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# FEASIBILITY STUDY

# OF THE

# Sudan. MANUFACTURE OF PULP OR PAPER

# IN THE

# UPPER NILE PROVINCE

# REPUBLIC OF THE SUDAN

221 p.

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Prepared

for

THE UNITED NATIONS

by

Dr Julius Grant,

M.Sc., F.R.I.C.

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107, Fenchurch Street,
London, E.C.3.
England.

January, 1969.
Ref: 20392

S/F Pulp and paper
C/F SUDAN

# FEASIBILITY STUDY

# OF THE

# MANUFACTURE OF PULP OR PAPER

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# UPPER NILE PROVINCE

# REPUBLIC OF THE SUDAN

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## PART I

## INTRODUCTION

In accordance with a Special Service Agreement dated 15th October, 1968, between the Author of this Report and the United Nations, a visit was made to the Republic of the Sudan during the period 11th November to 5th December, 1968, inclusive.

The following were the terms of reference conveyed to the Author by Syd. Abdalla Abdel Wahab, Under-Secretary, Ministry of Industry and Mining, in Khartoum on the 11th November, 1968. "To study the feasibility of the manufacture of pulp and/or paper in the Upper Nile Province with special reference to the requirements of the Sudan; and to indicate likely alternative possibilities for such manufacture."

The Upper Nile Province is mentioned specifically in these terms of reference because it has been felt by the Government and by His Excellency, Clement Mboro, Minister of Industry and Mining, that the development of some local industries in the Province, preferably utilising local raw materials and local labour, would create confidence and have a general stabilising influence on affairs in the Upper Nile Province. For this reason it was asked that special attention be given to papyrus, which grows in large quantities in the Province, although other possible raw materials in the Province were also to be explored. It was appreciated at the outset by all concerned, that such a project might not prove to be viable or perhaps be only borderline economically.

However, it was felt that the whole matter should be pursued intensively so that the true facts regarding such a project could be established definitely, once and for all. This was particularly necessary in view of the fact that a number of reports (some of which are referred to in Part II) had already dealt with the subject, and most of them had been highly favourable to the use of papyrus; it was therefore essential to check whether this optimism was in fact really justified. It was further realised that a project which receives a good deal of publicity but which in fact, does not come up to expectations, could have a seriously adverse affect on local opinion - and in this respect would be even worse than no project at all; this obviously is a state of affairs which it was desired to avoid.

It should at this stage be recalled that in December, 1967, the Author carried out a Study and made a Report dated January, 1968, on the cardboard factory built at Aroma in the Kassala district. No further work was carried out on this particular matter in the course of the present Study. However, in view of the small overall paper and board consumption of the Sudan, the question of the future of the Aroma factory is to some extent inevitably bound up with that of any new development for manufacturing similar products. In addition therefore, to the subject matter of the present Study in the specific sense of its terms of reference, the whole question of a paper and/or pulp industry for the Sudan, has been considered in a more general way. In accordance with the terms of reference this has been done in some detail so far as the Upper Nile Province is concerned. Possibilities in other parts of the Sudan are indicated in outline only at this stage, pending a decision on the recommendations made in this Report.

## Diary and Travel Programme

This was as follows:

| | | |
|---|---|---|
| Sun. 10th Nov. | - | Departure from London. |
| Mon. 11th Nov. | - | Arrival at Khartoum: Sudan Industrial Research Institute (S.I.R.I.) - United Natione Industrial Development Organisation (U.N.I.D.O.) - Ministry of Industry and Mining. |
| Tues. 12th Nov. | - | Khartoum: Department of Statistics - El Tamaddon Printing Press - Government Printing Press - Department of Entomology, University of Khartoum - S.I.R.I. |
| Wed. 13th Nov. | - | Khartoum: Department of Statistics - Printing House, Ltd. - Government Printing Press - Department of Agriculture - Survey Department - S.I.R.I. |
| Thur. 14th Nov. | - | Khartoum: Pest and Infestation Division, Department of Agriculture - Department of Biology, University of Khartoum - Department of Entomology, University of Khartoum - Ministry of Commerce - The Shell Company of the Sudan, Ltd. - Sudan Railways. |
| Frid. 15th Nov. | - | Khartoum (weekly holiday): Sudan Mercantile, Ltd. - Studying files. |
| Sat. 16th Nov. | - | Khartoum: S.I.R.I. - Imperial Chemical Industries (Sudan), Ltd. - U.N.I.D.O. - Ministry of Co-operation and Labour - Packaging House, Ltd. |

| | | |
|---|---|---|
| Sun. 17th Nov. | - | Khartoum: S.I.R.I. - Hydrobiological Department, University of Khartoum - Stores and Equipment Department - Khartoum University Press - Blue Nile Packaging Co., Ltd. - U.N.I.D.O. |
| Mon. 18th Nov. | - | Khartoum: S.I.R.I. - U.N.I.D.O. - Ministry of Industry and Mining - Geological Survey Office - Survey Department. |
| Tues. 19th Nov. | - | Khartoum to Malakal. Conference at Commissioner's Office. Tour of district. |
| Wed. 20th Nov. | - | Malakal to River Sobat and Doleib Hill area by boat. |
| Thur. 21st Nov. | - | Malakal: Bum - Site investigations in district. |
| Frid. 22nd Nov. | - | Malakal to Tonga (by boat). |
| Sat. 23rd Nov. | - | Tonga - Wath Wang Kech - Lake No - Bahr el Jebel - Lake No (by boat). |
| Sun. 24th Nov. | - | Lake No - Bahr el Ghazal - Bentiu (by boat). |
| Mon. 25th Nov. | - | Bentiu: Aerial survey of Lake No and rivers area. Bentiu to Malakal (by air). |
| Tues. 26th Nov. | - | Malakal: Visits to sites; papyrus sampling and experiments. Malakal to Khartoum. |
| Wed. 27th Nov. | - | Khartoum: S.I.R.I. - Hydrobiological Department, University of Khartoum - U.N.I.D.O. |
| Thur. 28th Nov. | - | Khartoum: S.I.R.I. - Ministry of Industry and Mining - Geological Survey Department. |
| Frid. 29th Nov. | - | Khartoum (weekly holiday): Documentation. |
| Sat. 30th Nov. | - | Khartoum: S.I.R.I. - Ministry of Industry and Mining - Ministry of Health - U.N.I.D.O. |

| | | |
|---|---|---|
| Sun. 1st Dec. | - | Khartoum to Renk and to El Jebelein (Nyfer Quarries); return to Khartoum. |
| Mon. 2nd Dec. | - | Khartoum: S.I.R.I. - Department of Statistics - U.N.I.D.O. - Nile Cement Co., Ltd. - Industrial Development Corporation. |
| Tues. 3rd Dec. | - | Khartoum: S.I.R.I. - Khartoum University Press - Statistics Department - U.N.I.D.O. - Government Printer - Stores and Equipment Department. |
| Wed. 4th Dec. | - | Khartoum: S.I.R.I. - Packaging House, Ltd. - Steamers Department - Misr Printing Press - U.N.I.D.O. |
| Thur. 5th Dec. | - | Khartoum: S.I.R.I. - Egyptian Irrigation Department - Ministry of Industry and Mining - Dockyard (Shagara) - T.H. Barsamian - U.N.I.D.O. - Departure for London. |
| Frid. 6th Dec. | - | Arrival in London. |

## Personal Contacts

In the course of my work I received the utmost co-operation and courtesy from everyone with whom I came into contact. I particularly wish to record my appreciation of assistance in one form or another from:

His Excellency, Clement Mboro, Minister of Industry and Mining.

Abdalla Ali Gadalla, Commissioner, Upper Nile Province, Malakal.

Abdalla Abdel Wahab, Under-Secretary, Ministry of Industry and Mining.

J. Renart, Resident Representative, U.N.I.D.O., Khartoum.

Dr. M.H. El Halfawy, Director, Sudan Industrial Research Institute, Khartoum.

Valued assistance was also obtained from the following, who are listed in the chronological order in which they were met:

D.T. Manson, Assistant Resident Representative (Admin.), United Nations Development Programme, Khartoum (U.N.D.P.).

Abdel Fattah Mohed Salih, Engineer, Sudan Industrial Research Institute (S.I.R.I.).

Omer Mohamed Ali, Ministry of Industry and Mining.

Omar Abouzid, Managing Director, El Tamaddon Printing Press.

Mahmoud El Fadli, Government Printer.

Ahmet El Khirer, Acting Government Printer.

Dr. Feisal T. Abushama, Entomologist, University of Khartoum.

Gasin Musa, Director, Department of Statistics.

Ayoub Gebra, Sales Manager, Printing House, Ltd.

Khalid El Kheir Omer, Director, Department of Forests.

Abdel Wahab, Director, Survey Department.

Mohamed Abu El Futuh, Chief Survey Office, Topographical Survey.

G. Hillesley, Economist, (U.N.I.D.O.), S.I.R.I.

Salah El Din Hassan Ahmed, Director (Pests and Infestations), Department of Agriculture.

Dr. H.M. Hassan, Department of Botany, University of Khartoum.

\- Williams, Department of Entomology, University of Khartoum.

Ahmed El Tegany Salih, Senior Inspector, Ministry of Commerce.

Nabieh Sorial, Operations Department, The Shell Company of the Sudan, Ltd.

Barakat Osman, Acting Divisional Traffic Superintendent, Sudan Railways.

J. Thorington, Technical Manager (Agriculture), Sudan Mercantile Companies.

W. Aitken, Managing Director, Imperial Chemical Industries (Sudan), Ltd.

A.M. Warrad, Ministry of Co-operation and Labour.

Fouad Fadel, Works Manager, Packaging House, Ltd.

Professor Abbas El Hamidi, Department of Pharmacy, University of Khartoum.

Gely Hamed, Managing Director, Industrial Development Corporation.

D. Hammerton, Hydrobiological Research Officer, University of Khartoum.

Mousa Adel Rahman, Controller of Provision Office, Stores and Equipment Department.

Abdel Gabbar A. Mursall, Secretary, Khartoum University Press.

Mohamed Khogali, Managing Director, Blue Nile Printing Co., Ltd.

James Ogilo, M.P., Shilluk - South.

Joshua dei Wal, Personal Private Secretary, Minister of Industry and Mining.

Abdul Samis Ghandour, Deputy Commissioner, Upper Nile Province.

Chief Tor Akaiding, Doleib Hill, Malakal.

Mohamed Abu Shuk, Department of Agriculture, Malakal.

Chief Puok Mier, Wath Wang Kech.

Dar Lam, Wath Wang Kech.

Mohamed El Hassan Ibrahim, Acting Local Governor, Bentiu

Dr. Sayed Ibrahim El Sayed, Bentiu Hospital.

Capt. Tigani, Air Pilot, Ministry of Agriculture.

C.G.H. Govier, Industrial Adviser, Ministry of Industry and Mining.

Musa Mohd. Babiker, S.I.R.I. (Khashm El Girba Sugar Mill).

Abdel Latif Widatalla, Director, Geological Survey Department.

Capt. Middawi, Air Pilot.

Osman Kashawa, Assistant Commissioner, Northern District (Renk), Upper Nile Province.

Charge-hand, Nyfer Quarry, El Jebelein.

Police-Sgt. Joma Ishag Khalifa, El Jebelein.

Arabi Abdel, Secretary-General, Nile Cement Co., Ltd.

Dr. Mutwakil Ahmed Amin, Acting Director, Khartoum University Press.

T.E.L. Eley, UNESCO Expert, Khartoum University Press.

Mohd. Ahmi Salambi, Managing Director, Packaging House, Ltd.

Abdel Ghani, Works Manager, Misr Printing Press.

Dr. Farouk Shawan, S.I.R.I.

Shamam Omer, Economist, Industrial Bank, Khartoum.

Mohamedein Saleh, Deputy General-Inspector, Egyptian Irrigation Department.

Mohamed Sadik Al Karamany, Chief Engineer, Egyptian Irrigation Department, Dockyard, Shagara.

B.M. Katchikian, Manager, T.H. Barsamian.

## Plan of this Report

The Report is compiled under the following headings:

| | | |
|---|---|---|
| Part I | - | Introduction. |
| Part II | - | Background and History. |
| Part III | - | Market Study. |
| Part IV | - | Fibrous Raw Materials. |
| Part V | - | Chemicals and Other Raw Materials, Fuel and Electricity. |
| Part VI | - | Labour and Management. |
| Part VII | - | Site including Transport, Water and Effluent Disposal. |
| Part VIII | - | Processes, Plant and Capital Costs. |
| Part IX | - | Profitability Considerations. |
| Part X | - | Conclusions and Recommendations. |
| Part XI | - | General Summary. |

**The following points should be noted with regard to this Report:**

1. Unless otherwise stated all quantities are in

metric units and all values are in Sudanese pounds.

£(Sud)0.35 = $U.S.1.00

£(Sud)0.84 = £(Sterling) 1

2. Unless otherwise stated, the term "per day" means 24 hours.

3. Part XI is intended to be read independently of the remainder of the Report; it contains all the essential features of the latter including conclusions and recommendations, but without supporting details.

4. 1 feddan = 4,200 square metres = 1.037 acre.

References

"Mill Hydrobiology", Hydrobiological Unit, University of Khartoum, 4th Annual Report, 1956-7.

"Equatorial Nile Project", Jonglei Investigation Team.

"Water Hyacinth Control", Information Production Centre, Department of Agriculture, Khartoum, 1964.

"Water Characteristics of the Nile", J.F. Talling, Hydrobiologia, 1957, 11, 73.

"Conditions of Service for Worker Employees", Ministry of Co-operation and Labour, 1968.

"The Aroma Cardboard Factory", Julius Grant, U.N.I.D.O., 1968.

"Utilisation en Papeterie des Essences Tropicales et de Papyrus", J.R. Istas, A.R.I.P. Bull., 1958, 1, 19.

"Survey Report on the Possibilities of the Production of Pulp and Paper in Uganda and in Kenya", Julius Grant, London, October, 1956.

# PART II

## HISTORY AND BACKGROUND

### General

The terms of reference of this Study as set out in Part I, concern the investigation of the feasibility of the manufacture of pulp and/or paper in the Upper Nile Province. Also included are possible alternatives, the whole Study having special reference to the requirements of the Sudan.

It is natural that in the case of a country with a rapidly growing economy, such as the Sudan, the question of paper production should have the nature of a priority objective. The development of the industry inevitably goes hand-in-hand with educational programmes; and both require larger quantities of paper. As literacy spreads, so more books are required; and the demand for books stimulates requirements of paper - so that the whole system becomes an ever-increasing spiral of more demands for paper. The packaging side of industry and commerce also offers considerable scope for expansion in paper production, particularly where there is a cement industry in the making; or where carton production for the export of tinned goods, etc. is involved. These are all commonplace and recognised features of the developing economies of the smaller nations, and their significance in any particular country is one of degree rather than of principle. Apart from these purely internal considerations is the important saving in foreign currency which can result if a paper project can be used to cut down paper imports. The extent to which the increase in population, industrial development and greater literacy are affecting the consumption of paper, is discussed further in the Market Study (Part III).

Although therefore, a national paper industry is desirable both from a general economic and a prestige point of view, the arithmetical economics of such a development are not always as clear-cut. Paper, despite the many inroads into its functions by plastics and other materials, is still an extremely cheap product. It can be produced in large mills in the Northern Hemisphere cheaply enough to enable it to be exported to distant continents (such as Africa), at prices which are little more than those prevailing in Northern Europe. This is due almost wholly to the huge capacities of the mills concerned, and to their high technical efficiency. It most certainly is not due to cheap labour or to the cheapness of the fibrous raw material used (namely wood), though in most cases the chemicals required would be cheaper than in the more distant parts of the world. Compared with such countries a nation, such as the Sudan, might have some advantage in the lower cost of its raw material, whatever that may be; the elimination of freight costs from the exporting country to Sudan; and of course, the protective effects of the existing tariffs, which in Sudan vary from 10 to 20% according to circumstances and are usually the latter. Labour is also cheaper in the Sudan (on a man-hour basis), but more per ton of product would be required than in the highly sophisticated mills.

The question is therefore, bound to arise - at what annual production could a mill making paper or board in the Sudan be economically viable? Indeed, the whole objective of this Study is to establish this point, since it is the key answer to the terms of reference. In order to do this it is necessary to ascertain as accurately as possible, under present circumstances, the costs of the various items which go to make up the final production cost of the paper to be produced, and to balance this against the selling price, assuming that this is the same as that of the particular imported paper at present. Since the erection of a paper mill is an extremely expensive matter and all the production is centred around one complex and relatively costly machine, the manufacturing cost is often the least important factor in determining any profit made on the selling price. It is the overheads on the capital involved, such as the rate of depreciation and interest charges, plus working capital, which very often in such cases determine whether a project is viable or not. This will be apparent from a study of the figures given in Parts IX and VIII.

In approaching a Study of this kind, it is necessary to base the relevant calculations on present day conditions. Even under the most favourable circumstances, it is unlikely that a paper mill could be built from the start in under 2 years; but in the case of the Sudan, where equipment has to be brought from a distance, and where the natural and geographical difficulties are greater than in more industrial countries with better communications, at least 3 years should be allowed. Assuming therefore, that this Report is considered, a decision on it reached, and the necessary finance arranged by the end of 1969, then 1973 would probably be the first full year of operation of the mill.

It is obviously impossible to forecast what each of the many individual items involved in a production cost calculation would amount to at that date. Such a forecast might be possible for some of the items, but it would be even more misleading to use a 1973 figure for some of the data and 1968 figures for others. Therefore, as stated, the capital and running costs of the mill are calculated on present-day figures, as far as could be reasonably ascertained; and the same applies to the selling prices of the products. Even these, it must be admitted, are in some cases estimates, but the Study has endeavoured to take due account of this fact where relevant, by estimating as far as possible on the conservative side, so as to produce what may be regarded as the least optimistic picture.

<u>History</u>.

This is of course, not the first time that thought has been given to establishing a paper industry in the Sudan. A study of the numerous files on the subject showed that the matter has been under consideration from time to time for many years, and indeed, one of the earliest serious approaches to the subject was made so long ago as 1930. There is little relevance in recounting every detail of the past history of the studies on paper making in the Sudan, because of the numerous projects put forward only comparatively few can be regarded as having any serious foundation. However, the history of the subject with some more detailed consideration of the more important projects which have a bearing on the present Study, is set out below. In particular, attention is directed to those based on the Upper Nile Province and especially, the use of papyrus.

The subject is dealt with chronologically.

1912:

Apparently an attempt was made in this year to manufacture fuel briquettes from papyrus and/or sudd grass, and this is the origin of the factory at Lake No to which reference is made in Part IV. Apparently this company failed, partly because of the 1914 war and its German ownership, and partly because of unforeseen production difficulties. It is said that there was over-estimation of the amount of papyrus available, which seems rather strange in the light of subsequent and recent investigations; perhaps at that time there was less papyrus available in the Lake No area. On the other hand, judging by such of the equipment as still remains, the production difficulties are not difficult to understand; it bears no resemblance to paper making plant as used now or in 1912.

<u>1930</u>:

Between 1914 and this date there appear to have been certain sporadic suggestions for the exploitation of papyrus, but there are no complete records which indicate that these are of any permanent importance. In 1930 tests were made by the then Imperial Institute, London, on various plants from Sudan, such as swamp grass (voss), <u>Phragmites communis</u> (reeds), and papyrus. These were laboratory experiments only, and consisted of experimental digestions having as their object, methods of producing a bleached pulp with an approximate evaluation of its quality and of the yield obtained. Stems and flowering heads were treated separately, and it is recorded that the heads formed 33% by weight of the entire sample, which seems a very large proportion judged by more recent results. The cellulose content of the stems, as received, amounted to 51.7% on a dry basis, and fibre dimensions were as follows:

| | | |
|---|---|---|
| Length | - | 0.5 to 6.0 (average, 2.8) mm. |
| Diameter | - | 0.005 to 0.038 (average, 0.015) mm. |

Subsequent and rather more reliable measurements are given in Part IV.

The stems were chipped and cooked with caustic soda for 3 hours at 140°C. and yielded 43% of unbleached and 39% of bleached pulp.. The unbleached pulp gave a fairly hard, rather bulky, opaque paper, rather brown in colour and excellent in strength and quality. It was readily bleachable and to a fairly good colour.

The flowering heads had a cellulose content of 38.2% on the dry material, and the fibre dimensions were:

| | | |
|---|---|---|
| Length | - - | 0.6 to 5.0 (average, 1.5) mm. |
| Diameter | - | 0.0025 to 0.010 (average, 0.0048) mm. |

When cooked under the same conditions as the stalks, the yields were only 29% of unbleached and 24% of bleached pulp. The unbleached pulp was greyish-green, with a hard rattley handle, but could be bleached only to a pale cream coloured paper.

The general comments on the prospective paper making properties of papyrus are favourable so far as the stems were concerned at any rate, and the Sudan papyrus stems were regarded as better paper making material than papyrus stems from Northern Rhodesia, which gave a yield of only 27% of bleached pulp. Apparently this is due mainly to the smaller amount of pith in Sudan papyrus.

<u>1930 to 1955</u>:

During this period, and particularly prior to 1950, several groups of industrialists were interested in Sudan papyrus, although most of them were concerned with the exportation either of the reeds themselves, or of the pulp made from them. The manufacture of paper in Sudan from papyrus was not generally considered. Those projects interested in producing pulp for export were deterred by the difficulty of cutting and transport, and in meeting costs of competition in Europe.

<u>1956</u>:

A Swiss group investigated the possibility of a pulp mill in the Sudan, and produced what is described in the files as a favourable report, although records of this are not available. Their plan was to set up a collecting centre at Lake No, and to establish a factory at Kosti, to produce 100 tons of pulp per day.

<u>1959</u>:

(a) At the request of the Government at that time, and as a result of Marshal Tito's visit to the Sudan, Professor Andreevici visited the papyrus area of the Upper Nile. It is understood that he regarded the papyrue as a good material for paper manufacture, and his conclusions were even more favourable than those of the Imperial Institute report (above). However, nothing further appears to have been done concerning the building of an actual papyrus mill. Indeed, attention was subsequently directed to the Aroma project for making boards from cotton stalks (see 1963, below).

(b) The next major etep in the history of the papyrus project was due to Oloris Righini (other spellings occur in the files), an accountant from Asmara, Eritrea, who set up a company known as the Sudan Cellulose Paper Manufacturing Co., Ltd., having as its object the manufacture of celluloee, papers and many kinds of cardboard; the papers included newsprint, account book papers, wrapping papers and paper bags. Cotton stalks and papyrus were regarded as the possible raw materials, and the products of the mill were inteded to supply the Sudanese internal markets, the surplus being exported to neighbouring African countries and eventually to some European or Amercan markets. The output was to be 24 tons of pulp and approximately 24 tons of wrapping paper and other kinds of paper and board per day, made from cotton stalks and papyrus. The total investment cost at the time was thought to be in the region of £343,000 including buildings and erection, and a profit of £405,000 per annum was estimated. This was based on a cost of the raw materials (cotton stalke and papyrus) averaging £1.1s.0d. per ton.

The Righini investigation extended over a period of years, during the course of which the problem was investigated from a number of pointe of view (see below).

(c) In 1959 aleo, interest was shown by Messrs. Induetries Kontor, GMBH. There is a record of this project in a communication from the Ministry of Commerce and Industry and Supply, Khartoum, dated October, 1961, but no other information is on hand as to its eventual fate. A mill for 30 tons of paper per day was envisaged, involving a capital expenditure of approximately £4,000,000, and the intended production was principally newsprint, printing paper, notepaper, wrapping paper and paper for bags and sacke.

<u>1960</u>:

On the instruction of the Arabian Paper Manufacturing

Corporation of Khartoum, a survey was made on the subject by Eugen Schmidt, who visited the Sudan in April to May, 1960. He produced a well-documented study of paper consumptions and current statistics. He also assumed a mill of capacity of 30 tons of paper per day, the output being based on newsprint, wrapping and note paper, having an average sales value of £98 per ton, or £117 per ton including customs duties and local handling and freight charges. The "monosulphate" (monosulphite?) process was recommended, which meant importing sulphur. Kosti was regarded as a suitable location, and a meat processing plant, no longer in use, was intended to provide the buildings. The calculations of the Schmidt Study are based on the cost of the papyrus of £1.45 delivered Kosti, including transport and handling charges, which is equivalent to £5.37 on a dry basis, per ton. This figure assumes a specially low freight rate, whereas if the full freight rates were charged, the delivered price at Kosti, on a bone-dry basis, would have been £17 per ton.

The total capital expenditure was estimated to be £4.75 m. and the employment of 1,365 workmen was envisaged, 600 of whom would be unskilled labourers for handling papyrus and loading barges. On the above basis the annual surpluses on an output of 9,000 tons per annum were calculated to be approximately £138,100 and £327,100 assuming the full freight charges and the reduced freight charges, respectively.

The same report makes brief reference to other fibrous raw materials namely, bagasse and sisal, but these were not studied in any detail. Esparto is said to be available in abundance ith the south of the country, but this surely is an error.

1962:

In this year the Niles Cellulose and Paper Making Co., Khartoum, asked for the status of an "approved enterprise" as a cellulose and paper making company. This appears to have been a further development in the efforts of Mr. Oloris Righini, and the new objective was to make bleached and unbleached pulp, newsprint, wrapping paper, printing paper, writing paper, unbleached paper and cardboard, amounting to 16,000 to 20,000 tons per annum, at a factory at Malakal. The anticipated capital cost was approximately £3,820,000, and the raw material was to be principally papyrue but also other local vegetable matter. The average cost of the paper produced, including allowance for depreciation and interest charges, etc., was £62,286 per ton.

In this project Mr. Righini was associated with a Mr. Hartge and Baron Weiler, and the name of the company was later changed to the Two Niles Cellulose and Paper Manufacturing Co., Ltd. In its finalised form the output was estimated at 16,000 tons of paper per annum comprising:

| | | | | |
|---|---|---|---|---|
| Newsprint | - | 6% | - | 1,296 t.p.a. |
| Wrapping paper | - | 20% | - | 4,320 t.p.a. |

| | | | | |
|---|---|---|---|---|
| Printing paper | - | 19% | - | 4,104 t.p.a. |
| Writing paper | - | 15% | - | 3,240 t.p.a. |
| Carton paper and unbleached paper of various qualities | - | 40% | - | 8,640 t.p.a. |
| Total | - | | | 21,600 t.p.a. |

This would be equivalent to 72 tons of product per day assuming approximately 300 working days per annum. The total erected cost of the mill was forecast as 37,626,000 DM. (£3,150,000). It is interesting to note that the cost of collecting the papyrus in the Lake No area and transporting it by barge to Malakal was estimated at 12DM.(£1.0) per ton of raw (presumably green) papyrus. Calculations along these lines indicated a surplus of approximately £700,000 per annum, excluding charges for depreciation and interest. A further calculation from Mr. Righini, this time based on a toal capital requirement of approximately £4,000,000, was put forward in 1963.

<u>1963</u>:

(a) The authorship of a report of September, 1963, was not apparent from the copy made available for inspection, but it appears to be part of the Righini project. The report considers the previous conclusions in greater detail, especially regarding the site and area required. Production was still set at approximately 21,600 tons per annum, the same types and proportions of papers being made as those described in 1962 (above). Papyrus is again mentioned as the principal raw material, although it is stated that the cultivation of esparto grass has been designed for several areas not far from the mill. This is an astonishing statement. It is calculated that the average cost of the product at Khartoum would be £50.435 per ton; or £27.602 per ton without allowance for depreciation or after the depreciation period. The average selling price to consumers would be £130 per ton and, after allowing 10% for depreciation and 7% for interest, this would give a surplus of £1,600,000 per annum.

(b) In this year also an important study was made by the Japan Consulting Institute, entitled "A Basic Survey for the Industrialisation of the Paper Industry in Sudan". It is the result of a visit to Japan in 1962 of the Under-Secretary of the Sudan Ministry of Commerce, Industry and Supplies. In Sudan, visits were made to the papyrus area and estimates were made of the amounts available. Suggestions were put forward for collecting the papyrus and also for the yields of fibre likely to be obtained, and a site was chosen 5 miles to the north of Malakal on the right bank of the Nile, although the actual position is not stated. This is of interest in view of the site experiments and investigations described in Part VII of this Study. Pulping tests were also made on the papyrus and these are included in the summary of Part IV.

However, the stems sent were only about 70 cm. long, and 34% by weight was found to have decomposed. Several types of laboratory tests were made on the chipped material, and yields ranging from 28.9 to 42.9% were obtained, according to the cooking conditions. Both the monosulphite process and also straight caustic soda cooking were used at temperatures ranging from 160 to 170°C. The conclusion reached for the unbleached pulp was that papyrus is never inferior to that made from bagasse under identical conditions. Although pulp with higher folding endurance than papyrus pulp may be made from certain kinds of bagasse, papyrus pulp excels pulp made from any kind of bagasse in all other respects, especially in breaking length. Comparison between rice straw and papyrus shows that they are similar in all respects except for bursting strength, rice straw being the better. A similar relationship exists for the bleached pulps.

(c) The most important paper making event in 1963 was however, the start-up of a cardboard factory at Aroma, Eastern Sudan, which was intended to make 4,000 tons per annum from cotton stalks. The eventual capital cost was £480,000 and the project was sponsored by the Yugoslav Government. A Study dated January, 1968, based on the present writer's investigations in November - December, 1967, was made for The United Nations, at the request of the Sudan Government. This Study has a strong bearing on the present Upper Nile Province Study, and it is desirable here to give a resume of the position and the conclusions and recommendations made.

The mill was built to make 4,000 tons per annum mainly of millboard, using cotton stalks and possibly waste cement sacks, on 5 vat-type machines for converting the pulp into board. However, by using the method envisaged, cotton stalks were found to be an unsuitable material for making any but dark coloured, very heavy and rigid types of board, and in consequence the plant has never been run at anything like full capacity. It has occasionally run 2 shifts per day, but now only 1 shift per day is worked. One reason is the difficulty in selling the board due to its poor quality, and particularly bad cutting and variations in thickness and weight per unit area. This restricts its use to cheap suitcases, bookbinding covers and handbag stiffeners. Quite apart from the poor quality, a preliminary market study indicated that there cannot be a very large market in the Sudan for this particular type of board.

The difficulties are greatly aggravated by the fact that the Gash Agricultural Co-operation Board has decided to cease planting cotton in the region of the factory, thereby cutting off the principal raw material (cotton stalks). The possible use of castor stalks, which are being planted instead of cotton, is being actively pursued, but there is no certainty of its success.

Though the capacity of the mill is probably adequate, the machinery is in general crude and lacks the refinements necessary to obtain smooth and efficient running. An important deficiency was the absence of any proper system of technical control. A laboratory existed, but it was inadequately supplied with inferior material and, in 1967, it was almost useless. The mill had then 103 mill workers operating on a morning shift only. It was therefore, considerably overmanned, and an immediate 25% reduction was recommended. The poor state of maintenance and frequent breakdowns were partly due to the difficulty of obtaining spares owing to the closing of the Suez Canal. However, much could be done immediately by a properly-organised programme of preventive maintenance.

By using the figures in the mill records for the year ended June, 1967, a production cost was calculated showing a loss of over £60,000 per annum, excluding interest charges. A cost sheet based on conditions at that time, assuming the mill was able to make the specified 4,000 tons of board per annum from cotton stalks and waste paper with only 10% of substandard paper, showed a loss of about £20,000 per annum, excluding interest charges.

Recommendations made were that the question of a substitute raw material for cotton stalks should be pursued actively, the first choice being the castor plant stalks (*Ricinus communis*) understood to be available in 1968, from the Gash Board. A local bush, reeds from Kassala, and bagasse or kenaf stalks from Khashm el Girba, assuming cheap transport facilities were available, were less promising alternatives. If there is any possibility of the continued use of cotton stalks, then there should be a reappraisal of the present method of processing, so as to give a more flexible type of board.

Short-term recommendations made covered every aspect of the mill work from the collection of the raw material to the despatch of the finished board. Put into effect they should have resulted in significant economies resulting from purely operational procedures, and eliminating the principal customer complaints. Most of these recommendations could have been put into effect without delay, and at little cost. The labour situation should also be examined and the mill labour force reduced by about 25%. Technical control should be introduced immediately, and the overall maintenance of the mill should be brought up-to-date and kept thus.

The short-term recommendations were intended to reduce the losses. The real solution is a long-term policy. It was suggested therefore, that the mill abandons most of the manufacture of cardboard in sheets, and instead, produces a fairly wide range of papers and boards as a continuous web, which may be reeled up; there should then be little difficulty in selling 4,000 tons per annum of the new products. namely, cheap brown wrappings, the inside material (fluting) used in making corrugated cartons, boxboard, and in particular white-lined boxboard and a low grade carton paper.

To achieve the above involves re-arrangement of the 5 existing vat machines to form one long continuous machine, linked with the present tunnel dryer by means of press rolls and preliminary drying cylinders, so that the paper or board would emerge from the outlet end of the present dryer as a continuous roll. A preliminary study indicated that this solution is a distinct possibility. However, it needs to be studied in greater detail; subject to this, the cost of the conversion was estimated at about £70,000 in December, 1967. For the white-lined boxboard, importation of some bleached or unbleached coniferous sulphite pulp is involved, say 10 to 15% of the production.

Production cost sheets on these lines indicated an estimated profit of approximately £50,000 per annum, based on conditions at December, 1967. However, the major problem which determines the viability of the above recommendations is, always, the raw material position. Such a production policy would however, come into competition (so far as wrappings are concerned) with the mill operated by the National Paper Industries Ltd., in Khartoum (see below), assuming that this starts up again successfully.

The following is a verbation quotation from the 1967 Study:

"It is believed that the above long-term suggestion offers the only salvation for the Aroma Cardboard Factory. If for any reason it cannot be implemented, and if moreover it is not possible to find a suitable local raw material to be used at an economical price, then the factory cannot show a profit; and if interest and depreciation charges are taken into account the loss must inevitably be considerable. Unless such a loss is to be tolerated for other reasons (e.g., giving employment), then the only alternative is to shut the mill. In this event the use of the equipment elsewhere in the Sudan might be considered, as its selling value outside the Sudan would be extremely small. There is a suggestion that a study be made of the possibility of a pulp and paper industry for the Sudan as a whole. If such a study is made, the incorporation of the existing equipment from the Aroma factory would be logical although, as already pointed out, it is of very limited use while arranged to produce sheets instead of reels of paper or board."

During November - December, 1968, enquiries were made as to the present position at Aroma. It was understood that some of the short-term recommendations had been put into effect, and that promising results had been obtained with castor stalks. There was also the possibility that some land would be set aside by the Gash Board for growing cotton sufficient to supply the factory's requirement of stalks. However, the present output of the factory was only 2 tons per day. A committee had been set up to study the long-term recommendations, but it had not yet fully considered the matter.

The implications of the Aroma situation on the Malakal project are considered further in Part X of this Study.

(e) The year 1963 also saw the start-up of the factory of National Paper Industries, Ltd., Khartoum, a private sector operation. A short study of the position here was included as an Appendix to the January, 1968 Report. This was done because the mill was in financial and operational difficulties, and was built to make products similar to those envisaged for the Aroma factory. It is therefore, also desirable to summarise briefly here the findings of the earlier study.

Generally speaking, the condition of the machinery was poor, and had been badly maintained. The production cost sheet evaluated independently by the Sudan Industrial Research Institute suggested that, under conditions at mid-1967, the mill could just about break even. However, it was felt that under substantially the same operating conditions, but with increased efficiency, the factory could be run to show a profit of about £25,600 per annum, assuming a production of 1,500 tons per annum. The principal differences between this cost sheet and those already produced were in the amount of substandard paper made and the labour charges.

Raw materials presented a considerable problem. So far as concerned the start-up of the mill when the boiler (then broken down) was re-installed, production seemed to be assured for a time by the large accumulation of waste paper which had been made during the period of closure. If adequate supplies of waste paper cannot be obtained, then it is difficult to see where suitable supplies can come from. The Aroma factory cotton stalk pulp is not satisfactory, and in any case cannot be bought at a price which will enable that factory to survive. The importation of mechanical wood pulp had been considered but if 50% each of waste papers and mechanical wood pulp are used, the annual profit per ton was estimated at only £10,050.

