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No. 52

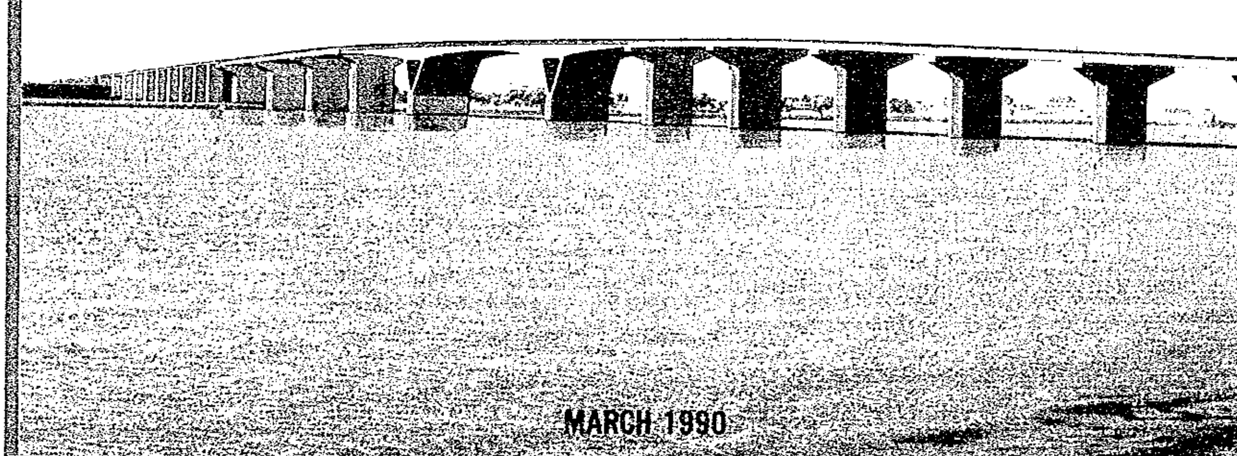
NATIONAL CAPITAL KHARTOUM

THE GOVERNMENT OF THE REPUBLIC OF THE SUDAN

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE IN THE REPUBLIC OF THE SUDAN

FINAL REPORT

VOLUME 1 : MAIN REPORT



MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

JICA

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P R E F A C E

In response to a request from the Government of the Republic of the Sudan, the Japanese Government decided to conduct a study on the construction of the new White Nile bridge in the Republic of the Sudan and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sudan a survey team headed by Mr. Hisashi Oshima, Nippon Koei Co., Ltd., composed of members from Nippon Koei Co., Ltd., and Central Consultant Inc. from January to March and from May to August 1989.

The team held discussions with the concerned officials of the Government of the Sudan, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Sudan for their close cooperation extended to the team.

