Report No. 639a-SU

# The Sudan
# Power Sector Review

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Public Utilities Projects Division
Eastern Africa Regional Office

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International Development Association

# THE SUDAN

## POWER SECTOR REVIEW

## CURRENCIES, WEIGHTS AND MEASURES

### CURRENCY EQUIVALENTS

| | | |
|---|---|---|
| US$1.00 | = | £Sd 0.400 |
| £Sd1.00 | = | US$ 2.50 |
| £Sd1,000,000 | = | US$ 2,500,000 |
| £Sd1 | = | 1000 millimes (mms) |

### WEIGHTS AND MEASURES

| | | |
|---|---|---|
| 1 meter (m) | = | 3.28 feet |
| 1 square meter ($m^2$) | = | 10.75 square feet |
| 1 kilometer (km) | = | 0.621 miles |
| 1 square kilometer ($km^2$) | = | 0.386 square miles |
| 1 cubic meter ($m^3$) | = | 35.3 cubic feet |
| 1 cubic meter per second ($m^3/s$) | = | 35.3 cubic feet per second |
| 1 kilovolt (kV) | = | 1000 volts |
| 1 kilowatt (kW) | = | 1000 watts |
| 1 kilowatt hour (kWh) | = | 1000 watt hours |
| 1 megawatt (MW) | = | 1000 kilowatts |
| 1 gigawatt hour (GWh) | = | 1 million kilowatt hours |

### GLOSSARY AND ABBREVIATIONS

| | | |
|---|---|---|
| ADB | = | African Development Bank |
| CEWA | = | Central Electricity and Water Administration |
| CEWC | = | Central Electricity and Water Corporation |
| ECUK | = | Electricity Council of the United Kingdom |
| GRS | = | Government of the Democratic Republic of the Sudan |
| PEWC | = | Public Electricity and Water Corporation |
| PWD | = | Public Works Department |
| SL&PCo. | = | Sudan Light and Power Company |
| BNG | = | Blue Nile Grid |

### F I S C A L  Y E A R

July 1 - June 30

# THE SUDAN

## POWER SECTOR REVIEW

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# I. INTRODUCTION

1.01 The power sector review of the Sudan was undertaken initially to focus attention on the power needs of Southern Sudan, which have not been reported on hitherto, and, in this context, to consider the possibilities of development of the hydroelectric potential of the rapid stretch of the White Nile near Juba - the headquarters of the Southern Regional Government. The review mission was required to advise on the urgent steps that can be taken to meet interim requirements in this Region until long-term solutions emerge. 1/ The mission was then required additionally (i) to review, in a cursory manner, the energy sector - its demand, supply, and pricing policies etc. - to provide a rough analysis of the present situation and future prospects, and (ii) to examine the organization of the power sector, its current state of development and the prospects of future development. The sector review was carried out concurrently with the appraisal in January/February 1974, of the Sudan Power II Project. This project would be financed by an IDA Credit in FY 1975, and the beneficiary would be the Sudan's Public Electricity and Water Corporation (PEWC), a central organization currently responsible for electricity supply in the whole of the Sudan.

1.02 A full report by the review mission on the potentialities of the White Nile (Bahr El Jebel) near Juba and on projects to meet the electricity requirements of the Southern Region was prepared in April 1974 and forwarded to the Government of the Sudan (GRS). The recommendations have been accepted by GRS and the project proposals included in the scope of Sudan Power II Project. Advance action on appointment of consultants, engineering and procurement has been authorized on the Association's usual conditions.

1.03 This report, based on the findings of the mission comprising of Messrs. C.K. Chandran (Mission Chief), R.L. Bloor (Consultant) and E. Bolte (Power Economist) sets out the conclusions of the power sector review against the background of the current energy supply situation, taking account of the Sudan's natural resource endowment and the problems of its power sector. The section on 'Finance' has been prepared by Mr. M.L. Heitner, Financial Analyst for the Power II Project appraisal. The legal, institutional, management and financial problems were reviewed in detail with GRS and the basic steps required to be taken for improvement were agreed during the mission. These have been covered in the Sudan Power II Project appraisal report. The draft report was discussed with PEWC and GRS in March 1975.

# II. SUMMARY AND CONCLUSIONS

2.01 The Sudan has a low energy consumption of 52 kg of petroleum equivalent per capita. It is below the average for Africa (62 kg in 1969) and among the lowest in the world. Imported oil supplies 96% of the total commercial energy, and hydroelectricity the balance. Although the country has

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1/ The report on the Southern Region (Annex 14) was forwarded to the Sudan Government in March 1974.

significant hydroelectric potential and production of hydroelectricity is expected to increase two-fold by 1980, the oil-hydro mix is not expected to alter significantly, notwithstanding the recent escalations in oil prices which have a severe impact on the Sudan's balance of payments. Substitution of electricity for oil as motive power for irrigation pumping, increased reliance on hydroelectric resources for electricity supply, and a fresh study of the prospects of utilization of vegetable wastes, e.g. cotton stalks of which the country has substantial quantities presently burnt away, are aspects to be considered.

2.02 Barring some self-generation by the Port Sudan Oil Refinery and a few industrial entrepreneurs PEWC's activities cover the entire power and urban water sectors in the Sudan. However, PEWC has not adjusted its organization to the change in its status from a utility serving greater Khartoum and Wad Medani in 1959 to the national entity it became in 1970. Government expects, as a matter of policy, that PEWC's would raise its own finances for operational requirements and construction. PEWC electricity operations are profitable but heavy losses on its water operations and lack of external financing of the water construction program have placed the corporation in a precarious financial situation. Abolition of the PEWC's Board of Directors in 1969, reversion from the status of an autonomous corporation to that of a Government department, stagnant water tariffs, deteriorating financial management (notwithstanding six years of employment of management consultants) and the utilization of revenue surpluses derived from its electricity operations (primarily due to high tariffs) to finance operational losses and construction of water supply, have resulted in a weak organizational structure for electricity supply and lack of a clear strategy for development of the power sector in Sudan. Lack of coordination between PEWC and the Ministry of Irrigation and Hydroelectric Power has also led to suboptimal use of available facilities and an inability to prepare economic programs of expansion in time.

2.03 Among the measures planned by GRS to redress the situation are to:

(i) enact the PEWC Act of 1975 which would restore full autonomy to the Corporation, reconstitute the Board of Directors and enlarge its functions in regard to planning and investigations (these steps have now been taken);

(ii) increase water tariffs consistent with past undertakings with the Bank and raise electricity rates to meet recent increases in fuel costs and wages;

(iii) separate the accounts of the electricity and water operations from FY1973/74, imposing a restriction on interdepartmental transfer of revenue surpluses; with a simultaneous study, with the assistance of the Electricity Council of the United Kingdom (ECUK) of the advantage or otherwise to the Sudan of continuing these two operations within a single utility;

(iv) reorganize PEWC administrative structure on lines suggested by the ECUK in 1973/74, and to contract with ECUK a comprehensive 2-year program of management assistance including the setting up of a proper planning organization;

(v) undertake a comprehensive power market survey, carry out investigations of specific schemes, and prepare a long-term power development plan for the period 1975-1990 using consultants and the planning unit mentioned at (iv) above; and

(vi) arrange for better coordination between the Ministry of Irrigation and Hydroelectric Power and PEWC to ensure optimum use of existing multiple-purpose storage reservoirs and on future hydroelectric projects. On the financial side, the above measures would provide PEWC with revenue surpluses adequate to meet the entire local costs of its construction program through 1980, with IDA/ADB loans and likely foreign loans and grants covering foreign costs.

2.04 On other aspects of policy, the mission recommends that:

(i) the present centralization of responsibility for electricity supply in the country should continue;

(ii) cost-reflecting tariffs should be introduced to encourage full use of available hydroelectric power (in seasons of abundance) and discourage consumption during periods (such as dry seasons of the year and peak hours) when costs are disproportionately high;

(iii) steps should be taken to increase the security of supply in the Blue Nile Grid where PEWC presently plans to meet all demands, but some industrial consumers are deterred from connection to the grid by PEWC's poor supply standards and resort to self-generation;

(iv) PEWC should change its policy in towns outside the Blue Nile Grid - where it currently plans no large expansions forcing new industries to resort to self-generation - to the nationally more economic alternative of connecting all consumers who are willing to pay the cost of supply; and

(v) PEWC should develop a policy of acceleration in electrification of small towns outside the Blue Nile Grid.

2.05 In the Southern Region the small amount of power required and the large size of the White Nile (Bahr El Jebel) River render a hydroelectric development unlikely until the mid-eighties. Mapping and collection of basic

data by GRS (as outlined and agreed) is an essential prerequisite for a feasibility study in 1978-80. A 5-MW diesel installation and an improved distribution system in Juba is the best interim solution and will meet electricity requirements of Juba until 1980. Useful small hydroelectric developments are possible on other small streams to meet requirements of remote centers such as Yei and Katire - Torit. Surveys and collection of data by GRS have been suggested in this connection.

## III. THE ENERGY SECTOR

### Energy Resources

3.01 Hydroelectric power is the only indigeneous source of commercial energy in the Sudan, there being no known reserve of fossil fuel. The country's non-commercial sources are forest and vegetable wastes; charcoal and bagasse (crushed sugar cane) are used fairly extensively for direct heat.

3.02 Pursuant to the Petroleum Resources Development Act of 1958, a number of oil exploration licenses were granted along the Red Sea Coast, but did not lead to any significant discoveries. In January 1974, the GRS signed a contract with American and British firms to renew the exploration efforts in the Red Sea area and commence exploration in Western and Southern Sudan.

3.03 The Government plans to extend Sudan's oil refining capacity of about 1.25 million tons per year by building a new refinery, also in Port Sudan. This project would be financed by private capital from Saudi Arabia and, with an annual capacity of 10 million tons, most of its production would be exported. A pipeline for "white oils" between Port Sudan and Khartoum with the initial capacity of 650,000 tons per year is under construction and will be in operation towards the end of 1976; the final capacity of this pipeline would be 1 million tons per year. The pipeline would probably have little effect on fuel prices in Khartoum and in the Western and Southern provinces of the country, but could improve substantially the reliability of supply which is subject to frequent interruptions due to railway transport problems.

### Hydroelectric Potential

3.04 The Sudan's hydroelectric resources have not been explored systematically, though limited investigations have been carried out during 1957-1963 for specific purposes. 1/ Consequently, available information on these potentialities is sketchy; but it is useful and illustrative.

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1/ In 1957 Siemens Schuckertwerke of Germany prepared reports on the development of sites on the Nile at Sabaloka, Berber and Merowe primarily from the point of view of meeting electricity requirements of Khartoum, and in 1963 Merz and McLellan of the UK reviewed the above and other possibilities (notably at Roseires, Sennar, thermal and others) in their 'Report on Electrical Power Development' which was confined to the requirements for the next 15 years.

3.05 The major possibilities of development of hydroelectric power are located in (a) the 168 km stretch of the Bahr El Jebel (one of the names for the White Nile in its upper reaches) in the extreme south of the country, in which the river level drops by about 162 metres, and (b) the Sabaloka gorge and the fourth and fifth cataracts of the Nile, located north of Khartoum. Apart from these construction of the Roseires storage dam at Damazin on the Blue Nile for irrigation has provided the opportunity for the first major hydroelectric project in the Sudan (90 MW, completed in 1972); its second stage of development, involving heightening of Roseires dam by a further 10 meters (increasing the storage from 3,000 million $m^3$ to about 7,600 million $m^3$) would provide additional potential at the Roseires Dam and at sites downstream. Besides these, there are possibilities of hydroelectric development on small tributaries. These possibilities, the installed generating capacity existing and ultimately projected are listed in Annex 1.

3.06 It is only possible to estimate approximately the probable annual energy generation, as this would depend on the degree of regulation of river flow achieved by construction of storage reservoirs, the extent to which the regulation subserves the interests of maximising hydroelectric generation during the periods of low river flows (which could conflict with irrigation uses) and, finally, the power market's ability absorb large seasonal energy generation. It is estimated that the total annual energy production from all those sites, when fully developed, would be of the order of 8,000 GWh. This compares with 380 GWh from 105 MW of existing hydroelectric generating capacity which is limited by present market and other constraints.

3.07 Hydroelectric installations on the Nile operate under modest heads ranging from 6 m to 36 m. During periods of reservoir draw down and high river flows, their effective capacities are greatly reduced--the existing Roseires and Sennar Dam power stations lose 40% of their normal capacity in this period. Optimum utilization of hydroelectric potential therefore requires thermal back-up. Further, close coordination is required with the development of irrigation, in view of the effect of irrigation releases on reservoir draw-down and the amount of water that could be utilized during critical periods (as the periods of maximum electricity demands - April to May - do not coincide with periods of maximum irrigation requirement from storage).

3.08 Close coordination with irrigation development is also required because the Nile is a large river and nowhere are there sites where a small dam could be built, at low cost, to supply a modest power installation. Existing hydroelectric developments have, therefore, all been at sites of storage dams built essentially for irrigation, the capital costs of the dams being borne entirely by irrigation. The Sennar Dam was constructed for irrigation in 1925; and the 15-MW power station at Sennar was constructed in 1962 by the Ministry of Irrigation and Hydroelectric Power and handed over to the PEWC for operation, which took over only the cost of the power installations.

The same principle applied to the 12-MW Khashm El Girba and 90-MW Roseires hydroelectric installations. 1/

3.09 The mission was informed by the Minister of Irrigation and Hydroelectric Power that the position mentioned at para 3.08 has been modified by two recent developments, (a) the high price of imported oil placing a higher premium on hydroelectric power and requiring the use of stored water for optimum generation of power and irrigation benefits rather than for irrigation only as in the past, and (b) the assessment that roughly half of the 4,600 million $m^3$ of additional storage that would be afforded by increasing Roseires dam by 10 m would meet the ultimate requirements of irrigation development in the Blue Nile Valley, leaving the balance available for maximizing electricity generation. The cost of heightening the dam is estimated at ŁSd 30.0 million at 1973 prices and it is unlikely that more than a fraction could be justified by the additional power benefits. However, the cost that could be borne by the power sector would increase when the consequential benefits of additional generation at Sennar, Sabaloka, and other downstream sites are also considered.

3.10 In the recent past, coordination between PEWC and the Ministry of Irrigation and Hydroelectric Power has not been satisfactory. A number of measures have since been agreed to ensure the coordination required in future between the PEWC and the Ministry of Irrigation and Hydroelectric Power both for operation of existing resevoirs to ensure maximization of benefits from existing facilities, and investigations and coordination of planning of all future projects on the Nile involving hydroelectric generation; these are detailed in paras 4.18 - 4.23.

Energy Demand and Supply

3.11 Commercial energy requirements in 1974 aggregated about 780,000 tons of petroleum equivalent. Ninety six percent of these requirements were met by imported oil and the remainder by hydroelectric generation. Demand for commercial energy has increased during the seven years between 1966 and 1973 by 5% annually, with consumption of hydroelectricity rising at a much higher rate (30% per year) from its low share of less than 1% of total energy demand in 1966. Energy consumption per capita is 52 kg of petroleum equivalent, which is somewhat below the average in Africa. 2/

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1/ At Roseires, exceptionally, the construction of the power house superstructure and the installation of generating sets were carried out by the PEWC, with the assistance of the first Bank power Loan 522-SU. In view of what is stated in para 5.07, the 12-MW capacity of Khashm El Girba has been excluded from the aggregate figures given in para. 3.06 and Annex 1.

2/ The African average consumption was 62 kg in 1969. The average for all developing countries was 250 kg in 1972.

3.12 The transport sector utilizes 40% of all energy; agriculture 25%, 1/ industry 20%; households 10%; and the public sector, the remaining 5%. It is of interest to note that at the intermediate stage of conversion of energy, electricity generation accounts for 10% of the country's fuel consumption. The energy requirements are listed in Annex 2.

Future Trends

3.13 The Ministry of Industry has prepared a projection of future commercial energy requirements in the Sudan. According to this projection, energy demand will increase at an annual rate of nearly 8% to over 1.2 million tons of petroleum equivalent in 1980. Demand for hydroelectricity would grow at the same rate, maintaining its 4% share in total energy requirements. Compared to the period 1966 to 1974, when energy demand increased 5% per year on the average at considerably lower oil prices, this projection appears to over-estimate future requirements. However, with no substitutes for imported fuel available - except hydroelectricity - demand for fuel in the Sudan is basically price inelastic. A higher rate of growth of Sudan's economy than in the past (GDP grew per year about 2% between 1966 and 1973), which appears probable, would lead to a higher growth of fuel consumption.

3.14 Recent oil price increases have placed a heavy burden on Sudan's balance of payments. The country paid US$24 million for fuel imports in 1973, i.e. about 5% of its total imports. The cost of fuel imports in 1974 is estimated at US$70 million, about 14% of total imports. If the ongoing explorations for oil in the Red Sea area and in Western and Southern Sudan are not successful, the Sudan will have to allot about 15% of its total spending on imports for oil, even at current price levels.

Non-Commercial Fuels

3.15 The Sudan has extensive agricultural wastes in the form of bagasse and stalks from cotton fields. Absence of indigenous fuel and the high economic cost of imported oil suggests their utilization to the fullest possible extent. Bagasse poses no problems and is used economically and extensively in the sugar factories in the country, primarily as a source of heat. No surpluses of bagasse are available for public electric supply.

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1/ Out of the 4.20 million feddans of irrigated area in the Sudan, 2.26 million feddans are fed by gravity flow systems, 1.65 million feddans by diesel driven pumps and 0.29 million feddans by electricity driven pumps. By 1980 ongoing schemes would increase the area dependent on electrically driven pumps to 1.10 million, and the annual electricity consumption from 88 GWh to 220 GWh. The coverage of gravity and diesel driven pumps is not expected to change significantly in this period. Conversion of diesel driven pump sets to electricity supply wherever feasible is one of the areas of energy planning requiring further study.