Regarding the monetary value of the plant at the time, its depreciated book value was a fair assessment of its worth on site. If however, it is intended to dismantle the plant and sell it on the open market then the amount to be expected from the sale would be very much less; indeed, much would be worth little more than scrap. If dismantling the plant is ever contemplated this might be considered in the context of any future developments in the papermaking industry in the Sudan. Bound up with this would also be the future of the Aroma cardboard factory. Selling the plant in its dismantled condition is only likely to realise anything like the present written-down value if the plant is used in the Sudan, or for some purpose where the low cost of the secondhand machinery compensates for its old-fashioned design and low productivity. In any case, a good deal of money will have to be spent on the machinery in the re-erection process.

Enquiries in December, 1968, indicated that the position as outlined above remained substantially unchanged.

1964:

(a) A White Nile Cellulose and Paper Manufacturing Co. report refers to the use of a mechanical harvester.

(b) A further short report appeared from Oloris Righini. It was along similar lines to those set out above. However, this may well be a copy of the preceding report abstracted from some other source.

Background.

It will be noted that the terms of reference direct this Study specifically to the Upper Nile Province. This is an extremely important feature of the present work. It is no secret that this part of the Sudan is at present economically poor in that it has little or no industry; the needs of the inhabitants are met solely, and at times inadequately, mainly by their own production from the land. This state of affairs has necessitated subsidy from the more northern and prosperous regions of the Sudan, and administration, medical and educational services depend largely on finance drawn from the northern part of the country. It is felt, and it seems with excellent reason, that the establishment of industry in the southern part of the Sudan would go a long way towards producing a state of stability, with the elimination of the political undercurrents which at present tend to retard its progress. Any increase in the standard of living of the people of the Upper Nile Province, due to the establishment of industry, would of course, be reflected in improved social stability.

The natural resources of the south are at present little exploited, and studies are being made on various aspects of them. Perhaps one of the most important products, which impresses the casual observer, is the large quantity of plant matter which grows in the Sudd region along and around the upper reaches of the White Nile and its tributaries. Prominent among these are of course, papyrus, the paper making material of ancient Egypt; reeds (Phragmites communis); and the tall "hippo" grass (Voss), which is present in considerable quantities also. It is natural to feel that some or all of these products might be usable as a raw material for paper, and it is this which has excited the imagination of prospective industrialists in the past. The history of the background of this project as summarised above demonstrates some of the approaches

charges, respectively.



mads, although, it must be admitted, few of them had any valid foundation in the light of what is known technically and economically of paper and pulp production.

Unfortunately, this part of the Sudan suffers severely from its geographical position, and particularly with respect to communications. Practically the whole of the industrial economy of the Sudan is centred around the "three cities" of Khartoum, Khartoum North and Omdurman, and these are some 724 km. north of the principal centre of the Upper Nile Province, namely, Malakal. The three-cities are themselves not ideally situated as industrial centres being 1,030 km. from Port Sudan on the Red Sea, which is the only real route for imports and exports, and they are practically dependent on an already over-stressed railway system. Even if communications were satisfactory from the point of view of travelling time (and with the closure of the Suez Canal this is far from being the case at present), the question of cost still arises.

The awkward communications between Malakal and Khartoum are also time-consuming and costly. In general, goods must be transported by railway from Khartoum to Kosti and then shipped by boat from Kosti to Malakal; the reverse procedure applies of course, when sending goods northward. This involves double handling, and probably losses by damage due to this. The reason for the slow development of the Upper Nile Province therefore, is not

wrapping
paper - 20% - 4,320 t.p.a.



entirely bound up with lack of exploitation of its natural resources; geographical location and in particular, transport, are very important influences.

Discussions with His Excellency the Minister of Industry and Mining served to clarify the above points. Nevertheless, he expressed the opinion that such a study should undoubtedly be made, firstly because no stone should be left unturned to explore every possibility which might help in the future development and prosperity of the Upper Nile Province; secondly, because of the several apparently attractive propositions which had been put forward for the manufacture of paper in this Province, the validity of which had not been proved to his satisfaction; and thirdly, so that the much-discussed question of whether papyrus could be used for paper making in the Province, could be settled authoritatively and independently once and for all.

The above facts, history and views, therefore, form the background to this Study.

# PART III

## MARKET STUDY

### General

The purpose of this Part is to endeavour to deduce what types of paper can most profitably be made by the proposed mill, and in what quantities. The problem has already been studied to some extent in the Report made on the Aroma factory in 1967; this of course, refers primarily to the types of board which Aroma was originally intended to make. However, the conclusions reached as a result of the Study referred to indicated that the Aroma factory might do better to include in its manufacturing programme the production of certain papers in addition to boards. It is appropriate here to refer to the quotation from this Report given in Part II of the present Study.

From this it is clear that there may well be some conflict in objectives between those of the Aroma factory and of the Upper Nile project at present under study. The position is further complicated by the existence of a paper machine making wrapping papers at the Blue Nile Packaging Co., Ltd., Khartoum, and even further by the situation at the National Paper Industries, Ltd., Khartoum. These also are referred to in the Aroma Report, relevant extracts of which are included in Part II of the present Study.

The answer to the question, which types of paper should be made, depends mainly on three factors, namely:

(1) current and future demand for the respective papers;
(2) availability of suitable raw materials for their manufacture;
(3) production costs, i.e., whether the papers can be sold competitively at a profit. The question of raw materials is dealt with in Parts IV and V, but at this stage it seems justifiable to assume that the most likely raw material to be found in the Upper Nile Province is papyrus; and that this will be capable of producing a fairly wide range of papers and boards, ranging from medium-grade writings and printings to wrappings (though excluding true kraft and the stronger wrappings, and also excluding newsprint). Corrugating medium (fluting) for the inside layers of cartons, and certain types of boarde could also be produced from papyrus. The economics of the more relevant of these types of manufacture are discussed in Part IX. For the purpose of the present market study therefore, it is necessary to ascertain the amounts of these products used at present, and likely to be used in the future in the Sudan.

Statistical.

The official statistics are necessarily the basic source of information on these points and they are shown in Tables 1 and 2 which give quantities and values respectively, for the years 1963 to 1968 inclusive. Table 2 also shows the principal exporting countries which supplied paper in 1967. Data prior to 1963 are not given, as in that year certain changes were made in the basis of classification by the Customs,

**Table 1**

**IMPORTS OF PAPER ETC. INTO THE SUDAN**

**(in tons)**

| Customs Item No. | | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 (est.) |
|---|---|---|---|---|---|---|---|
| 641-1000 | Newsprint | 969.5 | 1,675.3 | 1,348.8 | 1,629.6 | 2,327.7 | 1,560 |
| 2000* | Other writing, printing, duplicating and typing paper. | 3,308.7 | 3,420.0 | 2,211.7 | 1,750.5 | 3,220.1 | 2,950 |
| 3010* | Kraft paper and kraft cardboard. | 472.3 | 1,252.0 | 169.3 | 519.9 | 2,711.7 | 3,750 |
| 4000 | Cigarette paper (rolls) | 1.0 | 1.5 | 3.0 | 3.0 | 16.8 | - |
| 5000* | Other paper and paperboard not further treated (blotting, tissues, etc.) | 672.5 | 250.7 | 377.8 | 421.5 | 348.9 | 1,290 |
| 6000 | Building boards and boards for furniture including insulation board made of vegetable fibre. | 3,809.7 | 3,140.8 | 3,925.4 | 5,159.3 | 468.6 | - |
| 9000* | Coated, treated, ruled, etc. paper and paperboard not cut to size. | 318.4 | 657.1 | 244.9 | 1,195.4 | 485.1 | 1,050 |
| 642-1000* | Paper bags, cardboard boxes, and other paper and paperboard containers | 1,566.7 | 1,418.7 | 812.7 | 2,305.8 | 1,057.2 | 620 |
| 2000 | Envelopes, correspondence papers in boxes or pads, plain and correspondence cards. | - | - | - | - | - | - |
| 3000 | Registers, exercise books, account books and other stationery n.e.s. Articles n.e.s. of pulp, paper and cardboard. | - | - | - | 8.2 | - | - |
| 9100 | Cigarette paper cut to size. | 3.5 | 17.8 | 33.6 | 34.2 | 22.2 | 90 |
| 9200 | Carbon and stencil papers. | 69.2 | 58.9 | 67.2 | 96.5 | 60.7 | 106 |
| 9900 | Other articles n.e.s. | 2.7 | - | - | 4.0 | - | 42 |
| * | TOTALS | 6,418.6 | 6,998.5 | 3,816.4 | 6,193.1 | 7,823.0 | 9,660 |

**Notes:**

1. The totals refer to the asterisked items; i.e., grades which might be made in the Upper Nile project.

2. Data for 1968 are those for January to July inclusive, multiplied by 12/7.

## Table 2

## VALUES OF IMPORTS OF PAPER INTO SUDAN (£1,000)

| Customs Item No. | Principal Suppliers (1967) | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 (est.) |
|---|---|---|---|---|---|---|---|
| 641-1000 | Austria, Norway. | 59.3 | 110.3 | 84.4 | 102.8 | 156.6 | 112 |
| 2000* | Japan, Austria. | 319.6 | 316.3 | 213.3 | 198.1 | 316.5 | 245 |
| 3010* | Finland, Netherlands. | 326.6 | 79.7 | 15.5 | 119.6 | 185.9 | 223 |
| 4000 | U.S.A., India. | 0.7 | 0.6 | 2.5 | 1.4 | 6.5 | - |
| 5000* | U.K., Italy. | 48.4 | 25.3 | 47.9 | 52.3 | 60.7 | 83 |
| 6000 | Sweden, U.S.S.R. | 139.8 | 136.4 | 144.7 | 218.2 | 38.5 | 27 |
| 9000* | Netherlands, Norway. | 48.7 | 59.5 | 44.3 | 72.7 | 58.6 | 95 |
| 642-1000* | Netherlands, Sweden. | 206.0 | 247.5 | 132.1 | 371.1 | 232.1 | 180 |
| 2000 | Norway, U.K. | 19.5 | 31.4 | 25.6 | 10.8 | 14.9 | 46 |
| 3000 | Germany (D.F.R.), U.K. | 57.3 | 58.6 | 47.9 | 46.5 | 58.4 | 62 |
| 9100 | U.S.A., Austria. | 2.5 | 6.3 | 15.7 | 16.1 | 14.6 | 30 |
| 9200 | India, U.K. | 32.8 | 29.0 | 23.5 | 30.1 | 35.3 | 45 |
| 9900 | Germany (D.F.R.), U.K. | 201.0 | 175.4 | 191.5 | 242.0 | 215.8 | 146 |
| * | TOTALS | | | | | 853.8 | 826 |

**Notes:**

1. Totals refer to the asterisked items, i.e., grades which might be made in the Upper Nile project.
2. Values for 1968 are those for January to July inclusive, multiplied by 12/7.

which means that figures for the preceding years are not comparable with those of 1963 onwards.

The figures for the quantities of these papers, which might be made in the present project, e.g., from papyrus or bamboo from the Upper Nile Province, are asterisked; and the totals at the bottom of the columns refer to the totals for these papers only. These totals show no convincing sign of real increase until 1967, the total for which (7,823 tons) is substantially greater than that of 1966 (6,193 tons) although, strangely, 1964 was better than 1966, and very much better than 1965 in this respect. Unfortunately, the high figure for 1968 (9,660 tons) is only an estimate since it is based on the available figures of January to July, 1968, i.e., 7 months, grossed up to 12 months, by multiplying by 12 and dividing by 7; it cannot be assumed that the tonnage of imports for the latter period will be pro rata with that of the former period. However, it is useful to note that 1967 shows an approximate 32% increase over the average for the previous 4 years (5,900 tons); and that the estimated figure for 1968 represents (approximately) a 23% increase on that of 1967. Since the 1967 figure represents an advance of some 25% on that of 1966, it would seem that the 1968 estimate may not be far from the truth.

It is however, difficult to draw really reliable deductions from such variable and apparently inconsistent figures, in order to arrive at the likely consumption in say, the year 1973 - which might well be the first year of complete operation of a new mill. Discussions with individual users, which are reported in greater detail below, suggest in general, that future annual rates of increase may well be greater than in the past.

In order therefore, to be conservative and yet realistic, it is proposed to assume a 20% increase per annum in the above figures, starting with the 1968 estimates, i.e., an overall increase of approximately 2.5-times by 1973 namely, to about 24,000 tons per annum (see Table 3).

**Table 3**

**PROPORTIONS OF PAPER GRADES WHICH MIGHT BE MADE IN SUDAN**

| Customs Item No. | Consumption (est.) 1973 (tons) | Proportion for Sudan manufacture | |
|---|---|---|---|
| | | per cent. | tons |
| 641/2000 | 7,400 | 75 | 5,600 |
| 3010 | 9,400 | 60 | 5,650 |
| 5000 | 3,200 | 25 | 800 |
| 9000 | 2,600 | 25 | 650 |
| 642/1000 | 1,560 | 50 | 780 |
| Totals | 24,160 | | 13,480 |

Assuming an increase in value of approximately 20% per annum starting from the 1968 figure of Table 2, gives a value for 1973 of approximately £2,000,000, all representing foreign currency. This, of course, will depend more precisely on world prices, and on the proportions of the various papers imported since these vary considerably in price;

however, it will be noted that the estimated total value for 1968 is less than for 1967, indicating a reduction in overall price per ton. These value figures are of interest in that they indicate the magnitude of possible savings in foreign currency on these grades of papers; they are otherwise of no real significance in this Report. They are not even a reliable guide to the price per ton of individual grades of paper, since the Customs classifications bulk several grades of widely differing values under the same headings. Such information was however obtainable from individual users (see below).

A study based on the individual requirements of the principal paper users in Sudan supplemented by information given in the Report on the Aroma factory, suggests that only a proportion of the above tonnage of each Customs category could be made by a mill based mainly on papyrus. This conclusion assumes that the quality of the paper products produced would need to be as high as that of papers at present being imported in the grades considered. The appended Certificate of Analyses prepared by Hehner & Cox, Ltd. shows the basic standards to be attained in the case of typical papers in current use in the Sudan. The individual grades in each of the relevant Customs categories are described in Table 1 under the asterisked Item Numbers (641-2000, 3010, 5000, 9000; and 641-1000). It will be appreciated that these represent a very wide

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ANALYSIS OF A SAMPLE OF Papers (4)

RECEIVED ON 16th January, 1969

MARKED As shown

| | Fluting Medium | Wrapping MF. | Cover Paper | White-lined boxboard | |
|---|---|---|---|---|---|
| Substance (g.s.m.) | 126.7 | 107.0 | 103.5 | 256.4 | |
| Caliper (mils.) | 9.5 | 7.0 | 6.4 | 13.4 | |
| Apparent specific gravity | 0.53 | 0.60 | 0.63 | 0.75 | |
| Bursting strength (kg./sq.cm.) | 2.55 | 1.70 | 1.80 | 5.95 | |
| Burst factor | 20.1 | 16.0 | 17.4 | 23.2 | |
| Ash (per cent.) | 2.5 | 8.9 | 8.8 | 8.5 | |
| Fibre (approx. per cent.): | | | | Liner | Base |
| Semichemical hardwood | 100 | - | - | - | 50 |
| Mechanical coniferous wood | - | 50 | 70 | - | 50 |
| Chemical coniferous wood | - | 50 | 30 | 25 | - |
| Chemical hardwood | - | - | - | 75 | - |

Comments:

It should be possible to make papers of the above types from a mixture of unbleached or semichemical bamboo and papyrus pulps, with suitable addition of bleached wood pulp where appropriate.

p.p. Hehner & Cox Limited

J. Grant

range of products to be made in one factory, especially as the relatively low overall tonnage involved will allow the installation of only one paper machine unit, which would have to be very versatile and be constructed accordingly.

Moreover, in general, it is not regarded as good paper making practice to manufacture fairly good quality white grades of paper (such as writings and printings) in the same mill as brown papers of lower grades, such as wrappings and flutings. This is because the residues from the latter are difficult to remove from the paper making system when the former are being made; and dirt troubles can arise from contamination of the white papers with the brown pulp. However, with care and a certain sacrifice of output these difficulties can be overcome if such a policy is sufficiently desirable on other grounds. In the present instance, there is a further strong objection to such a policy. The capital cost of a mill producing white papers is considerablely greater pro rata with the selling price, than that producing unbleached (brown) papers, owing to the high cost of the bleaching plant, and the more elaborate digestion and effluent recovery methods; and there are also higher running costs due to the greater chemical consumption and to the proportion of sub-standard paper made and slower running speeds where white papers are involved. All these costs can be justified only if the quantity and value of the white papers to be made are sufficiently high, and this certainly does not apply in the present instance; at least not on the estimated 1973 consumption figures. There is also the problem of providing the much greater specialised knowledge and experience required in order to make white pulp and papers.

Table 3 shows the estimated totals for 1973 for the papers in the various Customs classification grades involved. Each of these classifications however, includes a variety of grades of paper, some of which could not be made initially in the type of mill envisaged; also the 642-1000 classification represents imported manufactured articles of paper, only a proportion of which is likely to be manufactured in Sudan in 1973. Table 3 therefore, also shows (in percentages and tons) the estimated proportions of paper in each classification which might be manufactured in the mill as initially envisaged. It will be seen that the total is approximately 13,480 tons per annum. This however, includes white papers, the manufacture of which is undesirable for reasons mentioned above and confirmed by the profitability calculations of Part IX.

In arriving finally therefore, at the type of mill which should be built, it has been felt advisable to restrict consideration to certain of the grades in the Customs Item Numbers 641-3010 and 642-1000 namely, medium to cheap grades of brown wrappings (excluding true kraft), fluting (corrugating medium), and possibly white-lined boxboard -

in other words the same grades as were envisaged for the Aroma factory of the future (see Part II).

According to Table 3 it is estimated that these would amount to a total of approximately 6,430 tons per annum; say, 6,400 tons, or 21 tons per day on a 300-working-day basis per annum. Provision could be made in designing the mill for the manufacture of white papers at a later date, and, of course, forincreases in production of both white and brown papers; this question is dealt with more fully in Part VIII. This whittling down of the mill's potential production is unfortunate, but it is an essential precaution if the sale of the total output of the mill is to be assured.

A side-light on this point is contained in the Aroma Study, where it is suggested that the wrapping paper and fluting medium requirements of Sudan should be made (with boards also) at that mill. There is unfortunately, insufficient tonnage in prospect in 1973 for both mills to make these classes of paper. The implications of this are discussed in Parts II and X.

__Prices__

Various prices for all the papers referred to above were obtained as a result of enquiries from actual users and importers. If an average is taken of these values, what are felt to be reasonably reliable, current figures are obtained as follows :

| | Wrappings and Bag Papers | Fluting | White-lined boxboard |
|---|---|---|---|
| Price, cif. Port Sudan | £52 | £45 | £64 |
| Duty 20% | £10 | £9 | £13 |
| Handling | £4 | £3 | £3 |
| Delivery to Khartoum | £5 | £5 | £5 |
| Totals, delivered Khartoum | £71 | £62 | £85 |

Notes:

1. The above cif. Port Sudan price for fluting papers is the average of £41, £45, £46 and £50 per ton.

2. The above price cif. Port Sudan for the wrappings is the average of £50 and £54 per ton.

3. As to duty, at least one company enjoys a concession of 10%, instead of paying the usual 20%, this being for 5 years of which only one year remains. This has been ignored in the above Table.

4. In some instances papers being sent to Sudan via the Cape of Good Hope during the closure of the Suez Canal bear a delivery surcharge of £8 to £9 per ton. In other cases, notably those coming from eastern European countries, the surcharge is less, or absent. No allowance for this is made above, since the general opinion is that the delivered prices will not differ greatly from those ruling at present when the Suez Canal is re-opened.

5. Handling charges are less for flutings than for wrappings because the latter are sent as reels and the former in wrapped packages of sheets.

6. The corresponding data deduced from the Aroma Report are as follows (prices per ton cif. Khartoum):

| | |
|---|---|
| Imitation kraft | £66 |
| Fluting | £66 |
| Thin boards and folder "manilla" | £95 |
| White-lined boxboard | £85 |
| Boards | £57 - £65 |

Price data were also obtained for the commoner grades of white papers. They are given below, although not strictly relevant to this Report (since their manufacture is not recommended). However, they are used in the hypothetical profitability calculation given in Part IX. The prices are given, delivered Khartoum, duty paid, having been derived similarly to those for the wrappings and flutings, above.

| | |
|---|---|
| Kraft liner | £77 per ton |
| Imitation kraft (envelope paper) | £70 per ton |
| Writings and Printings (wood-free) | £115 per ton |
| Writings - better grades | £150 per ton |

<u>Trade Enquiries</u>.

In order to obtain the information given above as to markets, and especially prices, it was necessary to rely partly on published statistics, and partly on the views of the more important users of paper and paper products in Khartoum. It was found that in all cases data as to quantity, future possible requirements and prices were given very freely, and this information contributed in no small measure to the conclusions arrived at and set out above.

The visits to paper users and importers are listed below with brief details of the type and scope of manufacture. For obvious reasons, exact tonnages and prices corresponding with each user are not recorded. In several cases, return visits to firms interviewed in connection with the Aroma project were made, and the information obtained a year ago was brought up to date.

El Tamaddon Printing Press - Initially this Company operated offset machines but now have a letterpress shop. Syd. Omar Abouzid, the Manager, had been trained in London, and was obviously very knowledgeable as well as enterprising. Sizes used are mainly 70 x 100 cm. in weights of 30 to 300 g.s.m., mainly writings and printings, including manillas, and totalling about 100 tons per annum. It is expected that this quantity will be doubled in about 5 years. Austria is the chief source of supply, and deliveries come via Genoa.

Government Printing Press (see Table 4) - Here some 150 grades of paper are used (or approximately 100 excluding

**Table 4**

**GOVERNMENT PRINTING PRESS**

**(tons)**

| Description | 1963/64 | 1965/66 | 1966/67 | 1967/68 |
|---|---|---|---|---|
| Coloured cover papers | 72 | 24 | 72 | 48 |
| Coloured manilla | 150 | 108 | 150 | 180 |
| Newsprint | 390 | - | 180 | 240 |
| Glazed mechanical printing | 270 | - | - | 540 |
| Coloured printings | 336 | - | 39 | 189 |
| Cream printings | 225 | 270 | - | 450 |
| White writings | 360 | - | 270 | 570 |
| Exercise book papers; C.W. bond | 525 | - | - | 90 |
| Esparto pulp board | 90 | - | 60 | - |
| Esparto M.F. litho | 15 | - | - | - |
| Totals | 2,433 | 402 | 771 | 2,307 |

differences in colour), and the principal printing processes are letterpress and offset. There is a separate department for printing security papers for passports, stamps, etc., and here higher rag qualities are used which have been ignored in the present Study.

There is likely to be considerable development in the production of exercise books; about 2,000,000 per annum have been produced in the past few years, but the immediate future demand is for about 11,000,000 - which cannot all be produced by the Government Printing Press; the private sector therefore, will be invited to make part of these, and this is being done at present. These books are for government schools only, and the stationery for the many non-government schools is made wholly by the private sector. Basic weights used are 40 to 100 g.s.m. It is anticipated that the consumption by the press will double in about 5 years. The chief present source of supply is Scandinavia, but Japan and China are now coming into the market with cheaper papers. No duty is paid by the Government Printer.

Printing House, Ltd. - This is under the same direction as the Packaging House, Ltd., see below. Papers used are mostly wood-free writings for exercise books, government and non-government publications, envelopes, account books, pads, covers (90 to 120 g.s.m.). The increase in production is said to be on the slow side because of competition, and the principal sources of paper are Japan and Holland.

Further information was obtained on a subsequent visit namely, quantities used are:

| | |
|---|---|
| Wood-free writings and printings | 1,200 to 1,500 tons per annum mostly for manufactured stationery; a probable increase of 25 to 30% is expected in 3 years. |
| Exercise books, cover paper (from tinted waste), and imitation kraft envelope paper. | 500 to 600 tons per annum. |

Stores and Equipment Department (Table 5) - This was again visited. A big increase in certain aspects of their work, especially that for the police and army, was reported. The requirements are summarised in Table 5, and it is expected that these will be increasing steadily.

Table 5

STORES AND EQUIPMENT DEPARTMENT

(est. consumption 1967-68)

| Description | Weight (tons) |
|---|---|
| Paper, wrapping, brown | 150 |
| Paper, foolscap, ruled | 155 |
| Paper, double foolscap, plain | 85 |
| Paper, typewriter, foolscap (thick) | 160 |
| Paper, typewriter, foolscap (thin) | 140 |
| Paper, duplicating, foolscap | 450 |
| Paper, duplicating, foolscap (lower grade) | 140 |
| | 1,280 |

<u>Industrial Development Corporation</u> - The Corporation was visited as a possible paper user, since they are interested in the development of new industries which might be potential users of paper and board. It was reported that little change in the position had taken place since the enquiry made in December, 1967 (Aroma factory Report). However, the new cement company (see Part V), will require paper sacks, although it is envisaged that these must be made of true kraft and it is thought that they will be purchased ready-made as at present. Fertiliser production will also require bags, but polythene-lined jute is preferred although bitumenised papers, from Russian sources, have been suggested.

<u>Khartoum University Press</u> - This Press is undergoing substantial development in association with advice from a UNESCO - UNICEF expert; new machines are being installed and a high standard of printing (and therefore of paper) is anticipated. It is intended to install a new type of reel-fed offset machine to print sheets (reel-width mainly 25 in.). The likely future requirements are summarised in Table 6, with comments.

This textbook programme is independent of the Government Printing Press. As to grades of paper, 2 will be used: (a) smooth, machined wood-free paper; Japanese paper is preferred but Dutch and British paper are also used. Substance, 80 g.s.m., tonnage 75 tons per annum. (b) Smooth antique wood-free, 70 g.s.m.,

## Table 6

## PAPER FOR SCHOOL USE

(per Mr. T.E.L. Eley, UNESCO- UNICEF
Khartoum University Press, December, 1968)

| Year | | Children in School | | % of Age-group |
|---|---|---|---|---|
| 1965/66 | Actual: | Elementary | 489,011 | 30.1 |
| | | Intermediate | 61,380 | 4.4 |
| | | Secondary | 25,692 | 2.4 |
| | | Total | 576,083 | |
| 1968/69 | Estimated: | Elementary | 599,300 | 34.9 |
| | | Intermediate | 74,400 | 4.8 |
| | | Secondary | 30,193 | 2.3 |
| | | Total | 703,893 | |
| 1971/72 | Projected: | Elementary | 715,000 | 38.9 |
| | | Intermediate | 95,000 | 5.8 |
| | | Secondary | 39,000 | 2.6 |
| | | Total | 849,000 | |

Notes:

(1) If growth rate holds, school population will achieve about 50% of the age group for elementary schools of about 1,000,000, in 1979; subject to population total growth not "leap-frogging" ahead.

(2) Proceeding from the Unesco criterion that each elementary pupil needs a minimum of 400 pages for the first 5 years, this gives, for the elementary 4-year cycle in Sudan, a demand of about 300 tons of 70 g.s.m. paper "spread" over the 4 years; or 75 tons annually from 1968/69, increasing to 100 tons p.a. for 1971/72.

(3) However, the total of 201 tons per year for the whole system is regarded as a more realistic target, as this includes provision for diversified curricula requirements.

(4) This would involve an increase to 235 tons p.a. in 1971/72. This smaller relative increase arises from the smaller growths in the intermediate and secondary categories.

(5) Extra allowance should be made for extra-scholastic projects, especially literacy projects, involving perhaps 75 tons spread over a 4-year period.

125 tons per annum. (c) The UNESCO-UNICEF Science Teaching Programme should use 50 tons per annum.

(d) The UNESCO special 4-year investigation on illiteracy should use 75 tons per annum. All the above data are tentative. However, in the next 10 years there will be many more school enrolments, and these will increase considerably the demand for text books and exercise books.

Nile Cement Co., Ltd. - This Company is referred to under the Calcium Carbonate supplies, in Part V. It is scheduled to start in January, 1969, and will use some 2,000,000 bags per annum, 6-ply type. However, these will mostly be made from pasted "Klupak", a specialised type of kraft paper, which is outside the scope of the proposed paper factory.

Blue Nile Packaging Co., Ltd. - The paper machine installed at these works (see Aroma factory Report) is now making 800 tons per annum, mainly board from the mill's own waste. The rate of expansion is reckoned at approximately 10% per annum.

Misr Printing Press - This Company also was visited in connection with the Aroma Study, and in general, their requirements are the same as at that time namely, imitation kraft, light, high grade, 60 g.s.m., manilla type filing cover board, binding cover boards and boxboards, and white printings (30 and 62 g.s.m.). They now use wood-free (60 g.s.m.), about 360 tons per annum; 30 g.s.m., 120 tons per annum, white and tinted; mechanical printing, 54 g.s.m., 220 tons per annum. Most of their requirements are purchased through an agent T.S. Barsamian (see below).

Packaging House, Ltd. - This firm now produces 70 to 100 tons per day of cartons, i.e., 65% of the capacity of their corrugating machine. Various types of kraft liner are used, some being pure kraft and some imitation kraft. This Company should also be an important customer for fluting paper if it was made by the proposed mill. Prices of paper from Europe remain relatively low - especially if they come from Finland, because they are then carried in subsidised East German ships around the Cape of Good Hope, and freight rates are in consequence low.

An important major requirement is therefore, fluting paper (corrugating medium) for the manufacture of the wavy inside portion of cartons, and the present consumption is approximately 600 tons per annum having a substance of 130 to 135 g.s.m. A sample was obtained, and an analysis is given on Page 43. This is a likely product for the proposed mill to make. Reels are a 160 to 220 cm. wide. The factory is now working in shifts, but only at 60 to 70% capacity, although trade is increasing; however, the carton trade depends very largely on the development of other industries. As for the fluting paper, the colour is not important but the price is very keen, and the present supplies come from the U.K. Also used is kraft liner, but this must be true kraft and not imitation kraft, as it is used for the highest grades of cartons. The quantity is approximately 1,200 tons per annum.

White-lined duplex boxboard, is also used and a sample of this was obtained, and an analysis is given, on Page 43.. This is 220 to 500 g.s.m. but mostly 250 g.s.m. The quantity used is 1,500 tons per annum, in sheets and reels.

Also used are cigarette and pharmaceutical boxboard, which is a white, high quality material; and white-lined boxboard 1,200 tons per annum, again a potential product for the proposed mill.

T.H. Barsamian - These are the biggest single suppliers of paper to users in Sudan who do not buy direct from the foreign mills, i.e., the comparatively small users. They handle approximately 200 tons per annum, the chief sources of supply being Japan, followed by Czechoslovakia and Austria. Most of the paper is imitation kraft.

# PART IV

## FIBROUS RAW MATERIALS

### Criteria of Fibrous Raw Materials for Paper and Board

It is as well to consider at this stage what is required of fibrous raw material for the manufacture of paper and board; the term board is included, because it could be involved in the recommendations made in this Report (Part X). Theoretically, any material containing fibrous cellulose (i.e., any vegetable plant) can be used for the manufacture of pulp for paper and board. The value of any one particular plant species for the production of pulp depends however, on the following considerations.

Technical

1. Ease with which the non-fibrous constituents (e.g., pith, wood, resins, etc., as the case may be) can be removed.

2. Colour-to-strength ratio. The strength is reduced as colour is improved by processing, and vice versa; it is desirable to obtain the optimum balance between the two for each kind of pulp.

3. Suitability for the purpose in question.

4. Suitability for treatment at an economic figure.

5. Yield of cellulose.

6. General cleanliness.

Economic Considerations

1. Quantities available; waste materials having no other use are preferable.

2. Ease of harvesting or collection.

3. Transport facilities and costs. Many suggested raw materials which satisfy the other considerations have proved uneconomical for this reason.

4. Regularity of supplies, as regards both quality and quantity.

5. Cost of processing, including chemicals, and steam and power, and with this is bound up the purpose for which the pulp is required. A pulp having exceptional properties can sometimes command an exceptional price; the cost of production can then be a minor consideration.

6. Ease with which supplies may be replaced. Thus annuals are better than perennials from this point of view, and plants which take a long time to reproduce themselves (trees), are at a disadvantage, in this respect at any rate.

It is safe to say that, on the whole, wood fulfils these requirements, taken together, to a greater extent than any other plant material. Supplies are plentiful; they can be replaced when exhausted, although time is required; and a variety of processes has been involved, enabling wood to be converted into pulps suitable for most present-day requirements. Moreover, these processes have been the subject of close scientific study and control over many years, so that regularity of output and quality are ensured.

The following possible raw materials for use in a mill in the Upper Nile Province, are considered in this Study.

## Papyrus

### General and Historical

There is no doubt that potentially, this plant appears at first sight to be the most promising of the fibrous raw materials available in the Upper Nile Province. Its use there has in the past, certainly been the subject of considerable thought and study - and a good deal of speculation. So far as the writer is aware, papyrus is not in use and has not been used anywhere in the world on any scale, with the possible exception of a small and rather primitive mill in Uganda, which made a rather crude wallboard (see below). This does not mean that it could not be successfully used on the large scale; but only that its use has not been studied or, in localities which have been studied it is undesirable economically, for for some other good reason. The writer did in fact, make a study on the possible uses of papyrus in Uganda for pulp and paper manufacture, in 1956. The conclusions reached were favourable to the project under the conditions of that time, but its further development could not be recommended because it was felt that a mill based on pine wood in Kenya could better serve the requirements of both countries.

Since so little of a practical nature is known of papyrus as a fibrous raw material for paper, it is useful to summarise the writer's experience in Uganda. Uganda papyrus has attracted attention for many years in the past, probably because of the very large quantities available. Papyrus was among the raw materiale sent to the British Paper and Board Industry in England for investigation. The samples actually supplied were cut from plants growing to heights of 2.5 to 3.5 m. and it was found that they were easily reduced to pulp by cooking under pressure or by mechanical treatment at atmospheric pressure in the presence of hot caustic soda.

A special feature of papyrus is the presence of a relatively high proportion of pith cells and, in this respect, papyrus resembles bagasse, which contains 30% of pith, approximately. However, the pith cells of papyrus are rather smaller than those of bagasse, and this should if anything facilitate their removal. Recent work suggests also that they are much less objectionable in paper making than are those in bagasse and that their complete removal is of less importance. Thus, it was found that the pulps prepared from papyrus were more suitable than were bagasse pulps for the production of wrapping and bag papers. The tearing resistance was better, and so also was the resistance to air permeability, while the bursting and tensile strengths were well maintained. However, papyrus is a short-fibred material, and therefore, it is subject to all the limitations of such materials when used in the manufacture of strong papers. From this point of view therefore, the necessity still exists for the addition to it of a longer-fibred material, and suggestions of this nature are given below.

The more important laboratory pulping tests on papyrus are summarised in Table 7. The results show that if the papyrus could be harvested at a reasonable cost then, from a technical point of view, the papyrus may be regarded as a promising general-purpose raw material, assuming always that long-fibred material is available to add to it in the manufacture of strong papers.