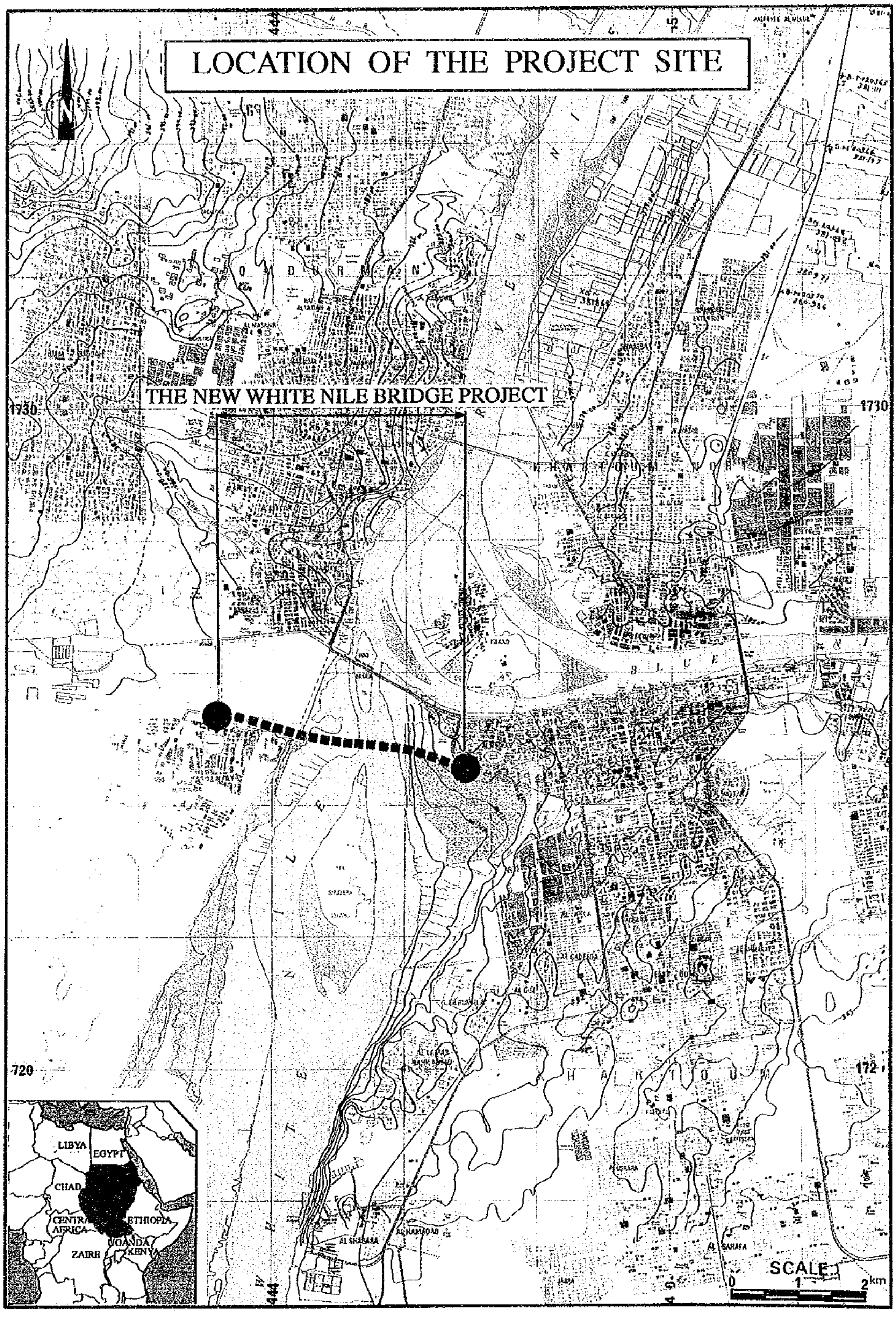
March, 1990

Kensuke Yanagiya

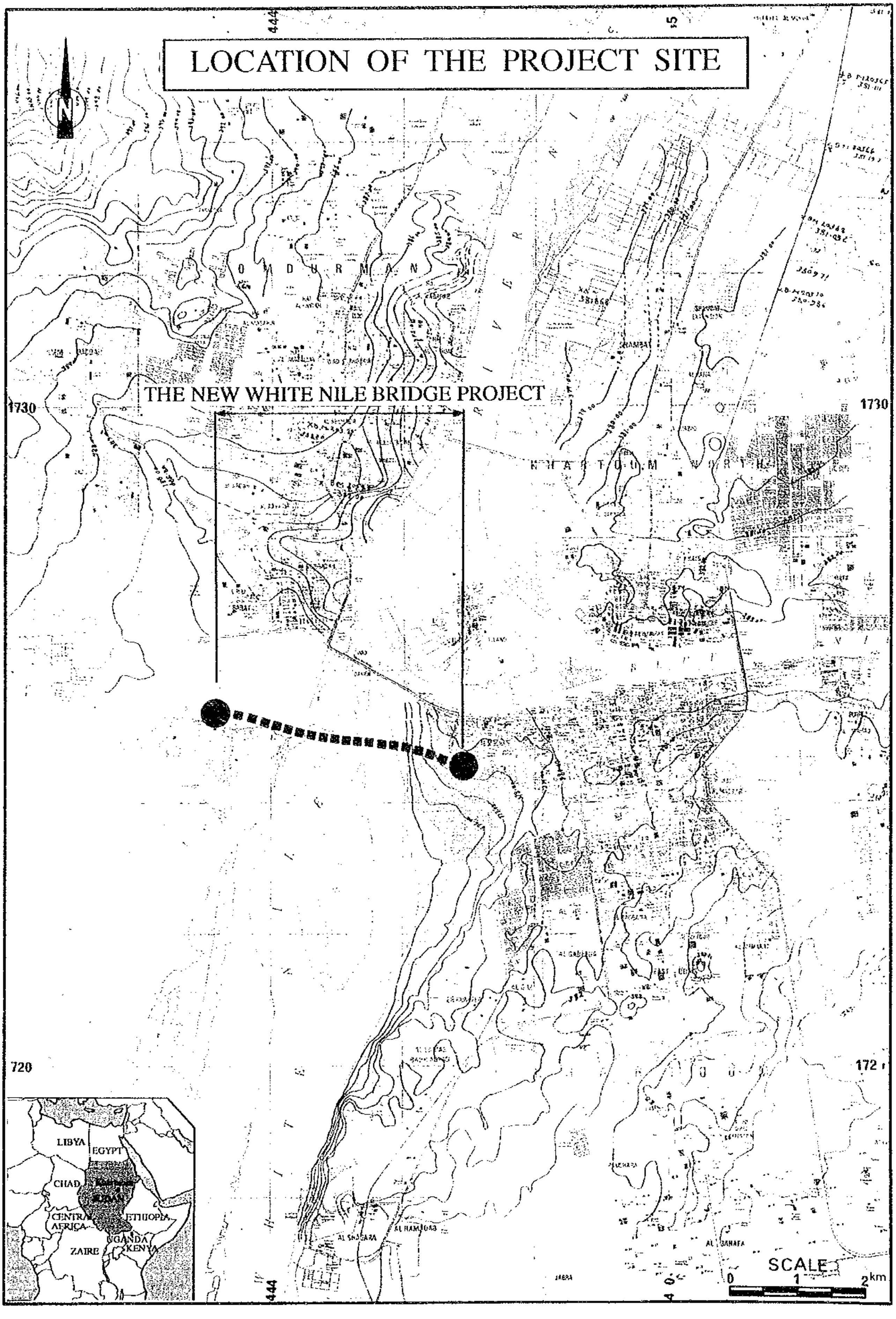
Kensuke Yanagiya

President

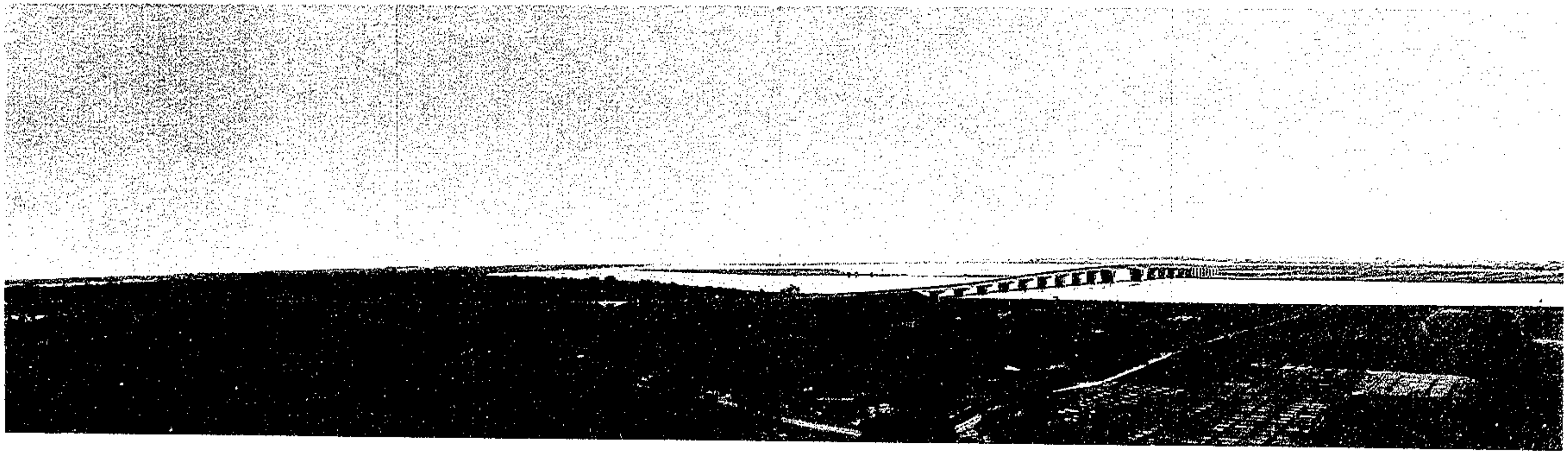
Japan International Cooperation Agency



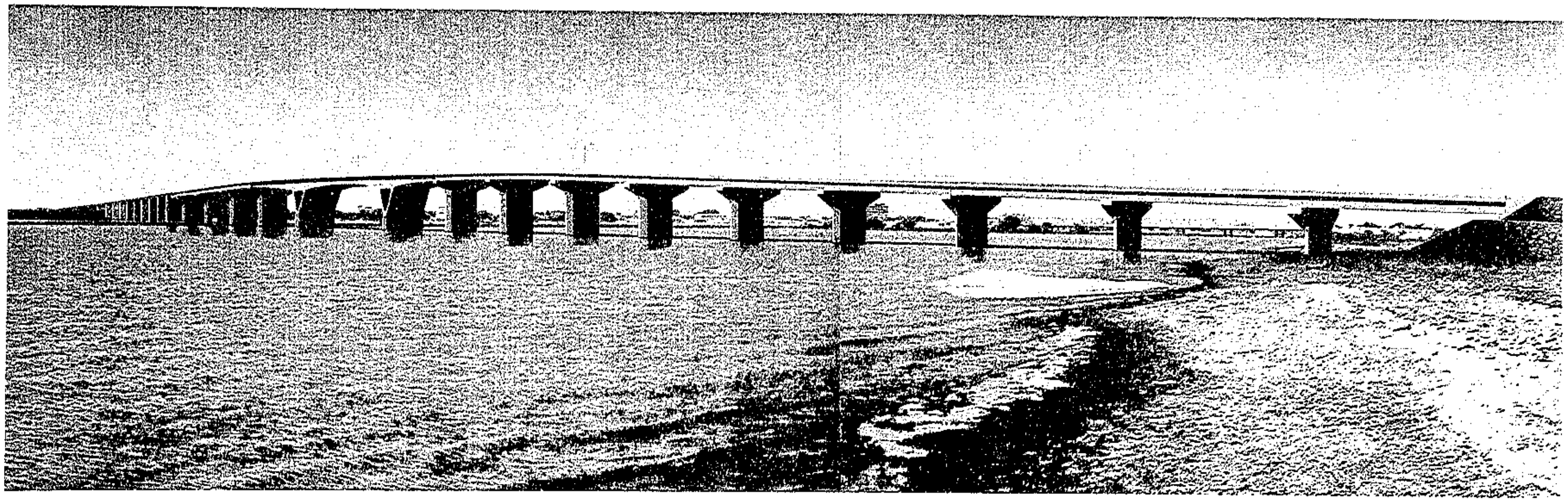
LOCATION OF THE PROJECT SITE
THE NEW WHITE NILE BRIDGE PROJECT
LIBYA
EGYPT
CHAD
ETHIOPIA
ZAIRE
KENYA
SCALE
0
1
2km



LOCATION OF THE PROJECT SITE
THE NEW WHITE NILE BRIDGE PROJECT
OMDURMAN
KHARTOUM NORTH
1730
720
444
SCALE
0
1
2km
LIBYA
EGYPT
CHAD
CENTRAL AFRICA
ETHIOPIA
ZAIRE
UGANDA
KENYA

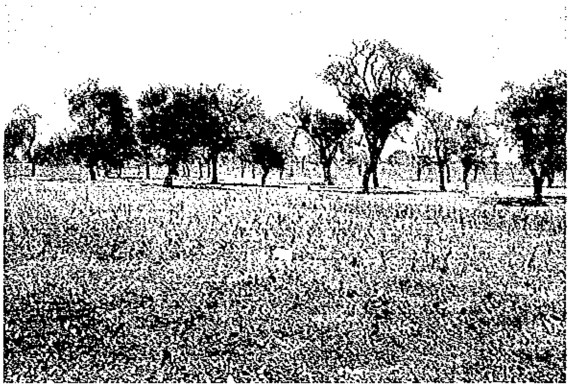


Perspective view of the proposed New White Nile Bridge and approach road viewed from the roof of the Hotel Hilton.



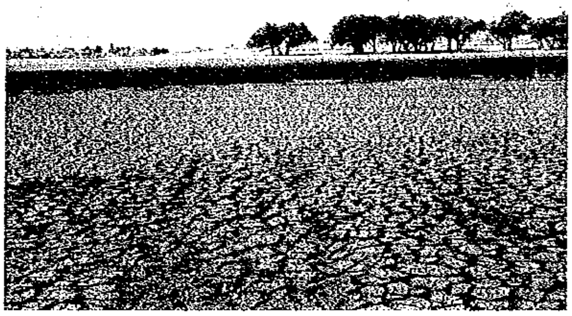
Side view of the proposed New White Nile Bridge viewed from the up-stream. The existing bridge can be seen in the background.

PROPOSED PROJECT SITE AND OTHER RELATED PLACES

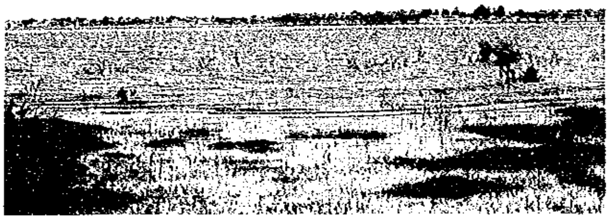


Sunt Wood near the proposed approach road on the Khartoum side
(This is thought to be a promising borrow area for embankment material.)

Test pit neer Sunt Wood excavated by JICA Study Team

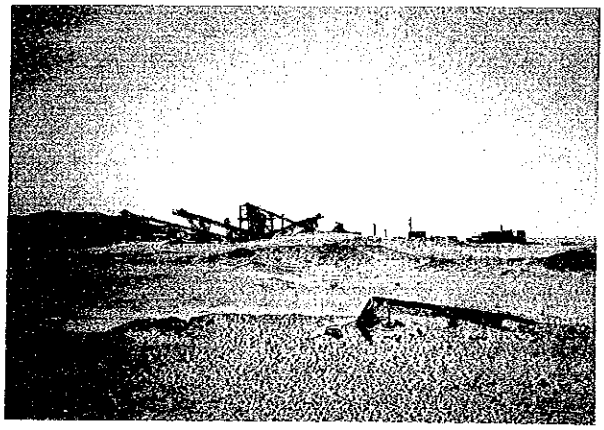


Riverside in the vicinity of the proposed approach road on the Omdurman side
(This area is inundated in the flood season and numerous cracks occur on the ground surface after the flood recedes.)



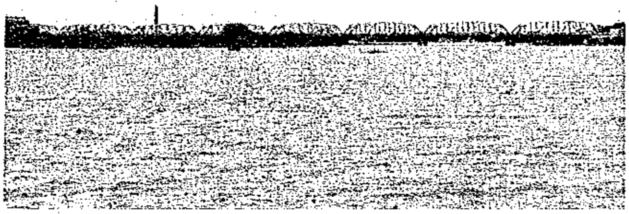
Flood condition at the proposed location of the New White Nile Bridge

Quarry site at Gebel Siretat (Granite rock covers this area.)

