focus its attention on the phased implementation of irrigation schemes based on the extension of the National Grid along the Okavango River and incorporating a hydroelectric power generation scheme at the Popa Falls.

feasibility study of the provision of a power distribution system along the Okavango River deriving power from the National Grid. In conjunction with this a feasibility report on power generation from the Popa Falls is also a requirement.

In summing up the broader implications of this report it can be said that it discusses the development of one of the few areas of South West Africa/Namibia where there occurs precious resources - land and water in close proximity to each other. Many experts, noting the mistakes and catastrophes from around the world with respect to developing countries, have concluded that the creation of wealth and viable economies must be firmly founded upon a sound and vigorous agricultural sector. Therefore there is an urgent need for a realistic Regional Development Strategy for the Kavango based upon a socio-economic approach. An approach and strategy which will address itself to the upliftment of the people and the development of the natural resources for the good and wealth of the country.

If this report can serve as a point of departure in the achievement of this, then it will have more than served its purpose.

9. RECOMMENDATION

It is recommended that:

9.1 the Directorate of Development Coordination, in consultation with the Department of Agriculture, Administration for Kavango's, appoint

9.3 the Directorate of Development Coordination initiate a Development Strategy for the Kavango, wherein cognisance is taken of the findings of this report and the findings of the two above proposed studies.

9.4 the Department of Agriculture of the Administration for Kavango's Commission a report upon the crops and cultivars which might be commercially grown and comment upon what research would need to be carried out.

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H PETTENBURGER
B VOLKMANN

A. Cashman

Compiled by: A CASHMAN

Date : 15 APRIL 1985.

10. APPROVAL OF RECOMMENDATIONS

10.1 This Report has been read and approved for submission to the Director: Investigations.

CHIEF: PLANNING

DATE : 16/4/85

10.2 I support the Recommendations set out in this Report and submit it to the Secretary for Water Affairs for approval in principle.

DIRECTOR: INVESTIGATIONS

DATE: 18/4/85

10.3 The recommendations in this Report have been decided upon as follows:

Approved.

