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PRE-FEASIBILITY REPORT

for

El Obeid - Nyala Transportation Corridor

Darfur/Kordofan Region, Sudan

November 1987

Prepared for: United States Agency for International Development

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on assignment from USDA - Forest Service

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I. EXECUTIVE SUMMARY.

Sudan has a population of 21 million people and an extensive land area of 2.4 million sq. km. Rainfall varies from 1500 mm per annum in the south to 25 mm per annum in the north. The movement of goods and services, livestock and people back and forth between the east and west has been and continues to be a major concern for the country. In response to these concerns, the Sudanese government has initiated a long term design and construction program for a major all weather transportation system. This system will be responsive to the existing and developing economic needs of the country.

This pre-feasibility report addresses that portion of the developing national Sudan transportation system which runs from El Obeid west to Nyala and will be the connecting link for the primary national east-west roadway.

Many documents, reports, existing road plans and specifications and other information were used as background material. Personal interviews with Sudanese, World Bank and USAID personnel were key in obtaining additional information. Additional input was obtained through a field trip to El Obeid and Nyala to view current construction practices and field conditions. Finally, a trip to the African Center for Remote Sensing in Nairobi, Kenya was made to view the latest satellite imagery over the area and to assess the potential for its use in supporting field operations.

The current east-west rail system west of El Obeid consists of a lightweight, poorly equipped and inadequately maintained railway which runs southwest from El Obeid to En Rahad and then west through Abu Zabad, Babanusa and Ed Da'ein to Nyala. Major washouts are common during the rainy season in the Ed Da'ein area. There are no all weather roads between El Obeid and Nyala. Truck transport is along the many existing tracks which crisscross the approximately 700 km between the cities. These tracks pass through numerous villages. Alternate routes are taken depending on the dry or rainy season, and the trip normally takes seven to ten days. There is a gravel road from Nyala to El Fasher and a paved road from Nyala west to Zalingei.

The economy of western Sudan is based on rain fed agriculture; to grow and sell sorghum, millet, groundnuts, sesame and gum arabic; and the sale of livestock, primarily sheep and cattle. Major marketing and distribution centers in western Sudan are El Fasher, Nyala, En Nahud and El Obeid. Most farmers sell their excess crops in these cities. In addition, large numbers of sheep and cattle are trekked to Omdurman for sale because of greater demand and higher prices. An all weather east-west transport system would expand the market for sedentary

farmers and increase profits from sales at major population centers in eastern Sudan.

Three alternative transportation corridors were evaluated, with El Obeid designated as the starting point and Nyala as the terminus. All pass through En Nahud because of its economic and administrative importance. The Northern Corridor generally follows an existing track through Wad Banda, Dam Gamad, Umm Kaddada to El Fasher and then south over the existing gravel road to Nyala. The Central and Southern Corridors generally follow existing track routes southwest to Ogr. The Central Corridor then goes west, where no well defined tracks exist, to Nyala. The Southern Corridor follows existing tracks southwest to Ed Da'ein and then follows the railway alignment to Nyala. These corridors are shown as appendix material to the report.

Each of the alternatives were evaluated against environmental, construction, maintenance, drainage, water availability and economic considerations. The economic analysis was made along transportation links and user benefits were calculated based on increased market value, reduced transportation costs and; increased market value for crops, reduced transportation cost, decreased mortality and reduced weight loss for livestock. Other private sector benefits including people transport, increased production and health and welfare were analyzed for each alternative. The computed rate of return over a 30 year period for the three alternative corridors was: Central 16.16 percent, Southern 12.35 percent and Northern 11.44 percent. Based on this analysis the Central Corridor is the recommended alternative.

It is recommended that photogrammetry be used to locate and design the road, supported by field survey where major drainages are encountered or where grade and alignment need to be precise. Also, because of the uniform terrain and lack of serious grade controls, greater flexibility in preparing design and contract documents is recommended, which could significantly reduce preconstruction costs. It is further recommended that the construction sequence be divided into five segments from east to west, generally breaking at major cities or points of different construction conditions. Estimated time of total construction is eight years at an estimated cost of LS 480,284,000.

In summary, the analysis documented in this report supports the feasibility of an east-west paved transport system from El Obeid to Nyala. This facility would stimulate the economic growth of western Sudan, provide expanded private sector opportunities and improve the health and welfare of the sedentary and nomadic people in the area.

II. INTRODUCTION

The purpose of this document is to present a pre-feasibility study for several alternative transportation corridors in western Sudan between El Obeid and Nyala. The study was commissioned on behalf of the Sudanese people by the United States Agency for International Development (USAID).

USAID solicited the assistance of the United States Department of Agriculture, Forest Service for technical assistance in preparing this pre-feasibility report. A team composed of three civil engineers and a remote sensing specialist was assembled in Khartoum October 24 thru November 11, 1987. The group possessed extensive experience in the practical application of civil engineering concepts in the planning, design and construction of all weather transportation systems. Team participants were civil engineers Pete Hager, Robert Bowers, Terry Gossard and remote sensing specialist, Ray Allison. Team direction was provided by USAID Chief Engineer, Ken Rikard.

Many documents, reports, studies and other information were used in the assembly of this study. Those documents which provided particularly valuable information and are often quoted by the team include: *The Western Sudan Transport Study*, 1984, produced by the Sudan Ministry of Finance and Economic Planning; the *Staff Appraisal Report Sudan Stock Route Project*, 1984, produced on behalf of the International Fund for Agricultural Development by the World Bank; and the *Sudan Road Survey, An Engineering Analysis of Construction, Maintenance and Vehicle Operation, Final Report*, 1967. Other reference material used are listed as Exhibit A in the Appendix.

Personal interviews were key in obtaining additional information and direction. The following Sudanese and other officials were briefed on the purpose of the study and provided input to the team:

Mr. Hussein Ibrahim, Director of Planning, Department of Roads and Bridges Public Corporation (RBPC) and his deputy, Mr. Osman El Obeid.

Mr. Abdel Rahim Ibrahim, Head of Transport Section/MFEP, Ministry of Planning.

Mr. Mohamed Abdulal, Director, National Remote Sensing Center.

Mr. Abdullah Ahmed Mohamed, Director of Photography, National Survey Department; and his assistant, Mr. Ahmed Muniez El Shihh.

Dr. Adam Mohamed Ahmed, Deputy Director of Darfur.

Mr. Hashim Yousif El Hag, Director General of the National Rural Water Corporation (NRWC).

Mr. El Amein Adam, Manager, NRWC Data Base Office.

Mr. Mohamed Ahmed Ibrahim, Operations Officer, World Bank.

The following USAID officials also provided support to the team during this assignment:

Mickey Feldt, Mohamed Yahia Babiker and Carl Maxwell, Engineering Section; Dr. George Ghobrial, Senior Agronomist, Agriculture Section; Tex Ford, Director, Agricultural Section; Ed Birgells, Associate Director, Projects Office and Azhari Karim, Projects Office.

The team spent two days in the field including stops at El Obeid and Nyala to assess ground conditions in these key areas. A reconnaissance flight was flown from El Obeid to Nyala and return to assess terrain, materials and drainage conditions for the study area. Messrs. Rikard and Feldt accompanied the team during this period. The team also visited the African Center for Remote Sensing in Nairobi, Kenya to evaluate existing remote sensing imagery and discuss opportunities to use remote sensing technology to support this project.

The report contains four primary sections: (1) current situation and project criteria, (2) description of alternative corridors, (3) analysis of alternatives and recommended corridor and (4) project implementation considerations. Existing social, economic and transportation conditions are addressed for the area. Environmental conditions, construction, maintenance, drainage, water availability and economic benefits are described for each alternative corridor. These factors were evaluated along with rate of return projections to arrive at the recommeneded corridor. Project implementation considerations for locations, design and construction procedures are presented, including a proposed sequence for constructing road segments.

Where specific data were lacking, assumptions were made and are documented within the report. Numerous exhibits are also provided as Appendix material to supplement the body of the report. A monetary exchange rate of LS 4.5 = 1 US$ was used, and all references to tons are metric tons.

III. CURRENT SITUATION AND PROJECT CRITERIA

A. SOCIAL AND ECONOMIC

Western Sudan, which consists of the provinces Northern and Southern Darfur and Northern and Southern Kordofan, occupies a total surface area of approximately 377,000 sq. kms. Within this large area there is considerable diversity in the demographic, geographic and climatic features. The most outstanding features common to the entire region are the remoteness from main centers of economic activity, total dependence on fluctuating rainfall for cultivation, scarce drinking water during the dry season, relatively low level of income and poor transport infrastructure. The 1983 population census estimated the total population for these provinces to be 6,585,000, of which only 11 percent was recorded as urban and the rest as either rural or nomadic.

1. Geography And Climate

The climate of western Sudan varies from desert in the north with annual rainfall of less than 25 mm to tropical savannah in the south with more than 900 mm of annual rainfall. There is considerable seasonal variation in rainfall, and there is evidence to suggest either a secular decline in rainfall or at least a downward phase of a long term rainfall cycle. This, combined with overgrazing and overextraction of trees for fuel, has led to the southward creep of the desert; a process which appears to have been accelerated in the last few years. Desertification is now perceived as probably the major problem faced by the region. One effect of desertification has been to stimulate a southward migration of population.

Western Sudan can be divided into a number of broad geographical/climatic regions starting with the desert in the north of the region, between latitude 20°N - 16°N, covering approximately 19 percent of western Sudan's land. The semidesert region extends between latitude 16°N - 13°N, covering approximately 21 percent of the region. The third region is characterized by low rainfall and savannah woodland vegetation and extends between latitude 13°N -8°N, covering approximately 60 percent of the area.

There are four main soil types. The sandy soils are found mainly in the northern part of the savannah area. The cracking clays, commonly called "black cotton", found mainly in South Kordofan are fertile and can be cultivated by both traditional and mechanized means. The noncracking clays (nagaa soils) found mainly in South Darfur are infertile and are not cultivable by traditional methods.

The gardad soils found in the west are productive when cultived by mechanical means. Most of western Sudan is flat or undulating, but important exceptions are found in Jebel Marra and the Nuba Mountains.

2. Population

The estimated population of western Sudan by 1983 reached a level of 6,585,000, forming 30 percent of the total estimated population of the country. A detailed breakdown is shown in Table 1.

TABLE 1

REGIONAL PUPULATION DISTRIBUTION ESTIMATES

	1983 (000)	Annual Growth (%)	1990 (est.) (000)
Darfur Region	3,093	2.9	3,779
Kordofan Region	3,092	2.9	3,779
Total Western Sudan	6,585	2.9	7,558
Total Sudan	21,584	3.0	28,059

SOURCE: Department of Statistics

The majority of population in western Sudan is rural. The 1983 population census suggests that the breakdown of urban and rural population in the region was 11 percent and 89 percent respectively. Nomads form about 20 percent of the region's population. World Bank Report No. 6491-SU states that western Sudan population has increased by 1.2 million due to drought refugees from other countries.

A number of significant urban centers have developed serving regional, provincial and local needs. El Obeid and Nyala are by far the most important centers, providing not only services for the immediate surrounding areas but also acting as central marketing distribution points for Kordofan and Darfur respectively. El Fasher, El Geneina, Kadugli and En Nahud have important administrative functions under the new regional/provincial structure besides being important distribution centers. En Nahud is also a primary market for agricultural surpluses and a major seed oil processing center. The following table shows major urban centers in western Sudan with their 1983 population.

TABLE 2

URBAN CENTERS IN WESTERN SUDAN

North Kordofan	Population (000)	South Kordofan	Population (000)
El Obeid	140	Kadugli	43
En Nahud	31	Dilling	25
Um Ruwaba	27	Babanusa	19
Er Rahad	16	Abu Gebeiha	15
Bara	11	Muglad	13
Abu Zabad	10	Abbasiva	8
Sodari	4	Others (5)	4
Total	239	Total	127
North Darfur		South Darfur	
El Fasher	87	Nyala	125
El Geneina	56	Ed Da'ein	31
Kutum	10	Zalinge	18
Um Kaddada	7	Total	174
Total	160		

3. Economy

The economy of western Sudan is almost totally dependent on rain fed agriculture, which remains the dominate economic activity for the foreseeable future. Industrial production, except for oilseed processing and cotton ginning, is very limited and does not contribute much to the economy. The potential for rain fed production in western Sudan is exploited under a number of different types of socio-economic systems:

- Nomadic groups who move north-south in the region taking advantage of the available grazing.

- Seminomadic groups who combine some crop production with herding and a division of labor within social groups.

- Sedentary traditional farmers cultivating basic food crops and a cash crop, generally oil seeds.

Mechanized farming is increasing in Sudan, but nearly all activities are located east of this project. Most of the agriculture served by this project fall within the category of semisubsistance agriculture, producing food grains as well as cash crops. In all systems livestock plays a very important role. Livestock contributes a very substantial portion of total farmer income.

It is estimated that improvement in public health and welfare would improve the productivity of the people and their average income would increase.

4. Production

a. Crops

Crop production in the region is almost entirely dependent on rainfall, which fluctuates considerably from year to year. Analysis of the recent past shows that for every five years the rainfall, and consequently the agricultural production, is excellent for one year, average for two years and below average for two years. But no one can forecast which year is going to fall in which category and in what order these good or bad harvest are likely to occur. Thus, no dependable pattern of transport demand can be projected for western Sudan. Table 3 represents two situations: (1) bumper harvests (high base) which result in large marketable surpluses and enhanced regional incomes, and consequently greater demand for consumer and development goods and (2) below average (low base) harvests which reduce marketable surpluses of cash crops, cause inward movement of food grains to meet shortages and result in seriously reduced regional incomes and consequently depressed demand for consumers and producer goods. Most of the sesame, gum arabic, cotton and groundnuts are either exported or marketed outside the area.