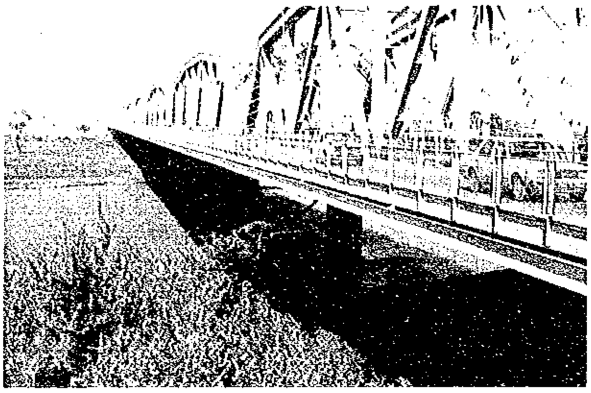


Quarry site at Gebel Torya
(Basalt rock covers this area.)

PRESENT SITUATION OF THE EXISTING WHITE NILE BRIDGE

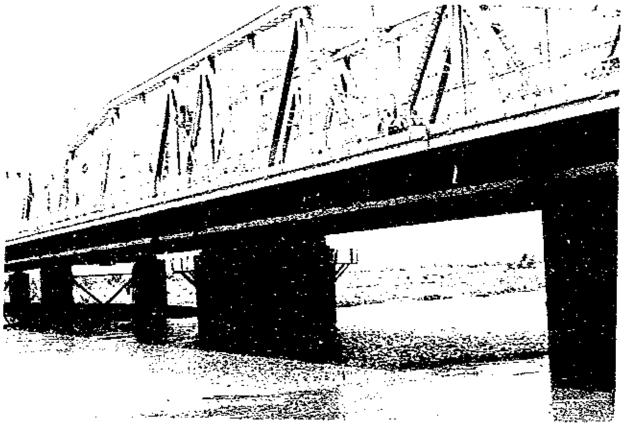


Upstream view of the existing White Nile Bridge



Exterior deck which allows only light vehicle to pass (A number of major members at deck level reported corroded.)

Pile bent piers supporting steel truss girder (Severe corrosion of the piers reported.)



Large pier supporting swing span (The swing span wedges were frozen and now no longer support the superstrucrure adequately.)

Khartoum side approach road to the existing bridge

Omdurman side approach road to the existing bridge

SUMMARY

CONTENTS OF SUMMARY

SUMMARY

A. CONCLUSION AND RECOMMENDATION OF THE STUDY

A.1 Bridge Location and Route

The construction of the New White Nile Bridge (the Project) aims to unplug the traffic bottlenecks on the existing White Nile Bridge between Khartoum and Omdurman, where the most severe traffic congestion has been occurring for the last decade.

The location of the New White Nile Bridge would be at 1,400 meters upstream on the west bank and 1,100 meters upstream on the east bank from the existing White Nile Bridge. The route of the Project would start at the turning point of Abu Sayid Road on the Omdurman side, then passing the above-mentioned new bridge, and will end at its connection point with AL Gaaba Road on the Khartoum side. The total length of the Project would be 4.4 kilo-meters.

A.2 Major Facilities

(1) Bridge

a) Bridge Width : 22.75 meters
(two lane dual carriageway)

Roadway = 8.75 meters in both directions
Sidewalk = 2.00 meters on both sides
Median Strip = 1.25 meters

b) Total Bridge Length : 757.2 meters

Main Span Bridge	= 172.0 meters
Side Span Bridge (Khartoum side)	= 326.2 meters
Side Span Bridge (Omdurman side)	= 108.6 meters
Omdurman side Viaduct	= 150.4 meters

c) Main Span Bridge

Type : Cast-in-place Prestressed Concrete
Continuous Box Girder with V-shape Pier

Span Arrangement : 46.0 m + 80.0 m + 46.0 m

d) Side Span Bridge on the Khartoum side

Type : Prestressed Concrete Composite I-girder
Span Arrangement : 9@36.2 m
(Reinforced concrete slab in which each three spans will be constructed as a continuous structure.)

e) Side Span Bridge on the Omdurman side

Type : Prestressed Concrete Composite I-girder

Span Arrangement : 3@36.2 m
(Reinforced concrete slab in which every three spans will be constructed as a continuous structure.)

f) Omdurman side Viaduct

Type : Reinforced Concrete Continuous Hollow Slab

Span Arrangement : 3@15.0 m + 3@15.0 m + (3@15.0 m + 15.4 m)

(2) Approach Roads

a) Road Width : 30.0 meters

Roadway = 9.5 meters in both directions
Sidewalk = 4.5 meters on both sides
Median Strip = 2.0 meters

b) Total Length of Approach Road : 3,642 meters

Omdurman side = 2,285 meters
Khartoum side = 1,357 meters

c) Roadway Elevation : RL + 382.100 meters (Minimum)

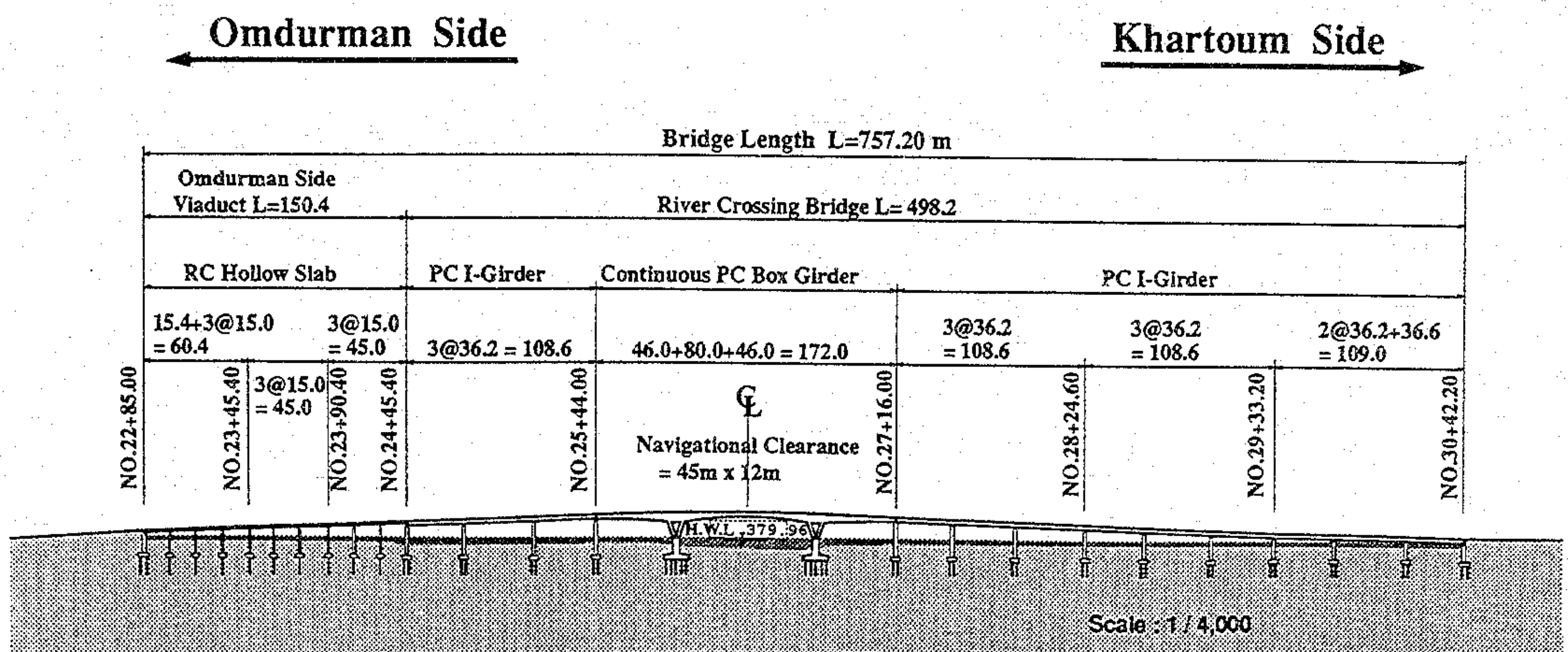
(3) Intersections

a) Location : 2 places: start point on the Omdurman side and end point on the Khartoum side

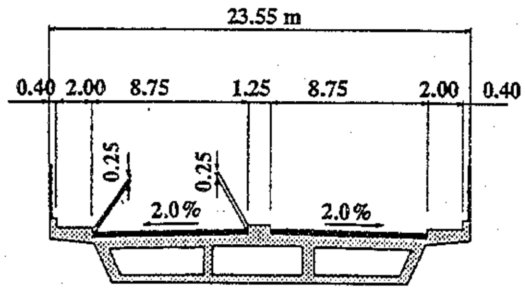
b) Intersection Type : At-grade intersections