On the other hand, the heat content of cotton stalks, currently burnt away in the fields, is considerable; Merz and McLellan estimated in 1963 that the output of cotton stalks of Gezira and Managil extensions alone have an annual electrical potential of 2,250 GWh, enough to sustain a 500-MW station. Further studies are required to overcome the numerous difficult problems of collection and storage of cotton stalks without risk of spreading pests and diseases. Primarily because of the high cost of mobile equipment required in this process and prevailing fuel costs, Merz and McLellan concluded in 1963 that there was no economic merit in pursuing the use of cotton stalks for power generation on a commercial scale. However, the technical feasibility and economic viability of the proposition now need to be reviewed. PEWC plans to carry out a study in the Atbara Valley.

## IV. ORGANIZATION OF THE POWER SECTOR

### Historical Background

4.01 Annex 3 indicates the growth of electricity supply in the Sudan. It was introduced in 1908 when a small 100-kW steam station employing reciprocating engines and direct current was installed at Khartoum. By 1925 its capacity was increased to 500 kW. By this time, the situation called for the introduction of proper modern services of electricity and urban water supply in Khartoum, and the adjoining towns of Omdurman and Khartoum North. A group of British Companies was then invited to negotiate an agreement with the Sudan Government which led, in 1925, to the formation of the Sudan Light and Power Company Limited (SL&PCo). Under this Agreement all the physical assets of the public services as and when provided became the property of the Sudan Government and the company acted as management agents.

4.02 With the growing activities of the Sudan Plantations Syndicate, Wad Medani, the capital town of the Blue Nile Province and center of the Gezira Irrigation Scheme, also needed utility services to provide domestic water and electricity supplies. A further agreement was then negotiated giving a concession to the Wad Medani Light and Power Company; however, as its operations were on a much smaller scale, the agreement stipulated that SL&PCo would provide the local management and technical needs. Coincident with the work of the SL&PCo, the Public Works Department (PWD) of the Sudan Government also intiated and continued to develop electricity and water supplies in remote areas of the country on a small scale.

4.03 In 1956 the Sudan became a sovereign state. The Central Electricity and Water Administration (CEWA) was set up in 1959 as a Government Department directly responsible to a Minister. CEWA in effect took over the functions of SL&PCo and supplied electricity and water to Greater Khartoum and Wad Medani. In 1962 the first 15-MW hydroelectric station was commissioned at Sennar Dam and the Blue Nile Grid was formed. Over the years PWD continued to expand the number of isolated electrical networks in the smaller towns and villages with diesel generation. By 1963 CEWA's generating capacity had increased

to 42 MW, while the PWD's isolated power stations in the provinces contributed a total of 14 MW.

4.04 In 1966, a new enactment

(a) set up the Central Electricity and Water Corporation (CEWC) to take over the functions of CEWA;

(b) established CEWC as a public corporation (as opposed to a Government Department) with a Chairman and a Board of Directors directly responsible to a Minister;

(c) assigned CEWC the function of supplying electricity and urban water generally throughout the Sudan; and

(d) provided that CEWC would take over all the isolated PWD systems in the Sudan on a date to be decided.

4.05 In 1967, with the assistance of a Bank Loan (522-SU), CEWC embarked on a major program of expansion of its generation facilities with 90 MW of hydroelectric generating capacity at the existing Roseires Dam and a 15-MW gas turbine at Khartoum -- and 220-kV extensions to its Blue Nile Grid. The CEWC took over the operation of all the electricity and water supply facilities operated by the PWD in July 1971. With the exception of some industrial establishments, CEWC 1/ became responsible for all electricity supply in the country. It operates 21 power stations with an aggregate capacity of 198 MW 2/ and supplies electricity to about 130 towns and villages.

4.06 In 1969, PEWC's Board of Directors was abolished by a resolution of the Council of Ministers and the powers of the Corporation were transferred to the Minister in charge. The General Manager, the Corporation's Chief Executive, who, in the absence of statutory authority under the 1966 Act, was running the corporation (with informally delegated authority) was removed from service. The staff lost some of their salary advantages and morale sagged.

4.07 PEWC has not actually adjusted its organization in response to the change from a utility serving the Khartoum area to a national undertaking. The present organizational structure is shown in Annex 4. It is hardly representative of the working of the corporation, as several top posts are either vacant or manned by personnel chosen on the basis of seniority, without the necessary expertise. Actual responsibility for much of the work devolves on staff at lower levels, who, though well educated, work without clearly defined responsibilities and adequate training. There is no forward planning through proper power market studies and investigations of economic alternatives for expansion.

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1/ Under the PEWC enactment of 1975 (para 4.10), the name of the CEWC has been changed to the Public Electricity and Water Corporation (PEWC).

2/ Excludes 17 MW of hydroelectric capacity of Khasm el Girba station. The figure will increase to 210 MW when this capacity, and derating of some old diesel stations, is allowed for (Annex 6).

4.08 In 1972, a Commission was set up by the Government to evaluate PEWC's work and performance, formulate proposals to reorganize it and strengthen its legal position. The Commission recommended, inter alia, reconstitution of the Board of Directors to restore PEWC's autonomy and a study aimed at determining a time schedule within which separation of the water supply and electricity operations could be completed without harming the public interest. These recommendations were not implemented.

4.09 In January 1973, the Electricity Council of the United Kingdom (ECUK) was requested by the General Manager to assist in reorganizing PEWC's electricity operations, reviewing its organizational structure, preparing job specifications for various posts, and setting up appropriate training programs. A report submitted in September 1973 dealt fairly exhaustively with the causes of trouble and their symptoms and presented specific recommendations to deal with them and restructure the corporation. ECUK agreed with the main recommendations of the 1972 Commission (para. 4.08).

The New PEWC Act of 1975; The Executive Administrative Board

4.10 The PEWC Act of 1975 was passed by the National Assembly in April 1975 to reorganize PEWC and, particularly, to restore its autonomy. Under the Act all executive responsibility will vest in an Executive Administrative Board, headed by the General-Manager, with all the necessary powers to frame administrative and financial regulations. The new Act stipulates that the General Manager will be responsible for all the day-to-day work of the Corporation. The General Manager would be appointed by the President of the Sudan on the recommendation of the Minister, while the other members would be appointed by the Minister. The Board Membership proposed by GRS is purely internal, comprising the General Manager, the Deputy General Manager, the heads of departments, and three representatives of unions of PEWC's staff. Two outside members are expected to be added to give the Board greater strength--the Director General, Irrigation Affairs, and one outsider with experience of financial and commercial operations.

4.11 The new Act gives the Executive Administrative Board the authority to develop efficient and financially viable electricity and water supply systems throughout the country, and to carry out all necessary investigations and prepare long term plans. The Board would have full powers to appoint its staff. It would require ministerial approval mainly for its borrowings, approval of PEWC's annual budget and changes in tariffs.

Planning Board

4.12 The PEWC Act of 1974 would also create a Planning Board comprising a Chairman and 23 members, appointed by the Minister and representing government departments, People's Executive Councils in the provinces, trade unions, large consumers and important public personalities. This Board's role is to review general policies and criteria for assigning priorities for PEWC's proposals for expansion, and to make management responsive to the needs of consumers and the country's requirements.

4.13 Although it is more usual for a Board to be independent of the actual operational management, the Executive Administrative Board has all functional responsibilities and neither it, nor the General Manager, will be fettered in the discharge of their day-to-day functions.

Impact of the People's Local Government Act 1971

4.14 The Local Government Act passed in 1971 came into force early 1973. One of its aims was to decentralize civil authority to the fifteen provinces of the Sudan. Commissioners for each province would be given responsibility for public services, though the form of this responsibility has still to be decided. In some cases, in the Southern Region, for instance, the mission was informed by the local authorities that electricity supply had become a local responsibility and that under the proposed Credit, funds for the components of the Sudan Power II project to be implemented in the South should be transferred directly to the Southern Regional organization concerned and not to the PEWC. This view was not shared by the PEWC or the representatives of the Sudan Government at Khartoum (Chairman and Director-General of the National Planning Commission) who felt that electricity supply throughout the country continued to be a responsibility of the PEWC. Handing over responsibility for the isolated electricity supply networks to the Provincial Governments would be an undesirable step at this time in view of the limited expertise available in the country. The Planning Board (para 4.12) provides for local representation from the Provincial Commissions, and this should ensure that the Public Electricity and Water Corporation functions more effectively in the remote areas of the country than in the past.

4.15 It is possible, however, that water supply (other than irrigation which would continue with the Ministry of Irrigation/Agriculture) would be placed under the control of the Provincial Commissions. This is one of the reasons which led the PEWC Reorganization Commission of 1972 to suggest that the time had come for separation of the electricity and water supply functions. GRS and PEWC have agreed that PEWC's water supply operations, and the advantage or otherwise to the Sudan economy of continuing the combination of these functions within a single utility will be immediately reviewed by the ECUK and its recommendations given due consideration.

The Proposed PEWC Orgnizational Structure

4.16 GRS has accepted, in principle, a three-tier organizational structure for the PEWC, with a policy-making and directing head office at Khartoum and functional area and district managements in charge of all operations. Detailed specifications have been drawn up for the key positions of the new organizational structure (Annex 5). ECUK services will be used to implement a comprehensive two-year program, covering assistance in selection of personnel to fill key posts in the new structure, provision of experienced expatriates for periods ranging from one month to two years, where necessary, improvement of management and operations, and intensive training of PEWC staff.

4.17 ECUK has agreed to assist in building up a planning unit which would prepare comprehensive rolling development plans. It has been proposed to organize a power market survey to obtain realistic demand forecasts. Based on these and other data, comprehensive annual development plans would be prepared working five years ahead. Responsibility for preparation of the plan within the PEWC would that of the Chief Electrical Engineer.

Coordination with Development of Irrigation

4.18 The electricity supply industry has to cooperate with a number of outside organizations. One of the most important is the Ministry of Irrigation and Hydroelectric Power. Fifty percent of the electricity generation comes from dams built for irrigation; as demand grows, the proportion is expected to increase to seventy-five percent by 1980.

4.19 The dam structures which provide the power potential in most cases have been economically justifiable only in association with schemes which have been initiated for irrigation and have borne the entire costs of the dams. Electricity therefore has been regarded as a by-product of the dams. The needs of irrigation have had priority over electricity generation but the best overall results are not being achieved. With better planning and close cooperation, water could be released with more attention to the time of day or even to the date. In this way the needs of irrigation would be met just as well as they are at present, but electricity generation would become more economical and secure. In connection with Loan 522-SU, a Committee was to be constituted by GRS to coordinate the operation of Roseires reservoir in the best interests of irrigation, power and other needs for water. It has been constituted in February 1974, but has not yet functioned effectively. It is important that it do so.

4.20 A number of improvements in the cooperation between PEWC and the Irrigation Department have been suggested: i) Director-General of the Irrigation Affairs be appointed ex-officio as a part-time member of the PEWC Board (para 4.10), ii) better operation could be achieved by the organized exchange and discussion of plans between the staff of the two authorities and iii) it might be desirable sometime in the future for control staff of the Irrigation Department to be located in the same control center as the electricity system-control staff to facilitate better day-to-day working.

4.21 Coordination between these two sectors is also needed in long-term planning and project investigations, as evidenced by the fact that early in 1973, PEWC's consulting engineer, assigned the task of planning the most economic next expansion of the Blue Nile Grid, could not obtain authentic information needed on the pattern of irrigation releases from Roseires reservoir and ultimately relied on estimates of his own.

4.22 The Ministry of Irrigation and Hydroelectric Power is basically responsible for delivering water to irrigated fields through gravity schemes but it also operates pumping schemes on the White and Blue Niles, and exercises general supervision over basin irrigation of the main Nile. It has

technical responsibility for agricultural reform schemes. Traditionally, it has carried out investigations of the feasibility of hydroelectric development at sites of irrigation storage dams (para 3.08). After construction of the power stations it has handed them over to the PEWC for operation (para 3.08).

4.23 PEWC, operating independently, under other ministries, did not undertake any investigations of hydroelectric projects, or prepare a long-term program of schemes for generation, arranged in order of economic priority. Its earlier terms of reference did not specifically require it to do so, but the PEWC Act of 1975 makes this its specific responsibility. In view of what has been stated at paras. 4.17 and 4.18, it is important that all investigations of sites on rivers in the Sudan should be properly coordinated. The GRS confirmed that the Committee for coordination of operation of Roseires reservoir (para 4.19) will, in future, coordinate the investigations of all projects involving hydroelectric generation. If these arrangements are effectively implemented, there should be no need for a major reorganization of ministerial responsibility to combine irrigation and electricity under a single ministry to ensure proper coordination.

Training

4.24 PEWC provides two types of training programs to its staff. Under a recently established program, about 30 engineers are sent each year for practical or academic training abroad for periods ranging from 18 to 24 months. PEWC also runs a 4-year apprenticeship program for skilled workers which includes two years of theoretical training and two years of on-the-job training. The present training program, which is not entirely satisfactory, has been reviewed by ECUK and a more comprehensive program will be worked out and implemented along with the proposed reorganization. The emphasis will be shifted from academic training to practical training both in the Sudan and in the U.K.

## V. POWER MARKET AND SUPPLY SITUATION

### Existing Supply Facilities

5.01 PEWC's existing facilities are listed in Annex 6, which also provides a description of its system. It has a total installed generating capacity of 210 MW (Annex 6, page 1). The total generating capacity of self-generating establishments in the Sudan is about 30 MW.

Past Trends and Present Supply Position

5.02 Electricity supply in the Sudan falls under five broad groupings:

(i) Khartoum and the Blue Nile area, with its 220-kV Blue Nile Grid serving Greater Khartoum, Hassa Heisa, Wad Medani, Meringan, Sennar, Rabak and Damazin (Roseires);

(ii) Eastern area, with a 66-kV Grid serving Khashm El Girba, New Halfa, Showok, Gedaref and Kassala;

(iii) Northern area, serving Atbara, Berber and Damer;

(iv) Provincial undertakings;

(v) Self-generating industries viz Sudan Textiles in Khartoum North, Sugar factories at Guneid and Khashm el Girba, and seven food processing factories.

More than 80% of the total publicly supplied electricity (groups (i) to (iv)) is generated in the Blue Nile Grid; the small Eastern and Northern Grids and the isolated undertakings supply less than 20% (see Annex 3). The systems are not interconnected. Except (i) and (ii) above, where interconnection possibilities may develop, distances involved preclude their interconnection for the foreseeable future.

5.03 Electricity use in the Blue Nile Grid has doubled during the past six years (1967-1973) to 352 GWh (Annex 7) but has not kept pace with the historical growth rate of 16.4% per annum in the preceding 5-year period. Industrial consumption accounts for 43% of the total sales followed by domestic consumption with 36%. The share of agriculture has increased from 6% in 1967 to 12% in 1973.

5.04 The growth of maximum demand on the Blue Nile Grid from 48 MW in 1967 to 82 MW in 1973 has been slower than the energy growth rate, as the system load factor increased by about 10% in this period. The annual system load factor is presently about 60%.

5.05 The power market in the Blue Nile Grid is characterized by marked seasonal variations, which are significant both for system operations and for planning capacity expansions. The maximum requirement (both demand and energy) occurs in April and May (when the agricultural processing industries, mainly cotton ginneries, work to full capacity) then falls off sharply by abmut 15-20% during the rains (July-August). The demand increases again to its maximum when irrigation pumping resumes in October. The needs of irrigation pumping and agricultural industries are complementary, but for a short interval in the winter, the demand slackens. With the increasing share of irrigation pumping, the October peak has recently been moving towards the April-May demand.

5.06 The power supply situation in the Blue Nile Grid is currently satisfactory in that adequate generating capacity is available to meet the current maximum demand and, given proper coordination between PEWC and the Ministry of Irrigation and Hydroelectric Power in the use of Roseires reservoir, there should be no shortage of firm energy to meet energy generation requirements. The distribution systems are generally of adequate capacity. However, difficulties with Roseires generating units and transmission line failures have contributed to unreliable supply, and uneconomic operation of thermal installations at Khartoum, which are maintained as emergency reserves, longer than would otherwise have been necessary.

5.07 Although the Eastern Grid has an installed nameplate generating capacity of 17 MW, the load carrying capacity is limited to about 5 MW -- the capacity of the diesel installations -- because the use of hydroelectric power at Kashm El Girba station has been severely restricted by the increased irrigation water requirements and a recent Government decision to curtail all downstream water releases. The demand has already exceeded the available firm capacity in this area.

5.08 PEWC has little reliable detailed information on the growth of electricity supply in the isolated provincial supply areas. The position in the Southern Region has been separately detailed in Chapter VIII. In some of the towns, e.g., Atbara, El Obeid, Port Sudan, there are prevailing shortages and restrictions in supply with no new consumers connected since 1967. In El Obeid alone there is a waiting list of 4,000 domestic consumers and 200 light industrial consumers.

5.09 Among self-generating industries, the textile industry and Port Sudan Refinery have the largest installations adequate to meet power requirements. With bagasse available as fuel the sugar industry is able to minimise oil consumption. Further expansion of the sugar industry is rightly being planned on the basis of self-generation. Apart from this, GRS has a plan under consideration to set up a petro-chemical complex at Port Sudan with captive power installations of adequate capacity to meet anticipated requirements. Except that the plans are ambitious, the mission could gather no detailed information.