TABLE 3

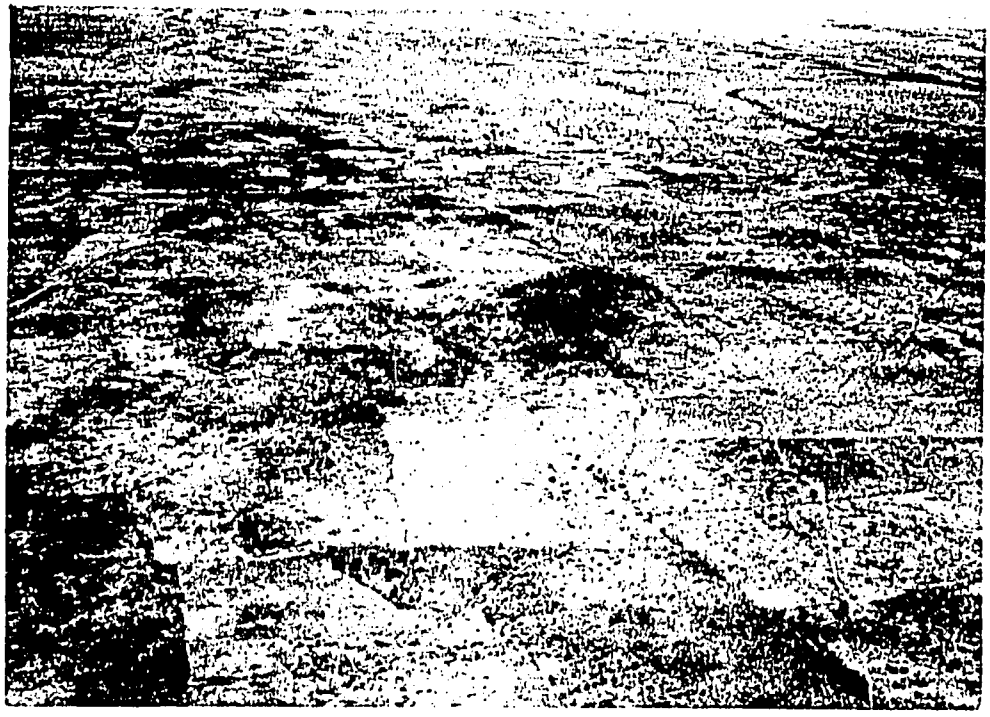
ACTUAL AND PROJECTED PRODUCTION OF MAJOR CROPS IN WESTERN SUDAN (000 TONS)

	1981/82 HIGH BASE	5 YEARS AVERAGE LOW BASE	PROJECTIONS 1991/92 HIGH	LOW	ACTUAL 1986/87	EST. VAL. 1987 LS(000)
Sorghum	465	217	570	270	137	246,247
Dukn (Millet)	480	318	510	320	254	442,570
Groundnuts	464	288	490	330	199	644,116
Sesame	112	73	120	90	74	257,263
Gum Arabic	32	33	50	49	44	1,538,200
Cotton	5	6	18	6	6	22,048
Total	1,558	935	1,758	1,065	714	2,150,440

The estimated value of goods exported and marketed outside the area is 1,460,627 LS(000)

Source: World Bank Report 6491-SU and Study Computations

TYPICAL VILLAGE



FARMING PRACTICES

For purposes of this analysis the average imports and exports were used to project annual savings (see Table 4). However, a major benefit of the project is the ability to distribute emergency relief supplies via trucks rather than helicopters during extreme drought periods. It is estimated there is approximately a 500,000 ton difference in crop production and area consumption needs during these drought periods. The World Bank estimated that approximately 975,000 tons of relief were provided in the 1982-1984 drought.

TABLE 4

PROJECTION OF FARM CROP AND INDUSTRIAL FLOWS
TO AND FROM THE REGION

WESTERN SUDAN 1991/92 (000 TONS)

CATEGORY	HIGH	LOW	AVERAGE
Imports	550	500	525*
Exports	678	475	575

* Does not include emergency relief commodities.

It is estimated that the above average exports will be increased by 20 percent because of improved access to currently unmarketable commodities and modernized farming practices. The total exports would then be 690,000 tons.

b. Livestock

The Staff Appraisal Report, Sudan Stock Route Project indicates there are 6,400,000 cattle, 8,000,000 sheep, 3,390,000 goats and 1,350,000 camels in western Sudan. Table 6 of the same report shows that approximately 158,000 cattle and 471,000 sheep are marketed in the Khartoum area (Omdurman) or exported. Goat surpluses are reduced by local consumption and most camel exports are to Egypt and are transported by trekking.

Trekking costs for 1983 from Nyala to Omdurman range from LS 38 to LS 138 per animal for cattle and LS 9 to LS 29 per animal for sheep, or about LS 0.11/km for cattle and about LS 0.017/km for sheep. Completion of the Stock Route Project will provide improved conditions along the project corridor, so trekking costs should be reduced. Upon completion of the Rail Upgrading Project, it is estimated that approximately 20 percent of the sheep will be transported by rail, leaving 377,000 sheep and 158,000 cattle to be hauled by truck or trekked. It is estimated that 50 percent of those would be hauled to market by truck over this project at an average rate of LS 0.17/km/ton.

Meat demand in Khartoum fluctuates during the year with peaks coinciding with festivals, but supplies do not coincide with demand causing price fluctuations in the local market. Current sheep prices varied between LS 260 and LS 325 per animal and cattle prices varied between LS 1,200 and LS 1,500 per animal at El Obeid and Ed Nahud. Table 8 in the Stock Route Project Report shows a 63 percent increase for cattle and a 77 percent increase for sheep marketed in Omdurman versus Nyala. Implementation of this project would level variations due to location of the market and should result in increased revenues to the owners of LS 100 for sheep and LS 390 for cattle, after finishing costs. It is also estimated that mortality would be half the 4 to 5 percent mortality experienced from trekking, and weight loss would be reduced from 10 percent for trekking to 5 percent for hauling by truck. These savings are the equivalent of 4,190 cattle and 10,840 sheep annually.

Table 5 summarizes the estimated savings in livestock losses if the project was implemented.

TABLE 5

Benefits (LS per animal)

ITEM	SHEEP 1987	CATTLE 1987
Market leveling	100	390
Mortality and weight loss	20	107
Total	120	497

B. TRANSPORTATION

1. Railways

Railway construction in Sudan was undertaken during 1895-1914 when the original lines were constructed from Wadi Halfa and Port Sudan to Khartoum. Sennar was connected to Khartoum by 1909 and the rail line reached El Obeid by 1911. The second phase started in 1954 and a number of branch lines were constructed, often using track reclaimed from the older parts of the system. During this phase the western link to Babanousa and Nyala was completed by 1959 and the southern spur to Wau was finished in 1961.

A large part of the railway within western Sudan is, therefore, of relatively recent construction. Unfortunately, it was constructed as a light railway track with limited drainage structures, poor embankments and little ballasting. Therefore, it

suffers from frequent washouts during the rainy seasons and is subject to severe speed and load restrictions.

The rail track between Kosti and Nyala provides the main transport link between western Sudan and Khartoum/Port Sudan. Historically the railway carried almost all long distance traffic, but its importance has declined in recent years.

2. Roads

Western Sudan has a limited system of engineered all weather roads but does have an extensive system of established track routes used by trucks, light vehicles and foot traffic. The track network in western Sudan can be categorized into two functional groups; the east-west corridor and north-south connecting links.

A paved road from Nyala west to Zalingei exists at the western end of the corridor.

A gravel surfaced road exists from Nyala north to El Fasher, also at the western end of the corridor. A gravel road on the north-south corridor runs south from El Obeid 103 km to Ed Debibat and continues on as a paved road 196 km through Dilling to Kadugli.

a. East-West Corridor and the Transportation Needs

The main east-west corridor runs parallel to the rail route for approximately 440 km from Khartoum south to Sennar and then west to El Obeid. Current construction of a paved road from Kosti to El Obeid will provide all weather access from Port Sudan to Khartoum and El Obeid. From El Obeid west to En Nahud (216 km) the corridor runs approximately 80 km north of and roughly parallel to the rail route on unimproved tracks. The tracks then take several different routes the remaining distance to Nyala, the shortest of which is approximately 500 km. Depending on weather and products hauled, trucks generally take a south route in dry conditions or a north route if wet conditions exist. The north route of El Fasher is sandy material and is stable when wet, but loose and soft when dry. Trucks will take the fastest, most economical route possible in order to save time and equipment. The south route in dry weather provides the fastest, most comfortable route because it generally passes through clay/silt areas from Ed Da'ein to Nyala. The short route seems to be used intermittently depending entirely on weather conditions.

b. Track Routes

Following is a description of the major existing track routes west of El Obeid. Locations are numbered and shown in Exhibit B in the Appendix.

(1) El Obeid - En Nahud

This is an important track in the main interregional network because it links the Regional Capitol, El Obeid, with the Provincial Capitol at En Nahud. The track covers 216 km through flat to gently rolling terrain with sheet sand and clay materials.

(2) En Nahud - Um Kaddada - El Fasher

This is the north link covering 406 km and is a sandy track with few wadi crossings. An improved IO km stretch exists near El Fasher.

(3) En Nahud - Babanousa - Ed Da'ein

This is the southernmost link covering 374 km and is utilized by trucks supplying Babanusa and collecting agricultural output at El Odayia. The track is used year round but becomes difficult in wet seasons because of clay sections.

(4) El Fasher - Nyala

This is an existing gravel road 199 km in length and connects the Regional Capitol at El Fasher to the Provincial Capitol, Nyala. Some sections are subject to washouts during wet conditions, but the road is maintainable. There is some concern that a few Irish crossings may require replacement with bridges to prevent washout if the road were to be paved.

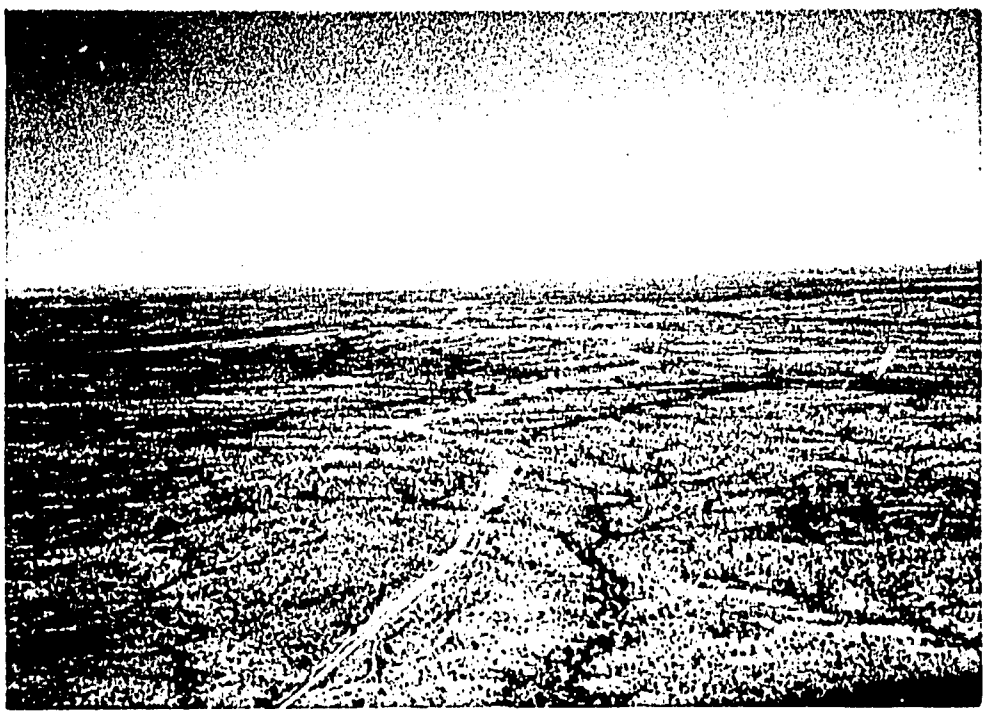
(5) Ed Da'ein - Nyala

This is an important link 209 km long. It passes through sandy and clay/silt areas, which are deeply rutted, and causes problems in wet seasons. Trucks pass throughout the year but may take several days during the rains.

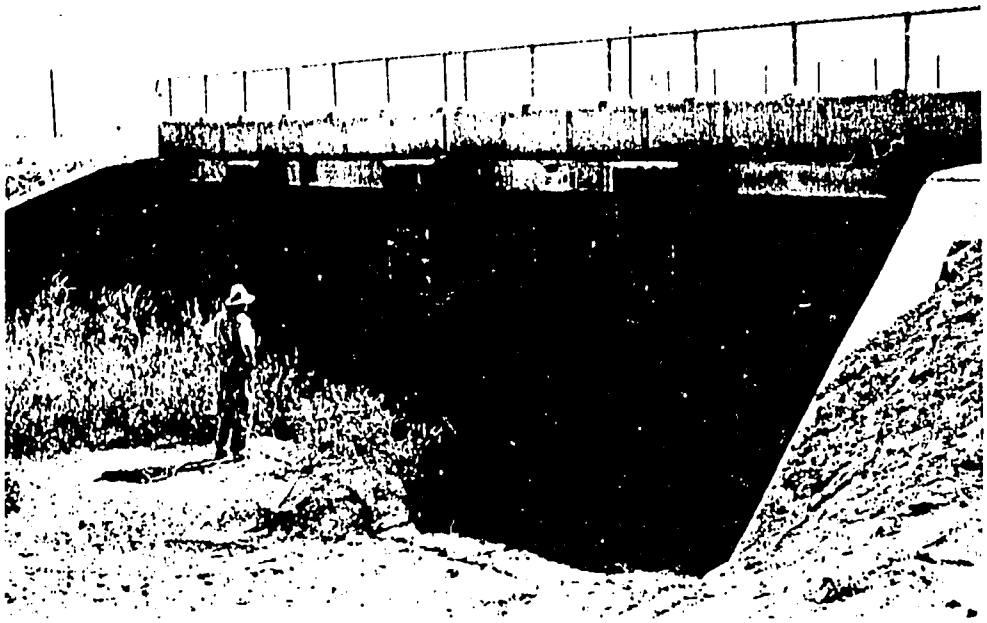
(6) En Nahud - Ogr - Ed Da'ein - Nyala

This is the most direct route and is approximately 500 km long. This route saves about 175 km from the north route and nearly 150 km from the southern route. It is mainly sandy track with clay/silt patches which are deeply rutted in wet weather. The track joins the southern route for the last 209 km from Ed Da'ein to Nyala.