Omdurman side : T shape with separate turning lanes

Khartoum side : Branch with separate turning lanes

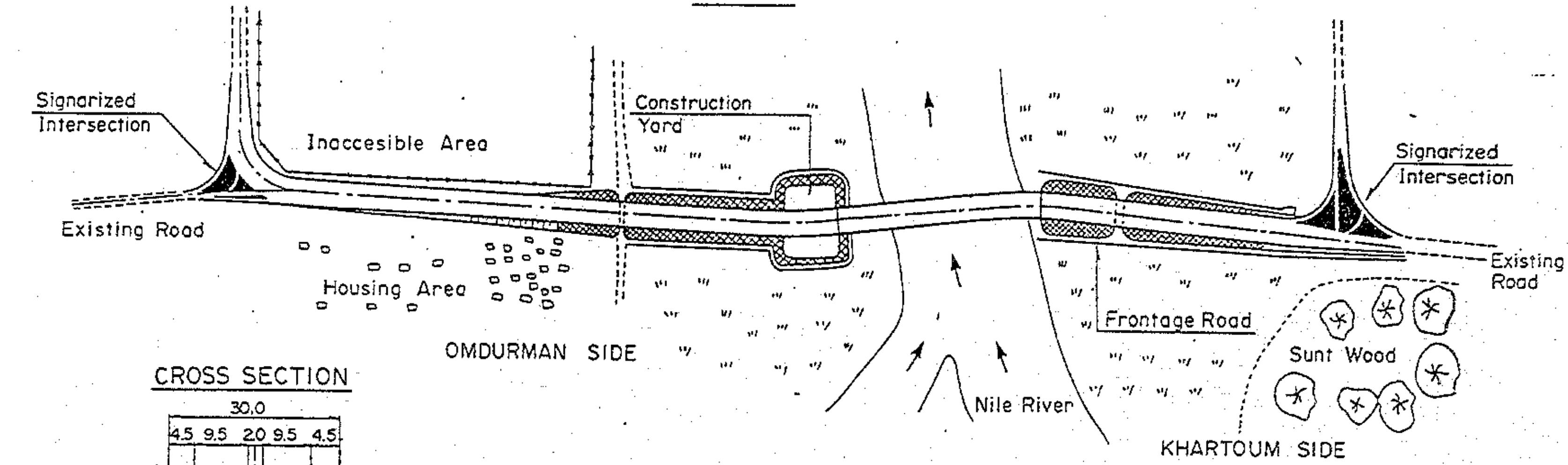


LONGITUDINAL SECTION

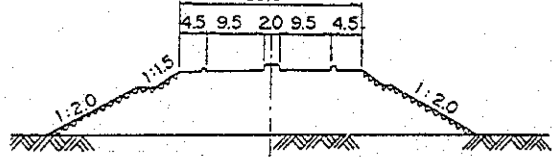


CROSS SECTION Scale 1:400

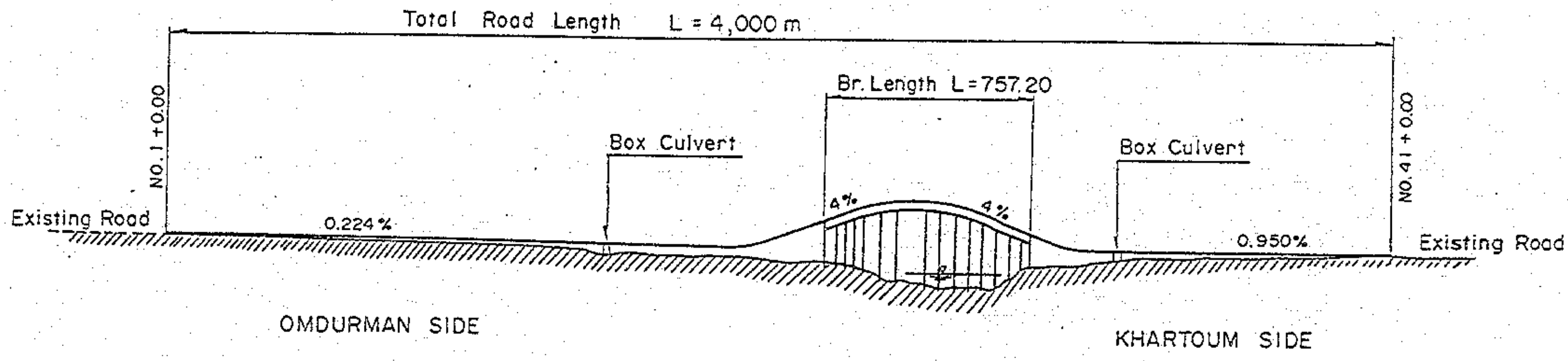
PLAN



CROSS SECTION



PROFILE



Note ; Not to Scale

A.3 Project Cost

	Unit : 1000 Ls
Construction Cost	288,640
Detailed Design and Construction Supervision Cost	30,070
Land Acquisition and Compensation Cost	104,600
NCK's Administration Cost	2,340
Tax and Quay Due	42,610
Contingency	14,430
Total	482,690

The above cost was estimated based on the prevailing prices in August 1989 and the official exchange rate of US$1.0 = Ls4.5 = ¥140

A.4 Project Feasibility

It is concluded that the Project is technically and economically feasible with an internal rate of return (IRR) 17.7%.

A.5 Necessity of the Project

According to the results of the traffic survey in February 1989, the existing White Nile Bridge is carrying about 60,000 PCU in a day and serious traffic congestion occurs every morning and evening peak hour at present. When no measure is taken (do-nothing case), future traffic volume on this existing bridge is expected at 104,000 PCU in a day for the year 2015 and more serious traffic congestion will occur not only on the bridge but also its associated access roads.

In order to unplug these traffic bottlenecks, the construction of a new bridge as a by-pass route connecting AL Fittaihab Town and AL Gaaba Road near Sunt Wood is thought the most favorable route.

As a result of the construction of a new bridge, the traffic capacity between Khartoum and Omdurman cities can be strengthened effectively. In this case, the future traffic volume on the existing bridge in the year 2015 is expected to be about 56,000 PCU, almost the same traffic volume as the present volume, and the new bridge will carry about 90,000 PCU in a day. Further, traffic congestion on the associated approach roads can be released.

If the construction of the New White Nile Bridge is implemented, the following benefits will be expected in addition to the improvement of traffic movements in the future:

- In the short term, the completion of the new bridge would facilitate the development of AL Fittaihab Town in Omdurman city.

- Distributing the traffic between the existing bridge and the new bridge would allow rehabilitation of the existing White Nile Bridge which is showing serious signs of deterioration, such as damage to a number of major members at deck level, wear on the swing span wedges to the extent that they no longer support the bridge adequately, and severe corrosion of the piers located in the river.

Additionally it may be expected that significant social and other unquantified benefits will result from implementation of the Project.

A.6 Conclusion

It is concluded that the construction of a new bridge across the White Nile, 1.4 km and 1.1 km south (upstream) of the existing bridge on the west and east banks, connecting Khartoum and Omdurman cities is technically and economically feasible, and accordingly recommends that it be immediately implemented.

B. SUMMARY OF THE STUDY

B.1 Introduction

B.1.1 Study Background

Recognizing the importance of the constructing of a New White Nile Bridge (the Project) to link Khartoum and Omdurman cities in Greater Khartoum, the Government of the Republic of the Sudan (GORS) requested the Government of Japan (GOJ) to provide assistance for a feasibility study on the Project. In response to this request, GOJ decided to conduct the Feasibility Study on the Construction of the New White Nile Bridge (the Study) in accordance with the relevant laws and regulations in force in Japan, and entrusted it to the Japan International Cooperation Agency (JICA), the official agency responsible for implementation of the technical cooperation program of GOJ.

B.1.2 Objective of the Study

The objective of the Study was to carry out a feasibility study in order to examine the technical and economic viability of constructing a New White Nile Bridge connecting Khartoum and Omdurman cities.

B.1.3 Reports

The following reports were submitted to NCK.

- Inception Report, January 1989
- Interim Report (I), March 1989
- Interim Report (II), August 1989
- Draft Final Report, January 1990
- Final Report, March 1990

B.2 Existing Road Network and Traffic Characteristics

B.2.1 Condition of Socio-economic and Road Facilities

B.2.1.1 Socio-economic Conditions

(1) Urbanization Pattern

Greater Khartoum consists of three cities; Khartoum where the main governmental institutions and business centers are located, Omdurman historical and residential area, and Khartoum North residential area with the largest industrial area in the country. The spatial development of Greater Khartoum has been conditioned by the Nile rivers and railway transportation, but since the 1960s it has also been dictated by the construction of arterial highways along with other infrastructure.

(2) Population in Khartoum

In Khartoum, urbanization had already spread to almost 75% of the whole Khartoum region by 1983. The population in Khartoum increased at an annual growth rate of 4.8% to 1.8 million in 1983 from 0.5 million in 1955/56. During the same period, the urban population has increased at rate of 6.8% per annum.

(3) Existing Land Use

Khartoum City is the center of the capital area and many government agencies and commercial activities are concentrated there. Omdurman City is an old built-up area and Khartoum North City has the biggest industrial area in Greater Khartoum. As the population grows, the housing area is expanding to the southwestern part of Omdurman, the southern part of Khartoum and the eastern part of Khartoum North. Although the urbanized area is rapidly expanding recently no new sub-center has grown up, which has caused serious chronic traffic congestion around the CBD (central business district) in Khartoum City.

B.2.1.2 Existing Road Conditions

(1) Road Network

Roads in Khartoum, Omdurman and Khartoum North can be classified as primary distributors, district distributors, local distributors and access roads according to the British Standard.

The existing road network in Greater Khartoum forms a grid pattern in each area, hence there are problems of direct connection of access roads to both primary distributors and district distributors, which may lead to disturbance of the main traffic flow as well as cause traffic accidents at small intersections.

(2) Road Conditions

According to the UNDP Study in 1983, "Khartoum Traffic Management and Public Transport Study" by BCEOM, 276km of roads in Greater Khartoum (169km in Khartoum, 53km in Omdurman and 54km in Khartoum North) are asphalt paved roads. In addition, there are 39km of gravel roads and 63km of earth roads. Hence, the total road length in Greater Khartoum is 378km.

(3) Condition of Road Facilities and Traffic Regulations

In general, major intersections in Greater Khartoum are roundabouts, and traffic signals have only been installed at certain busy intersections. Since the capacity of a roundabout is less than the capacity of a signalized intersection over a certain level of traffic volume, these roundabouts have become bottlenecks for traffic flow under the condition of rapidly increasing traffic volumes in Greater Khartoum.

(4) Condition of Existing Bridges

Three cities are connected by four existing bridges; the White Nile Bridge between Khartoum and Omdurman over the White Nile; the Blue Nile Bridge and the Burri Bridge between Khartoum and Khartoum North over the Blue Nile; and Shambat Bridge between Omdurman and Khartoum North over the River Nile.

B.2.2 Traffic Characteristics

B.2.2.1 Existing Traffic Characteristics

(1) Hourly Fluctuation

The hourly traffic volume in the morning peak hour towards Khartoum on both the White Nile Bridge and the Blue Nile Bridge reached a level of about 4,000 PCU, while the off-peak hourly traffic volume on the White Nile Bridge for both directions was also as high as about 2,000 PCU.