Fybro (Uganda), Ltd. was a small but enterprising hardboard factory which already made sheets of hardboard from papyrus near Kampala. The material, which was cut from a nearby swamp, averaged 2 m. in height and was cut as near to the ground as possible. After 6 months it had grown again to approximately 2 m., but was then thinner and contained less pith. The cut papyrus was allowed to dry in clearings to about 20% moisture; it was then delivered in 1½-ton bundles or lots, costing Sh.45/- on the site. One labourer would cart approximately 1 ton per day, and 3 tons per day are consumed by the factory. It was estimated that 20 stalks are obtained per square metre of swamp, and weigh approximately 3 kgm. when dry. Since this is equivalent to about 12 kgm. when green, the average weight of a green stalk is about 0.6 kgm., which is close to the 0.5 kgm. found in Sudan for the stalks,

## Table 7

## SUMMARY OF LABORATORY PULPING TESTS

## ON PAPYRUS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Origin: | Sudan | Uganda 1 | Sudan | Uganda | | Congo | Sudan | Sudan |
| Laboratory: | Imperial Institute | Stoneywood (U.K.) | B.P.B.I.R.A. | J. Grant | | Belgium | Germany (Righini project) | Japan Consulting Institute |
| Date: | 1930 | 1948 | 1954 | 1956 | | 1958 | 1960 | 1963 |
| Caustic soda (% on dry papyrus) | 15 | 5 | 22 | 20 | 17 | 14 | - | 15 |
| Pressure (atm.) | 2.7 | 4.3 | 7.2 | 1.0 | 4.3 | 1.0 | - | 4.6 |
| Time on pressure (hr.) | 3 | 7 | 3 | 0.5 | 4 | 0.8 | - | 1.0 |
| Yield (% dry basis): | | | | | | | | |
| Unbleached | 43 | - | 39 | 55 | 55 | 50 | 34 | 43 |
| Bleached | 39 (Rhodesia 27) | 43 | 34 | - | 48 | - | - | 38 |
| Quality | - | Resembles straw pulp. | Good colour on bleaching. | Unbleached pulp, suitable for boards and wrappings. | | Semi-chemical pulp. | - | Resembles rice straw pulp, but lower burst. |

less flowering tops (see below). However, the yield per square metre is much lower than the 100 stalks found for Sudan papyrus from Lake No and Malakal (see below).

Since the Fybro factory was in the centre of a papyrus swamp, some 5 km. wide, and was linked with the edges of it by good roads, the conditions for collection approached the ideal. The swamp, moreover, was comparatively dry, and many of the problems which arise when papyrus grows in water did not occur here. In particular, one has to bear in mind the hazards to workers due to water snakes and to the fact that many of the clumps of river papyrus are actually floating.

At the Fybro factory the raw material was chopped in a rotary knife chopper to pieces 5 cm. in size, and blown into an air-insulated digester where they were cooked for 2-hr. with 7% caustic soda on the weight of raw material as received, at 6 atm. pressure; 2 hr. was the complete digestion cycle, and the use of caustic soda was economised by re-using some of the spent black liquor. The digesters were emptied under pressure through a cyclone and the contents pumped to a beater and thence to a forming machine, where they were made into sheets. These were 1.25 m. square, and were heated and pressed on perforated trays. The yield was 57% including any pith retained. Swamp papyrus was found to be preferable to river papyrus in this respect because it contained more fibre and less water, as well as being easier to harvest. Actually the top thin half of the papyrus was better than the bottom thick portion, seeing that the former contains more fibre and less water.

There are also considerable quantities of papyrus growing under river conditions as distinct from swamp papyrus; e.g., at Namasagali on the Victoria Nile, which was visited as a possible site for a proposed factory.

The above experience is confined to the handling of comparatively small amounts of papyrus and to papyrus obtained from swamp growths. In a factory of the type envisaged at Malakal, the amounts of papyrus involved would be much greater (e.g., some 160 tons per day, green). Moreover, papyrus would almost certainly have to be drawn from the river as distinct from swamp growths. In Uganda information was sought as to the growth habit and cycle of papyrus under these conditions. Opinions on the latter subject varied considerably and various authorities expressed the views ranging from 4 to 12 months as the regeneration period.

The question also arose whether the papyrus would reproduce itself truly, i.e., according to type. Little is known fundamentally regarding the reproductive habits of the papyrus plant, but it was interesting in this connection to have the opportunity of studying the structure of the rhizomes of papyrus, and in particular, to note that the underground growth takes place usually in a horizontal position. The rhizome is covered with brown scale leaves in its young and mature parts, but the older parts are bare and woody. When mature it can be as much as 10 cm. in diameter. In the older roots the cortex disintegrates leaving a loose leathery sheath on the root, and lateral roots which may branch once or several times, developing from the central axis. Thus there are 3 types of root, namely the primary and secondary (which become highly lignified and are dark in colour),and the wiry roots. In view of this, any suggestion that the whole of the papyrus plant should be uprooted with drags and used for paper manufacture, would be most unacceptable. Moreover, if the root, which is highly coloured and lignified, is digested with the stalks, then cooking conditions would have to be so adjusted to resolve the root. As a result, the stalks would be badly overcooked with no resulting advantage in quality and little yield derived from the root. The high silica and manganese contents of the roots also are objectionable from the pulping point of view.

In Uganda the stalk grows at first at about 0.5 m. per week, the girth remaining almost constant at the base. The rate then increases to about 1.6 m. per fortnight, after which it falls gradually. Thus, the majority of plants attain a height of some 3 m. while a few reach 4 m. in a month. It therefore, appears that a reasonable re-growth in water can be counted on in 4 to 6 months at the most, after cutting. However, it is not yet possible to say what will happen after repeated cutting; although this may not be a major consideration in the Sudan in view of the vast reserves available.

As indicated above, much laboratory work has been carried out on the pulping of papyrus for paper manufacture, by the writer included. The more important data from such work are summarised above in Table 7, and it will be seen that the results are encouraging. There are however, inevitable gaps between laboratory and mill procedures. The former if properly carried out and interpreted, will indicate whether a new fibrous raw material is worth further investigation or otherwise. Pilot scale trials are then required to confirm this and to reveal any practical problems. If there are none or if they are surmountable, then the full scale trials are required in order to set the seal of final approval on the material. In the case of papyrus only the laboratory experiment stage has been reached; moreover, as a rule the procedures used have not approached very closely the techniques of modern pulping. However, since such laboratory tests give encouraging results, it seems reasonable to assume that up-to-date techniques should, if anything, give even better results. The important point is however, that papyrus is not a known practical paper making material, and that further investigations on the best methods of using it are essential.

Table 7 summarises the principal laboratory experiments and results. They are not strictly comparable, because different techniques, apparatus and parts of the plant were used. They do however, indicate that an unbleached pulp suitable for medium grade wrappings and similar papers can be obtained with a yield of about 45%, and this figure is used in the present Study.

**The Papyrus Plant.**

Papyrus grows more widely than is realised and in consequence its possibilities have been explored in several parts of the world. In Africa these include Egypt, Sudan, Congo, Uganda and Bechuanaland, where it occurs in usable quantities. The term "paper" in fact, is derived from the word papyrus and originates from the fact that in ancient Egypt a writing material was made by slitting the stalks, opening them up and beating them to a thin layer; a further layer, with the fibres running in the opposite direction, was placed on top of the first layer and beaten down onto it, and by repeating the operation a compact sheet of strong writing material was obtained. The papyrus plant figures prominently in ancient Egyptian illustrations, and hieroglyphics, and papyrus writing material still exists in museums today. The procedure used in Egypt however, bears no relationship to modern paper making, in which non-fibrous raw material is removed from the substance of a plant chemically or mechanically, and the remaining cellulose fibres are reassembled (after purification and bleaching if necessary), in such a way that the fibres intermesh and so produce a strong web of paper.

The plant itself (Cyperus papyrus, L.) may be regarded as a large form of grass, with a marked root structure which comprises 80% of the weight of the plant. The stem or haulm can grow up to 5 m. in height though the average height is usually nearer 3.5 m.; certainly, in those papyrus areas of the Upper Nile Province visited. There are a number of sub-species of papyrus, some of which are little known, and it is very gregarious especially in swampy areas.

The stalk bears flowers at the top, is erect, triangular in cross-section and free from nodes; and it varies from a maximum of approximately 3 cm. thickness at the top to 7 cm. thickness at the bottom. The root or rhizome is thick and actively developed and can attain one metre in length (see above).. The stalk has no branches and although it flowers and forms seeds, these are prevented reaching a suitable medium for growth by the masses of the root below the plant. Reproduction is therefore, from the rhizomes. The life-cycle of the plant is usually approximately 2 years, but after cutting, new growth appears in 6 to 8 months when growth is quite rapid, and the height is a maximum after about one year. The papyrus varies somewhat in character according to the type of ground or swamp on which it grows. Thus, slightly different types exist on solid ground, on marsh and in water, and a third type is encountered on small floating islands. However, these shades of difference do not appear to affect the present Study.

A transverse section of the stalk shows a lignified network of fibres, with the fibres grouped towards the edge of the stalk to form a compact elastic fibrous tissue. The interior of the section consists largely of non-fibrous parenchymous material (pith) varying in amount and nature between that of bagasse and that of straw. It is generally recognised however, that from a paper making point of view the pith is not such an objectionable feature of papyrus as that of bagasse, and that it need not be removed before the pulping process. The fibres are similar to those of a grass, being narrow and pointed at the ends, and characterised by irregular horizontal rays. The dimensions are as follows:

| | | |
|---|---|---|
| Length | - | 0.4 to 3.20 (average, 1.26) mm. |
| Diameter | - | 0.007 to 0.022 (average, 0.012) mm. |
| Wall thickness | - | 0.001 to 0.009 (average, 0.004) mm. |

The fibres are therefore, similar in length to those of bagasse, but have a smaller diameter. These figures are somewhat at variance with those derived for the early Imperial Institute researches (Part II), but in the writer's experience are the more reliable.

The root contains only 10 to 15% of fibre although it comprises 80% of the plant, and its use for paper making is not under consideration in the present instance. The leaves represent a small proportion of the plant by weight and also in fibre content, and these also are not considered as good paper making material.

The analysis of the plant fibres is as follows (percentages of the dry fibres):

| | | |
|---|---|---|
| Pentosans | - | 23 to 27 |
| Cellulose | - | 56 to 59 |
| Alpha-cellulose | - | 41 |
| Lignin | - | 15 to 20 |
| Ash | - | 3 to 4 |
| Silica in ash | - | 1% ($SiO_2$) |

It has been suggested that the roots could be used as a fuel, but if the roots are removed the plant does not grow again, and in any case, this is not a practicable course in the present instance.

Location.

The above comments on papyrus are of a general nature, but they are applicable to Sudanese papyrus although none growing so high as 5 m. was seen in the areas inspected. It was recognised that a considerable area of papyrus exists in the Upper Nile and Lake No regions, but it was felt that the statements of previous investigators should be confirmed or otherwise.

A journey therefore, was made from Malakal, by boat (the "Akheila"), to Lake No and to a stretch of the Bahr el Jebel (White Nile) beyond it; and also along the Bahr el Ghazal which flows out of Lake No in a south-westerly direction, as far as Bentiu. By travelling only by day it was possible to observe the papyrus growth throughout the region traversed at the water's edge. However, it was not possible to gauge accurately the depth of growth between the water edge and the adjoining land behind it, and it is in this respect that extravagant claims have sometimes been made in the past. This is obviously a very important point, because it is essential to establish the shortest distance the papyrus must be transported to the mill (for example to Malakal); and this will be determined by the amount available in the river areas concerned. Obviously if the inland growth is deep, the river distance for transport to the mill will be correspondingly shorter.

The observations made by water were therefore, supplemented by a low-altitude aerial survey, not only over the above rivers, but over the whole river system and the land between, covering an area of radius about 200 km. from Malakal in a southerly, and south-easterly and westerly direction.

The procedure and results of the river survey are set out below (see Maps, Figs. 1, 2 and 3; Fig. 1 is in Part VII).

22nd November, 1968.

10.30 hours - Departure from Malakal. Narrow strips of papyrus growth seen on both banks, but usually away from water's edge. Amounts inconsiderable.

20.30 hours. Moored at Tonga for the night. On this part of the journey the Bahr el Zaraf was not traversed, and it was subsequently inspected during the aerial survey. Such papyrus as was seen during the day was mostly on the left bank, but mixed with much swamp grass (Vossia).

23rd November, 1968.

06.00 hours - Departure from Tonga. Papyrus seen mostly on left bank with grasses or reeds separating it from river to the extent of about 10 m. Growths were intermittent. Subsequently they ceased. At about 6 km. from Tonga, the papyrus was again apparent, growing high and to some depth starting from the water's edge, but seldom on both sides at the same time. Here it was growing almost at the water's edge. Increasing amounts of *Vossia* grass and *Phragmites* reeds seen.

08.30 hours - Arrival at Wath Wang Kech. The village, which is 30 km. from Tonga and is a military station, was visited, and the question of cutting local papyrus was discussed with the local Chief. It was stated that the papyrus grows again to its full height within 6 months of cutting, and that 2 men could cut 2,000 stalks in an 8-hour day, working as a team from a canoe. This would include removing the top flowering portions and bringing the accumulation of papyrus stalks to the village. It was also stated that much papyrus is to be found on the Khar Tirru and Khar Yirr Gowol, but these rivers are difficult to approach by water.

It would appear from this therefore, that most of the requirements of papyrus for a mill making 20 tons of paper per day could be obtained between Berboi and Wath Wang Kech (see Fig. 3 and Table 9).

15.00 hours. Junction of Lake No and Bahr el Jebel (White Nile) reached. Much papyrus seen on both sides on proceeding up the Bahr el Jebel, between its left bank and Lake No; and on the right bank, as far as could be seen. These stands were virtually 100% papyrus of height 2 to 3.5 m. This part of the river is very narrow for manoeuvering several barges at a time, and is obstructed considerably by an accumulation of floating water hyacinth.

17.30 hours. Anchored in Lake No (Lake Lel-Nuer)

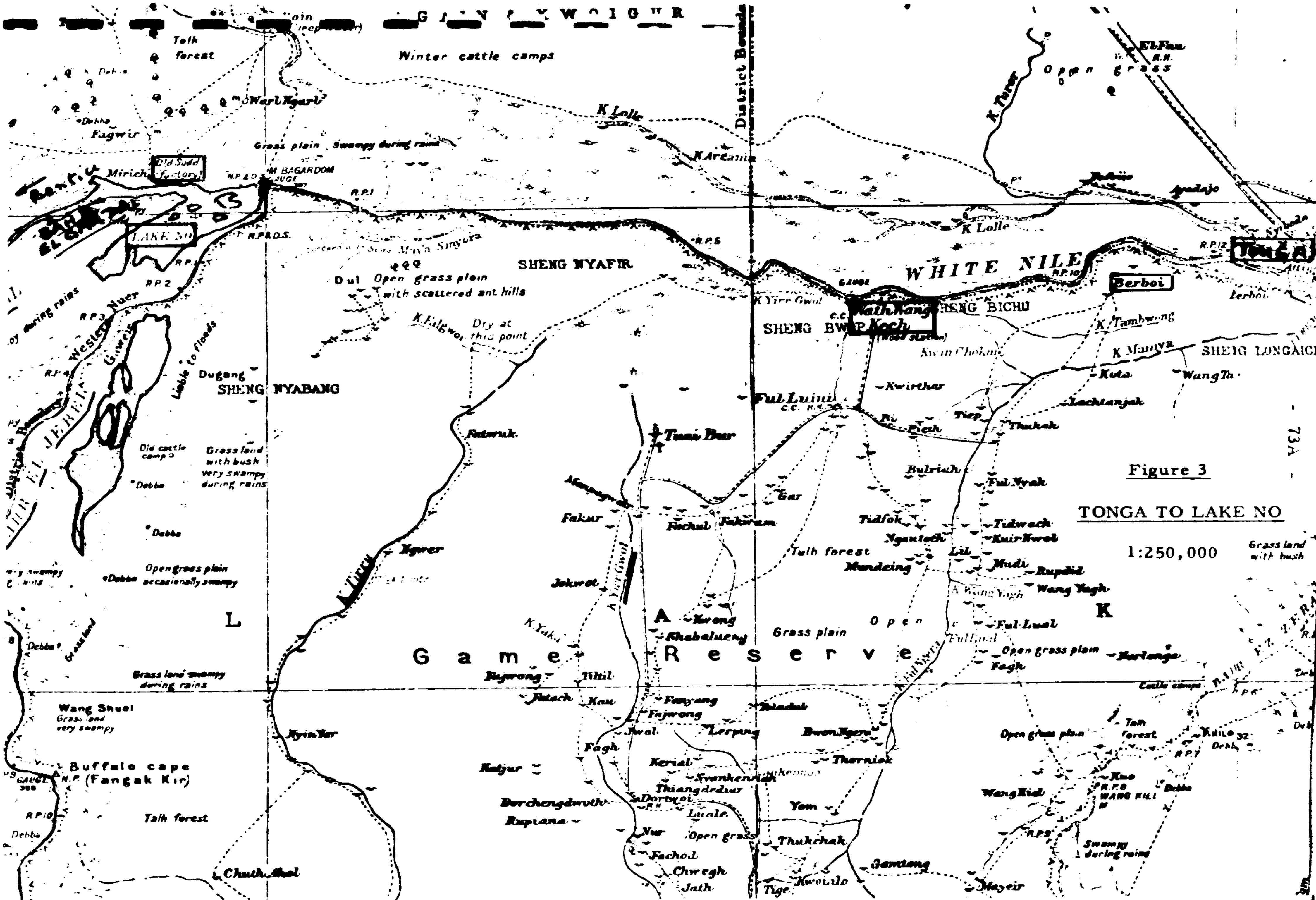



Figure 3

TONGA TO LAKE NO

1:250,000

for the night.

24th November, 1968.

06.00 hours - Departure from Lake No. The disused factory site was visited and the remains of the machinery inspected (see Part II); some was made by Ernest Lehmann (Manchester, 1913). Much papyrus was seen on the north shore of the lake, and also on the north shores of the island opposite. However, it was not possible to see from the boat the growth on the other islands or in the centre of the larger islands. It was noted that the prolific growths of papyrus end near the site of the old factory.

It was near this region that the density of growth was measured and a figure of approximately 100 sticks per square metre was arrived at (Table 8). The papyrus here has an overall thicknees of approximately 4.5 cm. at the base and 1 to 2 cm. near the tip, and the stalks are 3 to 4 m. long.

On progressing down the Bahr el Ghazal, a gradual decline in the growth of the papyrus was noted; this was replaced by swamp. Water hyacinth was absent but prolific growths of water lilies were noted. *Phragmites* reeds and *Vossia* grass were also absent, and Sudd grass was the principal type of vegetation. Further up the river a fairly continuous edge growth of small papyrus was observed; this was about one metre high but thin and sparse.

17.15 hours. Arrival at Bentiu.

Aerial Survey.

This was made in a 3-passenger Cessna (United Nations) aircraft, and observations were assisted by existing aerial photographs, although taken at considerable altitude, of certain parts of the Nile around Lake No. As 5 passengers travelled from Bentiu to Malakal, 2 double journeys had to be made by the pilot, so that it was possible to make 3 runs, observing different parts of the surrounding country and rivers on each run. The observations were as follows:

(a) Circuit of Lake No. From the air at low altitude, the north shore east of the disused factory, was shown to have papyrus growths 100 to 200 m. in depth. On the south-west side of the lake there was virtually none. On the south-east side the distance between the lake and the Bahr el Jebel, and a similar distance beyond including that between the Bahr el Jebel and the unnamed lake (at Gaweir), was thick with papyrus. No wide stands were seen beyond this. The smaller of the islands was shown to consist entirely of papyrus growth; on the larger islands the papyrus was at the water's edge, but not in the centre.

(b) White Nile and Lake No to Tonga. The observations made by boat were confirmed, but it was seen that the growths of papyrus seldom exceeded 50 m. from the water's edge. Fairly large quantities of papyrus were observed in backwaters, but as a rule these were unapproachable from the main river.

(c) <u>South of The White Nile</u>. This covered the country between Lake No to and including the River Sobat. Contrary to reports, virtually no papyrus was seen in any quantity, apart from that on the right bank of the Nile (see boat journey, above). None was seen in the valleys of the Khar Tirru, Khar Yirr Gowol or Bahr el Zeraf. The amounts south-west of Tonga were insignificant.

River studies similar to that carried out in the present instance have also been made by the Hydrobiological Research Unit of the University of Khartoum. Their study covered a longer stretch of the Nile namely, from Kosti to the mouth of Lake Ambadi, which is above Bentiu on the Bahr el Ghazal.

The growth of papyrus was estimated at intervals, in December, 1956, and it was found to be moderate at Kosti then decreasing and becoming greater around Renk, and decreasing again to a comparatively low level up to Kr. Harami, which is the name given to one arm of the Nile slightly upstream of Malakal. This is very near the favoured site for the factory, see Part VII. From this point onwards the growth of the papyrus increases considerably up to Lake No, but on proceeding up the Bahr el Ghazal it falls off rapidly, rises to another peak at Bentiu, and it falls off to a low figure again. These results are summarised graphically in Figure 6.

In general, these results compare fairly closely in essential respects with those observed during the present Study.

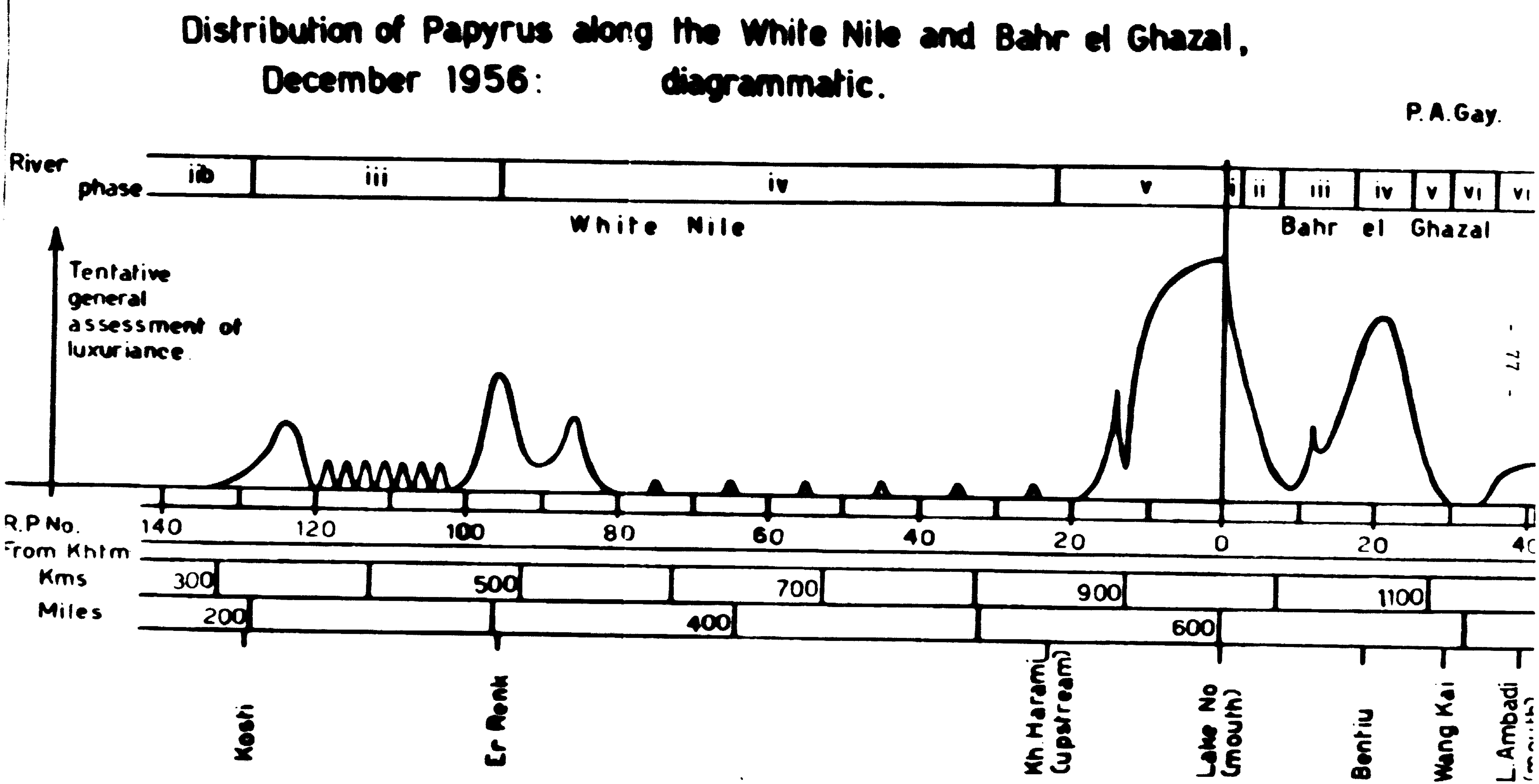



Figure 6

PAPYRUS GROWTH SURVEY

However, the fairly large quantities recorded for the Renk region and for the stretch of river between Malakal and Tonga, do not appear to be reproduced in the graph of Figure 6. The same applies to the peak shown for Bentiu. It may well be that the extent of growth of papyrus varies from one part of the river to another in successive years; or that there is a general cyclical change which produces the effects observed over a period of some 12 years. However, the outstanding feature of the comparison of the two studies is the exceptionally high peak before and at Lake No, which indicates the certainty of an adequate supply of papyrus for the mill while the river maintains its present overall character.

The precise form of distribution of papyrus in the Nile is, of course, unknown, but there are reasons to believe that in the times of Ancient Egypt it was much more extensively distributed than at present. Attempts have been made by the above mentioned Hydrobiological Institute, to relate the occurrence of papyrus with such characteristics of the river as the nature of the sediment (as determined by chemical analysis), the pH value (or active acidity) of the water, and the rate of flow, etc. However, no reliable relationship has been found, and there always appear to be exceptions which confound any possibility of a generalised theory.

Reference to the Jonglei Report on the Equatorial Nile Project, is made elsewhere in this Part, and this implies the possibility of a change in vegetation following a change in factors brought about by the operation of the project. However, the Hydrobiological Unit believes that this does not necessarily follow, because the history of a hydrobiological community must always be taken into account in such instances. Thus, the theory put forward in 1965 was that the accumulations at Kosti and Renk, then much larger than at present, were the residue from a former continuous distribution and are not recently established colonies. This may well be true since they appear to be much less in 1968 than in 1956. If indeed, this is true, it may well be that the only really dense areas of papyrus are from the Kh. Arami to Lake No and that, in the course of time, these too may gradually become eroded. However, the fact remains that, at present, the areas available are considerably in excess of the requirements of any mill envisaged in the future; and that unless there is a very marked change in the general character of the River Nile over this stretch, this situation will remain valid.

It is evident from the above that, under present conditions:

(a) Ample papyrus for a mill making 21 tons of paper per day can be obtained from the region between Tonga and some 20 km. upstream; assuming 2 crops per annum.

(b) The village of Wath Wang Kech, at present a military post, but standing on fairly elevated and dry ground on the right bank of The White Nile, appears to be an ideal collecting centre for the papyrus from this area; from here it could be taken down to Malakal by barges.

(c) In the event of larger quantities of papyrus being required, it would be necessary to exploit the stands at Lake No and the area between it, and the Bahr el Jebel. The quantities here are considerable, but the cost of transport to Malakal would be correspondingly greater because the longer distance would involve having more barges and tugs in circulation; these are a costly item.

It was therefore decided that, for the purpose of this Study, it would be assumed that the papyrus for a mill at Malakal would be collected from the river near the village of Wath Wang Kech; brought there for any treatment, baling or storage; and transported from there to Malakal.

It has been proposed to cut at some future date, a canal from near Doleib Hill to Jonglei (Bor) on the upper reach of the Nile, thereby by-passing the whole of the bend of the Bahr el Jebel. This scheme has been discussed for many years, but it has never yet materialised. From a navigational point of view it will obviously be of tremendous advantage to the locality, but there are theories that the resulting alteration in the flow of the Bahr el Jebel may affect the location and amount of existing papyrus. These however, are only theories, and it is impossible to say to what extent they will be justified. Under the circumstances it was felt advisable for the purpose of this Study, to ignore the possible effects of this scheme on the papyrus supplies. However, if the project should materialise, such possibilities should not be ignored.

The papyrus stands were inspected at close quarters at Lake No, and it was established that the growth density is approximately 100 stalks per square metre. A number of stalks (17) were also cut at Malakal, for a moisture test, and weighed green; this showed that they had an average weight of approximately 0.48 kgm. after removal of leaves and approximately 8 cm. of adjoining stalk. The moisture content experiments are described in Table 8; for the purpose of the evaluations of this Study an overall average weight of 0.5 kgm. and a moisture content of approximately 75% are assumed. The data given in Table 7 suggest that, of the 25% of dry material in the stalk, the usable paper making material will amount to approximately 45 to 50% (unbleached), so that the yield of such material on the green stalk is approximately 10%. On this basis the calculations given in Tables 9 and 10 would apply.

Harvesting the Papyrus.

The problem of cutting the papyrus and transporting it to the mill gives rise to certain well-defined problems, which may be described as probably being a key to the whole viability of the project. These problems arise principally from the fact that the papyrus grows in water or swampy areas, which is really accessible only from the river; that a large number of stalks have to be cut in order to obtain the requisite quantity of fibrous material for a day's production of the mill; and because of the bulky nature of the papyrus stalks once they are

## Table 8

## MOISTURE CONTENT OF GROWING PAPYRUS

On the 26th November, 1968, 17 sticks of growing papyrus were cut from a clump in The White Nile at Malakal, from a position in the water near the right bank. Healthy-looking plants were selected, averaging 3.5 m. in length. The plants were cut just below water level, the tops were removed with about 8 cm. of stalk, and the remaining stalks were at once weighed in 2 batches of 8 and 9, respectively, care being taken to avoid loss of moisture between cutting and weighing.

The stalks were then taken to Khartoum,, and dried to constant weight at 105°C. in the laboratory of the Sudan Industrial Research Institute.

The results obtained were as follows:-

| | | |
|---|---|---|
| **Green stalks:** | | |
| Total weight (17 stalks) | - | 8.09 kgm. |
| Average weight (1 stalk) | - | 0.48 kgm. |
| **Dry matter contents:** | | |
| Batch 1 (8 stalks) - | - | 21.8% |
| Batch 2 (9 stalks) | - | 23.5% |
| Average | - | 22.7% |
| **Moisture** | - | 77.3% |

Table 9

LENGTH OF RIVER TO SUPPLY PAPYRUS

FOR 6,400 t.p.a. OF PAPER

| | |
|---|---|
| Annual paper output | 6,400 tons |
| Papyrus pulp (80%) | 5,100 " |
| Bamboo pulp (20%) | 1,300 " |
| Papyrus (green) required (approx. 10% yield) | 51,000 " |
| Papyrus stalks required (0.5 kg. each); approx. | 100 million |
| Area to be harvested (100 stalks per sq.m.; 2 crops p.a.) | 500,000 sq.m. |
| Length of river bank (50 m. growth depth); per annum | 10 km. |
| per day | 35 m. |

Since the papyrus seldom grows in any depth at both sides of the same stretch of the river in this region, the distance of 10 km. would apply to the river itself. With Wath Wang Kech as centre, this would be about 5 km. in each direction of the river.

cut and ready for transportation. Since nearly 100 tons of green papyrus have to be cut to provide one ton of paper (i.e., about 200 tons per day), the magnitude of the problem will be appreciated.

Interference with cutting operations by water hyacinth is also a possible difficulty which has not been taken into account in this preliminary Study. A note on this plant in the Nile is given at the end of this Part.

The problem falls under two main headings namely, the cutting and the transportation, and these will be dealt with separately.

(a) Cutting Papyrus.

Table 10 shows a calculation based on cutting the papyrus by hand. It assumes that 2 men, working as a team from a canoe, could in an 8-hour day, cut 2,000 stalks and transport them to a collecting centre at say, Wath Wang Kech (see above). This information was based on a conversation with the Chief of that village and general local opinion (see Part VI). The local Chief's notion of the rate of remuneration was higher than that given in the calculation, but the latter is based on current rates for this type of work in the Upper Nile Province. However, his estimate of 1,000 stalks per day per man (one every 30 sec.) seems high.

It will be apparent from Table 10 that the cutting of papyrus by hand is comparatively cheap; and moreover, it would require a team of approximately 340 men in order to cut sufficient raw material for 21 tons of paper per day. This of course, would help the local employment situation, but it would also mean housing and other facilities on the spot, which might present difficulties. Moreover, if it was found that the output of the mill could be increased at a later date, the large addition to the team of men required for this purpose would make the whole system completely unwieldly.

Table 10

COST OF CUTTING PAPYRUS

BY HAND

| | | |
|---|---|---|
| Daily mill output (paper) | | 21 tons |
| Papyrus pulp required (80%) | | 16.8 tons |
| Green papyrus required | | 168 tons |
| Green stalks required (0.5 kgm. each) | | 336,000 |
| Cutting force (1,000 stalks per man) | | 336 |
| Pay rate per man per day | | £0.20 |
| Total labour cost per day | | £67.2 |
| Cost per ton of: | green papyrus | £0.43 |
| | pulp | £4.3 |
| | paper | £3.2 |

It is felt that the estimate of 1,000 stalks per man per day is an overestimate. In addition to this, a force of men would be required at Wath Wang Kech to handle the papyrus on receipt, and load it onto the barges for transport to Malakal. If say, 30 men are allowed for this purpose at the same pay rate, then an additional daily cost of £6.00 per day would be incurred. This is equivalent to a total wage rate of about £73 per day, equivalent to £0.435 per ton of green papyrus.

In view of the element of uncertainty in these figures, for the purpose of the present calculations a figure of £0.50 per ton will be used.

The alternative to hand-cutting is some form of mechanical harvester. This is a problem which has called for consideration over a number of years in similar connections. Two very relevant similar examples occur firstly, in Norfolk, England, where reeds are collected for thatching roofs and other purposes; and also in the delta of the Danube in Rumania, where reeds are collected for paper making, among other purposes. In both instances, mechanical forms of harvesting have been devised. These consist essentially of a boat with a cutter mounted in its bows, which approaches the growths of reeds from the water direction and cuts them just above or just below water level, as required. A conveyor lifts the reeds into the rear of the boat, from which they are subsequently transferred to barges, and then carried to a storage depot.

Operations on these lines have produced successful results in both of the instances mentioned. The whole question was explored by the writer in a Study he made for the Uganda Government on the collection of papyrus from the upper reaches of the Nile, between Lake Kyoga and Lake Victoria, where the problem is very similar (see above).

The question of the utilisation of this type of cutter has been followed up in England and Denmark, and tentative details occur below. The two types are as follows:

Howard & Dennis, Ltd., Bedford, describe their machine (Fig. 4) as a standard unit form, supplied with 2 types of cutters. One of these is a standard fixed blade cutter in which the whole cutter arm and blade oscilate. The makers describe it as suitable for maintenance of a watercourse once it has been initially cleared of unwanted growth. It therefore, appears to be more suitable for reed growth than for cutting the thicker and taller papyrus. The second type of cutter can be attached in place of the fixed blade cutter, and is a double-bladed reciprocating saw-and-shear blade, similar to the reaper blade but having two moving blades instead of the conventional one. This has not actually been tried out on papyrus, but would appear to be suitable if the aperture between the cutting edges is sufficient to accommodate the thick lower extremities of the papyrus stalks. The price for a single machine with this type of cutter only (without conveyor), is approximately £7,000 (sterling) fob. U.K. port, but the price would be reduced if more than one machine is required.

In their practical experiments Messrs. Howard & Dennis, Ltd. investigated the effect of the mat of papyrus root on the cutting efficiency of their machine and found that where this is some 45 cm. below the water level no difficulties were experienced, as the hull can easily bend down to the lower uncut part of the stems. However, where the mat of roots is at the surface of the water, it has either to be pressed to one side or downwards to allow the passage of the hull of the boat. It is therefore, suggested that the hull below water-line should be pointed, so as to force the root mat sideways; it should also have a very gradual slope from the bottom of the hull up to the water-line, to press down any roots which are not forced to the side. This does not seem to present any particular difficulty, but where the growth is extremely dense and solid the roots would have to be pressed downwards, and where there is sufficient depth of water to allow this to occur the problem would resolve itself into giving sufficient propulsive effort from the paddles. Once a channel of open water is produced in the stands of papyrus, the passage of the cutter and the problem of the roots is largely solved, because the boat can pass over the cut bases of the stems.