PAVED ROAD WEST: NYALA - ZALINGEI

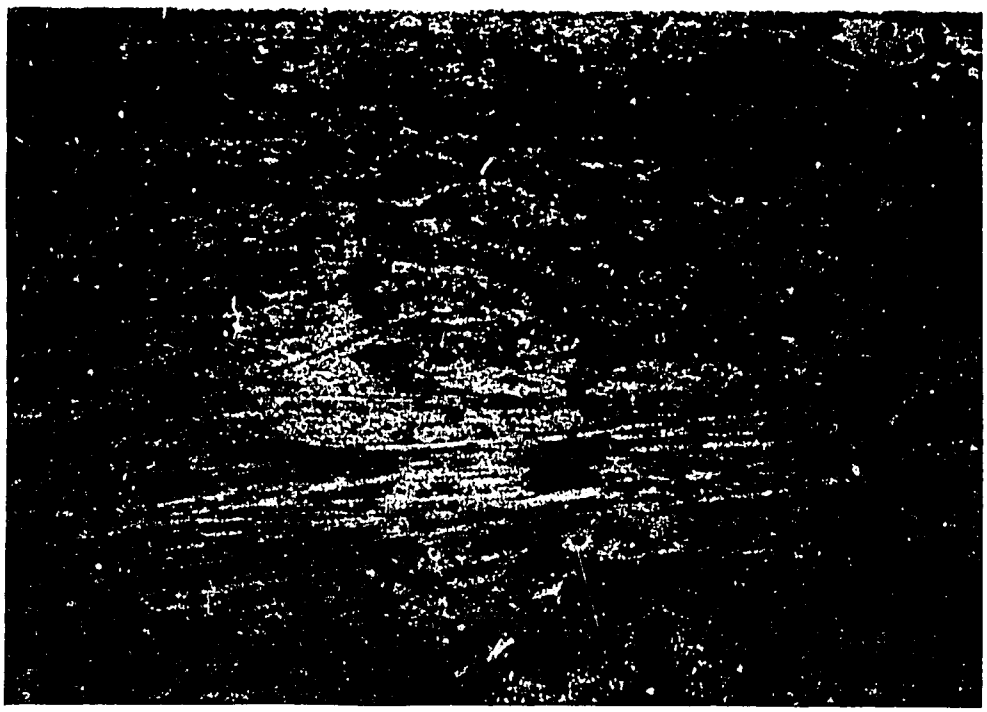


GRAVEL ROAD NORTH: NYALA - EL FASHER

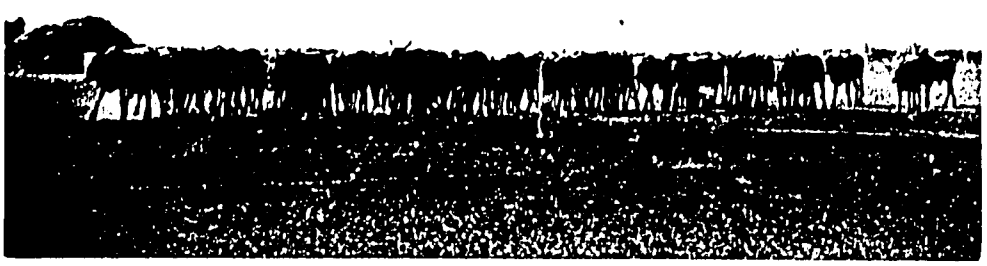


TYPICAL BRIDGE SITE

TYPICAL CULVERT



TRACK ROAD TRAFFIC



TREKKING CATTLE

c. Traffic Flow

Traffic flows throughout western Sudan are light, resulting from the dispersed distribution of population and production. At low levels of traffic, considerable variations in daily traffic flows can be expected. Consequently, in undertaking traffic analysis on these roads other information such as observer counts were incorporated whenever available. Table 6 shows average daily traffic flow for trucks between major population centers in western Sudan. A review of the July 1987 Road Toll Feasibility Study confirms the Nyala - El Fasher truck traffic, but shows twice as much truck traffic between Nyala and El Obeid.

TABLE 6

ORIGIN/DESTINATION MATRIX
AVERAGE DAILY TRAFFIC FLOW (TRUCKS), 1983

	El Obeid	Kadugli	En Nahud	Ed Da'ein	Nyala El	Fasher	Total
El Obeid	-	17.50	26.71	3.34	1.13	0.17	48.85
Kadugli	14.00	-	-	-	-	-	14.00
En Nahud	35.38	-	-	1.50	-	3.99	40.87
Ed Da'ein	2.17	-	1.50	-	24.5	2.75	30.92
Nyala	1.26	-	1.50	16.00	-	15.00	33.76
El Fasher	0.84	-	1.41	1.20	8.5	-	11.95
Total	53.65	17.50	31.12	22.04	34.13	21.91	180.35

(Portion of Table 12 of Western Sudan Transport Study, 1984)

d. Traffic Projections and Vehicle Mixes

Louis Berger International,Inc., estimated in their Economic Reappraisal report for the Kosti - El Obeid Road that there would be a 10 to 20 percent increase in average daily passenger traffic the first year due to the construction of the road. Their estimate was that generated traffic would be in the form of bus, passenger car and pick-up truck traffic. The report further estimated that passenger traffic and freight traffic would increase at a rate of 5 percent per year. This is a conservative estimate based on uncertainties in an economic situation which is not expected to improve much in the foreseeable future.

Vehicle mix, which is now 90 percent medium truck, will change by 1997 to 43 percent medium truck, 10 percent buses, 29 percent passenger cars and 18 percent large trucks.

a. For the purpose of this report, traffic and passenger benefits are accounted for in the metric tonnage and numbers of livestock traveling a link. Benefits are

derived by calculating the savings that would be realized by the user based on the change in cost between the current situation and providing a fully surfaced road.

e. Road Transport Rates

The current road transport rates used in this report were obtained from the Toll Road Feasibility Study, July 1987. The Western Transport Study emphasized that rates vary according to the time of year and state of the market. During the peak season when rail capacity is insufficient or when a bumper harvest takes place, export rates rise considerably. On the connector links, costs rise sharply during the wet season when travel conditions are poor and many vehicles are taken off the road for annual overhaul. Wet season rates were often quoted as double the dry season rate.

There are four main forwarding points for east-west traffic; Port Sudan, Khartoum/Omdurman, Kosti and El Obeid. El Obeid is an important railhead and acts as an important distribution center. Rates from Port Sudan and Khartoum are lower on a ton/km basis than rates from Kosti or El Obeid. This reflects the proportion of the trip made on paved roads. Freight rate structure along the corridor results from the marked imbalance in traffic; truckers attempt to recover round trip costs on the inward journey and charge whatever they can obtain on the backhaul. In many cases trucks return from the west with no cargo. Return rates must be close to the marginal costs of returning loaded rather than empty. Passenger rates depend upon whether the passenger travels inside the cab or on the back of the truck. It is clear that even carrying a few passengers can make a substantial difference to the financial profitability of a trip, easily covering the apparent loss in the freight rate.

f. Vehicle Operating Costs

The following vehicle operating costs were used in this study. It is a reproduction of Table 8 in the Toll Road Feasibility Study, July 1987.

THE VEHICLE OPERATING COSTS BY TYPE OF ROAD AND VEHICLE (ECONOMIC ESTIMATES)
LS PER 1000 KM

	Type of Vehicle						
	Light Veh.	Bus 2 Axle	Truck 2 Axle	Truck 3 Axle	Truck 4 Axle	Truck 5 Axle	Truck 6 Axle
Paved Road	542	1305	1178	1307	2725	2855	3191
Gravel Road	629	1592	1437	1594	3324	3483	3893
Good Hard Sand Track	753	1931	1720	1908	4115	4311	4318
Loose Sand Track	911	2584	2332	2587	5913	6195	6924
Corrugated Track	954	2806	2509	2784	6295	6595	7371
Clay Track Rainy Season	1014	3145	2827	3137	7358	7709	8616

g. Construction Costs

The Ministry of Finance and Economic Planning's Road Toll Feasibility Study estimates road construction costs for a road section containing double bituminous surface treatment, 6 m wide with 2.0 m shoulders, at LS 370,000 per km for the El Obeid to En Nahud section and LS 645,000 per km for the En Nahud to Nyala Section.

Experience has shown that the heavy loads imposed on the road with this type of surface will begin to destroy the investment in a very short time and accelerate maintenance costs to a high level. The substitution of 5 cm thick asphaltic concrete in lieu of double bituminous surface treatment will increase the cost estimate to LS 703,500/km, but will reduce the maintenance costs over the economic life of the project. It is projected that a 30 to 40 percent savings will be realized in the first 6 to 8 years alone.

The Western Sudan Transport Study analyzed feeder links and found that to provide basic access the cost would be 10 percent of the cost of a paved road on the same alignment. Nothing has changed in the four years that have passed since the report was published that would indicate anything different.

h. Road Maintenance Cost Considerations

With few exceptions, the existing tracks are not maintained to any standard of roadway templet nor do the tracks receive any attention to assure drainage and erosion protection. On most tracks it is impractible, if not impossible to perform maintenance in dry sand or wet clays.

Any expansion of the existing paved and improved roads in the area will necessitate substantial increases in the road maintenance budgeted for the area. The increase will be necessary if the initial investments are to be protected and estimated user benefits are to be realized over the life of the project.

The maintenance costs identified in the July 1987 Road Toll Feasibility Study were LS 12,600 per km (adjusted to October 1987 price index)for the Nyala to Zalingei paved road. Routine maintenance and patching are annual expenditures and the cost for sealing and overlay are annualized for the purpose of this pre-feasibility study.

IV. ALTERNATIVE CORRIDORS

GENERAL DISCUSSION

This pre-feasibility study considered two transportation corridors between El Obeid to En Nahud; (1) a direct route 216 km from El Obeid to En Nahud and (2) a route along the existing gravel road south out of El Obeid towards Kadugli, a distance of 50 km, then west a distance of 180 km.

Three alternative corridors were considered from En Nahud west. They are:

En Nahud to El Fasher to Nyala (Northern)

En Nahud to Ogr to Nyala (Central)

En Nahud to Ogr to Ed Da'ein to Nyala (Southern)

All alternatives were analyzed using the following criteria:

- The running surface will be asphalt paved 7 meters wide. The roadway shoulders will be sealed gravel surface 1.5 meters wide. Drainage crossings will be all weather.

- Sand embankments will have a cement treated base course. All other embankments will have a crushed agregate base course.

- Most livestock originate in the northern provinces of the study areas.

- Most crops originate in the southern provinces of the study area.

- Crops and livestock entering the transportation orridor will do so at a uniform rate along the corridor.

- Summary of products to be hauled on the project:

  70% of the average annual imports (see Table 4) - 368,000 metric tons.

  70% of the average annual exports (see Table 4) - 403,000 tons.

  50% of the average annual sheep marketed - 189,000 head

  50% of the average annual cattle marketed - 79,000 head

- Average increase in value per animal transported due to better market, reduced mortality rate and weight loss costs is LS 120 for sheep and LS 497 for cattle (see Table 5).

- 25 sheep equal 1 ton and 3 cattle equal 1 ton

An economic analysis was made of each alternative using the following

criteria to determine the benefits of the project. The project was divided into transportation links, and combinations of links formed each alternative (see Exhibit C in Appendix). Benefits are based on the premise that it costs less to transport crops and livestock to market trucked on a paved road versus trucked on a dirt track and/or trekking. Timely response to market conditions and reduction in losses suffered through mortality or spoilage have a value, and there will be increased production due to improved methods available because of the paved road. The improvement of the resident workforce, health and welfare will improve their productivity. The formula for determining the benefits by link is:

$$B = (\%L \times S \times Vs) + (\%L \times C \times Vc) + (\%L \times C/3 \times (D1/2 + D2)\ Fc) + (\%L \times S/25 \times (D1/2 + D2)\ Fs) + (\%Cr \times IE \times (D1/2 + D2)\ Ft) - (\%Cr \times IE/2 \times (D1/D2 + D2)\ Fa) - (\%Cr \times IE/2 \times (D1/2 + D2)\ Fb$$

Where: B = Benefits

- %L is the percentage of the total livestock to be transported.

- S is the total sheep to be transported by truck.

- Vs is the increased value of sheep transported by truck.

- C is the total number of cattle to be transported by truck.

- Vc is the increased value of cattle transported by truck.

- D1 is the distance of the link in km.

- D2 is the sum of the distances of all adjoining links east to El Obeid

- %Cr is the percentage of total crops to be transported.

- Fc is the saving in haul costs per ton vs. trekking costs for cattle.

- Fs is the savings in haul costs per ton vs. trekking costs for sheep.

- IE is tons of import and export to be trucked over the project.

- Ft is cost per ton per km of trucking on an existing track.

- Fa is the cost per ton per km of trucking on a paved road using a 6 ton truck.

- Fb is the cost per ton per km of trucking on pavement using a 25 ton truck.

- Vc and Vs were computed by converting the trekking cost in the Stock Project Report to the October 1987 index in LS per ton, then subtracting the LS .17 per ton trucking cost computed in this report.

The summary of the results from the above computations for each link is shown in Exhibit H-1 of the Appendix. These results, along with construction and maintenance costs, were analyzed using the software package Civil Tools (CAW, Inc.) to compute rate of return for each alternative. Results are discussed in Section V.

A. EL OBEID TO EN NAHUD

The direct route was chosen for the following reasons: (1) it is historical route between Regional Capitol in El Obeid and Provincial Capitol in En Nahud; (2) it follows the primary trekking route for cattle and sheep; (30 existing wells and those being constructed through the Stock Route Project appear adequate for providing water for construction as well as livestock; and (4) En Nahud has major oilseed processing facilities and the project would facilitate exports.

1. Environmental Conditions

The route between El Obeid and En Nahud, a distance of approximately 216 km, passes in the vicinity of several small villages. This route is currently being used as a major east-west corridor for the movement of people, goods and livestock. It is characterized by vast homogenous areas of sandstone type soils with the prevalent vegetation type savannah woodland. Rainfall annually is approximately 400 mm. In addition to the sedentary population in the villages, the area includes both seminomadic and nomadic groups.

2. Technical Considerations

a. Construction Considerations

The route is primarily in the Nubian sandstone formation highly weathered with sandstone outcrops, sand dunes and some sheet sand. The sand material is locally called qoz sand and classifies as a borderline A-2-4 and A-3 soil. The qoz has sufficient structural bearing capacity when confined and is rated good when used as subbase material. Addition of additives to stabilize or a layer of filter fabric to separate subbase and base materials will be required. Stabilization will require a minimum of 5 percent cement or 6 percent cutback asphalt and a high degree of mix control.