Future Power Demand

5.10 PEWC does not have the expertise necessary to carry out the detailed power market surveys required for its complex system in which the peak demands and energy requirements have seasonal variations. The short-term (5-year) forecasts mentioned above were inadequate, for long-term planning. Figures forwarded to the Bank, after a brief review by PEWC's consultants, were found to be overestimated by 50%, looking barely a year ahead. PEWC has now agreed to initiate a long-term power market survey utilizing experienced consultants and the planning units within PEWC which would gain experience of this work and thereafter continue it.

5.11 As PEWC's most recent forecast of annual electricity requirements of the Blue Nile Grid up to 1980 could not be taken as realistic, PEWC prepared separate low, median and high forecasts (Annex 8) of maximum demand and energy requirements during the mission. PEWC also provided detailed evidence of developing industries and progress of large irrigation projects (which account for 30% of the increase in demand) to support acceptance of its low forecast as an adequate basis for projection of revenues. As this estimate did not provide any allowance for unforeseen loads, it was agreed that planning for generating capacity expansions should be based on PEWC's median forecast. According to the median forecast, maximum demand would grow over the next eight years at an average annual rate of 11% reaching 206 MW in 1981/82. Energy generation would grow faster at 12% per year to 1,180 GWh in 1981/82.

5.12 Growth of demand in the Southern Region has been covered in Chapter VIII. As stated in para 5.08, PEWC has little detailed information on historical trends in growth of demand in provincial areas, which have been brought under its scope in 1970. Its hesitant approach to the question of expanding its facilities to meet all expected demands in these areas has also been covered (paras 6.01 and 6.02). Even in areas where it has programmed expansions, they are very modest based on meeting the most compelling demands.

Expansion Program - Current and Long-term

5.13 PEWC's short-term expansion program (1974-1979) in the Blue Nile Grid aims at covering a shortage of generating capacity of 53 MW expected by 1980 on the basis of projections indicated at para 5.11 above by (a) a fourth 42-MW hydroelectric generating unit at the existing Roseires power station, (b) 15 MW of diesel capacity at the Burri station, near Khartoum, and (c) complementary extensions to the Blue Nile Grid (see Map 1).

5.14 The interim expansion program in the Southern Region (1974-1976) has been detailed in para 8.12. In addition, PEWC has undertaken to expand diesel generating capacity by a total of 15 MW, during 1975-1977, at Atbara, Port Sudan, Khashm El Girba, Gedaref and El Obeid.

5.15 The above program should meet the currently anticipated demands in the Blue Nile Grid until about the end of this decade. PEWC's long-term expansion program in this region is inevitably uncertain in view of what has been stated earlier (paras 5.10 and 5.11). It is expected that by 1976, when the results of (a) the long-term power market survey, (b) investigations of all feasible alternatives for expansion, and (c) preparation of a development plan for 1980-1990 have been well advanced, it would be possible to obtain a clearer picture of the most advantageous next step. This most likely would be either:

(i) partial heightening of Roseires dam (for limited purposes of power generation) and installation of additional (up to three) 42-MW generating sets;

(ii) 10 m heightening of Roseires dam (for both irrigation and power generation) and installation of additional generating sets;

(iii) installation of new power stations at Jebel Aulia or Sennar, or development of the new Sabaloka site, or

(iv) further extension of diesel/thermal capacity.

5.16 An amount of ŁSd 230,000 has been provided under the Rahad Irrigation project for foreign costs of investigation of a Stage II development project which would cover the best use of Roseires reservoir (including heightening of the dam) for development of both irrigation and electricity generation. Eighty percent of the costs would be provided under IDA credit 364-SU and the balance from the Kuwait Fund. These investigations would cover items (i) and (ii) of para. 5.15. The proposed IDA credit for Sudan Power II project, scheduled for FY 1975, provides ŁSd 380,000 for item (iii) and the associated power market survey (item b, para. 5.15).

5.17 In the Southern Region, after GRS has collected the basic engineering data required, the feasibility study of a modest development of Bahr El Jebel near Juba, and a complementary power survey would have to be undertaken. It seems likely that modest hydroelectric schemes in the upper reaches of the Kinyeti Valley and at Yei would also have taken shape by then.

## VI. PLANNING AND INVESTMENT

### Planning in the Power Sector

6.01 PEWC is responsible for all planning in the power sector. It has estimates of financial outlay, looking five years ahead, which are revised annually after coordination with the Government. The Government plays a passive role and its impact is apparent only on the small town electrification program where it preferred a larger program. This is broadly consistent with the approach of GRS that PEWC should not depend on Government sources for its finances. In PEWC, planning is performed by two divisions: one under the Chief Electrical Engineer which plans transmission and distribution expansion, and the other under the Chief Mechanical Engineer, which is responsible for new generation facilities. Insufficient coordination between the two has resulted in avoidable expenditures. For example, in several small towns (Dongola, Nyala, Um Ruaba) diesel power stations were built, but the distribution system was constructed a year later. The planning process in PEWC is unscientific, slow and uncoordinated with the growth of the market. No systematic power market surveys are carried out; in the smaller isolated centers existing and prospective larger industrial and agricultural electricity consumers plan to satisfy their needs by self-generation, since PEWC does not expand or install generating capacity in time. It has been agreed that the

planning unit referred to at para 4.17 will undertake a comprehensive program - covering a long-term power market survey, investigation of specific projects, and preparation of a development plan for 1975/1990 based on least cost solutions. Funds for consultancy assistance for this has been provided in Sudan Power II Credit.

6.02 In the past, there has not been a clearly defined development strategy for the power sector. Different planning criteria were used for its expansions in the Blue Nile Grid, isolated areas and small towns/rural areas. In the Blue Nile Grid which is supplied by cheap hydro power, PEWC's plans were made to satisfy all demand. The position in towns outside the Grid areas with existing public electricity supply, has been explained in paragraph 6.01. (Exceptions are the large towns of Atbara, Port Sudan and New Halfa where supply facilities have been expanded). In small towns and rural areas, which are presently without electricity and where it can be introduced only at a financial loss, there has been no significant development. 1/

6.03 The mission suggests that PEWC should plan expansion of electricity supply on the basis of the economic rate of return criterion. Investments in the power sector should have an economic return which is not lower than the return on investments in other sectors of the economy. When calculating the economic rate of return, capital and operating costs of an investment should be valued at economic prices taking especially into account the scarcity of foreign exchange and unemployment. Economic benefits of power investments in urban areas of the Blue Nile Grid and in large towns outside the Grid are adequately represented by revenues from power sales. But, in small towns and rural areas presently without electricity, economic benefits of electrification would be higher than revenues due to external effects on economic development. On the cost side, economies of scale which are currently not taken into account, should be considered. In the Blue Nile Grid and in larger towns outside the Grid integration of isolated diesel power stations into the public supply system would save fuel and create larger systems, reducing the overall cost of supply. Rural electrification in the Blue Nile Grid should take into account only the incremental cost of supply. In cases where transmission and distribution investments are justified by and made for irrigation, they should be excluded.

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1/ An electrification program for 80 towns and villages was established in the Ministry of Works which subsequently was reduced to 30 centres. The program was abandoned as unprofitable by PEWC, when the Corporation took over all public electricity supply in the Sudan. Seven towns were put back into PEWC's development plan at the request of the Government, but PEWC postponed most of the program to the second five-year plan (1974/75 - 1979/80). PEWC has shown the same reluctance in rural electrification of some villages in the Blue Nile area. This project has become feasible only after the Gezira Farmers Union financed 50% of the investment cost.

6.04 Applying these planning principles in the Blue Nile Grid, PEWC should continue its present strategy of expanding supply to all urban consumers who are willing to pay the cost of supply. PEWC's main problem here is to increase the security of supply with improved operation of Roseires power station, strengthening of transmission lines and better maintenance. This would induce some large industrial consumers presently supplied by their own diesel units to connect to the public grid at a considerable saving of fuel. In larger towns outside the Blue Nile Grid with isolated supply systems, where electricity supply is financially viable, PEWC should modify its present policy and increase the generation and distribution capacity so that all potential consumers can be connected. In addition PEWC should progressively take over the installations of self-generating establishments in these towns and provide larger and more efficient generating units, thus reducing the overall cost of supply.

6.05 PEWC's present rate of electrification of small towns -- one to two towns per year during the next five years -- is modest and could be increased to the advantage of the economy. PEWC has sufficient staff to plan, install and operate more isolated supply systems, but Government's and PEWC's ability to subsidise electrification limits the size of the program. Calculations performed by PEWC and the mission demonstrate that subsidization of small town electricity supply during the first years after the installation of a system is necessary, since cost-covering tariffs would be so high that most domestic consumers could not afford electricity. Further, the calculations showed that the financial rate of return on investments in small town supplies would be low, but when adjusting financial cost for high duties and taxes on imported equipment and fuel and shadow pricing foreign exchange cost, it would approach the estimated opportunity cost of capital in the Sudan. Taking into account that the benefits of electrification are usually higher than reflected by revenues, then small town electrification is economically viable in the Sudan. The mission proposes that PEWC prepare a small town electrification program taking into account the evaluation of economic benefits. Within this program, a schedule should be prepared listing the towns whose electrification would satisfy the two criteria viz (i) Only those towns should be electrified where revenues can be expected, after a time of no more than 5 years, to cover operating cost including depreciation; and (ii) The rate of return on investment of electrification of a small town, after deducting from the cost of investment and operation taxes and import duties, should be at least 7%, assuming that the opportunity cost of capital is about 10% in the Sudan. The difference between the two rates would likely be covered by the additional benefits of electrification not represented by revenues.

6.06 There are 47 small towns in the Sudan, each with over 5,000 inhabitants still without electricity supply, most of which would probably satisfy the two proposed criteria. The amount of subsidies available would, therefore, determine the number of small towns which can be electrified each year. PEWC is being burdened with losses in its water supply operation and it finances its investment program in both sectors without Government assistance. PEWC's ability to subsidize an electrification program is limited and has to be

supplemented by Government subsidies, if a sizeable program of, say, 5 to 7 towns per year is to be established. PEWC should develop alternative programs of small town electrification involving different levels of subsidies for investment and operation and determine, together with Government, a financially feasible program.

6.07 Applying the same criteria to rural electrification in the Sudan, only areas supplied by the Blue Nile Grid can be economically connected to electricity supply. Incremental costs of supply in the Blue Nile Grid are comparatively low, due to the large proportion of hydro power and small incremental investment cost, when constructed in accordance with the ongoing program of electrification of irrigation pumps. However, even here electricity supply tends to be a financial loss during the first years. The 1967 Act provided that Government would subsidize operational losses in areas not programmed for connection by the PEWC and where the extensions are directed by the Government. GRS has recently embarked on an extensive program of electrification of 140 villages outside the Blue Nile Grid. A preliminary examination shows that most of these centres would not satisfy economic criteria. GRS is implementing the scheme directly as PEWC did not agree to undertake it. In view of this, it is important that not only PEWC, but GRS should also adopt the economic criteria referred to in paragraph 6.05. GRS agrees.

Investment in the Power Sector

6.08 In the Sudan's first five-year plan for 1970/71 - 1974/75, the total planned public investment was ŁSd 200 million, of which PEWC's program in the power sector was about ŁSd 14 million, or about 7%. Actual expenditures indicate a different picture. During the first four years of the plan, about 80% of planned expenditures were realized in the power sector, whereas the actual investment in the public sector reached only 40% of the plan. PEWC's investment expenditures during the three years 1970/71 - 1972/73 were ŁSd 8.9 million, or 14% of total public investment of about ŁSd 65 million, which is about average for African countries. For example, in Zaire power investment has varied between 18% to 27% of the total public investment in recent years (before construction of Inga II power station and of the Inga-Shaba transmission line). In Kenya, about 10% of public investment have been spent in the power sector. Past investment in Sudan's power sector appears, however, more modest when viewed in the context of overall economic activity. Power investment was only about 0.5% of GDP, compared to 2% in Zaire and 1% in Kenya, reflecting the low level of public investment in the Sudan compared to Zaire and Kenya (public investment was 4% of GDP in the Sudan, but 9% in Zaire and 10% in Kenya).

6.09 Eighty percent of the ŁSd 8.9 million invested in the power sector in 1970-1973 was spent on the Roseires power project and on transmission and distribution expansions in the Khartoum and Blue Nile areas. The two main projects for expanding electricity supply to new areas, the electrification of villages in the Gezira irrigation area and the 20-town-electrification program, were dropped from the five-year program.

6.10 Investment for rural electrification was small at ŁSd 40,000 in 1973/74 for a few villages in Dinder. Small amounts were continuously spent on the electrification of villages in the context of the electrification program for diesel irrigation pumps in Blue Nile area. However, the main project of rural electrification, the Gezira village electrification, for which consultants prepared a study in 1969, was not implemented, although ŁSd 320,000 had been provided for in the five-year plan for this purpose.

6.11 The Government has not yet presented its Second Five-Year-Plan 1975/76-1979/80 and plans for future public investment are not definitely known. PEWC has prepared an investment program until 1980/81 (Annex 9) showing expenditures of ŁSd 37.7 million at 1974 prices, roughly ŁSd 5.4 million per year on average. This is about twice the amount spent annually in the past and power sector investment should rise above 2% of GDP. In spite of the heavy investment planned for the extension of the Blue Nile Grid, the program is regionally more balanced than the earlier ones. About 40% of the investment program is planned for Khartoum and the Blue Nile Grid compared to 80% in the past. Twenty percent (ŁSd 6 million) will be spent in other areas - Juba, electrification of seven towns, and the ADB project - which have not received any investment at all during the past four years. The remainder is still unidentified, but it can be expected that with an enlarged small town electrification program and a reinforcement of existing isolated supply systems about 40% of this amount would be spent outside the Blue Nile Grid and 60% in the Grid.

Access to Electricity Supply

6.12 While per capita consumption of electricity in the Sudan (24 kWh) is one of the lowest in the world, a relatively large part of the population has access to supply. Eighty percent of the Sudan's urban population lives in towns 1/ with electricity supply and between 1.1 and 1.3 million people -- 8-9% of the total non-nomadic population--have access to electricity. This compares favorably with other African countries; e.g., in Zaire only 2% of the population has access to supply, in Cameroon 3%, and in Kenya 5-6%. In Ivory Coast, where GDP per capita is US$340 compared to US$110 in the Sudan, about the same percentage of the population as in the Sudan is connected to electricity. Even rural electrification in the Sudan is relatively advanced. Ninety-one villages, most of them on the outskirts of Khartoum and in the irrigated areas of the Blue Nile province, have electricity supply, but their population is only a small fraction of Sudan's 10.6 million, non-nomadic, rural dwellers.

6.13 Regionally, electrification is concentrated in the Khartoum and Blue Nile provinces, where 50% of the country's urban and 40% of the total population live. Seventy-five percent of PEWC's connections are in these two provinces and only 3 of the 28 towns are without supply. Access to electricity

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1/ In accordance with the 1973 census, a town is a locality with more than 5,000 inhabitants.

supply is more limited in provinces which are distant from the developed part of the country around Khartoum. In Kordofan province, for instance, only 1 out of 15 towns is electrified. Similarly, in the three provinces of the Southern Region, Equatoria, Bahr-el-Ghazal and Upper Nile, only 3 towns -- one in each province -out of 14 have public supply. In the whole of the Sudan, 40 towns of a total of 87 are electrified, leaving several urban centers with more than 25,000 inhabitants without public supply. For details of the level of electrification in the Sudan see Annexes 10 and 11.

6.14 The small-town-electrification program (para. 6.02) would extend power supply to an area with some 200,000 people, although during the early years only about 200-300 connections per town are expected on the average. Of the 20 towns tentatively identified, 1/ 11 towns will be electrified in the Northern, Eastern and Darfur provinces, where urban power supply already is widespread. The remaining 9 urban centers to be electrified are in the Kordofan province and in the Southern Region where the use of electricity is least widespread. The program is shown in Map 2.

6.15 Access of new consumers to public electricity supply is limited by several factors. The most important reason is the size of the country and the regional distribution of the population. Most of the country's 12.2 million rural dwellers live in low density areas, where economic electricity supply is not feasible. This is particularly so for the 1.6 million classified as nomads. Electricity could be extended economically only in the irrigated areas of Blue Nile and the Eastern provinces and on the outskirts of larger towns where rural population density is relatively high and sources of supply are not distant. The size of the country also limits the access to supply of a large part of the urban population. Cheap hydro power is available to consumers in Khartoum and Blue Nile provinces and, in the future, to the Northern and Eastern provinces; in the rest of the country, thermal power is the source of supply, which is expensive partly due to high cost of oil and its transport.

6.16 In March 1974, furnace oil was priced at £Sd 14.00 per ton in Port Sudan, £Sd 18.65 in Khartoum and £Sd 23.58 in the Western and Southern provinces, the differences between the prices indicating the high cost of transport. Although substitutes for electricity may be even more expensive, high tariffs in the isolated systems resulting from the high cost of supply would limit expansion of electricity supply to a comparatively small number of households with above-average incomes. In addition, PEWC charges a connection fee of about £Sd 6.00 and a deposit of £Sd 3.00, which is more than half a month's salary of a Government worker. In some areas (e.g. Malakal and Wau in the Southern Region) spare capacity exists but high tariffs and the cost of connection deter additional consumers from connection. Consideration should be given to lowering connection charges in the isolated grids.

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1/ Assistance for this expanded program is being obtained from the Federal Republic of Germany.

## VII. PEWC's FINANCES AND TARIFFS

### Finance

7.01 PEWC has experienced serious difficulties over the past 5 years in the fields of finance and accounting which can be attributed to (i) the absence of well qualified accountants; (ii) the inadequacies of the successive Chief Financial Officers; and (iii) the introduction of computerized billing in Khartoum. Management consultants who assisted PEWC between 1967 and 1973 were of little use. As a result the quality of the data provided by PEWC is poor.

