AFRICAN DEVELOPMENT BANK

THE DEMOCRATIC REPUBLIC OF THE SUDAN
MINISTRY OF TRANSPORT
ROADS AND BRIDGES PUBLIC CORPORATION

FEASIBILITY AND PRELIMINARY ENGINEERING STUDY OF ROAD PROJECT EL OBEID-UM RUABA

FINAL REPORT

MARCH 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Democratic Republic of the Sudan and the African Development Bank, the Government of Japan decided to conduct a feasibility study on road construction between EL OBEID and UM RUABA in the Central Sudan and Japan International Cooperation Agency (JICA) carried out the study.

Noting the importance of this project which constitutes part of the east - west national trunk road of the Sudan and in view of it being the first case under the technical cooperation programme agreed upon between the African Development Bank and the Government of Japan, the Agency dispatched a preliminary survey team to the Sudan and the African Development Bank in November 1976 for planning and preparation of the study.

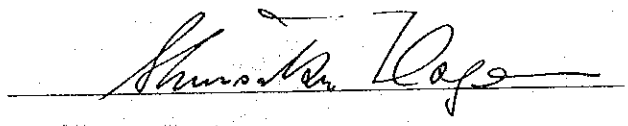
Following this, a supervisory group headed by Mr. Toshiyuki OHNO, Director of Road Planning, Kanto Regional Bureau, Ministry of Construction and a study team headed by Mr. Noritomo OKUDA executed the field investigation from March to June 1977.

After discussion on the Interim Report and later on the Draft Final Report by the Government of the Sudan, the African Development Bank and the study team, the Final Report has been completed for submission.

I sincerely hope that the report would contribute to the socio-economic development in the Sudan and at the same time serve for enhancement of the friendly relationship now existing among the Sudan, the African Development Bank and Japan.

Finally, I would like to take this opportunity to express my heartfelt appreciation to all the members who have participated in this study and to all the authorities which have facilitated the study.

March 1978



Shinsaku Hogen
President
Japan International
Cooperation Agency

March 20, 1978

Letter of Transmittal

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency
Japan

Under the contract between Japan International Cooperation Agency and Mitsui Consultants Co., the feasibility and preliminary engineering study of the road project, El Obeid-Um Ruaba, has been conducted. Submitted herewith is the final report of the above study for the road of 134 km in length situating in Northern Kordofan Province, the Democratic Republic of the Sudan.

The subject road consists part of a national truck road extending from east to west. El Obeid, from which the project road starts, has played an important role as a regional centre in economy and transport of the western part of the Sudan.

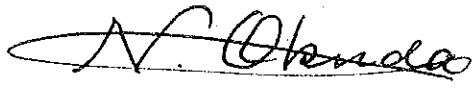
The purpose of the study was to prepare alternative plans with preliminary engineering, to conduct economic studies including benefit cost evaluation, and to present the best construction plan together with the project cost.

Field studies were conducted from March to June in the Sudan including aerial photo taking. The study continued at the home office of the consultants in Japan covering the analysis of data collected, preparation of engineered plans, economic evaluation, and the editing of reports. Assigned by the Sudanese government, four counterpart staffs were with the team, during the period of field study and three of them joined in the home work for two months as on-the-job training.

It is to be noted that there were a number of meeting held with attendants of the JICA staffs, supervisory committee members and the consultants, in which problems raised in the course of the study were discussed and advices were given to the study steam. Comments on Interim and Draft Final Reports, given by the Sudan and African Development Bank in November and February, were incorporated in the Final Report. The content of the report was agreed by the supervisory committee.

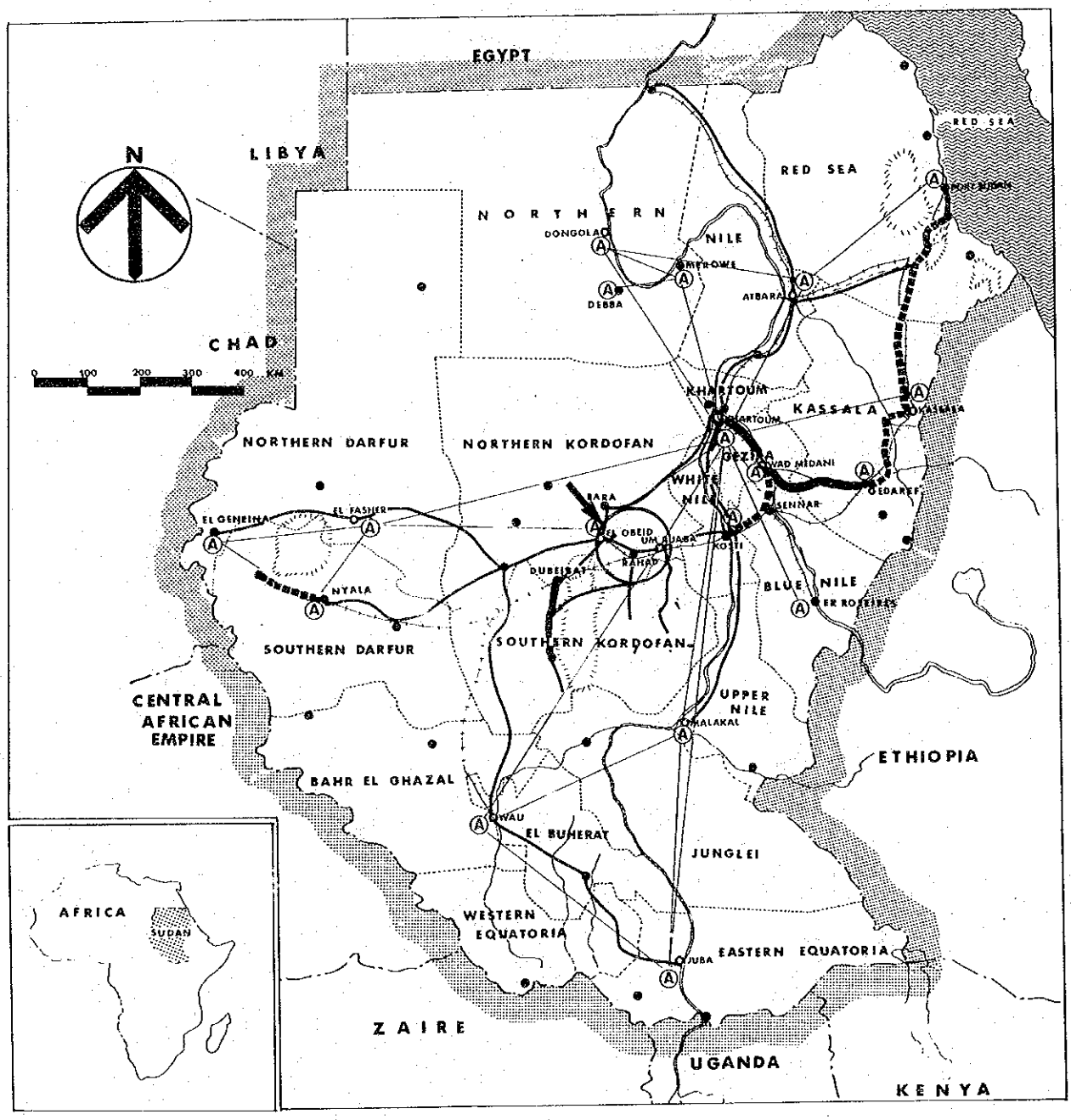
I would like to extend my full hearted appreciation to the people and the government staffs of the Sudan, specially of Roads and Bridges Public Corporation, and to the Ambassdor of Japan and his staffs in the Sudan. Without their assistance,

the team could not complete the study. Finally, I like to note my wish that the project be implemented immediately as recommended in the report.



Noritomo Okuda
Team Leader
Feasibility Study Team For
El Obeid-Um Ruaba Road Project

THE SUDAN



LEGEND

- PAVED ROADS
- UNDER CONSTRUCTING ROADS
- EARTH ROADS
- RAILWAYS
- AIRPORTS
- INTERNATIONAL BOUNDARY
- PROVINCIAL BOUNDARY
- MOUNTAINS
- PROJECT AREA

ABBREVIATION

1.	AASHTO	:	American Association of State Highway and Transportation Officials.
	ADB	:	African Development Bank
	ASTM	:	American Society of Testing and Materials
	JICA	:	Japan International Cooperation Agency
	MOC	:	Ministry of Construction of Japan
	RBPC	:	Roads and Bridges Public Corporation of the Sudan
	RRL	:	Road Research Laboratory
	UK	:	United Kingdom
	UN	:	United Nations
2.	AC	:	Asphalt Concrete
	DBST	:	Double Bituminous Surface Treatment
3.	ADT	:	Average Daily Traffic
	O-D, OD	:	Origin and Destination
4.	J.	:	Jebel (Mountain)
	K.	:	Khor (River, Stream, Watercourse)
5.	Max.	:	Maximum
	Min.	:	Minimum
6.	US$	:	United States Dollar
	LS	:	Sudanese Pound (LS 1.000 = US$2.52)
	PT	:	Piasta (Piasta 100 = LS 1.000)
	mm	:	Merrium. (mm 1,000 = LS 1.000)
7.	fed	:	Feddan (1 fed = 0.42 hectars, 100 fed = 0.42 km^2)
	K	:	Kantar (1 kantar = 45 kg)
8.	lb	:	Pound in Weight

SUMMARY AND RECOMMENDATIONS

SUMMARY AND RECOMMENDATIONS

1. Purpose

The Sudan, the largest country in African continent, has an urgent necessity to develop an efficient nation-wide transport network which will contribute to the social and economic growth of the country. The east to west trunk road of Kosti - El Obeid - El Fasher is one of the sections to be improved at an early stage. El Obeid is the regional centre of economy, administration and transportation in the western half of the Sudan with an urban population of 100,000. The project road starts from El Obeid and runs eastward to Um Ruaba in a sand dune savanna area. Existing conditions of the earth track are poor causing inconvenience to the people and high transport costs to the economy.

The purpose of this study is to explore the economic feasibility of the construction plan by means of a preliminary engineering study of the road. The best construction plan is to be developed by assessing alternative plans proposed in the course of the study.

2. Studies in the Field and Home Office

In accordance with the terms of reference, prepared jointly by Roads and Bridges Public Corporation (RBPC) of the Sudan, African Development Bank (ADB) and Japan International Cooperation Agency (JICA), engineering and economic studies in the field were carried out from March to June, 1977. Studies in the Sudan covered the fields of economies, traffic, inventories, soils and materials, surveying, cost information, etc.

The study team analysed the data collected after ruturning to the home office and has prepared an Interim Report in which Plan 2 was selected from other alternative plans after appraising engineering and economic studies. The first stage of the study, extending from the above inventory studies to the selection of the best route, was presented in the Interim Report. A meeting was held to discuss that report in mid-November at Khartoum with the attendance of RBPC, ADB and JICA members.

In general, the study presented in the Interim Report was accepted by RBPC and ADB, while some comments and advice were given to the study team. Revisions to the Interim Report were made and the second stage study was conducted and incorporated into the Draft Final Report. The optimum construction plan for the project road was proposed after studying minor alternatives on the best route such as plans for bypasses, staged constuction, pavement structures, etc. The Draft Final Report was presented to the RBPC of the Sudan and the African Development Bank in February 1978. Comments on the Draft Final Report were incorporated in this Final Report.

3. Construction Plan

The optimum construction plan proposed after the economic evaluation is summarized as follows. Construction work is divided into three sub-sections El Obeid - Nawa, Nawa - Semeih and Semeih - Um Ruaba.

3-1 Proposed Road

		Section I	Section II	Section III	TOTAL
Length (km) :	Main Road	46.00	40.50	46.95	133.45
	Access Road	-	1.53	1.04	2.57

Route Location : Section I,(El Obeid - Nawa:46.00km) following the existing route of the northern side of the railway.

Section II,(Nawa - Semeih:42.03km) following the existing route up to Rahad and running in sand dune areas.

Section III, (Semeih - Um Ruaba:47.99km) passing throug sand dune areas to the northern side of the railway. (detouring the flood plain of k. Abu Habl).

Design Speed : 100 km/hr for flat terrain and 80 km/hr for hilly terrain.