The embankments need to be constructed with a 10:1 side slope in order

to allow a self-cleaning pavement. Surface slopes steeper than 10:1 will allow deposits of sand to accumulate. If stabilized qoz is used for base material, road shoulders will require a seal coat to control shoulder and embankment erosion.

Although there are outcrops of sandstone, it is not good base material nor suitable for embankment construction. Any aggregate needed for base or pavements will have to be imported from existing quarries or developed as a part of the project.

The first 40 km is in the undifferentiated schist group and will require very little embankment. A stable road can be achieved by placement of 15 cm to 20 cm of aggregate base and 5 cm of asphaltic concrete pavement.

b. Maintenance Considerations

This link will require a maintenance work station at En Nahud; one already exists at El Obeid. The major maintenance problems will be with blowing sand, shoulder erosion and plugged drainage facilities. The entire length will require sealing in six to eight years following construction to protect the initial investment.

c. Drainage Considerations

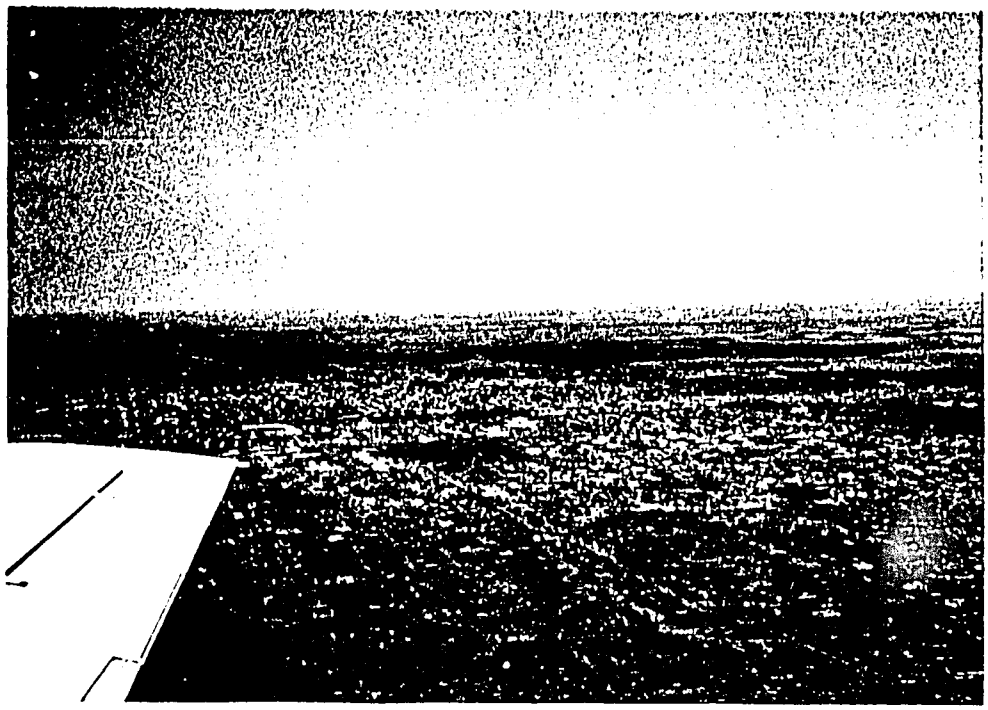
Along the existing track road there are no well defined drains. There are two broad wadis approximately 1.5 - 2.0 km wide with meandering channels. Culverts can be used to control the runoff and protect the roadway in these areas.

d. Water Availability

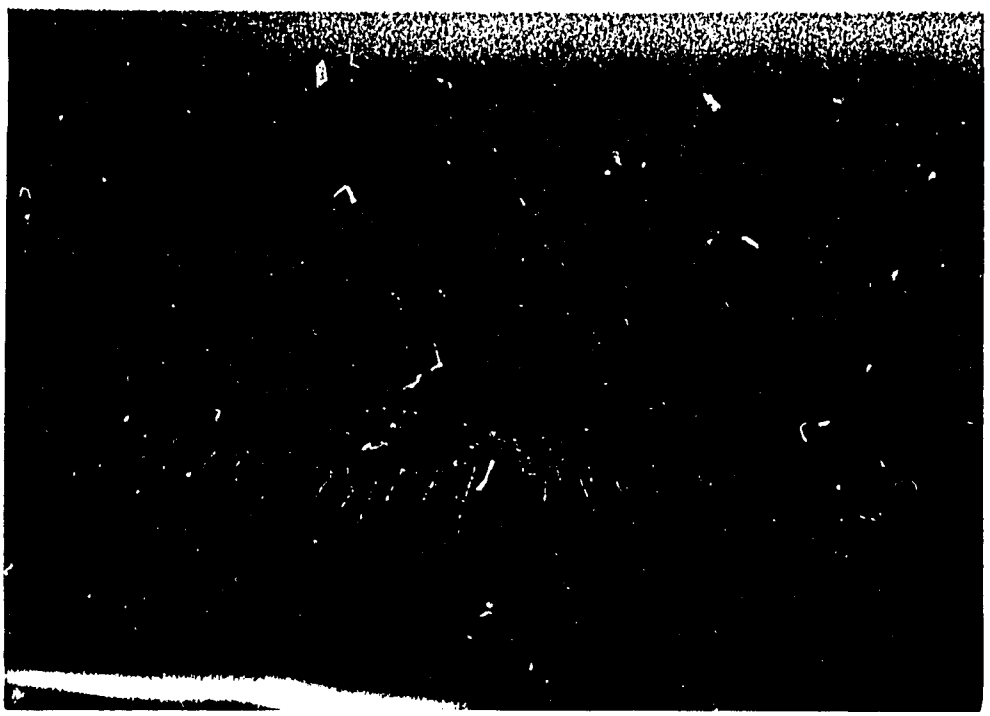
This route follows the main traditional stock route used to trek livestock through En Nahud and El Obeid to Omdurman. Surface water is normally available between August and November, and existing boreholes are used during the dry season in competition with the sedentary population. There are four new boreholes being constructed along this route as part of the Sudan Stock Route Project. Public water systems exist in the cities of El Obeid and En Nahud. In addition, much of the route lies over the Nubian sandstone formation, which contains the best acquifers in Sudan and would make drilling additional wells feasible if needed.

3. Economic Considerations

This corridor link will be the eastern connector to all three alternative corridors. It is estimated it will serve as a transportation head for 32 percent of crop exports and imports and 32 percent of marketed livestock.



EL OBEID



EN NAHUD

No economic return was computed for this segment alone since it is a link in all the alternative corridors. Construction of this link, in conjunction with the rest of the links in the selected alternative, will significantly contribute to private sector development in El Obeid and En Nahud, with a combined population of 171,000 people.

B. NORTHERN CORRIDOR (EN NAHUD TO EL FASHER TO NYALA)

1. Environmental Conditions

The northern route runs from En Nahud in the east to El Fasher in the west and then follows the existing road south to Nyala, a total distance of approximately 600 km. The route passes in the vacinity of several sizeable villages such as Wad Bandah, Umm Kaddadah and Khurayt. Both nomadic and seminomadic groups are present. Rainfall is approximately 300 mm per annum. The principle vegetation type is savannah woodland. Scattered cultivated fields occupy 10 to 15 percent of the land use in the eastern portion of the route, with cultivation increasing to approximately 20 percent in the El Fasher to Nyala portion of the route.

2. Technical Considerations

a. Construction Considerations

The first 320 km of this route would pass through the Nubian sandstone formation with outcrops, sand dunes and sheet sands. The road construction will require the same considerations for this first section as those in the El Obeid to En Nahud link. East of El Fasher 100 km the road would pass through schist and gneiss groups with outcrops. These groups are in the A-2-4 classification. They are granular materials with soil and are good to excellent for use as embankments and subbase materials. The base material for the pavement structure should be crushed aggregate 15 to 20 cm in depth with 15 to 20 cm of controlled compaction subbase. The first 320 km will require imported aggregate to be used as base material or will require sand stabilization.

The last 199 km from El Fasher to Nyala has an existing improved road with Irish crossings at major drainages. The road is gravel surfaced and will require an additional 10 to 20 cm of aggregate and 5 cm of asphaltic concrete. Existing Irish crossings may need to be replaced with bridges to provide an all weather facility and to lower maintenance costs caused by major washouts. There are adequate sources for crushed aggregate near El Fasher; therefore, haul is not a big factor for construction in the El Fasher area.

b. Maintenance Considerations

Maintenance compounds will be needed approximately every 200 km and will be located at En Nahud, Umm Kaddadah and El Fasher. Construction costs increase approximately LS 90,000/km average due to maintenance compounds. There are existing compounds at El Obeid and Nyala. There will be problems with blowing sand and shoulder erosion in the first 320 Km. The remainder should not have any major maintenance problems beyond routine drainage clearing and repair of washouts. The entire length will require sealing in six to eight years following construction to protect the initial investment.

c. Drainage Considerations

There are no major drainage basins or wadis along this route between En Nahud and El Fasher. Approximately six well defined intermittant drains will require CMPs and small bridges. The only other drainage requirements for this section appear to be those necessary for relief drainage along the roadway itself. Drainage considerations for the section between El Fasher and Nyala were discussed under Construction Considerations.

d. Water Availability

Much of this route overlays the Nubian sandstone formation. Yields less than those available between El Obeid and En Nahud can be expected since annual rainfall decreases rapidly in the northerly direction. The basement complex geology along the 100 km east of El Fasher contains little ground water. Exploitation in these impervious rocks has been restrained due to the uncertainties of finding water in sufficient quantities for general use or consumption. Also, surface water will be less plentiful and available for shorter periods of time. There is water available in the villages along this route but most is needed for the sedentary population. This route is not a major trekking route, and no new boreholes are planned as part of the existing Stock Route Project. Public water systems exist at El Fasher and Nyala.

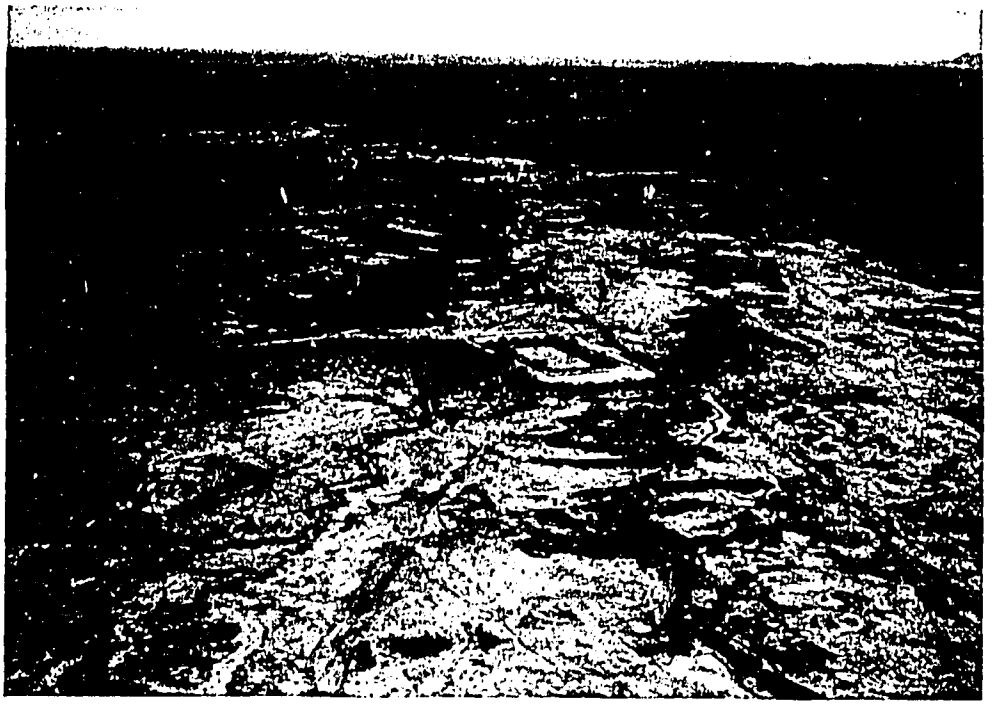
3. Economic Considerations

It is estimated that the En Nahud to El Fasher link will serve as a transportation head for 50 percent of the livestock and 10 percent of the crop imports and exports. The existing road from El Fasher to Nyala will serve as the transportation head for 18 percent of the livestock and 58 percent of the crops.

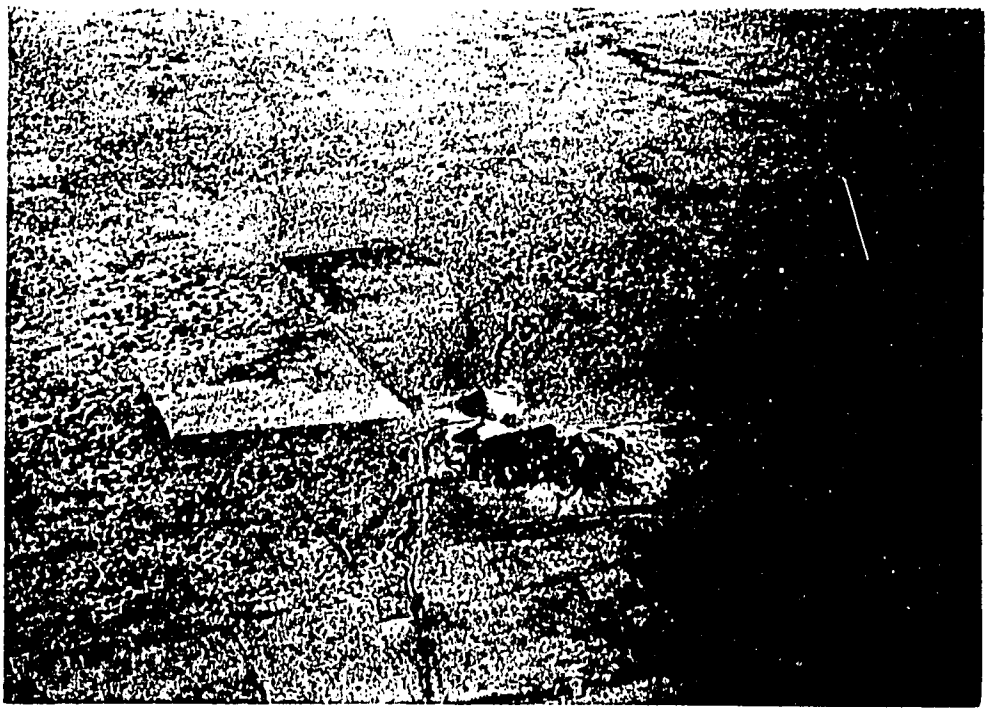
Betterment of the El Fasher to Nyala link would provide an all weather link between the Regional Capitol, El Fasher, with the Provincial Capitol, Nyala. The

IRISH CROSSING

HAFIR



WATER IMPOUNDMENT



SOURCE OF AGGREGATE

rate of return of this alternative is 11.44 percent, the lowest of the three alternatives primarily due to the need to transport marketable crops in the south through El Fasher then east to El Obeid. The El Fasher to En Nahud link would connect the minimum number of villages, since most settlements fall south of the corridor.