7.02 A financial study of the power sector in itself is further complicated by the fact that PEWC is also responsible for urban water supply and the accounts are not fully separated. The data analyzed below reflect the mission's best judgement on PEWC's overall financial situation.

7.03 Annex 12 shows PEWC's actual and forecast financial results for the 1971 - 1981 period at current prices. PEWC's water operations have been running at a loss since 1971. As GRS did not make funds available to finance the water construction program, PEWC had to use surpluses from its electricity operations for this purpose as well as short term borrowings and working capital. As a result, PEWC's overall liquidity position seriously deteriorated. Introduction of computerized billing caused a rapid increase in accounts receivable and aggravated the problem.

7.04 In the 1971 - 73 period, PEWC's electricity operations earned an average rate of return of 8% and internal cash generation was sufficient to cover 80% of the total cost of the electricity construction program.

7.05 Because of a large increase in the price of oil, in July 1974, PEWC has asked for a 30% electricity tariff increase, and GRS intends to authorize its implementation on July 1, 1975. While the tariff increase will yield an average rate of return of 11% over the next three years, considering that PEWC's assets are undervalued and that PEWC did not contribute to the cost of Roseires dam, the real rate of return will be less than 11%. PEWC is to complete an evaluation of its assets by December 31, 1975.

7.06 PEWC is taking other steps to remedy this situation and the following measures are underway:

(i) ECUK is assisting PEWC in recruiting a Chief Financial Officer; he is to take up the post in the near future;

(ii) ECUK will provide assistance in financial management, budgetary control and computerized billing;

(iii) A successful effort has already reduced the accounts receivable to 5 months' sales equivalent;

(iv) PEWC is to increase its water tariffs shortly to attain a 4% rate of return level and the government has agreed to provide the balance of funds necessary to finance the water construction program; and

(v) From FY 1973/74 onwards, the electricity and water accounts will be separated.

7.07 Over the 1974-1979 period, PEWC's construction program (estimated at current prices) in the electricity sector will amount to ŁSd 43.9 million of which ŁSd 14.9 million will be for generation, ŁSd 9.2 million for transmission and the balance for distribution. PEWC has already obtained a ŁSd 1.6 million loan from the African Development Bank to finance diesel generation sets for four isolated towns and is in the process of obtaining a ŁSd 8.0 million IDA credit which will be used for the Blue Nile Grid extensions, the city of Juba in Southern Sudan and consultancy services. GRS would onlend to PEWC ŁSd 3.3 million to finance the foreign cost of electricity investment for the Rahad irrigation scheme. PEWC's electricity operations will generate the balance of the funds required to finance the electricity construction program in the period - about ŁSd 29.7 million or 65% of the total.

Tariffs

7.08 PEWC's tariffs for the Blue Nile, Khartoum, Northern and Eastern Regions are summarized in Annex 13. They were introduced in 1967 following a study of PEWC's management consultant with the purpose of improving the Corporation's financial position by raising the tariff level. The structure of the prevailing tariffs - a block system, with decreasing rates for higher blocks, and largely independent of the maximum demand - was left unchanged. It was expected in 1967 that the tariff structure would be reviewed and modified prior to the completion of the first stage of Roseires hydroelectric power station.

7.09 When Roseires power station was actually commissioned in 1972 the necessary tariff review was not undertaken. In May 1973, a World Bank mission reviewed the position and recommended that, in the special circumstances of the Sudan - with a great abundance of hydroelectricity in some periods and extremely high costs of providing thermal supply at others - a change in its structure to reflect the cost of supply was urgently needed. Due to lack of reliable information, mainly on investment costs and PEWC's development plans, the mission discussed methods of determining cost reflecting tariffs in the Sudan assuming likely alternative programs. In principle, PEWC agreed to implement the suggestions, by January 1976. The ECUK, who are now providing management assistance to the PEWC, will assist in preparing this new cost reflecting tariff system. ECUK will also propose more appropriate tariffs for the isolated supply systems which PEWC took over from the Ministry of Works in 1972.

7.10 PEWC's prevailing tariff system for Khartoum, Blue Nile, Northern, and Eastern areas differentiates between the following five tariff groups:

- Domestic and Commercial
- Light Industrial
- Agricultural
- Heavy Industrial at 11 kV
- Industrial at 415 V

In the Red Sea area, the bulk and large industrial consumers have individually negotiated tariffs, while all other consumers are charged on the basis of a standard tariff. In the rest of the country, where there is little industry connected to public supply, only the consumption of refrigerators and workshops is excepted from a general flat rate tariff. In the Khartoum, Blue Nile Northern and Eastern areas, the electricity tariff is characterized by sharply declining blocks, the last block for large consumer being 40% cheaper than the first. Domestic and commercial consumers pay much more, on the average, than other groups connected to the same voltage level. Similarly, domestic and commercial consumers in the Blue Nile Province pay more than the same group in Khartoum, although they are connected to the same grid. In the Northern area, which is supplied by expensive diesel power, heavy industry pays less on an average than the same consumer group connected to the cheaper hydro power of the Blue Nile Grid.

7.11 The following table shows the average revenue in mms per kWh for different consumer groups in 1972/73:

| | Domestic & Commercial | Light Industry | Heavy Industry | Agri-culture | Average |
|---|---|---|---|---|---|
| Blue Nile Grid /1 | 24.5 | 17.8 | 10.6 | 10.1 | 16.7 |
| Eastern Area | 32.3 | 28.0 | 16.7 | 12.2 | 21.8 |
| Northern Area | 38.3 | 17.8 | 9.8 | 14.2 | 19.3 |
| Other Areas | - | - | - | - | About 22.0 |
| TOTAL SALES | - | - | - | - | 17.7 |

/1 Khartoum and Blue Nile areas.

7.12 PEWC's tariffs continue to be independent of time of day and season of the year, notwithstanding the fact that in the Blue Nile Grid which

is supplied by thermal and hydro power, cost of supply is heavily dependent on the time of use. In the flood and wet seasons and at the beginning of the dry season, ample low cost hydro energy is available during the off-peak hours of the day and during most of the peak hours; during the rest of the dry season power supply is more costly since hydro power has to be backed-up by expensive thermal generation, especially during the peak hours of the day.

7.13 An analysis of PEWC's tariffs indicates several important defects which need to be removed on the lines suggested by the tariff mission. The most important feature of the new tariff system recommended is its adjustment to incremental cost of supply. In the Blue Nile Grid, a tariff differentiating according to season has been suggested for all larger industrial and agricultural consumers reflecting the changing availability of hydro power in the system. It has been further recommended that larger consumers should be charged according to a time-of-day tariff in all systems. This would tend to raise the load factors of the systems, and to some extent reduce the need for additional generation and distribution capacity. 1/ Apart from differentiating on the basis of the time of consumption, a differentiation on the basis of voltage of connection is justified. Therefore, consumers connected to high voltage should get a reduction. Similarly, there appears to be little justification for charging more to domestic and commercial consumers in the Blue Nile area than the same consumer group in Khartoum.

7.14 The declining block structure of the prevailing tariffs are in most cases unjustified by cost of supply. The last blocks in the large industrial tariff, 7.5 mms per kWh, and the agriculture tariff (9 mms) do not cover even the fuels cost. This indicates the existence of cross-subsidization in PEWC's present tariffs. Small consumers are subsidizing large consumers, and domestic and commercial consumers are subsidizing heavy industry and agriculture.

7.15 The question of subsidization arises also for the smaller isolated supply systems. At present, revenues in some of these sytems (e.g. in Juba, Malakal and Wau in the Southern Region) cover only the salaries of local personnel. In evolving the new tariff, the degree of subsidization should be identified, if any, and a policy should be developed which would define the acceptable amount of subsidies, considering the obligations of the Government under the PEWC Act.

## VIII. ELECTRICITY SUPPLY IN THE SOUTHERN REGION

### Background

8.01 The Southern Region comprises the provinces of Equatoria, Bahr el Ghazal, and Upper Nile, extending 1,680,000 $km^2$ and representing a quarter of

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1/ Prevailing daily load factors are of the order of 75% and the scope for further increase is small.

the Sudan's area. Its population is estimated around 4.3 million. The mission was required to focus attention on the power needs of this Region, and to advise on the steps that could be taken to meet immediate requirements. In the context of meeting the immediate requirements of Juba, the rapidly expanding headquarters of the Southern Regional Government, the mission was specifically required to consider the possibilities of development of the hydroelectric potential of the rapid stretch of the White Nile (Bahr El Jebel) near Juba.

Existing Demand/Supply Situation in Juba

8.02 Records of output and sales of the existing electricity supply system in Juba are non-existent. Readings taken recently indicated a maximum demand of under 700 kW at the Juba power station. The demand is quite evidently suppressed by inadequate generation and poor distribution facilities.

8.03 The existing generating plant is antiquated and inefficient. It consists of 5 Ruston generators of 76.5-KVA rated capacity, installed in 1953; two 235-KVA Ruston sets installed in 1965; and one 394-KVA English Electric unit acquired from the Roseires construction power station in 1972 after being in operation there for a decade. The distribution system comprises 11 miles of 3.3-kV overhead lines with about 16 miles of low voltage distribution lines. House service lines are in extremely poor condition.

8.04 The power supply problem in Juba is further complicated by the fact that the 394-KVA English Electric set cannot be operated in parallel with the Ruston sets with the existing switchgear arrangements at the power station. During periods of maximum demand the distribution system in the city is therefore sectionalized and the generating sets are arranged to feed the market separately. These switching operations cause frequent and prolonged interruptions in power supply to consumers. Further power reductions are necessitated by the need to limit total output to the capacity of the generators. There is an urgent need for a power station with new generating equipment and an upgraded distribution system in the town of Juba.

Growth of Demand in Juba

8.05 Assessment of the existing demand is itself difficult as metering is insufficient and faulty. Revenue figures cannot provide an indirect indication of the demand due to poor billing and unsatisfactory collections. Under the circumstances, estimates of existing demand and growth are subject to uncertainty.

8.06 Existing connections total 1,319, of which 1,084 are for domestic consumers, 204 for commercial enterprises (shops, offices, etc.) and 31 for light industries (including workshops, grain mills, cigarette factory and a few others). Records indicate that PEWC's water pumps in the power station compound utilize roughly 30% of the energy output of the station.

8.07 The population of Juba has expanded considerably in recent years. The total population is believed to be of the order of 70,000. Only 10% of the households have electrical connection at present, limited by generating capacity and PEWC's ability to connect new consumers. Apart from some 100 pending applications, the Regional Ministry of Housing and Public Utilities has a plan for construction of 2,800 houses during the next ten years, of which 2,000 would be financed by the Government of Kuwait. Since very few electrical household appliances (such as air conditioners) are in use, domestic demand should increase fairly rapidly given adequate and more reliable power supply.

8.08 Juba is the largest urban center and also the main (river) port of the Southern Region. There is very little light industry in the town; almost all processed and manufactured goods are imported. With the gradual return to normalcy after the hostilities of the last decade, it is expected that the market for all types of goods, and particularly the demand for the outputs of light processing and manufacturing industries, will expand quite rapidly. Twenty-eight applications for power supply have been received by the Regional authorities for the establishment of a wide variety of industrial enterprises, including grain and oil mills, spice mills, soap factory, a brewery and a soft drink plant. It is difficult to assess how many of these enterprises will actually be set up, but the list of applications is clearly indicative of the substantial expansion in industrial power demand which could take place in the near future.

8.09 Another significant block of demand to increase rapidly is that of government agencies and the water supply system. Juba is the seat of the Regional Government of the South and a number of public buildings, financed by the Yugoslavian Government, are nearing completion; they comprise a House of Parliament, and 10 buildings to house Ministries. Additional demand in the public sector is expected from army camps, a new cultural center, a hospital, several schools and training centers and from street lighting and there is a program underway for the extension of water supplies which would require additional electricity for pumping.

8.10 On the basis of the information collected by the mission, it is estimated that the level of unrestricted 1/ peak demand by the end of 1973 was about 700 kW and can be expected to expand as follows:

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1/ Allows a margin of 10% for the result of prevailing restrictions.

| End of Year | Public Sector | Commerce & Industry | Households | Water Supply & S/Light | Total |
|---|---|---|---|---|---|
| | | | kW | | |
| 1973 | 250 | 140 | 200 | 110 | 700 |
| 1974 | 350 | 220 | 300 | 130 | 1,000 |
| 1975 | 1,530 /1 | 300 | 400 | 250 | 2,480 /1 |
| 1976 | 1,600 | 360 | 500 | 260 | 2,720 |
| 1977 | 1,700 | 430 | 600 | 270 | 3,000 |
| 1978 | 1,800 | 520 | 700 | 280 | 3,300 |
| 1979 | 1,900 | 620 | 850 | 290 | 3,660 |
| 1980 | 2,000 | 730 | 1,000 | 300 | 4,030 |
| 1981 | 2,150 | 860 | 1,150 | 320 | 4,480 |
| 1982 | 2,300 | 1,000 | 1,300 | 350 | 4,950 |

/1 Increase of public sector consumption by 1,200 kW due to new Government center.

Alternatives to Meet the Demand in Juba

8.11 The possibilities of hydroelectric development of the Bahr El Jebel (White Nile) and its tributaries to meet the estimated demand for power in Juba were examined in detail by Mr. R.L. Bloor (consultant). His findings, described in the report at Annex 14 were conveyed to PEWC and GRS during the mission. They have been accepted by the Sudan authorities. Broadly, the conclusions were:

(i) The Nile River in Southern Sudan (above Juba) is of interest for the development of power; other streams are of limited interest. The 162-km reach of the Nile north of the Uganda border, which could be developed for power, falls an average of 1.6 m per mile with a number of rapids and a well-defined channel.

(ii) Electricity requirements in Southern Sudan are small and nearly all in the town of Juba; they can best be fulfilled for some time by diesel generation.

(iii) The problem of hydroelectric development on the Nile is the small amount of power required and the large size of the river. A Nile hydro-electric development above Juba is unlikely to be economically feasible for some time to come but mapping and collection of data by the Government on this

and other rivers in Southern Sudan would be useful to confirm or change this conclusion and provide the basis for a power survey in 1978-80.

(iv) The Bank should finance a 5-MW diesel installation and an improved distribution system in Juba in 1975. The Government should map the Nile between Juba and Nimule and carry out a program of gauge installations and stream flow measurements in that vicinity and on the basis thereof the Bank should finance a power survey of Southern Sudan in 1977. 1/

Juba Electrification Extensions Proposals

8.12 Sudan Power II Project provides for the following generation and distribution projects, to be implemented in Juba during the period 1974-1976:

(1) A new power station consisting of five diesel engines and alternators (rated 1 MW each) complete with all accessories, and

(2) Distribution extensions consisting of:

(a) 27 miles of 11-kV overhead lines; and

(b) 90 miles of 415/240-volt overhead lines.

Other Centers in the Southern Region

8.13 Besides Juba, Malakal and Wau are the only two centers now receiving the benefit of public electricity supply, all from small diesel installations installed by PWD many years ago. The present situation at these centers seems to be similar to that of Juba -- viz, run-down generating plant and inadequate distribution facilities, resulting in load shedding and restriction in expansion. Following its general policy outside the Blue Nile Grid, PEWC has concerned itself so far merely in maintaining existing supply arrangements, leaving it to new industries to provide their own generation. The mission was not informed of any significant imminent demand for electricity in these areas, but it recommended that PEWC should modify its approach and plan on the basis of meeting the requirements of all consumers who can pay the costs of supply (para. 6.04).

8.14 The requirements of the Katire-Torit area, in the extreme south-east at the foothills of the Imatong mountains, need special mention. The mission visited this area where a private saw-mill, now operated by the Department of Forestry, has taken advantage of the potential of a perenial hill torrent at Katire at the head of the Kinyeti Valley. The Sudan Ministry of Irrigation and Hydroelectric Power estimated that 11-MW could be theoretically developed here with an available fall of 600 m and a discharge of

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1/ Excerpt from Mr. R. L. Bloor's report (Annex 14).

2 $m^3$/sec. The discharge of the Kinyeti river was actually assessed at below 1 $m^3$/sec by the mission when it inspected the site in February 1974, which was not the driest part of the year. The site therefore diminishes in importance from the point of becoming a source of power for Juba -- situated 120 miles away -- which was the main concern of the mission at this stage. It has considerable significance, however, from the point of view of meeting local requirements in the Torit-Katire area -- particularly in the context of planned afforestation and development of forest-based industries. In February 1974 the mission, therefore, recommended that GRS should take the action recommended at para. 15 of Mr. R. L. Bloor's report (mapping and gauging of the Nile between Juba and Nimule and gauging of the other rivers in Equatoria Province) to enable timely utilization of the obviously attractive potentialities for hydroelectric development in this area.

Action on Mr. Bloor's Report by GRS

8.15 Late in 1974, the Ministry of Irrigation and Hydroelectric Power of GRS prepared a report outlining the possibility of construction of a dam 20 m high (to be eventually increased to 44 m) at Bedden rapids on the Nile (one of the important sites referred to in Mr. Bloor's report) with an installation of 75 MW and capable of generating 522 GWh annually. This report indicates the further field investigations needed and is intended to guide the work of consultants whom GRS intends to appoint immediately. A sum of ŁSd 150,000 has been provided in the GRS budget for 75/76 for the purpose. The Minister for Irrigation and Hydroelectric Power explained that the larger installation (Mr. Bloor felt that an installation of 20 MW would be appropriate for the mid eighties) is based on the expectation of rapid agricultural and industrial development of the Southern Region after completion of the Jonglei Canal project, the first stage of which is about to be commenced. The Jonglei project area is located about 500 km from the Bedden site.