It is estimated that this machine should cut at least 3,000 square metres per hour, and that it can be operated by 2 men. This is equivalent to 300,000 stalks weighing 150 tons, i.e., nearly one day's requirement of green papyrus for the mill as envisaged. It should however, be emphasised, firstly that this machine has not actually been tried out on papyrus itself; and secondly, that the price includes only the self-propelled boat and the cutting unit. When the reed is cut it must still be collected and transferred to a larger boat or to a collecting point. So far as the first proviso is concerned, it should be pointed out that Howard &

Dennis, Ltd. have investigated this problem on the spot in Uganda, and have been responsible for the design and fabrication of specialised swamp clearing and weed cutting machinery for a large number of years on the Victoria Nile. On one of these occasions extensive practical trials were carried out, and this led to the development of the machine now described.

An outline specification is as follows (see Fig. 4) :-

Hull. Constructed of mild steel plate, suitably gussetted and stiffened.

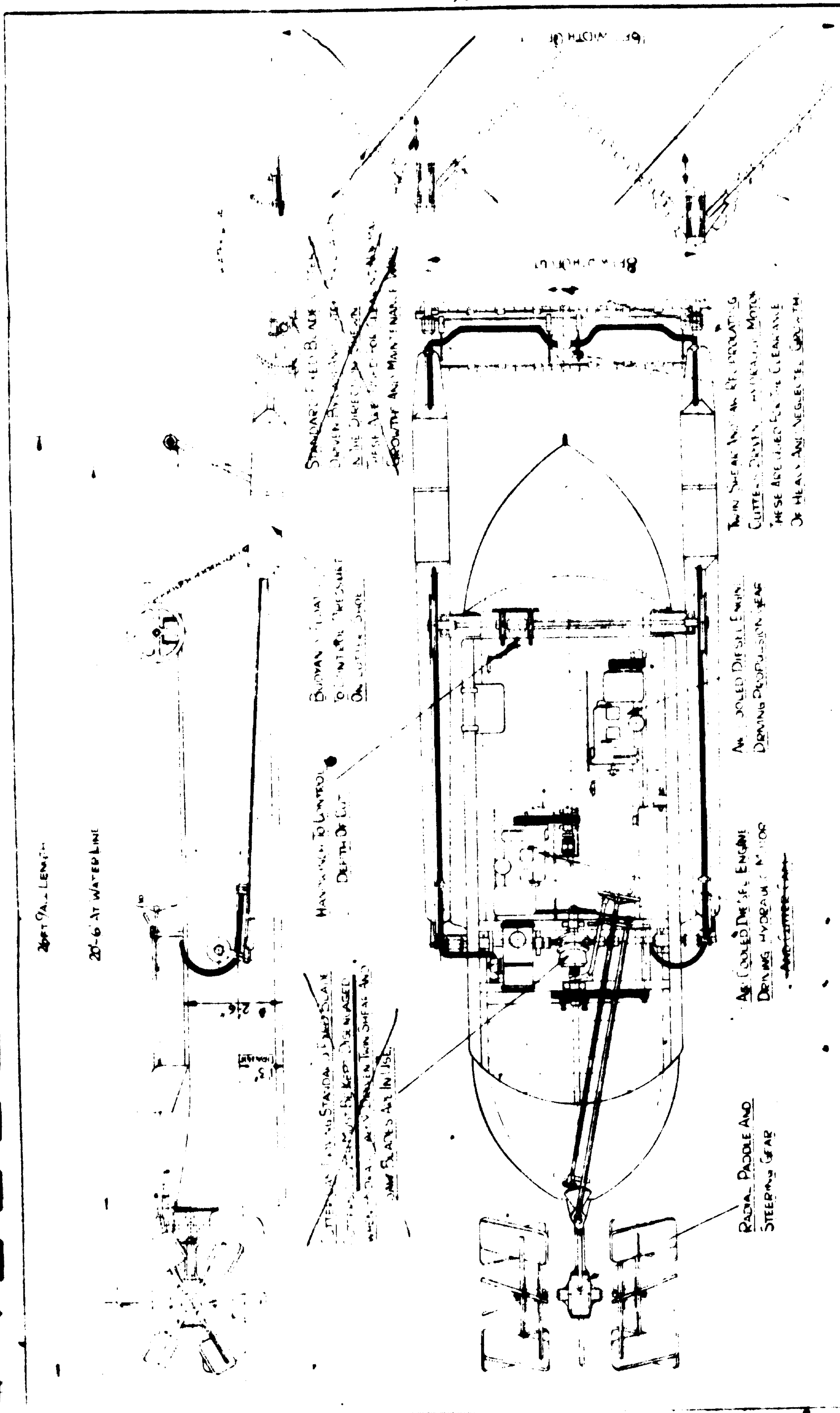
Propulsion and Steering Gear. By means of twin paddles at stern. The whole paddle gear is hinged vertically and directed as a rudder by steering wheel.

Power Unit for Paddle Gear. Two-cylinder, air-cooled diesel engine, 12 H.P., complete with self-contained friction clutch, speed control governor, fuel tank and exhaust silencer.

Driving Gear. The power is taken from the engine through the friction clutch and chain reduction to the main shaft; from there by bevel gears to the paddle shaft and paddles.

Cutting Gear. Special cutting gear for initial clearance. This consists of combined reciprocating shear-and-saw cutter blades for operating in either direction of travel. Width of cut, 5.3 m. The blades are fixed on the front and rear of the cutter arm brackets for cutting in either direction of travel, and are driven by an oil motor.

The cutter arms are suspended from an oscillating




GEN ARRGT OF K TYPE WEEDCUTTER

Figure 4

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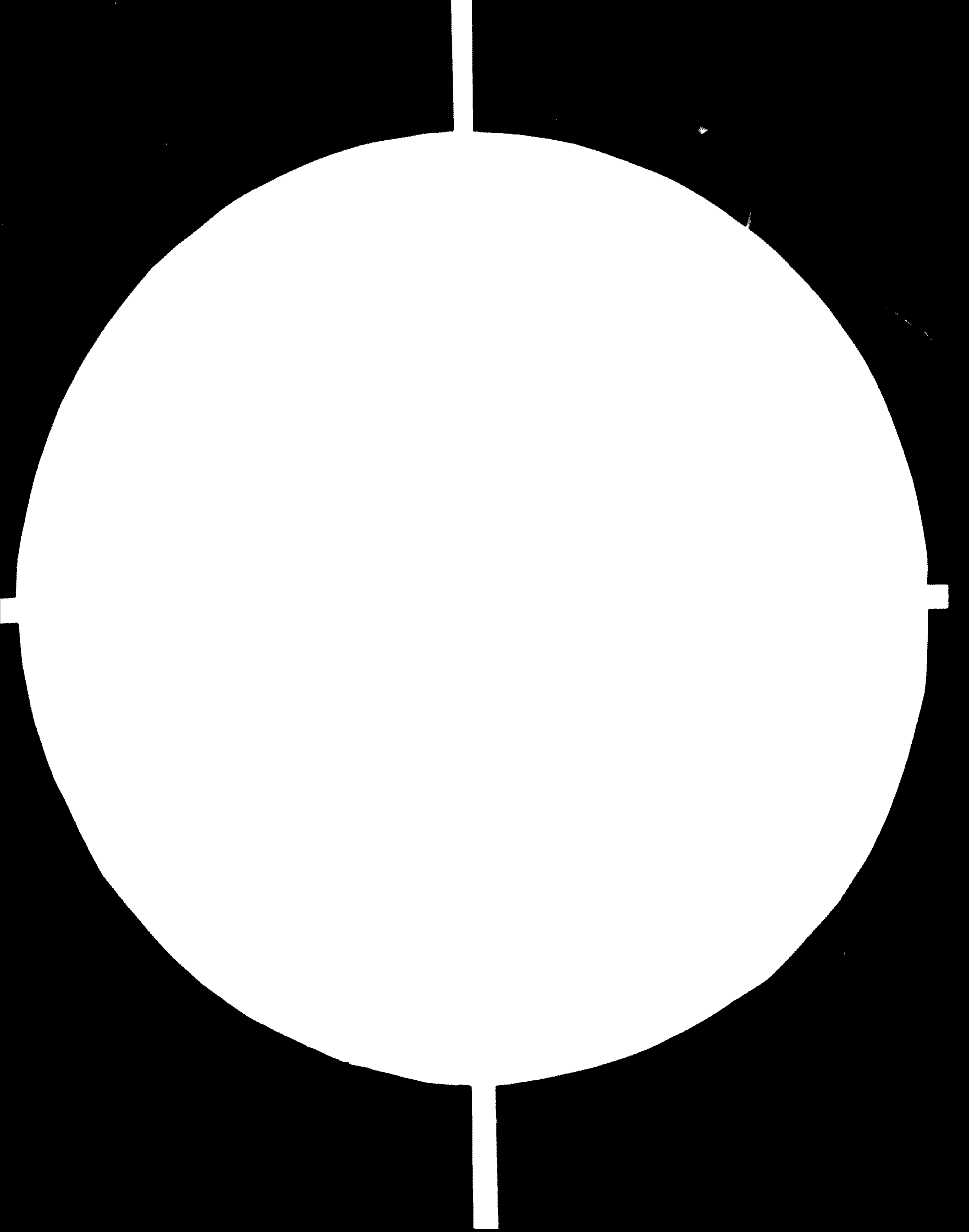

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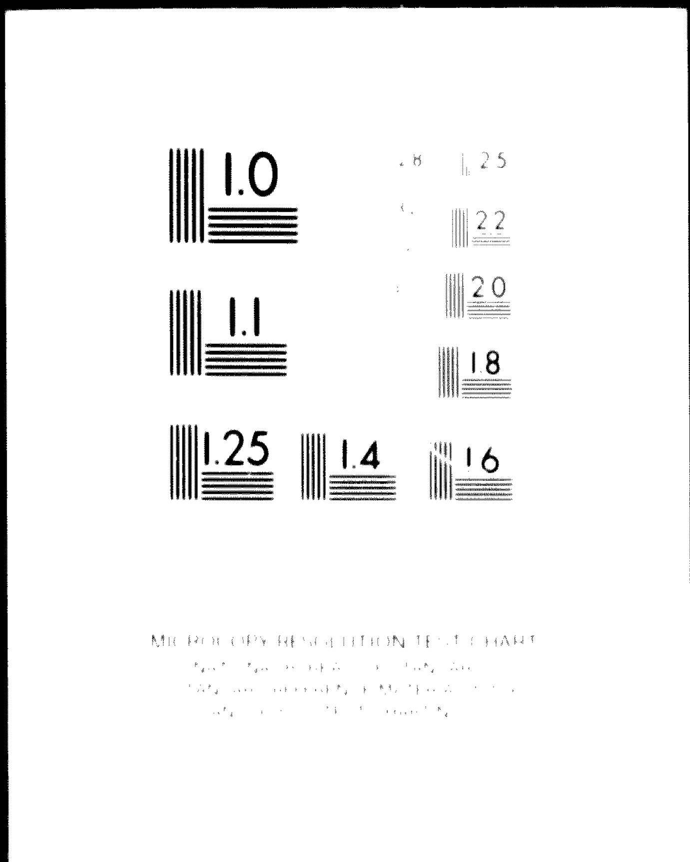


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lever which is driven from the power unit. The cutter brackets fitted on the lower end of the arms are fitted with a suitable shoe on the underside to enable them to ride over obstructions.

The knives are mounted to permit setting at various angles to suit the depth of cut. If the boat is riding on the bed of the waterway they automatically follow its contour; but by means of a small hand winch they can be raised to operate at the depth required. Width of cut, 5.3 m. Each blade is hinged, and while not allowed to drop below the horizontal, it is free to rise if an obstruction is met.

Power Unit for Cutting Gear. A 10 H.P., two-cylinder, air-cooled diesel engine supplies the power for the cutter.

Depth Control of Cutting Gear. This is by means of a hand winch which can control both arms together when the saw-and-shear blades are in use; or each independently when the oscillating types of cutters are used.

Painting and Finish. The hull and machinery are thoroughly coated with three coats of good quality paint.

| | | | |
|---|---|---|---|
| Hull Dimensions (approximate) | - | Length | 7 m. |
| | | Width | 2 m. |
| | | Depth | 0.8 m. |
| | | Draught | 36 cm. |
| Shipping Particulars (approximate) | - | Gross Weight | 4.25 tons |
| | | Net Weight | 3.5 tons |
| | | Length | 7.5 m. |
| | | Width | 2.6 m. |
| | | Depth | 1.5 m. |

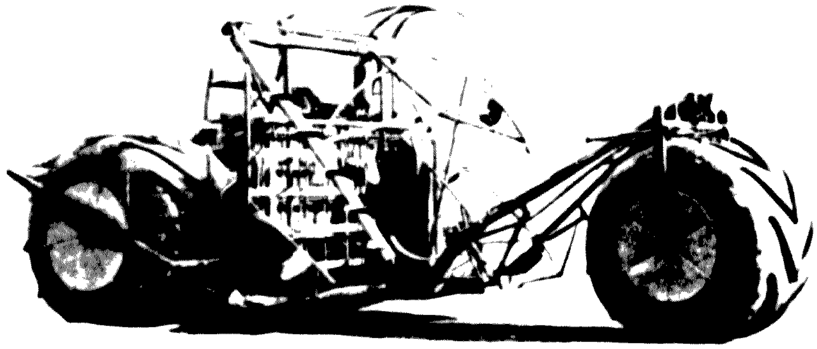
A/S Seiga Harvester Co., Ltd., Copenhagen, Denmark, make an alternative type cutter (Fig. 5); however fuller details are not at present available. This machine also, has been devised for cutting crops as jute, kenaf, reed, etc., and machines have also been supplied to the Rumanian Government for harvesting reeds in the Danube delta. Here again no tests have been made on papyrus itself, but it is claimed that the machines are satisfactory on swampy ground when used with reeds.

It does not appear to be possible to use the machine in water deeper than 60 cm. as it must travel on the river bed. It is stated that the capacity of the harvester is very difficult to indicate because it depends primarily on whether the wheels have any ground contact. It appears that the harvesters are specially suitable for working on mud, but as stated, contact with the ground can be kept to within a depth of 60 cm. of water. It would appear from the illustrations that these machines are more suitable for working with reeds in swamps, but there seems no reason why they should not be adapted to papyrus.

However, assuming the maximum theoretical rated capacity of 1 hectare per hour, this would be equivalent to 1,000,000 stalks, i.e., 500 tons of green papyrus. This is such a high figure that confirmation of the rate of cutting 1 hectare of papyrus (as distinct from reeds) should be obtained. No doubt operation in deep water will affect the position

Figure 5

# SEIGA AMPHIBIOUS REED HARVESTER



Model: PELIKAN M

**DO NOT LEAVE WHEEL-TRACKS**
**DO NOT SPOIL VEGETATION**

Mastering any terrain
including floating islands

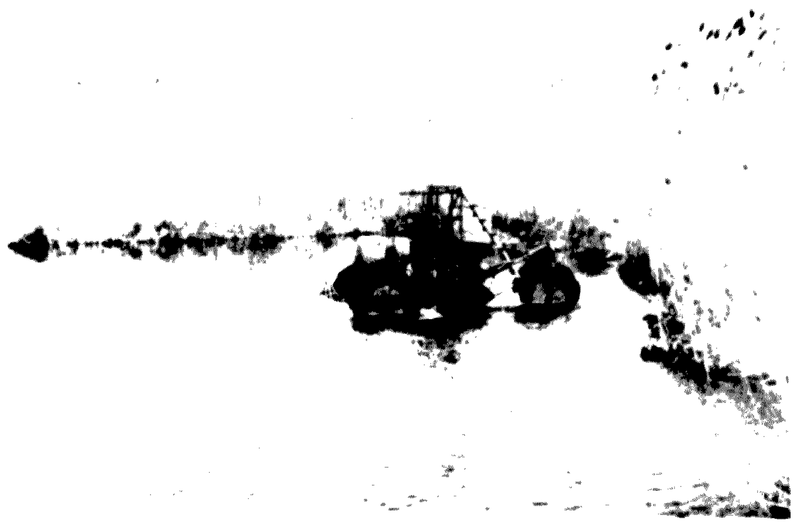
**GROUND PRESSURE**
**40 gr per sqrcm.**

## SPECIFICATION

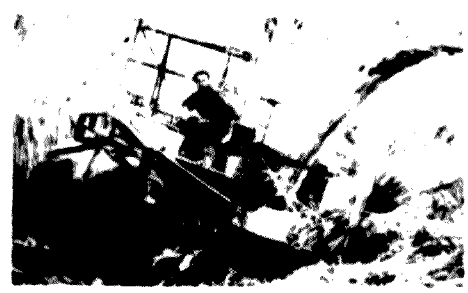
| | |
|---|---|
| Length | 4,60 m |
| Width | 3,35 m |
| Height | 2,10 m |
| Cutting height (hyd. adjustable) | 60 - 600 mm |
| Cutting width | 1.520 mm |
| Operational speeds | 5 or 10 km/h |
| Capacity (theoretically) | 1/2 - 1 ha/h |

Mechanical rear-wheel-drive
Hydraulic front-wheel-steering

**Motor:** VW Industry Type 126A
**Tyres:** SEIGA Special Low Pressure
**Weight:** 1.250 kg

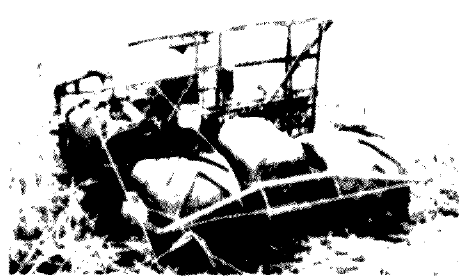


PASSING DEEP WATER



POPS OUT OF SMALL GAPS

HARVESTING ANY HEIGHT OF REED



– AND CROSSES THE BIG ONES

**A/S SEIGA HARVESTER COMPANY LTD.**
**SCT. THOMAS ALLE 15, - COPENHAGEN - DENMARK**
TELEPHONE EVA 3015 TELEGRAM SEIGAHARV

considerably.

The harvester costs £3,500 and the transporter £2,500 both in sterling, fob. Danish port, making a total of £6,000 (sterling).

The important point which arises from the above is that it should be possible to harvest the papyrus mechanically, and for the purpose of the present Study, the data given for the Howard & Dennis machine, being rather more definite, will be used so far as concerns capital cost, output, and labour requirements.

Some doubt has been expressed whether the papyrus should be "headed", i.e., whether the flowering portion and top of the stalk should be removed at the time of cutting, or subsequently. It would obviously save labour to do so when cutting, but this might introduce a complication into the cutting procedure when performed mechanically, because of the variation in height of the papyrus stalks. Where these are almost the same in height then it would be possible to set the machine so as to cut at or just below water level at the bottom, and just below the head at the top. Obviously, if the papyrus stalks in one particular stand vary appreciably in height, then the setting would have to be adjusted so often as to make the whole procedure uneconomical. In these circumstances, the heading of the papyrus would have to be carried out later. Similar difficulties could arise where papyrus is not growing vertically but at an angle or even leaning sideways; this does not often arise, as the stands of papyrus seen were on the whole, upright and regular.

It should not prove difficult or expensive to head the papyrus while it is being collected, and experience may even show that heading is unnecessary. Pulping experiments on the leaves alone (above) have shown that their paper making value is low, especially as regards yield and quality. The small amount of leaf compared with stem might make it advisable or even desirable to digest the complete stalk, the small amount of leafy portion being "lost" in the process. This procedure might involve a small increase in the amount of chemicals required, but so long as it does not contribute any undigested portions of leaf to the pulp, the disadvantages would be outweighed by the advantages. These are all questions which need to be explored more thoroughly in the event of the project proceeding, and it is only possible at this stage to deal with them conjecturally in the light of past experience of similar circumstances.

Incidentally, it was also suggested in the course of work carried out in Uganda, that either the papyrus itself or the mat of roots could be used as a source of fuel. This is mentioned incidentally as a matter of interest, although it is outside the scope of the present Report. The roots would, of course, have to be cut out and air dried, when it was estimated that approximately 80 kg. could be obtained per square metre. Preliminary experiments were carried out using the pulversied papyrus root to provide fuel for the burning of cement clinker. Another alternative was the use of papyrus or the root to obtain methane gas by a process of anaerobic fermentation. It was felt that the high temperatures of the surrounding air might assist this and so avoid external heating. It was estimated that approximately 50 kg. of dry fuel could be obtained from a square metre of swamp. The Uganda experiments were concerned mainly with the clearing of the waterways from papyrus growth to keep the Nile water flowing. Thus the papyrus had to be cleared whether it was used or not, so that the expense of cutting it could be charged to the clearance of the river rather than to the production of a usable product.

Table 11 is an estimate calculation of the cost of cutting green papyrus using the Howard & Dennis machine. It should be compared with Table 10 (hand-cutting).

Table 11

COST OF CUTTING PAPYRUS

BY MACHINE

| | | |
|---|---|---|
| Annual mill output (paper) | | 6,400 tons |
| Papyrus pulp required (80%) | | 5,120 tons |
| Green papyrus required | | 51,200 tons |
| Cost of harvester, conveyor, etc. | | £10,000 |
| Interest at 5% p.a.<br>Depreciation at 8% p.a. ) | | £1,300 p.a. |
| Wages: | 1 man at £300 p.a. | £ 300 |
| | 2 men at Pt.0.40 per day | £ 288 |
| Maintenance | | £ 500 |
| Fuel etc. (est.) | | £ 750 |
| Total annual cost | | £3,138 |
| Cost per ton of green papyrus | | £0.06 |

It will be seen that on the basis of Table 11, cutting papyrus by machine is much cheaper than hand-cutting (Table 10), despite the cost of the machinery and the fact that for a production of 6,400 tons per annum it would be in use only for a small portion of each working day. However, the above calculation makes no allowance for a spare machine in the event of breakdowns.

Nevertheless, as this is a relatively small item in the production cost of the paper; in view of the unknown factors attached to the mechanical harvester of this type; and because of the importance of providing employment; the cost of hand-cutting (Table 10) has been used as the basis of the profitability calculations of Part IX. If the project is pursued further, and especially if a large production is ever contemplated, mechanical cutting should undoubtedly be investigated thoroughly.

(b) Storage.

It is assumed therefore, that the harvesting of the papyrus will be carried out by hand or by some type of machine as that described above, and that the stalks will be brought to the central collecting depot at Wath Wang Kech, where they will be allowed to air-dry as far as possible, and stacked ready for transport to Malakal. For ease of handling it might be considered desirable to bundle or bale the papyrus, but this is another matter that is best decided if the whole question is to be investigated more fully. Assuming the mill's daily requirements are about 160 tons per day, in the green state after heading, then obviously it will be preferable to put as much as possible of this into barges near the cutting point and to take it direct to Malakal without an intermediate stop at the depot at Wath Wang Kech. However, it will also be necessary to build up a reserve stock at the latter place, and it is this stock which will have the opportunity of drying out.

It has been estimated that if papyrus is allowed to dry in the sun in the dry period of the year, its moisture content will fall from approximately 75% to approximately 40%. Papyrus sticks which have dried down to the latter figure will, of course, be somewhat less expensive to transport (see Table 12, below); but, for the purpose of the present calculation, it is assumed that the papyrus as transported, will have an overall average moisture content of approximately 55%. i.e., that it will comprise some green material and some dried-out material. In the wet weather, of course, the papyrus will not dry out so readily.

There is a possible danger of damage by termites on storage. Opinions vary as to the likely effects of insects, and inclined to the view that they constitute a major danger to the keeping properties of the papyrus, whether in the dry or wet state and whatever the time of the year. The particularly dangerous termites are said to be those which enter the papyrus from the earth, i.e., those which are likely to contaminate it after cutting and baling, etc. Insects on the growing plant are relatively few and harmless, namely spiders, of which there are several families, grasshoppers, beetles, flies, stick insects, and cockroaches. These would be mainly killed or shaken off by the cutting and/or baling operations, and their effect could be ignored. It would therefore, appear that so long as the stocks of papyrus can be protected from ground contact after the cutting, then the danger from termites could be reduced considerably. If it was still found to be a threat, then the use of a pesticide such as dieldrin or gammexane should be effective. This of course, would add to the cost of collection, but should not otherwise impair the smooth running of the collecting operation.

While the mill is using only 160 tons per day of green stalks, the problem of keeping it supplied should be soluble with a minimum of storage time, especially if a high-capacity cutter of the Howard & Dennis type is used since this can cut the required amount in a very short time. It could however, be a very different and more difficult problem if the mill production is increased at a later date.

(c) Transportation.

The question of transport from the cutting area to Malakal does however, present certain problems, more of a capital cost nature than otherwise. It is felt that such transport should be carried out in fairly large barges of which several at a time could be propelled by a single tug. This is the usual form of local large-scale transport. The question then arises what type of barge should be used, and the relative merits of wooden and metal barges were explored. The usual river barges seen in the Malakal area were either completely covered or had hatchways for loading or unloading. They were of course, intended for the transport of goods, perishables especially, which must be protected from the sun and/or the rain during the long voyage from Khartoum up the Nile. The problems involved in the transport of papyrus are rather different. In the first place it must be easily loaded and unloaded in bulk, and secondly, the necessity for protection is very much less (assuming no insect attack). The effects of hot sun or rain are likely to be unimportant but of course, heavy rain must not be allowed to fill up the barge and affect the general load. It is felt therefore, that large open barges should be used, and these would have to be built specially for the purpose as the usual covered hatch type of barge is not regarded as suitable; and that provision should be made for sheeting with waterproof tarpaulins in wet weather.

Visits were paid to the Steamers Department of Sudan Railways and also to the Egyptian Irrigation Department's premises in Cairo and their boatyard at Shagara, in order to obtain further information on this question of water transport. The immediate problem was the choice between the rather large metal barges they use, and the smaller wooden vessels which are used for fishing and local trading purposes. A 100 x 22 x 6-foot barge made by the Steamers Department is said to cost approximately £1,600 if built on the Nile, or £55,000 if purchased from outside. A towing unit suitable for up to 6 such barges costs £60,000. A crew of 16 is used for each towing unit and 6 barges, using a 4-watch-day. If a 2-watch-day can be managed, then the crew would be 12, i.e., 1 engineer, 2 semi-skilled men and 9 labourers. Rates of travel are estimated at 12 to 13 km. per hour downstream, loaded; and 8 to 9 km. per hour upstream, unloaded. Malakal to Wath Wang Kech is approximately 80 river-km. It should be noted that duties of the crew do not include loading and unloading. Dieseline fuel suitable for the towing unit, costs £15 per ton at Malakal. However, the Steamers Department were unable to undertake the building of such barges, and the matter was not pursued further with them.

The Egyptian Irrigation Department at Shagara expressed a definite preference for metal as compared with vessels made from local woods; the former wear much better, and since the life of a metal vessel is more than twice that of a wooden vessel, they are therefore, said to be more economical in the long run. The Department manufactures barges for its own use at Shagara, but the capacity is small; only one tug can be made at a time, and this takes about 10 months per tug. Outside commissions could not be considered. However, the following useful data and estimated costs were obtained (based on Shagara operations):-

| | | | |
|---|---|---|---|
| <u>Barges</u>: | 140-ton barge (150 cu.m.) | - | £10,000 |
| | 20-ton barge (80 cu.m.) | - | £8,000 |

The latter could accommodate 100 cu.m. if the contents are heaped.

| | | |
|---|---|---|
| Life | - | 30 years |
| Overhauls | - | 8 years |
| Cost | - | £1,200 |

Tugs (twin-screw):

| | | |
|---|---|---|
| 400 H.P. | - | 12 barges |
| 200 H.P. | - | 6 barges |
| Cost | - | £25,000 |
| Life | - | 25 years |
| Maintenance | - | annual |
| Cost | - | £400 |

Speeds:

| | | |
|---|---|---|
| Upstream, unloaded | - | 6 to 8 km. per hr. |
| Downstream, loaded | - | 6 to 8 km. per hr. |

Fuel (diesel):

| | | |
|---|---|---|
| Cost (Malakal) | - | £25 per ton |
| Consumption | - | 16 gal./hr.<br>250 gal./ton<br>1 ton/ 16 hours |

Crew:

Captain, mate, helmsman, 2 greasers, 4 hands, plus 1 man per barge (on a 12-hr. day basis). Total, 15 for tug and 6 barges.

On the above basis it is possible to estimate the cost of transporting papyrus from Wath Wang Kech to Malakal, as follows (Table 12).

## Bamboo.

### General.

Bamboo is a well-established paper making fibre. It has been used in India for the last 50 years and is one of the mainstays of the paper industry of that country. The methods of pulping it have undergone improvements over the years. The most suitable process is the kraft or sulfate process, and a

Table 12

COST OF TRANSPORTING PAPYRUS

FROM WATH WANG KECH TO MALAKAL

(per day)

| | | |
|---|---|---|
| Papyrus required (green, per day) | - | 170 tons |
| Barges required ( 3 x 140-tons nominal, 60 tons actual at £10,000 each) | - | £30,000 |
| Tug required (1 at 200 H.P.) | - | £25,000 |
| Total | - | £55,000 |
| Depreciation (5% p.a.) ) Interest (6% p.a.) ) | - | £6,050 |
| Crew's wages (per 12-hr. day): | | |
| Captain | - | £2.00 |
| Mate | - | 1.50 |
| Helmsman | - | 1.00 |
| Greasers (2) | - | 1.00 |
| Tug hands (4) | - | 1.20 |
| Barge hands (3) | - | 0.80 |
| Total | - | £7.50 |
| Total cost per return journey (2 days): | | |
| Depreciation and interest | - | £33.00 |
| Crew's wages | - | £15.00 |
| Fuel, oil, etc. | - | £40.00 |
| Maintenance, etc. | - | £5.00 |
| Total | - | £93.00 |
| Cost per ton of green papyrus | - | £0.55 |
| Add, cutting and collecting cost | - | £0.50 |
| Cost of green papyrus delivered to mill per ton | - | £1.05 |

Notes:

(1) It is assumed that 3 barges with 1 tug would operate with a 170-ton load in accordance with the following schedule:-

| | | |
|---|---|---|
| Day 1 | - | Load at Wath Wang Kech |
| Night 1 | - | Travel to Malakal |
| Day 2 | - | Unload at Malakal |
| Night 2 | - | Return to Wath Wang Kech |
| Day 3 | - | Load at Wath Wang Kech, etc. |

While this unit is travelling to Malakal (Night 1), a similar unit would be at Wath Wang Kech ready to load on Day 2.

(2) It is assumed that travel, loaded downstream and unloaded upstream, will each take about 12 hr., and a 12-hr. day has been assumed for the crew. Loading and unloading are unlikely to take the 12 hours allowed for each of these operations.

(3) The cost, running and maintenance figures obtained from the Shagara boatyard are used, but it is appreciated that these facilities may not be available to the paper factory. The price of fuel is based on information received from a local supplier (see Part V).

(4) It is assumed that the papyrus will not dry out appreciably between cutting and transportation. It should do so in the dry season, but to little or no extent in wet weather. The transport costs are unlikely to be greatly affected, as the bulk will not alter greatly on drying.

(5) Nor has baling been allowed for. In principle this is desirable, as handling and checks on quantities bought and used are easier, and a greater weight can be loaded per barge.

However, little is known of the technique and cost of baling papyrus, and of the effect of termites on the bales, and for the purpose of this approximate preliminary calculation the question has been deferred. It certainly should not be ignored, however, in any future development of the project.

(6) No provision has been made for a spare tug. In the event of a breakdown, one tug would deal with 6 barges.

(7) In order to allow a margin for unforeseen eventualities, the cost of the green papyrus, cut by hand and delivered at Malakal, is taken at £1.3 per ton for the purposes of the present Study.

modern bamboo pulp mill is similar in practically most respects to a kraft mill operating on pine wood. Bamboo is also being successfully pulped by the new rapid continuous methods, and one of the newest mills in India uses such a method.

The properties of bamboo pulp have in consequence been closely studied. The fibre averages 3 mm. in length, that is to say, it is comparable in this respect with the coniferous woods. Bamboo pulp has a high tearing strength, but a relatively low tensile strength. When used in combination with the strongly-bonding pulps, such as those of straw or sugar cane bagasse, it can produce a full range of papers from white writing papers to multiwall sack papers. Thus, the need for long-fibred material by a paper industry can be met with bamboo.

The Indian bamboos used for paper manufacture are usually the Dendrocalamus, Bambusa, Melocanna and Ochlandra species. In the Philippines the Schizostachyum species is used. In Burma it is proposed to use the Cephalostachum species; and in Ethiopia Oxytenanthera abyssinica and Arundinaria alpina. Members of the Oxytenanthera and Arundinaria species also occur in India, but they are different varieties than those found in Ethiopia and less is known of their suitability for paper pulp as compared with the Bambusa species. Paper making operations in other countries, e.g., Japan, Taiwan and the Philippine Islands, have also usually involved Bambusa species, and it is this species which is grown in the Sudan at Doleib Hill (see below). Actually it will be appreciated from the above that from the point of view of this particular Study, bamboo has important unique properties in that it is rapid growing and yet is has a comparatively long fibre. The latter is not so long as those of the coniferous woods, but considerably longer than those of the other fibrous materials available. In this sense therefore, bamboo can be regarded as a welcome substitute for coniferous wood, if not a complete substitute from the quality point of view for admixture with papyrus pulp.

Bamboo grows on an annual basis, but the roots are perennial. Normally full growth is obtained after about 7 years, but from the point of view of pulp production it is often convenient to cut after 3 or 4 years and then to allow re-growth to take place. This occurs very rapidly, namely in some parts of Nepal to 25 feet in the first year, although in subsequent years the sticks may attain no greater height although the walls thicken. As pointed out above, there are many different varieties of bamboo, and these vary markedly in properties such as height, diameter and wall thickness. In consequence the yield per acre also varies; in India this can be as low as approximately 0.75 ton per acre per year. The fibre length also shows some variation and in the case of the principal Indian varieties the average length is 2.5 to 3.2 mm.

In one very important respect (namely, the frequency of flowering) different varieties of bamboo have a different habit; and indeed the same varieties may present different habits under different climatic conditions. When a bamboo plant flowers it dies off, and several years must elapse before growth occurs again and the bamboo is ready for cutting for pulp manufacture. It is even possible for the roots to die off or be otherwise destroyed in the interval, and the plant so lost. With some African bamboos the flowering takes place regularly every 8 years or so, and can be anticipated. Conseqently if the bamboo is grown for pulping, allowance can be made for flowering in assessing the amount required for operation on a sustained yield basis.

In India however, the flowering intervals are much longer and less certain; they can be 30 to 50 years or even more. If the actual date at which flowering is to be expected is not known, then its unanticipated onset can be a very serious matter for a pulp mill which relies entirely on local bamboo. Unfortunately, when flowering takes place, a whole forest (not just individual clumps) can be affected simultaneously, so that the whole reserve supply can be lost. In the case of natural bamboo growing in forests, it is very difficult to foresee and to allow for this, because the histories of the individual plants are not known. However, with cultivated bamboo it is possible to put down plantations at intervals which will allow for the ultimate flowering. If a species which flowers at long intervals (e.g., over 30 years) is chosen, then the problem becomes a long-range one, and can be dealt with accordingly. This would appear to be the position at Doleib Hill. In any case it can probably be overcome because cultivated bamboo is involved.

Bamboo, although a grass, consists of a long woody stalk (or culm) with thickened denser areas at intervals, known as nodes. Methods of processing the bamboo have to be so adapted as to contend with these nodes, which resist penetration of the liquor. Consequently there is a tendency to overcook the remainder of the woody portion in order to resolve the nodes. In the early work on bamboo carried out in India by Raitt, some 35 years ago, this was achieved by digesting in two stages. In recent years however, more attention has been given to the preparation of the bamboo for the cooking process, i.e., by crushing the culms and then either chipping or shredding them. This has given good results in single-stage continuous processes, with yields of bleached pulp of around 40%. In this way culms ranging in diameter from 1 to 3 cm. and cut to lengths of from 3 to 5 m. can be handled.

