CHAPTER - VIII

PRELIMINARY ROAD ENGINEERING

CHAPTER-VIII PRELIMINARY ROAD ENGINEERING

8.1 GENERAL

Based on a careful reconnaissance survey and the results of various field surveys, a preliminary road engineering study was carried out. The preliminary road engineering study consists of alignment, cross-section, pavement, drainage and intersection design. In the above mentioned studies, horizontal alignment and cross-section studies are conducted to using the drawings which longitudinal leveling and cross-section survey.

8.2 DETERMINATION OF PLANNING CONDITIONS

8.2.1 The Route To Be Designed

In Chapter-V, five (5) alternative routes A-1, A-2, B-1, B-2 and C are discussed for selection of location for the New White Nile Bridge. As a result, Route B-1 is selected as the most favorable route for construction of the bridge.

All the studies in the subsequent chapter are discussed based on the Route B-1.

(1) General Alignment

This route begins at the turning point of the existing Abu Syaid Road at Al Fittaihab Town, then runs southeastwards along the concrete military boundary wall, crossing over the White Nile about 1.0 km upstream from the existing White Nile Bridge almost at right angles, and passing the northern edge of the Sunt Wood, and ends at its connection with the existing Al Gaaba Road. The road length including the bridge section is 4,000 m in total based on the results of the topographic survey conducted by the Study Team.

(2) Functions and Characteristics of the Project Road

The functional classification of roads in Greater Khartoum is divided into four (4) categories namely Primary Distributor, District Distributor, Local Road and Access Road as discussed in the Interim Report (I).

The project road can be classified as a Primary Distributor, which forms part of the trunk road network in Greater Khartoum, taking into consideration its existing and future road network, traffic flow characteristics, land use plan and urban environmental aspects. It will form a part of the Beltway which was planned in a previous report, the UNDP Khartoum Traffic Management Study , as a Primary Distributor in the future when the construction of the Beltway will have been completed.

(3) Traffic Operation on the Project Road

Although any urban road generally requires car parking space on both sides, such car parking space can be eliminated in the project road taking into consideration the land use conditions along both sides of the project road.

Considering the above-mentioned matters and traffic safety, the project road will be planned on assumption that the following traffic operations be prohibited.

a) Car parking on the project road
b) U-turns on the project road

8.2.2 Design Speed

The project road is classified as a Primary Distributor which collects long trip vehicles and is required to maintain a high running speed for such vehicles. The Beltway to which it may be connected is also classified as a Primary Distributor and has a design speed of 80 km/h.

Taking into consideration the future road network configuration as well as the functions and characteristics of the project road, the design speed of the project road is determined at 80 km/h.

8.2.3 Design Criteria and Standards

There is no authorized standard for road design in Sudan so far, and therefore the usual practices of road design have been made based on AASHTO or BSI standards.

Accordingly, the Study Team determined that the following should be adopted:

a) JRA (Japan Road Association) standards will be basically used.

b) In addition, AASHTO or BSI standards will be used to supplement JRA standards when appropriate.

8.3 GEOMETRIC DESIGN

Table 8. 1 summarizes the geometric standards for road design of three (3) countries, i.e. Japan, USA and UK for reference purpose. Table 8.1 shows also the figures adopted in the Study.

Table 8.1 Geometric Standard Elements
(Design Speed = 80 km/h)

Items	Unit	Geometric Element			
		Japan *1	USA *2	UK *3	Adopted
1) Horizontal curve					
Minimum length	m	230	282	265	900
Desirable length	m	400	-	493	900
2) Curve length	m	140	-	-	335
3) Critical radius for clothoid	m	900	-	1,200	900
4) Critical radius for limited super-elevation	m	3,500	-	1,800	900
5) Maximum gradient	%	4	4	4	4
6) Length for limited					
gradient 5%	m	600	-	-	-
ditto 6%	m	500	-	-	-
ditto 7%	m	400	-	-	-
7) Vertical curve length	m	70	-	45	100
8) V. curve radius					
- At crest	m	3,000	2,500	2,000	4,500
- At sag	m	2,000	2,200	2,000	4,000
9) Sight distance					
Absolute minimum	m	110	106	-	200
Desirable minimum	m	-	137	137	-

Remarks :

*1 Japanese Highway Standards
*2 A policy on Design of Urban Highways and Arterial Streets
*3 Roads in Urban Areas

8.4 DESIGN

8.4.1 Horizontal Alignment

A study of the horizontal alignment was carried out in accordance with the route selected in the Phase I Study. The basic considerations were as follows:

a) The starting point is at the turning point of Abu-Syaid Road at Al Fittaihab Town in Omdurman City.

b) The alignment on the Omdurman side traverses an open space between the military area and a residential area. The military area is considered as a restriction on the alignment. In addition, land acquisition and compensation for leveling existing houses should be minimized in the residential area.

c) The alignment where the proposed bridge is located should cross the White Nile at right angles as much as possible to eliminate the additional cost of a skew bridge.

d) The end point is at the turning point of Al Gaaba Road near Sunt Wood.

e) The alignment design should be made not only to meet at least the design standards given in Table 8.1 but also to facilitate the development of other future plans as much as possible.

(1) Alternative Alignments

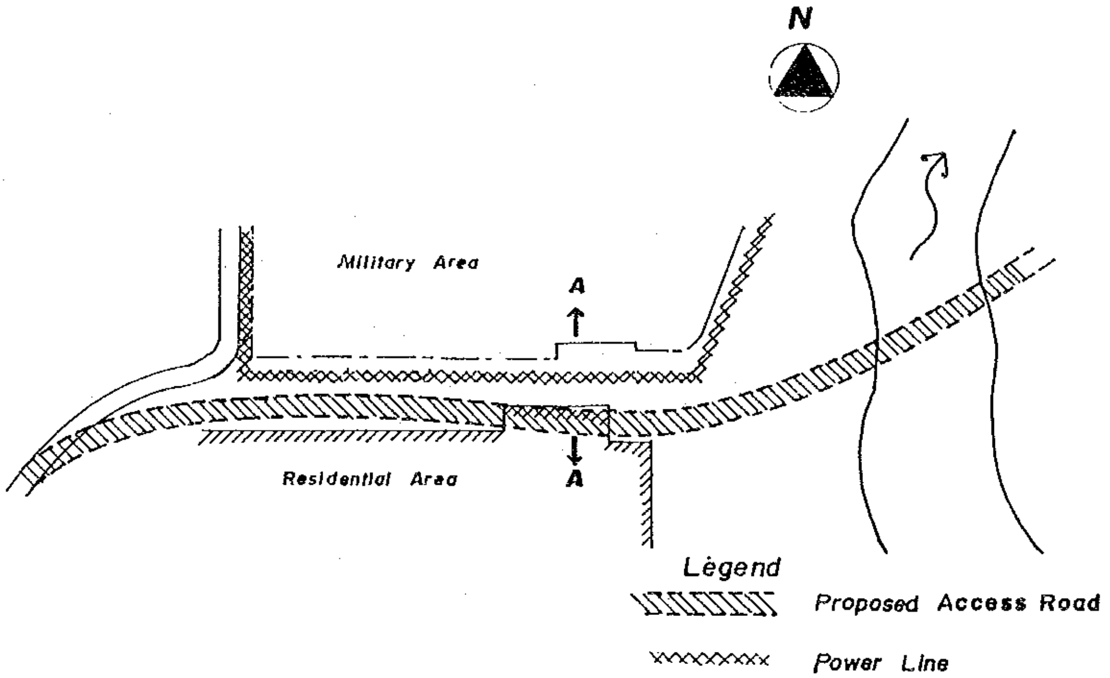
An electric distribution line had been planned and designed in detail on a similar alignment to pass through the open space between the military area and residential area on the Omdurman side. The alignment of the approach road of the New White Nile Bridge would be incompatible with that of the electric distribution line which requires clear space for safety purposes.

Accordingly, two (2) alternative alignments were proposed as shown in Figures 8.1 and 8.2, for resolving this issue.