8.16 The mission discussed the matter in detail with officers of the Ministry of Irrigation and Hydroelectric power pointing out (a) the difficulty of economic justification of such a large development at this stage (b) the need for continuing examination of alternatives both on the Nile and its tributaries on the basis outlined in Mr. Bloor's report and (c) the need to coordinate activities of the Ministry of Irrigation and Hydroelectric Power with the PEWC, who were unaware of the developments referred to at paragraph 8.15. It was agreed that (a) collection of hydrological data recommended by Mr. Bloor at Bedden rapids would be commenced soon by the Ministry of Irrigation and Hydroelectric Power and (b) that the terms of reference for consultants assigned to carry out the initial field investigations should be drafted to cover economic possibilities of development of about 20 MW. The importance of employing experienced consultants was stressed by the mission and appreciated by GRS engineers.

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# THE SUDAN

## POWER SECTOR REVIEW

### Potential Hydroelectric Sites
### Capacity Planned/Installed

| | | Planned Capacity MW | Installed Capacity MW |
|---|---|---|---|
| I. | BLUE NILE | | |
| | (a) Roseires | 210 | 90 |
| | (b) Sennar (I & II) | 30 | 15 |
| II. | BAHR EL JEBEL | | |
| | Nimule-Juba | 300-500 | - |
| III. | WHITE NILE | | |
| | Jebel Aulia | 25 | - |
| IV. | THE NILE | | |
| | (a) Sabaloka | 108 | - |
| | (b) Berber (5th Cataract) | 175 | - |
| | (c) Merowe (4th Cataract) | 300 | - |
| V. | ATBARA RIVER | | |
| | (a) Khasm El Girba | 12 | 12 |
| | (b) Setit River | 15-30 | - |
| | TOTAL | 1157-1342 | 117 |

SOURCE: PEWC, Ministry of Irrigation and Hydroelectric Power

THE SUDAN

POWER SECTOR REVIEW

Primary Energy Requirements

| | 1966 | | 1974 | | 1980 | |
|---|---|---|---|---|---|---|
| | Actual | Metric Tons Petroleum Equivalent | Actual | Metric Tons Petroleum Equivalent | Projected | Metric Tons Petroleum Tons |
| Hydroelectricity 1/ | 50 GWh | 42,000 tons | 420 GWh | 34,900 tons | 833 GWh | 69,100 tons |
| Liquid Fuels | | 576,700 tons | | 742,700 tons | | 1,150,700 tons |
| - Aviation Fuels | 34,000 tons | | 46,500 tons | | 54,000 tons | |
| - Kerosene | 43,100 tons | | 34,400 tons | | 102,500 tons | |
| - Gasoline | 81,700 tons | | 106,200 tons | | 143,000 tons | |
| - Gas Oil | 194,000 tons | | 328,500 tons | | 621,000 tons | |
| - Diesel | 23,800 tons | | 26,000 tons | | 30,000 tons | |
| - Furnace Oil | 185,100 tons | | 177,700 tons | | 166,000 tons | |
| - Lubricants | 14,000 tons | | 23,400 tons | | 34,200 tons | |
| Total Primary | | 579,900 tons | | 777,600 tons | | 1,219,800 tons |

1/ Conversion factor
1 GWh = 83 tons of fuel

Source: Ministry of Industry

ANNEX 2

# THE SUDAN

## POWER SECTOR REVIEW

### Growth of Electricity Supply in the Sudan

| Year Ending 30th June | Installed Capacity MW | | | Generation Peak (MW) | | | Generation Energy (GWh) | | |
|---|---|---|---|---|---|---|---|---|---|
| | BNG | Provinces | Total | BNG | Provinces | Total | BNG | Provinces | Total |
| 1908 | 0.1 | -- | 0.1 | .06 | -- | .06 | .2 | -- | .2 |
| 1925 | 0.5 | -- | 0.5 | .30 | -- | .30 | 1.0 | -- | 1.0 |
| 1945 | 3.0 | 0.1 | 3.1 | 2.1 | .07 | 2.17 | 6.3 | .2 | 6.5 |
| 1950 | 5.8 | 0.5 | 6.3 | 4.3 | .3 | 4.6 | 14 | 1.0 | 15 |
| 1955 | 9.0 | 3.7 | 12.7 | 7.0 | 2.4 | 9.4 | 20 | 8 | 28 |
| 1960 | 29 | 7.7 | 36.7 | 17 | 6 | 23 | 72 | 18 | 90 |
| 1965 | 72 | 23 | 95 | 37 | 12 | 49 | 179 | 40 | 219 |
| 1969 | 86 | 40 | 126 | 57 | 17 | 74 | 297 | 60 | 357 |
| 1970 | 86 | 40 | 126 | 61 | 19 | 80 | 333 | 66 | 399 |
| 1971 | 110 | 40 | 150 | 67 | 21 | 88 | 335 | 72 | 407 |
| 1972 | 170 | 40 | 210 | 74 | 23 | 97 | 380 | 80 | 460 |
| 1973 | 170 | 40 | 210 | 82 | 25 | 107 | 432 | 88 | 520 |

Source: PEWC

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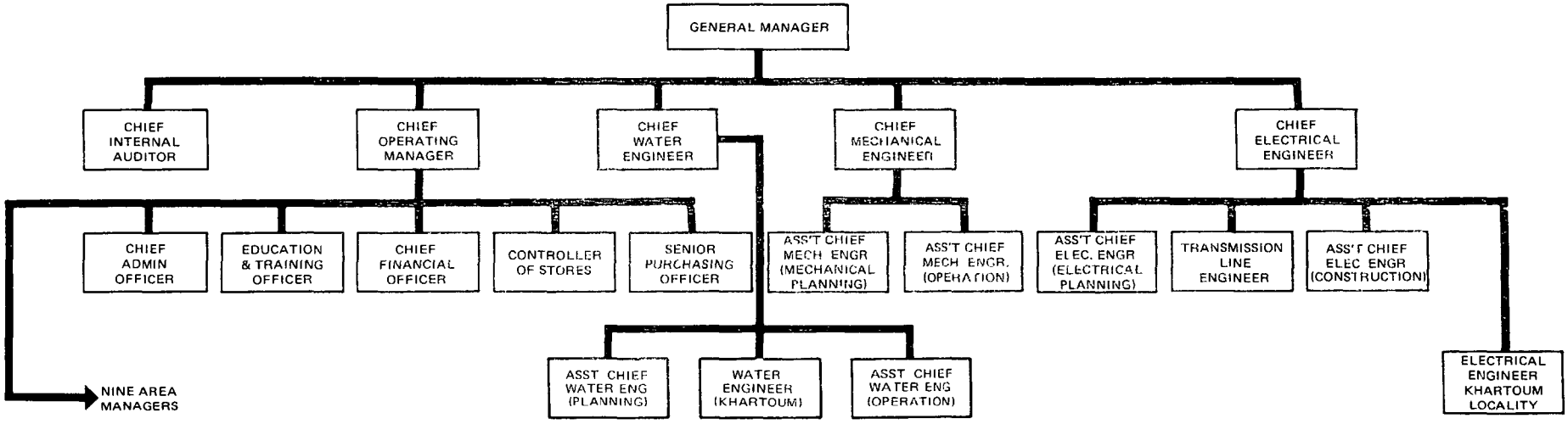
POWER SECTOR REVIEW
PUBLIC ELECTRICITY AND WATER CORPORATION
EXISTING ORGANIZATION CHART

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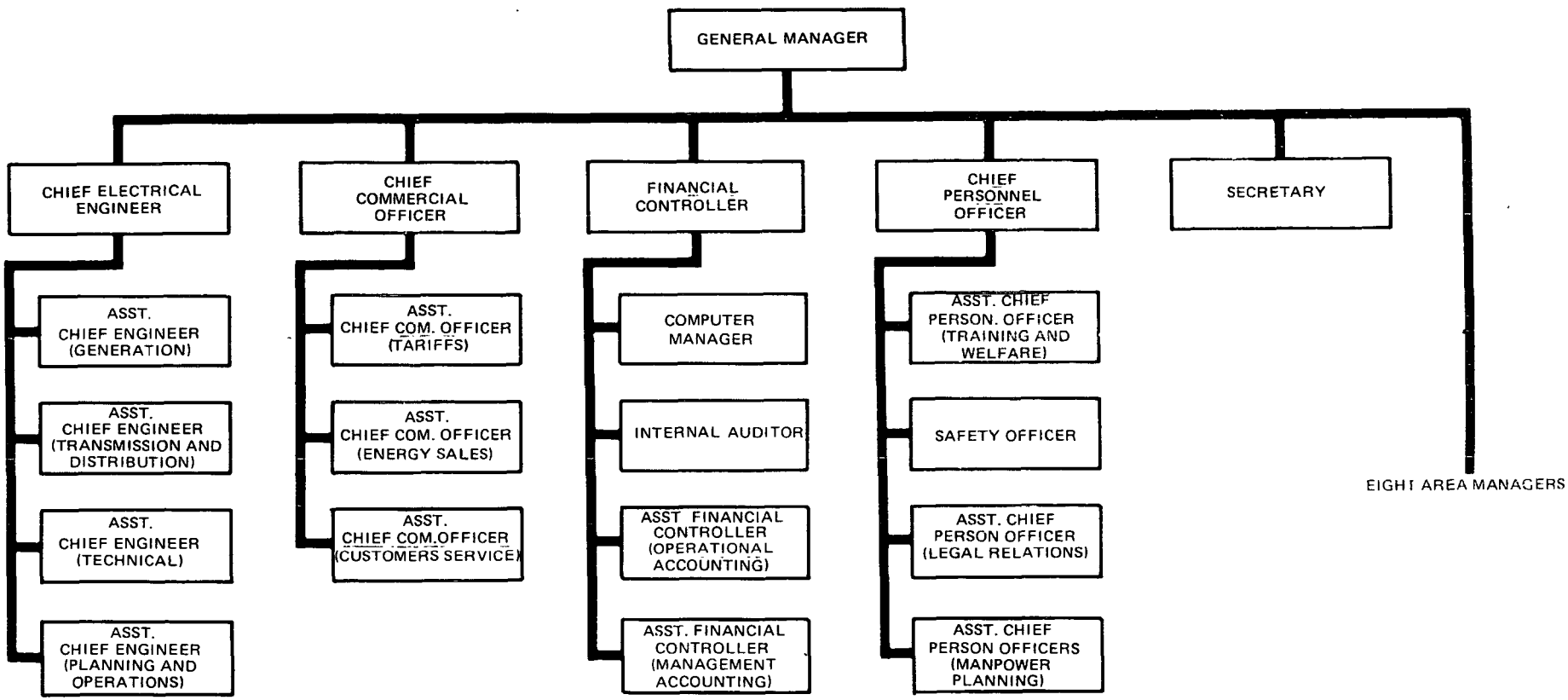
ANNEX 4

# THE SUDAN
# POWER SECTOR REVIEW
## PUBLIC ELECTRICITY AND WATER CORPORATION
## ORGANIZATION CHART
## PROPOSED BY THE ELECTRICITY COUNCIL OF THE U.K. 1/




1/ In accordance with Ecuk's recommendation, the chart excludes the water operations of PEWC

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ANNEX 5

THE SUDAN

# POWER SECTOR REVIEW

## PUBLIC ELECTRICITY AND WATER CORPORATION

## INSTALLED PLANT CAPACITY IN JANUARY 1974

| Area | Location | No. of Units | Type | Capacity (kW) | Year Installed |
|---|---|---|---|---|---|
| Blue Nile Grid | Khartoum | 13 | Diesel | 18,500 | 1927-1964 |
| | Khartoum | 4 | Steam Turbine | 26,000 | 1957-1961 |
| | Khartoum | 1 | Gas Turbine | 14,700 | 1969 |
| | Roseires | 3 | Hydro | 90,000 | 1971-1972 |
| | Sennar | 2 | Hydro | 15,000 | 1962 |
| | Wad Medani | 8 | Diesel | 5,500 | 1948-1963 |
| | Total Blue Nile Grid | | | 169,700 1/ | |
| Blue Nile Isolated Stations | El Duiem | 3 | Diesel | 800 | 1963 |
| | El Geteina | 3 | Diesel | 150 | 1969 |
| | El Gourashi | 4 | Diesel | 760 | 1962 |
| | Total Blue Nile Isolated | | | 1,710 | |
| Darfur | El Fasher | 5 | Diesel | 450 | 1967 |
| Eastern | Kassala | 9 | Diesel | 1,660 | 1956-1972 |
| | Khasm el Girba 2/ | 4 | Diesel | 5,000 | 1954-1973 |
| | Total Eastern | | | 6,660 | |
| Kordofan | El Obeid | 12 | Diesel | 1,510 | 1948-1973 |
| Northern | Atbara | 9 | Diesel | 8,200 | 1955-1961 |
| | Dongola | 4 | Diesel | 200 | 1972 |
| | Shendi | 7 | Diesel | 950 | 1959-1970 |
| | Total Northern | | | 9,350 | |
| Red Sea | Port Sudan | 9 | Diesel | 6,800 | 1955-1964 |
| Southern | Juba | 8 | Diesel | 920 | 1960-1973 |
| | Malakal | 5 | Diesel | 840 | 1962-1970 |
| | Wau | 6 | Diesel | 600 | 1960-1971 |
| | Total Southern | | | 2,360 | |
| | GRAND TOTAL | | | 198,540 3/ | |

1/ Due to age of some of the diesel thermal generating units, the effective capacity of the machines has been derrated by about 5,000 kW.
2/ Excludes 17,100 kW of hydroelectric capacity.
3/ This would increase to about 210,600 kW when allowances are made for (1) and (2) above.

THE SUDAN

POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

DETAILED DESCRIPTION OF PEWC'S FACILITIES AND OF THE PROPOSED PROJECT

PEWC's Existing Power System

1.01 At present the Blue Nile grid constitutes the main interconnected power system in the Sudan and comprises the following:

220-kV System

(a) The Roseires hydro power station at the foot of the Roseires dam on the Blue Nile with three hydro sets rated 30 MW each. The units have been designed to operate under a head range from 17.0 m to 48.0 m and deliver 22 MW at the lowest head;

(b) A 220-kV double circuit tower line (with a single circuit strung initially), approximately 485 km long, connecting Roseires power station to a receiving station at Kilo X near Khartoum:

(c) An intermediate 220/110-kV stepdown station at Meringan and a terminal 220/110-kV substation at Kilo X.

110-kV System

(a) A hydro power station at Sennar situated at the Sennar dam on the Blue Nile with two hydro sets rated 7.5 MW each. The units operate under a head range of 6.2 m to 17.5 m and deliver a total of 7.5 MW under low head conditions;

(b) A diesel station at Wad Medani with an aggregate capacity of about 8 MW situated approximately midway between Sennar and Khartoum, and interconnected to the main system at Meringan substation;

(c) A gas turbine at Kilo X rated at 15 MW and interconnected to the main system via a stepup 11/33-kV, 18.8-MVA, transformer;

(d) A thermal power station at Burri in the outskirts of Khartoum with total capacity of 44 MW and interconnected to the main system via 33-kV subtransmission power lines (particulars of plant appear in Annex 2);

(e) A 110-kV single circuit transmission line, 270-km long, connecting Sennar power station to Kilo X, with two intermediate 110/11-kV stepdown substation at Meringan and at Hassa Heissa town;

(f) A 110-kV single circuit line, 110 km in length, from the Sennar power station to the Rabak 110/33/11-kV receiving station on the White Nile near Kosti;

(g) A 110-kV double circuit overhead power line 15 km in length connecting Kilo X substation to Khartoum North Substation.

Subtransmission Network

PEWC's subtransmission network comprises the following:

(a) A 33-kV line from Sennar to Singa town about 60 km in length, to supply the pumping schemes, villages and towns enroute;

(b) A 33-kV Sennar-El-Suki line, about 45 km long, supplying El-Suki pumping scheme and the ginning centers, villages and towns enroute;

(c) Five 33-kV power lines from Khartoum North subtransmission substation to the load centers of Khartoum area and for interconnection with Burri power station.

Local distribution is at 11 kV and lower voltages.

1.02 The eastern Khasm El Girba system comprises the following existing generating installations at the Khasm El Girba dam:

| | | |
|---|---|---|
| (i) | 2 Kaplan generating units (2 x 3600 kW) | 7,200 kW |
| (ii) | 3 pump turbine units (3 x 1900 kW) | 5,700 kW |
| (iii) | 3 diesel generating units (3 x 1400 kW) | 4,200 kW |
| | | 17,100 kW |

1.03 A fairly extensive (200 km) 66-kV grid connects Khasm El Girba power station to the New Halfa town, as well as Showak and Gedaref. The use of hydro power has been severely restricted due to increased irrigation water requirements and a recent decision to curtail all downstream water releases. The only reliable source is the diesel unit, and the prevailing maximum demand is limited to its output. Further diesel capacity of 5000 kW has been ordered to meet load growth in the system.

1.04 In order to increase water supplies for irrigation the possibility of constructing dams at sites upstream in the Atbara valley in being actively investigated, with an emphasis on maximizing hydro generation. The question of linking the Eastern Grid at Gedaref with the Blue Nile Grid, through extensions from Meringan or Singa is also concurrently under consideration.

Other Blue Nile Grid Extensions

Sennar Substation

2.01 In connection with power supply to the Rahad Irrigation Project (Stage I) (Cr. 364-SU), construction of a stepdown substation, with a 50 MVA power transformer and the following associated electrical equipment at Sennar is being arranged.