The culm part of the stem usually refers to the woody portion of a hollow tube, but there is also present in it some parenchyma tissue which contains no fibrous material suitable for paper making, and is similar to pith. Consequently this is lost in the pulping process, and its presence only reduces the yield. The crushing of the bamboo stems breaks the nodes and renders the fibre bundle separable. This aids the penetration of the cooking liquor since, unlike wood, there are no means of conducting the liquor into the bamboo plant substance in a horizontal direction.

Cultivated Bamboo.

It appears that at Doleib Hill cultivated bamboo grows very well. The small plantations seen were in a healthy condition, and the bamboo appears to grow well in comparatively little space. Such bamboo is grown privately for sale, mainly for constructional purposes, and the prices obtained for it are relatively high compared with what could be paid by a pulp mill. Local discussions on the cultivation of bamboo, indicated that it would be inadvisable to rely on local producers for supplies of bamboo, both on availability and price grounds. The alternative would be for the mill to operate its own cultivated bamboo plantation. The calculations of Tables 13 and 14 (below) given an indication of the area required (based on the writer's experience in Nepal).

Bamboo in the Malakal Area.

In the course of another journey by river along the Sobat River, from Malakal, stands of bamboo were noticed near the right bank of the river at Doleib Hill (Fig. 2). They were therefore, investigated further on land. It was found that these stands were cultivated by local farmers and that they take 3 to 4 years to mature from planting to the degree of maturity at which they could be cut for paper making. They are said to be immune to termites, and their flowering period is not known, although it is believed to be not less than 40 years. The stands seen were relatively thin, but this may have been due to regrowth after burning, since there were indications of this.

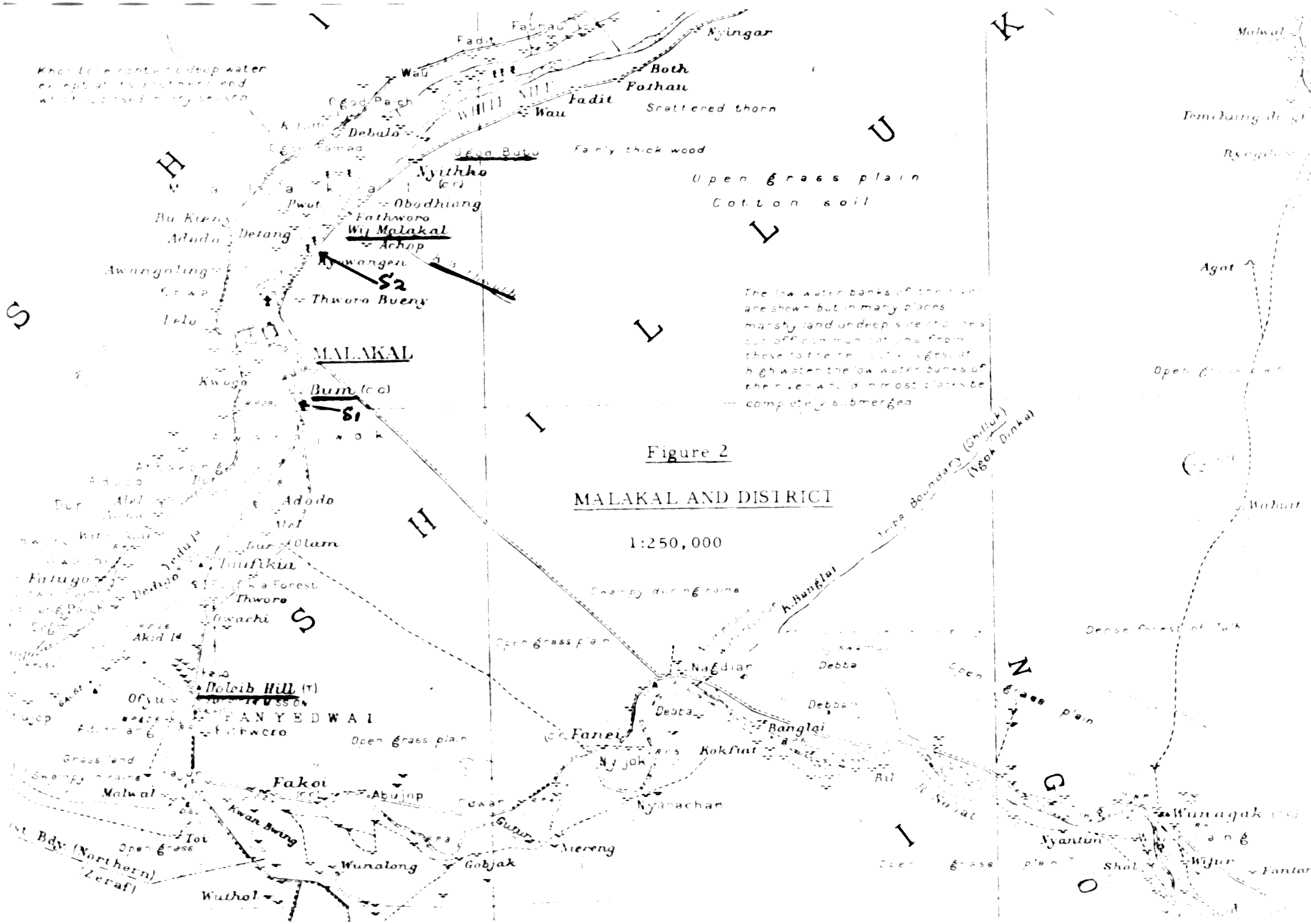



Figure 2

MALAKAL AND DISTRICT

1:250,000

At present the sticks are cut mainly for constructional purposes, but some are sent to Khartoum where they fetch Pt.5 to 20 per stick, according to size.

The attraction of this bamboo from the present point of view is its good paper making properties (see above). It is superior to papyrus in strength, and the techique of processing it into pulp is well understood from experience in India. A further great attraction is the proximity of the stands at Doleib Hill, to the proposed site at Bum (Part VIII), which is only approximately 20 km. distant by road. The river distance is approximately 50 km. This means that the handling and transport costs would be materially reduced if the road could be used instead of the river to take the bamboo direct to the mill. The present road between Bum and Doleib Hill is a dry-weather road only, but the bad stretches are relatively few and short, and in any case, it is understood that it will be made an all-weather road in the near future. This is essential if the road is to be used for transporting bamboo supplies.

It would appear that the quantity of bamboo pulp to be used might approximate to 20% of the total pulp requirements, the remainder being papyrus It is believed that (subject to trials) the combination of these two fibres should give excellent results for a wide range of papers being made (see p. 116).

In order to produce sufficient quantities of the bamboo to supply this particular need, the bamboo would have to be cultivated and, assuming a 6-year cycle, much land would be required. Fortunately, this is available locally near the river bank. On the other hand, it is unfortunate that no information whatsoever is available as to local conditions, which would enable the production cost of the bamboo stalks to be calculated even approximately. In order to arrive at the likely price at which bamboo for pulp might be made available, it has been necessary to recourse to a study made by the writer in Nepal where the circumstances and climate are very similar to those in the present instance. Taking the Nepal report, the following estimate of the cost of bamboo was obtained (Tables 13 and 14).

Bamboo also occurs wild, to the south-east of the Upper Nile Province, but little is known of its extent and growth cycle, and of the relevant communications. This particular aspect was not examined further.

## Other Fibrous Raw Materials

Several other fibrous raw materials for paper making grow in the Upper Nile Province, particularly along the river banks. The more important of these are listed below. They are not dealt with in any great detail because either the amounts available in any one place are comparatively restricted; or else it is obvious that the cost of collecting them in any great quantity would be greater than for papyrus.

### Reeds (Phragmites communis)

Experiments on this reed have been carried out both experimentally and on a large scale, with a view to its use in paper making. In general, successful results have been obtained,

Table 13

AREA REQUIRED FOR CULTIVATED BAMBOO

| | | |
|---|---|---|
| 1 average clump contains | | 40 sticks |
| | = | 1 ton (as cut) |
| 1 average clump occupies | | 6.5 x 6.5 m. |
| | = (say) | 45 sq.m. |
| 1 ton green bamboo as cut gives | | 0.25 ton paper |
| Hence 1 ton paper requires | | 180 sq.m. bamboo forest |
| Bamboo re-growth cycle (see Note 1) | | 6 years |
| Hence, on a sustained yield basis: 1 ton paper requires (see Note 2) | | 1,080 sq.m. |
| Average annual requirement of bamboo pulp (as paper) | | 1,280 tons |
| Area required for cultivation: | | 138 hectares |
| | = | 345 acres |
| | = | 335 feddans |

Notes:

(1) In Nepal the average growth cycle for cultivated bamboo is about 5 years; 6 years allows a margin for any differences in the Doleib Hill area.

(2) It is assumed that, as in Nepal, green bamboo contains approximately 50% of water, and that the yield of pulp is approximately 50%, dry basis.

(3) The above is a fairly large area, but there appears to be considerable uncultivated land available at Doleib Hill. On the assumption that the pulp mill owns the plantations, then the approximate cost of the bamboo can be calculated as shown in Table 14.

Table 14

ESTIMATED PRODUCTION COST (DRY BASIS)

OF CULTIVATED BAMBOO

| | |
|---|---|
| Area required for plantations (see Table 13 and Note 1) | 138 hectares |
| Cost of land preparation and planting (see Note 4) | £240,000 |
| Interest on above at 5% per annum | £12,000 |
| Interest cost per ton for 2,560 tons dry bamboo per annum | £4.70 per ton |
| Plantation costs (planting and maintenance): 7 men at (average) Pt.25 per day, per head | £0.25 per ton |
| Cutting costs (see Note 2) | £0.60 per ton |
| Transport to mill site at Bum | £0.50 per ton |
| Cost delivered to mill (dry basis) | £6.05 per ton |

Notes:

(1) It is assumed that the land would be available free.

(2) This figure is derived on the basis that one man will cut 40 culms (sticks) of green bamboo in an 8-hour day. One large stick of bamboo weighs 27 kg., but if it is assumed conservatively that the average weight of a stick is 22 kg., then one man will cut about 0.9 ton per day. Assuming he is paid Pt.25 per day, then the cutting cost of 1 ton (green) will be, conservatively, £0.30 per ton as cut. This will include cutting to a suitable length and stacking at a convenient point for transport to the mill site.

(3) Experiments showed that the Nepal cultivated bamboo had an approximate moisture content of 50%, and this figure is used in the present calculations. A sample of cultivated Nepal bamboo was subjected to a preliminary digestion experiment and the results are given with comments, in the appended Certificate, ref. 25870.

(4) The land preparation and planting costs will of course, be spread over several years, so that the annual interest cost per ton is on the high side. It is stated that 3 years suffice to produce a fully-grown clump, so that sufficient could be made available for the first complete year of mill operation in say, 1973. The growth cycle after cutting has been taken as 6 years, as in Nepal, but this may be on the high side.

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OUR REF JG/PAL 25870

YOUR REF

21st July, 1964

**ANALYSIS OF A SAMPLE OF** Bamboo Chips (Nepal Study)

**RECEIVED ON** 1st June, 1964.

**MARKED** Cultivated (near Bhadrapur)

**SEALED** .............

| | |
|---|---|
| Moisture (as cut) | 55.3% |
| Digestion Trial: | |
| Pressure | 80 lb. per sq. in. |
| Time on pressure | 4 hours |
| Caustic soda | 20% on dry chips |
| Alkalinity of black liquor | nil |
| Yield (unbleached) | 48% dry basis |
| Bleachability | 6% chlorine on unbleached pulp. |
| Yield (bleached) | 45.5% dry basis |
| Brightness | 73 GE units. |

Comments:

Under the above digestion conditions a pulp with a strong handle was obtained in a fairly good yield. However, it bleached only to a fair colour and had a fairly high chlorine consumption.

p.p. Hehner & Cox Limited,

[signature]

especially where the manufacture of fairly strong wrappings is concerned. Unfortunately, along the banks of the Nile the reeds grow in irregular patches, and insufficient are found in one area to render harvesting on a large scale an economic operation. Such reeds also have a fairly high chemical requirement, and the yield of dry unbleached pulp is only in the region of 40%.

Hippo Grass, or Vossia (Vossia cuspidata, Roxb.)

This is a broad-leaved, long grass, characteristic of the Sudd area of the Upper Nile and prolific in the swamps, which are said to cover an area of 300 miles long, and sometimes almost 100 miles wide. The quantities here are considerable, not only along the stretch of the Nile traversed from Tonga upwards, but also along the Bahr el Jebel. Sometimes whole floating islands of the grass occur; sometimes it grows immediately by the riverside; and sometimes behind the papyrus growths. Laboratory experiments have been carried out on this material by the writer and others, and it has been shown that a reasonably good paper can be made from it even in the bleached state. In this respect it has been shown to be very similar to the elephant grass (Pennisetum purpurem), found in other parts of Africa. Yields of 45% have been obtained, but the chemical consumption is high. In general, this grass is less accessible than the papyrus, and individual leaves are considerably less in weight, in the green state. This means that cutting would have to take place over considerable areas in order to collect sufficient tonnage for the mill's requirements.

The bulky nature of the cut grass would also render transport difficult and expensive. This possibility also was therefore, not pursued further at this stage.

Note on Water Hyacinth (Eichornia crassipes, Solms.)

The growth of this plant in the River Nile and especially in the upper reaches, is of considerable economic importance locally, and although its bearing on the present project may be only slight, it is important to record the facts concerning it so far as they are relevant. Water hyacinths are native to South America, but they have been widely spread throughout the world. The plants were first observed in the Nile in Egypt in 1958, and it was believed that they were brought to Egypt for decorative purposes. They flourish in a swampy habitat with warm, slowly-moving water, and the Nile from Kosti upstream provides an excellent medium for their growth. In 1962 it was estimated that some 1,800 feddans were infested between Kosti and Lake No, a river distance of about 650 km. During the present Study, particularly large accumulations were noted on the Bahr el Ghazal between its junction with Lake No to about 30 km. upstream, beyond which the river was not followed. Infection is readily communicated from one part of the river to the other by means of river craft and in consequence, the pest is also found on the Sobat River. Strangely, it is not to be found on the Bahr el Jebel.

The mature plants float in the water, being buoyed up by their petioles, and fibrous branch roots extend below the water surface, being attached loosely to soft mud in the water. The flowers are decoratively blue, mauve or light lilac, and after blooming the stems bend over and the flowers wither under the water. Propagation is by vegetative multiplication, and each rosette produces numerous runners, which separate finally from the parent plant. This results in a dense and continuous carpet, or else in large floating masses.

Sometimes these grow close to or are carried alongside the banks of the river, and in such instances they would form a barrier between harvesting equipment and the papyrus on the swampy shores. Certainly if operations were being carried out on a big scale on the Bahr el Ghazal or at Lake No this would introduce a serious practical difficulty to harvesting. Actually, in the river stretch in the immediate neighbourhood of Wath Wang Kech, the trouble was less apparent than elsewhere at the time of my visit, although the conditions at other times of the year or years may be better or worse.

Many attempts to control water hyacinth have been made throughout the world; large costly machines have been used to cut trails through clogged streams, and large quantities have been picked up physically and carted away in barges. This produces only a temporary relief from the pest and the introduction of water mammals and a variety of snail, which feed on the plant, have also been considered, although a real solution to the problem has not been found. It has even been suggested that the plant should be used for the manufacture of paper, but this is hardly an economical proposition.

In 1960 a scheme was developed for controlling the pest by spraying with a herbicide, and for containing it at the dam at Djebel Aulia, some 40 km. south of Khartoum. Control by herbicide is at present in common use on the Nile and though, no doubt, it is effective in the sense that the nuisance would be very much worse without it, the floating masses of water hyacinth are still sufficient to impede traffic at times.

As stated above, the water hyacinth has no direct bearing on the present project, but it may well prove to be a nuisance which has to be overcome; the cost of doing so could be material, and it has not been taken into account in the present calculations. One of the difficulties in using a herbicide is the possible effect of the herbicide on the papyrus growing in the immediate vicinity of the hyacinth. The herbicide favoured is 2,4-dichlorophenoxy acetic acid. However, herbicide treatment is not satisfactory for opening up canals in densely-carpeted areas of the river. This must be done mechanically, and the herbicide used to keep down subsequent growth. There are also problems in approaching the hyacinth in order to carry out these opening-up operations; this must be done by boat, as to wade or swim is obviously dangerous owing to snakes, crocodiles and bilharzia.

# PART V

# NON-FIBROUS RAW MATERIALS, CHEMICALS FUEL AND POWER

## Non-Fibrous Raw Materials and Chemicals.

The amounts and nature of the chemicals required by a pulp or paper mill depend on the type of product to be made, and on the process to be used. In this section of the Study, sources of supply and prices of the major chemicals likely to be used in the near or more distant future, are considered; and the data deduced are used in the various production costings given in Part IX.

The chemicals used may conveniently be divided into requirements for pulping and for paper making, respectively, as follows:-

### Pulping Chemicals.

Caustic Soda (Sodium Hydroxide). In the case of papyrus or bamboo the preferred method of removing the non-cellulosic constituents from the plant material is by boiling under pressure with a solution of caustic soda; or of caustic soda with sulphur or a sulphide. The amounts of chemicals used depend on the particular plant material, and can range from 5 to 15% on the dry weight of the latter. It is obviously undesirable that such quantities of used chemicals should be rejected to waste in the form of digester liquors ("black liquor"), both because of the highly-polluting nature of the liquors and also because of the value of the chemical itself. It is therefore, usual to evaporate the black liquor and to burn the residue. The organic matter contained in the residue provides heat to operate much of the pulping process; and the sodium compounds derived from the original caustic soda are converted into sodium carbonate (soda ash). By heating with milk of lime, this can be converted back again into caustic soda. This last operation involves the production of a sludge of calcium carbonate, which can be filtered off, washed, dried and burned to give lime for use again.

This recovery process varies in efficiency from about 35% with some cereal straws to 80% with coniferous woods, and the resulting loss of caustic soda is usually made up by the addition of soda ash (which is usually cheaper than the caustic soda). This added soda ash is turned into caustic soda (along with the soda ash produced from the burned black liquor) by the lime treatment (above). Naturally, the removal of the caustic soda and organic matter in this way, overcomes the main pollution problem.

In large mills it is common and convenient to make caustic soda by the electrolysis of common or solar salt (sodium chloride), since this operation also produces the chlorine required for bleaching the pulp. The economics of doing this in the present instance are discussed below under the heading of Salt.

Caustic soda is also used in a small amount (about

2% on the unbleached pulp) as a neutralising agent in the multistage bleaching of pulp.

The current price for caustic soda imported in solid form, in non-returnable drums in 5-ton lots, is as follows; source, Imperial Chemical Industries (Sudan), Ltd.:-

| | |
|---|---|
| Basic price cif. Port Sudan | £30.00 per ton |
| Import duty, 20% | £6.00 |
| Clearing and forwarding | £2.00 |
| Freight from Port Sudan to Malakal | £15.60 |
| Total | £53.60 |
| Surcharge for travel via the Cape | £8.00 |
| | £61.60 |

This assumes that the goods will travel as Class 9 on the Sudan Railways.

This is an extremely high price for caustic soda, due very largely to the high transport cost to Malakal. The possibility of manufacturing caustic soda from lime and soda ash, the former to be obtained from Magadi in Kenya, was therefore explored and this is dealt with below. Also, the basic price of £30 per ton is that for the relatively small quantities at present being imported and is open to negotiation for larger users. In view of this and the disappearance of part at any rate of the surcharge due to the Suez Canal closure, a price delivered to Malakal of £55 per ton has been used for the purpose of this Study.

Soda Ash (commercial Sodium Carbonate). As stated above, where the soda ash is cheaper than caustic soda, it is used for make-up purposes in the recovery process. Its use in this way is economic only if the cost of the lime and the processing offers some advantage over the direct use of caustic soda. However, in the present instance, since a recovery process is not envisaged at the initial stage of the project, the use of soda ash becomes of importance as a possible economical way of making caustic soda. The importation of soda ash from Europe for this purpose is likely to be as expensive (as in the case of the caustic soda), and was not therefore, considered. There is the possibility of supplies being obtained from Egypt, at an economical figure, but data on this are not available at the present moment.

Thought was therefore given to the possibility of importing the soda ash from Lake Magadi in Kenya, and the following calculations, which are comparable with those given for caustic soda above, then apply. The Magadi grade contains 97% sodium carbonate (as $Na_2CO_3$), and the delivered price is made up as follows:-

| | |
|---|---|
| Basic price cif. Port Sudan | £20.00 per ton |
| Import duty, 20% | £4.00 |
| Clearing and forwarding | £2.00 |
| Freight to Malakal | £17.00 (estimated) |
| Total | £43.00 |

It will be noted that this soda ash is only 97% purity, whereas that normally imported is over 99%. However, this only means that more will be required for the purpose. In order that soda ash may be converted into caustic soda it must be treated with lime and supplies of this product are considered below.

Lime (CaO). This chemical is used for the causticising process already referred to, and also as an ingredient of bleaching liquor when this is prepared on the site from chlorine. In the present instance however, its principal interest is as a means of producing caustic soda from soda ash. It is made by burning limestone in a kiln.

There is a growing cement industry in Sudan and a large and modern factory has recently been erected at Rabak on the bank of the Nile opposite Kosti, near the border of the Upper Nile Province. The actual supplies of limestone are however, obtained from Nyfer (see Map, Fig. 1), which is a series of deposits 22 km. north-east of El Jebelein, and approximately 95 km. north of Renk. These quarries were visited; they have only just been developed by a Yugoslavian company for The Nile Cement Co., Ltd. and are not yet in full operation. The road from El Jebelein, which is the nearest port on the River Nile, is poor even in dry weather, and unusable from June to September. The Nyfer plant consists principally of crushers and sieves, and it was understood that these have been tested out and will start up in January, 1969. The crushed and graded limestone will be taken from Nyfer to Rabak by road, but the road from Nyfer to Rabak is better than that from Nyfer to El Jebelein, and it is the latter which would have to be used in the event of the limestone coming to Malakal.

The quarries consist of several small deposits, some of them under a tilth of surface soil approximately 20 m. below ground level. Only one was fully exposed during the visit, and covered an area of about 100 x 50 m. The quality appeared to be very good in places, and is understood to consist of calcite (marble) - a pure form of limestone. According to the geological report the limestone from the other quarries is poorer in quality (see Table 15). It would seem that when the deposits are being worked it will be necessary to pick the areas yielding the best grades, and to leave the other grades behind. Grades containing magnesium (dolimitic grades) are being rejected. Approximately 150 men are employed at the quarries.

At present only small local kilns are used for the manufacture of lime at Nyfer (since lime is not required by the cement factory), and it will be necessary for the paper mill to operate its own lime kilns using the Nyfer calcium carbonate. This is best done at Malakal owing to the difficulty of transporting lime. The quayside at El Jebelein was therefore inspected, but there are no loading facilities or any means of handling the quantities of limestone involved conveniently. Apart from this, there are two steamers each way, weekly, between El Jebelein and Malakal, and subject to the road improvement and loading

Table 15

SELECTED ANALYSES OF NYFER MARBLE

| Depth (m.) | CaO (%) | MgO (%) | Ign. Loss (%) | Total (%) |
|---|---|---|---|---|
| 1.8 - 2.8 | 50 | 4.2 | 44.4 | 98.6 |
| 3.3 - 4.30 | 30 | 1.6 | 25.6 | 57.2 |
| 3.85 - 5.10 | 37 | 7.9 | 40.0 | 84.9 |
| 4.0 - 5.0 | 44 | 0.85 | 37.8 | 82.65 |
| 1.0 - 2.0 | 49 | 1.50 | 41.2 | 91.70 |
| 1.7 - 2.7 | 52 | 0.70 | 42.1 | 94.8 |
| 1.5 - 2.5 | 56 | 0.80 | 43.4 | 100.2 |
| 1.1 - 2.1 | 52 | 0.3 | 43.4 | 95.7 |
| 1.3 - 2.3 | 53 | 0.6 | 42.8 | 96.4 |
| 3.8 - 4.8 | 27 | 2.2 | 34.1 | 63.3 |
| 3.4 - 4.4 | 51 | 1.3 | 42.5 | 94.8 |
| 3.0 - 4.0 | 54 | 1.7 | 44.2 | 99.9 |
| 4.2 - 5.2 | 20 | 14.3 | 30.6 | 64.9 |
| 2.5 - 3.5 | 40 | 11.4 | 45.2 | 96.6 |
| 2.6 - 3.6 | 46 | 4.8 | 40.8 | 91.6 |
| 2.3 - 3.3 | 51 | 0.8 | 43.2 | 95.0 |
| 1.7 - 2.7 | 54 | 0.4 | 43.0 | 97.4 |
| 2.0 - 3.0 | 39 | 9.8 | 44.1 | 93.9 |

Note:

Of 127 samples analysed from this area, 55% had a CaO content of greater than 50%, corresponding with a $CaCO_3$ content greater than 90%. Such limestones would be suitable for the manufacture of caustic soda, as envisaged.

facilities, there should be no difficulty in supplying crushed stone delivered to a barge at El Jebelein. The estimated cost according to a S.I.R.I. Study, is approximately £1 per ton for delivering the stone to El Jebelein.

Enquiries were made at the Head Office of the Nile Cement Co., Ltd. in Khartoum, as to the possibility of taking say, 5 to 10 tons per day, of crushed limestone from the quarry for use at Malakal. This of course, is a very small quantity compared with the total amount being quarried, and it was not envisaged that any particular difficulty would arise or that the cost would be more than nominal. However, it was not possible to make contact with anybody who could give a firm decision on this point, in any case, the investigation will have to be pursued further at a later date if the possibility offers any promise.

In order to ascertain this point, the calculation shown in Table 16 was used. In effect this calculates the price of the limestone, delivered Malakal (A), which would enable soda ash at £43 per ton delivered Malakal, to be converted into caustic soda at £62 per ton delivered Malakal. The calculation allows for the impurity of the lime and soda ash, but is otherwise theoretical. Thus, it does not take into account the cost of converting the calcium carbonate into lime; or the cost and overheads on the capital involved for the plant which would have to be installed, although this is not high; or the running costs; similarly, labour charges are not included.

## Table 16

## PREPARATION OF CAUSTIC SODA FROM LIMESTONE AND SODA ASH

| | | |
|---|---|---|
| Limestone (ex Nyfer) | = | £A per ton |
| Soda ash (ex Magadi) | = | £43.00 per ton |
| Caustic soda (ex U.K.) | = | £62.00 per ton |

The price equation expressing the conversion of soda ash and lime into caustic soda may be given quantitatively, thus:

$$120A + 106 \times 43 = 62 \times 80$$

$$A = \underline{£3.35}$$

Notes:

(1) All prices are delivered Malakal, duty paid.

(2) The quantity of limestone used in the calculation assumes 20% for loss of yield on conversion and impurities in the limestone and Magadi soda ash.

It will be seen that the limestone would have to be delivered at Malakal at about £3.4 per ton, in order to fulfil the above conditions. If the cost of carrying the stone from Nyfer to El Jebelein is £1 per ton (see above), then even if the limestone is obtained free, the cost delivered at the Malakal factory is unlikely to be as little as £3 per ton, bearing in mind the handling involved and the transport costs on the river. It would therefore, appear that the use of the limestone to convert Magadi soda ash into caustic soda is likely to be less economical than buying caustic soda direct, despite the high price of the latter. As the only other source of limestone in Sudan within reasonable distance of Malakal is at Khashm el Girba, and the transport from here would be considerable, this possibility was abandoned with reluctance.

Chlorine (Cl). This is normally required for bleaching purposes. It is transported in liquefied form, in specially-made, heavy-duty cylinders, which are difficult and costly to carry, and which must be returned for refilling. When, as in the present instance, the chlorine comes from abroad, the transport can be costly to an extent out of all proportion with the value of the actual chlorine. For factories situated on a continent the problem is solved by the use of 15- or 10-ton railway tank-wagons, and if 3 or 4 of these are in circulation for a particular mill, this usually suffices. However chlorine cylinders for transport by sea hold only 1,792 lb. of chlorine and therefore, many must always be in circulation in order to keep the mill supplied fully. It is apparent that the practical difficulties of transporting liquid chlorine to Malakal render its use there wholly out of the question, on the scale at present envisaged. However, the possibility that it might be produced on the spot, from salt, was considered, see below.

Salt (Sodium Chloride). Large mills making bleached pulp find it economical to electrolyse salt to produce caustic soda and chlorine. As a rule solar salt is used for this purpose, but it sometimes requires a slight measure of preliminary purification. It usually happens that in making the chlorine for a pulping process, an excess of caustic soda is produced over that required by the process itself. This applies particularly if a soda recovery process is used for the caustic soda (see above). In this event, it is often possible to find a local market for the surplus caustic soda, and a profitable sideline may then be developed.

Salt is produced in Sudan and is in fact, a nationalised industry having a present capacity of 60,000 tons per annum, of which the Sudan consumption is approximately 45,000 tons per annum. An extension giving another 10,000 tons per annum is planned; and at a later date, there will be a new project giving a further 20,000 to 30,000 tons per annum. There is therefore, likely to be ample supplies of salt in the Sudan. Unfortunately, this all occurs on the Red Sea, and the price quoted for supplies in 100-kgm. jute bags, is £3.825 per ton (coarse grade) or £4.525 per ton (fine grade) fob. works. Much of this is sold to merchants in Port Sudan, who arrange the freight and are allowed 5% profit on the delivered cost. Transport costs are adjusted so as to give the same price all over the Sudan. Assuming that it would travel under Code 14 in the Sudan Railways freight list, the freight charge from Port Sudan to Malakal would be £4.470 per ton. The delivered price would therefore be made up as follows:

| | |
|---|---|
| Basic price (coarse grade) fob. works | £3.825 per ton |
| Freight, Port Sudan to Malakal | £4.470 per ton |
| Total | £8.295 per ton |
| Merchants' profit (5%) | £0.415 per ton |
| Total cost delivered Malakal | £8.710 per ton |
| Allowance for extras, say, | £9.000 per ton, delivered. |

Owing to the high delivery costs, even though these are low in relation to other commodities, this salt is still expensive for electrolytic purposes. The possibility of transporting it in bulk instead of bags, which would reduce the gross cost considerably, was explored. The practical difficulties of doing so are however, considerable, and a special study would have to be made if this possibility offered any promise. In addition to this, transport between Port Sudan and Sennar is inclined to be uncertain, especially on the portion of the line between Sennar and Kosti during the 4 wet months of the year. Washouts can occur, mostly in the Kassala region.

Nevertheless it was felt that it would be of interest to explore the cost of the electrolytic production of caustic soda from salt, and Table 17 provides an estimated figure. In compiling this Table it has been necessary to make certain assumptions as to the prices of imported items such as mercury, graphite, and barium chloride, as the prices of these in the Sudan are not known. As may be expected, the viability of such a decision depends principally on the prices of salt and electricity.

Table 17

## ELECTROLYTIC PRODUCTION OF CAUSTIC SODA AND CHLORINE FROM SALT

| Cost Items | Amount | Unit Cost | Cost per 2.1 ton of Products (£) |
|---|---|---|---|
| Salt | 1.75 ton | £9.00 per ton | 15.75 |
| Mercury | 0.77 lb. | £1.60 per lb. | 1.23 |
| Graphite | 7.50 lb. | Pt.17 per lb. | 1.28 |
| Barium chloride | 8.82 lb. | Pt.6 per lb. | 0.53 |
| Soda ash | 17.64 lb. | Pt.2 per lb. | 0.35 |
| Electricity | 4,700 kwh. | Pt.1.0 per kwh. | 47.00 |
| Labour | 36 man-hr. | Pt.12 per hr. | 4.33 |
| Repairs and maintenance | - | - | 3.20 |
| Management and control | - | - | 0.80 |
| | | | 74.47 |
| Interest | £450,000 | 7% | |
| Depreciation | £450,000 | 10% | 15.30 |
| | Total | | 89.77 |

Cost of: caustic soda - £45 per ton
chlorine - £48 per ton

Notes:

(1) Total capital cost, £450,000.

(2) Production: 2,725 t.p.a. of caustic soda with 2,475 t.p.a. of chlorine.

(3) Graphite and mercury are electrode materials; barium chloride and soda ash are purification chemicals (average quantities used).

(4) The price of electricity given above, assumes a mill large enough to justify its own thermoelectric generating station (at Malakal) using fuel oil to raise steam.

It is apparent from the figures that caustic soda produced in this way would be cheaper than that imported from abroad. However, this would apply only if a comparatively large electrolytic plant was installed, and since, for reasons set out in Part VIII, bleaching would not be a practical possibility at this stage, the problem of the surplus chlorine would arise. If caustic soda is to be made from salt by electrolysis, it will be more logical to do it somewhere where electricity is cheap. If that place is not too remote from Malakal, the caustic soda could be supplied to the latter factory, and would then in any case, be very much cheaper than the imported product. If at a future date, the suggested paper factory at Malakal manufactures papers from white pulps, then the electrolytic production of caustic soda and chlorine from Red Sea salt would be an obvious step to take.

Chemicals used in the Paper Making Process.

Rosin. This is used, with alum, for the sizing of paper, i.e., to prevent ink from "feathering", and to confer a certain amount of water resistance on the surface. It also assists in hardening the sheet during the paper making process, when the sheet goes over the drying cylinders. Rosin is added to paper at the pulp preparation stage, and it can be added either in the form of an emulsion with water or alkali, in which case it is purchased in paste form; or the crude rosin can be dissolved in caustic soda or emulsified in the mill, and added in this form. The addition of the alum then precipitates the rosin on to the fibres and in intimate contact with them, so that when the web of paper is formed a sized effect is produced. For the present purpose, the use of rosin as such will be considered, because the alternatives in paste or emulsion form contain a fairly high percentage of water and this would add to the transport cost. The grade of rosin used depends on the class of paper made; for example, for white papers a relatively colourless grade is used whereas for packing papers, where in any case the sizing is not so important, a more coloured grade can be tolerated.

As an indication, prices were obtained for rosin W.W. grade. These were: minimum 1-ton lots, £138, cif. Port Sudan. Packing - galvanised drums containing 255 kgm.

Papermaker's Alum (Aluminium Sulphate). This is added in solution to the pulp during the pulp stock preparation stage, after the rosin. It precipitates the rosin on to the fibres, and so produces the desired sizing effect (see above).

Prices quoted for the grade 17 to 18% $Al_2O_3$, and assuming that the iron content and content of other impurities is satisfactory from a paper making point of view, were £33 cif, Port Sudan, in 50-kgm., or 100-kgm., gross, jute bags, with polythene liners. The alum is obtainable in granular or lump form, the latter being generally preferable.

China Clay (Kaolin). This also is added to the pulp at the pulp preparation stage. It is a fine, white pigment used as a loading to cheapen the paper, or as a filler to improve printing papers. The amounts which are likely to be used in the Malakal factory are limited because the addition of china clay lowers the strength of the paper, and it can be suitably used only where the raw material fibre is itself strong. However, china clay is a definite advantage in printing papers, and in some cases so much as 25% is added. Most of the best china clays originate in Cornwall, and therefore have to be imported, and prices are of the order of £20 per ton cif. Port Sudan, in paper bags. If the clay could be taken in bulk, the price would be about £18 per ton cif.

Other Chemicals used in the Paper Making Process.

These include colouring matters, wet strengthening agents, etc. The amounts used are relatively small, and are without significance to the conclusions of the present Study. The question of their availability and prices therefore, was not pursued.

Fuel and Electricity.

There is no main supply of electricity at Malakal, local requirements being generated from imported gas oil. Two 250-kilowatt diesels and one 150-kilowatt diesel are at present installed. This is a comparatively expensive procedure.

With large pulp and paper mills it is most economic for the factory to raise steam for process work (principally digestion and drying purposes) and power generation in one unit. This is because the low - pressure steam obtained from the turbines generating the electricity can be used for process work. However, where these two requirements are out of balance, and where the output is too small to justify the capital expenditure involved, it is usual to buy electricity and to generate sufficient steam at a lower pressure for process work. In the present instance, the latter system must be used, but since electricity cannot be purchased, it must be generated by a diesel unit. This is a relatively expensive procedure (see Part IX).