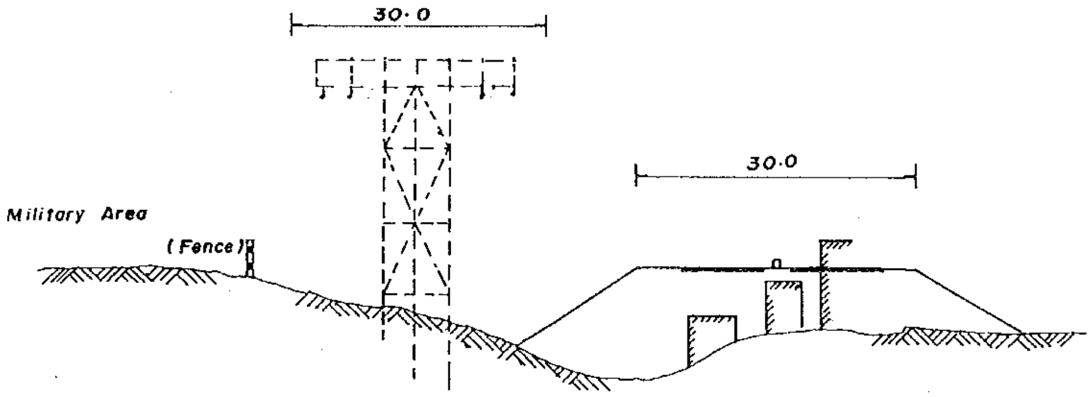
The configurations of these alternatives are as follows:

<u>Alternative Plan A</u>: The project road passes between the electric distribution line and the residential area, and the alignment of the electric distribution line is shifted northeastwards, towards the military area, as much as possible.

Alternative Plan A

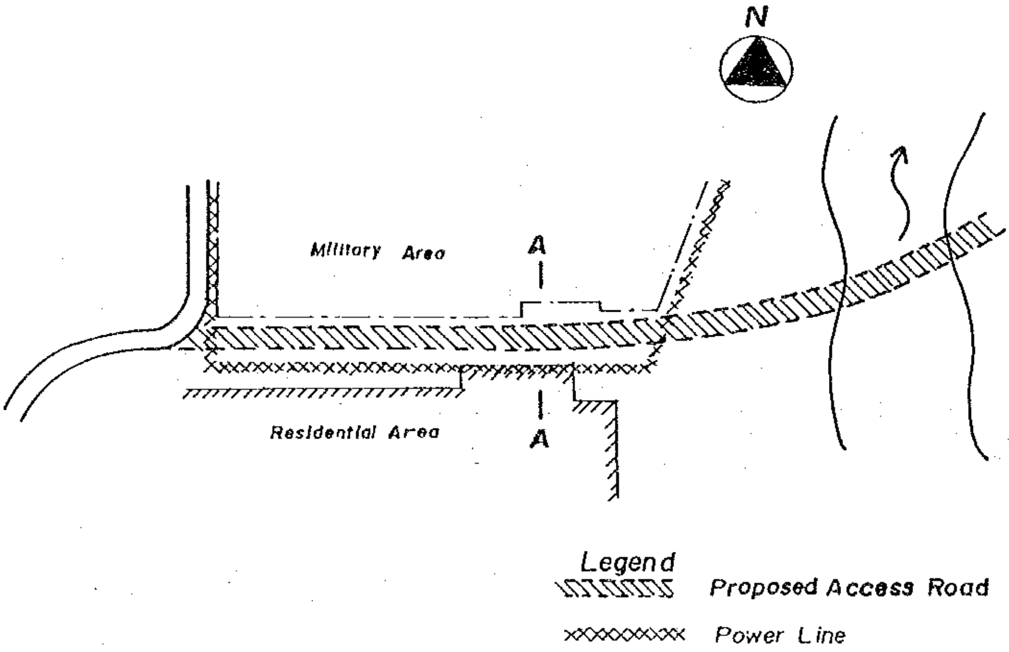


A _ A Cross _ Section

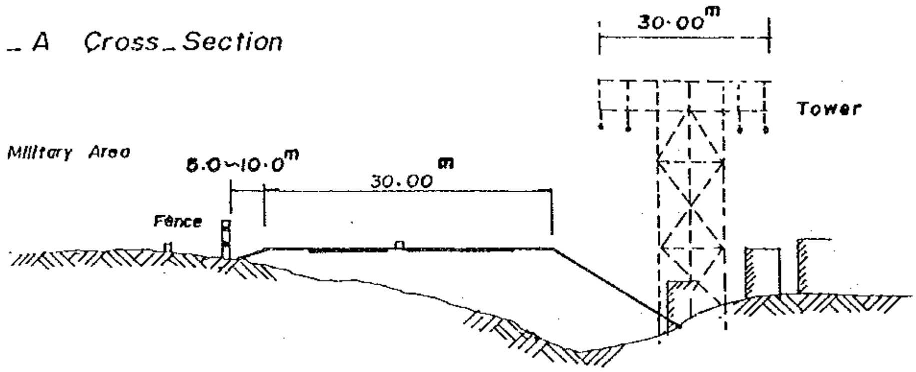


THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.1	ALTERNATIVE ALIGNMENT PLAN A
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Alternative Plan B



A _ A Cross _ Section



*Not To Scale

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.2	ALTERNATIVE ALIGNMENT PLAN B
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Alternative Plan B: The project road passes to the military side of the said open space, and the alignment of the electric distribution line passes between the right of way of the proposed road and the residential area.

Many discussions took place with the Housing and Town Planning Department of Ministry of Works,and NCK regarding these alternatives from March to July, 1989. As a result, Alternative Plan B was recommended by the Study Team. Central Physical Planning Committee (CPPC) chose Alternative Plan B officially in July, 1989.

The main reasons were 1) to achieve the minimum construction cost and 2) to minimize leveling of the residential area.

(2) The Proposed Alignment

The horizontal alignment preliminary design was conducted taking into account the road function and characteristics, geometric design standards, the results of a full field reconnaissance survey conducted and the existing land use based on the above mentioned "Alternative Plan B" route. The results of the preliminary design of the horizontal alignment are summarized as below;

A) Minimum Curve Radius

According to the geometric design standards for a design speed of 80 km/h, the minimum curve radius is stipulated as 230 to 280 meters. In this project, however, the minimum curve radius adopted is 900 meters considering the existing ground conditions and restraints on route location at the site.

B) Inter Angle Point

Three(3) horizontal curves are included in the proposed alignment. The curve elements of three(3) inter angle points are described in Table 8.2.

Table 8.2 Alignment Elements

	IP1	IP2	IP3
IA	21° 32′ 07"	21° 22′ 36"	21° 20′ 36"
R	1,000 m	1,500 m	900 m
TL	190.175 m	283.110 m	169.596 m
CL	375.862 m	559.637 m	335.261 m
SL	17.923 m	26.483 m	15.840 m

Notations

IA : Internal angle
R : Radius of alignment
TL : Tangent length
CL : Curve length
SL : Sine length

C) Curve Length

The minimum curve length with an 80 km/h design speed is stipulated as 149 meters according to the design standards. In this project, however, the minimum curve length used can be 335 meters.

D) Sight Distance

There are no problems for sight distance in the horizontal alignment due to the comparatively large curve radii used.

E) Critical Curve for Clothoid Alignment

According to the geometric design standards for an 80km/h design speed, a clothoid alignment should be introduced when the horizontal curve is less than 900 meters horizontal curve radius.

As mentioned previously, the horizontal curve radius on this project is more than 900 meters, so a clothoid curve alignment is not provided on this project.

8.4.2 Vertical Alignment

(1) Basic Consideration

The vertical alignment design was carried out for the selected horizontal alignment discussed in the preceding Subsection 8.4.1. The basic considerations were as follows:

a) Maximum longitudinal grade is 4.0 % based on the geometric design standards while the minimum one is 0.0% (flat).

b) The lowest the height of road surface is RL + 382.0 m (RL:reduced level above Mean Sea Level at Alexandria). It is obtained by HWL plus 2.0-meter freeboard. The 2.0 meter freeboard aims to protect the pavement structure from water penetration in the flood season. (In this way, better condition and less maintenance cost of asphalt concrete pavement can be expected.)

c) The navigational clearance is maintained at the deepest portion of the White Nile with not less than a clear width of 72 meters and a clear height of 12 meters as discussed in Chapter VII.

(2) Control Points

Control points dominating the vertical alignment design were examined taking into consideration the above-mentioned basic considerations.