C. CENTRAL CORRIDOR (EN NAHUD TO OGR TO NYALA)

1. Environmental Conditions

The Central Route covers the area between El Nahud west through the vicinity of Ogr to Nyala, a distance of approximately 430 km. This route passes through several sizeable villages. Population varies from sedentary to seminomadic to nomadic groups. Cultivated fields occupy approximately 20 percent of the land use in the area. Several large wadis are present in the western portion of this route. Rainfall increases slightly from the northern route to 500-600 mm per annum. The principle vegetation type remains savannah woodlands.

2. Technical Considerations

a. Construction Considerations

The first 110 km is in the Nubian sandstone formation and some minor schist formations with schist outcrops. The next 70 km is through Umm Rawaba formation materials with sands, some gravel, clays and shales. The Umm Rawaba will classify in the A-2-6 to A-6 range. There are approximately 140 km of the route that are borderline Nubian sandstone and Umm Rawaba formations with classification A-2-4 to A-6. There may be pockets of A-6 material, but for the most part the material should be good to fair for embankments. The last 105 km to Nyala crosses the undifferenciated basement complex with some major outcrops of batholic granites near Nyala. This material is assumed to be in the A-2-4 classification group and will require further soil testing to verify classification category.

There are several wadi crossings that will contain materials in the A-2-6 classification and will require major drainage structures.

The first 110 km will require similar construction techniques as discussed in the El Obeid to En Nahud section. The Umm Rawaba material is suitable for embankments if selective placement is employed. The road through the Umm Rawaba material will require 15 to 20 cm of aggregate base material, and in places 15 to 28 cm of aggregate subbase or fabric when A-6 materials are encountered. This area will require more intensive field varification of surface material thickness and underlying soil structure in order to finalize design criteria.

The basement complex should provide good to excellent embankment materials, and the granite outcrops should provide an adequate source of crushable material for base course aggregate. The road will require 15 cm of aggregate base through the basement complex. The entire route will be paved with 5 cm of asphaltic concrete with sealed shoulders.

b. Maintenance Considerations

Maintenance compounds will be located at En Nahud, Ogr and the existing compounds at El Obeid and Nyala. Maintenance compounds will increase construction costs LS 90,000/km on sections where located. There will be problems with blowing sand and shoulder erosion through the Nubian material. Borderline materials will provide similar problems with additional culvert and drainage clearing and repair of washouts. The basement complex should provide a very stable road with few maintenance problems if protected from washouts in and around the major wadi crossings.

The road surface will require resealing in six to eight years to protect the initial investment.

c. Drainage Considerations

There are no major drainage features along the existing track between En Nahud and Ogr. Between Ogr and Nyala there are approximately 30 drains that will require culverts and 6 major wadi crossings that will require bridge structures. Wadis are within 105 km of Nyala, and significant runoff occurs from the slopes of Jebel Marra where rainfall approaches 800 mm per year.

d. Water Availability

This route follows the major livestock trekking route from Nyala through En Nahud, El Obeid and on to Omdurman. There currently exists approximately 80 wateryards in a 5 to 50 km wide zone along this route. Each wateryard has one or more deep wells which are designed to produce about 75 liters/minute. Many of these wateryards have old deteriorated machinery and equipment, brought about partly by lack of maintenance, and no longer provide reliable water points.

The Stock Route Project is constructing 12 additional boreholes between Nyala and En Nahud to supplement existing waterholes. The first 320 km west of En Nahud pass over Nubian sandstone and Umm Ruwaba formations. Test borings done in conjunction with the Stock Route Project do not reveal significantly different yields in these formations. Well yields range from 60 to 110 liters/minute. The final portion of this corridor (approximately 110 km) passes over the

basement complex, which yields little subsurface water. Surface water may be available from the two large wadis in this area during the rainy season. The city of Nyala has a public water system.

3. Economic Considerations

It is estimated that the En Nahud to Ogr link will serve as a transportation head for 28 percent of both crop imports/exports and livestock. The Org to Nyala link will serve as the transportation head for 40 percent of both crop import/exports and livestock. The rate of return for this alternative is 16.16 percent; the highest of the three corridor studies. The primary reason is that it serves the livestock and crop transportaiton needs equally well. The corridor also connects a moderate number of settlements and provides opportunities to increase farming by mechanized means. It provides the most direct route between three major markets for agricultural surplus, thus providing opportunities for increased income to agents and farmers alike.

D. SOUTHERN CORRIDOR (EN NAHUD TO OGR TO ED DA'EIN TO NYALA)

1. Environmental Conditions

The southern route traverses the area between En Nahud, Ogr, Ed Da'ein and Nyala. From Ogr the route runs south to the railway corridor at Ed Da'ein, then generally follows the railroad to Nyala a distance of approximately 500 km. There are numerous small villages scattered throughout the area. In addition to the sedentary population in these villages, the area is occupied by both seminomadic and nomadic groups. Cultivated activity presently represents about 20 percent of the land use. The western portion of the route is characterized by several large wadis. Rainfall is approximately 500 to 600 mm per annum, and savannah woodland is the dominate vegetation type.

2. Technical Considerations

a. Construction Considerations

The construction of embankment, base course and surfacing is essentially the same as for the Central Corridor. More of the Umm Rawaba formation is encountered, specifically 40 to 50 km either side of Ed Da'ein. It can be assumed that more A-6 classification will be encountered, which will necessitate increasing the embankment heights and increasing base and subbase thicknesses to 20 cm each. The A-6 material may require fabric underlayment to separate subbase and base materials from soil embankments and minimize effects of the elastic nature of the material. The aggregate for the base and subbase will have to be

imported due to the lack of available outcrops and developed quarries. Large quantities of excellent aggregate are available in the Nyala area and could be developed for use on the Ed Da'ein to Nyala link.

Native grasses should be used to help stabilize the embankment against erosion and erosion induced failures. The entire length will be surfaced with 5 cm of asphaltic concrete. Again, the aggregate will need to be imported for the surfacing mix.

b. Maintenance Considerations

Maintenance compounds will be required at Ogr, Ed Da'ein and En Nahud. Existing compounds are at El Obeid and Nyala. Maintenance compounds increase the construction costs approximately LS 90,000/km on the sections where located. Maintenance of this route will be the same as discussed in the Central Corridor. Additional roadside vegetation and embankment maintenance may be required due to the higher elastic nature of local materials and higher incidence of native vegetation in the area. The entire length will require sealing in six to seven years to protect the initial investment.

c. Drainage Considerations

The section of this corridor between Ogr and Ed Da'ein contains no well defined drains. From Ed Da'ein to Nyala the corridor runs parallel to and just north of the existing railroad and crosses two large wadis (approximately 6 to 8 km wide along the first 160 km). For the last 50+/- km to Nyala the railroad appears to go within a broad wadi with many channels. There are numerous small side drains that discharge into this wadi. The corridor should be located to the north of the railroad and up out of the wadi to minimize extensive construction and maintenance drainage expenses.

There will be approximately 15 major crossings that will require bridge structures.

d. Water Availability

The corridor between Ogr and Ed Da'ein passes between the northern and dry season stock routes used for trekking livestock. There are numerous villages along the corridor which have wells. Annual precipitation in the area averages approximately 500 mm. The corridor passes over the Umm Rawaba formation, which contains more clay than the Nubian formations to the north. This provides for better surface water retention during the dry season. The corridor from Ed Da'ein alternates between alluvial wadi fills and basement complex material.

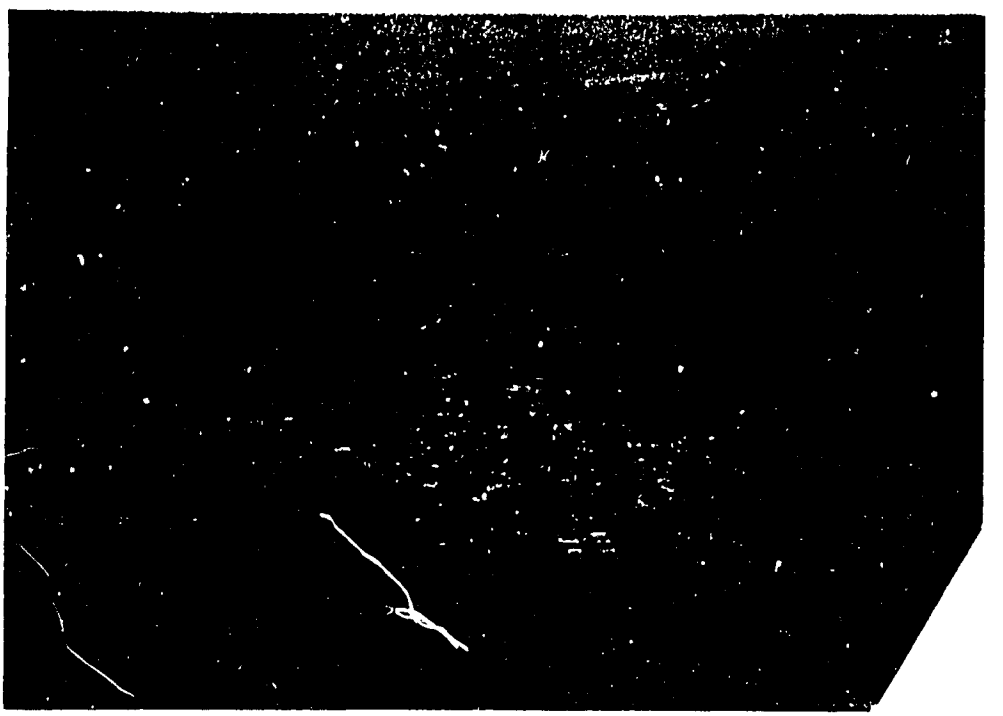
Surface water may be available from the large wadis. No new wells are planned by the Stock Route Project. Nyala has a public water system which should serve for construction purposes.

3. Economic Considerations

The En Nahud to Ogr link will be the same as for the Central alternative. The Ogr to Ed Da'ein link will serve as a transportation head for 16 percent of the crop imports and exports and livestock. The Ed Da'ein to Nyala link will serve as the transportation head for 24 percent of the crop import and exports and 20 percent of the livestock.

The rate of return for this alternative is 12.35 percent. It serves the area similar to the Central alternative but favors the transport of crops over livestock.

NYALA



ED DA'EIN

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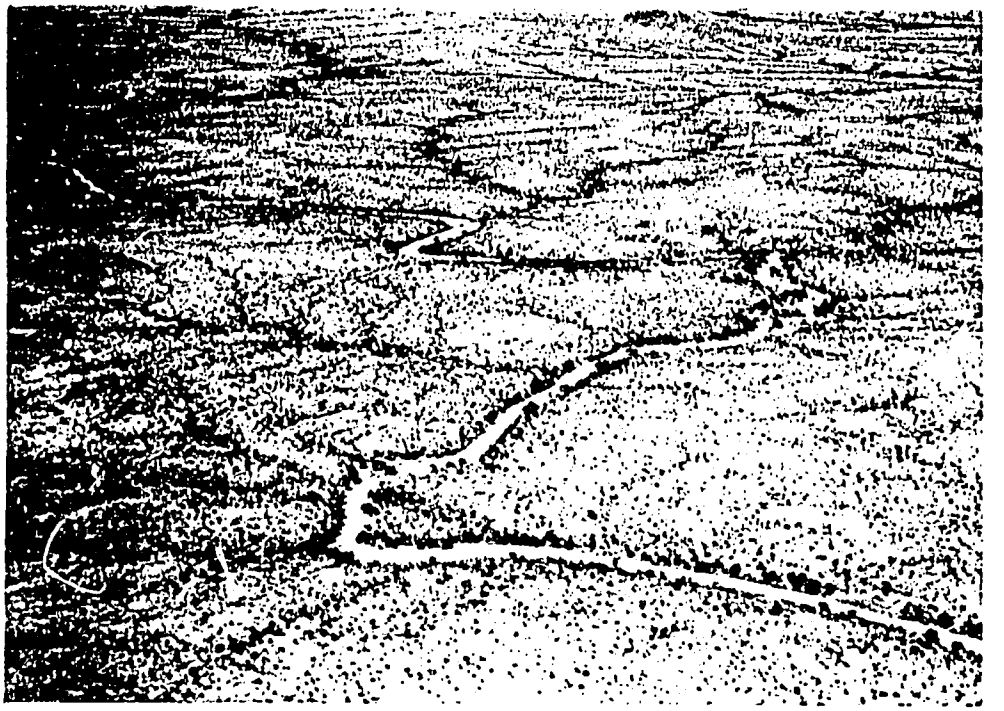


WADI

LARGE WADI

V. ANALYSIS OF ALTERNATIVES AND RECOMMENDED CORRIDOR

The evaluation criteria used for selection of the preferred alternative are (1) socio-economic, (2) technical and (3) environmental.

The socio-economic factor is accounted for in rate of return percentages. A positive rate of return will increase income and improve social status and values, since the benefits used are a reflection of the social values. Development of private enterprise along the corridor was considered and included in the benefits through traffic projections and increased incomes to the population of the area. Private development activity is inevitable for any alternative. The technical factors include construction methods and materials, as they relate to the reliability of the facility; drainage crossings, since they effect the reliability of the facility; and maintainance due to climatic and user traffic conditions. The environmental factors include the direct effect of the facility on the environment and the social effects implementation might have on the environment. Increasing the numbers of passengers and changing traditional ways of operations will affect the environment, and controls will be necessary to prevent adverse impacts. A summary of cost/benefit calculations used to evaluate all alternatives is shown in Exhibit H-I in the Appendix.