Fuel oil for burning (e.g., for steam-raising) is not at present sent to Malakal, but if the quantity justifies doing so, say up to 20 tons per day, then it could be sent in bulk by railway from Port Sudan to Kosti, and then by barge from Kosti to Malakal. Under these circumstances Sudan Railway would supply the barges and tugs. A depot would have to be set up at Malakal to take say, 2 months' stock, and the oil would be brought up river in barge loads of say, 80 tons. Normally there are 2 sailings per month from Kosti to Malakal, but lack of tugs might prove to be a difficulty in arranging more sailings. The journey from Kosti to Malakal takes 7 days by river, and the return journey (downstream) 3 to 4 days. It is obviously quicker to bring the oil this way, since it takes approximately 8 days from Port Sudan to Khartoum. Stocks would have to be held owing to the possibility of washouts on the railway between Port Sudan and Kosti.

On the above basis the total delivered cost of fuel oil would be made up as follows:-

| | |
|---|---|
| Basic price, cif. Port Sudan | £8.2 per ton |
| Freight, Port Sudan to Kosti | £5.3 per ton |
| Freight, Kosti to Malakal | £2.9 per ton |
| Total | £16.4 per ton |

This presumably, would be a Grade 6 fuel oil having a calorific value of approximately 18,800 B.Th.U. per lb., and would be used for steam-raising only. For the generation of electricity diesel oil would be used as at present.

There is actually a Government electricity authority for the country namely, The Central Electricity and Water Administration, but the factory at Malakal would be outside its present ambit and would have to rely on its own resources.

The above oil prices are basic figures for small quantities. The prices of larger quantities are open to negotiation, and it seems that a discount of about 10% could be counted upon in the present instance. In these circumstances the following prices (which are those used in the calculations of the present Study) would apply:-

| | Fuel Oil | Diesel Oil |
|---|---|---|
| cif. Port Sudan less 10% | £7.38 | £13.50 |
| Freight to Malakal | £8.20 | £8.20 |
| | £15.58 | £21.70 |

# PART VI

## LABOUR AND MANAGEMENT

Labour.

Tables 18 and 19 show the type and number of workers likely to be required to operate the proposed factory at Malakal, according to departments, assuming three 8-hour shifts per day, and a 300-day year, i.e., 21 tons per day of finished product in order to produce 6,400 tons per annum. This would be made up as follows:-

| | |
|---|---|
| Output per day | 21.5 tons |
| Output per week (6 days) | 129 tons |
| Output (approx.) per year (50 weeks) | 6,400 tons |
| Total shut periods for holidays and maintenance | 2 weeks |

Tables 18 and 19 refer to shift and day workers, respectively. Table 20 shows the existing wage rates as given in "Conditions of Service for Worker Employees, Unestablished" 1968. These are set up by the Government, but rates paid by private industry may vary from those given in the Table. Owing to the lack of industry in the Upper Nile Province, it may well be that productivity (in the first instance any rate), would be low at Malakal; and allowance has been made for this in assessing the numbers of workers required.

In addition to the basic wage, it has been felt advisable to allow 30% of the total wage bill for housing, social services such as hospitals, schools, etc., and other amenities.

## Table 18

## FACTORY SHIFT WORKERS

| Department | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Total |
|---|---|---|---|---|---|
| **Cutters:** | | | | | |
| Cutting | - | - | - | 2 | 2 |
| Handling | - | - | - | 2 | 2 |
| **Digesters:** | | | | | |
| Chemicals | - | - | 1 | - | 1 |
| Filling | - | - | - | 2 | 2 |
| Emptying | - | - | 1 | - | 1 |
| Handling | - | - | - | 1 | 1 |
| **Stock Prepn:** | | | | | |
| Screw-press | - | - | 1 | - | 1 |
| Handling | - | - | - | 1 | 1 |
| Pulpers | - | - | 1 | 1 | 2 |
| Refiners | - | 1 | - | - | 1 |
| **Machines & Presses:** | | | | | |
| Foreman | 1 | - | - | - | 1 |
| Sheet removal | - | - | 8 | - | 8 |
| Washing | - | - | - | 1 | 1 |
| Handling | - | - | - | 2 | 2 |
| **Driers:** | | | | | |
| Foreman-mechanic | - | 1 | - | - | 1 |
| Feeding | - | - | - | 2 | 2 |
| Emptying | - | - | - | 1 | 1 |
| **Finishing:** | | | | | |
| Foreman | 1 | - | - | - | 1 |
| Calenders | - | - | 2 | 2 | 4 |
| Trimming | - | - | 2 | 2 | 4 |
| **Totals:** | | | | | |
| Per shift | 2 | 2 | 16 | 19 | 39 |
| Per day | 6 | 6 | 48 | 57 | 117 |

## Table 19

## AUXILIARY SERVICE AND DAY (ONE-SHIFT)

## WORKERS

| Department | Grade 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| **Stocks-Cutters:** | | | | | |
| Loading | - | - | - | 3 | 3 |
| Trucking and Unloading | - | - | - | 2 | 2 |
| **Engineering:** | | | | | |
| Boilers | 1 | - | - | - | 1 |
| Electrician | 1 | - | - | - | 1 |
| Maintenance | 1 | 2 | 2 | 2 | 7 |
| Masons and Joiners | - | 1 | 1 | 1 | 3 |
| **Watchmen:** | | | | | |
| Water | - | - | - | 1 | 1 |
| Houses (12 hr.) | - | - | - | 1 | 1 |
| Factory (12 hr.) | - | - | - | 2 | 2 |
| Reserve | - | - | - | 1 | 1 |
| Drivers | - | 2 | 2 | - | 4 |
| Messengers and Cleaners | - | - | - | 2 | 2 |
| Totals (per day) | 3 | 5 | 5 | 15 | 28 |

## Table 20

## GOVERNMENT PAY RATES FOR UNSKILLED LABOUR IN THE SUDAN, 1968

1. For the first half year of service, payment is on daily basis; with no payment for holidays. Rate - Pt.17.5 per 8-hour day.

2. For the second year the rate continues at this level, but payment for holidays is included.

3. After this workers can join the government service and thus have all the rights of a government permanent worker, viz. vacations, travelling licences, pensions, etc. Pay rates then follow the group pattern after each promotion. The groups are seven, and the rise within the groups are the ordinary annual increments. Monthly rates are:-

Group 1: Start, £13.900. After 3 years, £14.600. Annual increments for next 8 years to £20.200.

Group 2: Start, £16.700. After 5 years, £17.550. Annual increments for next 7 years to £24.350.

Group 3: Start, £20.000. After 5 years, £21.000. Annual increments for next 9 years to £30.000.

Group 4: Start, £28.000. Annual increments for 5 years to £34.800.

Group 5: Start, £33.250. After 4 years, £34.700. Annual increments for next 7 years to £44.800.

Group 6: Start, £39.850. Annual increments for next 9 years to £55.150.

Group 7: Start, £45.900. After 4 years, £48.000. Annual increments for next 8 years to £64.800.

Since it is envisaged that most of the employees will be drawn from the town of Malakal (see below), individual housing has not beenallowed for, except in the case of key men; it is felt that the labourers will come from their present houses, although transport may be provided for the more distant workers.

In assessing the total amount to be charged to workers' wages, the rates of Table 20 have been taken as a basis (since the factory will be in the government sector of industry); and the workers have been divided into 4 main categories; see Table 21. This procedure simplifies the matter without introducing an appreciable error into a calculation which is already inevitably approximate.

Table 21 thus shows the 4 categories of workers, with their mean monthly rates.

Table 21

| Number | Status | Monthly wage |
|---|---|---|
| 1 | Foreman | £50 |
| 2 | Skilled | £40 |
| 3 | Semi-skilled | £30 |
| 4 | Unskilled | £15 |

Tables 18 and 19 show the factory workers required for each of the above grades for shift work (39 per shift) and on day work (28), respectively; the total is therefore, 117 shift workers plus 28 day workers i.e., 145. Workers involved in the collection of papyrus and transporting it to the mill are considered and charged separately as part of the delivered cost to the mill of the papyrus (see Part IV); these total 366, making a grand total of 511 workers.

There is considerable unemployment in the Upper Nile Province. Semi-skilled labour for some special trades is available and it should be possible to train men locally assuming that teachers can be found who will live in the area. Unfortunately, many schools in rural areas have been closed owing to local disturbances but, in general, there has been a migration of population to the towns where facilities of this kind have been developed. The residential school system practiced in these areas has provided educational facilities outside the envircnment of the village and the local schools.

It is anticipated that all of the unskilled men and most of the semi-skilled men will be recruited locally without great difficulty. The remainder of the semi-skilled men and most of the skilled men could be local men who receive special training while the mill is being built; and the foremen and key skilled men will have to be brought from outside the Upper Nile Province (or even from outside Sudan), in the first instance at any rate. Under these conditions some 70% of the worker payroll, say about 100 workers, would be of local origin, plus nearly all of the papyrus harvesting workers - say about 450 in all.

As stated above the question of labour for cutting papyrus and work outside the factory, needs special consideration. The general feeling was, that if this is done at Wath Wang Kech, a wage of Pt.20 per day (8 hours) would be appropriate for a basic wage, plus 10% for fringe benefits, etc., making a total of say, Pt.25 per day. However, the labour force of the actual Malakal factory has been costed at the same rates as for Khartoum (Table 20), especially as a number of the workers will have to be brought to the site, because locally trained people are not available.

Local types of houses are "rondavels" with thatched roofs, and while this type of dwelling might be acceptable and indeed, often preferred by the labourers, they would have to be constructed rather better than at present, i.e., with windows and a stone floor, and some form of division of rooms inside. Constructions of this kind have proved very successful in factory sites in other parts of Africa, and the cost is not high. Conventional housing for the whole labour force would be extremely expensive; a figure of £450,000 was mentioned locally as the cost of housing 230 people of whom 150 are labourers. This seemed unrealistic and is obviously not a capital cost which could be carried by the factory. The location of the factory near an urban area where housing already exists (see Part VII) should eliminate this problem, except for houses for management and key men brought from outside.

The total annual cost of the mill worker payroll may thus be calculated as follows:-

| Classification | Workers | Monthly rate | Monthly cost |
|---|---|---|---|
| 1 | 9 | £50 | £450 |
| 2 | 11 | £40 | £440 |
| 3 | 53 | £30 | £1,590 |
| 4 | 72 | £15 | £1,080 |
| Total: per month | 145 | | £3,560 |
| per annum | | | £43,800 |
| Add 25% for "benefits" | | | £10,950 |
| Grand total per annum | | | £54,750 |
| per ton of paper | | | £8.55 |

Management and Staff.

The importance of employing a first class General Manager cannot be overstressed. He should have practical paper mill experience, and be able if necessary, to deal with day to day works problems himself. It is desirable that he is engaged before the mill is built, so that his services and advice are available during the building operations. The Works Manager can be a senior foreman type, and he also may have to be an alien in the first instance.

Table 22 shows the estimated requirements and rates of remuneration for management and staff (monthly rates). The additions for fringe benefits are in line with general experience, and with the General Manager, this allows for annual leave in the case of an alien.

Table 22

MANAGEMENT AND STAFF

PAYROLL

| Position | Annual Salary | Fringe Benefits | Total |
|---|---|---|---|
| | £ | % | £ |
| General Manager | 4,000 | 50 | 6,000 |
| Works Manager | 2,500 | 30 | 3,250 |
| Chief Engineer | 1,000 | 25 | 1,250 |
| Chief Clerk | 750 | 20 | 900 |
| Laboratory Assistant | 800 | 20 | 960 |
| 2 Typists | 600 | 20 | 720 |
| Total: per annum | | | 13,080 |
| per ton (6,400 t.p.a.) | | | £2.04 |

## PART VII

## SITE - INCLUDING TRANSPORT, WATER SUPPLY AND EFFLUENT DISPOSAL

It is first necessary to state the criteria which go to make up the ideal site for a pulp and paper mill. These are as follows:-

1. Availability of Water of Adequate Quantity and Quality. This is by far the most important consideration and, if it cannot be satisfied completely, then a site must be rejected on this ground alone. Although both quality and quantity of water are important, because of the availability of modern methods of water treatment, the quantity is perhaps the more important. Nowadays natural waters can be purified both chemically and mechanically to give a supply of any desired purity. However, water which is very impure to start with, especially in respect of finely-divided or colloidal matter, may require a great deal of treatment and relatively large quantities of chemicals may be consumed. Consequently, the treatment cost of such water may become a significant factor in the production cost of the pulp or paper.

A specification for a water suitable for the manufacture of the bleached grades of papers, as envisaged for the production of the proposed mill, is given in Table 23.

With respect to quantity, the following approximate volumes are required by pulp and paper mills:-

Table 23

ANALYTICAL VALUES (MAXIMA) FOR

WATER FOR PAPERMAKING

(in parts per million)

| | White papers | Wrapping papers | |
|---|---|---|---|
| | | bleached | unbleached |
| Turbidity | 10 | 40 | 100 |
| Colour | 5 | 25 | 100 |
| Total hardness ($CaCO_3$) | 100 | 100 | 200 |
| Calcium hardness ($CaCO_3$) | 50 | - | - |
| Methyl orange alkalinity ($CaCO_3$) | 75 | 75 | 150 |
| Iron | 0.1 | 0.2 | 1.0 |
| Manganese | 0.05 | 0.1 | 0.5 |
| Free chlorine | 2 | - | - |
| Soluble silica | 20 | 50 | 100 |
| Total dissolved solids | 200 | 300 | 500 |
| Free carbon dioxide | 10 | 10 | 10 |
| Chlorides (Cl) | 75 | 200 | 200 |

| | |
|---|---|
| Manufacture of pulp and paper in an integrated mill. | 220,000 to 300,000 litres per ton of paper produced. |
| Manufacture of paper from supplied pulp. | 50,000 to 110,000 litres per ton of paper produced. |

These quantities must be available day and night throughout the year, i.e., even during the driest season.

It will be appreciated that these figures refer to the types of paper envisaged for manufacture in the proposed mill (see Part III). The possibility of future increases in production must also be borne in mind. Experience has shown that there is usually a tendency to underestimate the water requirements of a pulp and paper mill project. In general, it is advisable to consider only surface water, i.e., rivers and lakes. Water below the ground can be a very uncertain factor where such large quantities are concerned, although many large mills operate on well water. Such water involves sinking wells at some expense. Fortunately, since it is intended to use the River Nile in the present instance, these problems do not arise.

2. Effluent Disposal. Most of the water taken from the river or other source for process work will ultimately be discharged from the mill. There will, however, be certain losses, e.g., through evaporation in a soda recovery plant and also during the drying of the paper on the paper machine. The water returned to the river will mostly be less pure than when taken, and the impurities will contaminate the river water to a corresponding extent. It will be appreciated that during the digestion process approximately 50% of the substance of the

plant is removed in order to produce the 50% yield of unbleached cellulose fibre commonly obtained.

Where pulp is made most of this organic matter is destroyed by burning the evaporated digester liquors in the soda recovery process, and the heat obtained thereby is usefully employed (see Part V). However, in order to wash the pulp after it has been digested, a considerable amount of water is needed, and although very efficient methods of washing are now used, impurities may be rejected to the mill effluent at this stage. These consist of a very small amount of caustic soda, a certain amount of suspended fibrous matter of a very fine nature, and some dissolved organic matter usually in a colloidal state. These materials are very difficult to remove, but methods are available which enable a reasonably pure effluent to be obtained. Much depends on the type of process and raw material used.

One means of partial purification of the effluent involves passing it through sedimentation tanks, where most of the suspended matter is removed. The liquor can also be aerated in lagoons, artificially or otherwise, and a certain amount of organic matter can be removed by oxidation in this way. A further alternative is to segregate the worst portions of the effluent and to lagoon them separately, allowing only the least polluting portion to overflow directly into the river. The pollution takes the form of what is known as the biological oxygen demand (B.O.D.). The B.O.D. is a measure of the extent to which the effluent will remove the oxygen present in a river when the two waters are mixed together. If the dissolved oxygen is decreased to a low level this has adverse effects on the fauna and flora of the river. The natural plant life cannot then grow, and so cannot re-oxygenate the river; the river thus gradually becomes cumulatively worse in this respect.

It is apparent from this that, after water supply, effluent disposal facilities represent an extremely important factor in selecting the mill site. If suitable facilities do not exist, then the site must be rejected. The above considerations apply mainly to pulp mills. The purification of paper mill effluents is much less difficult. However, the selection of a site for a paper mill often has to be made with the possibility in mind of a pulp mill as a future development. Fortunately, in the present instance, the use of the River Nile for effluent disposal eliminates many of these difficulties owing to the high degree of dilution it provides by reason of its huge volume. Nevertheless, steps must be taken to remove from the effluent constituents which can be profitably re-utilised (e.g., fibre), or which might be a nuisance locally or affect fish life.

3. Proximity to Raw Materials and Markets. It is usually necessary from an economic standpoint to locate the mill in a central point with respect to its fibrous raw material requirements. This location is sometimes relative - thus many mills transport their fibrous materials from fairly distant points, but close proximity of the fibrous material is obviously a great

advantage. The same considerations apply to other materials, such as chemicals and the paper markets. In the present instance they are the weak spot of the project.

4. Transport. The above considerations indicate that transport facilities are an important factor. It is a great advantage to locate the site so that it has both rail and road transportation. As shown below, railway, road and water transport all come into consideration in the present instance, and some special problems arise in each case.

The applications of the above criteria to the present Study will now be considered.

## Malakal District.

### General.

The reasons for seeking a site for the factory in the Malakal area have been indicated in Part II. Actually the terms of reference cover the whole Upper Nile Province, and it will be apparent from the map (Fig. 1) that this extends northward so as to include Renk; this latter town might not be regarded as a good geographical centre even if it was desirable on technical grounds. Under the circumstances, and in view of the location of the most likely fibrous raw material (namely, papyrus), serious consideration was given only to Malakal and Renk, with a strong preference for Malakal.

Malakal is the largest town in the Province; it is the administrative and military centre, and the seat of the Commissioner; and it has the best river port facilities,

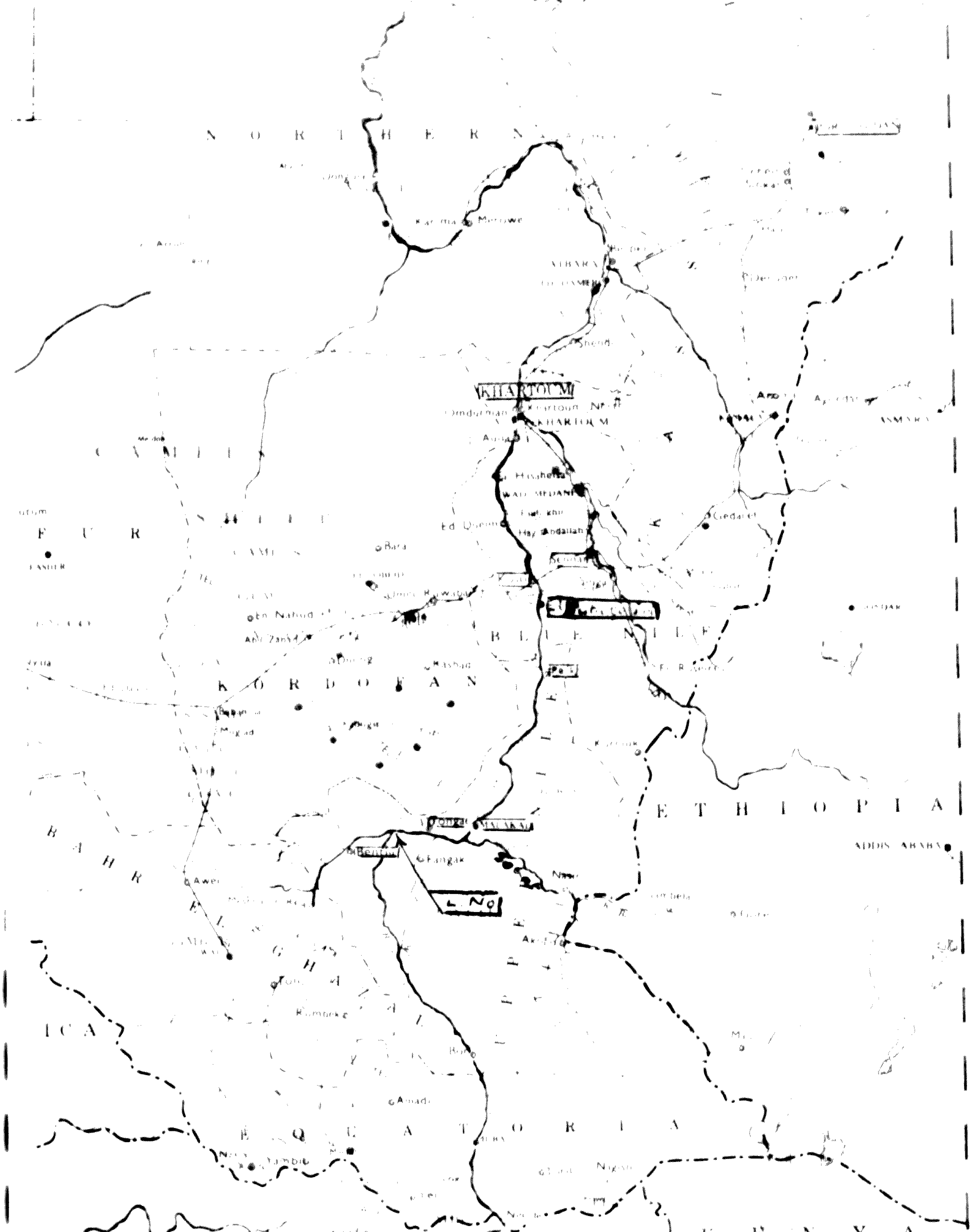



Figure 1

THE SUDAN

hospital, school, shopping and social amenities. Electricity is generated locally for town use only and there are no facilities for a factory supply (see Part V).

Climatic information is as follows (averages):-

| | | |
|---|---|---|
| Temperature: | maximum | $39^{o}$C. (March) |
| | minimum | $19^{o}$C. (January) |
| Relative humidity: | maximum | 87% (August) |
| | minimum | 25% (January) |
| Rainfall: | maximum | 183 mm. (April) |
| | minimum | 0.2 mm. (January) |
| Flow of River Nile | | 3.2 to 4.0 km. per hour |
| Flood levels: | maximum | 11.3 m. |
| | minimum | 9.8 m. |

Distances are shown in Table 24.

Table 24

TABLE OF DISTANCES

| | |
|---|---|
| Malakal to Kosti | 500 km. (river) |
| Kosti to Khartoum | 950 km. (rail) |
| Kosti to Sennar | 115 km. (rail) |
| Sennar to Port Sudan | 1,045 km. (rail) |
| Malakal to Lake No | 150 km. (river) |
| Malakal to Bentiu | 250 km. (river) |

Population (Malakal and district) 25,000. Mainly Shilluk, with elements of the Nuer and Dinka tribes. Religion, approximately 85% pagan, 15% christian.

Water Supply.

Table 25 is an analysis of the River Nile water at Malakal, together with the point and details of collection. The analysis was made by the Hydrobiological Research Unit of the University of Khartoum.

Table 25

ANALYSIS OF WHITE NILE WATER

Sample: White Nile river water collected at Bum, Malakal by Dr. J. Grant.

Date: 26th November, 1968, 11.20 hours.

| | | |
|---|---|---|
| Conductivity (megohms $^{-1}$ at 20°C.) | 220 | |
| pH value | 7.8 | |
| Chloride (as Cl) | 2.8 | parts per million |
| Alkalinity | 72.5 | " " " |
| Calcium (as Ca ++) | 9.4 | " " " |
| Magnesium (as Mg ++) | 5.0 | " " " |
| Total dissolved solids | 115 | " " " |
| Total hardness | 70.4 | " " " |
| Silicate (as $SiO_2$) | 26 | " " " |

Comparison of these figures with those given in Table 23 as criteria of purity of water for paper making shows that this water should be quite satisfactory, although the alkalinity and silica contents are on the high side. However, these are not serious objections. It should nevertheless, be pointed out that this sample was taken in late November, 1968, so that it does not represent the dry weather flow. In this respect the most important figure is the chloride content,and existing results show that this usually is approximately 9 parts per million in dry weather at Malakal. As a precaution this figure should be checked when the dry weather period returns in early 1969, the last figure having been obtained in May, 1966. However, it seems most unlikely that the purity of the water will offer any problem in the present instance.

Transport.

As is evident from Parts IV and V dealing with the various raw materials required, transport to and from Malakal must be largely by river. On the one hand all the fibrous raw material (e.g., papyrus) will come in from the south, and this will have to be transported by river from Wath Wang Kech. The possible methods of doing this are indicated in Part IV under fibrous raw materials (papyrus).

More important from the economic point of view however, are possibly, the transport of fuel and chemicals to Malakal, and of the finished paper from Malakal to Khartoum. These problems were discussed with the various government departments and other bodies concerned. This transport is in the hands of the Sudan Railways and normally, only cargo is carried by water between Kosti and Juba with a call at Malakal. Transport between Kosti and Khartoum is by railway or road, which is regarded as quicker and more convenient than river because of the presence of the Djebel Aulia dam. The barges used range in capacity from 5 to 150 tons, and up to 10 barges can be taken per sailing depending on the height of the river. The relevant freight charges are given in the appropriate places in the text of this Report, and they include loading and unloading, and other expenses.

Oil fuel and caustic soda are among the more important products in this category, and the transport costs are discussed in Part V. It should be pointed out that these are based on present standard rates, and that for large quantities over long periods meriting contract treatment, they would probably be less than the figures given. Much the same would no doubt apply also to transport of paper from Malakal to Khartoum, which if carried under the heading of Class 9 (i.e., wrapping papers), would cost £5.600 per ton from Malakal to Khartoum, again subject to negotiation for quantities of a contract magnitude.

It should be noted that it is general comment in Sudan that railway transport gives rise to problems especially in the south; difficulties are due to washouts in wet weather and to shortage of rolling stock at all times, and this applies even on the Port Sudan line. It is therefore necessary to carry big stocks of essential materials in order to safeguard against these possibilities.

Site Selection.

Two principal sites were inspected in the Malakal area namely, as follows:-

(1) Bum. This site is on the right bank of The Nile, and about 5 km. from the centre of Malakal in a southerly direction, just past the Peace Village and the highly concentrated township of rondavel huts housing several thousands of people. The site is shown on the maps of Figs. 2 and 7 where it is

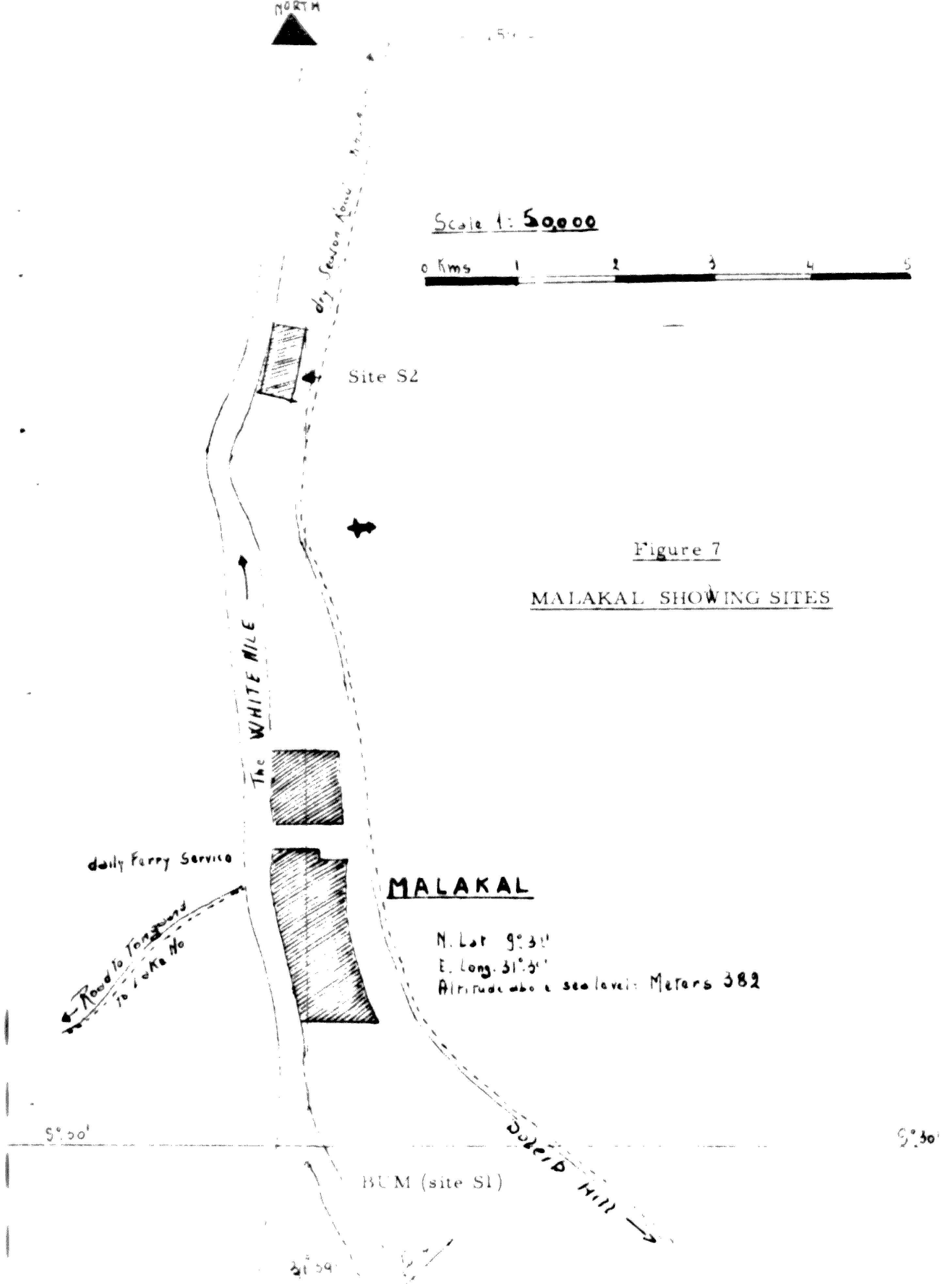



Figure 7

MALAKAL SHOWING SITES

marked S1, For Figure 2 see p. 111.

The land selected has a good water frontage from which it slopes up gently to higher, level ground, where there is a road running parallel with the river between Malakal and Doleib Hill. This is the continuation of a metal road from the town for 2 to 3 km., but it is a dirt road at the site. There is a further road to Doleib Hill to the east, but neither is an all-weather road although one which is the shorter route to Doleib Hill (map, Fig. 2, p. 111), will be made an all-weather type road shortly.

The only disadvantage of the site is that, as the maps show, there is a peninsular of reeds and grasses in the Nile opposite the water front, so that part of the site is, in effect, at the mouth of a backwater. It is understood that at times the river in front of the proposed site is shallow, and that in extremely dry weather it can even dry up. This however, is a difficulty which should readily be overcome by cutting a channel through the end of the peninsular and dredging the ground between it and the shore. Indeed, the whole tip of the peninsular could be cut away, so providing an extra width of river in which to manoeuvre the barges and other river traffic serving the site. If this is done, then the site is provided automatically with a natural harbour where mooring and unloading facilities can readily be installed, the papyrus and chemicals, etc., being brought into the factory by means of conveyors from the riverside. Naturally, the whole question of dredging needs to be explored further by experts on the subject before the site is finally accepted. In other respects the site is ideal.

At Malakal it is also important that the site is on the right bank of the river, otherwise most or all of the personnel would have to be ferried across. The landing of the papyrus would present no difficulty, whatever the side, and the same would apply to the traffic in and out by boat. However, the labour question and the question of easy contact with the facilities of the town of Malakal are important.

It is understood that a private agricultural scheme is under consideration for this area, involving some 400 feddans, and that sugar cane cultivation is among the possibilities to be considered. This could be an interesting associated project in itself, since sugar cane bagasse can be used for the manufacture of paper (see Part X). However, it would appear that, at present, there is ample room for both the factory and for any scheme of this kind although it is, of course, important that the factory has precedence so far as proximity to the river is concerned. If necessary the site alongside the river, which extends for some 1.5 km., could be used; although the width of high ground between the river and the road is only about 70 m. wide. However, the factory could be continued on the other side of the road, or the route of the dirt road could easily be altered to circumvent the factory. These are relatively small points which, owing to the undeveloped nature of the terrain, can easily be dealt with as development of the site proceeds.

One special advantage of the Bum site is that a considerable source of labour is available within 1 to 2 km. distance, where there is already a well-developed urbanised area with proper housing and associated facilities. This would obviate the expensive necessity of providing housing for the bulk of the workpeople. Another material advantage is the proximity to and ease of communication with the source of bamboo at Doleib Hill (see Part IV).

To sum up, if the dredging problem can be resolved without great difficulty, this is in every way an ideal site.

(2) West of Malakal. The right river bank in this direction was explored, and several possible sites were looked at. These were as follows :-

(a) Wij Malakal - Approximately 8 km north of the town just before the Wathwath Swamp (see S2, Fig. 7). To reach this one follows the metalled road to the airport for 4.0 km., and then a dirt track over the grass. The building site is a good one, being flat and dry, and apparently good building ground, but unfortunately there is a fairly wide flood area between the good ground and the actual edge of the water. This would make access from the Nile difficult. It would be necessary to build some kind of bridge or causeway or else to cut a boat channel through the reeds and to keep it clear, or even to dredge out a considerable area. Conveyors might be used, but the distance involved is rather great. Adequate good building land is available, but new approach roads are required and in any case, it would be necessary to keep the site well clear of the airport because there is talk of extending the latter to take international plane services. This site would also be fairly convenient for labour, which would have to be transported from Malakal, a distance of some 11 km. It is nevertheless less convenient than the Bum site in this respect.

This site appears to have been favoured by previous investigators, (see Japan Consulting Institute and O. Righini projects, Part II), although it is not pin-pointed precisely in their reports. The question of dealing with the portion of the site which is subject to floods is however, not mentioned in these Reports.

(b) Ogod Butu (Fig. 2, p. 111) - A suggested site inspected here was regarded as unsatisfactory, as it is too far from the River Nile.

(c) Ayowangen (Fig. 2, p. 111) - This site was also rejected because there is history of extensive flooding in the wet season.

On the whole the site at Bum is favoured, although the question of cutting away the peninsular and dredging the river at the bank at this point might arise. There is obviously an advantage in having the mill upstream from Malakal because the barge traffic bringing in papyrus would otherwise interfere with the river traffic between Malakal and Kosti; the former being very much more than the latter. This is not a major point, but the question of manoeuvering barges across the river will arise as a daily event, and it is better that this takes place where the river is wide and unencumbered by other traffic. The port facilities at Malakal are not very well developed, but this again will not matter because the mill will have to provide its own facilities. These will have to be built in the first instance, to enable the machinery for the mill to be unloaded; the maximum unloading operation ever carried out at Malakal has been that of engines weighing only 13 tons.

Renk District.

As the map (Fig. 8) shows, this town is also in the Upper Nile Province, although less important and less centrally placed than Malakal. It was nevertheless thought advisable to explore its possibility as a site because Renk is so much nearer Khartoum. Although the papyrus would have to be brought further (from near Tonga, assuming that adequate supplies could not be found locally), the chemicals, fuel, etc., to be brought from Port Sudan, and the paper to be sent to Khartoum, would all incur lower transport costs.