The control points obtained in this study are as described in the following:

a) Intersection at Omdurman side, Station No.2 + 68.0 m, is set at an elevation of RL + 385.272 m (existing roadway elevation).

b) The lowest roadway elevation is set at RL + 382.0 m.

c) At the center point of the navigation channel (Station No.26 + 30.000 m), roadway elevation is set at RL + 399.7 m as follows:

- High Water Level (HWL)	: RL + 380.0 m
- Navigational Clearance, Vertical	: 12.0 m
- Girder Depth	: 3.7 m
- Influence of Vertical Transition Curve	: 3.6 m
Total	RL + 399.3 m

d) Khartoum side intersection, Station No.41 + 0.0 m, is set at an elevation of RL + 379.250 m (existing roadway level).

(3) Proposed Vertical Alignment

The vertical alignment study was conducted based on the basic considerations and control points mentioned above. The vertical alignment is elaborated on the basis of the leveling survey drawing at a scale of 1:2,500 which was conducted by The Study Team in July 1989. The general plan of the vertical alignment is shown in Figure 8.3 and the details are presented in the "Drawing". The results of the preliminary design of the vertical alignment are summarized as below;

a) Maximum Gradient

According to the geometric design standards for an 80 km/h design speed, the maximum longitudinal gradient was stipulated as 4.0 %.

Considering the need to minimize construction costs especially of the bridge, the maximum longitudinal gradient in the project is adopted as 4.0 %.

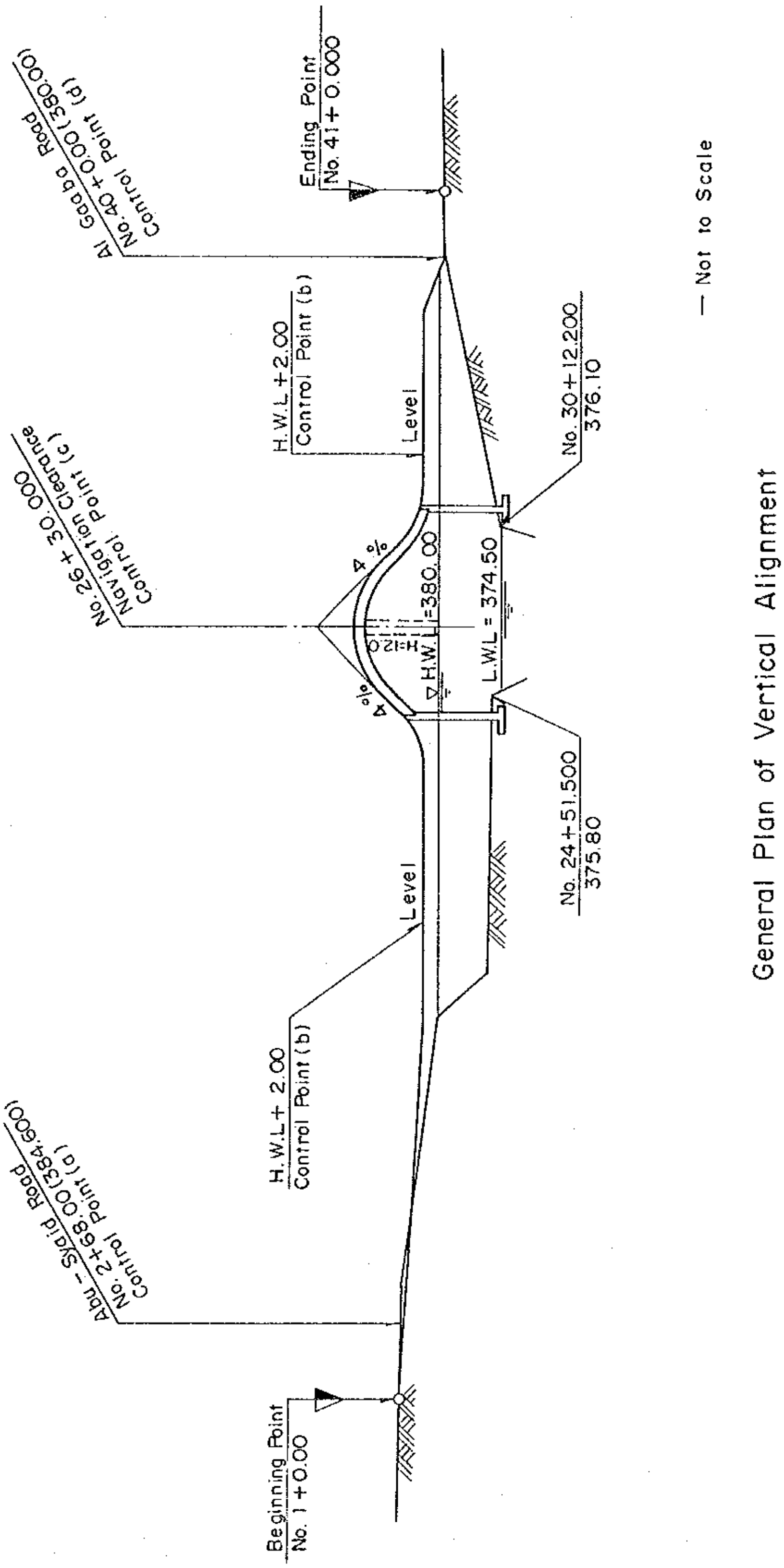
b) Minimum Gradient

According to the geometric design standards, the minimum longitudinal gradient was not a stipulation. Taking into account drainage treatment for the carriageway, it is better to set up a 0.2 or 0.3 % longitudinal gradient. In this project, however, a 0.0 % longitudinal gradient on some parts of the alignment are introduced in order to decrease construction costs and to harmonize with existing ground conditions.

c) Vertical Curve Radius

According to the geometric design standards for an 80 km/h design speed, the minimum vertical curve radius for "Crest" and "Sug" are stipulation as 3,000 meters and 2,000 meters respectively.

Considering traffic comfort, the vertical curve radius of "Crest" and "Sag" in this project are adopted as 4,500 meters and 4,000 meters respectively.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.3	GENERAL PLAN OF VERTICAL ALIGNMENT
	JAPAN INTERNATIONAL COOPERATION AGENCY	

d) Sight Distance

According to the geometric design standards, the minimum sight distance is stipulated as 110.0 meters. The minimum sight distance for this project is adopted as about 208.0 meters.

8.5 CROSS-SECTION

8.5.1 Cross-section Elements

The cross-section of the project road consists of the following elements:

a) Lanes
b) Shoulders (right and left)
c) Central reserve
d) Sidewalks

The widths of these elements are discussed below.

(1) Lane Width

A width of 3.5 meters is adopted as one lane width either on the bridge section or the approach road sections for the following reasons:

a) Since design speed of the project road is relatively high, at 80 km/h, it is necessary to provide a wide lane width in order not only to ensure traffic safety but also to keep smooth traffic flows.

b) Large vehicles will make up a high proportion of the traffic flow on the project road, 20% approximately. This requires a wide lane width.

c) According to the design standards of USA and/or UK, a Primary Distributor requires a lane width in the 3.3- to 3.6-meter range.

d) In the case of the Japanese standards, a 3.5-meter lane width is adopted for a Primary Distributor.

(2) Shoulder Width

Shoulders having 1.25 and 0.5 meters along right and left sides of the carriageway are adopted on the bridge section and 2.0 and 0.5 meters on the approach road sections for the following reasons:

a) The minimum requirements of right shoulder width are 1.25 meters, 1.2- to 1.8-meter range and 1.2- to 1.5-meter range in the various standards of Japan, USA and UK respectively.

b) As the right shoulder width on the road section of Beltway was planned at 2.0 meters in the Khartoum Traffic Management and Public Transport Study and the project road may connect with this Beltway, a 2.0-meter shoulder width is desirable for the project road.

(3) Central Reserve Width

Central reserve widths of 1.25 and 2.0 meters are adopted for the bridge and approach road sections respectively taking into consideration the following:

a) The minimum required width of central reserve specified in Japanese standards and USA standards are 1.25 and 1.2 meters respectively.

b) Since the Beltway may be continued as a road network in Greater Khartoum, a 2.0-meter central reserve width is desirable for the approach road section.