A. ANALYSIS

1. Northern Corridor

The Northern Corridor has a rate of return of 11.44 percent per year (see Exhibit H-2), the least of all the alternatives. This is an indication that this alternative would not serve the public welfare as well as the other two alternatives. Approximately 320 km of the En Nahud to El Fasher link would require soil cement to stabilize the base. This construction method would be less of a benefit to the local economy, since it would have to be imported and the aggregate could be produced locally.

The technical construction consideration for the En Nahud to El Fasher link would be minimal. Upgrading of the road between El Fasher and Nyala will be complex because of the large number of drainages. However, the drainage problem would be less on this link than the western part of the Central and Southern Corridors, since the drainages tend to be less well defined the further south they flow.

There may be times when the road would be closed due to blowing sand along the En Nahud to El Fasher link. The environmental considerations would be

most severe since implementation of the project would surely increase activity along the corridor and accelerate desertification

2. Central Corridor

The Central Corridor has a rate of return of 16.16 percent per year (see Exhibit H-3). This is an indication that this alternative would serve the public welfare the best of all the alternatives. Approximately 300 km of the En Nahud to Nyala link would require an aggregate base rather then soil cement, therefore increasing the benefit to the local economy since it can be produced locally rather than being imported. Since this alternative connects a large number of settlements and passes through more agricultural land, it will enhance the private sector development along the corridor. The usability of this corridor is enhanced for the livestock owner because the corridor generally follows the proposed stock trekking route from Nyala to Omdurman.

The technical considerations are insignificant from En Nahud to Ogr but become complex from Ogr to Nyala because of several large wadis with poorly defined drainage patterns and the potential for road closure due to washout. This is partially offset by the good construction materials encountered on the west 300 km of the corridor.

The environmental impacts of this alternative are minimal except for the impact of drainage structures in large wadis and private sector development along the route. Wadi crossings will be complex and special construction considerations will be necessary to avoid environmental damage. Administrative controls will be necessary to avoid private sector development in environmentally sensitive areas.

3. Southern Corridor

The Southern Corridor has a rate of return of 12.35 percent per year (see Exhibit H-4). This is an indication that the route would serve the public welfare better than the Northern Corridor but less than the Central Corridor. The west 380 km of the road would require aggregate base rather than soil cement, therefore increasing the benefit to the local economy since it can be produced locally rather than being imported. This benefit would be greater than any of the alternatives, but only because the corridor is longer than the Central Corridor. This corridor would connect more settlements and pass through more farm land, and therefore would best serve private sector development along the corridor. This benefit would be offset somewhat because it would not serve the livestock owners as well as the other two corridors.

The technical considerations are similar to those in the Central Corridor,

PRIVATE SECTOR DEVELOPMENT

FIREWOOD

however they are more complex because the drainage is less defined. The roadway would have to cross significant sections of wadi drainage patterns, requiring major drainage structures. Parts of the corridor traverse some difficult soil conditions. The environmental considerations are more significant than the Central Corridor because of the effects of the project on broad undefined drainage areas, danger of washouts and generally poor construction materials resulting in large borrow areas. Special construction considerations would be required to avoid environmental damage at the wadi crossings and the difficult soil areas.

B. RECOMMENDED CORRIDOR

The following is a matrix of the ranking of the evaluation by factors for each alternative. All factors are assumed to be of equal consequence and carry the same weight. Ranking values range from high = 1 to low = 3.

Corridor	Economic Rank	Technical Rank	Environmental Rank	Total
North	3	1	3	7
Central	1	2	1	4
South	2	3	2	7

The recommended alternative is the Central Corridor.

C. ITEMS REQUIRING ADDITIONAL STUDY

1. People Transport Benefits

The team reviewed the 1984 Western Transport Study and the 1987 Toll Road Feasibility Study and felt there was insufficient data to project passenger benefits. The team feels that passenger tranport and communication will be a major benefit and should be investigated further.

2. Industrial Transport Benefits

The team did not find adequate documentation to project industrial export benefits. Industrial imports were included in the import benefits.

3. Emergency Relief

The team understands there is a group working on an emergency relief program for Sudan. Upon completion of that effort, an analysis should be made to determine cost savings that would be realized by implemenation of this project.

IMPLEMENTATION CONSIDERATIONS

VI. IMPLEMENTATION CONSIDERATIONS

A. ROAD LOCATION AND DESIGN

1. Photogrammetry

It is recommended the road be located using photogrammetric procedures supplemented with Global Positioning System (GPS) technology. Exhibit D in the Appendix is an index map of existing horizontal and vertical control for the area. For planning purposes the following assumptions are made:

a. Project length is approximately 720 km. Two addtional IOO km strips of reconnaissance flight are needed for the last 100 km east of Nyala.

b. A second order control net will be established between El Obeid and Nyala passing through En Nahud and southwest through the vicinity of Ogr and Muhagiriya.

c. Supplemental third order stations will be established along the selected corridor.

d. A reconnassiance flight of vertical aerial photography (1:40,000 scale) will be flown along the proposed corridor and controlled using the previously mentioned GPS control Points.

It is estimated the above scenario can be accomplished for approximately LS 191,000 per 100 km. A detailed estimate for the reconnaissance flight and resulting map products is shown as Exhibit E in the Appendix.

The resulting strip map and photo mosaic can be used to define the preliminary center line and to define major drainage problem areas. It is envisioned that much of the construction can be accomplished by the balanced section method (areas of minimal relief) and that these products may suffice for center line design in these areas. Larger scale photography (1:6,000) can be acquired for major drainage structure design and areas of heavier construction. Control can be supplemented in these areas using previously established GPS points for differential positioning and photogrammatric transfer of additional image points from the 1:40,000 scale flight. Final construction staking can be tied to these larger scale products. Based on review of existing thematic mapper satellite imagery, existing aerial photos and a reconnaissance flight along the corridor, there are an estimated four major wadi crossings between El Obeid and Nyala. Exhibit F in the Appendix is a cost estimate for a typical major drainage site map using photogrammetric methods. Exhibit G in the Appendix is a cost estimate for a typical 10 km section of design scale photography and strip maps using photogrammetric methods.

2. Supplemental Survey Procedures

To supplement photogrammetric measures, conventional survey methods may be required. Survey methods can be conducted at varying levels of accuracy, and therefore can drastically increase the costs involved in preconstruction engineering.

The USDA - Forest Service is recognized as the world's largest manager of low volume roads. This organization has developed, over the last two decades, accuracy standards that are economical, commensurate with traffic volume, road user needs and construction tolerance class. For low volume roads (farm to market) the construction tolerance is dependent on design speeds to be accommodated and are as follows:

Item	Tolerance Class 1/					
	A	B	C	D	E	F
Roadbed Width (cm)	+15	+30	+30	+30	+30	+61
Subgrade Elevation (cm)	±3	±6	±15	±30	±61	±91
Centerline Alignment (cm)	±6	±15	±30	±30	±61	±91
Design Speeds (km per hr.)	Greater than 80		50-80		15-50	Less than 15

1/ Maximun allowable deviation from construction stakes and drawings. A plus (+) indicates measurement can exceed by table value but cannot be less than staked measurement. A plus-minus (±) indicates measurement can vary between but not exceed table value.

The corresponding accuracy standards have been developed and are shown in Exhibit J.

Because of the relatively flat terrain, supplemental surveys will only be necessary where major drainages are encountered or where grade and alignment need to be precise. The photogrammetric methods will provide acceptable accuracy for estimating design quantities. Supplemental surveys will be required for quantities at locations for major bridges or where rock excavation may be encountered.

B. DESIGN DRAWINGS

Design drawings should be accomplished by superimposing route alignment on photo images and using computer design for estimating quantities. Simplified design is possible due to the terrain and long tangents. Cross section intervals can be increased to at least twice conventional procedures to reduce

design costs without sacrificing accuracy. Drawings will consist of typical sections, existing ground profile generated by photogrammetric procedures, profile grade, quantities and structural drawings for bridges. Bridge site drawings can be accomplished using a combination of photogrammetric and field survey procedures. The field trip verified that very few drainage structures or culverts will be required until the route approaches Nyala.

C. CONSTRUCTION SURVEY METHODS

In order to transfer design measurements and quantities accomplished through photogrammetric procedures, field construction staking techniques will be necessary.

The USDA - Forest Service has for several years been using low standard construction staking techniques for their transportation system. They have found that only centerline staking and "up slope" slope stakes are required on the majority of their roads.

Where long tangents and relatively constant side slope or flat terrain are encountered, slope stakes are placed at 300 to 400 feet along the alignment and reference stakes are set at every other section. Slope stakes are only set on the up slope side. Culvert locations require staking and references at both the inlet and outlet ends.

Base course staking, when paving is required, is accomplished by reestablishment of centerline from slope stakes and thickness control by random measurement. "Blue top" surveys are almost never used.

Surfacing thickness is controlled by automatic screed adjustments on the laydown machines.

Similar procedures to these can be used throughout the length of the recommended route and will result in a minimum of 50 percent reduction in construction staking costs.

D. WATER SOURCES

The location of existing water sources will be an important location consideration. The average rainfall along the recommended corridor is 400-500 mm/yr. There are approximately 130 existing wateryards along the livestock trekking route which follows the corridor. These normally contain surface water during the rainy season (August-November). During the dry season these wateryards are supplemented with existing deep wells, which are designed to produce approximately 75 liters/minute. Maintenance of existing machinery and equip-

ment and competition for livestock water needs must be a location consideration.

In addition to the existing wateryards and deep wells, the Stock Route Project is constructing 16 new wells along the corridor between En Nahud and Nyala. Of these, three are considered high risk, five medium risk and eight low risk. The estimated investment cost for a completed well ready for operation is LS 278,000, or approximately LS 1,400 per/m assuming a 200 m depth. Average yield expected would be 75 liters/min.

At major wadi crossings temporary retaining ponds could be constructed to capture rainy season runoff for dry season use. The cities of El Obeid, En Nahud and Nyala have public water systems to support construction requirements within 50 km of these cities.

The National Rural Water Corporation (NRWC) has a data base of existing water sources in rural Sudan. This corporation and the Livestock Route Company, being established in conjunction with the Stock Route Project, are recommended contacts for detailed water sources along the recommended corridor.

E. SOILS AND MATERIALS

Satellite imagery should be used to assist in the classification of existing soils and potential aggregate sources. U.S. thematic mapper scenes exist over western Sudan, and French SPOT imagery can be obtained as well. Thematic mapper multispectral resolution is approximately 30 m and SPOT multispectral resolution is approximately 20 m. SPOT panchomatic (black and white) resolution is increased to 10 m. These resolutions are sufficient for preliminary classification. Ground truth verification will be required to verify classifications along the selected route.

The National Center for Remote Sensing, located at the University of Khartoum, has copies of thematic mapper scenes and some reproduction capability. The African Center for Remote Sensing in Nairobi has full acquisition and reproduction capabilities for both thematic mapper and SPOT products. Dr. Hassan M. Hassan, Director of the Nairobi facility, is a recognized expert in remote sensing technology and should be consulted to support soil and aggregate classifications along the recommeded corridor.

F. CONSTRUCTION SEQUENCE

The El Obeid to En Nahud link is the logical first priority for construction and can be undertaken by one donor. It would be better strategy to split the 216 km into two sections with construction beginning at terminus points toward the

center. The intent of this strategy is to lower the impact for financial responsibility for any one donor, thereby increasing the probability of completing the section within a 3-year span.

The En Nahud to Ogr link should be constructed by one donor and is second priority for sequence. This is a relatively uncomplicated section with few materials problems expected; therefore, construction progress should be above average.

The Ogr to Nyala link is the longest link in the corridor and by far the most complex in terms of construction operations. This section should be split between two donors, each starting at terminus points. There are two major material types in the corridor and each approximates one half the length of the link. This would provide near homogenious construction methods and materials for each contractor.

In summary, it appears the logical sequence of construction should be two contractors on the El Obeid - En Nahud link (construction time three years). The En Nahud Ogr link should be one contractor (construction time two years). The final link, Ogr to Nyala, should be split between two contractors (expected construction time three years). With this sequence the east-west corridor could be open and in service eight years after initial construction starts, opening up western Sudan for development and increased production.

APPENDIX

EXHIBIT A

REFERENCE MATERIAL USED

1. Agricultural Situation and Outloook, Ministry of Agriculture and Natural Resources September Report, October 24, 1987.

2. Economic Reappraisal of the Kosti-El Obeid Road, Louis Berger International, Inc., November 1983.

3. Morin, W. J. and Todor, Peter C., Laterite and Latertic Soils and Other Problems Soils of the Tropics (vol. I & II)

4. Project Identification Document, Sudan - Western Agricultural Market ing Road Project (650-0069), 1983.

5. Road Toll Feasibility Study, Ministry of Finance and Economic Planning, Main Report and Annexes, Draft, Khartoum, July 1987.