Detailed Description of Sudan Power II Project

3.01 The project comprises the following seven main sub-projects:

(i) Addition of 15 MW (3 x 5-MW) of diesel generating capacity at Burri thermal station in Khartoum by 1977 (the first two units to be installed in 1976);

(ii) addition of a 42-MW generating unit at Roseires hydro-electric power station by 1978;

(iii) stringing of the second 220-kV circuit from Roseires to Sennar (238 km) on the existing double circuit tower line by 1978;

(iv) construction of a 110-kV single circuit line from Sennar to Meina el Sharif (60 km) by 1977;

(v) Addition of 5 MW (5 x 1 MW) at Juba diesel power station;

(vi) upgrading (from 3.3 kV to 11 kV) and extending the Juba distribution system;

(vii) long-term planning studies.

15-MW Extensions at Burri

3.02 This would consist of the following:

(i) Preparatory engineering, comprising preparation of tender specifications, invitations to tender, scrutinizing offers and placing contracts;

(ii) purchase, erection and commissioning of 15-MW diesel generating plants comprising the following:

(a) three diesel engines complete with all accessories, working on furnace oil and each of adequate power to run 5-MW alternators continuous rating at site conditions;

(b) three alternators capable of developing 5 MW each at 0.8 P.F. generating at 11 kV; and

(c) the ancillary equipment.

Addition of the Fourth Generating Unit at Roseires

3.03 Engineering work to decide on the exact rating of the generator; preparation of tender specifications, invitations to tender, scrutinizing offers and placing contracts. Purchase, erection and commissioning of the fourth generating set at Roseires comprising the following:

(i) Preliminary works;

(ii) Civil engineering comprising:

(a) Civil works;

(b) Gates and penstock to suit the existing structure;

(iii) Mechanical and electrical engineering comprising:

(a) Vertical shaft Kaplan turbine similar to the three existing turbines; and

(b) Vertical shaft, salient pole synchronous generator to be rated according to the results of the engineering study referred to above, with generation voltage of 11 kV, suitable to work in parallel with the existing generators, complete with excitation equipment.

220-kV Grid Extensions

3.04 This involves stringing the second 220-kV circuit on the existing double circuit tower line under live line conditions, duplicating the present transmission line capability from Roseires to Sennar. It requires a rearrangement of the equipment at the switchyard at Roseires. Special safety precautions would need to be instituted for live line construction. The work covers consultancy for initiation of such procedures, preparation of suitable specifications and for contracting and supervising the construction of this work.

110-kV Grid Extensions

3.05 The cost estimates are for the construction of a 110-kV line between Sennar and Meina el Sharif. The Consultant will prepare specifications for procurement of equipment and materials and construction services.

New Juba Diesel Station

3.06 This project would consist of the purchase, erection and commissioning of the following:

(i) Five diesel engines complete with all accessories working on furnace oil and each of adequate power to run a 1-MW alternator continuous rating at site conditions;

(ii) five alternators capable of developing 1 MW each at 0.8 power factor generating a 11-kV; and

(iii) ancillary equipment.

Juba Distribution

3.07 This project consists of erection and commissioning of the following:

(i) 150 km of 415/240 overhead lines;

(ii) 45 km of 11 kV overhead lines; and

(iii) ancillary equipment.

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POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

BLUE NILE GRID

GROWTH OF CONSUMPTION BY CATEGORY
(Figures in GWh)

| | A C T U A L | | | | | | | F O R E C A S T | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year Ending June 30 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
| Domestic | 75 | 79 | 84 | 91 | 98 | 110 | 129 | 139 | 153 | 165 | 178 | 190 | 202 | 216 | 231 |
| Commercial | 8 | 9 | 10 | 10 | 11 | 11 | 11 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| Industrial | 74 | 83 | 93 | 107 | 121 | 136 | 153 | 163 | 179 | 195 | 212 | 232 | 253 | 277 | 309 |
| Agriculture | 12 | 20 | 26 | 24 | 24 | 34 | 41 | 47 | 59 | 68 | 81 | 99 | 120 | 141 | 160 |
| Street Lighting | 6 | 6 | 6 | 7 | 7 | 6 | 6 | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 9 |
| Interdepartmental | 12 | 11 | 10 | 10 | 11 | 11 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 18 | 18 |
| TOTAL | 187 | 208 | 229 | 249 | 272 | 308 | 353 | 384 | 427 | 465 | 511 | 562 | 618 | 680 | 748 |

Note:
(1) Includes PEWC's sales and interdepartment supplies (not charged for) mostly for water operations.

(2) Follows the prevailing main tariff categories of the PEWC.

Source - PEWC

ANNEX 7

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POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

PEWC'S POWER MARKET FORECAST - BLUE NILE GRID

| Year Ending June 30 | MAXIMUM POWER DEMAND (MW) | | | ENERGY GENERATION (GWh) | | |
|---|---|---|---|---|---|---|
| | Low | Median | High | Low | Median | High |
| 1973/74 | 91 | 91 | 91 | 480 | 480 | 480 |
| 1974/75 | 99 | 101 | 102 | 528 | 537 | 545 |
| 1975/76 | 108 | 112 | 116 | 581 | 600 | 619 |
| 1976/77 | 117 | 123 | 130 | 639 | 670 | 701 |
| 1977/78 | 127 | 135 | 144 | 703 | 749 | 795 |
| 1978/79 | 138 | 150 | 161 | 773 | 838 | 902 |
| 1979/80 | 149 | 168 | 186 | 850 | 940 | 1030 |
| 1980/81 | 164 | 184 | 205 | 935 | 1050 | 1170 |
| 1981/82 | 181 | 206 | 231 | 1030 | 1180 | 1320 |

ANNEX 8

THE SUDAN

POWER SECTOR REVIEW

PEWC's INVESTMENT PLAN 1974/75 - 1980/81 1/
(£Sd 1000)

| | 1974/75 | 1975/76 | 1976/77 | 1977/78 | 1978/79 | 1979/80 | 1980/81 | Total |
|---|---|---|---|---|---|---|---|---|
| IDA Project | - | - | 1,589 | 4,061 | 3,187 | 679 | - | 9,516 |
| ADB Project (15 MW Thermal Units) | 2,594 | 74 | - | - | - | - | - | 2,668 |
| Small Town Electrification Program | 141 | 155 | 154 | 153 | 153 | 153 | 151 | 1,060 |
| Rahad Electrification | 401 | 2,271 | 1,053 | 330 | .- | - | - | 4,055 |
| Other | 2,894 | 2,043 | 2,766 | 2,900 | 2,849 | 3,428 | 3,874 | 20,358 |
| Total Construction Program | 5,634 | 4,534 | 5,562 | 7,444 | 6,189 | 4,260 | 4,025 | 37,657 |

1/ In 1974 prices

SOURCE: PEWC

ANNEX 9

THE SUDAN

POWER SECTOR REVIEW

ACCESS TO ELECTRICITY SUPPLY

| Province | Number of Towns | Urban Population | Number of Towns Electrified | Population in Towns Electrified | Rural Population | Number of Villages Electrified | Number of Connections |
|---|---|---|---|---|---|---|---|
| Khartoum | 3 | 850,000 | 3 | 850,000 | 263,000 | 53 | 102,000 |
| Blue Nile | 25 | 509,000 | 23 | 467,000 | 3,085,000 | 32 | 43,100 |
| Darfur | 6 | 210,000 | 3 | 148,000 | 1,566,000 | - | 1,800 |
| Kassala | 10 | 235,000 | 4 | 200,000 | 635,000 | 5 | 13,300 |
| Kordofan | 15 | 262,000 | 1 | 90,000 | 1,534,000 | - | 6,600 |
| Red Sea | 4 | 169,000 | 2 | 138,000 | 130,000 | 1 | 8,600 |
| Northern | 10 | 169,000 | 6 | 130,000 | 737,000 | - | 15,000 |
| Equatoria | 7 | 149,000 | 1 | 57,000 | 607,000 | - | 1,400 |
| Bahr-el-Gazal | 6 | 106,000 | 1 | 55,000 | 1,291,000 | - | 1,000 |
| Upper Nile | 1 | 37,000 | 1 | 37,000 | 761,000 | - | 800 |
| TOTAL | 87 | 2,698,000 | 45 | 2,172,000 | 10,583,000 | 91 | 193,900 |
| Nomads | - | - | - | - | 1,623,000 | - | - |

Source: 1973 Census (preliminary data)
PEWC

ANNEX 10

SUDAN

TOWNS WITH PUBLIC ELECTRICITY SUPPLY

(Preliminary Population Figures from Census 1973)

| PROVINCE | POPULATION |
|---|---|
| **Khartoum** | |
| Omdurman | 313,000 |
| Khartoum | 370,000 |
| Khartoum North | 167,000 |
| **Blue Nile** | |
| Wad Medani | 110,000 |
| Kosti | 62,000 |
| El Suki | 35,000 |
| Sennar | 31,000 |
| El Dueim | 27,000 |
| Senga | 21,000 |
| Mairno | 17,000 |
| Rabak | 15,000 |
| El Managal | 19,000 |
| El Hasaheissa | 18,000 |
| Rufa'a | 16,000 |
| El Roseires | 7,000 |
| El Gezeira | 16,000 |
| El Kamlin | 7,000 |
| Abu Oshar | 8,000 |
| El Getaina | 7,000 |
| El Masalania | 5,000 |
| El Damasin | 5,000 |
| El Hilalia | 9,000 |
| **Darfur** | |
| Nyala | 59,000 |
| El Fasher | 50,000 |
| El Ginaina | 58,000 |
| **Eastern** | 107,000 |
| El Gedaref | 67,000 |
| New Halfa | 18,000 |
| Kash - el - Girba | 8,000 |

Source: 1973 Census, preliminary data

| | |
|---|---|
| Kordofan | |
| El Obeid | 90,000 |
| Red Sea | |
| Port Sudan | 125,000 |
| Toker | 13,000 |
| Northern | |
| Atbara | 64,000 |
| Shendi | 23,000 |
| El Damer | 18,000 |
| Berber | 13,000 |
| Dongola | 6,000 |
| Halfa | 6,000 |
| Equatoria | |
| Juba | 57,000 |
| Bahr-el-Gazal | |
| Wau | 55,000 |
| Upper Nile | |
| Malakal | 37,000 |

THE SUDAN

POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

ACTUAL AND FORECAST CONSOLIDATED CASH FLOWS
(LSd Thousands)

| Year Ending June 30 | Actual 1971 | Actual 1972 | Actual 1973 | Forecast 1974 | Forecast 1975 | Forecast 1976 | Forecast 1977 | Forecast 1978 | Forecast 1979 | Six Year Summary 1973/74-1978/79 | Forecast 1980 | Forecast 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOURCES | | | | | | | | | | | | |
| Internal Cash Generation | | | | | | | | | | | | |
| Net Income Before Interest | 1,936 | 1,929 | 3,037 | 2,209 | 521 | 5,753 | 6,090 | 7,179 | 7,215 | 28,967 | 8,532 | 8,903 |
| Depreciation | 1,200 | 1,433 | 1,699 | 1,854 | 2,025 | 2,243 | 2,506 | 2,970 | 3,426 | 15,024 | 3,720 | 4,025 |
| Other | | | | | | | | | | | | |
| Sub-Total | 3,136 | 3,362 | 4,736 | 4,063 | 2,546 | 7,996 | 8,596 | 10,149 | 10,641 | 43,991 | 12,222 | 12,928 |
| Borrowings | | | | | | | | | | | | |
| Bank of Sudan | 2,400 | 600 | | | | | | | | | | |
| CRS | 236 | 3,557 | 3,040 | | 2,405 | 3,380 | 3,197 | 2,302 | 2,740 | 14,024 | 2,723 | 3,678 |
| IBRD (Loan 522-SU) | 1,965 | 1,092 | 1,201 | | | | | | | | | |
| Proposed IDA Credit | | | | | | 1,266 | 3,405 | 2,851 | 482 | 8,004 | | |
| ADB | | | | 162 | 1,376 | 81 | | | | 1,619 | | |
| Sub-Total | 4,601 | 5,249 | 4,241 | 162 | 3,781 | 4,727 | 6,602 | 5,153 | 3,222 | 23,647 | 2,723 | 3,678 |
| Other Sources | | | | | | | | | | | | |
| Change in Current Liabilities | 402 | 1,286 | 423 | 682 | 2,327 | 1,133 | 1,063 | 1,215 | 1,297 | 7,717 | 1,529 | 1,451 |
| Total Sources | 8,139 | 9,897 | 9,400 | 4,907 | 8,654 | 13,856 | 16,261 | 16,517 | 15,160 | 75,355 | 16,474 | 18,057 |
| APPLICATIONS | | | | | | | | | | | | |
| Construction 1/ | | | | | | | | | | | | |
| Electricity | 5,512 | 3,445 | 1,939 | 3,788 | 5,252 | 8,719 | 11,624 | 10,244 | 6,555 | 46,182 | 7,968 | 9,479 |
| Water 2/ | 1,186 | 2,342 | 1,961 | 2,425 | 1,625 | 2,925 | 3,225 | 3,525 | 3,825 | 17,550 | 4,225 | 4,625 |
| Interest Capitalized | 276 | 390 | | | | | | | | | | |
| Sub-Total | 6,974 | 6,177 | 3,900 | 6,213 | 6,877 | 11,644 | 14,849 | 13,769 | 10,380 | 63,732 | 12,193 | 14,104 |
| 3/ | | | | | | | | | | | | |
| Debt Service | | | | | | | | | | | | |
| Amortization | | | 251 | 198 | 209 | 269 | 324 | 530 | 782 | 2,312 | 900 | 1,026 |
| Interest Not Capitalized | 1,287 | 1,508 | 2,297 | 624 | 511 | 843 | 1,254 | 1,712 | 1,972 | 6,916 | 2,156 | 2,308 |
| Sub-Total | 1,287 | 1,508 | 2,548 | 822 | 720 | 1,112 | 1,578 | 2,242 | 2,754 | 9,228 | 3,056 | 3,334 |
| Other Applications | | | | | | | | | | | | |
| Change in Cash | -38 | 43 | 26 | 46 | 1,297 | 495 | -1,055 | -596 | 984 | 1,171 | -77 | -626 |
| Change in Other Current Assets | 1,290 | 2,280 | 3,780 | -3,718 | -740 | 605 | 889 | 1,102 | 1,042 | -820 | 1,302 | 1,245 |
| Other Application - Net | -1,374 | -111 | -854 | 1,544 | 500 | | | | | 2,044 | | |
| Sub-Total | -122 | 2,212 | 2,952 | -2,128 | 1,057 | 1,100 | -166 | 506 | 2,026 | 2,395 | 1,225 | 619 |
| Total Application | 8,139 | 9,897 | 9,400 | 4,907 | 8,654 | 13,856 | 16,261 | 16,517 | 15,160 | 75,355 | 16,474 | 18,057 |
| Debt Service Covered by Internal Cash Generation (Times) | 2.44 | 2.23 | 1.86 | 4.94 | 3.54 | 7.15 | 5.45 | 4.35 | 3.86 | | 4.00 | 3.88 |
| Accumulated Cash at End of Year | 85 | 128 | 154 | 200 | 1,497 | 1,992 | 937 | 341 | 1,325 | | 1,248 | 622 |

1/ The detailed electricity construction program appears on page 6 of Annex 21
2/ The detailed water construction program appears on page 7 of Annex 21
3/ The detailed debt repayment schedule appears on page 8 of Annex 21