(4) Sidewalk Width

The most pressing need for sidewalks is at points of community development that may result in pedestrian concentrations between the central business district in Khartoum City and Al Fittaihab Town in Omdurman City.

Sidewalks having a width of 2.0 meters will be provided on both sides on the bridge and with a width of 4.5 meters on the approach roads.

8.5.2 Number of Lanes

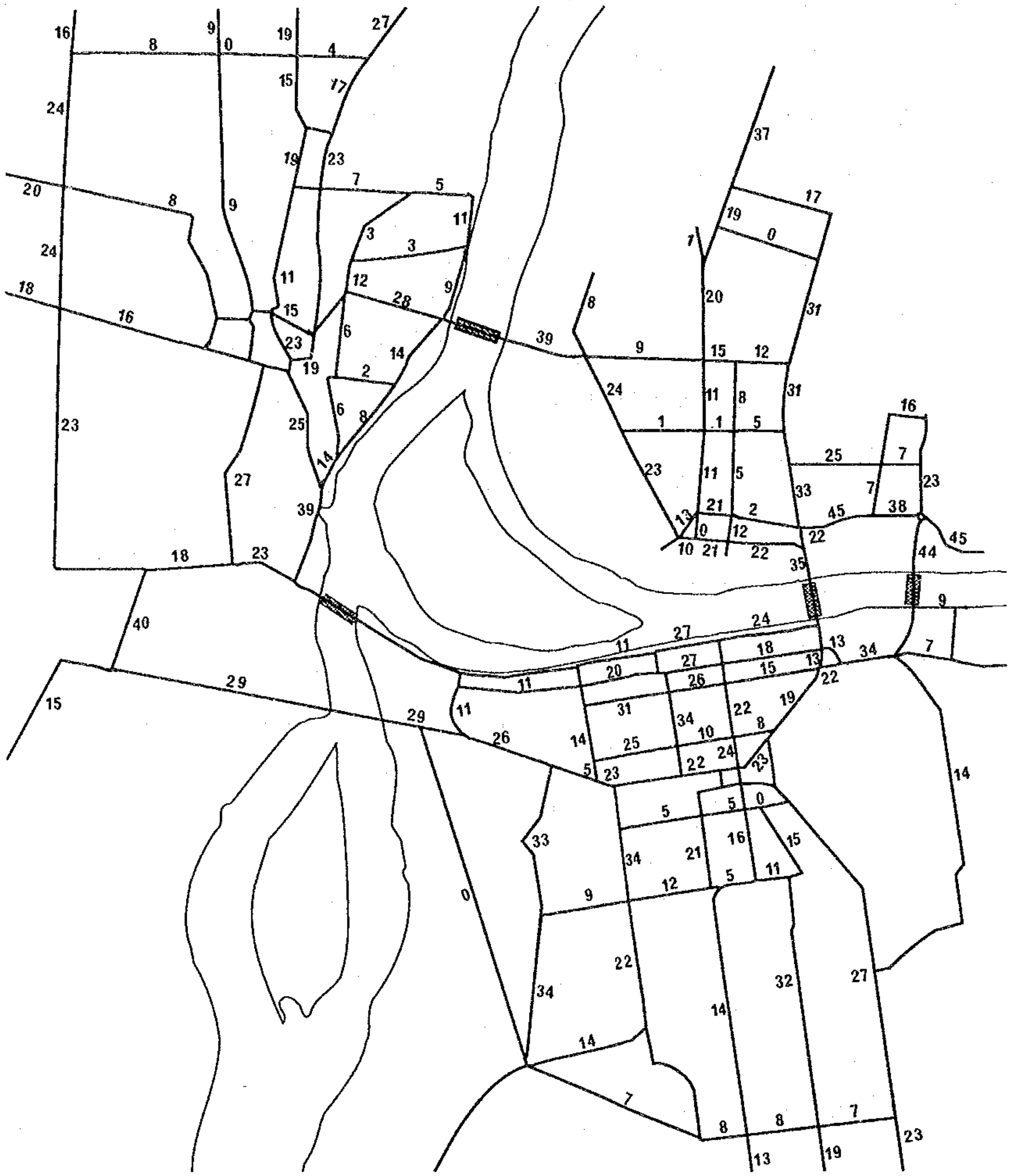
(1) Traffic Volume

The future traffic volumes in 1995, 2005 and 2015 were forecast based on the various traffic survey results, socio-economic aspects and other related conditions.

The details were discussed in Chapter IV of this Report.

The traffic volumes on the project road in 1995, 2005 and 2015 are summarized in Table 8.3 and shown in Figures 8.4 to 8.6.

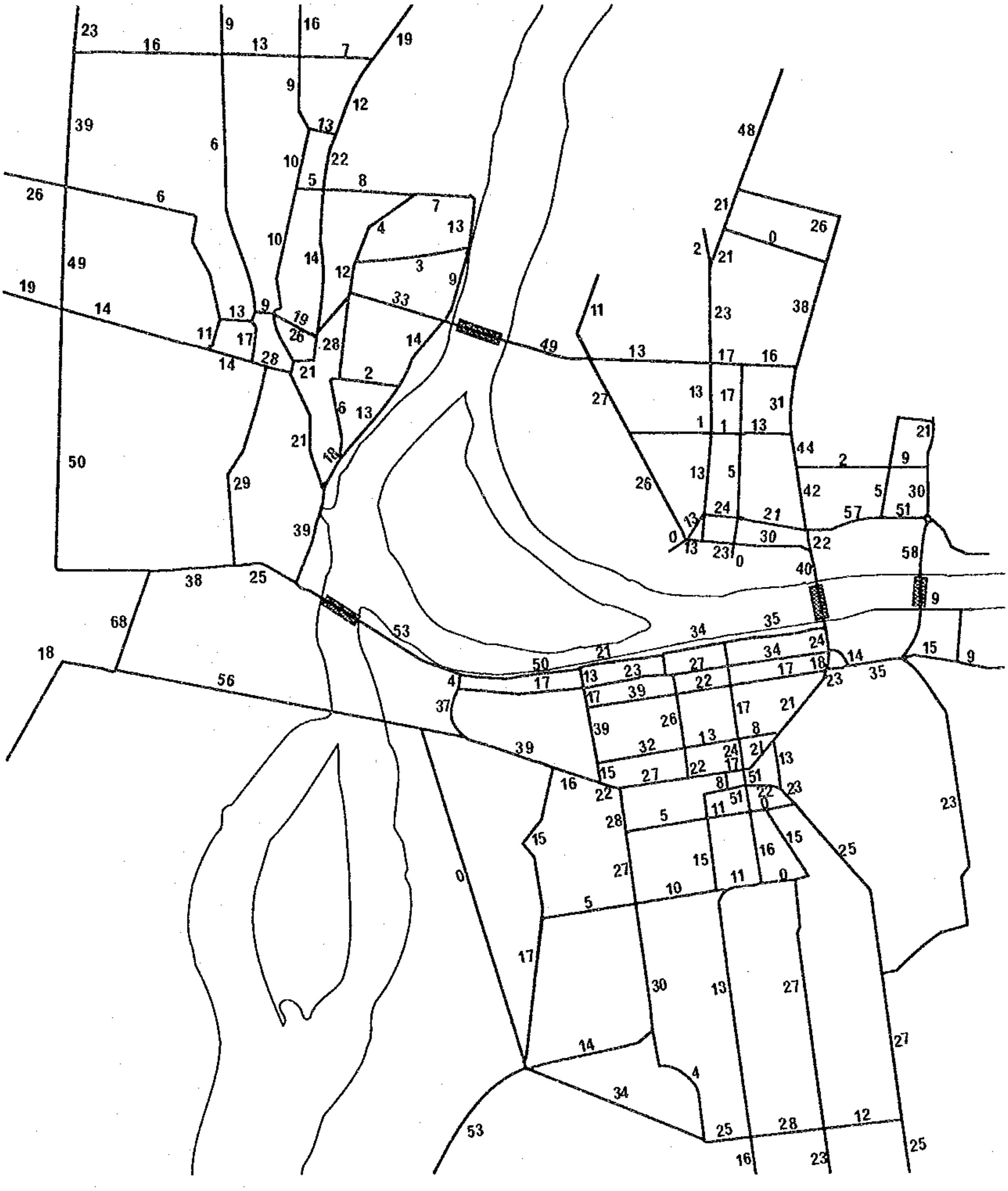
CASE B-1 1995



UNIT: 1000pcu/day

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.4	RESULT OF TRAFFIC ASSIGNMENT IN 1995
	JAPAN INTERNATIONAL COOPERATION AGENCY	