6. Staff Appraisal Report, Sudan Stock Route Project, August 31, 1984.

7. Sudan Problems of Economic Adjustment, Vol. II, Document of the World Bank, June 19, 1987.

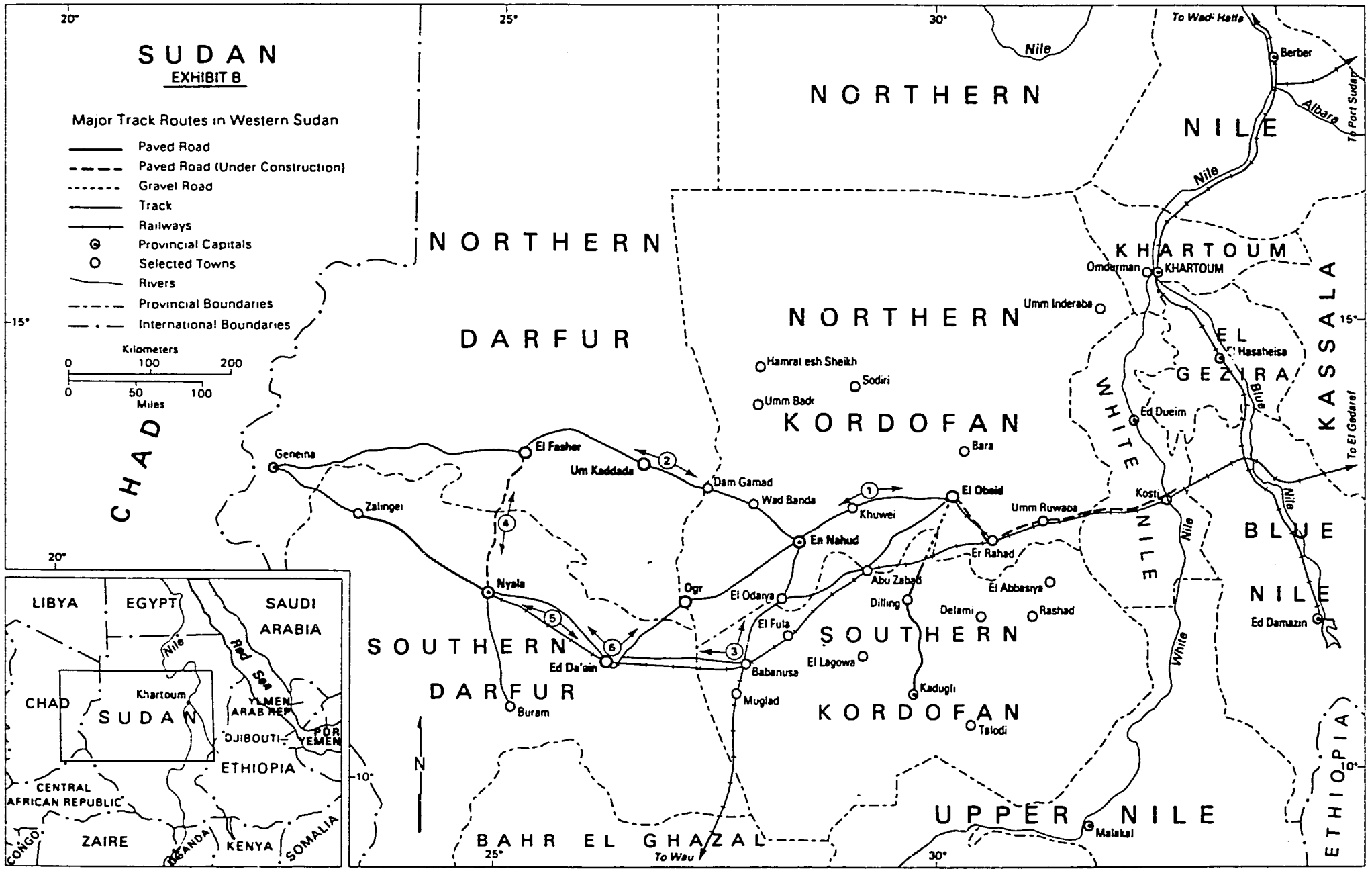
8. Sudan Railways Emergency Recovery Program, Staff Appraisal Report, Draft, September 18, 1987.

9. Sudan Road Survey: An Engineering Analysis of Construction, Maintenance and Vehicle Operation, Final Report, September 1967.

10. Sudan, Kordofan Region Agricultural Marketing and Transport Study, Louis Berger International, Inc., March 1983.

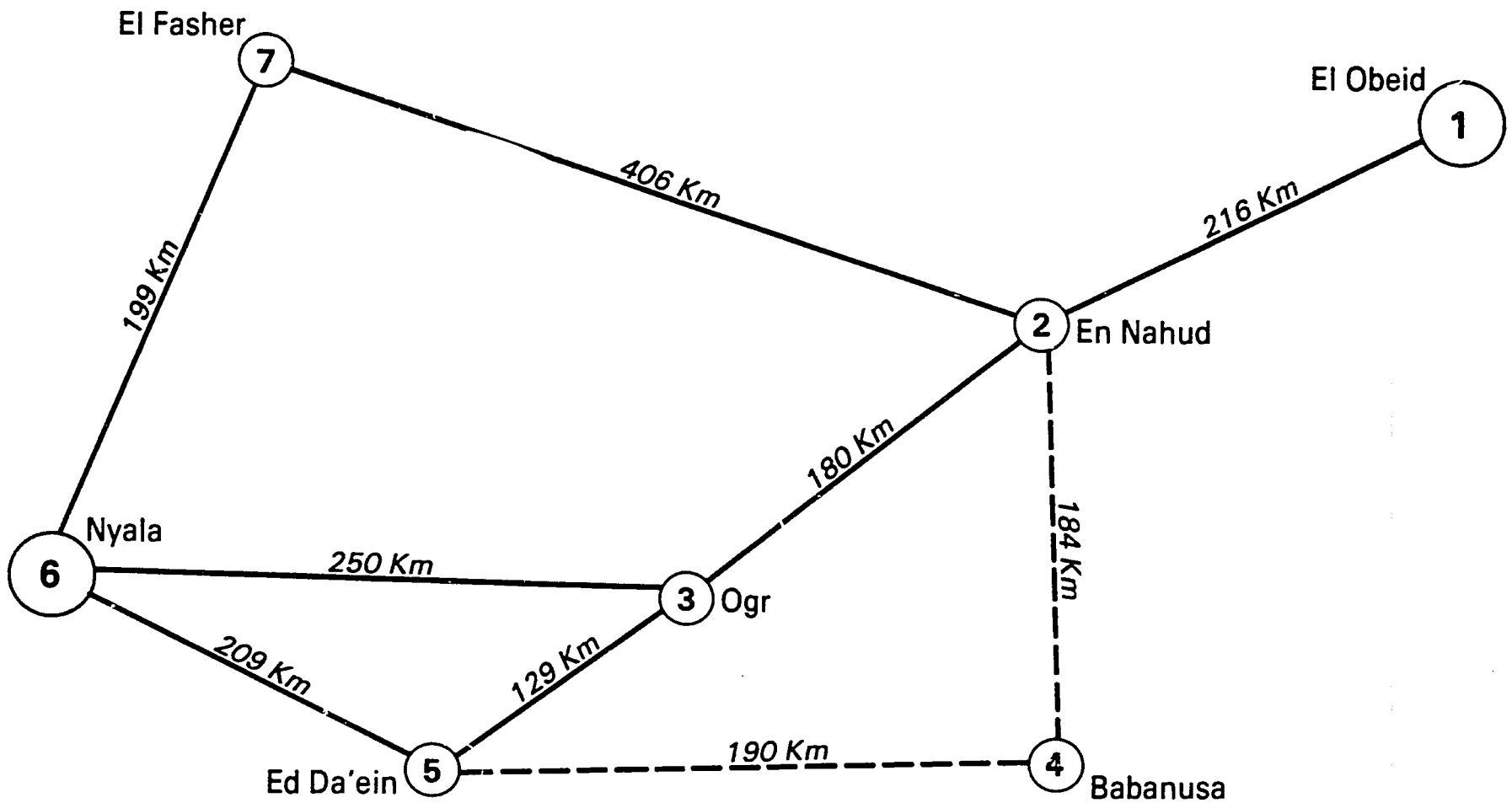
11. Thematic Mapper Scenes 175/51; 176/51, 52; 177/51, 52; 178/51, 52.

12. Western Sudan Transport Study (vol. 1 & 2), Democratic Republic of Sudan, Ministry of Finance and Economic Planning, Khartoum, 1984.


SUDAN
EXHIBIT B
Major Track Routes in Western Sudan
Paved Road
Paved Road (Under Construction)
Gravel Road
Track
Railways
Provincial Capitals
Selected Towns
Rivers
Provincial Boundaries
International Boundaries
Kilometers
0 100 200
0 50 100
Miles
NORTHERN DARFUR
NORTHERN KORDOFAN
NORTHERN NILE
KHARTOUM
EL GEZIRA
KASSALA
WHITE NILE
BLUE NILE
SOUTHERN DARFUR
SOUTHERN KORDOFAN
BAHR EL GHAZAL
UPPER NILE
CHAD
ETHIOPIA
Nile
Albara
Blue
White
To Wad Halfa
To Port Sudan
To El Gedaref
To Wau
Berber
Omderman
KHARTOUM
Umm Inderaba
El Hasaheisa
Ed Dueim
Kosti
Umm Ruwaba
Er Rahad
El Abbasiya
Rashad
Ed Damazin
Malakal
Talodi
Kadugli
Dilling
Delami
Abu Zabad
El Obeid
Bara
Khuwei
Hamrat esh Sheikh
Sodiri
Umm Badr
Dam Gamad
Wad Banda
En Nahud
Ogr
El Odaiya
El Fula
Babanusa
El Lagowa
Muglad
Um Kaddada
El Fasher
Geneina
Zalingei
Nyala
Ed Da'ain
Buram
N
LIBYA
EGYPT
SAUDI ARABIA
Red Sea
Khartoum
CHAD
SUDAN
YEMEN ARAB REP.
DJIBOUTI
PDR YEMEN
ETHIOPIA
CENTRAL AFRICAN REPUBLIC
CONGO
ZAIRE
UGANDA
KENYA
SOMALIA

41

40



Northern Route	1-2-7-6
Central Route	1-2-3-6
Southern Route	1-2-3-5-6
Future Analysis	2-4-5 . . . Feeder Links

EXHIBIT C

Transportation Link Diagram

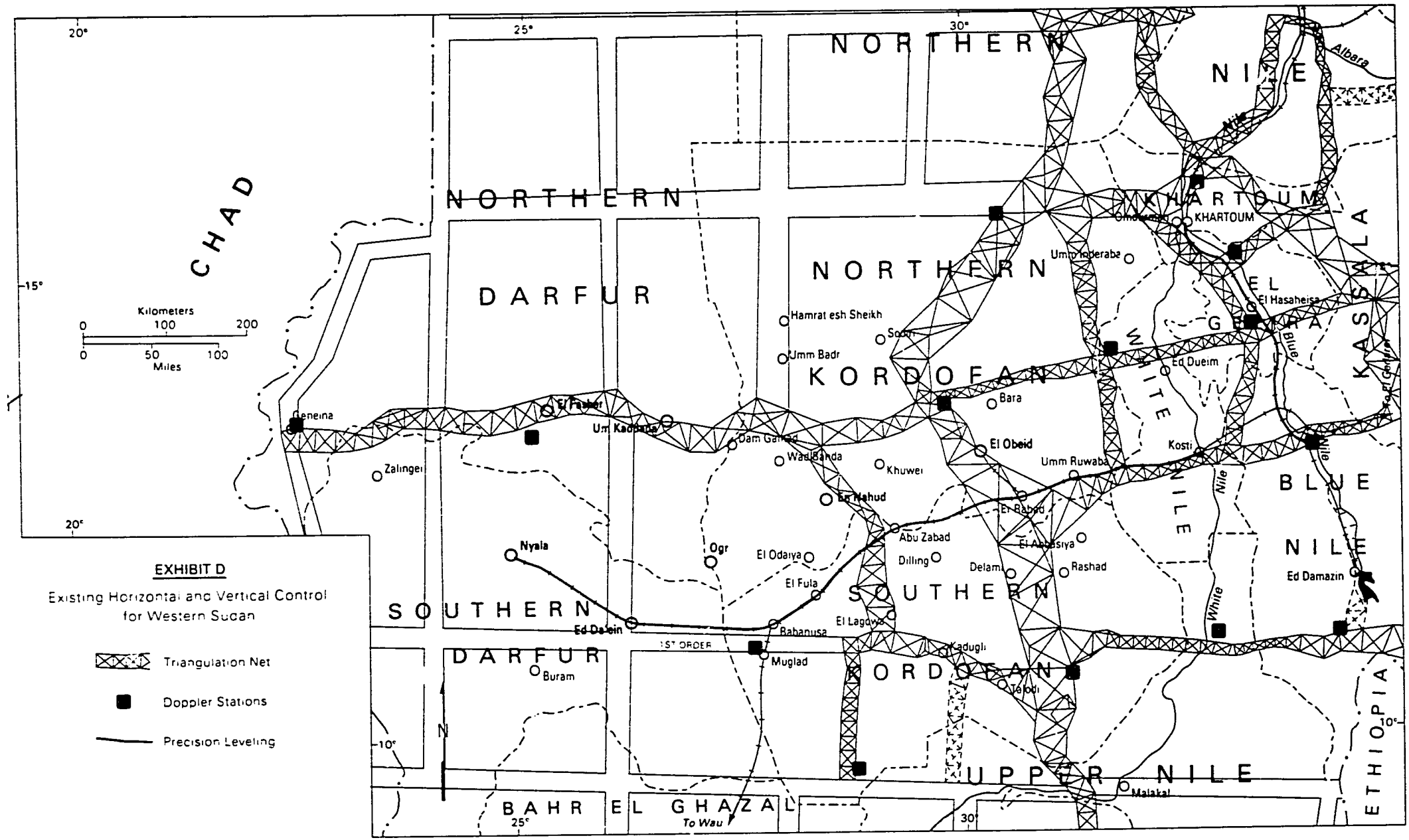


EXHIBIT D
Existing Horizontal and Vertical Control for Western Sudan
Triangulation Net
Doppler Stations
Precision Leveling
Kilometers
0 100 200
0 50 100
Miles
CHAD
NORTHERN DARFUR
NORTHERN KORDOFAN
NORTHERN NILE
KHARTOUM
KHARTOUM
EL GEZIRA
KASSALA
WHITE NILE
BLUE NILE
SOUTHERN DARFUR
SOUTHERN KORDOFAN
UPPER NILE
BAHR EL GHAZAL
ETHIOPIA
Albara
Blue Nile
White Nile
Geneina
Zalingei
El Fasher
Um Kadada
Dam Gamad
Wad Banda
Hamrat esh Sheikh
Umm Badr
Khuwei
Bara
El Obeid
Umm Ruwaba
Kosti
Ed Dueim
El Hasaheisa
Umm Inderaba
Abu Zabad
Dilling
El Odaiya
El Fula
Ogr
Nyala
Ed Daein
Babanusa
Muglad
Buram
El Lagowa
Kadugli
Delami
Rashad
El Abbasiya
El Rahad
Ed Damazin
Malakal
To Wau
1ST ORDER
20°
25°
30°
15°
10°