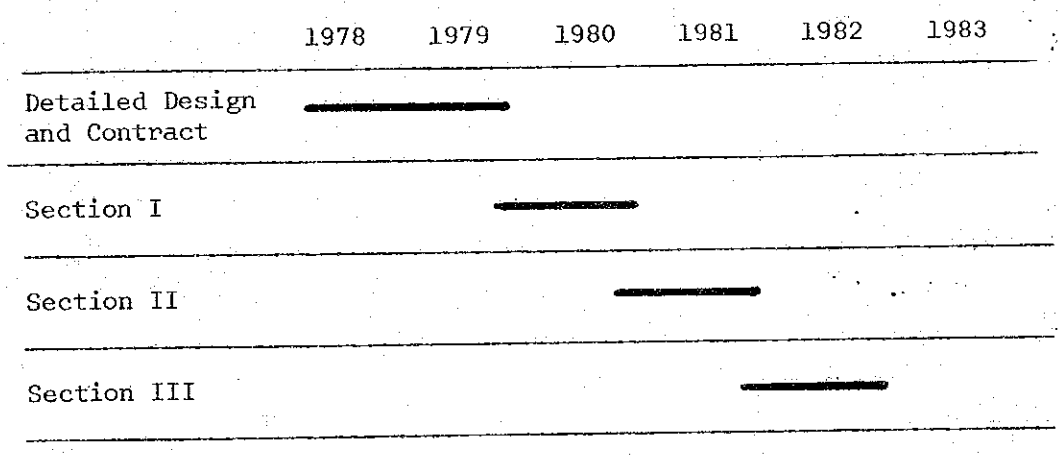
Alignment : Minimum horizontal curve R=1,000 m

Maximum longitudinal gradient 4.67%

Pavement : DBST on 6 m carriageway

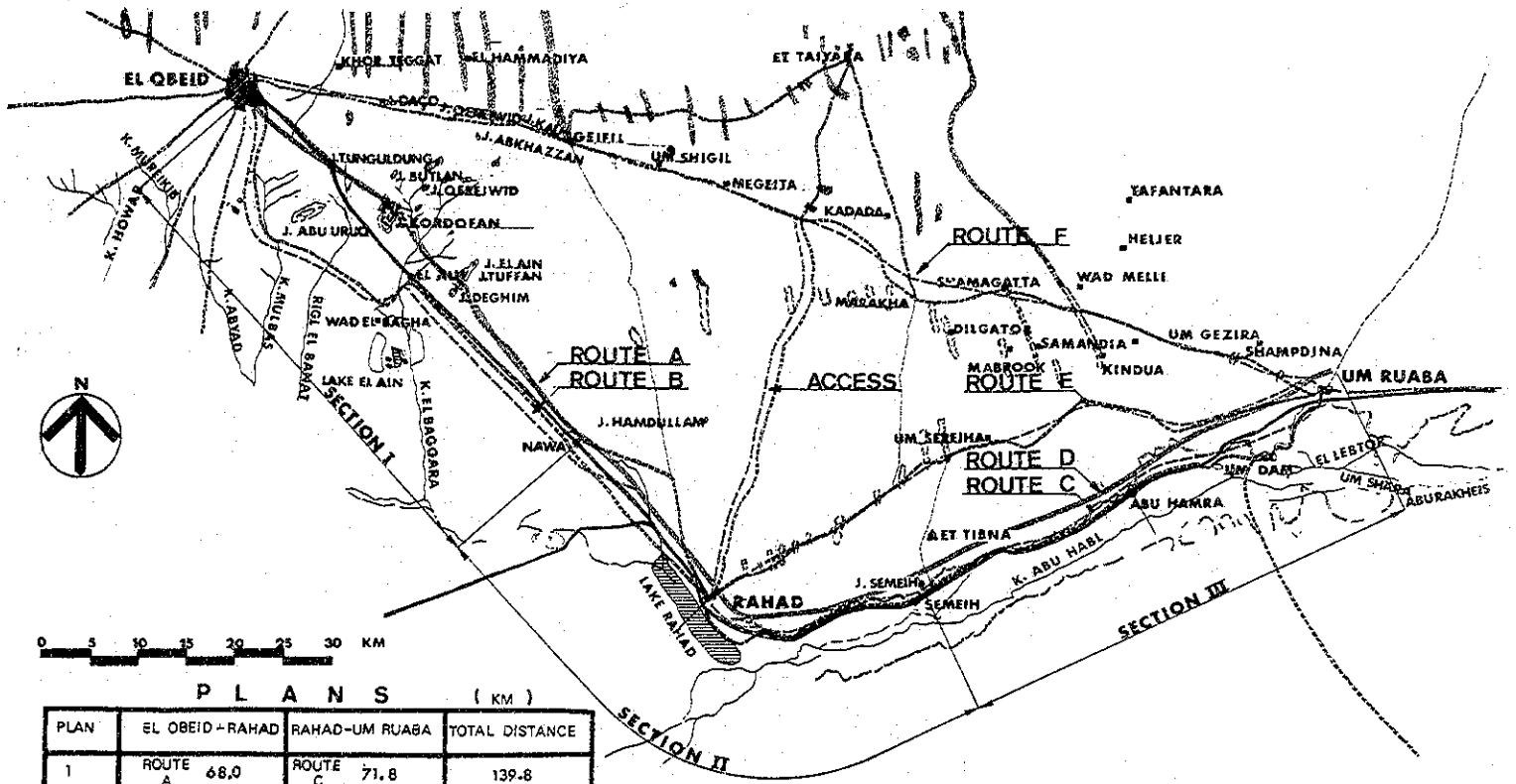
Bridge : Reinforced concrete bridge.

3-2 Time Schedule



LOCATION MAP

(ALTERNATIVE ROUTE PLANS)



P L A N S (KM)

PLAN	EL OBEID - RAHAD	RAHAD - UM RUABA	TOTAL DISTANCE
1	ROUTE A 68.0	ROUTE C 71.8	139.8
2	A 66.4	D 67.1	133.5
3	A 68.0	E 67.3	135.3
4	B 73.0	C 71.8	144.8
5	B 73.0	D 66.6	139.6
6	B 73.0	E 67.3	140.3
7	F 114.7 +	ACCESS 40.8	155.5

LEGEND

- EXISTING ROADS
- RAILWAYS
- RIVERS (KHORS)
- QOZ
- THE BEST ROUTE (PLAN 2)
- ALTERNATIVE ROUTES

4. Project Cost [2]

(US$ '000) [1]
LS '000

A. Implementation	Foreign Component	Local Component	Total Economic Cost	Taxes Customs	Total Financial Cost
Section I	(5,547)	(3,578)	(9,125)	(1,948)	(11,073)
	2,201	1,420	3,621	773	4,394
Section II	(5,529)	(3,568)	(9,097)	(1,943)	(11,040)
	2,194	1,416	3,610	771	4,381
Section III	(8,051)	(5,189)	(13,240)	(2,827)	(16,067)
	3,195	2,059	5,254	1,122	6,376
Total	(19,127)	(12,335)	(31,462)	(6,718)	(38,180)
	7,590	4,895	12,485	2,666	15,151
per km	(141)	(91)	(232)	(48)	(280)
	56	36	92	19	111
B. Detailed Design					
Total	(1,023)	(141)	(1,137)	(171)	(1,308)
	406	45	451	68	519
per km	(5)	(3)	(8)	(2)	(10)
	2	1	3	1	4
C. Total					
Total	(20,150)	(12,449)	(32,559)	(6,889)	(39,488)
	7,996	4,940	12,936	2,734	15,670
per km	(149)	(91)	(240)	(50)	(290)
	59	36	95	20	115

Notes: 1) Exchange rate LS 1.00 = US$ 2.52.

2) Inflation factor of 10% p.s. is assumed from 1977 to the year of expenditure by the programme. The figures includes price contingency.

5. Economic Benefits and Evaluation

The traffic growth rate is estimated after studying changes in GDP, vehicle fuel consumption, and other related factors. The average daily traffic (ADT), with the growth rate of 7% p.a., up to 1992 and afterwards 5% p.a. up to 2002, is estimated as follows (the total of normal, diverted and generated traffic).

	1983	1992	2002
ADT	220	405	660

Economic benefits are estimated to accrue in normal, diverted and generated traffic in the form of savings in transport cost. Development benefits are not considered in the benefit cost calculation. It is recognized that the road project will generate unquantified and social benefits for the region and the country. BC analyses result in the following figures, where a discount rate of 10% p.a. was applied for B/C and B-C.

	Assumed Growth Rate of Traffic	
	7%: ~ 1992 5%: ~ 2002	5%: ~2002
Section I		
Economic rate of return	16.3%	13.3%
Benefit cost ratio (B/C)	1.56	1.26
Present worth (B-C)	LS 1,392,000	LS 645,000
Section II		
Economic rate of return	19.4%	16.1%
Benefit cost ratio (B/C)	1.92	1.53
Present worth (B-C)	LS 2,057,000	LS 1,185,000

	Assumed Growth Rate of Traffic	
	7%: ~ 1992 5%: ~ 2002	5%: ~ 2002
Section III		
Economic rate of return	17.1%	13.9%
Benefit cost ratio (B/C)	1.68	1.33
Present worth (B-C)	LS 1,963,000	LS 949,000
All Sections		
Economic rate of return	19.1%	16.0%
Benefit cost ratio (B/C)	1.93	1.55
Present worth (B-C)	LS 7,058,000	LS 4,186,000

The project, as presented by the preliminary engineering, is technically sound and economically feasible. It is recommended that the road construction plan be incorporated in, with high priority, the development programme of the Sudan and implemented as soon as possible.

6. Recommendations

6-1 Studies in other Development Projects

For the overall development of the regional economy, it is desirable to develop other investment projects (e.g. spinning, tannery) that dovetail with the road construction project. It is strongly recommended that other development plans should be coordinated with this project and further studies on the development of the region should be conducted to gain the maximum benefit from the investment in the road. There should be little difficulty in organizing such studies from the standpoint of time since the road construction project will not be completed for several years.

6-2 Road Maintenance

The road maintenance system should be extended to cover the project road when it is completed. For such a road of 130 km in approximate length, one or two maintenance offices will be able to cover the daily work of maintenance and repair.

6-3 Traffic Safety

It is anticipated that vehicles will run at high speeds on the new road which creates a traffic hazard. In order to miminize traffic accidents on the road, traffic control and regulations for vehicle maintenance and licensing should be enforced effectively.

6-4 Vehicle Loading Regulation

The pavement structure should be protected from excessive loading by trucks. The legislation and effective enforcement in controlling the vehicle loading, including the installation of weigh-bridges, are recommended.

6-5 Transport Market

Policies should be implemented to distribute the benefits not only among the vehicle operators but to all users. In regard to such policies, it is recommended that operation of transport service on the road be open to all those who are interested in participating in it. Also, a variety of transport services with appropriate pricing should be developed in a competitive manner so that passengers and cargo shippers can select from a variety of transport services.

TABLE OF CONTENTS

Table of Contents
(Page 2)

Table of Contents
(Page 3)

Table of Contents
(Page 4)

Table of Contents
(Page 5)

LIST OF TABLES

List of Tables
(Page 2)

LIST OF FIGURES

CHAPTER I

1.00 INTRODUCTION

1.01 Purpose

An inter-regional transport system in the Sudan has been developed in parallel to the River Nile which runs from south to north through the country. The next target of the development programme will be to improve the transport lines crossing the vast country from Port Sudan to the western area. There are several on-going studies and on-going construction work of roads and railways under this programme.

The existing unimproved road under study in this report runs from El Obeid to Um Ruaba and is a 150 km section of the 1,800 km trunk road crossing the country from the east at Port Sudan to the west at the border with Chad, El Geneina. This trunk road from Port Sudan to Chad is nominated as part of the trans-African highway network. When it is improved, the friendly relationship between the Sudan and Chad will be strengthened and the growth of the economy in both countries will be benefited by it.

The purpose of the study is to explore the economic feasibility of the construction plan together with the preliminary engineering study of the road after a series of field studies. The best construction plan was developed by assessing the economic impacts of the alternative engineered plans on the road users and the regional economy.

1.02 Background

Based on an urgent necessity to improve the nation's transportation system, the Government of the Sudan requested technical cooperation

regarding the feasibility and engineering study of this road project to the African Development Bank (ADB) and the Government of Japan in early 1976. The Government of Japan has already agreed to carry out technical cooperation in studying projects which are included in the lending programme of the Bank. The Sudan, ADB and Japan agreed in November, 1976 that the Government of Japan would finance the study of the project under a technical cooperation programme while ADB maintains it in its pipeline of projects.