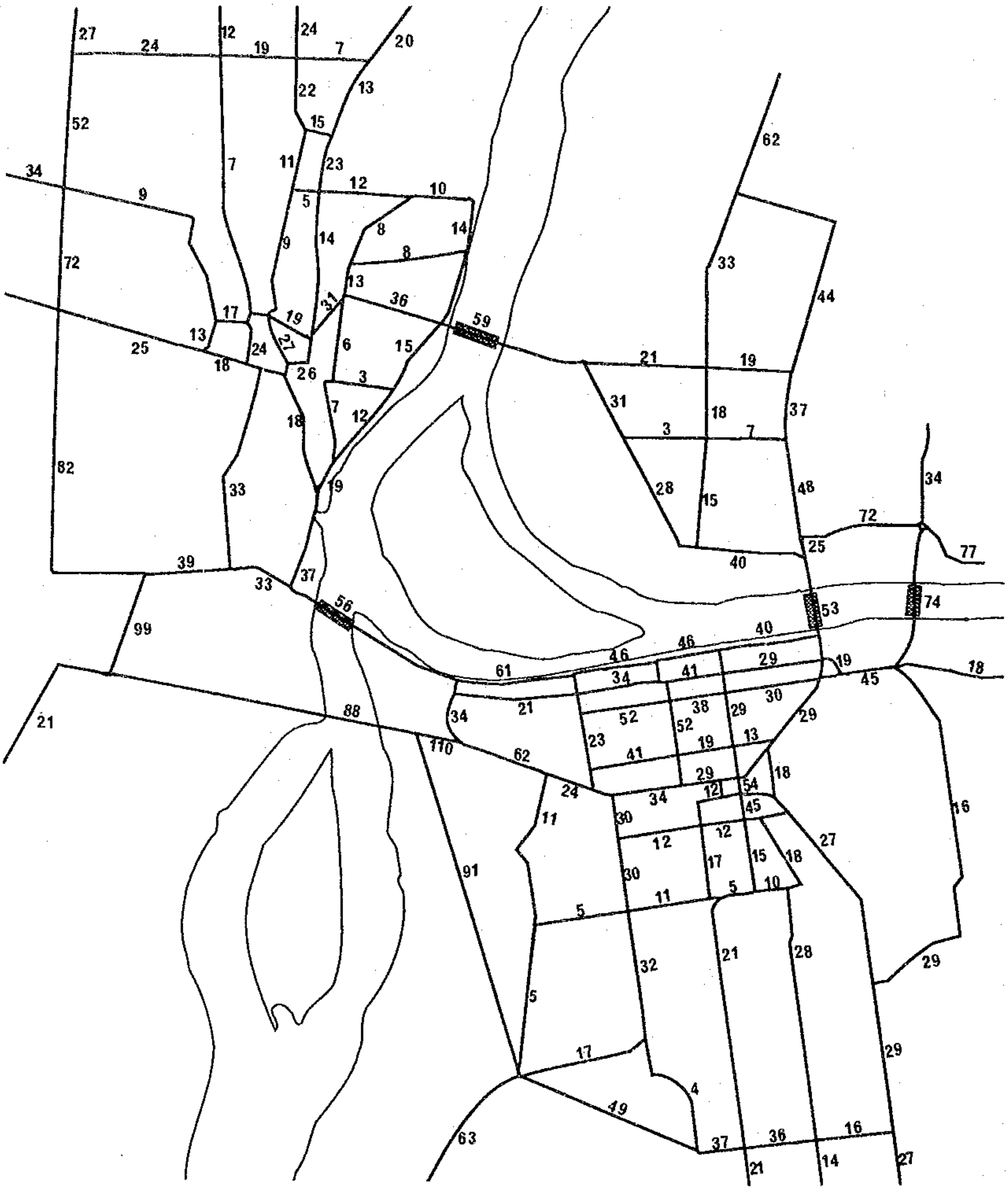
CASE B-1 2005



UNIT: 1000pcu/day

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	**Fig.** 8.5	RESULT OF TRAFFIC ASSIGNMENT IN 2005
	JAPAN INTERNATIONAL COOPERATION AGENCY	

CASE B-1 2015



UNIT: 1000pcu/day

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.6	RESULT OF TRAFFIC ASSIGNMENT IN 2015
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 8.3 Traffic Volume on the Project Road

Year	Traffic Volume (PCU/day)
1995	28,500
2005	56,400
2015	88,200

(2) Capacity

Based on the cross-section elements as discussed in the preceding Section 8.5.1, the traffic capacities of bridge and road sections can be calculated by means of the following formula.

$$C = C_B \times r_L \times r_C \times r_T \times r_I$$

Where, C : Traffic capacity in PCU/h
C_B: Basic Capacity in PCU/h
r_L: Revision ratio for a lane width
r_C: Revision ratio for a shoulder width
r_T: Revision ratio for truck percentage
r_I: Revision ratio for road side conditions such as housing, etc.

The peak ratio is used as a conversion factor between PCU/day to PCU/h.

a) Capacity of 4-lane Bridge

Table 8.4 Capacity of 4-lane Bridge

Items	Conditions	Revision Ratio
C_B	-	2,200 PUC/h/L
r_L	3.50 m	1.0
r_C	1.25 m	1.0
r_T	20%(4%)	0.800
r_I	Urban area	0.888

Nominal capacity for one lane:

C = 2,200x1.0x1.0x0.80x0.888 = 1,563 PCU/h

Capacity for four lanes:

C = 6,252 / peak ratio (8.7%) = 71,629 PCU/day,
say 72,000 PCU/day.

b) Capacity of 4-lane approach road

Table 8.5 Capacity of 4-lane Approach Road

Items	Conditions	Revision Ratio
C_B	-	2,200PCU/h/L
r_L	3.5 m	1.0
r_C	2.0 m	1.0
r_T	20% (0%)	0.88
r_I	Urban area	1.00

Nominal Capacity for one lane:

C = 2,200x1.0x1.0x0.88x1.0 = 1,936 PCU/h/L

Capacity for four lanes:

C = 1,936 x 4/peak ratio(8.7%) = 89,011 PCU/day,
say, 89,000 PCU/day.

(3) Number of Lanes to be Required

The number of lanes may be checked by comparing the capacity with traffic volume. The traffic volume - capacity relation is illustrated in Figure 8.7, from which the following is pointed out.