THE SUDAN

POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

ACTUAL AND FORECAST INCOME STATEMENTS - ELECTRICITY
(LSd Thousands)

| Year Ending June 30 | Actual 1971 | 1972 | 1973 | Forecast 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy Sales 1/ | | | | | | | | | | | |
| Domestic - GWH | | | | 139 | 153 | 165 | 178 | 190 | 202 | 216 | 231 |
| mms/kWh | | | | 24.90 | 24.90 | 35.70 | 35.70 | 35.70 | 35.70 | 35.70 | 35.70 |
| Revenue - GWH | | | | 3,461 | 3,810 | 5,890 | 6,355 | 6,783 | 7,211 | 7,711 | 8,247 |
| Commercial - GWH | | | | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| mms/kWh | | | | 17.80 | 17.80 | 23.80 | 23.80 | 23.80 | 23.80 | 23.80 | 23.80 |
| Revenue | | | | 249 | 267 | 381 | 405 | 428 | 452 | 476 | 500 |
| Industrial - GWH | | | | 163 | 179 | 195 | 212 | 232 | 253 | 277 | 309 |
| mms/kWh | | | | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 | 10.60 |
| Revenue | | | | 1,728 | 1,897 | 2,067 | 2,247 | 2,459 | 2,682 | 2,936 | 3,275 |
| Government - GWH | | | | 7 | 7 | 7 | 8 | 8 | 8 | 8 | 9 |
| mms/kWh | | | | 38.70 | 38.70 | 38.70 | 38.70 | 38.70 | 38.70 | 38.70 | 38.70 |
| Revenue | | | | 271 | 271 | 271 | 310 | 310 | 310 | 310 | 348 |
| Agriculture - GWH | | | | 47 | 59 | 98 | 81 | 99 | 120 | 141 | 160 |
| mms/kWh | | | | 10.10 | 10.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 |
| Revenue | | | | 475 | 596 | 1,027 | 1,223 | 1,495 | 1,812 | 2,129 | 2,416 |
| Other Areas - GWH | | | | 78 | 87 | 105 | 115 | 124 | 136 | 149 | 159 |
| mms/kWh | | | | 62.10 | 22.10 | 29.40 | 29.40 | 29.40 | 29.40 | 29.40 | 29.40 |
| Revenue | | | | 1,724 | 1,923 | 3,087 | 3,381 | 3,646 | 3,998 | 4,381 | 4,675 |
| Total Units | | | | 448 | 500 | 556 | 611 | 671 | 738 | 811 | 889 |
| Average Price | | | | 17.65 | 17.53 | 22.88 | 22.78 | 22.54 | 22.31 | 22.12 | 21.89 |
| Operating Revenues | | | | | | | | | | | |
| Energy Sales | 5,493 | 6,556 | 7,728 | 7,908 | 8,764 | 12,723 | 13,921 | 15,121 | 16,465 | 17,943 | 19,461 |
| Operating Expenses | | | | | | | | | | | |
| Gen. and Trans. | 915 | 999 | 1,221 | 1,167 | 1,353 | 1,461 | 1,578 | 1,705 | 1,841 | 1,988 | 2,147 |
| Fuel | 1,220 | 1,333 | 970 | 1,421 | 3,037 | 3,214 | 3,432 | 3,597 | 3,863 | 4,112 | 4,273 |
| Distribution | 767 | 1,221 | 1,491 | 1,566 | 1,816 | 1,961 | 2,118 | 2,288 | 2,471 | 2,668 | 2,882 |
| Depreciation | 890 | 1,031 | 1,253 | 1,311 | 1,434 | 1,564 | 1,731 | 2,090 | 2,432 | 2,600 | 2,768 |
| Total Operating Expenses | 3,792 | 4,584 | 4,935 | 5,465 | 7,640 | 8,200 | 8,859 | 9,680 | 10,607 | 11,368 | 12,070 |
| Operating Income | 1,701 | 1,982 | 2,793 | 2,443 | 1,124 | 4,523 | 5,062 | 5,441 | 5,858 | 6,575 | 7,391 |
| Other Income Net | 319 | 389 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 |
| Net Income Before Interest | 2,020 | 2,361 | 3,243 | 2,893 | 1,574 | 4,973 | 5,512 | 5,891 | 6,308 | 7,025 | 7,841 |
| Interest Not Capitalized | 1,287 | 1,508 | 2,297 | 624 | 511 | 675 | 956 | 1,241 | 1,354 | 1,334 | 1,290 |
| NET INCOME | 733 | 853 | 946 | 2,269 | 1,063 | 4,298 | 4,556 | 4,650 | 4,954 | 5,691 | 6,551 |
| Operating Ratio % (after depreciation) | 69 | 70 | 64 | 69 | 67 | 64 | 64 | 64 | 64 | 63 | 62 |
| Average Rate Base | 19,549 | 26,828 | 33,580 | 34,661 | 37,173 | 39,806 | 43,501 | 54,060 | 63,625 | 66,265 | 68,722 |
| Rate of Return | 8.70 | 7.35 | 8.32 | 7.05 | 3.02 | 11.36 | 11.64 | 10.06 | 9.21 | 9.92 | 10.75 |
| Depreciation as % of Average Gross Asset | 3.63 | 3.15 | 3.08 | 3.05 | 3.06 | 3.06 | 3.07 | 3.04 | 3.01 | 3.03 | 3.04 |

1/ The first five categories apply to the Blue Nile Grid only.

THE SUDAN

POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

ACTUAL AND FORECAST INCOME STATEMENT - WATER
(£Sd Thousands)

| Year Ending June 30 | Actual 1971 | 1972 | 1973 | Forecast 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Connections | 116 | 168 | 179 | 194 | 214 | 227 | 242 | 259 | 277 | 296 | 316 |
| Total Population | 2,007 | 2,105 | 2,210 | 2,320 | 2,435 | 2,557 | 2,684 | 2,819 | 2,961 | 3,110 | 3,267 |
| Population Served | 719 | 1,056 | 1,113 | 1,200 | 1,321 | 1,406 | 1,503 | 1,607 | 1,717 | 1,835 | 1,960 |
| % Population Served | 36 | 50 | 50 | 52 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Volume Produced | 49,300 | 71,400 | 90,800 | 95,100 | 99,900 | 104,100 | 112,000 | 120,500 | 128,400 | 138,000 | 145,900 |
| Volume Sold - Water | 29,100 | 42,100 | 53,600 | 59,900 | 68,900 | 75,000 | 81,800 | 89,000 | 95,000 | 102,000 | 109,000 |
| Unaccounted for Water | 41 | 41 | 41 | 37 | 31 | 28 | 27 | 26 | 26 | 26 | 25 |
| mms/$m^3$ | 40.76 | 40.76 | 40.76 | 40.76 | 40.76 | 69.00 | 69.00 | 80.00 | 80.00 | 90.00 | 90.00 |
| OPERATING REVENUES | | | | | | | | | | | |
| Water Sales | 1,188 | 1,719 | 2,185 | 2,442 | 2,808 | 5,175 | 5,644 | 7,120 | 7,600 | 9,180 | 9,810 |
| OPERATING EXPENSES | | | | | | | | | | | |
| Production | 472 | 808 | 1,062 | 1,167 | 1,423 | 1,602 | 1,861 | 2,163 | 2,488 | 2,889 | 3,298 |
| Distribution | 490 | 941 | 1,255 | 1,416 | 1,847 | 2,114 | 2,430 | 2,789 | 3,211 | 3,694 | 4,193 |
| Depreciation | 310 | 402 | 446 | 543 | 591 | 679 | 775 | 880 | 994 | 1,120 | 1,257 |
| Total Operating Expenses | 1,272 | 2,151 | 2,763 | 3,126 | 3,861 | 4,395 | 5,066 | 5,832 | 6,693 | 7,703 | 8,748 |
| Operating Income | -84 | -432 | -578 | -684 | -1,053 | 780 | 578 | 1,288 | 907 | 1,477 | 1,062 |
| Other Income Net | | | 372 | | | | | | | | |
| Net Income Before Interest | -84 | -432 | -206 | -684 | -1,053 | 780 | 578 | 1,288 | 907 | 1,477 | 1,062 |
| Interest Not Capitalized | | | | | | 168 | 298 | 471 | 618 | 822 | 1,016 |
| NET INCOME | -84 | -432 | -206 | -684 | -1,053 | 612 | 280 | 817 | 289 | 655 | 44 |
| Operating Ratio % (After Depreciation) | 107 | 125 | 126 | 128 | 138 | 85 | 90 | 82 | 88 | 84 | 89 |
| Average Rate Base | 8,377 | 10,518 | 12,293 | 13,855 | 15,109 | 16,699 | 18,987 | 21,475 | 24,153 | 27,051 | 30,207 |
| Return on Average Rate Base | -1.00 | -4.11 | -4.70 | -4.94 | -6.97 | 4.67 | 3.04 | 6.00 | 3.76 | 5.46 | 3.52 |
| Depreciation as % of Average Gross Asset | 3.10 | 3.22 | 3.04 | 3.24 | 3.18 | 3.27 | 3.26 | 3.25 | 3.23 | 3.23 | 3.22 |

THE SUDAN

POWER SECTOR REVIEW

PUBLIC ELECTRICITY AND WATER CORPORATION

ACTUAL AND FORECAST INCOME STATEMENTS - CONSOLIDATED
(LSD THOUSANDS)

| YEAR ENDING JUNE 30 | ACTUAL 1971 | 1972 | 1973 | FORECAST 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OPERATING REVENUES | | | | | | | | | | | |
| ENERGY SALES REV | 5493 | 6556 | 7728 | 7908 | 8764 | 12723 | 13921 | 15121 | 16465 | 17943 | 19461 |
| WATER BILLINGS | 1188 | 1719 | 2185 | 2442 | 2808 | 5175 | 5644 | 7120 | 7600 | 9180 | 9810 |
| TOTAL OP REVENUE | 6681 | 8275 | 9913 | 10350 | 11572 | 17898 | 19565 | 22241 | 24065 | 27123 | 29271 |
| OPERATING EXPENSES | | | | | | | | | | | |
| LABOR | 915 | 999 | 1221 | 1167 | 1353 | 1461 | 1578 | 1705 | 1841 | 1988 | 2147 |
| FUEL | 1220 | 1333 | 970 | 1421 | 3037 | 3214 | 3432 | 3597 | 3863 | 4112 | 4273 |
| TRANSMISSION/DISTR | 767 | 1221 | 1491 | 1566 | 1816 | 1961 | 2118 | 2288 | 2471 | 2668 | 2882 |
| OTHER | 472 | 808 | 1062 | 1167 | 1423 | 1602 | 1861 | 2163 | 2488 | 2889 | 3298 |
| OTHER II | 490 | 941 | 1255 | 1416 | 1847 | 2114 | 2430 | 2789 | 3211 | 3694 | 4193 |
| DEPRECIATION | 1200 | 1433 | 1699 | 1854 | 2025 | 2243 | 2506 | 2070 | 3426 | 3720 | 4025 |
| TOTAL OP EXPENSE | 5064 | 6735 | 7698 | 8591 | 11501 | 12595 | 13925 | 15512 | 17300 | 19071 | 20818 |
| OPERATING INCOME | 1617 | 1540 | 2215 | 1759 | 71 | 5303 | 5640 | 6729 | 6765 | 8052 | 8453 |
| OTHER INCOME NET | 319 | 389 | 822 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 |
| NET INCOME BEF INT | 1936 | 1929 | 3037 | 2209 | 521 | 5753 | 6090 | 7179 | 7215 | 8502 | 8903 |
| INTEREST NOT CAPIT | 1287 | 1508 | 2297 | 624 | 511 | 843 | 1254 | 1712 | 1972 | 2156 | 2308 |
| NET INCOME | 649 | 421 | 740 | 1585 | 10 | 4910 | 4836 | 5467 | 5243 | 6346 | 6595 |
| OPERATING RATIO % (AFTER DEPR) | 76 | 81 | 78 | 83 | 99 | 70 | 71 | 70 | 72 | 70 | 71 |
| AVERAGE RATE BASE | 27926 | 37346 | 45873 | 48516 | 52282 | 56505 | 62488 | 75535 | 87778 | 93316 | 98929 |
| RATE OF RETURN | 5.79 | 4.12 | 4.83 | 3.63 | 0.14 | 9.39 | 9.03 | 8.91 | 7.71 | 8.63 | 8.54 |

THE SUDAN

POWER SECTOR REVIEW

PEWC'S ELECTRICITY TARIFFS

| Consumer Groups | Khartoum Area | Blue Nile Area | Nothern Area | Eastern Area | Red Sea Area | Kordofan Darfur, Southern Area |
|---|---|---|---|---|---|---|
| Domestic & Commercial | 0-75 KWh-30 mms<br>76-300 KWh-24 mms<br>Over 200 KWh-20 mms<br>Minimum 450 mms | 0-75 KWh-35 mms<br>76-200 KWh-26 mms<br>Over 200 KWh-20 mms<br>Minimum 450 mms | 0-75 KWh-40 mms<br>76-150 KWh-29 mms<br>Over 150 KWh-21 mms<br>Minimum 450 mms | 0-75 KWh-35 mms<br>76-200 KWh-26 mms<br>Over 200 KWh-20 mms<br>Minimum 450 mms | | |
| Light Industrial | 0-250 KWh-25 mms<br>251-500 KWh-20 mms<br>Over 500 KWh-16 mms<br>Minimum 450 mms | Same as Khartoum | Same as Khartoum | Same as Khartoum | Ordinary Tariff<br>35 mms | Ordinary Tariff:<br>50 mms |
| Agriculture | 0-50 KWh-15 mms<br>51-200 KWh-10 mms<br>Over 200 KWh-9 mms<br>Fixed charge 400 mms per H.P | " | " | " | Sudan Railways<br>36 mms | Refrigerator<br>Tariff: 30 mms |
| Heavy Industry at 11 KV | 0-30,100 KWh<br>-12.3 mms<br>dropping in tranches to 7.5 mms<br>M.D. charge of 900mms/ KVA | " | " | " | | |
| Heavy Industry at 415 V | 0-30000 KWh<br>-12.3 mms<br>dropping in three tranches to 7.7 mms<br>M.D. charge of 920mms/ KVA | | | | | |

ANNEX 13

# THE SUDAN

## POWER SECTOR REVIEW

### Projects to meet Electricity Requirements of Southern Sudan
### Report of Mr. R. L. Bloor

This report is in fulfillment of Terms of Reference dated December 7, 1973. I was in The Sudan January 15 - 27, 1974. Some time was spent in Khartoum to gather information on Southern Sudan from the Public Electricity and Water Corporation (PEWC) of the Ministry of Housing and Public Utilities and from the Irrigation Affairs Directorate of the Ministry of Irrigation. I spent January 18 - 25, 1974 in Juba in Southern Sudan from which points of interest were visited and discussions were held with the Southern Minister of Housing and Public Utilities and his Director, the Area Manager of PEWC and local UNDP and FAO representatives.

Summary

i. The Nile River in Southern Sudan (above Juba) is of interest for the development of power; other streams due to their small dry season flows are of limited interest.

ii. Rainfall is heavy but seasonal. There are 50 years of gage and flow records on the Nile and records of varying lengths on other streams.

iii. The 105 mile reach of the Nile north of the Uganda border which could be developed for power falls an average of five feet per mile with a number of rapids and a well-defined channel.

iv. Electricity requirements in Southern Sudan are small and nearly all in the town of Juba; they can best be fulfilled for some time by diesel generation.

v. The problem of hydroelectric development on the Nile is the small amount of power required and the large size of the river; on other streams developments may be useful, but they will be small. A Nile hydroelectric development above Juba is unlikely to be economically feasible for some time to come but mapping and collection of data by the Government on this and other rivers in Southern Sudan would be useful to confirm or change this conclusion and provide the basis for a power survey in 1978-80. Supervision missions should check on the progress of these activities.

Conclusions and Recommendations

The Bank should finance a 5 MW diesel installation and an improved distribution system in Juba in 1975. The Government should map the Nile between Juba and Nimule and carry out a program of gage installations and stream flow measurements in that vicinity as set forth in para. 15 hereof; and on the basis thereof the Bank should finance a power survey of Southern Sudan in 1977.

## Introduction

1. The White Nile River (known locally in the upper part as the Bahr El Jebel) enters the Sudan at Nimule on the Uganda border about 100 miles downstream (northward) from Lake Albert; at Lake Albert it also receives flows from Lakes Victoria and Kyoga. At Nimule it begins an average descent of about 5 feet per mile (1 m per km) for 105 miles (168 km) to Juba, the provincial headquarters of Equatoria and the capital of Southern Region. At this point it loses interest for Southern Sudan as a power stream because about 30 miles (50 km) downstream therefrom it enters the vast swamp, the Sudd, through which it flows for some 400 miles (650 km) before emerging as a well-defined river with low banks and a very flat slope (1 cm per km near Khartoum). Between Lake Albert and the swamp the river has numerous tributaries but none is perennial where it joins the Nile; there are also parallel rivers flowing northward from the higher lands on the Uganda and Congo borders but these empty into the swamp and most of them have no perennial flow except a few with very small dry season flows in their upper reaches. Juba and several towns downstream therefrom have flood problems which probably can best be solved by levees, but power developments upstream from Juba should not be allowed to aggravate the problems.

## Rainfall

2. Rainfall increases toward the south and averages 1200 mm per annum between Juba and Nimule. It is somewhat higher on the higher lands along the border and averages 1500 mm in the Imatong Mountains some 120 miles east of the Nile River. There are distinct wet and dry seasons; the wet season extends from April/May to November/December.

## Stream Flow

3. The mean monthly flows of the Nile at Nimule for high, low and average years for the 50-year period of record 1911-1922 and 1925-1962 are shown in the Annex. It may be noted that the lowest mean monthly flow is nearly 500 $m^3$/sec (the observed minimum is 312 $m^3$/sec); that the flows are well regulated during the dry seasons by the equatorial lakes mentioned in paragraph 1. Wet season flows increase on the order of 25% during low and average years due to the combination of heavy rainfall and fast run off due to thin overburden producing spates out of the tributaries (torrents). This 25% will approximately double at Juba due to the additional torrents. Low year flows are on the order of 75% of average year flows at Nimule, and about 60% at Juba. The magnitude and pattern of flows and their repetitious nature are judged to form a good basis for the production of substantial amounts of power at reasonable costs.

4. Stream flow on the northward flowing rivers and Nile tributaries in Southern Sudan is generally intermittent and consequently of little interest for power development. Two exceptions are a firm flow of possibly 0.5 $m^3$/sec. in the Kinyeti River at Katire where it flows from the Imatong Mountains and a firm flow of possibly 0.25 $m^3$/sec. at Aga Falls on the Yei River about 70 miles west of the Nile; there are also perennial flows of unknown (but small) amounts on the upper reaches of the Koss and Kit

(Ayi) Rivers. At Katire a head of 400 m might be developed and provide a small public power supply (there is a small sawmill at present); at Aga Falls the head is only 30.5 meters and development would be suitable only for a small mill, pumping, etc.

Gages

5. Gage readings are available for Nimule and Juba. The range of stage at Nimule is 4.29 meters and at Juba is 3.09 meters. These small ranges reflect high velocities and relatively uniform flows.

6. Under the Anglo-Egyptian regime many gages were established in Southern Sudan on the Nile and its tributaries and other northward flowing rivers. Many of these have been destroyed and others are not now being read. Records apparently are available (some in Egyptian files), but only a few, not on the Nile itself, will be of interest for power development. Many of these gages were established as a basis for planning the regulation and conservation of water for irrigation purposes and all of them are not needed for power studies.