The study is being carried out by the Japan International Cooperation Agency (JICA), an official executive agency for foreign technical cooperation of Japan, which selected a study team of Mitsui Consultants in February, 1977. The team entered the Sudan in March, 1977. The field study continued to mid-June, followed by home work scheduled to be completed in March, 1978. In September and October three Sudanese counterpart staffs were in Japan to work with the staffs of the study team. The interim report was submitted in November to the Roads and Bridges Public Corporation of the Sudan (RBPC) and ADB. The comments and advice on the text of the interim report were incorporated in the Draft Final Report which was submitted by February, 1978. Additional comments on the Draft Final Report were received and incorporated in the Final Report.

JICA has organized a supervisory committee for the study of the project. The committee members are selected from among the staffs of the Ministry of Construction of Japan. They give advice on the study at appropriate times while attending meetings with the Sudan and ADB.

CHAPTER II

2.00 METHODOLOGY

2.01 The Study

There are two corridors in the project area; one is the northern corridor linking El Obeid and Um Ruaba directly, the other is the southern corridor. The latter is longer than the northern route and runs parallel to the railway passing through the populated areas, including Rahad town. In the southern corridor six alternative routes are proposed for comparative study. They are proposed by considering the alignment of railways, the soil conditions, and the terrain. Accordingly, seven alternatives, in total, are to be studied to determine the best route between El Obeid and Um Ruaba.

In the first stage, a comparative study of the seven alternative routes was conducted. A bituminous surfaced two-lane road is proposed for the initial 13 years of the project. It is assumed that it will be overlayed with asphalt concrete in 1996. In the case of the northern route, the construction of an access road to Rahad was included in the project. The access road is designed as a one-lane bituminous surfaced road. The economic costs for all seven alternatives were estimated. Benefits realized by these alternatives were estimated as well. The benefit cost analysis was included in order to find the best alignment among the seven alternatives. The study up to this analysis was incorporated in the interim report of the study.

The second stage of the study includes not only the reviewing of the benefit cost analysis which was carried out in the first stage of the study, but also the economic evaluations of additional alternatives

such as by-passes, pavement designs, and bridge designs. The study of these minor alternatives is concentrated on the best route chosen through the first stage of the study in order to determine the best construction plan.

2.02 The Schedule and Methodology

The work schedule of the study is shown in Table II-1, and the system of the study is presented in the flow chart in FIG. II-1. The team was in the Sudan for approximately 100 days from mid-March, followed by office work in Japan. The interim report was presented in November, 1977, the draft final report in February, 1978 and the final report in March, 1978. The following is an outline of the scope of the study:

a) Photo Mosaic

A map to a scale of 1 : 250,000 and a photo mosaic of 1 : 48,000 taken in 1962, were supplied by the Sudanese Government. The team has used these data in the course of the first stage study of the seven alternatives.

b) A map of 1 : 5,000 scale

An aerial photo was taken on the southern corridor with a width of 5 km. A photo mosaic of 1 : 25,000 was produced. When the best alignment was determined, a map of 1 : 5,000 covering the area with a width of 500 m for each side of this alignment was developed. This map served in the second stage of the study for reviewing the best alignment and cost estimate.

c) Field Studies

The field inventory studies included findings on the conditions of the existing roads, such as slopes, surfaces in sections, the soil and the material. Tests on soils and materials were conducted in the laboratories of RBPC and the consultants. The hydrological survey included field observation, the collection of climatic data, and the analysis of these data.

d) Engineering

In the first stage of the study, preliminary engineering studies were conducted for the seven alternatives. In the second stage of the study, the first preliminary engineering studies on the best route were reviewed and revised. It also included other studies on minor alternatives on the best route, such as bypasses, staged construction, pavement designs and bridge structures, etc.

e) Cost Studies

The information necessary for the estimate of the project cost were obtained in the project area and in Khartoum. They were incorporated in the priced bill of quantity for the seven alternatives in the first stage study and the best route in the second stage. The economic and financial costs were estimated to determine the best construction plan.

f) Traffic Studies

A series of traffic studies was conducted in the project area and other related areas. Statistical data were provided by various government sources and by private organizations. Future traffic volume was then forecasted and transportation costs estimated.

g) Economies in the Project Area

The rural and urban economies of the project area were studied in their existing status and their prospects for the future. The development potentiality was considered in the above estimate of the future traffic. The benefit streams were estimated for the project life period of twenty years.

h) Economic Analysis

The result of the economic benefit cost analysis in the first stage not only presented the best alignment among the seven alternatives, but also suggested that the project, because of the satisfactory benefit cost figures, should be included in the development investment programme and given high priority. In the second stage, the benefit cost analysis was conducted for the determination of minor alternatives and for the determination of the best recommendable construction plan.

2.03 Members of Supervisory Committee and Study Team

2.03.1 Supervisory Committee

Chairman	Toshiyuki Ohno:	Kanto Regional Construction Bureau, MOC, Japan
Member of Committee	Mohei Miki:	Kanto Regional Construction Bureau, MOC, Japan
"	Tokuhisa Kakuchi:	Bureau of Roads, MOC, Japan
"	Kaoru Ono:	Kanto Regional Construction Bureau, MOC, Japan
"	Hiroshi Morimoto:	Bureau of Roads, MOC, Japan
"	Yasusuke Agata:	Kanto Regional Construction Bureau, MOC, Japan
Coordinator	Hiroyoshi Kurihara:	Japan International Cooperation Agency, Japan

2.03.2 Study Team

Team Leader:	Noritomo Okuda
Acting Team Leader and Economist:	Teruhiko Horie
Highway Engineer Cost Estimator:	Kunio Taniguchi
Agronomist:	Masae Yamazaki
Highway & Bridge Engineer:	Harumi Nishikawa
Transport Economist:	Shizuo Iwata
Highway Engineer:	Takeshi Tomiyasu
Hydrologist:	Masataka Miyagawa
Traffic Engineer:	Kunio Ohhashi
Geologist:	Ryuichi Ichihara
Chief Surveyor:	Yoshiaki Otoku
Surveyor:	Mikio Kurita

FIG.II-1 FLOW CHART OF THE STUDY ON EL OBEID-UM RUABA ROAD PROJECT

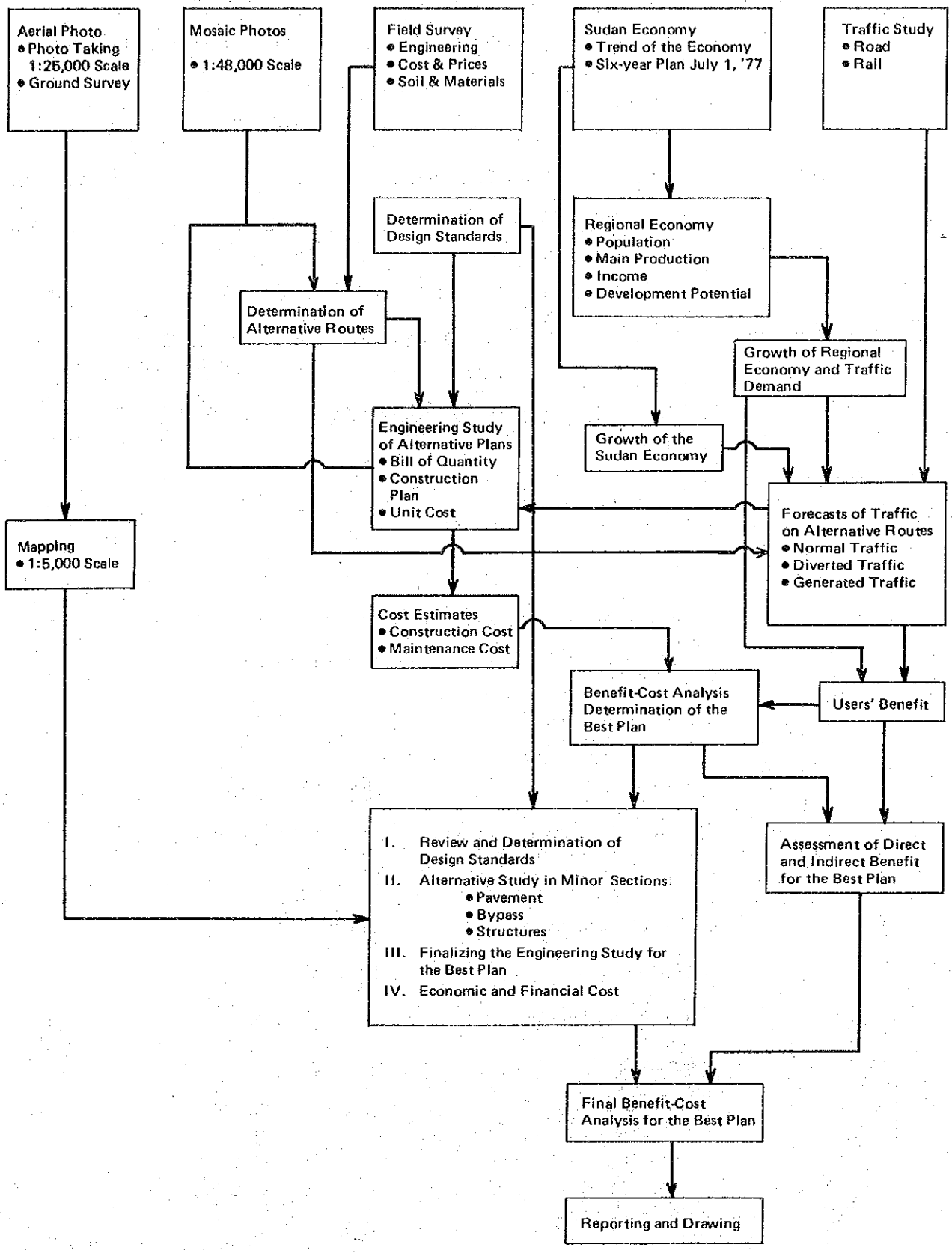
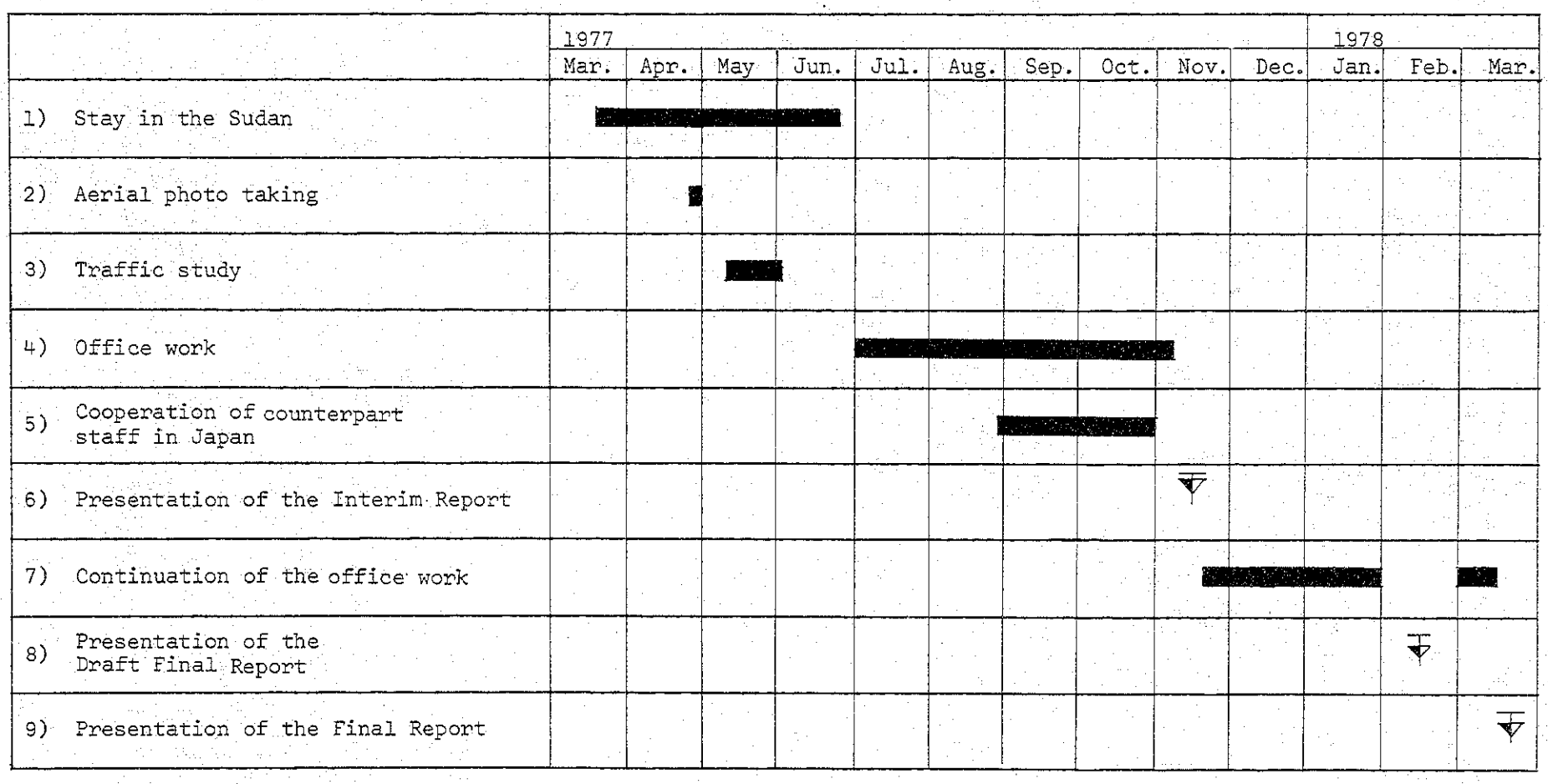


TABLE II-1 TIME TABLE OF THE STUDY



CHAPTER III

3.00 THE SUDAN IN GENERAL

3.01 Geography

The Sudan is located in the north-eastern part of the African continent surrounded by Egypt, Ethiopia, Kenya, Uganda, Zaire, Central African Empire, Chad and Libya. It has an area of 2.5 million km^2, being the largest country in Africa. It lies in the area between 4°N and 22°N latitude, stretching 2,040 km from north to south and 1,600 km from east to west in maximum distance. It faces the Red Sea on the north-east with a coast line of 650 km. Port Sudan is the only seaport and thus handles all exports and imports of the Sudan.