From a transport point of view the difference between the sites at Malakal and Renk may be summarised as follows:-

Papyrus - Malakal to Renk is approximately 350 km. As will be seen from Part IV, the transport of the mill's requirements of papyrus is approximately one day's river run for a distance of 80km. With the site at Renk, the distance is approximately trebled. This means at least 5 tug

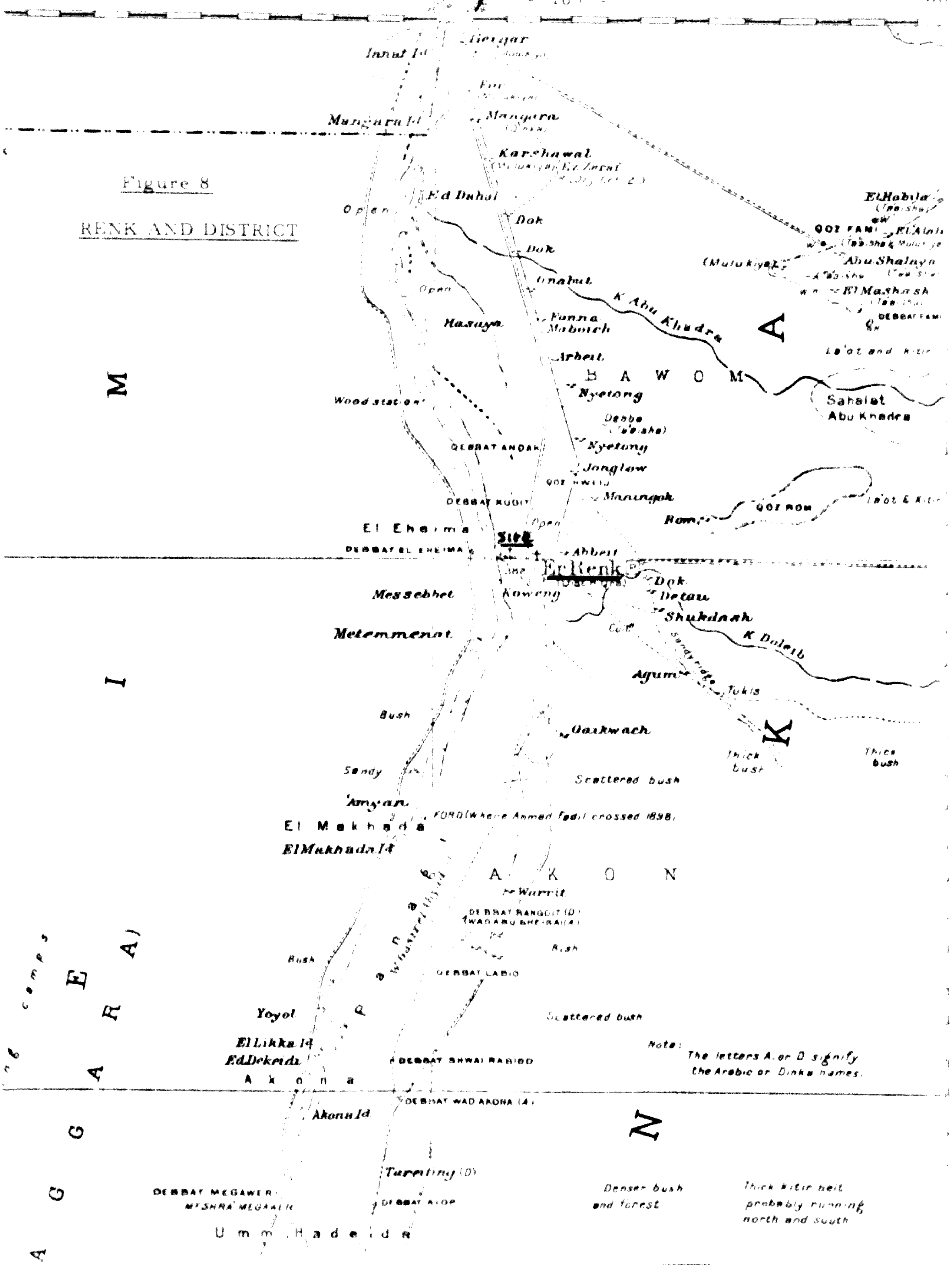



Figure 8

RENK AND DISTRICT

and barge units (unless a larger tug pulling 6 barges is used), and the extra crews, fuel, maintenance, etc., would increase the cost of delivering the green papyrus from £0.55 to about £1 .4 per ton. In terms of finished paper this is approximately £ .4 per ton, which represents the extra cost of transport of papyrus to a site at Renk.

<u>Chemicals and Fuel</u> - These will travel over a shorter distance, namely that between Renk and Malakal, i.e., less by approximately 320 km. This should result in economies of about £3 per ton on transport; say, about £4 per ton on the production cost of the paper.

<u>Paper</u> - A similar saving will be made in the transport of paper sent out of the mill to Khartoum (Part IX).

Hence the total saving in transport cost with the mill at Renk as distinct from Malakal will be about £6 per ton of paper, as against an extra transport cost for fibrous raw material, of about £14 per ton of paper (excluding that due to the bamboo, which has to come from Doleib Hill). These approximate figures show that considerable advantages in other respects will have to exist to justify Renk as the site.

The Nile and local country were explored around Renk, from Geigar to approximately 25 km. south of the town (Fig. 8). Odd stands of papyrus were seen, especially to the south, but these were unimportant in quantity from the present point of view. There was said to be more at Melut 170 km. to the south, but this was not apparent on the Malakal visit when it was possible to see this area from the air. Road transport from Renk to Khartoum exists, except from July to September inclusive, but the road is very poor and unlikely to be much better for some time to come. There is a cargo boat service to Malakal, and this journey takes 30 hours; and 24 hours to return.

The population of Renk is 300,000 in the district, and 15,000 in the town. It is mainly Moslem and Dinka in the main town on the right bank, but Shilluk tend to predominate on the left bank of the river. Agriculture is the principal occupation at present, and agricultural labourers receive Pt.15 per day. The nearest electricity supply is at Kosti, and so the same problem of generation would arise here as at Malakal (see Part V). Landing facilities are very poor indeed, but it is said that they will be improved upon by Sudan Railways. There are no crane facilities, but merely a short stone quay; there is apparently, deep water.

A suggested site was inspected between the airstrip and the Nile (Fig. 8); the former runs north - south and is to be extended, although being an earth strip it could easily be replaced elsewhere. At the suggested site there is good building ground, well above flood level and about 1.2 x 0.5 km. in extent. It is however, separated from the river by approximately 1 km. of swamp, which would mean dredging, or a conveyor, canal or causeway. The site therefore, offered no special advantages over the site S2 at Malakal.

South of Renk there is an island about 50 km. long, the upstream end of which is blocked by reeds to produce a closed backwater. This part of the area therefore, is ruled out as a possible site.

It was noted that reeds (Phragmites, Part IV) are widely used for fences in the Renk area, and they were said to be plentiful; however, none were seen near the river shores.

Geigar (Fig. 8) was also inspected. This is also just in the Upper Nile Province, and is at present an oil depot. Site possibilites were seen to the south from the air, but the north was marshy. It was felt that this offered no major advantages over Renk or Malakal, and it was not pursued further.

## Bentiu Area

The possibility of this as a site was considered, but was abandoned. It is too far from the papyrus growing area and in the wrong direction with respect to it (see Part IV); and it offers no compensating advantages.

# PART VIII

## PROCESS, PLANT AND EQUIPMENT.

## CAPITAL COST

### Plant and Equipment

Introduction.

The purpose of this Part is to indicate in outline the plant and equipment required to operate the proposed mill, and to form an approximate estimate of what it is likely to cost. From this can be deduced approximately the total capital cost of the mill. In order to do this it is necessary to anticipate some of the conclusions reached as a result of the profitability studies recorded in Part IX of this Report, and the conclusions and recommendations recorded in Part X. Obviously, one must know what is the best process to use before any attempt can be made to describe it, and the plant required for it. In the present instance, it has only been possible to arrive at this information by means of the market and profitability studies.

As Parts III and X show, the only possibility of establishing a paper mill in the Upper Nile Province depends on the utilisation of what is virtually used equipment, at a correspondingly reduced price. Even under these circumstances the economics of the project only show a borderline or break-even position, and there can be no certainty of this. The discussions which took place on the terms of reference of this Study however, indicated that the question should nevertheless be followed up along such lines;

and the problem of balancing government policy against economic desirability might arise in consequence. Also it was desired to establish quantitatively the viability or otherwise of the exploitation of papyrus in the Upper Nile Province. Consequently, the proposals put forward in the present Part and in Part X (dealing with the conclusions and recommendations) represent an extreme effort to find some way of establishing a paper industry in the Upper Nile Province; and they should be judged accordingly. If the social considerations mentioned above did not arise, then it would be more logical either to dismiss the project completely, or to approach it on the basis of a completely new plant.

Having clarified this background, the proposal now made involves utilising the complete equipment of the cardboard factory at Aroma. The Study on the latter made in December, 1967, has demonstrated quite clearly that the Aroma factory cannot be run at a profit as it is at present established; and that considerable alterations and additions to the machinery and process are required if it is to make a product which has a ready sale and can be manufactured in adequate tonnages (see Part II of the present Study). Under the conditions set out in the Aroma Study, the factory could run at a profit assuming always that the raw material shortage problem had been solved. Unfortunately, at the moment, this is far from being the case, although castor stalks have shown some signs of promise. In order to reorganise the Aroma factory on the proposed lines, it is necessary to dismantle a large proportion of the machines making the actual cardboard, and to rearrange them. This being the case, the additional cost of transporting the machines and re-erecting them in the Upper Nile would be less than would otherwise be the case. However, the remainder of the plant and machinery has also to be dismantled and transferred, and account of this is not taken in the calculations deduced for the profitability of the Aroma factory because it is not necessary in that case. In transferring the whole mill to Malakal obviously, considerable extra costs would be involved.

Apart from machinery there are the additional costs of buildings, site development, riverside harvesting and water transport facilities, none of which can be transferred from Aroma and which have to be provided new.

Nevertheless, as shown below, the savings made by using the Aroma plant would be considerable.

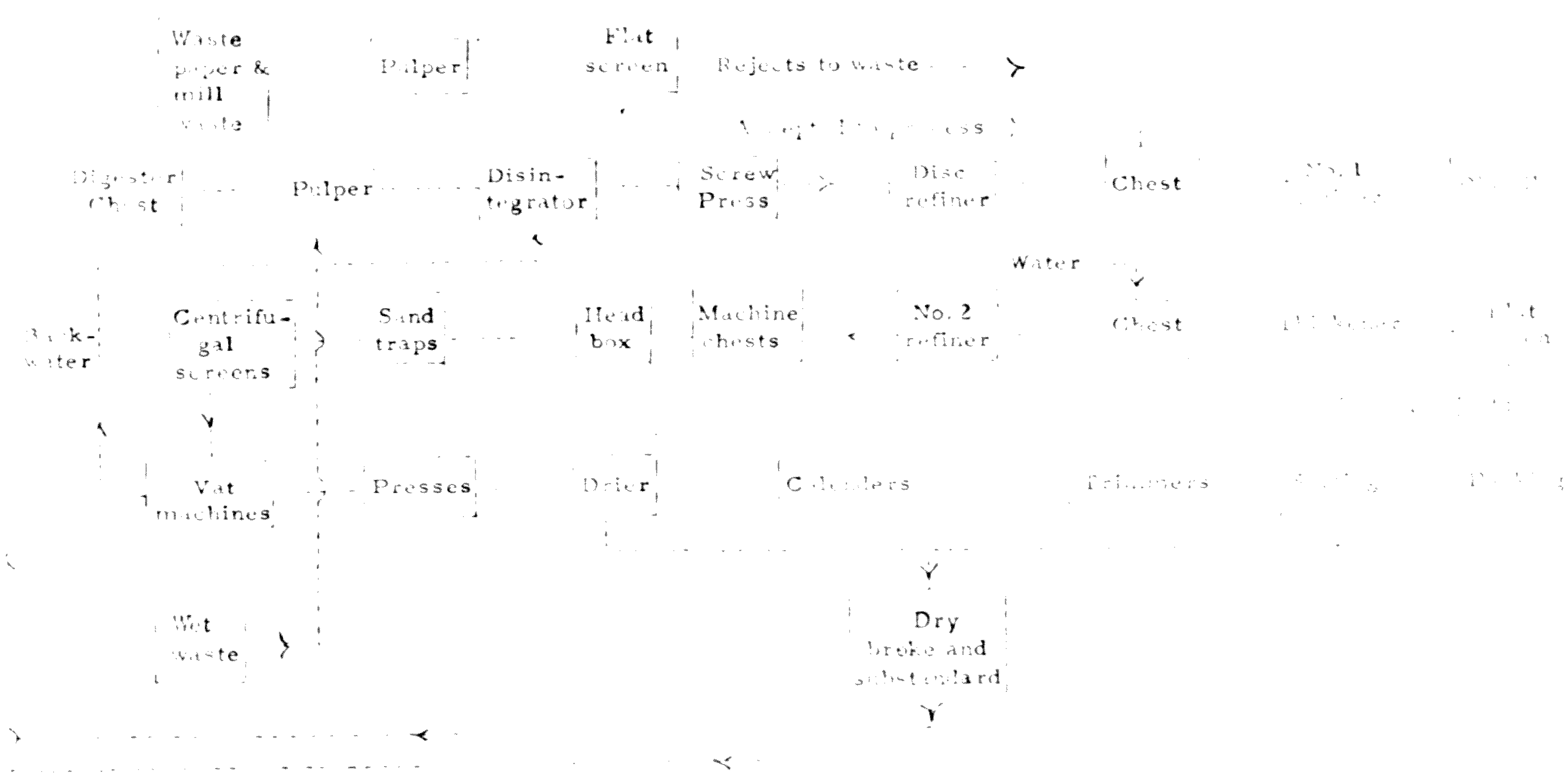
The details given in this Report are therefore, based on those of the Aroma Study, suitably adapted for use with bamboo and papyrus as envisaged for the Malakal factory. However, in addition, the cost of an entirely new plant for processing these materials in the requisite quantities is estimated, and the effect of this on the profitability of the project is shown and discussed in Part IX.

## Process.

As stated, this follows substantially the lines of the Aroma Study. It may be divided into headings as follows (see Fig. 9):-

Figure 9

FLOW SHEET - BOARD MILL



Cutting to Digestion. The papyrus will arrive at the mill green or partly air dry, and would be passed through a cutter. Air-drying may prove to be necessary. The existing Aroma cutter may have to be altered to accommodate papyrus, though there should be no great difficulty in this if the papyrus is reasonably dry at the time of cutting. In view of the storage period which is likely to elapse between delivery and cutting, the necessary air-drying should have time to take place.

The cut material will pass via a fan to a cyclone, and then over vibrating screens which will take out contrary material, of which there should be comparatively little in the case of papyrus. A certain amount of loose dust in the form of dry mud, and possibly leaves, might be removed at this stage. It is not certain whether the hammer mill used in the Aroma factory will be necessary after the vibrating screens, but this is a matter of experiment at a later stage.

From the hammer mill, the papyrus chips will pass through a fan to the storage silo feeding the digesters, as is the case at present with the cut cotton stalks at Aroma.

In the case of bamboo, it will probably be necessary to install roller crushers before the cutters, but otherwise the above procedure should be satisfactory. However, the hammer mill may well be found to be an advantage when processing bamboo.

Digestion. The two digesters at present at Aroma will be used very much as at present. The suggested processing times are tabulated below in Table 26. Emptying procedure will also be the same as at present but of course, with the recommendations made in the Aroma Study.

Table 26

PROCESSING CONDITIONS FOR UNBLEACHED OR SEMICHEMICAL PAPYRUS AND BAMBOO PULPS

| | Papyrus | Bamboo |
|---|---|---|
| Caustic soda (% on dry material) | 7.5 | 8.5 |
| Pressure (kg./sq.cm.) | 3 | 4.5 |
| Time on pressure (hr.) | 3 | 4.0 |

Stock Preparation. Figure 9 shows the flow sheet of the present Aroma factory, and it is generally applicable to the present instance. Thus, a conveyor belt will take the pulp, with its remaining associated black liquor, to a disintegrator with revolving arms. This will break up the lumps of pulp, and pass them to a screw press which will remove most of the remaining liquor. The processed pulp will then pass to a disc refiner, as shown, and then to the first storage test which feeds No. 1 reinfer and the Jonsson-type flat shaking screen. Rejects from the screen will be returned, so that they pass through the disc refiner again; and the accepted pulp will be thickened and sent to the second storage chest where water will be added prior to the pulp passing to the No. 2 refiner. The pulp is then ready for the paper machine feed chest.

Slight modifications to this process will be necessary according as the mill is making bag or wrapping papers, or lined boxboard. These will be controlled at the pulp preparation stage by means of wetness tests; and also by consistency tests taken before and after each refining and screening stage.

The Paper Machine Operation. The Aroma Study recommends that the 5 existing intermittent board machine units (one of which has 2 vats), are converted into one large unit by linking the machines together in series. Press rolls and drying cylinders will be added, and the drying of the paper will be finished off through the existing tunnel system.

In accordance with this scheme the prepared stock will pass through a suitable screening system as recommended in the Aroma Study, to the headbox of the composite machine. An overall picture of these suggestions is set out in Part II of the present Study, under the heading of the historical introduction.

It is felt that if the Aroma plant is used at Malakal, the opportunity should be taken to discard the tunnel as a final means of drying, and to instal further drying cylinders. Such cylinders are usually obtainable second-hand without difficulty, and the cost of purchasing and installing these would not be so very much greater than the cost of dismantling the tunnel, taking it to Malakal, and re-erecting it there.

To summarise therefore, the above suggestions - these are that the whole of the Aroma plant shall be dismantled and re-erected in Malakal in accordance with the long-term suggestions made for the Aroma factory in the January, 1968 Report. The papers and boards made would be substantially the same as those recommended in that Report and, in effect, the Aroma factory would become non-existent. The buildings could probably be used for other purposes, since to dismantle and re-erect is unlikely to be practicable It is important to realise that the suggested scheme enables both papers and boards to be made on the same machine. A new paper machine to achieve this end would be extremely expensive; the cost would be out of proportion to the relatively low production imposed by the present markets.

## Capital Cost.

In the first place it is proposed to consider the capital cost of carrying out the suggestions made above. This cost would be made up of the following items, estimated figures for which are given as follows :-

| | |
|---|---|
| Existing value of Aroma factory (see Study) | £480,000 |
| Improvements, etc. suggested in the January, 1968 Study | 70,000 |
| Cost of dismantling, transporting to Malakal, and re-erection | 22,500 |
| Additions to plant | 22,500 |
| Site preparation at Malakal | 25,000 |
| Papyrus collecting equipment and transport | 70,000 |
| Total | £690,000 |

The cost of buildings is not mentioned. It is included in the value of the Aroma factory, and it is assumed that they would be paid for by the sale of the existing buildings at Aroma. It is also assumed that the site would be free.

In comparison with the above figure it is estimated that the total cost of a new mill at Malakal, starting with completely new machinery and leaving the Aroma factory out of consideration, would amount to approximately £1,100,000, erected. The effect of this extra cost on the profitability is demonstrated in Parts IX and X. From this it will be seen that if new plant is installed the project is brought well onto the wrong side of the borderline and moreover, the Aroma factory problem remains unsolved. Indeed, it would be accentuated by the fact that the Malakal mill would be making the same type of paper product, but without any raw material problem.

Total Capital Requirement of the Project. On the basis of the utilisation of the Aroma equipment, the total capital requirement is made up as follows:-

| | |
|---|---|
| Plant, equipment and buildings | £642,500 |
| Transfer charges | 22,500 |
| Site preparation | 25,000 |
| | £690,000 |
| Interest during building | 34,500 |
| Working capital | 75,600 |
| Total capital requirement | £800,100 |

Notes:

(1) Interest during building is calculated at 5% for one year on £690,000.

(2) Working capital is based on 10 weeks' production (21 tons per day, 6 days per week) at £60 per ton.

(3) If new equipment is used, the total would be made up approximately as follows :-

| | |
|---|---|
| Plant, equipment and machinery (erected) | £1,100,000 |
| Buildings | 95,000 |
| Papyrus collection and transport | 70,000 |
| Site preparation | 25,000 |
| | £1,290,000 |
| Interest during building | 64,500 |
| Working capital | 75,600 |
| Total capital requirement | £1,430,000 |

(4) Engineering costs for the transfer of the Aroma equipment would be relatively small, as it is largely a re-erection job; and they are included in the total given. With a new mill however, they could be fairly considerable, and must be added to the above total.

# PART IX

## PROFITABILITY CONSIDERATIONS

In this Part estimated production cost sheets are given illustrating the various possibilities indicated as a result of this Study.

They are as follows:-

Table 27 - Production of 6,400 tons per annum of fluting paper and medium grade brown wrappings from a mixture of 80% papyrus and 20% bamboo pulps.

Table 28 - Production of 6,400 tons per annum of white-lined boxboard using unbleached papyrus pulp with 20% of imported sulphite wood pulp for the white lining.

From these figures are deduced the production cost for a mill making both of the above papers and board using the Aroma equipment.

Table 29 - gives this cost for a mill making these papers only, but with new equipment.

Table 30 - This is a hypothetical production cost calculation assuming the installation and capacity production of a mill making all the papers used in the Sudan which can be made from a mixture of bleached or unbleached papyrus and/or bamboo pulps. The objective is to indicate the approximate production necessary to break even under these conditions. This, of course, represents a picture of the future since the present paper requirements in the Sudan are far too small for such a mill.

Each production costing consists of numbered items corresponding with the Parts of the present Study in which their respective contributions to the total production cost are deduced. Correspondingly numbered notes are given explaining the figures and methods of calculation used for each item.

From the production costs are calculated the delivered costs (in Khartoum); and the difference between these and the respective selling prices of the papers (as given in Part III) gives the profitability or otherwise.

## Table 27

## PRODUCTION COST FOR THE MANUFACTURE OF 6,400 TONS PER ANNUM OF WRAPPINGS AND FLUTINGS, USING AROMA EQUIPMENT

| | Item | Quantity | Unit Price | Cost p.a. (£) |
|---|---|---|---|---|
| 1. | Papyrus | T.53,230 | £1.30 | 69,200 |
| 2. | Bamboo | T.6,000 | £6.05 | 36,300 |
| 3. | Caustic soda | T. 600 | £55.00 | 33,000 |
| 4. | Chemicals | T. 352 | £30.00 | 10,560 |
| 5. | Diesel oil | T.3,200 | £21.70 | 69,400 |
| 6. | Fuel oil | T.4,800 | £15.60 | 74,800 |
| 7. | Labour | 145 men | - | 54,720 |
| 8. | Management, etc. | - | - | 13,060 |
| 9. | Maintenance materials | - | - | 12,800 |
| 10. | Standing charges | - | - | 10,560 |
| 11. | Depreciation | £632,000 | 7.0% | 44,240 |
| 12. | Interest | £778,600 | 5.0% | 38,930 |
| 13. | Total | | | 467,570 |
| 14. | Substandard paper | T. 640 | £50.00 | 32,000 |
| 15. | Cost per annum | | | 435,570 |
| 16. | Cost per ton saleable paper (dry basis) | | | £68.05 |
| 17. | Cost per ton saleable paper (air dry) | | | £63.28 |
| 18. | Freight Malakal - Khartoum (per ton) | | | £5.60 |
| 19. | Cost delivered Khartoum | | | £68.88 |
| 20. | Average selling price per ton | | | £66.00 |
| 21. | Loss per ton | | | £2.88 |
| 22. | Loss per annum | | | £22,432 |

Notes.

1. Assumes 80% papyrus at 75% moisture and 45% yield (dry basis); 10% substandard paper and 5% loss of yield from pulp to paper.

2. Assumes 20% bamboo at 50% moisture and 50% yield (dry basis); 10% substandard paper and 5% loss of yield from pulp to paper

3. Average of 7.5% on papyrus and 8.5% on bamboo (raw material, dry basis) for unbleached and semichemical pulp, respectively.

4. For rosin-alum sizing and/or wet-strengthening agents, etc.

5. Based on reasonable current practice.

6. As (5).

7. As deduced in Part VI; labour for collecting and transporting papyrus is excluded, see Part IV.

8. As deduced in Part VI.

9. Based on experience at Aroma cardboard factory.

10. As (9).

11. Allows 5% for buildings and 7.5% for plant and machinery. See Part VIII.

12. Based on the total capital involved, including working capital. Seee Part VIII.

14. Assumes 10% substandard paper repulped, and valued at 75% of average selling price.

16. Is (15) divided by 6,400 tons.

17. Assumes that the paper as sold contains 7% moisture.

18. As quoted by Sudan Railways. No special item is included for packing, because the mill would make its own materials and labour costs are included in Item 7. It is assumed that all of the paper would go to Khartoum; the amounts going elsewhere are unlikely to affect the calculation materially.

20. Average present selling price cif. Khartoum, duty paid (see Part III). It is assumed that the mill would conduct its own sales, as it would have very few individual customers (see Part III). No item for selling costs is therefore included. It is also assumed that the present duty of 20% would be levied on imported papers.

21. Is (19) - (20).

22. Is (21) multiplied by 6,400 tons.

Table 28

PRODUCTION COST FOR THE MANUFACTURE OF 6,400 TONS PER ANNUM OF WHITE-LINED BOXBOARD, USING AROMA EQUIPMENT

| Item | | Quantity | Unit Price | Cost p.a. (£) |
|---|---|---|---|---|
| 1. | Papyrus | T.42,584 | £1.30 | 55,360 |
| 2. | Bamboo | T.4,800 | £6.05 | 29,040 |
| 3. | Wood pulp | T.1,667 | £70.00 | 116,690 |
| 4. | Caustic soda | T. 480 | £55.00 | 26,400 |
| 5. | Chemicals | T. 352 | £30.00 | 10,560 |
| 6. | Diesel oil | T.3,200 | £21.70 | 69,400 |
| 7. | Fuel oil | T.4,500 | £15.60 | 70,200 |
| 8. | Labour | 145 men | - | 54,720 |
| 9. | Management etc. | - | - | 13,060 |
| 10. | Maintenance materials | | - | 12,800 |
| 11. | Standing charges | - | - | 10,560 |
| 12. | Depreciation | £632,000 | 7.0% | 44,240 |
| 13. | Interest | £778,600 | 5.0% | 38,930 |
| 14. | Total | | | 551,960 |
| 15. | Substandard paper | T. 640 | £63.75 | 40,800 |
| 16. | Cost per annum | - | - | 511,160 |
| 17. | Cost per ton saleable board (dry basis) | | | £80.00 |
| 18. | Cost per ton saleable board (air dry) | | | £74.40 |
| 19. | Freight Malakal - Khartoum (per ton) | | | £5.60 |
| 20. | Cost delivered Khartoum | | | £80.00 |
| 21. | Average selling price per ton | | | £85.00 |
| 22. | Profit per ton | | | £5.00 |
| 23. | Profit per annum | | | £32,000 |

Notes.

1. Assumes 64% papyrus; as Table 27.

2. Assumes 16% bamboo; as Table 27.

3. Assumes 20% imported coniferous sulphite wood pulp, 90% dry; 10% substandard board and 5% loss of yield between pulp and board.

4. As Table 27, but allowing for the fact that no caustic soda is required for the wood pulp.

5, 6. As Table 27.

7. As Table 27 with allowance for the fact that wood pulp does not have to be digested.

8 to 13 (incl.). As Table 27.

15. Assumes 10% substandard board re-pulped and valued at 75% of average selling price.

16 to 23 (incl.). As Table 27.

From Tables 27 and 28 it appears that the profit from making approximately 3,200 per annum each of flutings and/or wrappings on the one hand, and white-lined boxboard on the other, is £(32,000-22,432) x 0.5, i.e., £4,784 per annum. Obviously the more boxboard the machine can make, the greater its profit, but market demands will be the limiting factor for the first few years.

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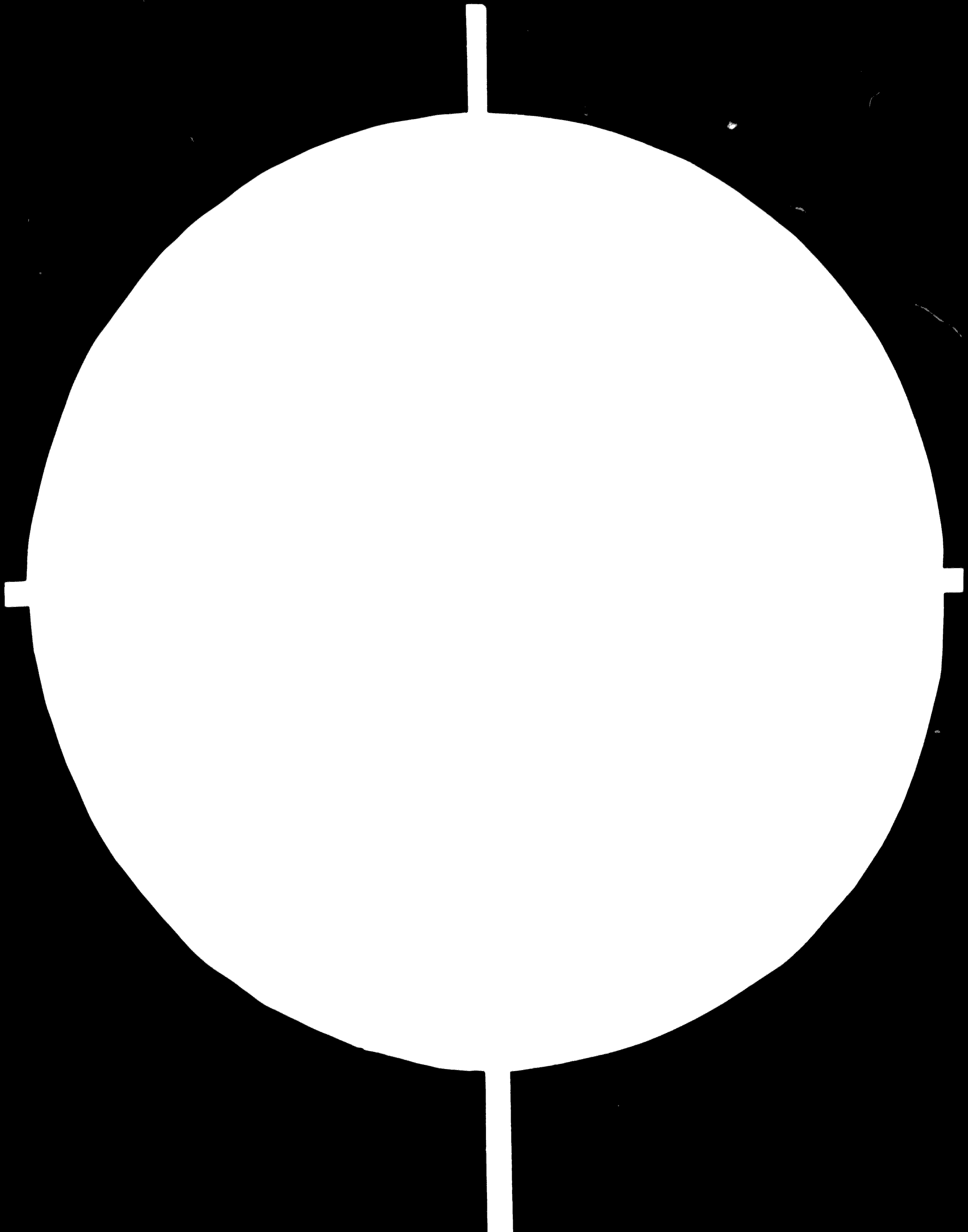

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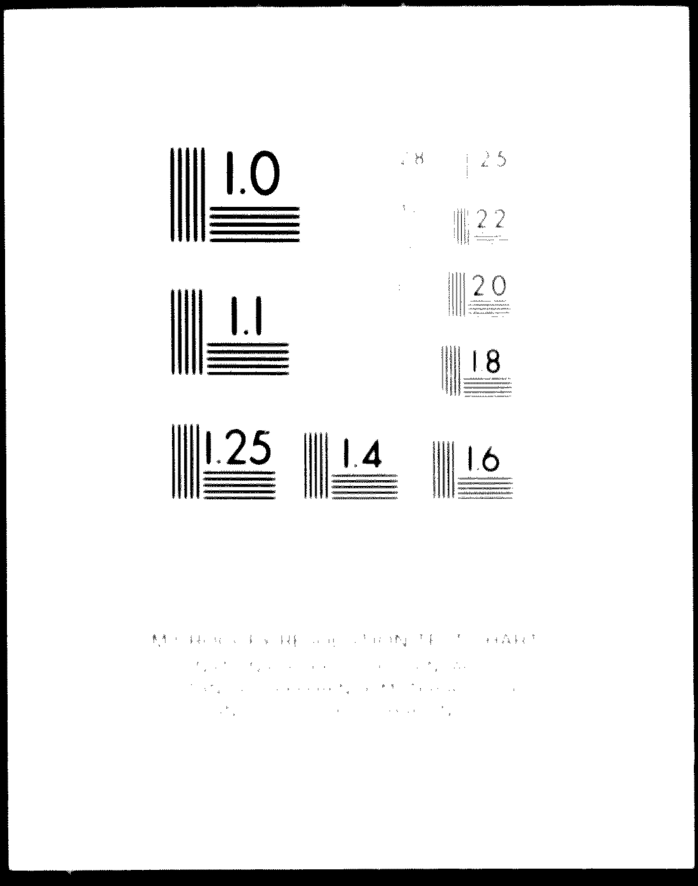


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Table 29

## PRODUCTION COST FOR THE MANUFACTURE OF 6,400 TONS PER ANNUM OF WHITE-LINED BOXBOARD USING NEW EQUIPMENT

| | | |
|---|---|---|
| Items 1-11 (inclusive) of Table 28 | | £468,790 |
| 12. | Depreciation £1,265,000 at 7.0% | 88,550 |
| 13. | Interest £1,392,300 at 5.0% | 69,615 |
| 14. | Total | 626,955 |
| 15. | Substandard paper | 40,800 |
| 16. | Cost per annum | 586,155 |
| 17. | Cost per ton saleable board (dry basis) | £91.58 |
| 18. | Cost per ton saleable board (air dry) | £85.17 |
| 19. | Freight Malakal - Khartoum (per ton) | £5.60 |
| 20. | Cost delivered Khartoum | £90.77 |
| 21. | Average selling price per ton | £85.00 |
| 22. | Loss per ton | £5.77 |
| 23. | Loss per annum | £36,928 |

Notes.

1 to 11, inclusive, will be substantially unchanged, except that the fuel costs may be somewhat less as new equipment is being used.

12. Depreciation is calculated on the following basis:-

| | |
|---|---|
| Plant and equipment, erected and including engineering | £1,100,000 |
| Buildings | 95,000 |
| Papyrus collection and transport equipment | 70,000 |
| Total | £1,265,000 |

13. Interest is calculated on the following basis:-

| | |
|---|---|
| Item 12, (above) | £1,265,000 |
| Site development | 25,000 |
| | £1,290,000 |
| Working capital (Part VIII) | 107,300 |
| Total | £1,397,300 |

14 - 23, inclusive. As Table 28.

It will be seen that the most profitable manufacture which can be envisaged for this mill (Table 28) involves a loss of some £37,000 per annum if a new mill is to be built. As there is in prospect insufficient demand for this product to absorb the capacity of the factory, then some wrappings and flutings would also have to be made. This would involve a much greater loss than the £22,400 per annum shown by Table 27. At present therefore, even a small new mill seems economically non-viable.