(2) Vehicle Composition

Since there is a regulation to control truck and trailers and bus traffic on the White Nile Bridge and the Blue Nile Bridge, the nature of the vehicle composition on each bridge is quite different.

In the case of the White Nile Bridge, the proportion of passenger cars is the highest at 43.2%, followed by taxis (23%), pick-ups (21.5%), mini-buses (7.5%) and buses (4.8%).

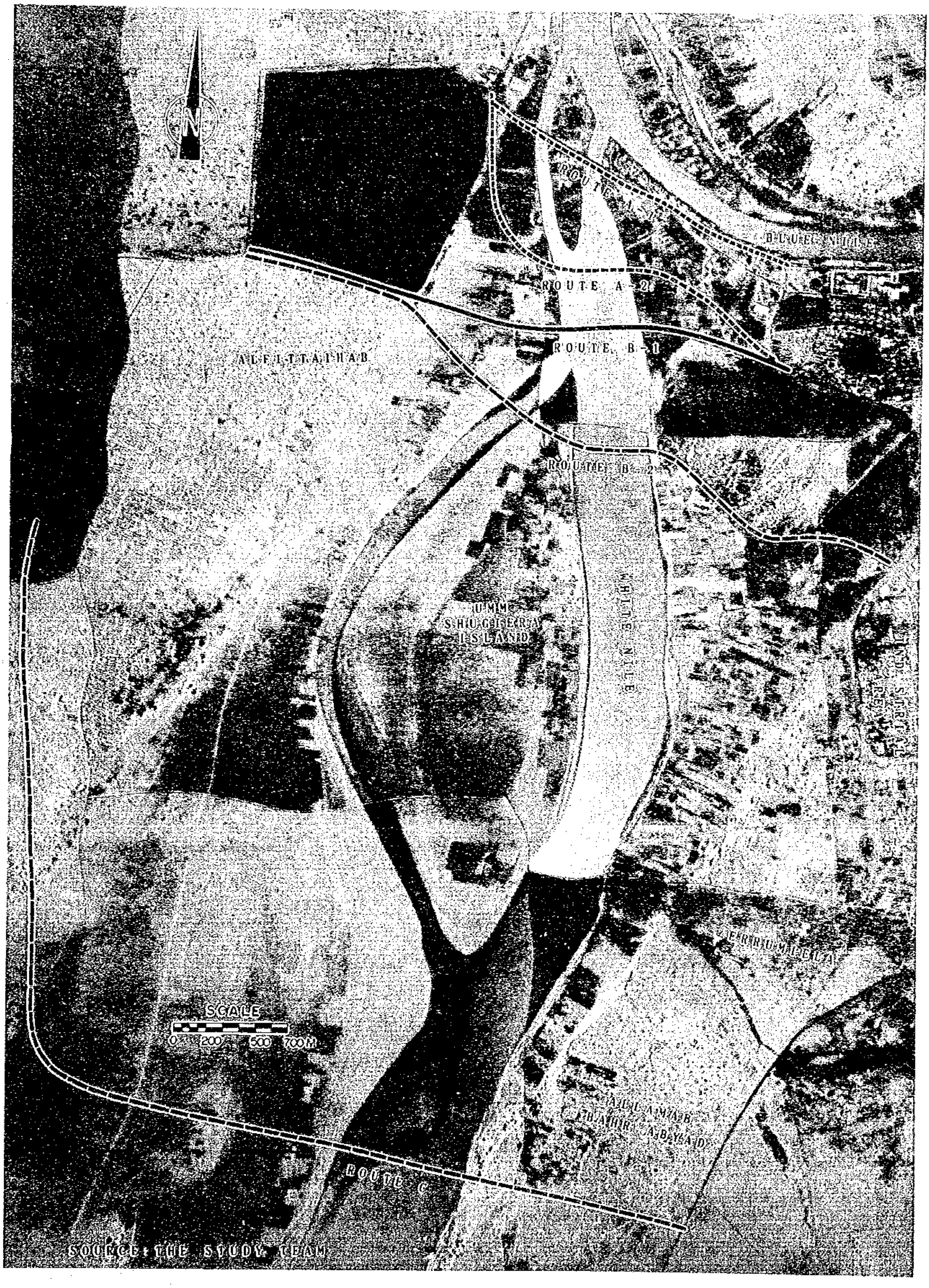
(3) Traffic Volumes on Major Roads

Based on the results of traffic volume counting at road sections as well as 24 hour traffic volume counting at bridges, it can be said that the heaviest traffic flows at each end of the White Nile Bridge are observed on AL Niel Road in Khartoum and AL Murradah Road in Omdurman. However, AL Gaaba Road and Abu Syaid Road also accommodate rather heavy traffic flows of 22,000 PCU and 26,000 PCU, respectively.

B.3. Bridge Location AND Route

B.3.1 Bridge Location and Route Alternatives

In the Interim Report (I) issued in March 1989, five alternatives were identified as shown in the following figure.



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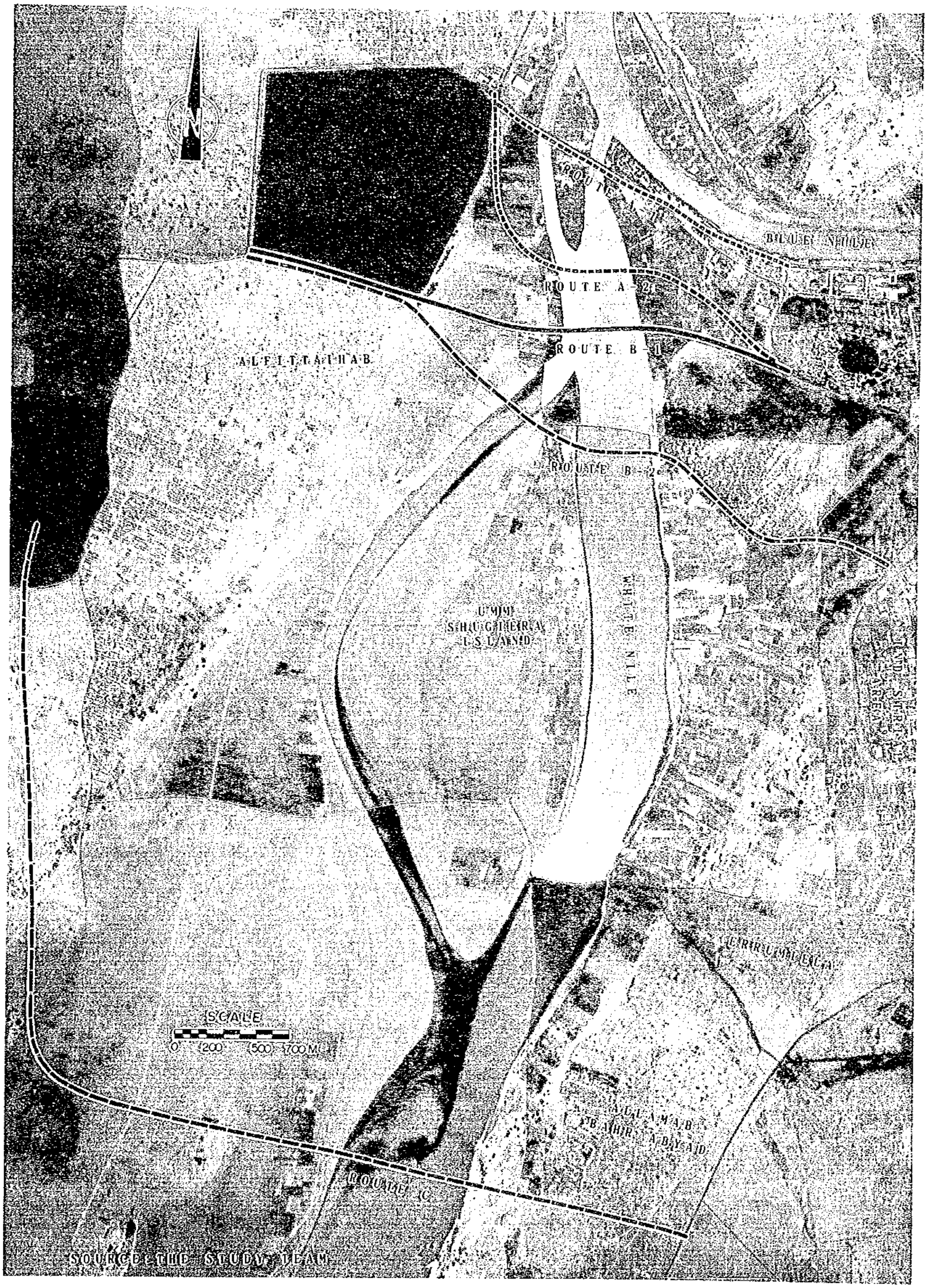


B.3.2 Traffic Forecast by Alternatives

The future traffic volume was forecast based on the future framework of several socio-economic variables as described below:

(1) Population

Future population growth rate was determined, by considering the past trend in population, the existing social and economic conditions, and the government strategies published recently.

(2) Employment

Future employment in the secondary and tertiary sectors were projected mainly from the growth rates suggested in the report "The Four Year Salvation, Recovery, and Development Programme 1988/89-1991/92".

(3) Registration of Private Cars

Projections of the future number of registrations of private cars were based on the car ownership rate by income class. Based on the above framework, the future traffic demand was forecast, using a regression model.

The future OD Table was forecast by distributing the above traffic demand (generated or attracted trips) into traffic zones with gravity model from which the future traffic on the alternative routes was estimated by assigning the future OD traffic volume on the alternative road networks. The future traffic volume crossing the B-1 route was forecast to be about 88,000 PCU/day in 2000 as shown below.