11. REFERENCES

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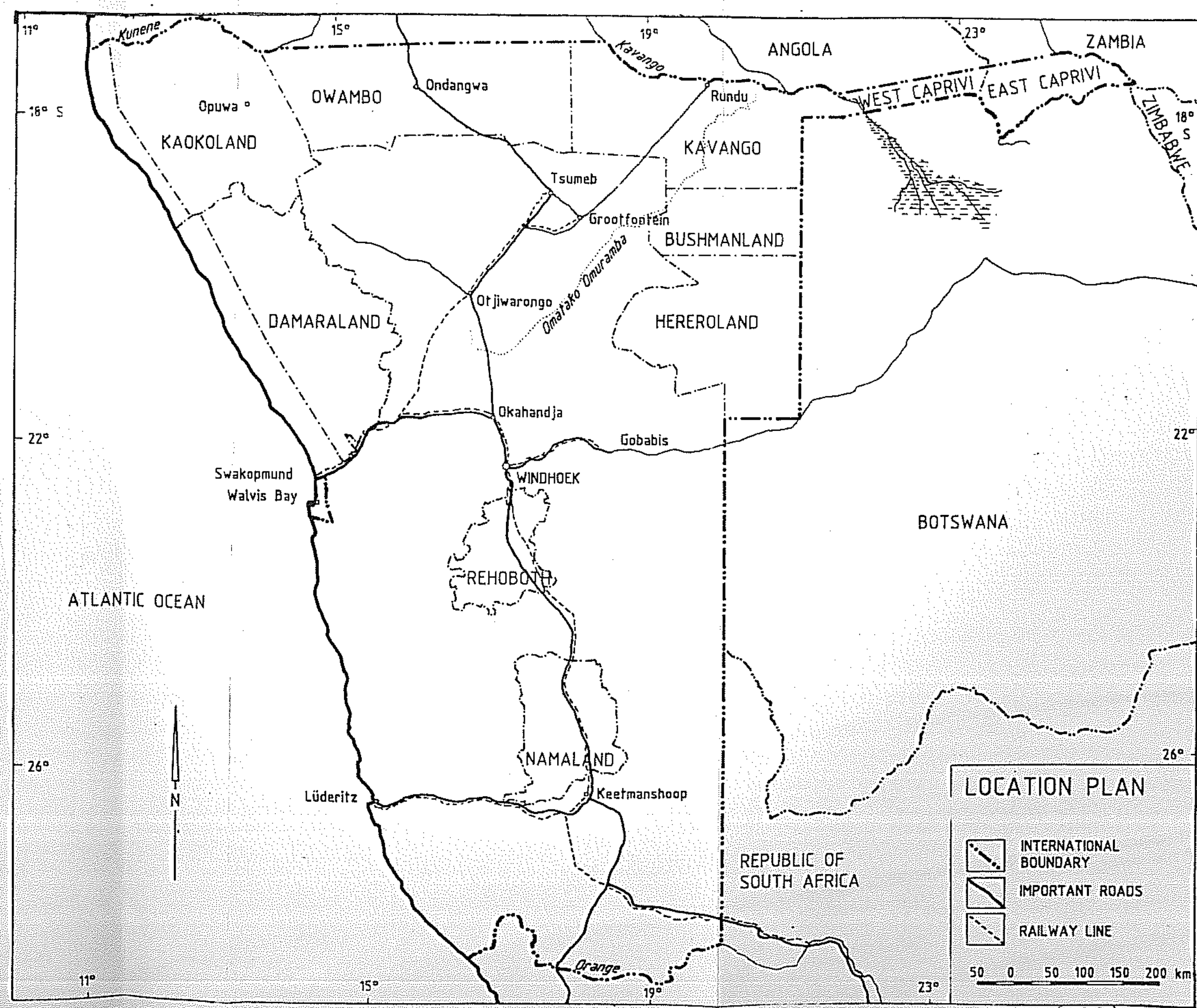
ANNEXURE 1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IMPORTANT ROADS
RAILWAY LINE
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ANGOLA
ZAMBIA
ZIMBABWE
WEST CAPRIVI
EAST CAPRIVI
BOTSWANA
REPUBLIC OF SOUTH AFRICA
ATLANTIC OCEAN
KAOKOLAND
OWAMBO
KAVANGO
BUSHMANLAND
HEREROLAND
DAMARALAND
REHOBOTH
NAMALAND
Opuwa
Ondangwa
Rundu
Tsumeb
Grootfontein