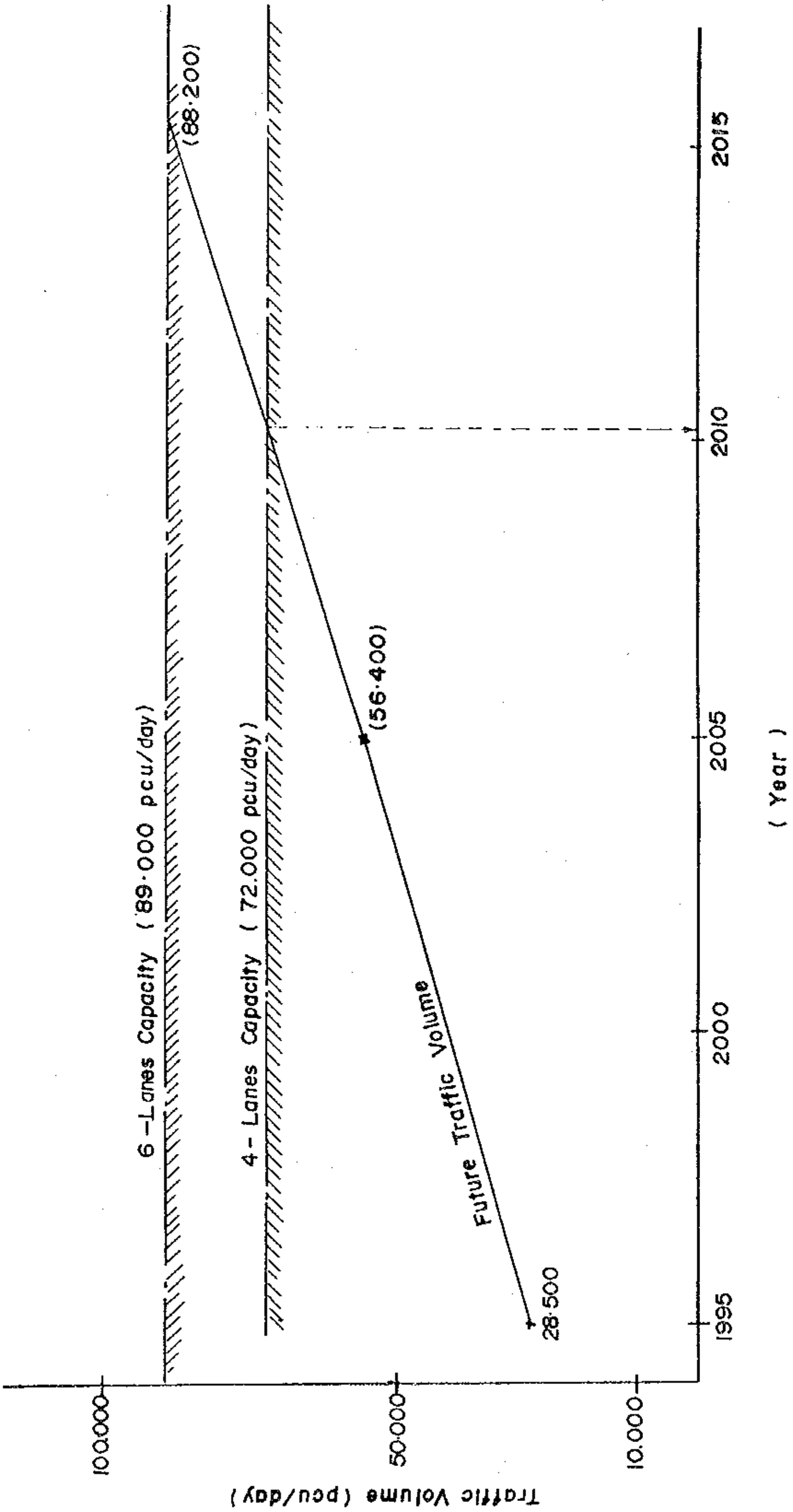
a) The traffic volume in 1995 and 2005 will not exceed the capacity of a 2-lane dual carriageway (4-lane road).

b) The traffic volume either in 2010 or in 2015 may exceed the capacity of a 2-lane dual carriageway.

Nevertheless, a 2-lane dual carriageway is preferable for both the bridge and approach road sections for the following reasons :

- Although the traffic volume in 2015 may exceed the capacity of a 2-lane dual carriageway, the actual widths of the proposed cross-sections can be used as a 3-lane dual carriageway. In this case, the capacity of the 3-lane dual carriageway is calculated at 89,000 PCU/day.

- The future traffic volume in 2015 is forecast as 88,000 PCU/day which is still less than the capacity of 3-lane dual carriageway (89,000 PCU/day).



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.7	RELATIONSHIP BETWEEN FUTURE TRAFFIC VOLUME AND CAPACITY
	JAPAN INTERNATIONAL COOPERATION AGENCY	

8.5.3 Typical Cross-sections

The elements which dominate the required cross-section are summarized below:

a) Nominal width for one lane is 3.5 meters.

b) A 2-lane dual carriageway is adopted both for the bridge section and the approach road sections.

c) Central reserve is provided in widths of 1.25 and 2.0 meters for the bridge and approach road sections, respectively.

d) Shoulders are provided on both sides of the carriageway in widths of 1.25 and 2.0 meters for the bridge and approach road sections, respectively.

e) Sidewalks are also provided on both sides of carriageway in widths of 2.0 and 4.5 meters for the bridge and approach road sections, respectively.

The cross-sections described above are shown in Figure 8.8.

8.5.4 Design elements

The preliminary design for cross-section is carried out based on proposed horizontal and vertical alignment, typical cross-section and other road related facilities conditions. The design is also conducted to use the drawing at a scale of 1to 200 which followed the cross-section survey by the Study Team in July 1989.

The main cross-section drawings for preliminary design are presented in the "Drawing".

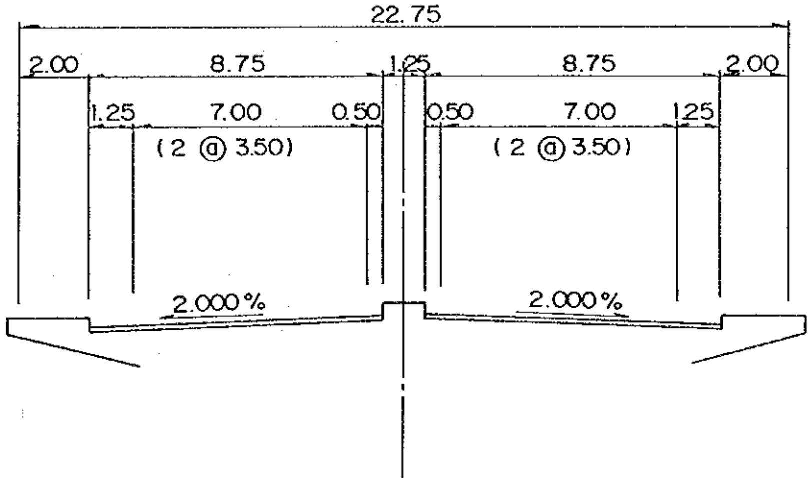
The results of the preliminary design of cross-section are summarized below;

a) Transition of Central Reserve

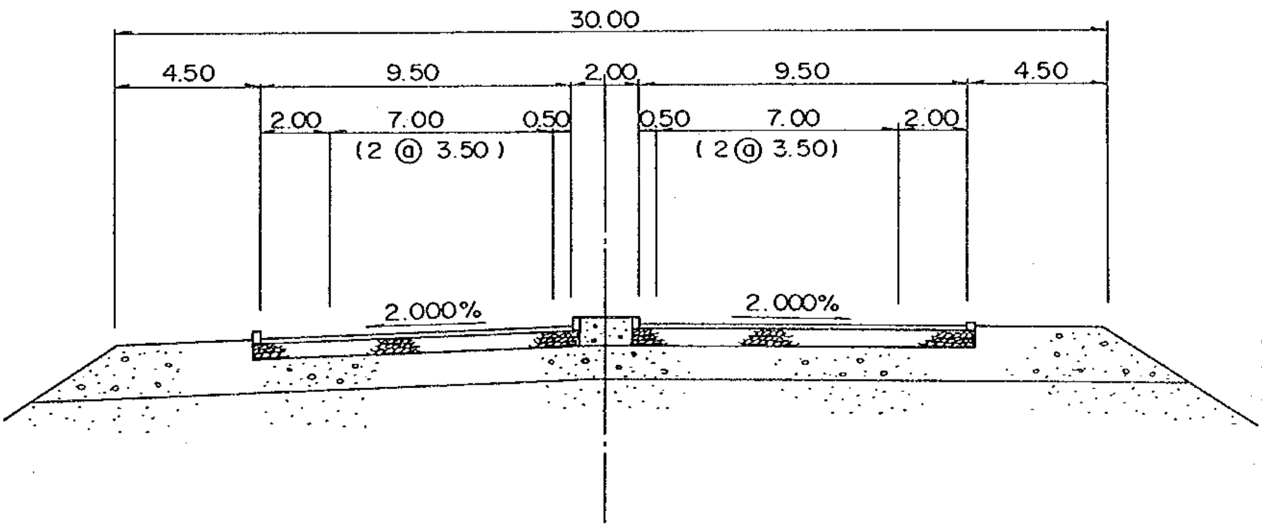
The width of central reserve of road and bridge section are designed as 2.00 meters and 1.25 meters respectively. The transition length of road and bridge section is designed to be 100.0 meters from the end of the bridge.