Comparison of Alternative Routes

	A-1	A-2	B-1	B-2	C
Traffic volume on New Bridge	79,880	69,847	88,213	80,079	45,713
Congestion degree on New Bridge	1.16	1.37	1.16	1.29	1.83

B.3.3 Route Selection

The following table summarizes the evaluation of the above five alternatives. As a result of the evaluation, alternative **Route B-1** was selected from the view points of economy, future road network aspects and engineering aspects.

Evaluation Table by Alternative Route

		Route Alternatives				
		A-1	A-2	B-1	B-2	C
Outline of Each Route	Functional Classification	Enlargement of Existin Arterial Road over the White Nile		By-pass with Potentiality of Beltway Connector		Beltway Connector
	Project Length	2,100 m	2,900 m	4,400 m	5,200 m	7,400 m
	Bridge Length	620 - 700 m	700 - 800 m	700 - 800 m	1,100 - 1,300 m	1,000 - 1,300 m
	Bridge Type	Movable Bridge	Fixed Bridge	Fixed Bridge	Fixed Bridge	Fixed Bridge
Evaluation	Economic Internal Rate of Return (EIRR)	8.9 %	15.6 %	21.3 %	16.0 %	16.6 %
	Road and Bridge Engineering Aspect	△	○	◉	○	○
	River Hydrological Aspect	△	◉	◉	◉	◉
	Navigational Safety	×	◉	◉	◉	◉
	Relief Degree of Traffic Congestion	△	△	◉	◉	○
	Further Maintenance	△	○	○	○	○
	Land Acquisition and Compensation	◉	○	○	○	△
OVERALL EVALUATION		△	○	◉	○	○

Recommended (B-1)

LEGEND:

- ◉ Very Good
- ○ Good
- △ Fair
- × Bad

<u>The Selected Route: Alternative Route B-1</u>

A) Alignment

This route would begin at the turning point of Abu Sayid Road at Al Fittaihab Town, then running southeastwards along the military boundary wall, crossing over the White Nile almost at right angles and passing the northern edge of Sunt Wood, it would end at the junction with Al Gaaba Road. The anticipated length of this route would be about 4,400 m in total.

B) Bridge

The location of the new bridge would be about 1,100m to 1,400m south of the existing bridge. Navigational clearance would be maintained at the main span of the fixed type new bridge.

C) Intersections

The anticipated intersections are:

Omdurman Side : 1 no. - at-grade intersection

Khartoum Side : 1 no. - at-grade intersection

B.4 Preliminary Engineering

Prior to the preliminary engineering study, the following field surveys were conducted for collection of basic data for bridge and road preliminary design.

a) River current velocity survey

b) Sub-soil investigation survey

c) Construction material survey

d) Topographical survey

B.4.1 River Hydrology

(1) High Water Level

According to the water level records at Mogran, the highest water level ever recorded was RL+379.96 m in August 1946, while the 1988 flood was the second largest flood. The highest recorded water level of RL+379.96 m at Mogran is applied for design high water level.

(2) Low Water Level

The lowest water level at the bridge sites was estimated at RL+373.54 m based on a discharge of 370 cu.m/sec and Manning's formula using the river cross-section surveyed, a roughness coefficient of 0.03 and an average riverbed slope of 1.400 around the bridge site.

(3) Flow Velocity

The flow velocities at low and high water levels were estimated as 0.35 m/sec and 1.32 m/sec respectively based on the recorded outflow discharge, river cross-section and longitudinal gradient of the river.

B.4.2 Subsoil Conditions

The main strata at the project site consist of Alluvial layers and the basal rock layer.
The characteristics of these layers are summarized below:

(1) Clay ACL1

Recent river deposit
It lies on the surface of the river-bed and is a few meters thick. N-value of SPT (standard penetration test) is 1, very loose and soft clay.

(2) Clay ACL2

Homogeneous clay
This contains a small quantity of silt. N-value averages 5, which shows a moderate consistency.

(3) Clay ACL3

This layer is distributed on both banks in the of a river terrace. The soil type is a silty clay which contains about 15% silt fraction. Its very hard condition is similar to cemented clay due to desiccation and dry weathering. This condition prevails except during an abnormal flood season. N-values 6 to 11.

B.4.3 Bridge

B.4.3.1 Navigation Requirement

Navigation clearance was examined by taking into account the existing river conditions, inland water transportation conditions, and tug boat and barge operations. In addition above, after many discussions between NCK, RTC and the Study Team, the following were decided:

a) Vertical Clearance : 12.0 m from high water level

b) Horizontal clearance : 45.0 m

B.4.3.2 Bridge Length

Determination of the bridge length is a major factor in the planning of a bridge since it may dominate the construction cost. The conditions to determine the bridge length, therefore, were carefully discussed with the NCK and other governmental staff concerned. After exchanging opinions with them, the following were set up as the requirements for the bridge length.

* Bridge Length crossing river = 16.1+560.7+30.0 = 606.8 m
* Viaduct Bridge Length = 150.4 m
* Total Bridge Length = 757.2 m

B.4.3.3 Bridge Type Selection

The following six bridge types as shown in the following figure were provided for selection of the optimum bridge type for the New White Nile Bridge.

Comparison Table By Alternative Bridge Type

BRIDGE TYPE: MAIN SPAN	BRIDGE TYPE: SIDE SPAN	SIDE VIEW AND SPAN ARRANGEMENT (UNIT; M)	STRUCTURAL FEATURES	MATERIAL PROCUREMENT & TRANSPORT	MAINTENANCE	AESTHETICS	CONSTRUCTION PERIOD	CONSTRUCTION COST (X 1,000 Ls)	OVERALL EVALUATION
TYPE-a STEEL LOHSE	PLATE GIRDER	PLATE GIRDER 3@38.0 =114.0 / LOHSE 40+80+40 =160.0 / PLATE GIRDER 8@41.625=333.0	△	×	×	◎	40 MONTHS △	SUPER : 336,060 SUB : 115,430 TOTAL : 451,490 △	×
TYPE-b STEEL TRUSS	PLATE GIRDER	PLATE GIRDER 2@45.0 =90.0 / TRUSS 64+80+64 =208.0 / PLATE GIRDER 8@38.625=309.0	△	△	×	×	37 MONTHS ○	SUPER : 350,460 SUB : 111,980 TOTAL : 462,440 ○	×
TYPE-c STEEL BOX	PLATE GIRDER	PLATE GIRDER 2@45.0 =90.0 / BOX 64+80+64 =208.0 / PLATE GIRDER 8@38.625=309.0	×	×	×	△	34 MONTHS ○	SUPER : 365,690 SUB : 111,980 TOTAL : 477,670 ×	×
TYPE-d P.C BOX (T-TYPE PIER)	T-GIRDER	T-GIRDER 3@35.0 =105.0 / BOX 49+80+49 =178.0 / T-GIRDER 9@36.0=324.0	△	○	◎	△	34 MONTHS ○	SUPER : 299,880 SUB : 131,020 TOTAL : 430,900 ○	○
TYPE-e P.C BOX (V-TYPE PIER)	T-GIRDER	T-GIRDER 3@35 =105.0 / BOX 49+80+49 =178.0 / T-GIRDER 9@36.0=324.0	○	○	◎	◎	34 MONTHS ○	SUPER : 299,880 SUB : 130,780 TOTAL : 430,660 ○	◎
TYPE-f P.C CABLE-STAYED	T-GIRDER	T-GIRDER 4@34.75 =139.0 / CABLE STAYED 110+70 =180.0 / T-GIRDER 8@36.0=288.0	△	△	△	◎	40 MONTHS △	SUPER : 286,310 SUB : 227,410 TOTAL : 513,720 ×	△

LEGEND : ◎ VERY GOOD ○ GOOD △ FAIR × BAD

As a result of evaluation of the alternative bridge types, a PC Box Girder with V-type piers and PC I-Girders is recommended for the New White Nile Bridge. The reasons are summarized as follows:

a) the space below the bridge girder is wider

b) the girder depth at the piers of the main span is smaller than other cantilever concrete bridge types

c) driving is more comfortable because of continuous girder type

d) construction materials for the structures are available in Khartoum except for cement, prestressing tendons and rebars

e) saving in maintenance cost is possible

f) agreeable aesthetics are expected

g) the construction period is shorter

h) the construction cost is as low as for a PC Box Girder with T-type piers

B.4.3.4 Preliminary Design of Bridge

The preliminary design of the bridge was conducted considering economic aspects, technical aspects and basic design criteria.

The results of the preliminary design are presented in the "Drawings" which contain the following.

a) A maximum longitudinal gradient of 4% is adopted.

b) The bridge is designed to carry a 2 lane dual carriageway with side walks (2.0 m) on both side.

c) The bridge is 752.2 meters in length and consists of continuous PC box girder, PC composite I-girder and RC hollow slab.

d) Center span; PC Box girder type of 80.0 meters

e) Side spans; PC Box girder type of 46.0 meters and PC I-girder type of 36.2 to 36.6 meters.

f) Approach spans; RC Hollow Slab type of 15.0 meters

g) Concrete Wall type is adopted for substructure.

h) Cast-in-place RC pile type is adopted for foundations

B.4.4 Approach Road and Intersections

B.4.4.1 Design Criteria

Based on the existing and future road network configurations, traffic characteristics and future development aspects, the following design criteria were established:

a) The approach road is classified as a Primary Distributor.

b) A design speed of 80 km/h is adopted.

B.4.4.2 Preliminary Design

The preliminary Design of approach roads was conducted considering economic aspects, technical aspects and basic design criteria. The results of preliminary design are presented in the "Drawings" which contain the following:

a) The road length including the bridge is 4,000 meters.

b) The road is designed as a two lane dual carriageway with side walks (4.5m) on both sides of the carriageway.

c) The slopes of embankments in flooded areas are protected by mortar rip rap.

d) Seven pipe culverts and two box culverts are provided.

e) One construction yard is provided.

f) Frontage roads of 10.0 m width are provided on both sides of the road in the flooded area.

g) Three leg at-grade intersections with signals are provided on the Omdurman and Khartoum sides.