Otjiwarongo
Omatako Omuramba
Okahandja
Gobabis
WINDHOEK
Swakopmund
Walvis Bay
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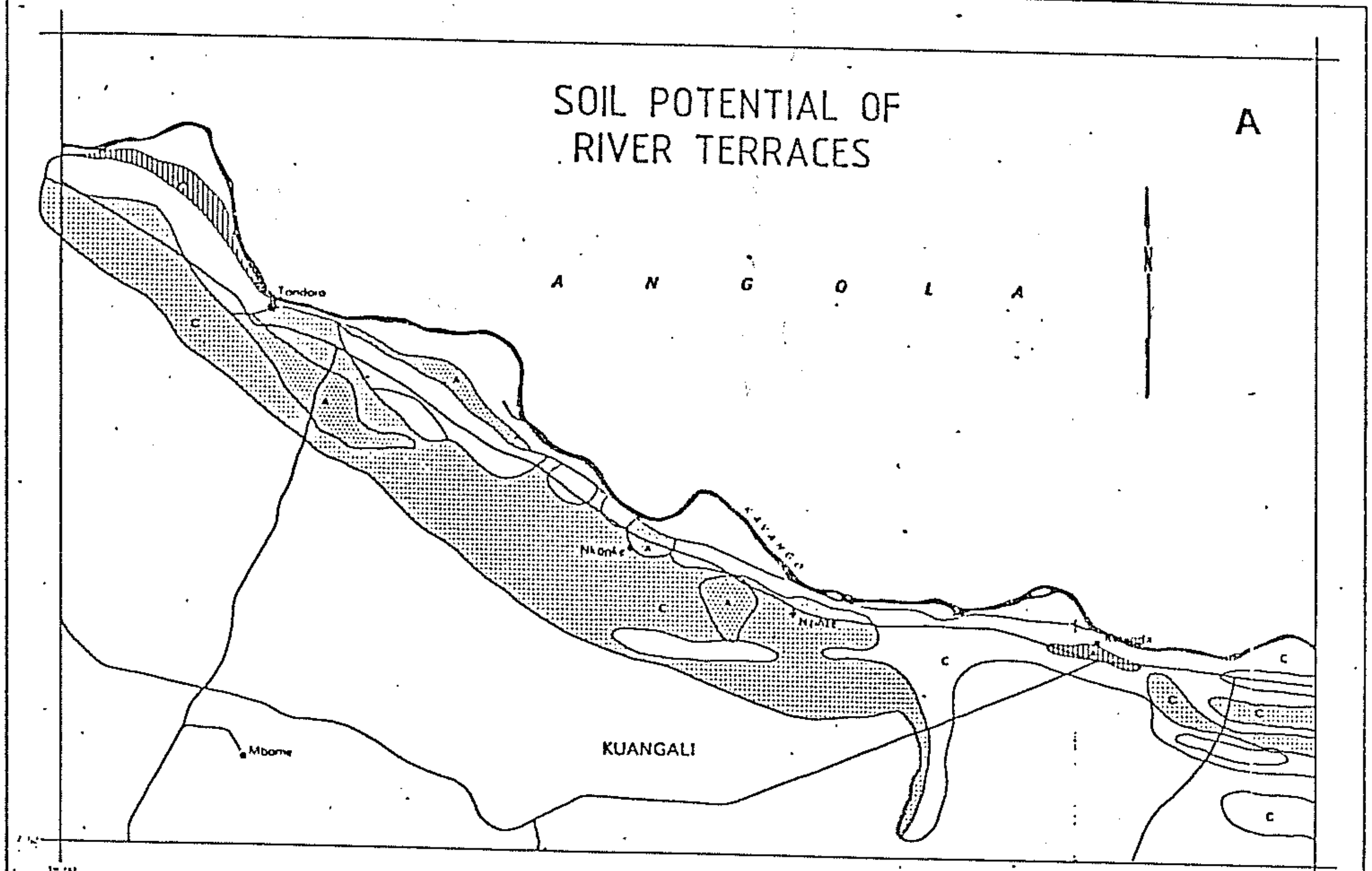
SOIL POTENTIAL OF
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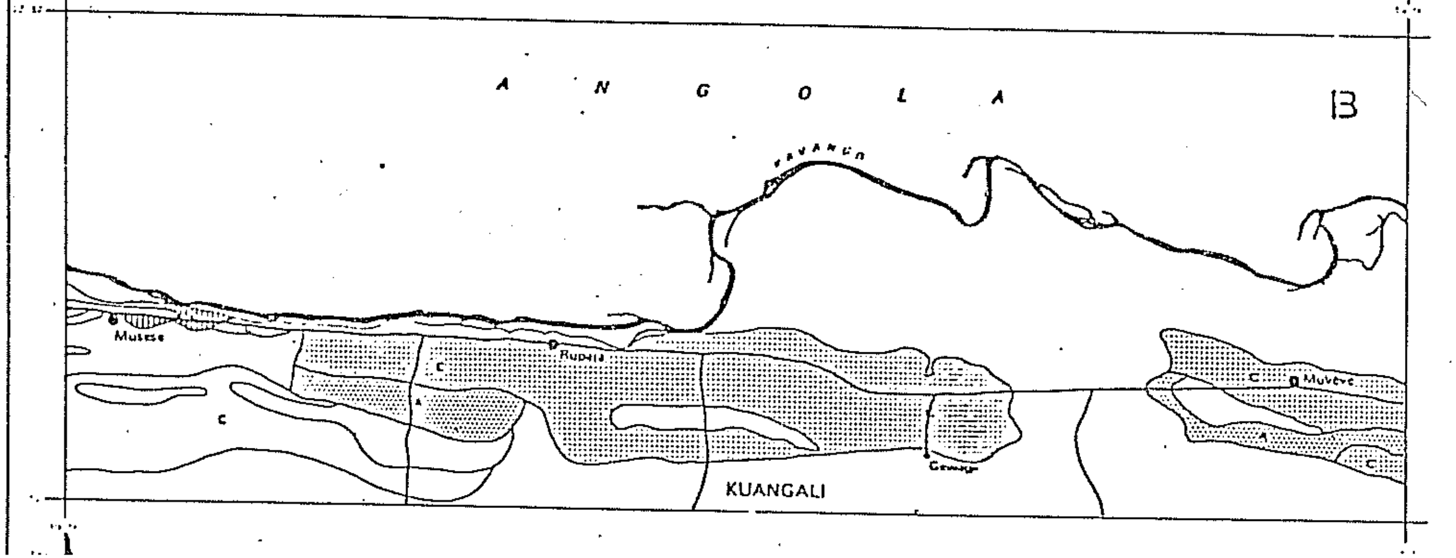
ANGOLA
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KAVANGO
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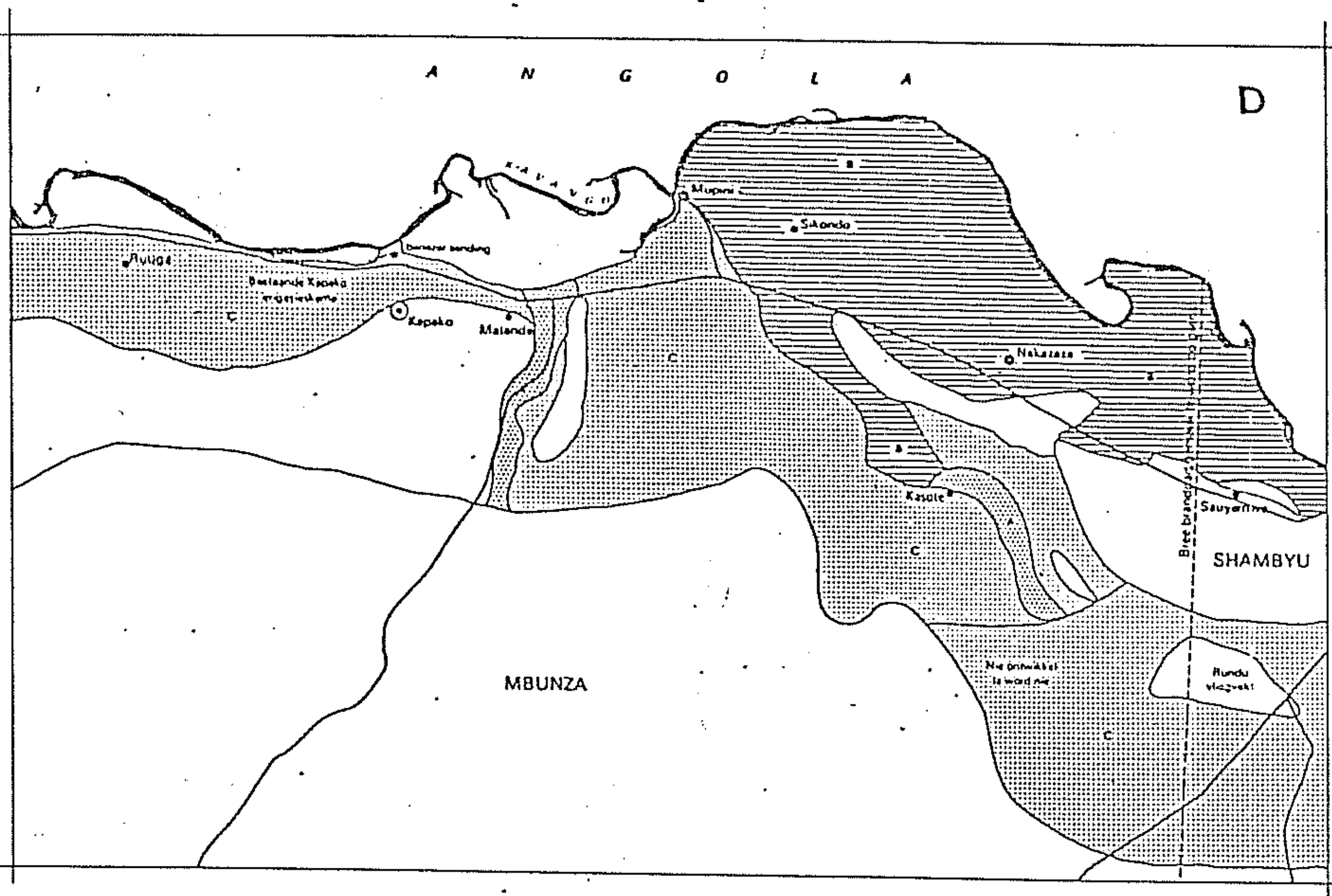
Rupara
Muveve
KUANGALI