Typical Cross – Sections

1) Bridge Section



2) Road Section



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.8	TYPICAL CROSS-SECTIONS
	JAPAN INTERNATIONAL COOPERATION AGENCY	

b) Transition of sidewalk

The width of sidewalk on the road and bridge section are designed as 4.50 and 2.00 meters respectively. The transition of sidewalk of road and bridge section is directly connected without transition length.

c) Construction Yard

The construction yard is provided from station No.21+0.00 to station No. 23+0.00 according to the construction works plan. The height of the crown of the embankment of the construction yard set up at 380.00 is high water level.

d) Guardrail

Guardrails are provided on the outside of sidewalks at embankment sections over three meters high and intersection areas considering pedestrians' safety. The details of the structure are presented in the "Drawing".

e) Road Lighting

Road lighting is provided on the carriageway side of sidewalks on both sides and at intersection areas.

f) Wave Protection

Wave protection is provided at station No. 15+50.00 to station No.21+0.00 on the Omdurman side and from station No. 30+42.00 to station No. 33+50.00 for keeping the embankment safe from breaking waves in the rainy season. The details of wave protection structures are presented in the "Drawing".

8.5.5 Embankment Structure

As discussed in the preceding Chapter-VI, the embankment height limits are estimated at 8.0 and 10.0 meters for normal embankment type and counter-weight type respectively. Accordingly, the maximum embankment heights of the project road are set at 10.0 meters on the Omdurman side and 7.5 meters on the Khartoum side. Meanwhile, the average embankment height of the approach roads is estimated at 5.0 meters.

In the embankment structure design, engineering consideration is given to the following:

a) The project site is located in a flood-prone area where the existing ground is inundated, about 4 meters in depth, for approximately three months every year.

b) As river water becomes almost static during the flood season, waves may occur when a strong wind occurs from the upstream direction of the White Nile. This could cause a significant wave height of about 2.0 meters .

c) According to the subsoil explorations conducted by the Study Team, a soft clay layer exists 2.0 to 3.0 meters below the existing ground surface.

d) The embankment materials are expected to be obtained from a borrow area, about 4 kilometers away from the proposed bridge site on the Omdurman side, from the viewpoints of easy transport and minimum construction cost. Material in this borrow area is categorized as clays soil.

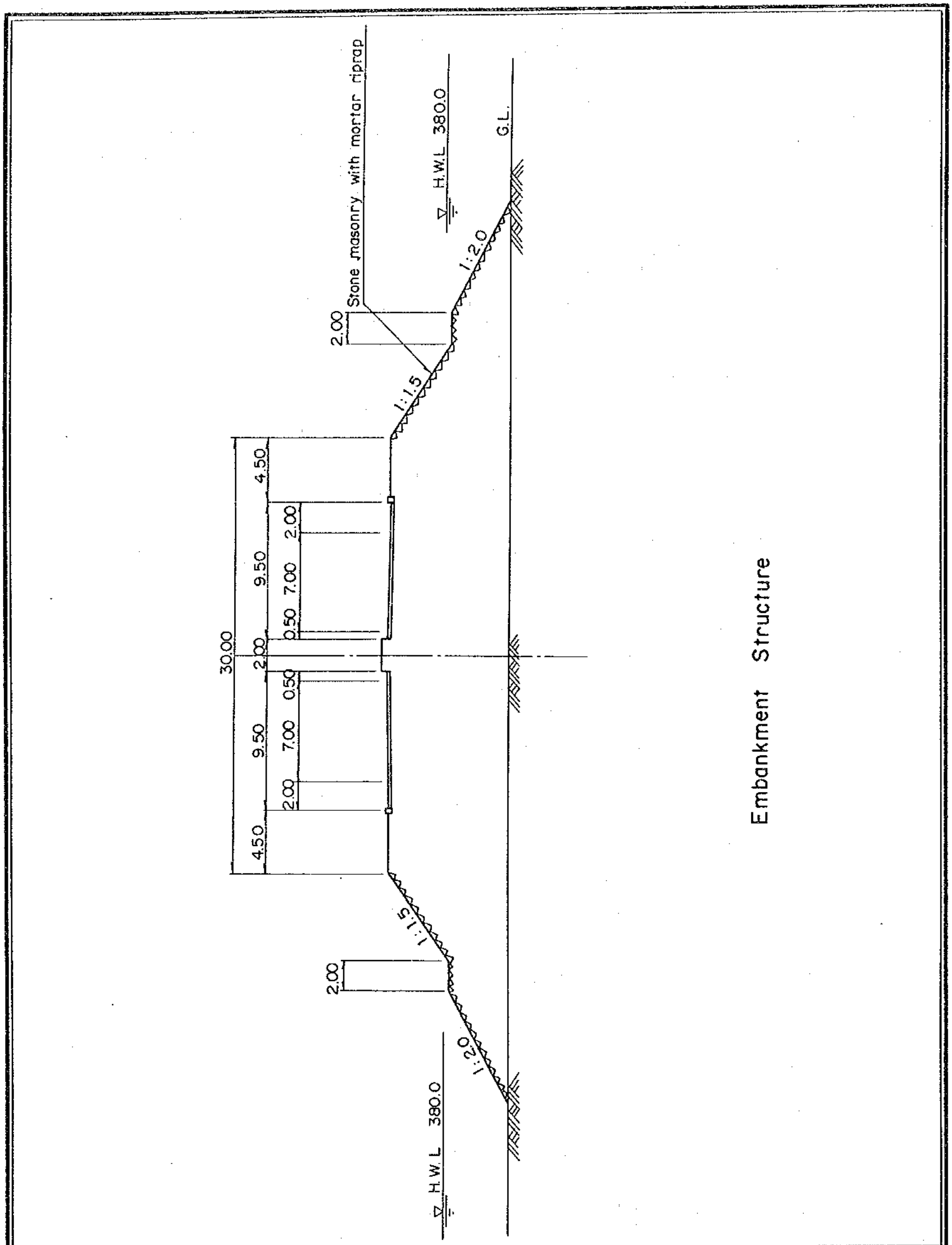
As a result of consolidation settlement, and safety against circular failure of the embankment, embankment structure is proposed as shown in Figure 8.9.

The configuration of embankment proposed is as follows:

a) Slope protection is provided by using mortar riprap so as to withstand wave action in flood time. This method is the same as that for the approach road section of the existing White Nile Bridge.

b) A 2.0-meter berm is provided longitudinally at the same elevation as HWL (high water level:RL+380.0 m above mean sea level at Alexandria) to ensure embankment safety against circular failure.

c) The gradients of slope are 1:2.0 below the berm and 1:1.5 above.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	**Fig.** 8.9	EMBANKMENT STRUCTURE
	JAPAN INTERNATIONAL COOPERATION AGENCY	

8.5.6 Slope Protection

(1) Necessity of Slope Protection

As described previously, the approach road station No.15+0.00 to station No.35+0.00 is located in flood area where the existing ground is inundated, about 4.00 meters in depth, during the rainy season, approximately three months every year.

The results of a current velocity survey of the existing water in the rainy season, gave an observed current velocity of flooded water of 0.20 m/sec. From this point, some slope protection is not required due to the low current velocity. However, when a 30.0 m/sec velocity wind blows, a wave height of about 1.93 meters occurs.

Judging from this wave height, some slope protection is required.

(2) Type of Slope Protection

Taking into account the local material to be used, the wind velocity and wave height conditions and the local construction method expected, the following slope protection types were considered.

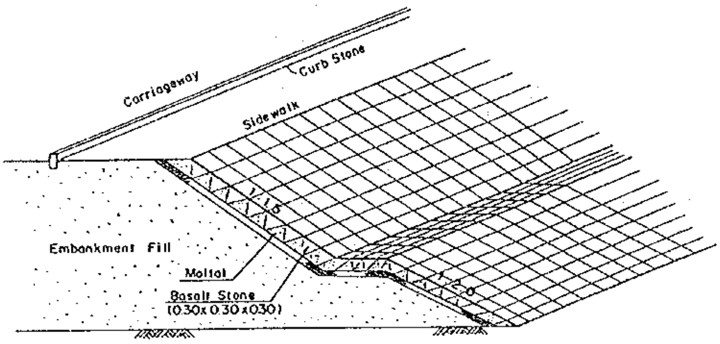
a) Mortar Riprap Method. (See Figure 8.10)
b) Concrete Placing Method (See Figure 8.11)
c) Rubble-Mound Breakwater method. (See Figure 8.12)

The above three slope protection types were compared and the results are summarized in Table 8.6.