The White Nile river originates in Uganda, and the Blue Nile enters from Ethiopia and passes through the southern portion of the country. Both Niles join in the centre of the Sudan to form the Nile, which continues north towards Egypt. Khartoum, the capital of the Sudan, is located at the confluence of the Blue and White Niles. The terrain is generally flat except for some highlands in the east, west and south. The Sahara Desert covers a portion of the country in the north. Savanna lies in the middle of the country. There are swamps, forests and jungles located in the south.

The climate of the Sudan is typical tropical and continental. Hot and dry north winds cover the northern part of the country throughout the year. In the middle and southern parts of the country, dry north winds and humid south winds alternate. The hottest season is from April to June, while the winter season extends from November to January.

Rainfall is rare in the northern part of the country. More rainfall is registered in the central and especially in the southern part. Annual rainfall is 20 mm in the north and 1,500 mm in the south. The rainy season occurs during the four months from June to September. Rainfall is heavy, sometimes accompanied by thunder. Sand carrying winds (haboob) occur frequently in the desert and savanna regions.

3.02 Population

A nationwide population census was carried out in 1955/56 and again in 1973. Due to a shortage of information, there are conflicting figures regarding the estimate of the nation's population. There are two versions, one by UN statistics and the other by the Statistical Department of the Sudan. The overall trends of population in the Sudan are noted in the following paragraphs.

According to UN statistics, the population was approximately 17.3 million in 1974 with an average growth rate of 2.6% per year during the past 8 years. The population of the country with the annual rate of increase since 1966 is shown in Annex III-1. Changes of population in urban areas is also shown. It is observed that there has been a continuous increase of population in urban areas. The rate of increase in urban population is estimated at 5.5% per year during the same eight-year period.

According to data published by the Statistical Department of the Sudan, the population in 1973 was 15.0 million, with an average annual rate of increase of 2.2% during the 17 years since 1956. Annex III-2 shows the population in the Sudan by province in 1955/56 and 1973.

The population density of the country was six persons per square kilometre in 1973.

The labour force (economically active population), defined as those who have a job and those who have the will to work in the age group over 15 years of age, is 8.4 million, comprising 55% of the people of that age group. The labour force is shown in Annex III-3, and indicates that 72% is in the agriculture and livestock sector.

3.03 Economy

Persons engaged in the agriculture sector occupy three-quarters of the labour force in the Sudan as shown in Annex III-3. The majority are in a subsistence economy, marketing part of their product for cash income.

According to the Year Book of Agricultural Statistics, 1974, at present 17 million feddans (71,000 km^2: 1 feddan = 0.42 ha) of land are cultivated out of a total arable land area of 200 million feddans. It is expected that the Sudan will become a major crop producing and exporting country since the Government is enthusiastically planning to utilize uncultivated land with the cooperation of foreign countries.

Cotton, groundnuts, and gum arabic contribute to the economy of the Sudan by sharing more than 75% of total exports. Major export items and their values are presented in Annex III-11. Dura and Dukhn are the main staples produced and consumed in the country. As shown in Annex III-4 the output and producing area of cotton decreased by 20% and 46%, respectively, during 1973/74 - 1975/76.

Other crops increased by 30%, on the whole, during the same period as shown in Annex III-5. Wheat, sugar, and some other crops are still imported. Domestic production and consumption of sugar in 1972/73 and 1975/76 are shown in Annex III-7, which indicates that imports of sugar comprise as much as 50% of the total consumption.

The total population of livestock was approximately 40 million in 1973/74 as presented in Annex III-8. The majority are raised by nomads who move continuously seeking fresh pastures. Part of the camel and goat population is exported to neighbouring countries from Port Sudan and Halfa. The export of cattle and sheep has been banned since the end of 1974 in order to maintain the supply of these livestock in the local market to offset price rises. The most serious problem to be solved in the livestock sector is to maintain and increase as much as possible the area of pasture land, while maintaining the huge population of livestock at an appropriate level.

Some characteristics of the processing sector of the economy are that raw materials are mostly agricultural products, that the government joins in investment both with domestic and foreign funds (e. g. : sugar, tannery, textiles), and that outputs are largely insufficient to meet domestic demand (e. g. : cement, textiles, tobacco). Investment from abroad is encouraged by the Development and Promotion Act of Industrial Investment of 1972. The percentage share of the manufacturing sector in GDP was around eight to ten percent from 1966/67 to 1975/76 (ref. Annex III-9).

The inflow of foreign capital increased from £S20 million in 1971/72 to £S142 million in 1975/76, while the balance of payments during the

same period grew in deficit from LS20 million to LS69 million. The balance of payments for the years from 1971/72 to 1975/76 are shown in Annex III-10.

Changes in GDP in the past nine years are shown in Annex III-9. It is observed that there has been little change in the sectoral composition during these years. The drought of the early 1970's and the world inflation after the Arab-Israeli War of 1973 occurred during this period. GDP at market price increased from £S533 million in 1966/67 to £S1,511 million in 1974/75. The latter is 2.8 times larger than the former and the average annual rate of increase is 13%. But, in terms of constant price, the GDP increased by only 20%, at a rate of only 2% per year in these years. However, in terms of constant price the average growth rate of GDP from 1971/72 to 1974/75 was 4% per year, which would reach 5% or more if the period is extended to 1976/77. The Table in Annex III-9 shows that the percentage share of agriculture grew from 33% to 39% while the service industry share decreased from 29% to 23%.

3.04 Transportation

The transport system in the Sudan consits of roads, railways, airlines and inland waterways. In addition, the traditional system of animal transport by camel and donkey is commonly used by the people. The railways are the major carriers of export and import commodities, and of inter-regional passengers and commodities as well. The railways carried approximately 70% of the inter-regional flow of passengers and commodities in 1973 as shown by the Table in Annex III-13. An increase of services by other modes of transport is necessary for the growth of

the economy. Accordingly, an improvement of the road network has been undertaken vigorously in the past several years.

a) Roads

The Roads and Bridges Public Corporation (RBPC) is a unit of the central government which administers planning, construction, and maintenance of the national road network. The government allocates revenue for the expenditures of RBPC, but it has no revolving funds. The organization of RBPC at mid-1977 is shown in Annex III-14.

Sudanese roads are divided, according to RBPC data, into paved roads of 756 km (i.e., 3.5%), roads under construction of 936 km (4.3%), gravel roads of about 6,000 km (27.7%), and earth and sand roads of about 14,000 km (64.5%). Earth and sand roads are in poor condition. The road network is shown in Annex III-15, and the roads already constructed, under study, and those proposed for study are shown in Annex III-16. RBPC is in charge of the maintenance of the above 756 km of paved roads. So far the total length of paved roads is relatively small, but maintenance has been fair and meets the minimum requirements as observed on the paved road between Khartoum and Wad Medani. Local authorities are responsible for the maintenance of approximately 20,000 km of gravel and unimproved roads. However, the maintenance work is poor due to a shortage of funds and staff.

Aware of the necessity of securing funds for road maintenance, the Government has organized a working committee to conduct a feasibility study for implementing a toll system on paved roads.

The Ministry of National Planning is coordinating the work of the committee and a recommendation is expected to be made by July 1978.

Passenger cars and small buses serve only urban areas and otherwise on surfaced roads, since the condition of roads outside urban areas is so bad. Vehicles running on the roads in savanna and desert areas consist mainly of large and medium size trucks, four wheel drive vehicles and buses, i.e., vehicles with large wheels and high power engines. Negative conditions, such as fine sand drifting on the tracks, have resulted in high costs for road transport.

Registered vehicles have increased from 50,000 in 1970 to 79,000 in 1975, an annual average growth rate of 12%, while fuel consumption by vehicles has increased 4.5% per annum during the same period. Due to a shortage of spare parts and fuel supply, it is difficult to conceive that vehicles could have increased their running mileage in proportion to the rate of increase in vehicle registrations. It is assumed that changes in fuel consumption on roads are more closely related to changes in traffic volume on roads. Related statistical data are shown in Annex III-17 and 18.

b) Railways

The Sudan Railways Corporation's headquarters is located in Atbara, 330 km north of Khartoum. The total length of track in operation is 4,800 km, all narrow gauge and single track. The section on which heavy traffic is most concentrated is between Khartoum and Port Sudan through Atbara, a distance of 800 km, where rails of 90 lb/yard have been installed. Other sections have rails of 75 or 50 lb/yard, which may be replaced in near future.

Tracks, workshops and rolling stock are generally obsolete, although replacement of some of them has been undertaken. In spite of work and efforts by the railway staffs, their current performance does not meet the transport needs of the country, often resulting in a shortage of goods in market places, such as vehicle fuel, vehicle parts, cement, sugar, etc.

According to the Sudan Railways Report [1], the share of petroleum products amongst the commodities transported from Port Sudan to Khartoum is approximately 40%. Most of the petroleum products will be diverted to a pipeline transport which commenced to operate early in November, 1977. It is expected that the railways will utilize the facilities, which will become available as a result of this diversion, for transporting other commodities or for allocating some rolling stock to other sections of the railways. The most urgent investment projects are to construct a double track system between Port Sudan and Haiya and to replace much of the obsolete capital equipment.

c) Airlines

There are 18 airports serving domestic airlines among which Khartoum and Port Sudan airports are operating for international services and also have facilities for night operation. The airports at Juba and El Geneina are able to handle flights to and from neighbouring countries. Flights between Khartoum and Port Sudan, Khartoum and El Obeid, and Khartoum and Juba are major domestic lines.

Note 1) The Sudan Railways Corporation, Annual Report 1975/76.

Passengers on these lines in 1973 numbered 15,530, 17,138 and 9,826, respectively. The chart in Annex III-15 shows the airports and airlines.

Demand for air transport services has increased rapidly in recent years. Domestic passengers carried by airlines totalled 94,000 in 1973/74. The growth rate in the number of domestic passengers during 1968/69 - 1973/74 was 11% p.a. (ref. Annex III-13). All domestic airlines are operated by Sudan Airways Corporation. Boeing 737 and Fokker 27 are the plane models being used. They cannot meet the demand adequately because of obsolete airport facilities, mechanical problems, and shortages of parts.

d) Others

There are several additional points to mention concerning the Sudanese transport system. a) Port Sudan is the only seaport serving all export and import by sea. Transport facilities to and from the port and berthing facilities are inadequate for the flow of goods. Congestion at piers and depots is quite common. b) River transport is prevalent on the Nile rivers. The major sections of this river transport are the Kosti-Malakal-Juba section on the White Nile river and the Karima-Dongola section on the Nile river. There are also ferry services crossing the rivers. c) Animal transport, mostly camel and donkey, are quite common in the country. The volume of such transport is impossible to estimate. However, they play a very important role in regions where rail and vehicle transport is non-existent. It is presumed, on the basis of cost, that some passengers prefer to use animal transport even over vehicle transport on paved highways.