A N G O L A
D
KAVANGO
Mupini
Sikondo
Rupara
Bestaande Kapako
Kapako
Malanda
Nakazaza
Kasote
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Bree brand
SHAMBYU
MBUNZA
Rundu
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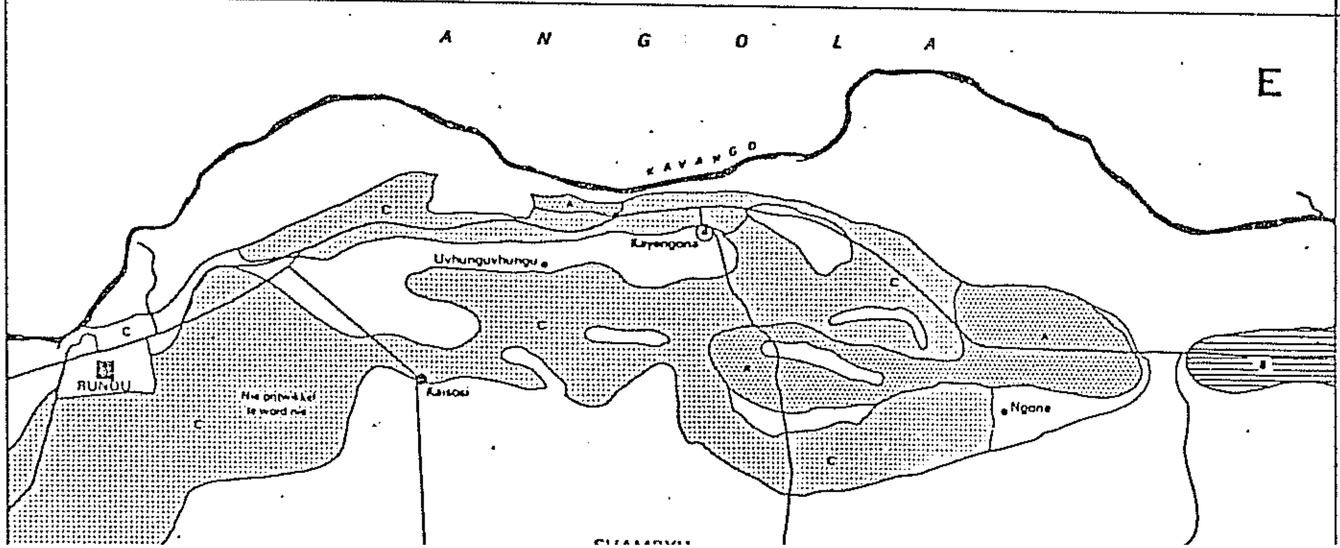
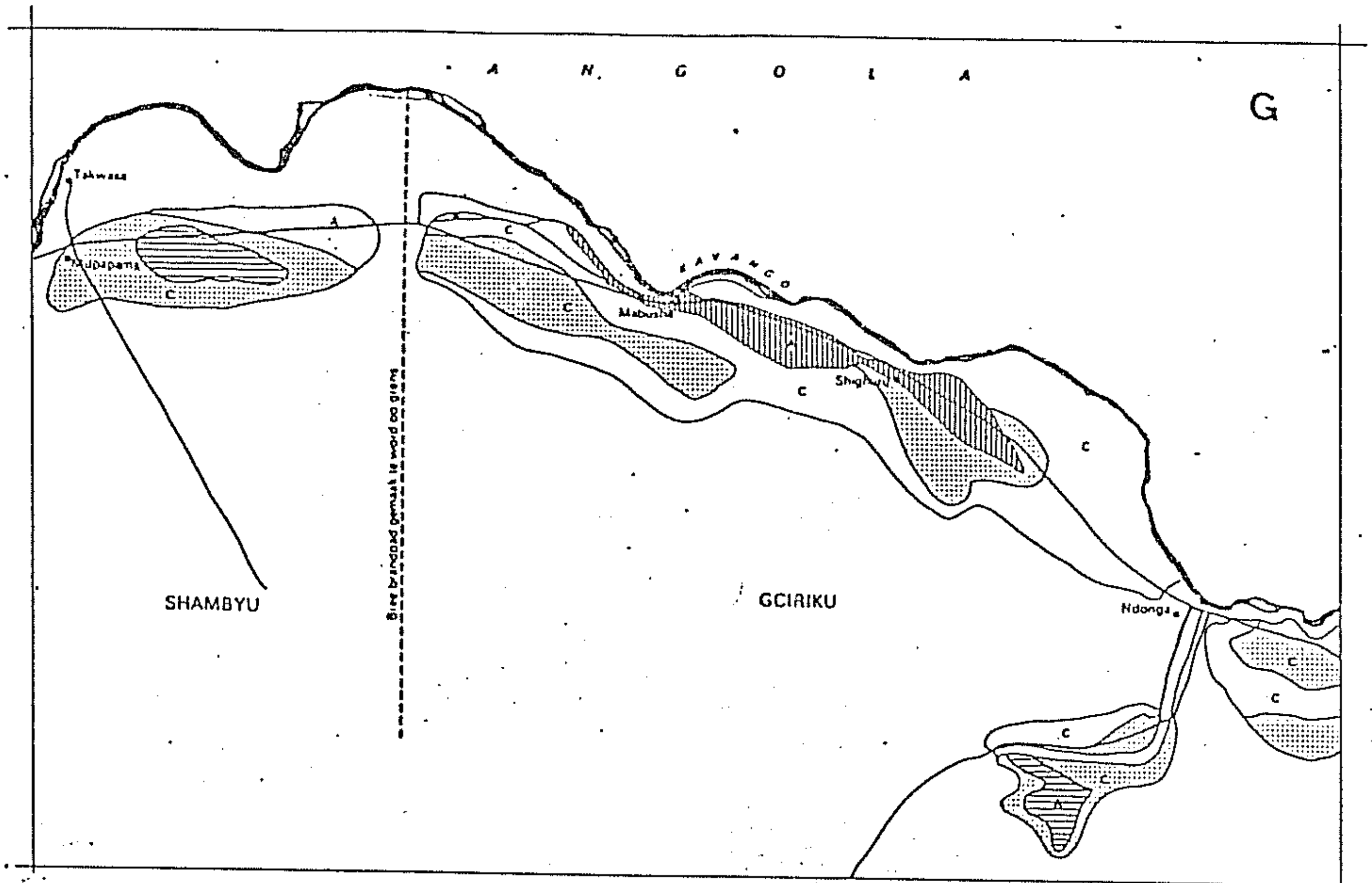
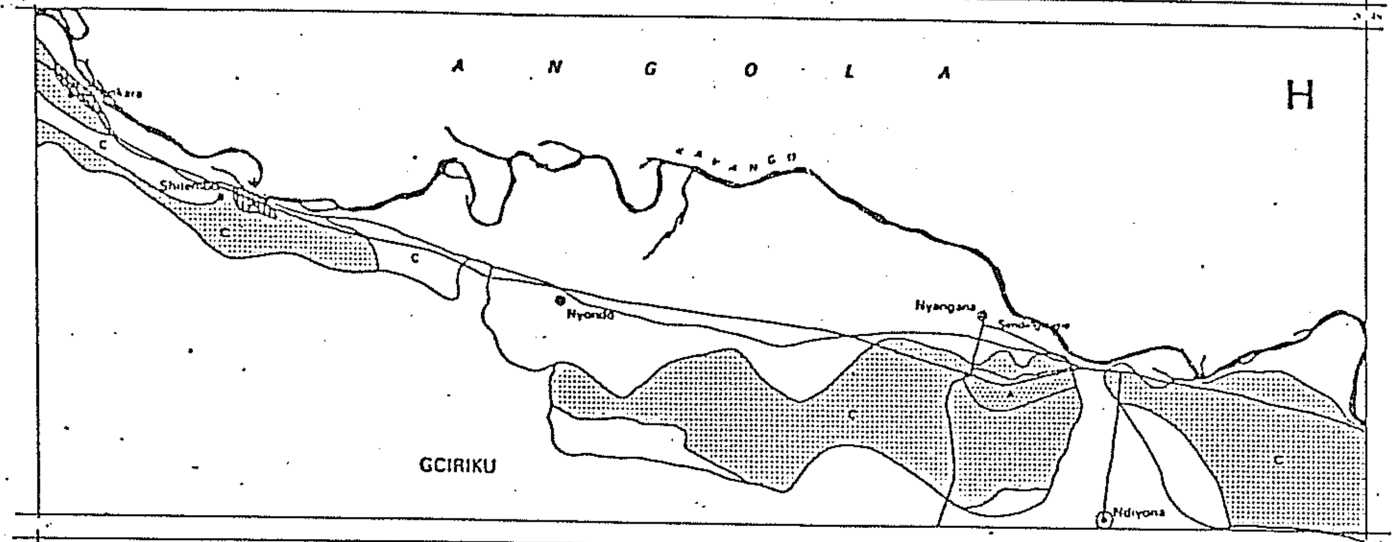
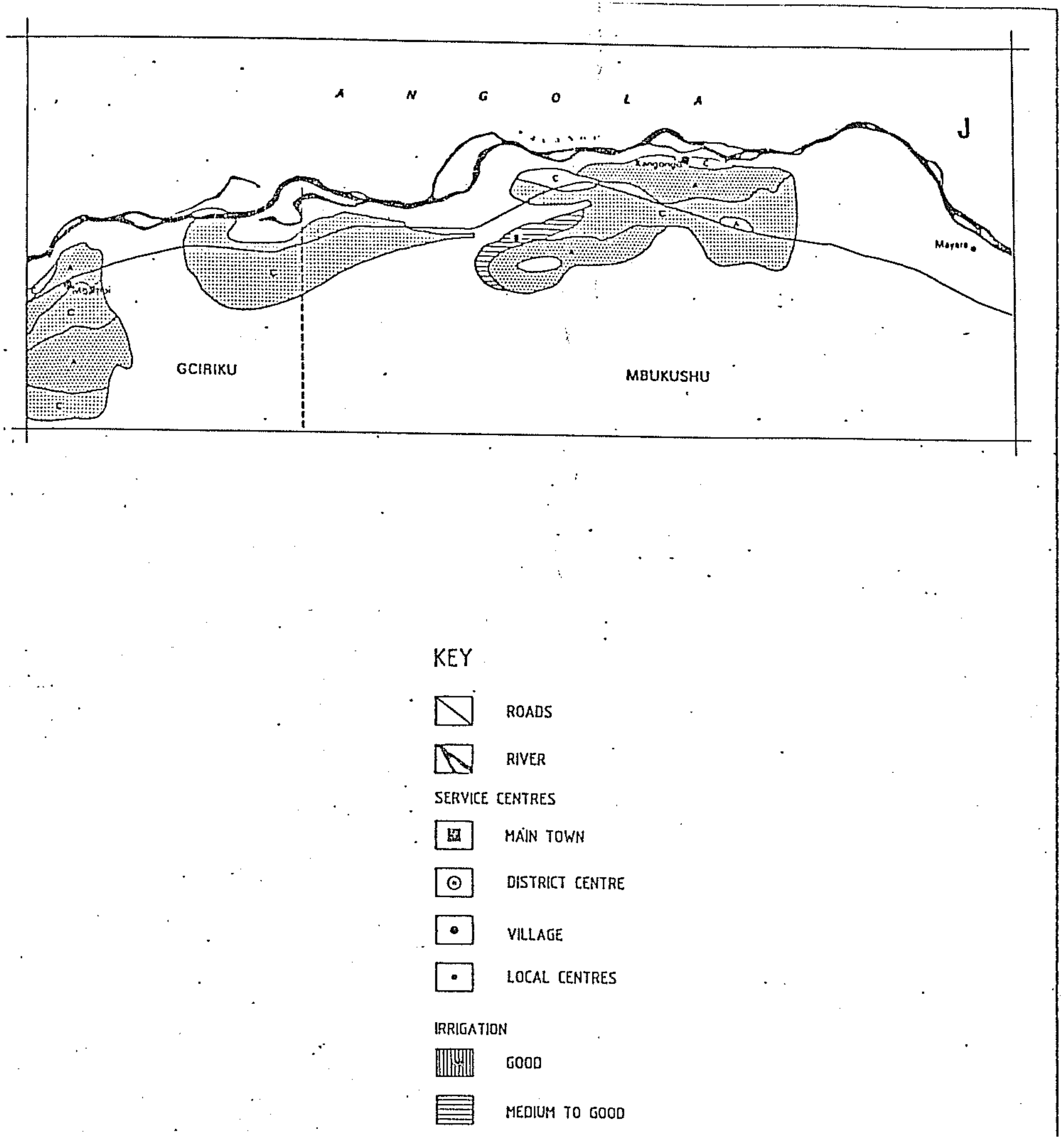
A
B