B.5 Project Cost

Financial capital cost is Ls482,690 thousand, equivalent to US$107,264 thousand. This comprises:

	Ls Thousand
Construction Cost	288,640
Detailed Design & Supervision Cost	30,070
Land Acquisition & Compensation Cost	104,600
NCK's Administration Cost	2,340
Tax and Quay Dues	42,610
Contingencies	14,430
Total	482,690

These costs are based on prices in August 1989, the reference date for the cost estimate, and an exchange rate of the Official Rate $1.0 = Ls4.5.

The construction period has been assessed as 42 months.

B.6 Economic Cost and Benefit

(1) Economic Cost

The financial construction cost was converted into economic cost with the following three conversion factors:

a) Shadow Exchange Rate

b) Standard Conversion Factor

c) Shadow Wage Rate for Unskilled Laborer

With the above conversion factors, the financial construction cost was converted into the economic cost shown in the following table.

Economic Construction Cost

(Unit : Ls 1,000)

Item		1991	1992	1993	1994	1995	Total
Detailed Design	FC	30344	0	0	0	0	30344
	LC	647	0	0	0	0	647
Land Acquisition	FC	0	0	0	0	0	0
& Compensation	LC	27719	27719	0	0	0	55438
NCK's Admini-	FC	0	0	0	0	0	0
stration	LC	371	159	233	260	217	1240
Tender Assistance	FC	0	12081	13992	15341	12756	54170
& Supervision	LC	0	588	1882	2131	1871	6471
Construction	FC	0	214133	244065	232714	214751	905663
Materials	LC	0	1447	2556	2730	3077	9810
Unskilled Labor	LC	0	4109	7259	7753	8738	27861
Skilled Labor	LC	0	1021	1804	1927	2172	6925
Sub-Total	LC	0	6578	11620	12410	13987	44596
Contingency	FC	0	10714	12194	11632	10733	45273
(Const. Cost x 5%)	LC	0	424	753	806	906	2889
Total (Foreign)	FC	30344	236928	270251	259687	238240	1035450
(Local)	LC	28737	35468	14487	15606	16982	111280
Grand Total		59081	272397	284738	275293	255221	1146730

(2) Benefits

The economic benefits derived from the proposed project comprise three items: vehicle operating cost savings, time savings, and maintenance cost savings for the existing White Nile Bridge.

(a) Vehicle Operating Cost Saving Benefit

Year	VOC Saving Benefit (Ls 1,000)
1995	11,805
2005	4,945
2015	3,370

(b) Time Saving Benefit

Year	Time Saving Benefit (Ls 1,000)
1995	77,599
2005	338,720
2015	2,159,919

(c) Maintenance Cost Saving Benefit

Reconstruction Cost Saving

The existing White Nile Bridge is assumed to require partial reconstruction in the year 2000 from the engineering viewpoint if the proposed New White Nile Bridge is not constructed. Therefore, if the New White Nile Bridge is completed, the estimated reconstruction cost of Ls 133,778,000 can be saved. In addition, as it could take four months to reconstruct the existing bridge without the proposed bridge, the traffic crossing the existing bridge would be forced to detour between Omdurman and Khartoum. However, if the proposed bridge is completed, the above detour could be avoided, which produces the time saving value of Ls 94,000,000 in 2000.

Maintenance Cost Saving for the Existing Bridge

The maintenance cost for the existing bridge would be saved as the traffic volume would not increase so fast after completion of the New White Nile Bridge. Therefore, the maintenance cost saving is estimated as follows:

Year	Maintenance Cost Saving (Ls 1,000)
1995	158
2005	184
2015	192

B.7 Economic Evaluation

Using cost and benefit streams, the three economic indicators were calculated as follows:

Benefit Cost Ratio	(B/C)	1.985
Net Present Value	(NPV)	Ls 782,154,000
Internal Rate of Return	(IRR)	17.7%

The proposed project is judged to be sufficiently viable, considering the values of the above three economic indicators as well as the results of the sensitivity analysis shown in the following table, which shows a 12.1% IRR even in the worst case of 20% cost increase and 20% of benefit decrease. In addition, the proposed project brings about many intangible benefits. These intangible benefits are summarized in the following categories:

(a) In the process of planning and design

- Demonstration effect
- Economic and educational effect

(b) During construction

- Demand effect for construction materials
- Demand effect for employment
- Technology transfer effect
- Resource development effect

(c) After completion of project

- Existing effect
- User's effect
- Energy saving effect

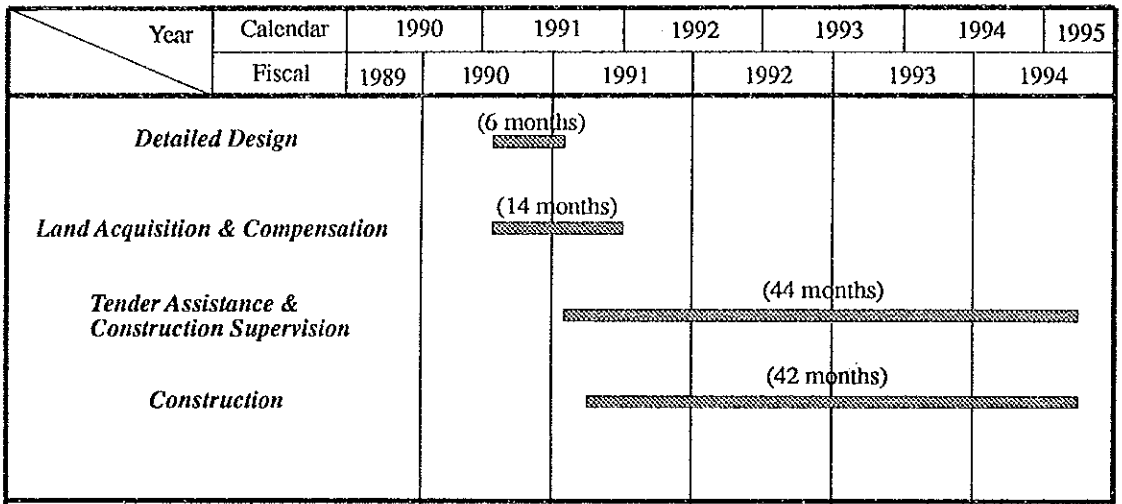
Sensitivity Analysis

Benefit Change \ Cost Change		0%	5%	10%	15%	20%
	B/C	1.985	1.890	1.726	1.527	1.323
0%	NPV	782154	742449	663039	543923	385103
	IRR	17.7	17.2	16.4	15.2	14.0
	B/C	1.886	1.796	1.640	1.451	1.257
-5%	NPV	703341	663636	584226	465111	306290
	IRR	17.2	16.7	15.9	14.8	13.5
	B/C	1.786	1.701	1.553	1.374	1.191
-10%	NPV	624524	584823	505413	386298	227477
	IRR	16.7	16.2	15.4	14.3	13.1
	B/C	1.687	1.607	1.467	1.298	1.125
-15%	NPV	545716	506010	426600	307485	148665
	IRR	16.2	15.7	14.9	13.8	12.6
	B/C	1.588	1.512	1.381	1.222	1.059
-20%	NPV	466903	427198	347788	228672	69852
	IRR	15.6	15.2	14.4	13.3	12.1

Unit : B/C ratio
NPV Ls 1,000
IRR %

B.8 Implementation Program

An implementation program covering the period from detailed design to construction has been prepared as shown below:



FUND REQUIREMENT		Total Cost	(Unit: 1,000 Sudanese Pounds) 1990	1991	1992	1993	1994
Detailed Design Cost	FC	5,970	5,970				
	LC	1,220	1,220				
Land Acquisition & Compensation Cost	FC						
	LC	104,600	52,300	52,300			
NCK's Administration Cost	FC						
	LC	2,340	700	300	440	490	410
Tender Assistance & Construction Supervision Cost	FC	10,670		2,380	2,760	3,020	2,510
	LC	12,210		1,110	3,550	4,020	3,530
Construction Cost	FC	179,760		42,200	48,940	46,210	42,410
	LC	108,880		16,060	28,370	30,300	34,150
Tax and Quay Due	FC						
	LC	42,610		29,830	4,260	4,260	4,260
Contingency (5% of Construction Cost)	FC	8,980		2,110	2,450	2,310	2,110
	LC	5,450		800	1,420	1,520	1,710
TOTAL	FC	205,380	5,970	46,690	54,150	51,540	47,030
	LC	277,310	54,220	100,400	38,040	40,590	44,060
Grand Total		482,690	60,190	147,090	92,190	92,130	91,090
(1,000 US Dollars)		(107,264)	(13,375)	(32,687)	(20,487)	(20,473)	(20,242)

Notes: (1) Cost estimate was made based on August 1989 prices and exchange rate US$1.0=Ls4.5=Y140.

(2) Land acquisition and compensation costs include value of land already owned by the Government of Sudan.

B.9 Conclusion and Recommendations

From the wide ranging engineering and economic studies which the Study Team has undertaken, the following conclusions have been reached: :

a) According to the results of the traffic survey in February 1989, the existing White Nile Bridge is carrying about 60,000 PCU in a day and serious traffic congestion occurs every morning and evening peak hour at present. The future traffic volume on the existing bridge is expected to be 104,000 PCU in a day for the year 2015 and more serious traffic congestion will occur not only on the bridge but also on its associated access roads.

In order to unplug these traffic bottlenecks, the construction of the new bridge as a by-pass route (Route B-1 on which a new bridge is to be located 1.4 km and 1.1 km south of the existing bridge on the west and east banks) connecting Al Fittaihab Town and Al Gaaba Road near Sunt Wood is thought to be the most favorable route.