EXHIBIT E

PHOTOGRAMMETRIC ROUTE LOCATION COST ESTIMATE

(920 km Reconnaissance Line)

Mobilization Planning	Mobilization and Project Planning	= $ 50,000
Control	Horizontal and Vertical Control 10 second order stations at 80 km spacing 10 stations @ $2,500	= $ 25,000
	50 third order stations at 16 km spacing with some redundancy stations 50 stations at $2,000	= $ 100,000
Aerial Photography	1:40,000 B/W high resolution aerial photography 60% overlap; single flight line; one model = 4 km along flight line. Note: 2 adjacent flight lines may be needed over portions of the corridor east of Nyala where alternative routes do not fall within an 8 km wide strip, and costs are reflected in the following computation for this purpose. 920 km divided by 4 km = 230 photos + 20% = 276 photos Flying cost = 920 km x $50/km	= $ 46,000
Processing	Processing, prints (3 sets) and film diapositives	= $ 9,000
Aerial Triangulation	Includes controlling flight for compilation and reading extra points for later design scale flight 276 plates at $100/plate	= $ 28,000
Stereo Compilation	Assumes 2000 C Factor instrument producing 10' CI (3m) 276 models at 3 hrs/model= 828 hrs @ $40	= $ 33,000
Drafting	276 models at 4 hrs/model = 1104 hrs @ $25	= $ 27,000
Photo Mosaic	Ratio, mosaic and drafting at 1 print hour 276 prints x 25	= $ 7,000
		$ 325,000
	20% Contingency	65,000
	Total estimate	$ 390,000
		(LS 1,755,000)

EXHIBIT F

PHOTOGRAMMETRIC COST ESTIMATE FOR MAJOR DRAINAGE SITE

Control	Control points based on $1,500 Per GPS control station; 5 vertical and horizontal control points required to control a six model block. Cost estimates based on the fact that existing GPS control exist from reconnaissance flight.	$ 7,500
Aerial Photography	1:6,000 scale B&W; 6" f.l. camera	$ 500*
Processing	Prints, film positives plus shipment	$ 200
Aerial Triangulation	Based on $100 per plate, 8 plates per site (includes plate preparation)	$ 800
Stereo Compilation	Assumes 2,000 C Factor instrument; .5 to 1.0 meter contour internal; based on 8 hours per neat model; 6 models at $35 per hour.	$ 1,700
Drafting	6 models at 10 hours per model; at $20 per hour.	$ 1,200
	Total	$11,900
	20% Contingency	$ 2,380
	Cost per site	$14,280
		(LS 64,260)

*This estimate does not include mobilization and deployment cost for the aerial photography and ground control crews and equipment. These costs will depend on the size of the project and the distance from the base to the project area.

EXHIBIT G

PHOTOGRAMMETRIC COST ESTIMATE PER 10 km DESIGN SECTION

Control	6 control pts. @ $1,500 per point 16 models are required to cover a 10 km strip. Optimum number of control points required is 6.	$ 9,000*
Aerial Photography	1:6,000 scale B&W; 6" f.l. camera	$ 400*
Processing	Prints, film positives plus shipment	$ 200
Aerial Triangulation	Based on $100 per plate, 17 photos per 10 km strip	$ 1,700
Stereo Compilation	Assumes 2,000 C Factor instrument; 0.5 to 1.0 meter contour interval cost calculated based on 5 hours per model at $35 per hour for 16 models; compilation strip map 1,000 meters wide.	$ 2,800
Drafting	Based on 8 hours per model at $20 per hour	$ 2,600
	Total	$16,700
	20% contingency	$ 3,340
	Total per 10 km section	$20,040
		(LS 90,180)

*This estimate does not include mobilization and deployment cost for the aerial photogranhy and ground control crews and equipment. These costs will depend on the size of the project and the distance from the base to the project area.

Exhibit H-I

SUMMARY OF COST/BENEFIT CALCULATIONS (BY ALTERNATE)

Alternate By Link	Dist. of Link/km	Ave.[1] Const. LS(000)/km	Cost of Link LS(000)	Ave. Maint. Cost	Annual Maint. Cost LS(000)	Benefit LS(000)	Rate of Return % Year
1 - 2	216	704	152,064	7,000	1,512	68,399	
2 - 7	406	704	285,824	7,000	2,842	102,572	
6 - 7	199	978	194,622	7,000	1,393	100,180	
NORTH							11.44
1 - 2	216	704	152,064	7,000	1,512	68,399	
2 - 3	180	704	126,720	7,000	1,260	70,169	
3 - 6	250	806	201,500	7,000	1,750	108,800	
CENTRAL							16.16
1 - 2	216	704	152,064	7,000	1,512	68,399	
2 - 3	180	704	126,720	7,000	1,260	70,169	
3 - 5	129	725	93,525	7,000	903	32,849	
5 - 6	209	1,072	224,048	7,000	1,463	46,730	
SOUTHERN							12.35

1 Costs are average and account for normal drainage. Costs include 5 cm of asphaltic concrete pavement, 7 m of pavement width, 1.5 cm shoulders, 15 cm base course, 20 cm subbase, 0.6 to 1.0 m embankment and maintenance/administrative units (maintenance unit adds LS 234,000/km).

EXHIBIT H-2

NORTHERN CORRIDOR ANNUAL RATE OF RETURN

AMOUNT	LS(OOO)	BEGINNING YEAR	ENDING YEAR
-152064	Construction	1	3
-285824	Construction	2	5
-194622	Construction	4	7
-1512	Maintenance	3	30
-2842	Maintenance	5	30
-1393	Maintenance	7	30
+271151	Benefit	4	30

RATE OF RETURN = 11.44 %PER YEAR

EXHIBIT H-3

CENTRAL CORRIDOR ANNUAL RATE OF RETURN

AMOUNT	LS(OOO)	BEGINNING YEAR	ENDING YEAR
-152064	Construction	1	3
-126720	Construction	2	4
-201500	Construction	4	7
-1512	Maintenance	3	30
-1260	Maintenance	4	30
-1750	Maintenance	7	30
+247368	Benefit	4	30

RATE OF RETURN = 16.16 %PER YEAR

EXHIBIT H-4

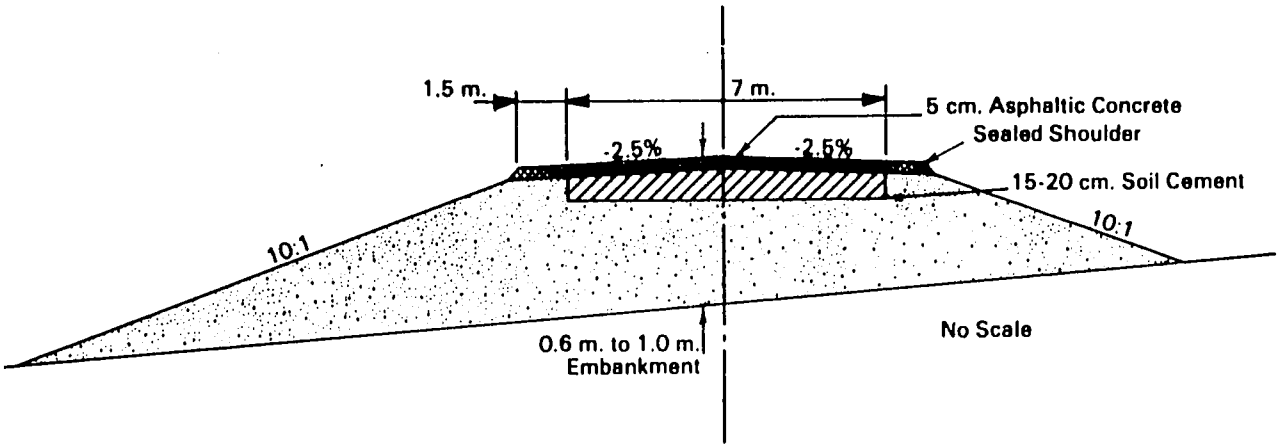
SOUTHERN CORRIDOR ANNUAL RATE OF RETURN

AMOUNT	LS(OOO)	BEGINNING YEAR	ENDING YEAR
-152064	Construction	1	3
-126700	Construction	2	4
-93525	Construction	4	6
-1512	Maintenance	3	30
-1260	Maintenance	4	30
-903	Maintenance	6	30
-1463	Maintenance	9	30
+218147	Benefit	4	

RATE OF RETURN = 12.35 %PER YEAR

TYPICAL SECTION - NUBIAN AREAS

EXHIBIT I-1



TYPICAL SECTION - UMM RAWABA AREA

EXHIBIT I-2

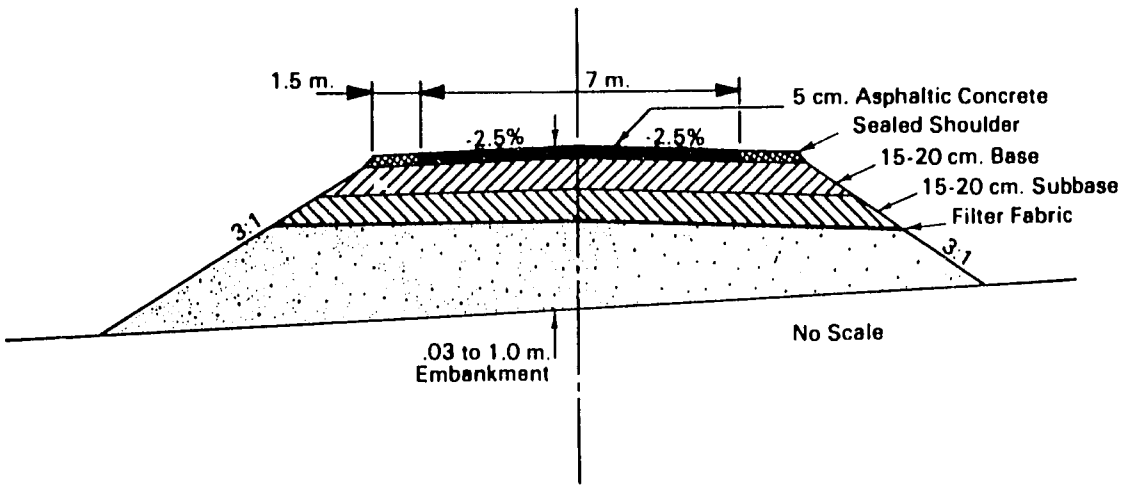


EXHIBIT J

Guidelines for Engineering Survey Accuracy

Accuracy Class	Construction Tolerance 1/	Design Method	Distance Accuracy	Elevation Accuracy	Benchmarks	References to Traverse	Cross-Section Accuracy	Deflection Angles	Typical Survey Instruments
High	A & B	RDS	1/1,500 or better	Nearest .01 ft. each reading	Start, end, and every 1,000 ft.	2 adjacent PI's every 1,000 ft.	All breaks of 1 ft. or more	30 degrees or less	Theodolite Transit Steel tape EDM Self-Leveling Level EZ Arc
Medium	C & D	RDS FLRDS	1/1,000	Nearest 0.1 ft. each reading	Start of project & every 2,000 ft.	2 adjacent PI's every 1,000 ft.	All breaks of 2 ft. or more; slope breaks of 5% or more	30 degrees or less	Jacobs Staff & Compass Steel tape LLOSI Self-Leveling Level Clinometer/Abney for X-sec.
Low	Usually E & F	FLRDS Field Design RDS	1/100	Nearest 0.2 ft. or 1% grade each reading	At start of project	2 adjacent PI's every 1,000 ft.	All breaks of 2 ft. or more; slope breaks of 5% or more	30 degrees or less	Hand Compass Clinometer/ Abney Cloth tape Hand level
Flag Line	Usually F	Field Design	1/30	Nearest 1% grade each reading	N/A	N/A	Average cross slope	N/A	Hand Compass Clinometer/ Abney Cloth tape Pacing
Condition Survey	2/	Reconstr	2/	2/	2/	At each work location	2/	2/	Initially: Odometer Wheel Subsequent: 2/

1/ Spec. 203. Construction Tolerance Table, Forest Service Standard Specifications for Construction of Roads and Bridges. (EM 7720-100).

2/ Determine based on site requirements.

EXHIBIT K

AVERAGE CONSTRUCTION COSTS USED IN BENIFIT CALCULATIONS

Estimated costs derived from Forest Service contract bid items, 1987 Dodge Estimating Guide and current USAID Contract Documents

Embankment

Range of quantity will be 6,000 to 34,000 cu yd/mi (.3m to 1.0m Emb.) Use an average of 10,000 cu yd/mi; because of flat terrain and sand material embankments will rarely exceed .3m to .5m.

Cost US $3 cu yd computed $3 x 10,000 cu yd/mi = $30,000/mi
Cost LS 83,700/km

Base/Sub Base

Average 3,000 ton/mi for 6" thickness (15 cm)

Cost US $20 ton including haul & compacted
$20/ton x $3,000 ton/mi = $60,000/mi

Cost LS 267,400/km

Geotextile Fabric

5,280 lin ft/mi

Cost US $2/lin ft - 14' wide

5,280 ft/mi x $2/lin ft = $10,000/mi one lane
$10,000/mi x 2 lane = $20,000/mi

Cost LS 55,800/km

Cement Stabilized Base (Soil Cement)

5% cement required
1.7 bags/cu yd
2,250 cu yd per mile of treated soil 6" thick
1.7 bags/cu yd x 2,250 cu yd/mi = 3,825 bags/mi
Mix and compact @ $20.50/bag

Cost US $20.50 bag x 3,825 bags/mi = $78,413/mi
Cost LS 218,770/km

Pavement - 2" Asphaltic Cement

14,080 sq yds of material/mi
$7.80/sq yd of 2" AC

Cost US $14,080 sq yd/mi x $7.80/sq yd = $110,000/mi
Cost LS 306,900/km

Bridges - Bridge Over Waterway (Major)

$88 sq ft x 23 sq ft/lin ft = $2,024 lin ft
Add $500/lin ft for location

Cost US $2,500/lin ft for composite deck structure
Cost LS 36,900 /m

Maintenance Camps

Cost US $4,000,000 (Avg. contract amounts)
Cost LS 18,000,000

Mtce. units to be spaced @ 200 km increments

Cost LS 90,000/km

Miscellaneous

(Move in costs, paving plant set-up, etc.)
Costs US $2,000/mi
Cost LS 5,000/km