A N G O L A
E
KAVANGO
Kayengona
Uvhunguvhungu
RUNDU
Kaisosi
Ngone
C
A
B


A N G O L A
G
Takwasa
KAVANGO
A
C
SHAMBYU
GCIRIKU
Ndonga


A N G O L A
H
KAVANGO
C
A
Nyangana
Ndiyona
GCIRIKU



A N G O L A
J
GCIRIKU
MBUKUSHU
KEY
ROADS
RIVER
SERVICE CENTRES
MAIN TOWN
DISTRICT CENTRE
VILLAGE
LOCAL CENTRES
IRRIGATION
GOOD
MEDIUM TO GOOD

APPENDIX A

CALCULATION OF EQUIPMENT COST

In Figure A1 a diagrammetric example of the mechanical equipment planning program is given.

SUMMARY OF OPERATIONAL COSTS

Implement	Purchase Price (R)	Lifetime (hours)	ESTIMATED RUNNING COST (R/h)			
			Maintenance	Depreciation	Fuel	Total
Tractor	22 000	10 000	2,20	2,33	5,10	9,63
Spreader	500	3 000	1,66	1,77		3,43
Ripper	1 200	5 000	0,25	0,25		0,50
Plough	1 200	2 000	0,60	0,64		1,24
Disk Harrow	1 600	2 000	0,80	0,85		1,65
Planter	5 000	2 000	2,50	2,65		5,15
Sprayer	2 000	2 000	1,00	1,06		2,06
	10 000	5 000	2,00	2,12		4,12
Harvester	16 000	5 000	3,20	3,40		6,60
Trailer	6 000	10 000	0,60	0,64		1,24

FUEL COST This has been calculated by assuming that a 48 kW tractor is used. It is assumed that it uses only on average 28 kW and that on average consumes 0,38 ℓ/kWh.

EQUIPMENT AND LABOUR COSTS FOR COTTON (15ha)

ACTIVITY	EQUIPMENT COST		
	h/ha	R/h	R/ha
Distribute Fertilizer	0,7	13,06	9,14
Rip	5,0	10,13	50,65
Plough	2,5	10,87	27,18
Harrow	1,0	11,28	11,28
Plant	2,5	14,78	36,95
Spray weeds	0,7	11,69	8,18
Thinning and Wee= ding, Spray pests (6x)	3,0	11,69	35,07
Pick, Bale and weight, Transport		10,87	10,87
TOTAL	15,4		189,32

EQUIPMENT AND LABOUR COST FOR MEALIES (15ha)

ACTIVITY	EQUIPMENT COST		
	h/ha	R/h	R/ha
Distribute Ferti= lizer	0,7	13,06	9,14
Rip	5,0	10,13	50,65
Plough	2,5	10,87	27,18
Harrow	1,0	11,28	11,28
Plant	2,5	14,78	36,95
Spray	0,7	11,69	8,18
Weeding Harvest Weight and Sack	5,0	16,23	81,15
Transport	[illegible]		

APPENDIX B

MONTHLY ABSTRACTION ALONG THE OKAVANGO RIVER

In order to determine the monthly average abstraction along the Okavango River during the growing season for irrigation the following method has been adopted.

A theoretical crop plus evapotranspiration curve for crops has been used. From this has been deducted the minimum monthly rainfall figures avera over the days in the particular month. Then for each month the difference between the depth supplied by rainfall and the crop requirements has been found and increased to allow for irrigation efficiency of 70%. This then gives the equivalent depth of water to be abstracted for each hectare. From this the quantity per hectare required to be abstracted can be found. Assuming that this quantity is extracted over a 20 hour day the required flow rate is derived, to supply one hectare.

This monthly flow figure coupled with the distribution of irrigible land then gives the cummulative quantity to be abstracted at any point along the river.

ANNEXURE 3 and FIGURE B1 illustrate the above procedure whilst the figures used for rainfall and required flows (used to derive the information) are given in the Tables below.

TABLE B1: RAINFALL DATA

MONTH	PRECIPITATION mm	N° RAIN DAYS	mm PER RAINDAYS	AVERAGE DAILY PRECIPITATION

TABLE B2: REQUIRED MONTHLY ABSTRACTIONS FOR IRRIGATION

MONTH	AVERAGE DEPTH OF WATER REQUIRED mm	AVERAGE QUANTITY PER DAY m^3/ha/day	AVERAGE REQUIRED FLOW ℓ/s/ha
October	1,2	12	0,14
November	1,6	16	0,19
December	3,8	38	0,44
January	5,7	57	0,66
February	5,3	53	0,61

The information given in FIGURE B1 can be compared with the hydrological information on the Okavango River flows, see FIGURE B2 in order to examine the sufficiency of the available low flows in meeting the irrigation demand. The Hydrology Divisions input is attached.

IRRIGATION ON THE OKAVANGO RIVER

1. INTRODUCTION

Following an investigation into potential irrigation water demand carried out by Planning Division a request was made to this Division to examine critical supply factors in the Okavango with respect to these possible irrigation demands. The analysis considered the river split into two reaches:-

Reach A:- Upstream of Cwito confluence
Reach B:- Downstream of Cwito confluence

2. FINDINGS

2.1 MINIMUM FLOW ANALYSIS

2.1.1 Nkurenkuru, Masese, Rundu to Ndiyona

Hydrology division have recorded water levels at Rundu since 1946 and have a satisfactory stage-discharge rating for the section. Flow at Rundu, especially during low-flow periods, can be taken as representative also of the flow between Nkurenkuru and the Cuito confluence at Ndiyona.

Since abstraction increases cumulatively in a downstream direction it can be taken that the situation at Ndiyona just before the confluence with Cuito will be the most

Table 1 gives the monthly minimum flows with return periods 1 in 2,3, 1 in 5, 1 in 10, 1 in 20 and 1 in 50 years for Rundu.