As a result of construction of the new bridge, the traffic capacity between Khartoum and Omdurman cities can be significantly increased. In this case, the future traffic volume on the existing bridge in the year 2015 is expected to be about 56,000 PCU, almost the same traffic volume as at present, and the new bridge will carry about 90,000 PCU in a day. Further, traffic congestion on the associated approach roads will be relieved.

b) As a result of the engineering studies and preliminary design, a 4-lane bridge having a total length of 757.2 meters recommended on the by-pass route which would begin at the turning point of Abu Sayid Road at Al Fittaihab Town on the Omdurman Side and end at the junction with Al Gaaba Road near Sunt Wood on the Khartoum side.

The proposed new bridge would consist of a 172 meter PC Box girder over the navigational course, 326.2 meter PC I-girder and 150.4 meter RC Hollow Slab on the Omdurman side.

Its approach roads would be 2,285 meters long and 1,357 meters long on the Omdurman side and Khartoum side. The construction works would require 42 months.

The construction cost has been estimated at Ls288,640 thousand, equivalent to $64,142 thousand, based on August 1989 prices and the Official Exchange Rate $1.0 = Ls4.5.

c) The construction of the New White Nile Bridge was judged very viable by the economic evaluation which showed an IRR of 17.7%.

d) If the construction of the New White Nile Bridge is implemented, the following benefits will be expected in addition to the improvement of traffic movements in the future:

- In the short term, the completion of the new bridge would facilitate the development of AL Fittaihab Town in Omdurman city.

- Distributing the traffic between the existing bridge and the new bridge would allow rehabilitation of the existing White Nile Bridge which is showing serious signs of deterioration, such as damage to a number of major members at deck level, wear on the swing span wedges to the extent that they no longer support the bridge adequately, and severe corrosion of the piers located in the river.

Additionally it may be expected that significant social and other unquantified benefits will result from implementation of the Project.

In conclusion the Study Team states that construction of a new bridge across the White Nile, 1.4 km and 1.1 km south (upstream) of the existing bridge on the west and east banks, connecting Khartoum and Omdurman cities is technically and economically feasible, and accordingly recommends that it be immediately implemented.

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Abbreviations and Notations (1/9)

a	parameter (Chapter-IV) angle (Chapter-VI) shape factor (Chapter-VII)
A	traffic attraction (Chapter-IV) flow area (Chapter-VI) vertical exposed area (Chapter-VII)
AASHTO	The American Association of State Highway and Transport Officials
Ai	zonal trip attraction in zone i
Aj	total trip attraction of zone j
Al	alluvial soil
B	buoyancy (Chapter-VII) coefficient for plugging effect at pile tip (Chapter-VII)
BC	beginning of curve
B/C	benefit cost ratio
BP	end of point
BSI	British Standards Institute
BT	total travel time saving
BUS	growth rate of buses registered
C	traffic capacity (Chapter-III) unit cost of vehicle operation (Chapter- V) saving of vehicle operation cost between i zone and j zone (Chapter-V) cohesive strength (Chapter-VI and VII)
CAR	car ownership
CB	basic capacity
CBD	central business district
CBR	California Bearing ratio
Cc	compression index
CD	drag coefficient
C.Di	congestion degree with the New White Nile Bridge in 2015

C.Do	congestion degree without the New White Nile Bridge in 2015 (do-nothing case)
CL	clay layer (Chapter-VI) curve length (Chapter-VIII)
CO	ship collision force
COM	growth rate of consumption
CPPC	Central Physical Planning Committee
CT	total vehicle operation cost saving
Cu	cohesive strength in slip surface
cu.m	cubic meter(s)
Cv	coefficient of consolidation
D	distance (Chapter-IV) width or diameter (Chapter-VII) air density (Chapter-VII) stop-distance of ship (Chapter-VII) dead load (Chapter-VII)
deg.	degree(s)
D/F	Draft Final Report
dp	increment stress caused by embankment
E	east (Chapter-II, Chapter-VI) export (Chapter-V) earth pressure (Chapter-VII)
EC	end of curve
EIRR	economic internal rate of return
EL	elevation
EMP	growth rate of secondary and tertiary employment
E/N	exchange of note
Eo	deformation modulas
eo	void ratio
EP	end of point
ER	erection and executive load

Etax	export tax
EXP	exponential
F	ship collision force
f	Lacey's silt factor
FC	foreign currency
fc	compressive strength of concrete at 28day
FEM	free exchange market
Fig.	figure
F.O.B	Free on Board
F/R	Final Report
FS	safety factor
G	trip generation
g	gravity acceleration
G/A	Gebel Aulia
GDP	gross domestic products
GF	quaternary gezira formation
Gi	total trip generation of zone i zonal trip generation in zone i
GL	ground level
GOJ	Government of Japan
GORS	Government of The Republic of The Sudan
G.S.	gauge station
H	wave height at slope (Chapter-VI) thickness of settlement layer (Chapter-VI) depth of girder (Chapter-VII) horizontal (Chapter-VIII)
h	embankment height (Chapter-VI) depth (Chapter-VI and VII)
HA	live load specified by British Standards

ABBREVIATIONS AND NOTATIONS (4/9)

HB	live load specified by British Standards
HLD	household
HWL	high water level
I	import (Chapter-V) rainfall intensity (Chapter-VI) impact (Chapter-VII)
i	average riverbed slope (Chapter-VI) zone (Chapter-iV)
IA	internal angle
IRR	internal rate of return
Itax	import tax
j	zone (Chapter-IV)
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
JRA	Japan Road Association
K	type of vehicle (Chapter-V)
k	parameter (Chapter-iV)
KD	coefficient determined from covering material
KEL	knife edge load
kgf	kilogram(s)
kgf/sq.m	kilogram per square meter(s)
kgf/cu.m	kilogram per cubic meter(s)
km	kilometer(s)
Km^2	square kilometer(s)
Km/h	kilometer(s) per hour
KRT-CE	central part of Khartoum
KRT-SE	south eastern part of Khartoum
KRT-SW	from Khartoum district to south-western part of Khartoum

KRTN-E	eastern part of Khartoum north
KRTN-W	from Khartoum district to western and northern part of Khartoum north
Kw.h	kilowatt-hour(s)
L	live load including sidewalk load
l	length
LC	local currency
LS	Lump Sum
Ls	Sudanese pound(s)
log.	logarithm
LWL	low water level
M	median width
m	meter(s)
mm	millimeter(s)
m/sec	meter per second
m^3/sec	cubic meter per second
Max.	maximum
Min.	minimum
min.	minute(s)
MOFEP	ministry of finance and economic planning
n	roughness coefficient (Chapter-) coefficient of stability (Chapter-) number (Chapter-)
N	north (Chapter-II, Chapter-VI) cretaceous Nubian formation (Chapter-VI) number of lanes (Chapter-VIII)
Nc	coefficient of bearing capacity
NCK	National Capital Khartoum
NEC	National Electric Corporation

ABBREVIATIONS AND NOTATIONS (6/9)

NPV	net present value
Ns	nubian sandstone
N-value	number of drops in standard penetration test
OD	origin and destination
ODM-CE	from Omdurman district to central part of Omdurman
ODM-SE	from Omdurman district to southern and western part of Omdurman
ODM-NO	from Omdurman district to northern part of Omdurman
P	pavement width (Chapter-V) force from stream current (Chapter-VI) wind pressure (Chapter-VII) principal load (Chapter-VIII)
PA	particular load
PAS	growth rate of private cars registered
PCU	passenger car unit
PCU/h	passenger car unit per hour
PC	prestressed concrete
POP	population growth rate of population
Px	pre Cambrian complex
Po	initial pressure
Q	quantity (Chapter-IV) discharge (Chapter-VI)
qd	ultimate bearing strength
QV	quantity and velocity
R	hydraulic radius (Chapter-VI) radius (Chapter-VIII)
r	unit weight
RBPC	Roads and Bridges Public Corporation
RC	reinforced concrete

ABBREVIATIONS AND NOTATIONS (7/9)

rC	revision ratio for A lane width
rI	revision ratio for road side condition
rL	revision ratio for A lane width
rT	revision ratio for truck contain percentage
Rd	road
R.D	relief degree of traffic congestion
Req.	required
RL	reduced level from mean sea level at Alexandria
R.O.W	right of way
RTC	River Transport Corporation
S	sidewalk or shoulder width (Chapter-V) subsidiary load (Chapter-VII)
	sand layer (Chapter-VI) amount of consolidation settlement (Chapter-VII)
SC	stream current force
SCF	standard conversion factor
SEMP	secondary employment
SL	sine length
SPT	standard penetration tests
sq.m	square meter(s)
STA	cumulative roadway station from beginning point
T	thermal force (Chapter-VII) generation or attraction (Chapter-IV)
t	log-time (Chapter-VI) required time for the final settlement (Chapter-VI)
TE	trip generation or trip attraction
TEMP	tertiary employment
tf	metric ton(s)
tf/cu.m	ton per cubic meter(s)

Ti	trip generation in i zone
Tij	inter-zonal trips from i zone to j zone inter-zonal trips after correction from zone i to zone j time distance from zone i to zone j
tij	inter-zonal trips before correction from zone i to zone j
Tj	trip attraction in j zone
TL	tangent length
TRU	growth rate of trucks registered
Tv	time factor (theory of consolidation)
T value	statistic indicator for testing parameters estimated by the regression analysis
UDL	uniformly distributed load
UK	United Kingdom
UNDP	United Nations Development Program
USA	United States of America
UTM	universal transverse mercator
V	velocity (Chapter-VII) volt(age) (Chapter-XI) time value (Chapter-XI)
VCL	vertical curve length
VEH	number of vehicles registered
VOC	vehicle operating cost
W	wind force (Chapter-VI) required weight of stone (Chapter-VI) weight (Chapter-VII)
W'	weight of section reduced by buoyancy
WC	counter weight
wo	unit weight of water
WP	wave pressure
wr	unit weight of stone

X	year
Xij	trips from i zone to j zone
Y	population
Z	scouring depth from riverbed around pier
Ø	internal angle of soil