Table 30

HYPOTHETICAL PRODUCTION COST FOR THE MANUFACTURE OF 25,600 TONS PER ANNUM OF MEDIUM GRADE WRITINGS AND PRINTINGS

| Item | | Quantity (tons) | Unit Price | Cost approx. per annum (£) |
|---|---|---|---|---|
| 1. | Papyrus | T.212,920 | £1.30 | 277,000 |
| 2. | Bamboo | T. 24,000 | £6.05 | 145,000 |
| 3. | Caustic soda | T. 2,400 | £45.00 | 108,000 |
| 4. | Chlorine | T. 2,000 | £48.00 | 96,000 |
| 5. | Chemicals | T. 1,400 | £30.00 | 42,000 |
| 6. | Fuel oil | T. 30,000 | £15.00 | 450,000 |
| 7. | Labour | - | - | 164,000 |
| 8. | Management, etc. | - | - | 25,000 |
| 9. | Maintenance materials | | | 35,000 |
| 10. | Standing charges | | | 30,000 |
| 11. | Depreciation | £12 million | 7.0% | 840,000 |
| 12. | Interest | £13 million | 5.0% | 650,000 |
| 13. | Total | | | 2,862,000 |
| 14. | Substandard paper | T. 2,560 | £86.50 | 221,000 |
| 15. | Cost per annum | | | 2,641,000 |
| 16. | Cost per ton saleable paper (dry basis) | | | £103.16 |
| 17. | Cost per ton saleable paper (air dry) | | | £95.93 |
| 18. | Packing and freight (Malakal-Khartoum) | | | £6.00 |
| 19. | Cost delivered Khartoum | | | £101.93 |
| 20. | Average selling price per ton | | | £115.00 |
| 21. | Profit per ton | | | £13.07 |
| 22. | Profit per annum | | | £33,500 |

Notes.

1. As Table 27.

2. As Table 27.

3. As shown in Part V, the only practicable way of obtaining chlorine in quantity in the Upper Nile Province is to make it there by electrolysis from sea salt. This produces caustic soda also, though at a cost less than that of the imported product.

Since there is no other local outlet for the caustic soda, the prices of Part V for the electrolytic products are used.

If it was necessary to instal a soda recovery plant to purify the effluent, then limestone (from El Jebelein) and soda ash (from Magadi) would be used instead of caustic soda (see Part V). This operation would also provide heat for process work. The combined costs of caustic soda and chlorine should therefore, in these circumstances, be rather less than those given above. However, it is unlikely that the difference would affect the conclusions reached.

4. See (3).

5. As Table 27.

6. For a mill of this kind a steam boiler plant with turbine and generator would be installed (Part V). The fuel oil requirements are based on this assumption.

7 to 10 (inclusive). Based on Table 27.

11. Based on current capital costs for this type of mill, with one large general-purpose machine. Otherwise as Table 27.

12. See (11).

14. As Table 27.

18. Freight charges from Khartoum to Malakal should be less than those of Table 27 because of the quantities involved. It is assumed that they would be partly balanced by the extra packing costs necessary for the better grades of paper.

20. Based on information given in Part III.

Conclusions from Part IX.

The following general conclusions may be drawn from Part IX.

(1) A mill at Malakal making 6,400 tons per annum of medium grade wrapping and fluting papers from local papyrus and bamboo, could just about break even if the plant from the Aroma factory is used for the purpose at its present valuation. The key figure is the delivered cost of the papyrus (about 16% of the production cost), and this is the result of a number of factors which it has been possible to evaluate only approximately.

One ton of paper requires approximately 10 tons of green papyrus; any inaccuracy in the calculated delivered cost of green papyrus is multiplied 10-times in the cost of the final paper. Thus, if the delivered cost of green papyrus is, say, £1.50 instead of £1.30 per ton (as used above), then the price of the final paper is increased by approximately £1.56 per ton. This, of course, could equally operate in the reverse sense, i.e., if the delivered cost of the papyrus is less than £1.30 per ton. In this connection it is relevant to point out that £0.25 per ton has been added to the calculated delivered cost of the green papyrus (see Part IV). The position therefore, must be regarded as very precarious economically (Table 27).

(2) Under precisely the same conditions, such a mill could make only white-lined boxboard (as for shoe boxes) at a profit of about £32,000 per annum (Table 28). The same

arguments as to the effect of the price of papyrus apply here.

(3) It is estimated that in 1973 the Sudan markets should be able to absorb the output of a mill making 50% of each of the above two types of products. In this event, the annual profit would be about £4,800; subject again to the above provisos. This is the only real present solution to the problem of a paper industry for the Upper Nile Province, and it is borderline and very precarious.

This course would involve importing about 850 tons of wood pulp per annum, costing foreign currency amounting to about £60,000 (see Table 28).

(4) The capital cost of new plant and equipment for this type of mill is such that a mill operating under the conditions of (3) above would run at a loss of about £37,000 per annum (Table 29). Such a course would not only leave the Aroma factory problem unsolved but would accentuate it by introducing competition for the Aroma factory markets.

(5) A new general-purpose mill making 25,600 tons per annum of medium-grade writings and printings is likely to be a profitable proposition. However, the profit is likely to be only of the same order as that achieved under the conditions of Table 28, i.e., manufacture of boxboard with Aroma equipment.

This however, is hypothetical because the estimated consumption of such papers in the Sudan for 1973 is only about 7,500 tons per annum. It would be necessary to make many lower grade and less profitable types of paper to keep the tonnage up to the capacity of the mill. The capital cost of such a mill could well be in the region of £13 million.

# PART X

## RECOMMENDATIONS

It is evident from the profitability studies made in Part IX that if profitability is the only or main consideration, then the whole idea of a pulp or paper mill in the Upper Nile Province, using papyrus or any other local fibre, should be completely abandoned. The reasons for this are:-

(a) The unfavourable geographical situation with respect to Khartoum, in view of existing transport conditions.

(b) The low consumption of paper in the Sudan and the apparently, slow rate of increase of such consumption, neither of which justifies putting up a mill of sufficient size to operate economically.

(c) The high cost of collecting the fibrous raw material especially, and of bringing fuel and chemicals to the site.

(d) The fact that the proposed mill would operate in competition with the Aroma Cardboard Factory.

The social implications of a paper making industry in the Upper Nile Province are fully appreciated, and it is realised that the arguments in favour of the industry are very strong from this point of view. Every effort has therefore, been made in this Study to find a means of enabling such a step to be taken without incurring too much financial risk. In view of this, the following possible Recommendations are made:-

(1) The whole plant and equipment at present installed at the Aroma Cardboard Factory should be dismantled, taken to

Malakal, and re-erected, together with the improvements suggested in the Study on the Aroma factory dated January 1968; and with certain additional improvements suggested in this present Study.

This without doubt is the least expensive way of setting up a paper industry, although it is far from ideal from many technical and economic points of view. However, it should be capable of providing employment in the neighbourhood, and of rendering the Sudan to some extent independent of imported papers of certain types with a consequent saving of foreign currency. It is appreciated that this recommendation accentuates the problem at Aroma. However, nothing material has been done at Aroma during the last year, and although some slight improvements have been made, the overall position is unaltered; unless the suggestions made in the January, 1968 Study are implemented, the mill will continue to lose money indefinitely and heavily.

It is most important to realise that there is no room in the Sudan for two mills (as at Aroma and at Malakal) making the same types of product. If one has to make the difficult choice between one or the other, then perhaps there is justification for building the mill at Malakal, where there is ample raw material, since lack of this is the main cause of the failure of the Aroma factory.

Quite apart from the question of cost however, there are the social and political implications of closing down the Aroma factory, since this also provides local employment. However, it may be thought that the social problems of the Upper Nile Province are of greater importance than those of Aroma; this certainly is not a matter on which this Report should express an opinion, apart from it pointing out that (bearing in mind the hand collection of the papyrus) a mill at Malakal will give employment to a larger number of individuals than that at Aroma.

2. It is possible that the above recommendation does not find favour, and that it is preferred to build a new mill at Malakal and to endeavour to put the Aroma factory on a profitable basis either by the methods suggested in the January, 1968 Study, or in some other way. In this event it may be that the only alternative which would be considered is to build the mill at Malakal to make the papers as described, but using new plant and machinery. In this case it could not even make the more profitable white-lined boxboard economically (Table 29), and it would be in competition with Aroma for the rest of its production. The additional capital cost, and the interest and depreciation charges thereon, would undoubtedly involve the mill in a fairly substantial loss (see Part IX), at any rate in the initial years. One would in fact, be gambling with the possibility of the paper and board consumption of the Sudan increasing much more rapidly than the data given in this Study seem to indicate. A recommendation of this nature therefore, cannot be made.

3. If any course involving the use of papyrus is decided upon, then a detailed study should be made of factors such as its botany, ecology, pulping behaviour and properties, storage behaviour, harvesting methods, transport costs, etc. The data given in this Study are based on general experience but they require to be evaluated more precisely since the delivered cost of the papyrus is a key factor in the economics of its use. It should again be emphasised that papyrus is not (nor has it been) used as yet anywhere in the world for paper making on the large scale. There is therefore, no precedent to draw on for experience.

4. Taking the more distant view, the time will undoubtedly come when the consumption of papers and boards of all kinds in the Sudan will be sufficient to support a general-purpose mill making bleached grades of paper, which sell at a higher price and have a higher margin of profit than the grades now envisaged. However, in view of the geographical position of Malakal and in particular, of the expense of conveying the necessary chemicals to the factory, such a mill would have to be completely self-contained with an electrolytic plant, bleaching plant, means of burning lime, power house, soda recovery plant, etc. This would mean a considerably greater capital cost, which could only be justified by a correspondingly large output. The hypothetical profitability calculation given in Table 30 in Part IX, shows that a mill making 25,600 tons per annum and requiring a total capital of about £13,000,000, could operate

profitably under present price conditions. However, it is unlikely to be more profitable than the manufacture of lined boxboard alone using the Aroma equipment at Malakal.

If therefore, social and allied considerations are not regarded as more important than economic viability, the recommendation now made is that the whole question is deferred until such time as the consumption of paper of all kinds would justify re-opening the matter on the above basis. This would appear to be in at least 8 years hence, at the present rate of increase in paper consumption.

5. The writer has now made two studies in Sudan, one dealing with an existing factory and recommendations to re-establish it on a profitable basis (Aroma); and the other dealing with a project in a particular part of the country and mainly with a particular type of raw material (Malakal). It has become apparent from these studies that neither Aroma nor Malakal is the best place for a paper mill of any size or type in the Sudan, in the immediate future; and that the fibrous materials so far involved namely, cotton stalks, castor plant, papyrus and cultivated bamboo, are either not the most suitable and certainly not the most economic fibrous material which is likely to be available in the country.

Far more promising results might be obtained by considering the possibility of utilising the bagasse from the present and proposed sugar mills in the Khashm El Girba area. This of course, was outside the terms of reference of the two studies already made. However, it would appear from preliminary discussions, that a mill in this area would be favourably situated on a railway between Port Sudan and Khartoum; it would have an adequate water supply and effluent disposal facilities; and if experience with bagasse elsewhere in the world is any criterion, it should be possible to utilise or create surplus bagasse for the purpose from the local sugar mills. Khashm El Girba is no great distance from Aroma, and a large efficient mill at the former place might be able to produce pulp of quality and price suitable for the Aroma factory, thereby solving the fibrous raw materials problem and many of the operational difficulties. Aroma could then be saved by the scheme suggested in the 1967 Study, and the new mill could make non-competing grades.

It would seem that if there is any solution to the problem of starting a pulp and paper industry in the Sudan, as rapidly and as profitably as possible, then it should be sought in this way and not in the Aroma or Malakal schemes.

# PART XI

## SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

This Part of the Report is summarised in such a way that it can be read independently of the more technical and detailed matters dealt with in Parts II to X, inclusive. It is therefore, intended primarily for those who desire to know of the general conclusions reached and the recommendations made, without the need to study the technical and other arguments on which they are based. It can therefore, be read quite independently of the remainder of the Report.

### Conclusions

1. The terms of reference of this Study are:-

"To study the feasibility of the manufacture of pulp and/or paper in the Upper Nile Province with special reference to the requirements of the Sudan; and to indicate likely alternative possibilties for such manufactures."

2. The Study is restricted to the Upper Nile Province because it is felt that the establishment of an industry in that area will assist the Province and indirectly, the nation, both economically and socially; thereby bringing to an end some of the difficulties which have arisen in that Province within recent years and providing conditions of greater stability.

3. The whole question of establishing a paper industry in the Upper Nile Province is, of course, bound up closely with that of a paper industry for the Sudan as a whole. This aspect of the question is particularly relevant because the total paper

consumption of the Sudan is by world-wide standards, relatively small; and there is not room for more than one factory making the same type of paper. It should be explained that one particular type of paper mill can make only a relatively restricted range of papers. Thus, papers and boards cannot normally be made on the same machine, and wrappings and white papers are also to a great extent incompatible in the same factory.

4. In the past there have been many investigations into the possibility of starting a paper industry in the Upper Nile Province, with special reference to the use of papyrus as a possible raw material. Some of these projects may be described as trivial, but a few of those carried out involved a good deal of work, and they merit serious consideration. In all cases, the indications found were highly favourable to the project, but in no instance has the matter proceeded further than the project stage. These investigations were carried out by or at the instigation of commercial enterprises, and it was therefore, desired to ascertain from a completely independent point of view how valid such a project might be. This past work is summarised in the history of the Study given in Part II.

5. As part of the background of the Study it is also important to realise that 3 paper or board mills exist in Sudan at the present. They are as follows:-

(a) <u>The Aroma Cardboard Factory</u>.

A Study was made of this for the United Nations, at the request of the Sudan Government in December, 1967, and the resulting Report (January, 1968) is the work of the present writer. This factory was built in 1965 to make 4,000 tons per annum of fairly heavy cardboard, using mainly cotton stalks. It has unfortunately, not been a success, and is making heavy financial losses. This arises from several factors namely the inefficiency of the equipment, the lack of a suitable raw material, and general operating considerations. Of these, the most important is probably the lack of raw material because the local cultivation of cotton stalks, which were intended to supply the mill, has been stopped. Experiments with alternatives are in hand, but there is no indication that a complete solution to the problem is anywhere near in sight.

In his 1968 Report the writer made a number of recommendations, both of a short-term and long-term nature. The former were intended to minimise the loss as the factory is running at present. The long-term recommendations involved the rearrangement, alteration and supplementing of the machinery to enable it to produce a wider range of products than at present. Thus, instead of, or in addition to, producing the cardboard, the mill would produce medium grade wrapping papers, fluting paper, (which is the basis of the corrugated material inside cardboard cartons), and white-lined boxboard (as used for shoe boxes). If the recommendations are carried out, it is believed that the mill could produce these in sufficient quality and quantity to show a reasonable profit. Moreover, the requirements of the Sudan at the present time, are sufficient to absorb all of the mill's production of these particular grades. However, this scheme depended basically on finding sufficient suitable raw material. Cotton stalks could be used but were far from ideal, and a small proportion of wood pulp would have to be imported for certain of the grades of paper.

The only alternative to the above recommendations would be to close the mill entirely. It is understood that a Committee has been set-up to consider these recommendations and to decide on the future of the mill, but that it has not yet arrived at its final conclusions.

(b) The National Paper Industries, Ltd.

This is a paper mill built in Khartoum from used machinery and plant, in 1963. Owing to an accident with the steam boiler it was shut down in 1967, and an Appendix to the Aroma Factory Report mentioned above, deals with the present and future possible situation of the National Paper Industries factory as the position existed in December, 1967.

The purpose of this factory was to make mainly medium grade wrapping papers, the principal raw material being waste papers although some mechanical wood pulp was also imported for the purpose. The capacity is about 1,500 tons per annum, but only about 500 tons were made over a 6-monthly period. The present writer's recommendations in this instance were directed to improve the efficiency of running the mill, together with certain alterations and improvements in the machinery where this was in such a condition or so out-of-date as to be virtually unusable.

It was shown that under these conditions and assuming that the mill produced approximately 1,500 tons per annum, from a mixture of waste paper and mechanical wood pulp in equal proportions, then the mill should make a small profit. By spending £30,000 on new equipment and making 3,000 tons per annum of such papers, a fairly substantial profit should be realised. However, it was pointed out that if this was done, the Aroma factory in its reorganised condition would be competing with National Paper Industries, Ltd. for a very restricted market of paper and that at present there was hardly room for both of them.

(c) Blue Nile Packaging Co., Ltd.

This is a company in Khartoum making cartons on a fairly large scale. They make paper or board on a cylinder mould machine in a rather primitive way, using the mill's own waste paper. The product is sold and not used by the company itself, and in appearance it compares favourably with the Aroma product. This factory therefore, is to some extent, a competitor for the same limited field of manufactured products.

It will therefore, be realised that before any consideration is given to a factory in the Upper Nile Province, there already exist 3 other factories making some of the products which might be made in a factory in the Upper Nile. What is more, none of these operates very efficiently on its own account, so that only a fraction of the present home market is at present being satisfied. If, however, each operated efficiently and up to capacity, then the present home market would not absorb the products of all 3 factories. The Aroma factory in its new form and National Paper Industries, Ltd. would either have to operate at low capacity and therefore lose money; or else close down.

6. The above provides the background to the present Study in the Upper Nile Province. This was supplemented by a market study in which all the factors influencing the present demand for paper and board were closely examined, and an attempt was made to project them into future years; for this purpose it was assumed that the first complete year of operation of any Upper Nile project would be 1973. To this end the statistics and customs records were analysed, and visits were paid to all the principal users and importers of paper in order to obtain their views on present and future consumption, and to obtain some indication of current prices.

Several indications pointed to the general conclusion that the overall demand in the Sudan for the paper products in question would be approximately 2.5-times that of 1968 by the year 1973. The data on which this conclusion is based are not too reliable, being inconsistent as from one year to the other, but more than one indication points in this direction and it is believed that this is certainly not an over-estimate. Thus, in the event of a local industry starting up which has a high paper requirement of a particular kind, then this figure could be very much more increased in any one respect. However, it is the figure used for the present Study. The data obtained may be summarised as follows:-

| | |
|---|---|
| Estimated consumption of paper of all kinds for 1968 (excluding newsprint and specialities) | 11,500 tons |
| Total value of above | £826,000 |
| Present total consumption of grades which could be made in a completely versatile factory in the Upper Nile Province assuming papyrus as the raw material | 9,660 tons |
| Estimated demand for these papers in 1973 | 24,160 tons |
| Present demand for papers which could be made in a small and comparatively inexpensive mill at the present time, i.e., mainly unbleached papers | 2,560 tons |
| Estimated demand of above in 1973 | 6,400 tons |

The important feature of the above figures is the fact that the total 1973 requirements of all papers which could possibly be made in the Sudan from local fibrous raw materials, in one factory, by one paper machine, is likely to be only about 24,000 tons. The cost of such a versatile factory would be considerable, and the depreciation, interest charges, and other overheads would be such that a total production of approaching 26,000 tons per annum would be required in order to make the scheme safely viable. However, one could not be sure that this production could be absorbed by the Sudan market.

It was therefore, necessary to turn attention to such papers as could be made in a much cheaper type of mill, i.e., a mill which does not produce white papers and therefore, does not require the expensive bleaching, soda recovery and chemical producing plant that is necessary for the more versatile type of mill. The 1973 estimated requirement of such papers in the Sudan is approximately 6,400 tons, and the present Study is therefore, based primarily on an output of this nature. The production would be made up as set out in the table below; also given in the table are the present average selling prices of the papers, delivered Khartoum duty paid. These are the averages of the prices as ascertained from the present users and importers of these papers, and they may be regarded as reasonably authentic.

| Grade of Paper | Annual 1973 Output (tons p.a.) | Price £ per ton delivered Khartoum |
|---|---|---|
| Medium grade wrappings and bag papers | 1,600 | £71 per ton |
| Fluting medium | 1,600 | £62 per ton |
| White-lined boxboard | 3,200 | £85 per ton |
| Total (average price) | 6,400 | £75.8 per ton |

The above data have therefore, been taken as the basis of this Study, and in particular of the production cost calculations of Part IX.

7. Journeys were made by road, water and air, to cover the region of the Upper Nile Province between Renk in the north, Bentiu on the Bahr el Ghazal in the west, and the lower reaches of the Bahr el Jebel, and the River Sobat to the south and east, respectively. The objectives were to ascertain what fibrous raw materials were available in this area, which might be suitable for the purpose; and to select a suitable site for the factory.

8. On the raw materials question, consideration was given to papyrus, bamboo, Vossia (hippo grass), and reeds (Phragmites communis). The growth of the papyrus was studied along the rivers between Malakal and Bentiu, and on the Bahr el Jebel, Bahr el Zaraf and River Sobat. Particular attention was given to the stretch of river between Tonga and Lake No, including part of Lake No and part of the lower reaches of the Bahr el Jebel. This is the region of maximum growth, density, height and widest area in the region studied. The moisture content of the papyrus as cut in the green state, was estimated and was found to be approximately 77%.

It is known from the writer's experience with papyrus in other parts of Africa and from laboratory experiments carried out in his and other laboratories, that an average yield of 45 to 50% might be expected from dry papyrus in the preparation of papers of the types that were to be made. On this basis it appeared that, in order to make one ton of paper, it would be necessary to collect approximately 10 tons of green papyrus. Thus, a mill making 6,400 tons of paper per annum would make approximately 21 tons per 24-hour day, and if this consisted entirely of papyrus it would be necessary to collect approximately 210 tons of green papyrus per day. Actually, as indicated below, it is anticipated that a certain amount of bamboo could also be used, in which case only 80% of the daily requirement would be papyrus, i.e., 168 tons of green papyrus would be required per day. The survey indicated that there should be no difficulty in collecting this quantity in the stretch of river between Tonga and Lake No and indeed, the existing village of Wath Wang Kech appeared to be a natural centre for the harvesting operation.

9. Consideration was next given to the method of harvesting. The simplest method would be to use manual labour. From local enquiries, it was estimated that 336 men would be required to harvest the quantity concerned; with approximately another 30 men on land to receive the cut papyrus and to stack it or bale it if necessary, ready for despatch to the mill site.

Rough estimates were also made of the density of growth of the papyrus. From these it was deduced that the requisite annual quantity could probably be obtained within a distance of 10 km. from Wath Wang Kech. This is on the basis of 2 crops per annum. The cost of harvesting by hand was estimated at £0.50 per ton of green papyrus, it being assumed that the labourers would provide their own canoe transport.

The alternative method of harvesting would be by machine, and in this case, the experience of the writer and others in Uganda and other parts of the world where reeds are harvested from water, was used. At least 2 machines have been built for this or similar purposes. Although neither has actually operated on papyrus on a large scale, in one case the machine was designed after experiments with papyrus growing in water as distinct from swamp. Such a machine, with the collecting facilities of a barge, could be operated by about 5 men, and it would cut the mill's daily requirements in a few hours. The capital cost of the machinery would, of course, be involved, but the labour cost would be much less. The comparison is summarised below (per ton of green papyrus):-

| Method of Cutting | Capital Cost | Labour required | Cost Landed |
|---|---|---|---|
| Manual labour | - | 336 men | £0.50 |
| Machine | £10,000 | 3-5 men | £0.06 |

In view of the desirability of creating employment, and the uncertainty attached to the use of a machine, the former figure is used for the calculations of the present Study, although it is the higher.

10. The problem of bringing the green papyrus from Wath Wang Kech to the mill site was then studied, and Malakal (or a site near that town) was taken as the location for this purpose. As indicated above, this involves transportation of approximately 170 tons per day of green papyrus. This is a bulky material consisting mainly of water, and the space it occupies it out of proportion with its weight compared with the goods normally carried by the Nile traffic. Consideration was given to drying the material so as to reduce its water content and lower the cost weight to be carried; however, this would not affect the bulk to any great extent. Consideration was also given to baling, but this is likely to be costly at the present stage and would certainly give rise to practical problems, not the least of which would be attack by termites. In consequence

of the above, it had to be accepted that the cost of transport would involve heavy capital expenditure in barges and tugs.

The system envisaged was a shuttle service of one tug and three 140-ton (nominal) barges each carrying 60 tons of green papyrus. There would be 2 units of this nature, and during every 48 hours one would load, travel to Malakal, unload and return to Wath Wang Kech, the actual journeying time each way being 12 hours. It is assumed that travel downstream loaded would take approximately the same time as travel upstream unloaded. Helpful advice as to the cost of building and running such river traffic was obtained from the Egyptian Irrigation Department at Shagara, Khartoum. This method of transport would involve a capital expenditure of approximately £55,000 and, after allowing for depreciation, interest and maintenance at the rates used at Shagara, the cost of the green papyrus delivered at Malakal would be made up as follows:-

| | |
|---|---|
| Harvesting and collection | £0.50 p r ton |
| Transport to Malakal | £0.55 per ton |
| Total | £1.05 per ton |

To cover contingencies, a figure of £1.30 per ton is used in the calculations of this Study.

11. In the course of one of the river journeys, stands of bamboo were noted at Doleib Hill on the Sobat River. Further investigations showed that these were cultivated by the local farmers, and that they were healthy, and apparently of the same species that grow in India where they have proved

excellent paper making material. Bamboo gives a stronger fibre than papyrus. The use of a proportion of it with the papyrus would enable the range of papers made to be extended to include some of the stronger grades of wrappings (although not the strongest wrappings or papers used for kraft cement sacks). Fortunately, a good deal is known of the technology of pulping and using bamboo, although nothing is known of the economics of producing bamboo on any scale in Doleib Hill.

The writer was therefore, compelled to fall back on his experience with cultivated bamboo as a potential raw material for paper gained in Nepal, where the problem was studied in some detail and where the general conditions are not greatly dissimilar from those of Doleib Hill. On applying the Nepal calculations and making suitable adjustments for conditions at Doleib Hill, the following estimates were arrived at. In order to produce sufficient bamboo to provide 20% of the pulp required to make the mill's production of 6,400 tons per annum, it would be necessary to cultivate 335 feddans (138 hectares) of land with bamboo. If one assumes a 6-year rotation of the crop (and this is probably high for Doleib Hill), then the cost of cutting the bamboo and delivering it by road to Malakal would be £6.05 per ton of green bamboo; and approximately 7 men would be employed in the cultivation work.

The present bamboo plantations at Doleib Hill are, of course, privately owned; and the bamboo is sold by the stick at a comparatively high price even so far distant as Khartoum.

However, it is assumed that in the case of the bulk growing of bamboo for paper making purposes, the plantations and operations would be owned by the Government or the mill, so that there would be no question of a middleman's profit. One great advantage of this use of bamboo is the fact that Doleib Hill is only 20 km. from Malakal by road, whereas the river journey is almost 50 km. Transport by road is obviously much more convenient that river transport over such a short distance. However, the present road is a dry-season road only, although it is understood that it is intended to make it an all-weather road in the near future. This is essential if the bamboo is to be carried regularly from Doleib Hill to Malakal in this way.

12. Consideration was also given briefly to the use of hippo grass (Vossia) and Phragmites reeds as possible raw materials. Experimental work has been carried out on each of these, with promising results, especially in the latter case. However, it was felt that the amounts available and the locations in which they grow make them less desirable than papyrus and bamboo, and their use therefore, was not followed up.

13. The question of site was next considered. Malakal is an obvious centre for an operation of this kind. It is the provincial capital, and has the accompanying amenities and facilities. Although it is some distance from the papyrus growing area, it is nevertheless between them and Khartoum and this is important from a geographical point of view. It soon became apparent that geography and communications are major

factors in the problem raised by this Study. On the assumption that the site is at Malakal, the following table summarises the transport problem. This shows the approximate quantities per day in tons, to be transported between Wath Wang Kech, Malakal and Khartoum, and Port Sudan in the case of imported materials. The approximate distances involved and nature of transport are also given.

| Journey | Material | Quantity | Distance (km.) | Method of Transport |
|---|---|---|---|---|
| Wath Wang Kech to Malakal | green papyrus | 170 | 130 | river |
| Doleib Hill to Malakal | green papyrus | 18 | 20 | road |
| Port Sudan to Malakal | caustic soda and chemicals | 4 | 1,660 | rail and river |
| Port Sudan to Malakal | fuel oil | 23 | 1,660 | rail and river |
| Port Sudan to Malakal | wood pulp | 5 | 1,660 | rail and river |
| Malakal to Khartoum | finished paper | 21 | 1,450 | river and rail |

It will be seen from the above table that a considerable proportion of the delivered cost of the product at Khartoum is made up of the transport costs of the materials used. Such costs are increased by the fact that goods passing from the Upper Nile Province to Khartoum or Port Sudan, have to be transhipped between river and railway, or vice versa, involving extra cost, and, in the case of paper, probably some damage.

14. Consideration was given to the manufacture in

the Sudan of the chemicals required. It appeared at first sight that the limestone deposits at El Jebelein between Kosti and Renk, offered the possibility for making cheap caustic soda by using lime in conjunction with cheap soda ash from Magadi in Kenya. However, calculations showed that again owing to transport problems and costs, it would be cheaper to import the caustic soda ready to use, despite the high cost of bringing it via Port Sudan to Malakal.

Similarly the question of the manufacture of caustic soda and chlorine by the electrolysis of salt was considered. An approximate calculation based on local conditions showed that the mill would have to use considerable quantities of these in order that this process could operate economically. Such a scheme may prove useful as a future development, but it is certainly not appropriate at the present time.

15. As regards the provision of fuel and electrical power for a factory at Malakal, there is no alternative but to import oil fuels which would be used to raise steam required, and also to generate the electrical power. There is no local grid electricity available, or likely to be in the near future. The steam and power requirements of a small factory are relatively large in proportion to its production cost, and this effect is enhanced in the present instance by the cost of transporting the fuel oils to Malakal. It is estimated that the overall amounts of liquid fuels required to produce these facilities is about 20 tons per day.

16 Journeys were made with the object of actually pinpointing likely sites. Five such possibilities were examined around Malakal itself; and a journey was also made to Renk for the same purpose. The position favoured is in Malakal, i.e., at the village of Bum (see Figures 2 and 7, Site S1) to the south of the town on the right bank of the river opposite a small peninsular of reeds which starts an arm of the river. There is adequate ground here beyond flood level, and ample room for expansion. The site is on the road to Malakal some 3 km. distance, and 20 km. from Doleib Hill, the source of the bamboo. Facilities for wharfage would have to be installed, and it may be necessary to dredge the river at this point, and possibly cut away the tip of the peninsular opposite in order to give adequate room for the river traffic to manoeuvre. This applies particularly when papyrus is being brought in from the south each day.

An alternative and less favoured site is to the north of Malakal; see map Figure 7, site S2. This is near the airport but has the disadvantage that the high, flood-free ground is separated from the river by swamp which would have to be bridged, built over or dredged away. It is also further from the urban area of Malakal than Bum. Also, it is downstream from Malakal, and the papyrus barge traffic might interfere with the normal traffic on the river passing between Kosti and Malakal.

17. It is estimated that the total labour requirements of the mill would be made up approximately as follows:-

| | |
|---|---|
| Management | 7 |
| Mill workers | 145 |
| Collecting papyrus by hand | 336 |
| mechanically | (5) |
| Storage and handling papyrus | 30 |
| River transport of papyrus | 12 |
| Bamboo production and cutting | 7 |
| Total | 537 |

Approximately 450 of the above would be unskilled or semi-skilled local people. Most of the remainder would be semi-skilled and skilled men specially trained for the work, or brought from other parts of Sudan or even from abroad. The senior management-staff would all have to be brought from elsewhere in the first instance, and understudied by local men of suitable calibre.

The cost of the mill labour was evaluated using the Government scheme as a basis, and assuming rates comparable with those of Khartoum for the semi-skilled and skilled workers. Fortunately, the suggested site at Bum is very near a thickly urban area of Malakal, and there should be adequate labour with existing housing within almost walking distance.

18. The total cost of the project was next considered. Assuming the mill is to be built new at the Malakal site, then the estimated approximate cost, excluding working capital, would be about £1. million. It was apparent

from a rough production cost calculation (Table 29) that the depreciation and interest charges on this would be such as to render the mill wholly unprofitable; the estimated loss is about £37,000 per annum.

19. In searching for a way to make the project viable, consideration was therefore given to the position at the Aroma factory, which has equipment which can be converted to a useful purpose but which has unsuitable and inadequate fibrous raw materials. The alterations recommended in 1968 to put the Aroma factory on a profitable basis involved dismantling and re-erection of the machinery, and supplementing it in some respects and improving it in others. If this machinery is re-erected at the Malakal site instead of at Aroma, then the raw material problem would be solved and the capital cost of the Malakal factory would be reduced considerably if the Aroma plant is taken at its 1968 valuation.

Such a scheme would, of course, cost more than the recommendations made for Aroma. Thus, the Malakal site would have to be developed, buildings would have to be erected, and certain items of equipment which were built-in at Aroma and could not be removed, would have to be constructed at Malakal. There are also the social and non-financial considerations which may arise from shutting the Aroma factory and transferring it to Malakal in this way. However, this appears to be the only possibility which exists for the establishment of a paper factory in the Upper Nile Province at the present time.

If such a suggestion is adopted then the total capital required for the project would be made up as follows:-

| | |
|---|---|
| Plant, equipment and buildings | £642,500 |
| Transfer charges | 22,500 |
| Site preparation | 25,000 |
| | £690,000 |
| Interest during building | 34,500 |
| Working capital | 75,600 |
| Total capital requirement | £800,100 |

20. Production cost sheets could now be compiled demonstrating the profitability or otherwise of the various possibilities indicated above. These are as follows; they are based on the use of papyrus and bamboo with, in some instances, a small amount of imported wood pulp.

| | | |
|---|---|---|
| Table 27-28. | Manufacture of medium grade bag papers and wrappings and white-lined boxboard and flutings using Aroma plant. Profit per annum. | £5,000 |
| Table 29. | As above, but using new plant. Loss per annum. | £37,000 |
| Table 30. | Manufacture of 25,600 tons per annum of medium grade writings and printings using new plant. Profit per annum. | £34,000 |

Table 30 is hypothetical because the present Sudan market for these papers is far less than the 25,600 tons of production assumed. The present market would not justify the high capital cost involved in the manufacture of white papers from papyrus and bamboo.

21. It is evident from these figures that only one present possibility exists for the mill, and that this is very borderline in character. It also has to be realised that if this possibility is adopted then the Malakal mill will be making the same types of products as proposed for the Aroma factory in its new form, and that it will also be overlapping to some extent in this respect with National Paper Industries, Ltd. and the paper machine at Blue Nile Packaging Co., Ltd. Certainly there is likely to be no immediate future for the Aroma factory.

22. It has to be recognised that neither the present Upper Nile Province project nor any of the 3 existing paper or board mill operations in the Sudan, represents the correct approach to the initiation of a paper industry for the country. It is unfortunate that a thorough feasibility study of the whole of the resources of the country in relation to site, transport and the numerous other conditions involved was not made before these projects were started. Such a matter is outside the scope of the present Study. However, it has become apparent to the writer from two visits to the Sudan that potentially, the best site for a paper mill site in the Sudan (from both the present and long-range points of view), is in the Khashm el Girba region.

Here the problems of communication, transportation, power and water supply, and effluent disposal, are very much less; even more important is the proximity of one existing and one prospective new sugar mill producing bagasse, which is a recognised fibrous raw material for paper in many parts of the world. This unfortunately, would not solve the social and economic problems of the Upper Nile Province.

23. Recommendations are therefore made as follows:-

(a) Consideration should be given to the relative merits of the social and economic position of the Upper Nile Province on the one hand as against the highly borderline nature of the paper mill project for that region indicated by this Study. The implications, social and political, of closing the mill at Aroma will also have to be taken into account. Such a decision can of course, only be made by the Government.

If it is decided that the financial risk of the paper project is justified by the other considerations, then a mill on the lines set out in this Report is recommended in the first instance, with provision for enlarging it as the paper requirements of the Sudan increase.

(b) Steps should then be taken for investigating more fully the growth behaviour, pulping properties and handling properties of papyrus. Similar attention should be given without delay to cultivated bamboo, as a mature supply will be needed when the mill starts up.

(c) If the decision goes against the mill in the Upper

Nile Province, then it is suggested that the feasibility of a mill in the Khashm el Girba area be considered as a longer-term project. This would have as its object the initiation of a paper making complex serving the whole nation for all or most of its paper and board requirements. The future of the Aroma factory could also be considered in this new context. It would be more logical to make the whole of the requirements of the country in one unit in one area. However, if it is desired to keep the Aroma project in being, it may be possible to manufacture the pulp requirements of that mill at the Khashm el Girba factory and to send the pulp to Aroma. These are, of course, ideas which need to be worked out in detail on a quantitative cost basis; but they would appear to be more promising than any of the previous approaches to the problem.

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