TABLE 1 MONTHLY MINIMUM FLOWS AT RUNDU

RETURN PERIOD (YEARS)	OCT m^3/s	NOV m^3/s	DEC m^3/s	JAN m^3/s	FEB m^3/s
1 in 2,3	36,0	34,5	50,0	93,0	180,0
1 in 5	27,5	26,0	39,0	61,0	108,0
1 in 10	22,5	21,8	32,5	47,0	76,0
1 in 20	18,7	18,7	28,5	39,0	59,0
1 in 50	14,8	16,3	25,5	33,7	46,0

Considering reach A, Table 2 gives the flows that can be expected to be remaining in the river after abstraction for irrigation and the ENWC, for Ndiyona.

TABLE 2 MINIMUM FLOWS AT NDIYONA AFTER ABSTRACTION

MONTH	ABSTRACTION m^3/s	1 in 2,3 m^3/s	1 in 5 m^3/s	1 in 10 m^3/s	1 in 20 m^3/s	1 in 50 m^3/s
October	6,64	29,4	21,1	15,9	12,1	8,2
November	7,74	27,1	18,6	14,4	11,3	8,9
December	13,56	36,4	25,4	18,9	14,9	11,9
January	18,84	74,2	42,2	28,2	20,2	14,9
February	17,64	162,4	90,4	58,4	41,4	28.4

TABLE 3 MONTHLY MINIMUM FLOWS AT MUKWE

RETURN PERIOD (YEARS)	OCT m^3/s	NOV m^3/s	DEC m^3/s	JAN m^3/s	FEB m^3/s
1 in 2,3	158	153	175	220	296
1 in 5	144	137	154	195	260
1 in 10	136	129	145	190	250
1 in 20	129	122	140	186	245
1 in 50	122	115	136	184	240

Table 4 gives the discharges that can be expected to be remaining in the river after abstraction for irrigation and the ENWC at Bagani.

TABLE 4 MINIMUM FLOWS AT BAGANI AFTER ABSTRACTION

MONTH	ABSTRACTION m^3/s	1 in 2,3 m^3/s	1 in 5 m^3/s	1 in 10 m^3/s	1 in 20 m^3/s	1 in 50 m^3/s
October	7,17	150,8	136,8	128,8	121,8	114,8
November	8,55	144,4	128,5	120,5	113,4	106,5
December	16,20	158,8	137,8	128,8	123,8	119,8
January	22,80	197,2	172,2	167,2	163,2	161,2
February	21,30	274,7	238,7	228,7	223,7	218,7

2.2 MEAN FLOW ANALYSIS

3. CONCLUSIONS AND RECOMMENDATIONS

As can be seen from the low flow analysis, flow in this stretch of the river can be very small. The 1 in 10 year minimum flow in November is 21,8 m^3/s, while the mean minimum flow is 34,5 m^3/s. Abstraction of 8,55 m^3/s is therefore a significant quantity. It must also be remembered that the potential irrigation demand figures are based on mean rainfall. In a poor rainy season, increased irrigation demand will very possibly coincide with exceptionally low river flow.

In addition, it should be noted that although the minimum flow figures given represent the mean flow over one day only, these low flows in October and November are very much the base flow of the river, and normally show little variation over a four or five week period, (eg 50/51 season:- flow in 1/10/50 25 m^3/s, 31/10/50 18 m^3/s, 30/11/50 17 m^3/s).

Downstream of the Cuito confluence, abstraction is considered to have very little effect on the river due to a consistently high base flow contribution from the Cuito river.

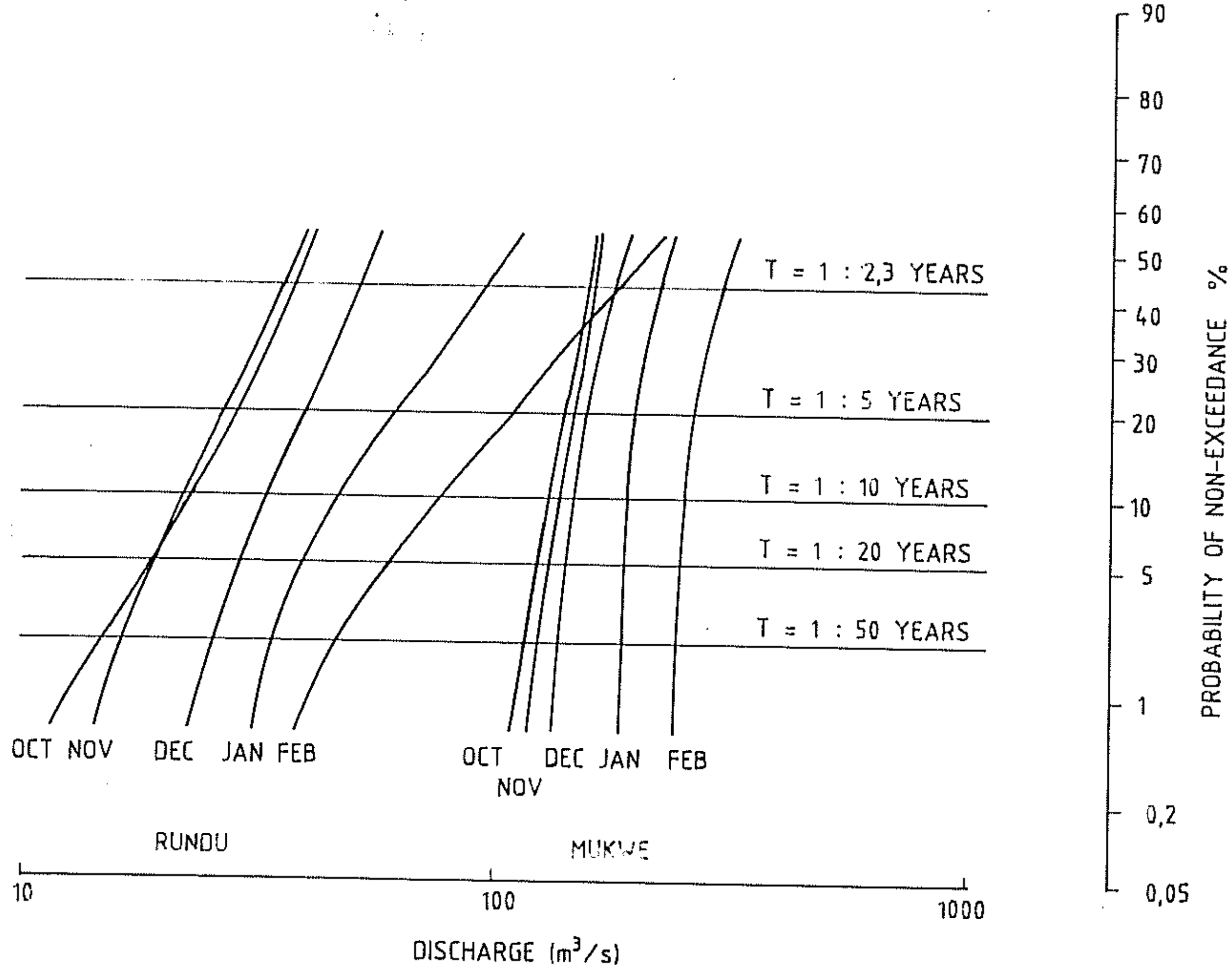
It is recommended that prior to any further planning with respect to irrigation that a complete hydrological study be carried out.