CHAPTER IV

4.00 THE ECONOMY IN THE PROJECT AREA

4.01 General Features of Influence Zones

4.01.1 General

The influence zones of the project will be shown followed by an estimate of population distribution, the economy in the project area, and prospects for the development of the regional economy. The existing status of transportation in the region is studied in CHAPTER VI.

The project locates in the vicinity of El Obeid, a regional urban centre in the western half of the Sudan. This town is the capital of Northern Kordofan Province and is situated 400 km south west of the national capital, Khartoum. With a population of 100,000, it is the third largest town and is the regional centre of administration, economy and the hub of transportation. It is surrounded by vast flat savanna where people make their living by traditional farming.

The direct influence zones of the project stretch towards the south-east and include the towns of Rahad, Semeih, and Um Ruaba. Since the project area is close to the Nuba mountain area of Southern Kordofan Province, where cotton is produced predominantly, cotton is also produced in the southern part of the project area. Most traffic between the north-eastern provinces, such as Khartoum, Gezira and the western provinces,

such as Southern Darfur Province and the western half of Northern Kordofan, passes through El Obeid where vehicles refuel and load and unload commodities and travellers.

4.01.2 Zoning

Zones have been determined in order to study the population, economy and traffic flow along the project road. The zones determined here are the same as the zones used in the traffic study (Ref. CHAPTER VI). The area of the project (direct influence zones) is delineated at a width of approximately 10 km on both sides of the existing road between El Obeid and Um Ruaba. The centre of each zone is set at the railway station or at a densely populated village. Ten zones are fixed, as shown in Table IV-1. The secondary influence zones are the areas outside the ten zones extending from Northern and Southern Kordofan Provinces to the whole country, as shown in FIG. IV-1. These indirect influence zones number 15.

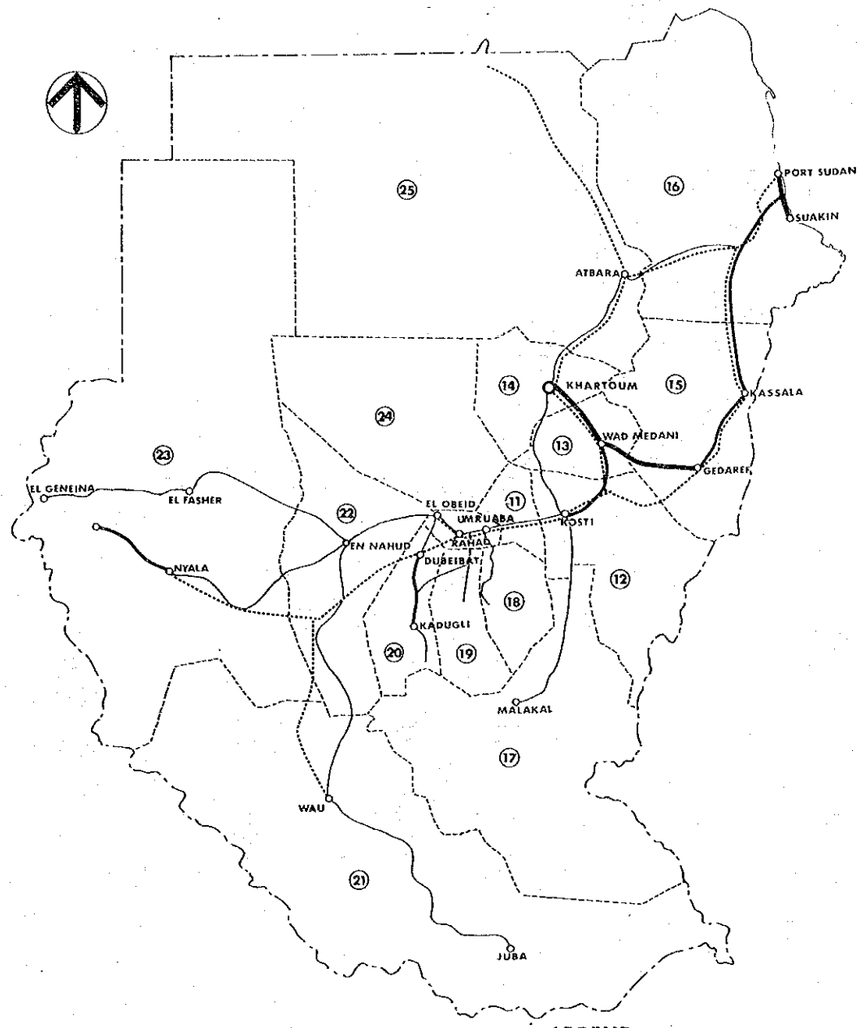
TABLE IV-1 DIRECT INFLUENCE ZONES

(km^2)

No.	Name	Area	Urban	Rural
1	El Obeid	675	20	655
2	Geifil	1,060		1,060
3	Et Taiyara	670		670
4	Shamagatta	920		920
5	Um Ruaba	770	2	768
6	Abu Hamra	870		870
7	Semeih	850		850
8	Rahad	700	3	697 *
9	Nawa	780		780
10	El Ain	850		850
	Total	8,145	25	8,120

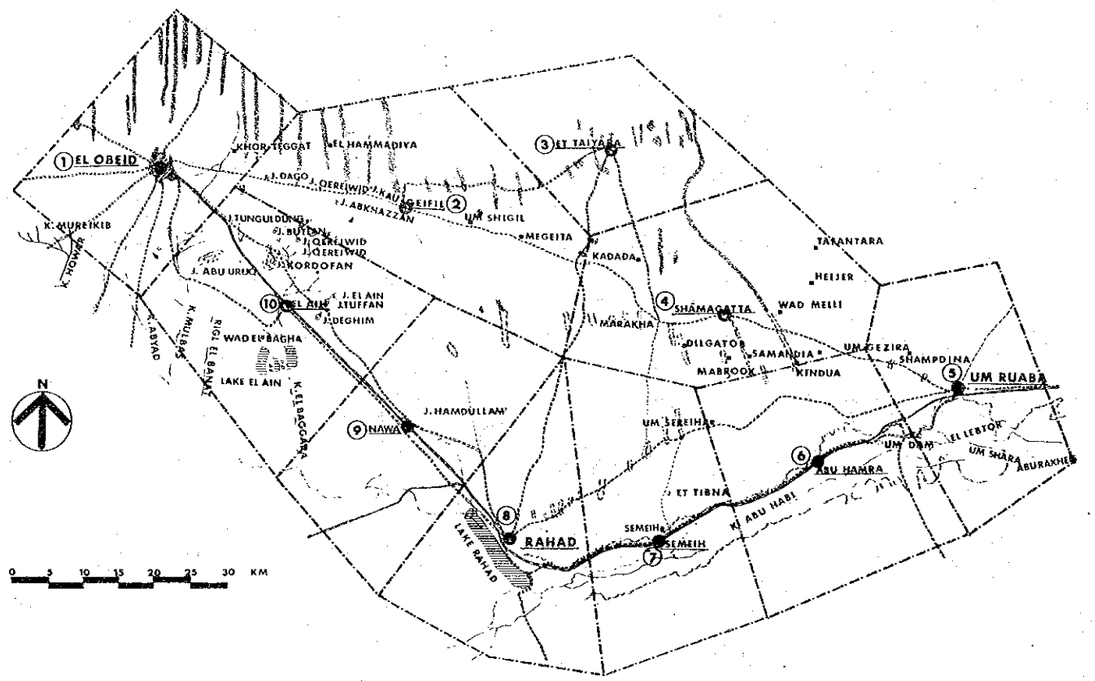
Note: * including the lake of 31 km^2.

FIG. IV-1 ZONE MAP AND ROAD NETWORK



LEGEND

- ⑯ ZONE NO.
- PAVED ROADS
- UNDER CONSTRUCTION ROADS
- EARTH ROADS
- RAILWAYS
- ZONE BOUNDARY



LEGEND

- EXISTING ROADS
- RAILWAYS
- RIVERS (KHORS)
- GOZ
- HILLS
- ZONE BOUNDARY
- NAWA ZONE CENTROID & NAME OF ZONE
- ⑪ ZONE NO.

ZONE NUMBER AND NAME

1	EL OBEID	11	TENDELTI	21	WAU-JUBA
2	GEIFIL	12	KOSTI-SENNAR	22	EN NAHUD
3	ET TAIYARA	13	WAD MEDANI	23	NYALA
4	SHAMAGATTA	14	KHARTOUM	24	BARA
5	UM RUABA	15	KASSALA	25	ATBARA
6	ABU HAMRA	16	PORT SUDAN		
7	SEMEIH	17	MALAKAL		
8	RAHAD	18	EL ABBASIYA		
9	NAWA	19	NUBA MOUNTAIN		
10	EL AIN	20	KADUGLI		

TABLE IV- 2 POPULATION ESTIMATES IN NORTHERN KORDOFAN PROVINCE, 1977

	Settled Population		Nomad	Settled Population Total	Rural Population including Nomad	Total
	Urban (1)	Rural (2)	(3)	(1) + (2)	(2) + (3)	(1) + (2) + (3)
Northern Kordofan Province	198,406	903,083	263,916	1,101,489	1,166,999	1,365,405
Central District	105,738	97,792	5,149	203,530	102,941	208,679
Eastern District	40,097	291,451	21,365	331,548	312,816	352,913
Western District	38,953	307,034	9,822	345,987	316,856	355,809
Northern District	10,479	140,693	15,285	151,172	155,978	166,457
North-Western District	3,139	66,113	142,395	69,252	208,508	211,647
Roving	-	-	69,900	-	69,900	69,900

Source: Estimated by the study team

4.02 Population

4.02.1 Northern Kordofan Province

A national population census was carried out in 1955/56, a census of urban area in 1964/66, and a nationwide census in 1973. The results of the latest census have not yet been published. Population in these years was estimated by the Government and some UN offices, separately. The estimate of population by a UN office shows the growth rate in the past as 2.6% p.a., as shown in Annex III-1. According to the population data provided by the Government, it is considered that the average annual growth rate of the population of the Sudan was 2.2% for the 18 years from 1955 to 1973, and that of Northern Kordofan Province 1.3% p.a. for the same period. The data provided by the Government and the provincial office are attached to Annexes IV-1, IV-2, IV-3. Based on these data and the information gathered at the project site, the populations of both Northern and Southern Kordofan in 1977 were estimated and are presented in Annex IV-4.

Further, the district population for urban, rural and nomads in 1977 is developed by using the above statistics. The results are presented in Table IV-2, which indicates that the total inhabitants of the province number 1,365,000.

As shown in Table IV-2, the nomads in Northern Kordofan Province total 260,000 in round number and together with those in Southern Kordofan Province they numbered nearly 400,000 in 1977. While the information source in

Northern Kordofan Province said that there were 286,644 nomads in the former Kordofan area in 1973, the preliminary estimate [1] by the Department of Statistics in 1973 offers a different figure, 406,274, for the same area. As this discrepancy indicates, it is difficult to determine the number of nomads since they move seasonally from one region to another.

4.02.2 Estimate of Population in the Zones

The population for each of the ten zones is estimated in the following way. The number of villages are surveyed on the aerial photo at 1 : 48,000 (produced in 1962) and on the map at 1:250,000 (revised in 1975). The villages are divided into three groups according to the number of houses. Assuming each house has a family average of five persons, the settled inhabitants in each village, and henceforth in the zone, are estimated. The result is shown in Table IV-3. The table also presents the population in urban areas, the number of farm households and those engaged in agriculture. The details of the estimate of zonal population is attached in Annex IV-5.

The population density is 6 for both Kordofan Provinces, while it is also 6 for the whole country (ref. Annex III-2). In the project area it is 33. The density is high because of El Obeid which embraces approximately 100,000 inhabitants.

Note 1) National Planning Commission, Economic Survey, 1974, Appendix Table 2-1.

TABLE IV-3 SETTLED POPULATION IN THE ZONES OF INFLUENCE, 1977

Zone No.	Total	Urban	Rural	Agricultural	Farm-households
1	119,688	105,738	13,950	11,718	2,344
2	13,340	-	13,340	11,206	2,241
3	10,970	-	10,970	9,215	1,843
4	13,950	-	13,950	11,718	2,344
5	41,041	23,141	17,900	15,036	3,007
6	9,614	-	9,614	8,076	1,615
7	12,922	-	12,922	10,854	2,171
8	29,226	16,956	12,270	10,307	2,061
9	6,750	-	6,750	5,670	1,134
10	12,800	-	12,800	10,752	2,150
Total	270,301	145,835	124,466	104,552	20,910

Source: Estimated by the study team

4.03 Economy in the Zones

4.03.1 Urban Area

The delineated influence zones of the project cover an area of 8,145 km^2 which is divided into urban areas of 25 km^2 (the three towns of El Obeid, Um Ruaba and Rahad) and a rural area of 8,120 km^2.