The Nimule-Juba Reach of the Nile

7. The 162 m fall in the 168 km reach between Nimule and Juba is partly concentrated in five rapids, i.e. where "white water" appears at low flows. The Bank has been furnished information on the principal rapids as follows:

| Name | Distance above Juba | Fall | Measured Over (Distance) | Theoretical Power at Lowest Observed Flow, i.e. 312 $m^3$/sec. |
|---|---|---|---|---|
| Fola | 155 km | 30 m | 7½ km | 97 MW |
| Makedo | 76 " | 7 " | 3½ " | 22 " |
| Bedden | 35 " | 7 " | 10 " | 22 " |

The information has limited value since the corresponding flows are not known except that based on the missions observations they must have been low; the distances over which falls are measured are arbitrary, e.g. at Fola there is a concentration of fall of 11 m in ½ km; the power figures are based on the falls and flow shown and do not represent real development possibilities. The falls would be expected to reduce substantially during higher flows since the stage below the falls would normally increase much more than the stage above the falls; this expectation was confirmed to the mission by several knowledgeable persons who had observed the rapids during both high and low flows.

8. The following observations are considered justified on the basis of the information available:

(a) The rapids indicate places where rock outcrops in the river bed and therefore probably indicate good dam sites.

(b) A power development at Fola near Nimule would probably offer the best head condition, but the site is only 6 km from the Uganda border and a dam of even moderate height would have international implications. It is also farthest from Juba, the nearest market.

(c) The slope of the river decreases in a downstream direction. A dam at Bedden might therefore offer better storage possibilities. Note the fall per km here is less than the average for the 168 km reach. This place is also closest to market and there is an island in the river which might facilitate diversion during construction or stage construction or both.

9. The river between Nimule and Juba is reported to be confined to a definite channel without flood plain for most of its length. This can be confirmed by the mission below Fola Rapids and at Bedden. A photograph of Makedo indicates the same condition there. The entire region appears to be characterized by hard rock outcrops and thin overburden. While access was too difficult and time was to short to make certain, it seems reasonable to expect that sites can be found for dams of reasonable lengths and possibly providing ample storage and capable of producing substantial amounts of power. Ecological effects would probably be minimal since the area is sparsely populated and improvements seem to consist of very small agricultural plots and thatched huts. There are practically no roads in the area likely to be flooded by a reservoir.

Electricity Requirements

10. Juba, with a population of some 70,000 is the only town with a public electric utility in the area of interest in Southern Sudan; Wau and Malakal are more that 300 miles (about 500 km) away. The present installation in Juba is about one megawatt of diesel generation which is rendered unreliable by lack of reserves, a poor distribution system, and an oil supply route from Port Sudan of some 1600 miles, nearly half of which is by unreliable rail and the remainder by barge upstream on the Nile.

11. It is evident that the power needed now in Juba must be developed from quickly available thermal sources. Power as a by-product of timber operations has been considered but such operations are too far from Juba and too small in scale to be significant. The need for additional diesel generation therefore seems clear.

12. The mission believes that potential demand and the need for reserves is such as to justify the installation of 5 MW of diesel generation and the improvement of the distribution system as soon as possible. It also estimates that an additional 5 MW of diesel generation may be needed by about 1982. Steps are being taken by the Government to improve transportation facilities; and the cost of the oil needed for the small amount of power is not expected to be excessive.

Power from the Nile

13. Consideration has been given to getting the increment of power needed in 1982 from the Nile. The problem is how to obtain economically a small amount of power such as 5 MW from such a large river. Old-fashioned water wheels have been thought of, but their practical size and inefficiency would necessitate a substantial array of these and to make them reliable (not floating) would require some fairly substantial civil works. Diversion by canal (tunneling is not practicable) has also been studied briefly. All evidence available indicates canal construction would have to be in solid rock and to get 5 MW, five meters of head using 100 $m^3$/sec of water (or some other combination of head and volume) would have to be developed. Even with steep slopes which are available in the river it seems clear that a 5 MW development of this type would not be economically justified except for a remote possibility at Fola.

14. It is evident that a conventional concrete dam and powerhouse on the Nile above Juba will not be economically justified for some time. As noted in para. 12 above, Juba may need 10 MW of capacity by 1982; by reference to para. 15 (v) below, it becomes clear that developments within 100 miles of Juba are going to be small and slow; Wau and Malakal, the nearest towns comparable with Juba, are using less than 1 MW each at present and being 300 to 400 miles in different directions from a dam site on the Nile above Juba will prevent them from becoming part of a market for upper Nile power for many years. There is not enough information to make even an order-of-magnitude cost estimate for a conventional hydroelectric plant on the upper Nile, but if it is assumed that a 20 MW plant may be justified by 1990 and worth $1000 per kW, a capital expenditure of only US$20 million would be justified. It is decidedly questionable whether this amount would be enough. The plant should be designed with a view to raising the dam and providing for the installation of many additional generating units, perhaps of the horizontal shaft bulb type of small capacity per unit.

15. For the purpose of developing electric power in South Sudan a list of proposed activities is given below.

(i) The Bank should include the financing of 5 MW of diesel generation and an improved distribution system in Juba in its loan to the Sudan scheduled for 1975.

(ii) The Government should proceed as soon as practicable to map the Nile from Juba to Nimule. The map should have a scale of about 1:50,000 (or whatever larger scale is standard in the Sudan), a contour interval of 5 m where feasible, and a width reaching to the divides between the next parallel major river systems on either side (a tributary to the Nile below Juba may be considered a parallel major river system).

(iii) There is a gage at Juba and it is being read. It should be ascertained that the readings are correct and are reaching permanent Government records. There was a gage at Nimule for many years. The mission could not determine whether the gage is still there or being read. If it has been destroyed it should be reinstalled at the same

location and at the same zero elevation soon by the Government and readings commenced. If current meter measurements have not been made at Juba and Nimule for some time they should be started soon in order to detect any change in channel control.

(iv) Gages should be installed soon by the Government immediately above and below the steepest falls at Nimule, Makedo and Bedden and prepare river bed profiles between point several kilometers above and below the falls. The readings from the gages and the profiles would assist in the design of dams at these places. Gage readers at Nimule should offer no problem, but they may at the other points. If so, minimum access roads should be considered with semi-monthly readings by Juba personnel. A flow measurement station on the upstream side of Makedo should be prepared and operated. The information described in paras 15 (ii), (iii), and (iv) hereof will serve to confirm or change the conclusions reached in paras. 13 and 14 above and will be essential for a power survey suggested in para. 15 (vi) below.

(v) Flows in the upper reaches of the Koss, Kinyet, Iyedo, Kit (Ayi), Yei and the lower reaches of the Assau should be examined by the Government and where they are significant they should be gaged and flows measured beginning within the next year. Even though the flows are small they may serve to establish small industries and, with the development of a good road system may make additional generation by diesel engines reliable. With such beginnings, continued growth by transmission from a Nile development or Juba may be feasible. The use of the Kinyeti for the electrification of Torit should be studied as soon as a reasonable amount of gage and flow material can be assembled. It is known that there was a gage at Katire and that a few flow measurements were made under the Anglo-Egyptian regime. If a market could be developed in Torit, which has a cotton gin and a pumped water supply, using initially the small amount of power from Katire, it might be possible to justify later a 70 mile transmission line to Juba for larger supplies in the not too distant future. Similar developments at Yei might come later. It should be noted that these rivers help support coffee and tea plantations in their lower reaches and reservoirs are being considered to provide dry season irrigation. It would appear that there need be no conflict with power development, but the situation should be studied.

(vi) Subject to the collection of data and the mapping mentioned above it would be desirable to begin a complete study of electric power development in Southern Sudan in the 1978-80 period and include funds for this in a Bank loan now scheduled for 1977.

(vii) Supervision missions to Sudan should check on the progress of mapping and data collection outlined above for the next several years.

## Monthly Mean Discharges at Nimule in $m^3/sec.$

Period of Record: 1911-22 and 1925-62

| | High Year 1971 | Low Year 1913 | Average Year |
|---|---|---|---|
| January | 1192 | 554 | 709 |
| February | 1181 | 568 | 666 |
| March | 1134 | 532 | 646 |
| April | 1138 | 483 | 689 |
| May | 1221 | 564 | 828 |
| June | 1303 | 601 | 821 |
| July | 1370 | 646 | 875 |
| August | 1396 | 686 | 1020 |
| September | 1566 | 668 | 1034 |
| October | 1904 | 564 | 974 |
| November | 1913 | 686 | 875 |
| December | 1806 | 679 | 775 |

May 1975

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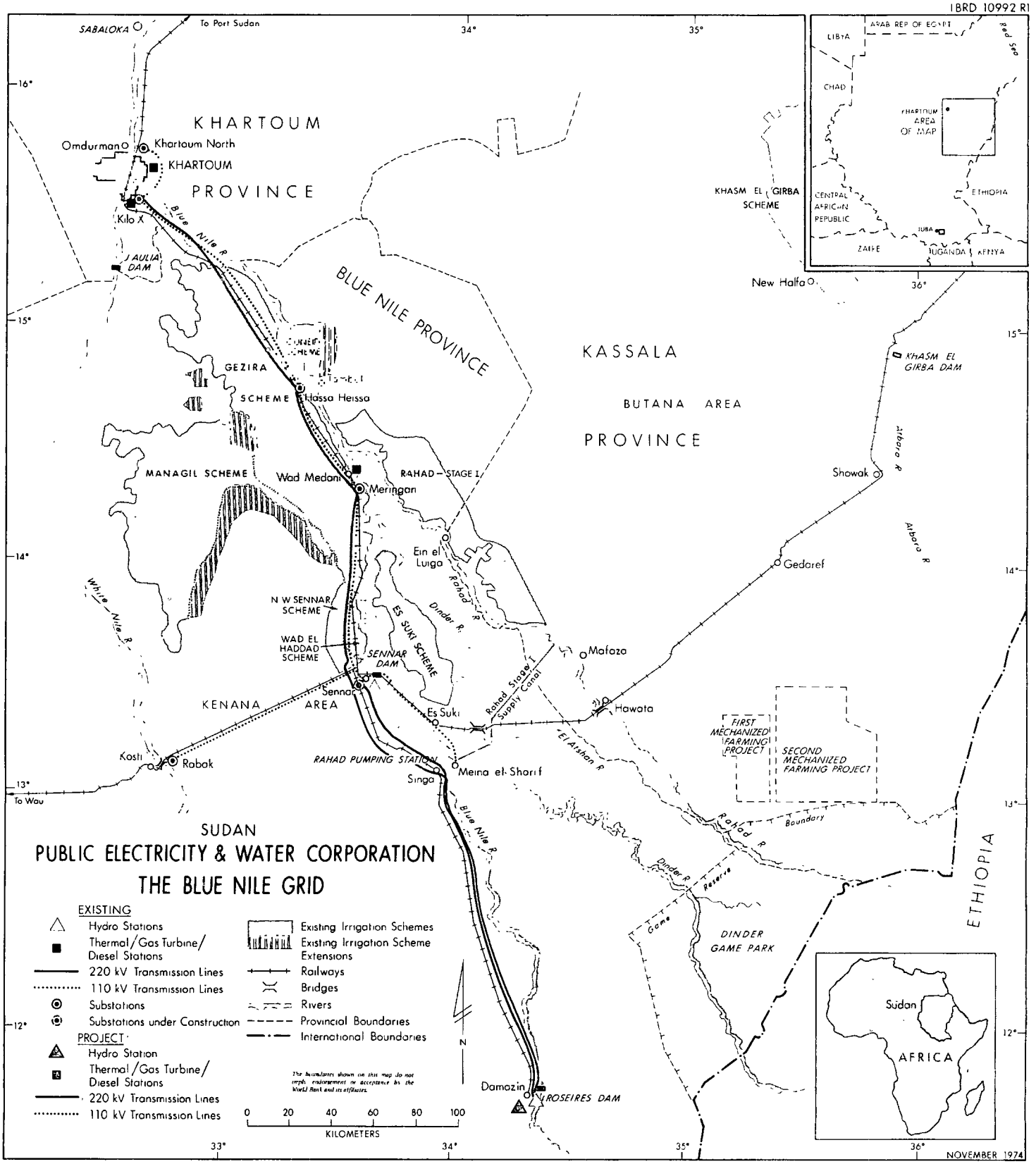

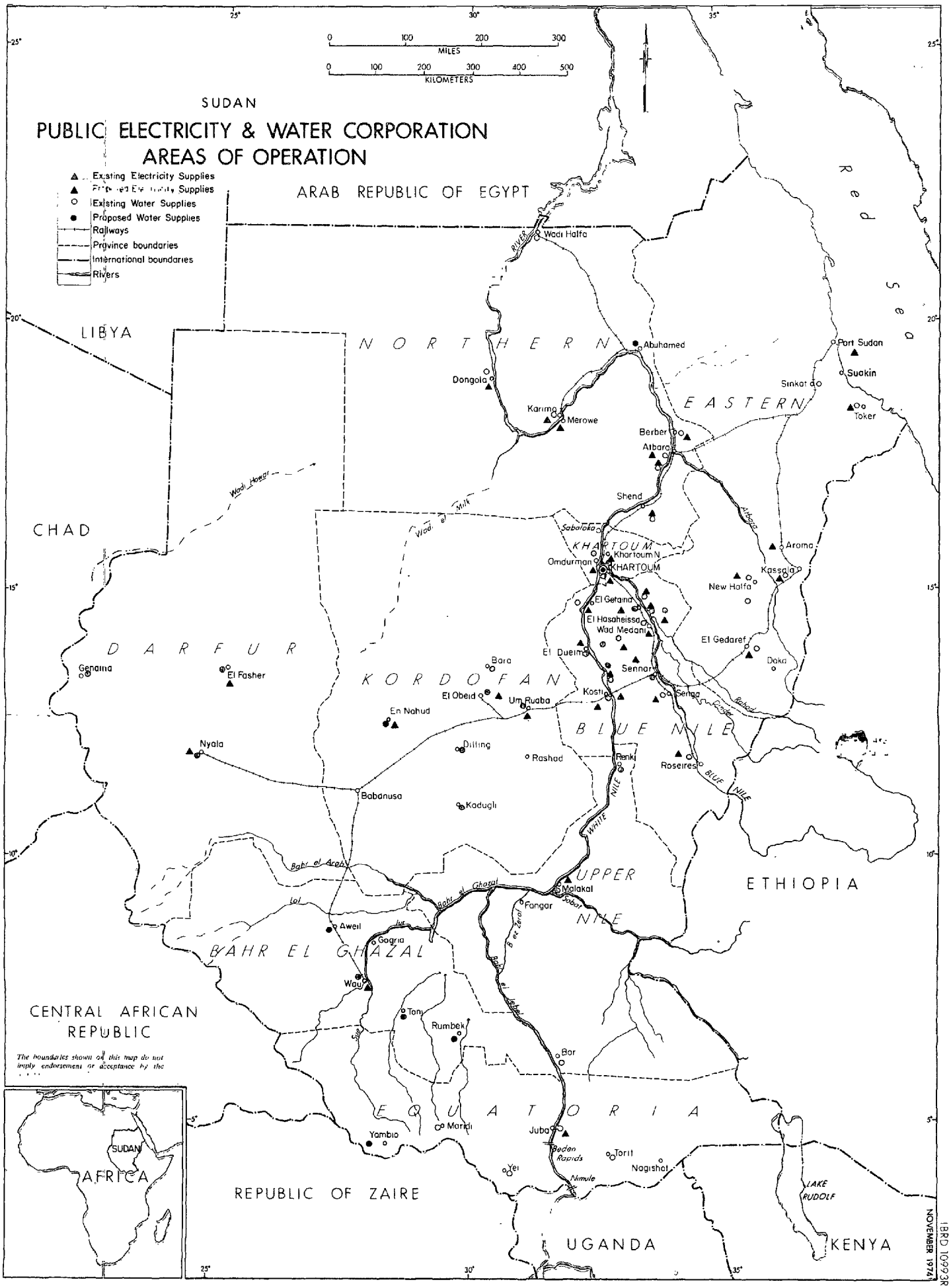
SUDAN
PUBLIC ELECTRICITY & WATER CORPORATION
AREAS OF OPERATION
Existing Electricity Supplies
Proposed Electricity Supplies
Existing Water Supplies
Proposed Water Supplies
Railways
Province boundaries
International boundaries
Rivers
0 100 200 300
MILES
0 100 200 300 400 500
KILOMETERS
ARAB REPUBLIC OF EGYPT
Red Sea
LIBYA
CHAD
CENTRAL AFRICAN REPUBLIC
REPUBLIC OF ZAIRE
UGANDA
KENYA
ETHIOPIA
NORTHERN
EASTERN
KHARTOUM
DARFUR
KORDOFAN
BLUE NILE
UPPER NILE
BAHR EL GHAZAL
EQUATORIA
Wadi Halfa
Abuhamed
Port Sudan
Suakin
Sinkat
Toker
Dongola
Karima
Merowe
Berber
Atbara
Shend
Wadi Howar
Wadi el Milk
Sabaloka
Khartoum N
Omdurman
KHARTOUM
Aroma
Kassala
New Halfa
El Getaina
El Hasaheissa
Wad Medani
El Gedaref
Doka
El Dueim
Sennar
Singa
Bara
El Fasher
Genaina
El Obeid
Um Ruaba
Kosti
Rahad
En Nahud
Nyala
Dilling
Rashad
Renk
Roseires
Babanusa
Kadugli
Malakal
Fangar
Aweil
Gagria
Wau
Tonj
Rumbek
Bor
Yambio
Maridi
Juba
Torit
Nagishot
Yei
Nimule
Bedon Rapids
LAKE RUDOLF
Bahr el Arab
Lol
Jur
Bahr el Ghazal
Bahr el Jebel
Sobat
Pibor
WHITE NILE
BLUE NILE
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NOVEMBER 1974