REFERENCES

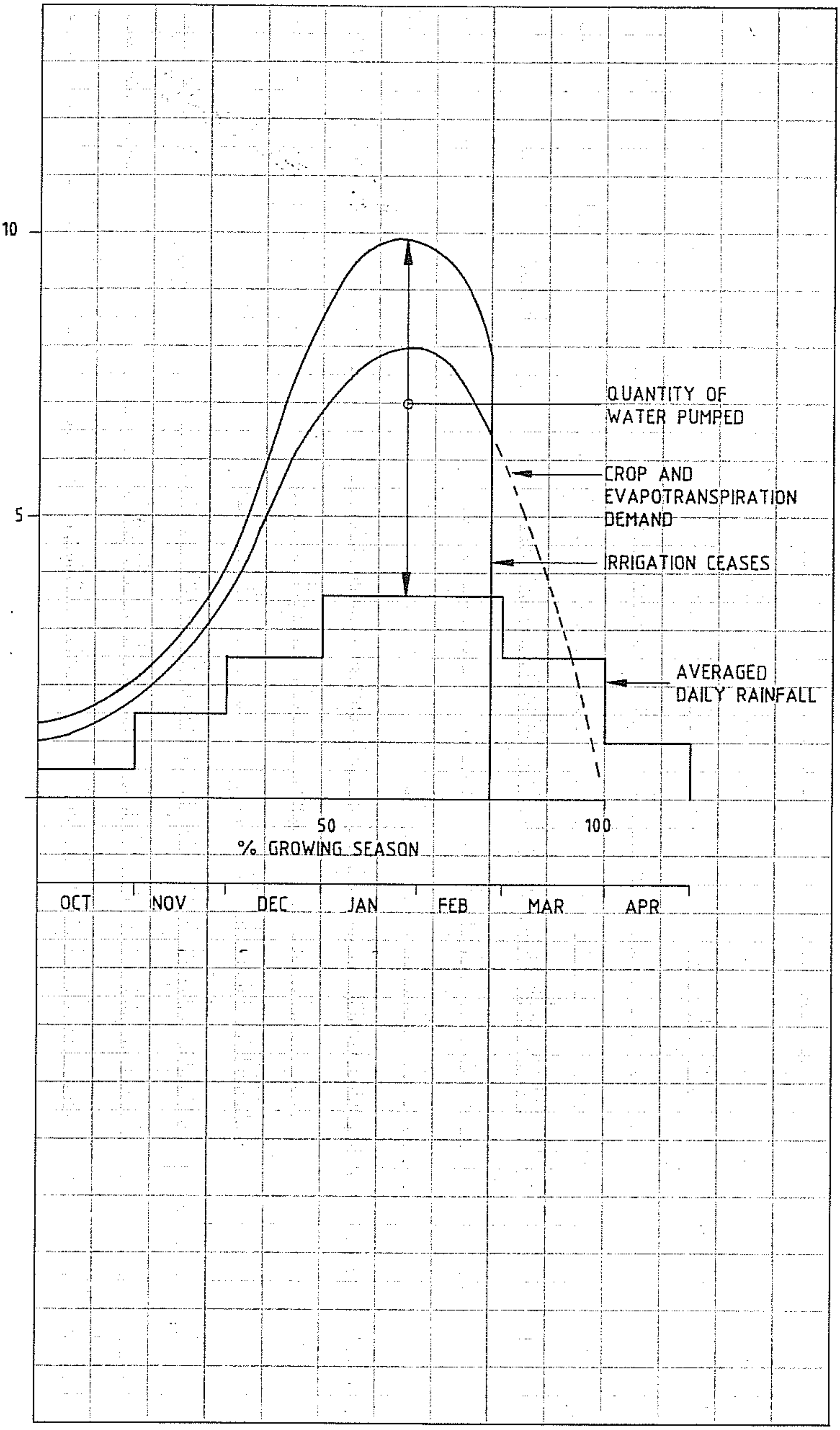
Haan, Charles T. Statistical Methods in Hydrology. Iowa State University Press, Ames, Iowa 50010, 1977.

2. Benjamin J R, Cornell C A, Probability, Statistics and Decision for Civil Engineers. McGraw-Hill Book company. New York 1970.

FIGURE B2



T = 1 : 2,3 YEARS
T = 1 : 5 YEARS
T = 1 : 10 YEARS
T = 1 : 20 YEARS
T = 1 : 50 YEARS
OCT NOV DEC JAN FEB
OCT NOV DEC JAN FEB
RUNDU
MUKWE
10
100
1000
DISCHARGE (m³/s)
90
80
70
60
50
40
30
20
10
5
1
0,2
0,05
PROBABILITY OF NON-EXCEEDANCE %



IRRIGATION WATER REQUIREMENTS