El Obeid has more than 100,000 inhabitants, and the provincial headquarters and the branches of the central government are located there. There is a power plant operated by diesel fuel which provides electricity for the town. The town has developed a water supply network, although it still suffers from chronic shortage of water. Social services are provided by such facilities as hospitals, clinics, primary and junior high schools, a senior high school with boarding facilites, crop and animal markets, fire stations, a court house, and a police force.

The transport system and its uses are noted in 6.01, CHAPTER VI. There is an industrial area where the processing factories for edible oil of groundnuts and sesame, and the garages serving vehicles are located. There are small cottage industries such as tailors, shoemakers and furniture makers centered around several market squares in the town. Warehouses which store crops and other products locate close to the truck terminal squares. The movement of goods in and out of the storehouses appears brisk.

There are several branches of banks including the Bank of Sudan. It is observed in the town that the supply of consumer good produced locally appears sufficient, while those imported to the

region at retail shops and wholesalers appear insufficient. Many people gather at night in the market places for shopping, eating, and tea drinking.

Though the results of a survey on job opportunities for urban workers in 1973 have not yet been released, it is assumed that the main sectors of employment are wholesale and retail shops, transport services including garages and petrol service stations, public services, and agriculture. Manufacturing is not developed yet and, therefore, does not provide jobs for a large number of workers.

Um Ruaba is the centre of the Eastern District with a population of 23,000. A characteristic point is that this town is the centre of edible oil processing in the region. There are ten factories in Um Ruaba while El Obeid has only five.

Rahad is the smallest town with a population of 17,000. An electricity system has not been constructed yet. The railways split here, one going to El Obeid and the other to Nyala. An animal feeding yard was constructed several years ago to serve the transport by rail of cattle from west to east. Unfortunately, it has not been used due to the policy of banning livestock export since 1974 and the shortage of cattle cars on the railways. However, a study to utilize this facility for animal transport was started recently.

4.03.2 Rural Area

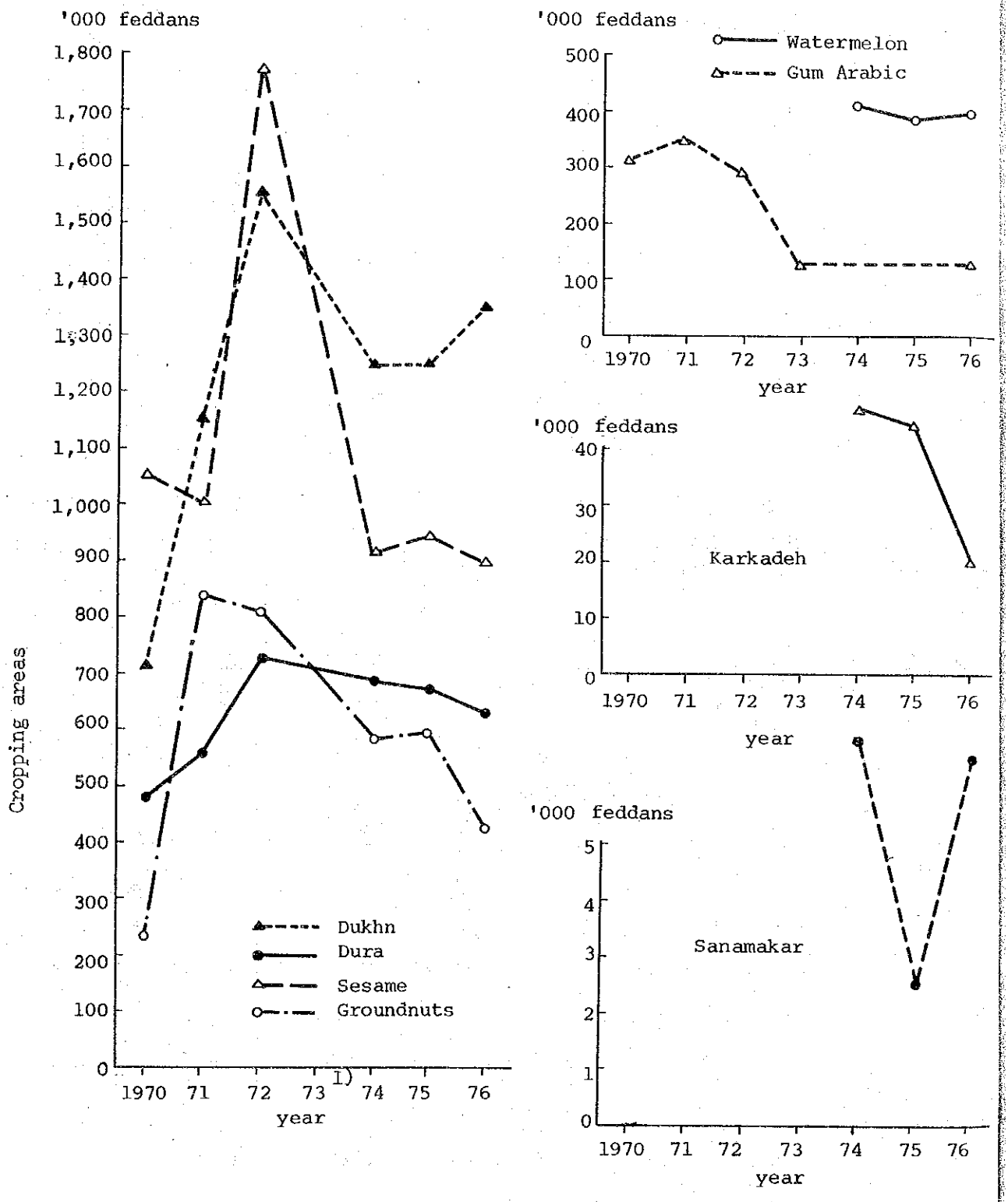
The rural area occupies 8,120 km^2 out of the total project area of 8,145 km^2. The farmers in the area lead simple, traditional lives. They live in huts of dry grass and dung. They consume

most of the harvest by themselves but sell the remaining surplus to middlemen or carry it to market by donkey or camel. Settled farmers keep animals for transportation and for their own milk and meat requirements. Most of the animals sold in the markets are raised by nomads. It is said that nearly 90% of the animals in the province are owned by nomads.

The cultivated land, including fallow areas of the province, is estimated at 4.4 million feddans. Traditional rain-fed farming is predominantly practiced by farmers. The main cash crops are dura, sesame, groundnuts, watermelon seeds, and gum arabic. Annual output has not been stable. FIG. IV-2 and Annex IV-6 show the changes in the areas of crops and production since 1970. Production in recent years has been more stable than in the early 1970's. The main reason for production instability is that annual rainfall in the province is not constant, varying in a range of 200 to 400 mm, which barely satisfies the minimum volume necessary to raise these crops. A restraint on any increase in production is that water reservoirs and irrigation systems are not available yet, so the farmers are unable to extend cultivation into uncultivated areas nor are they able to increase the annual cultivation time span.

Table IV-4 shows the area of main crops and products in Northern Kordofan Province and in the project area. Other noteworthy products in the province are firewood of 6,000 m^3, and charcoal of 12,100 tons. The project area, too, yields firewood and charcoal from its savanna trees. Output is estimated at nearly 1/5 of that of the province total. Both products are commonly used as fuel by the urban and rural populace.

FIG. IV-2 CULTIVATED AREAS BY MAIN PRODUCT TYPES IN NORTHERN KORDOFAN PROVINCE, 1970-1976



Sources : Produced from the data in Annex IV-6.

Note 1) The data for 1973 were not available.

TABLE IV-4 MAIN AGRICULTURAL PRODUCTIONS IN NORTHERN KORDOFAN PROVINCE, 1976

Items	Unit Yield		Cultivated Area		Production	
	kg/fed	ton/ha	Direct Influence Zones (feddan)	Northern Kordofan Province (feddan)	Direct Influence Zones (ton)	Northern Kordofan Province (ton)
Dukhn	120	0.29	174,000	1,300,000	20,904	156,000
Dura	150	0.36	88,440	660,000	13,266	99,000
Sesame	75	0.18	123,280	920,000	9,246	69,000
Groundnuts	350	0.83	71,020	530,000	24,857	185,500
Watermelon seeds	95	0.23	52,930	395,000	5,028	37,525
Karkadeh	12	0.03	4,958	37,000	59	444
Sanamakar	540	1.29	670	5,000	362	2,700
Gum Arabic	50	0.12	18,090	135,000	905	6,750
Total	-	-	533,388	3,982,000	74,627	556,919

Source: Estimated by the study team

Note ; 1) The cultivated area and production in the direct influence zones are estimated by the percentage composition of the farm households in the zones of those in the whole province.

One sector other than agriculture in the rural area of note is a cotton ginnery near Semeih railway station in Zone 7. The cotton is cultivated by a corporation system covering a clay soil area of 7,200 feddans to the south east of Semeih railway station. Cultivation in this area is by the flooded farming method using water from the Abu Habl river in the rainy season. Each of the 600 families there keeps 12 feddans, 6 feddans for cotton and the rest for dura. Also, seed oil processing factories locate in the three towns of the project area. They buy sesame and groundnuts around the area and send oil and oilcake to Khartoum and elsewhere.

4.03.3 Livestock

Nomads own approximately 90% of the livestock in the province. The North-western district is said to contain the greatest number of nomads and animals. They move northward in the rainy season and return deep into Southern Kordofan Province in the dry season, seeking pasture lands. A nationwide livestock census was conducted in 1976. The results were partially published. The animals in the Central and the Eastern Districts of the province are shown in Annex IV-7.

There are some animal markets in the urban areas. It seems that all animals brought to market are not always traded on the same day. Often, when the quality of the livestock does not meet the buyers' requirements, the owners, mostly nomads, take the animals back to their fields and return them to the

market a few days later, or sell them to a slaughter house. Normal veterinary services, such as vaccinations, are given at the markets. Animals for slaughtering are priced at the market. Since animals slaughtered in the markets number less than total consumption in the region and there are few animals exported to other regions, it is surmised that many animals are slaughtered privately in the villages. Their number exceeds by far those slaughtered at markets. The registered trade of animals at the markets is shown in Annex IV-8.

4.04 Average Household Income

An estimate of the main cash crops and cultivated land in each zone of the project area is shown in the table in Annex IV-9. Farmers market their surpluses immediately after the harvest, approximately 80% during the three months from November to January.

Market prices in 1977 at El Obeid are shown in Annex IV-10. Market charges are levied on the traded crops and are usually paid by the buyers. Charges per 100 kantar (equivalent to 4,500 kg) are LS0.20 in average; it is taken the charges are equal to 0.1% of the unit market price. Deducting the transport cost and the losses of crops during transport by animals or by trucks results in a net income of 90% of the market price for such rural produce.

The farmer doesn't own his land in one unit, rather it is quite common for a farmer to hold land in several parcels located close to his house or far away from the village. When they seed or harvest, they often live in temporary huts far away from their original village.

It is estimated that cash income per family in 1977 totalled LS155 (US$380)(ref. Annex IV-11). It thus comes to LS13 per month and LS30 (US$75) per person. On the other hand, in urban areas, statistics on distribution and job income are not available, however, the following income levels were available for El Obeid only.

	(LS per month)
Unskilled labour	25
Employee by service sector or factory worker	35
Driver and mechanic	45
Skilled labour	55
Junior office clerk	50
Senior office clerk	80

It can be seen from these figures that income level is higher in the urban area than in the rural area. The higher level of income in the urban area is a contributing factor to immigration from the rural to the urban area.

4.05 Future of the Regional Economy

4.05.1 Rural Economy

The climate in the project area, according to the climatologic classification of W.P. Koppen, is that of a desert or savanna climate with rainfall prevalent in the summer season. Annual rainfall ranges between 200 mm and 400 mm; however, it registers a wide range of variation including the volume per rainfall. The evaporation ratio is 15 mm per day in average, decreasing to one-half of that in the rainy season. Humidity averages 15% in the dry season and 50% in the rainy season. Temperatures average a maximum and minimum of 39°C and 24°C, respectively, in May and 31°C and 14°C, respectively, in January.

The range of changes in temperature is suitable for the growth of plants and livestock. Wind velocity, registering 3.5 m/sec in average, is generally mild except for the sandy wind (Haboob) during the dry season. However, the negative effect of the haboob on crops is lessened by the vegetation in the savanna.

The terrain is mainly flat with some gently sloping hills. The rivers or watercourses (khors) contain no water during the dry season. Clay soil covers the southern part of the project area. The region containing this kind of clay soil is called "Vertisols" region. The clay soil shrinks in the dry season and swells in the rainy season. Fertility is high. There is a high density sub-base stratum of which permeability is low. The clay soil

area extends from the southern part of Northern Kordofan Province to the Nuba mountain region in Southern Kordofan Province, where cotton is produced predominantly.

Most of the project area, except the above mentioned clay soil area, is covered by a soil called "qoz" which belongs to the Arenosols type. It is a stabilized mature sand soil covering the vast plain in uniform quality. Fertility is low. It becomes firm with the rain. Traditional rain-fed farming is quite common on this soil which produces dura, groundnuts, sesame, gum arabic and karkadeh. Yields are low compared to the average of the country. The relative yield figures are shown in Annex IV-12. Also, nomads move through the area grazing animals.

The problems to be encountered in the future regional economy are summarized as follows.

i. Water Resources

As mentioned in other sections, rainfall is insufficient, and it is irregular. The use of underground water should be developed further, together with the feasibility of constructing water reservoirs and an irrigation system. The shortage of water is the most serious problem to be solved in the course of agricultural development. It is a cause of the low productivity in the area and a restraint on the expansion of cultivated land, and forces farmers to concentrate traditional cultivation on land close to their villages.

Although farmers practice land-shifting by burning plants and fallowing, it is hard to sustain a higher yield under the existing conditions.

ii. Mechanized Farming

The adoption of mechanized farming in the existing rain-fed farming area seems to be economically unfeasible unless other inputs are mobilized simultaneously. Land ownership around the village can be appropriately reorganized as in the case of the Semeih cotton corporation programme referred to in 4.03.2.

iii. Shortage of Pasture Land

Tending a large number of livestock, nomadic people move north in the rainy season and return south in the dry season. Along the way they sell some of their livestock at urban markets or to farmers in the villages. Quite similar to the case of farmers, nomads need sufficient pasture land to feed their animals which steadily increase in number. Some policies and programme should be adopted to maintain the pasture for animals or control the number of livestock.

iv. Damage by Blight and Insects

Nematode is a cause of damage to vegetation and often occurs in the region. It is well known that this disease spreads easily on land where crops of the same kind are planted continuously year after year. One method of extermination is the spraying of chemicals on the soil. However, over a vast plain like

that of the project area, the only practical way to get rid of nematode is to apply a sequence of burning, shifting and fallowing on a scheduled basis.

The occasional diseases to livestock in the region are rinderpest, foot and mouth disease, and anthrax. Vaccination, routine observation by veterinary staff, and the establishment of animal check points are necessary to keep the livestock in a healthy condition.

In both sectors of farming and livestock, effective methods to prevent diseases have not yet been widely implemented. They are just commencing on a modest scale. The development of a disease controlling system will be encouraged by the new road construction, while attention should be paid to the possibility that the increased mobility resulting from the new road may increase the chance of diseases being brought into the area.

v. Demonstration Farm

The El Obeid office of the Ministry of Agriculture has already located several demonstration plots through which they can offer guidance to farmers. However, the scale of these activities is small, and the El Obeid office has not yet fixed a plan to develope these demonstration plots into an efficient organization becuase of a shortage of funds.

vi. Agricultural Development Project

There is no particular development project for agriculture and livestock in the project area, although persons concerned in the Government and Province have several ideas for investment to promote the growth of the regional economy. These ideas require study and fund allocation.

Through these study findings, it is concluded that the rural population in the area will grow slowly at a rate of less than 1% per annum and that the economy, consisting of rain-fed farming and livestock production, will grow steadily, similar to its past performance.

4.05.2 Urban Economy

As mentioned in 4.03, CHAPTER IV,the major products of urban manufacturing are the processing of the edible oil of crops grown by traditional methods of cultivation in the rural area. As already mentioned in 4.05.1, agricultural production will not increase rapidly if there are no improvements in the production and marketing systems. Accordingly, it is not likely that a rapid expansion of the outputs and new investment in the processing sector will be seen in near future.

It is also likely that there will be no rapid development in any sector of the service industry. The urban economy in the region will continue to grow at about the same rate as in the past decade.

4.05.3 Development Benefits

By considering the economy at its present stage, development benefits and development traffic will be negligible in relation to the investment in the road project. It has been decided not to quantify the development benefits in the benefit cost analysis.

4.06 Necessity of Associated Development Programmes

Under the current economic performances of the influence zones, it is apparent that associated development programmes are required in order to make use of the road investment to a fuller extent for the growth of the regional economy. The following plans are expected to be included in the studies of development programmes. In the several years before opening the project road, studies should be conducted, programmes prepared and some of them can be commenced.

4.06.1 Cotton Spinning Factories

The region around Nuba mountain in Southern Kordofan Province is one of the major cotton producing areas. Most of the products are ginned by factories in and around the region and exported passing through the southern part of the influence zone. No spinning factories nor other cotton processing factories are seen in the area. New establishment of such factories in the project area should be studied.

4.06.2 Leather Factories

Location of hide and leather processing factories should be studied because of the large number of livestock in areas around the project area. Other processing of the products of the livestock sector should be studied also.

4.06.3 Experimental Farms

There remain various points to be improved in the existing rain-fed farming system. Improvements should be tailored to specific soil and climatic conditions extending to methods of tilling, mulching and contouring, to improved varieties, to disease controls, to the use of fertilizers, to marketing, etc. If experimental farms are established, they will initiate the above improvements.

CHAPTER V

5.00 INVENTORY OF THE EXISTING ROADS

5.01 Road Condition Survey

The project area of this survey is a semi-dry district that conforms to a tropical savannah climate. El Obeid is located 575 m above sea level, Rahad, 496 m and Um Ruaba 450 m. The lay of the land, as a whole, is gently rolling.

On the west side of the road connecting Rahad and Et Taiyara, there are many rocky mountains such as J. Kordofan, 785 m above sea level, and J. El Ain, 759 m. These mountains are also the source of many streams in the area. The east side of the road is links land where dunes are observed every 1 - 2 km running in a south-north direction and approximately 15 - 30 m in height. The west slope of the dune is steeper than the east slope. South of the railway, between Rahad and Um Ruaba, the Abu Habl river runs eastward.

There are two roads between El Obeid and Um Ruaba, as shown in Annex V-1. One is the southward route running along the railway via Rahad and is about 150 km long. This road is utilized mainly during the dry season. The other is the northward route, via Shamagatta, with a length of about 120 km. This road is utilized mainly during the rainy season.

These roads, except in urban areas, are so called multi-choice tracks which are not maintained or repaired, and drivers are often forced to select better alignments.

As shown in Annex V-2, routes I, II and III pass through flat terrain. However, in routes IV and V, gradients of more than 3% are observed at several places due to crossing sand dunes. (ref. Annex V-3 and V-4)

5.01.1 Route I (El Obeid - Rahad, L=75.2 km via Kordofan Hills)

Route I connects El Obeid and Rahad, running along the north-east side of the railway, and has a total length of about 75.2 km. This route is divided into three sections for explanation purposes.

i. El Obeid - El Ain (L=27.3 km)

The starting point is at a T-type intersection in front of the El Obeid railway station. From the starting point, a 6-metre width road runs 2.2 km to the entrance of the airport. The road surface is penetration bituminous pavement and is bumpy. The road intersects with the railways at a point 2.9 km from the station. At the intersection, a sign of railway crossing is installed but no rail crossing or protection facility is provided. Therefore, the crossing is suitable only for vehicles with high ground clearance.

The road runs parallel with the railway for 9.1 km. Vehicles can run at speeds of 40 - 80 km/hr within a 200 m wide zone, selecting the most suitable course. There are no structures at waterway crossing, and during the dry season drivers cross the dry and sand-bottomed watercourse by finding the most suitable crossing point.

At a point km 16 (16 km from the starting point), the road separates into northward and southward courses and goes around the Kordofan hills. The northward course is the main route for large vehicles and ascends to the plateau of Kordofan at a 3% gradient. Between km 18 and km 20 the road becomes sandy. During the rainy season, the road is covered with water and deep ruts are formed.

On the southward route, there are numerous streams flowing down from the Kordofan hills although the gradient is not steep. Between km 22 and km 28 the route is crossed by many watercourses, one of which is the El Baggara river, the largest stream in this project area.

ii. El Ain - Nawa (L=22.2 km)

This road runs along the valley of J. El Ain. Large rocks are scattered on the surrounding slopes, and there is some danger of falling stones. From J. El Ain to Nawa, there is a gentle down grade. The width of the roadway is about 100 m and is deep rutted. Drivers select better routes at their disposal, avoiding the deep ruts formed during the rainy season. At the front of Nawa station, a watercourse, K. Nawa, flows and in the dry season the river bottom is utilized as a road, but driving conditions are poor.

iii. Nawa - Rahad (L=25.7 km)

This road joins another road which connects Rahad and Geifil at km 63. Starting at this junction, and continuing for 6 km, the road surface is fair. There is a gentle down slope which permits driving at 80 - 100 km/hr. Beyond this section, the road continues through a fine sand zone to Rahad.

5.01.2 Route II (El Obeid - Rahad, L=75.8 km via El Ain Reservoir)

i. El Obeid - El Ain (L=31.6 km)

The starting point is the same as Route I. Branching off at the airport entrance on the paved road, the road goes southward on the west side of the railway. About 5 km from the junction, vehicles can run more than 60 km/hr on the so-called multi-choice tracks. From km 8 to km 30 from the starting point a 10 m width earth road continues, which has some indication of surface work by a grader. This section is currently well maintained and repaired by the El Obeid Airport authority which uses it for transporting water from Lake El Ain for an Airport expansion project.

The road runs in the middle of a low, wide ridge up to km 15. This is the best section of this route, and it is not interrupted by crossing waterways. There is an Irish bridge to cross K. Mulbas at km 15, which has a width of 6.7 m and a length of 33 m. The surface is paved by concrete, and the shoulder is protected by gabion.

There is another route from El Obeid to the Irish bridge at K. Mulbas. It runs off at 3 km point on the road from El Obeid to Kadugli and Dilling, passes by the reservoir of Beinu and approaches to the Irish bridge. Although it is an earth road, vehicles can run on it at a speed of 60 - 90 km/hr.

The road meets K. El Baggara at km 31, where there is no crossing structure. According to local drivers, they sometimes can not cross the stream for a long period of two or three weeks during the rainy season, and of course, short waiting occurs frequently at other times.

ii. El Ain - Rahad (L=44.2 km)

This road runs parallel to the railway at its west side. The slope is gentle except for a sudden gradient change at the watercourse crossing. There are two crossings of the railway at km 65 and km 75 but crossing is very difficult since no crossing facility is provided. An Irish bridge was built at km 68 on K. Nawa. However, the structure of the bridge was ruined because of a lack of reinforced bars resulting in water erosion. Vehicles cross on the fine sand river bed instead of on the bridge.

5.01.3 Route III (Rahad - Um Ruaba, L=79.0 km along the railways)

As this route runs across the K. Abu Habl flood plain, it is only available during the dry season. Where sand dunes exist, the gradient of the road increases to 2 - 3% and driving

becomes very difficult due to loose sand. The flood plain is virtually a wide road and generally flat. There are small deep tracks and cracks in this cotton clay plain. The road intersects with the railways at two points near Abu Hamra and near Um Ruaba, on which no crossing facilities are provided.

5.01.4 Route IV (Rahad - Um Ruaba, L=72.5 km hill side)

On this route the road runs among sand dunes and is utilized during the rainy season. Where the road crosses sand dunes of 20 - 30 m height, sections of 3-5% gradient occur frequently. Moreover, on the sand dunes, deep ruts with loose sand are developed which makes driving difficult during the dry season.

Several places, which may turn into ponds during the rainy season, were observed in the valley of the sand dunes. The biggest such pond is at 18 km from Rahad. When necessary, vehicles detour around the pond.

5.01.5 Route V (El Obeid - Um Ruaba, L=114.7 km direct route)

As sand dunes occupy the major portion of this route, the road is mainly utilized in the rainy season and seldom utilized in the dry season.

In the suburbs of El Obeid, about a 2 km length of road, running toward the northeast, has been constructed of only subgrade with an embankment of between 0.5 m and 1.5 m in height. In the vicinity of Um Ruaba, although horizontal alignment is established, there is no base course nor subgrade treatment.

Between El Obeid and Geifil, the land lies flat, and the road surface is hard. Accordingly, driving is comparatively easy. Between Geifil and Um Ruaba, sand dunes similar to Route IV are formed regularly. Due to steep gradients and loose surfaces, the running speed of vehicles is about 20 km/hr in this area. Most villages are scattered around the summit of sand dunes, and the road passes near these villages.

5.01.6 Access Road (Rahad - Et Taiyara, L=40.8 km)

This route is the shortest one between Rahad and Route V, but it is a multi choice road where vehicles are capable of running on fine sand, following tracks. The gradient is gentle. No watercourse is encountered. Thus, vehicles are able to drive at 30-40 km/hr. However, at 13 km from Rahad ponds form during the rainy season.

5.02 Topographic Survey

The Survey Department has supplied a photo mosaic with a scale of 1 : 48,000 covering the project area. By adjusting the scale to 1 : 50,000 the photo mosaic, together with a map of 1 : 250,000, is used for engineering work in the first stage of this study.

The study team was given an airphoto of the southern route at a scale of 1 : 25,000 with a width of 5 km. A topographic map, at a scale of 1 : 5,000, is drawn for a width of 500 m on each side along the best alternative determined by the first stage study. The following ground surveys were conducted to supply necessary data for developing the map.

a) the installation of ground stations

b) the identification of the three triangulation stations of the Survey Department

c) traversing and levelling

d) azimuth observation

e) names of towns, rivers, mountains, etc.

The map to a scale of 1 : 5,000 has contours at 2.0 m intervals. The map on which the designed alignment is drawn, is to be attached to "the Drawings" of this report.

5.03 Soil and Material Survey

5.03.1 Soil

i. General

Soils in the project area have little variety and are classified into five kinds as follows;

a. Dune sand

b. Cotton clay

c. Sandy silt

d. Silty clay

e. Clay

The soil map is attached to Annex V-5. To investigate characteristics of soils as materials for subgrade and embankment, laboratory tests were performed. Samples of the soils were collected at 15 points as shown on the soil map, of which 8 representative samples were entrusted to RBPC laboratory for testing in compliance with AASHTO standards. The results of the test are shown in Annex V-6.

a.	Sieve analysis	(AASHTO T-88)
b.	Specific gravity test	(- " - T-100)
c.	Compaction test	(- " - T-99)
d.	Atterberg limit test	(- " - T-90)
e.	Shrinkage limit test	(- " - T-92)
f.	CBR test	(- " - T-193)

ii. Survey Results

a) Summary of Survey Results

a-1)As material for subgrade of the project road, dune sand and sandy silt are most suitable. Cotton clay, silty clay and clay are less suitable.

a-2)Dune sand and sandy silt are suitable for embankments, but since they are erosive, clay and gravel are recommended for use on the slope as covering for the above materials.

b) Features of Soils

b-1)The area's dune sand is red-brown fine sand of uniform size and is composed of crystalline rocks such as sand stone and granite which originate from the Nubian stratum[1)] of late pleistocene age.

The sand dunes run in a general south-north direction and are stablized at present by plants and sand particles coated by iron oxide. Dune sand belongs to A-3 of AASHTO classification and is suitable for subgrade and embankment materials. AASHTO classification of A-3, together with A-2-4, A-6 and A-7, is shown in Annex V-6. Also, due to easy erosion, slope protection becomes necessary.

b-2)The area's cotton clay is dark grey coloured alluvial clay accumulated on the flood plain of K. Abu Habl. Cotton clay has another name - dark cracking clay. Tortoise shell cracks occur in this layer during the dry season due to shrinkage, while swelling occurs

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Note: 1) Name of stratum of mesozoic era lying in the mid-north zone of the Sudan.

during the rainy season. Organic compounds are partially contained in this clay. A high value of liquid limit and plasticity index are identified. By AASHTO classification, this clay is classified as A-6 or A-7 and not suitable for subgrade or embankment material unless properly treated.

b-3)The area's clay is blue-grey coloured alluvial clay accumulated on low ground between sand dunes. Its properties are about the same as cotton clay.

b-4)The area's sandy silt and silty clay are distributed along the existing routes of I, II, V and a part of the access road. Sandy silt is red-brown or dark red-brown coloured aeolian soil and forms a thin cover over silty clay. Sandy silt contains 20-30% of fine grain with a diameter of less than 0.074 mm. This soil is classified as A-2-4 by AASHTO classification and is suitable material for subgrade and embankment. However, this soil erodes easily and requires slope protection.

b-5)The silty clay is fine grain soil, brown or yellow-grey coloured, involving silt and clay of 40-50%. Similar in nature to cotton clay, the volume of this soil changes considerably. By AASHTO classification, this material belongs to A-6 class and is not recommended as subgrade or embankment material unless suitably treated.

5.03.2 Bridge Foundation

Watercourses in the project area are located at cotton clay or silty clay zones. Bridge construction is considered necessary at the locations including the following points. They are shown in Annex V-5.

1) 7.4 km point from El Obeid
2) K. El Baggara
3) K. Nawa

At the above points, a seismic prospecting was performed to estimate the bearing capacity of the ground since there was no boring equipment in the project area.

The results of the seismic survey are shown in Annex V-7. The ground, on which a bridge construction is planned, is compacted with silty clay and the assumed N value is more than 22. A converted value to the bearing capacity is more than 25 t/m^2, which is considered satisfactory for the spread foundation as designed for this project road. Since the silty clay has a low degree of saturation and is tightly compacted, there will be little settlement due to consolidation.

One point to note is that a similar type of bridge is seen on the railways which has stood with little settlement for more than 50 years.

5.03.3 Materials

i. General

As shown in the location map of materials (ref. Annex V-8), almost all of the construction materials are located in the northwest part of the project area.

To investigate the suitability of rocks and gravel, a survey was conducted to find 15 sample points. Samples selected from these points were entrusted to RBPC to perform the following laboratory tests.

1. Specific gravity test (AASHTO T-100)
2. Los Angeles abrasion test (AASHTO T-96)
3. Absorption test (ASTM D-1228)
4. CBR test (AASHTO T-193)

In addition, as materials for the base course are scarce in the sand dune zone, the following stabilization test was performed in the Soil Mechanics & Foundation Engineering Division, Nihon University.

a) Cement stabilization test

Compaction test	(AASHTO T-134-70)
Unconfined compression test	(ASTM D-1633-63)
Wetting and drying test	(AASHTO T-135-70)

b) Lime stabilization test

Compaction test	(AASHTO T-134-70)
Unconfined compression test	(ASTM D-1633-63)

c) Asphalt stabilization test

Hubbard-Field stability test	(ASTM D-1138-73)
Marshall stability test	(- " - D-1559-75)

ii. Test Results

Test results are shown in Annex V-9 and summarized as follows:

a) Gravel deposits

Gravel deposits are scattered around rocky mountains in the form of pediment [1] or fluviatile deposit and are generally suitable as subbase course material. A gravel deposit at approximate 10 km from El Obeid has ample fine grain components and indicates low CBR value. However, by conducting a mechanical stabilization, these gravels can be used as subbase course material.

There is a gravel pit at J. Abu Uruq which is used for the El Obeid Airport runway construction. Quartz gravels of good quality in deposit of more than 500,000 m^3, are available. They are suitable as base course material by conducting a mechanical stabilization.

b) River bed deposits

River bed deposits near rocky mountains are mainly sand. Specifically, ample coarse sand is available from

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Note: 1) Pediment is an erosive surface of low relief, partly covered by veneer of alluvium or escarpments in arid and semi arid environments.

K. El Baggara. The shape of the sand particles is irregular and angular, and as clay and organic components are minimal, these sands are suitable as fine aggregate for concrete.

c) Rocky Mountains

Rocky mountains are formed with granite of plutonic rock, aplite of dyke rock, pegmatite and schist of metamorphic rock and are generally suitable as aggregates for pavement and concrete, especially recommendable are quartzite and fine grained acidic rock. At J. Dago, hard quartzite gravel is available as a good quality material for use in surface course and in concrete. J. Et Tibna, about 6.0 km north of Semeih, produces good quality material. However, as the trigonometrical station of the Survey Department is located there, no quarrying is allowed.

iii. Stabilization

Since there are few gravel deposits adjacent to the proposed routes in sand dune areas, a stabilization test was performed in order to examine the suitability of stabilized dune sand as base course material. As shown in Annex V-10 the test results in stabilization by asphalt or lime is less effective because dune sand is uniform fine sand. Cement stabilization is effective only when cement is added by more than 6%. It is widely known that 6% or more cement addition causes shrinkage of the layer, which deteriorates the surface course with reflection cracks. It is recognized that the

application of cement stabilization is not suitable in the area. For the estimate of preliminary cost, the use of natural gravel or crushed stone is assumed for all sections of the alternative plans.

5.03.4 Water for Construction

i. General

There are two series of underground water, the Um Ruaba series[1] and the Nawa series[2], which are the major water supply sources for the sand dune zone where no reservoirs exist. Reservoirs are located at the silty clay zone between El Obeid and Rahad, and at the cotton clay zone between Rahad and Um Ruaba. These reservoirs are utilized as water for the populace in El Obeid and Rahad and as water for irrigation at K. Abu Habl basin. Annex V-13 shows the location of reservoirs and wells. Water from the wells is insufficient in quantity for use in the construction of the road.

Water required for construction work can be secured from reservoirs at El Ain and Rahad. The El Ain reservoir is being expanded as noted in Annex IV-14. Capacity will be 5,500,000 m^3 upon completion. The Rahad reservoir has an abundant capacity of 56,000,000 m^3 and is being utilized for local inhabitants, cattle and irrigation, and there is still sufficient remaining for road construction usage.

Notes: 1) Name of stratum at tertiary or quarternary era.
2) Name of stratum at the paleozoic era.

5.04 Hydrological Survey

5.04.1 Climate in the Project Area

The rainy season occurs between June and September in which annual rainfall is about 400 mm. (Ref. Annex V-14) The meteorological elements of El Obeid and of Kosti are shown as follows.

TABLE V-1 CLIMATE IN EL OBEID AND KOSTI (1941-1971)

Location	Item	Month 1	2	3	4	5	6	7	8	9	10	11	12
El Obeid	Rainfall(mm)	0	0	0	2	14	27	113	143	68	19	0	0
	Humidity (%)	16	13	11	12	19	29	47	56	42	23	17	16
	Direction of Wind	N	N	N	N	N	SSW	SSW	SSW	SW	N	N	N
	Temp(C°) Max.	38.6	40.7	42.9	43.0	44.3	42.3	40.0	37.7	39.0	29.7	38.4	37.6
	Temp(C°) Min.	6.4	4.4	9.0	13.0	17.2	17.1	17.3	17.5	17.1	14.5	9.2	5.8
Kosti	Rainfall(mm)	0	0	1	2	16	39	111	142	63	21	1	0
	Humidity (%)	23	18	14	13	21	32	46	57	67	31	23	24
	Direction of Wind	N	N	N	N	N	SSW	SSW	SSW	SSW	N	N	N
	Temp(C°) Max.	40.2	42.2	44.8	45.3	46.0	44.2	41.5	40.2	40.8	41.6	40.8	39.1
	Temp(C°) Min.	10.3	10.6	12.4	14.4	17.0	18.4	18.9	18.9	19.0	18.2	13.1	10.1

Source: Meteorological Department, Sudan, 1977.

5.04.2 Probable Rainfall and Depth Duration Curve

i. Probable daily rainfall

Probable daily rainfall is calculated by the maximum value of the daily rainfall record for each year as shown in Annex V-15. The probable rainfall calculated by the Gumbel method is shown below and in Annex V-16.

Return Period	Maximum Rainfall (mm/day)
10 years	83.0
50 years	110.0

ii. Rainfall intensity formula

The rainfall intensity is strong for short periods in a limited area. The pattern of rainfall intensity is shown as follows:

Duration (min)	1,440	360	120	60	30
Accumulated percentage	100	95	90	86	80

Source: Meteorological Department, Sudan, 1977

Based on this pattern, the intensity is determined by the following formula

$$r = \frac{a}{t + 7.0}$$