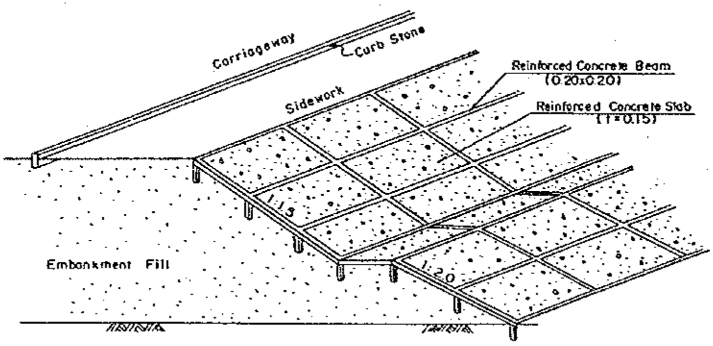
Judging from Table 8.6, the mortar riprap method is adopted for slope protection on this project.

Table 8.6 Comparison of Slope Protection Types

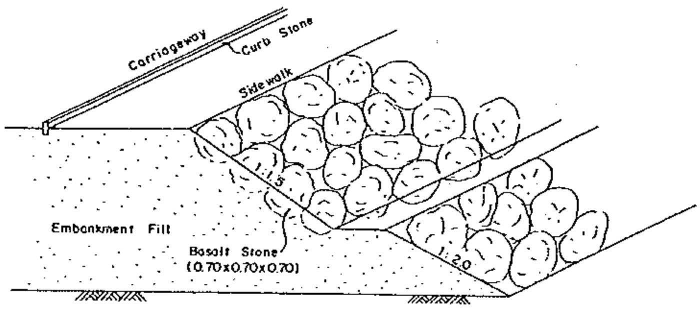
Item	Mortar Riprap	Concrete Placing	Rubble-Mound
1.Cost	303 Ls/sq.m	528 Ls/sq.m	305 Ls/m
2.Safety of Embankment	good	good	poor
3.Construction Period	long	long	long
4.Workability	good	poor	poor
5.Construction Size	small	large	large
6.Perspective	good	good	poor
7.Maintenance	easy	easy	difficult



Moltal Riprap Method



Concrete Placing Method



Rubble – Mound BreakWater Method

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.10	TYPE OF SLOPE PROTECTION
	JAPAN INTERNATIONAL COOPERATION AGENCY	

8.6 PAVEMENT

8.6.1 Pavement Type

There are basically two different pavement types, a flexible asphalt concrete pavement and a rigid cement concrete pavement. Flexible asphalt concrete pavement was selected for the project road for the following reasons:

a) The initial construction cost of asphalt concrete pavement is about 20 % less than that of cement concrete pavement(construction cost of asphalt concrete and cement concrete pavement is estimated as 457 Ls/sq.m and 544 Ls/sq.m respectively). In general, design lives of asphalt concrete and cement concrete pavement are expected to be 20 and 40 years, respectively. It is rather difficult to estimate maintenance costs of such pavements since they are likely to be affected by local climatic conditions and available data to evaluate the required maintenance costs are few. However, it may be said that asphalt concrete pavement would be preferable to a cement concrete pavement even in total cost for initial investment and future maintenance taking into account the traffic characteristics in Greater Khartoum.

b) Some materials cannot be produced sufficiently so far; production of Portland cement for cement concrete pavement is limited and production of reinforcing bars for cement concrete pavement and bituminous materials for asphalt concrete pavement are nil. Other materials,such as fine and coarse aggregates, are available in Greater Khartoum. In this regard, advantages can be recognized between the two pavement types.

c) All the paved roads in Greater Khartoum are paved with asphalt concrete and NCK has considered experiences of its construction and maintenance. Indeed, NCK has its own equipment for producing asphalt concrete mixture, which can be used for future maintenance work.

d) Considering the climatic conditions of Greater Khartoum with extremely dry weather and little rain, adoption of asphalt concrete is favored and a reasonable choice.

8.6.2 Pavement Structure

A material survey for asphalt concrete and reconnaissance for existing asphalt concrete pavement were conducted in Greater Khartoum.

The betterment project of the existing Gaaba Road was completed in June, 1989 by NCK. The pavement structures and materials used in this road betterment project were as follows:

a) Surface course : Hot-mixed asphalt concrete (t = 70 mm)

b) Base course : Natural gravel for mechanical stabilization (t = 150 mm), CBR > 60 to 80

c) Sub-base course : Natural gravel (t = 300 mm) CBR > 30

From the material survey by the Study Team, it can be said that material cost of crushed stone will be cheaper than that of natural gravel of which the transportation distance is very long.

After taking into consideration least construction cost, material availability, and traffic volume and its characteristics, the following is proposed:

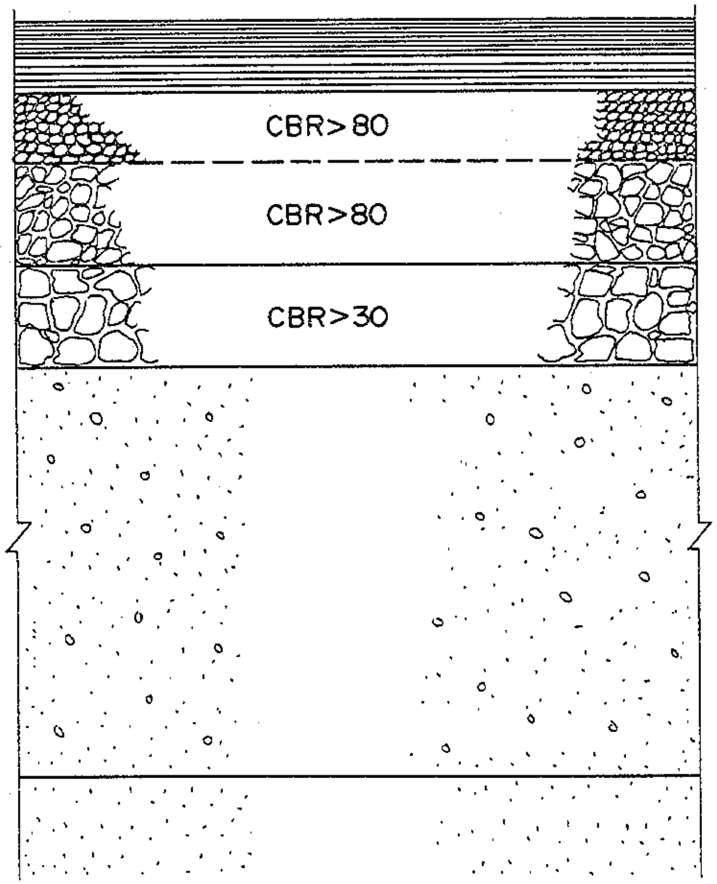
a) Surface course : Hot-mixed asphalt concrete

b) Base course : Asphalt stabilizer CBR>80

c) Sub-base course : Crushed stone CBR>30

d) Subgrade : Selected soil materials

The above-mentioned pavement structure is shown in Figure 8.11.



Items	Materials
Surface	Hot Mixed Asphalt Concrete t = 5cm
Binder Course	t = 5cm
Base Course	Crushed Stone for Asphalt Stabilization t = 10cm CBR>80
	Crushed Stone for Mechanical Stabilization t = 15cm CBR>80
Sub-base Course	Crushed Stone CBR>30 (Material from Jebel Toria) t = 20cm
Upper-Subgrade	Soil with Gravel CBR>8 (Materials from main Borrow Area) t = 100 cm
Lower Subgrade	Soil (Materials from Side Borrow Area)

Asphalt Concrete Pavement Structure

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE

Fig. 8.11

ASPHALT CONCRETE PAVEMENT STRUCTURE

JAPAN INTERNATIONAL COOPERATION AGENCY

8.6.3 Pavement Structure Thickness Calculation

(1) Methodology

In the previous section, the type of pavement was decided as asphalt concrete pavement considering the economic aspects and construction workability. The asphalt concrete pavement thickness depends on traffic volume, pavement materials and strength of subgrade materials.

The required thickness for the asphalt concrete pavement is derived from the following equations;

$$H = \frac{28.0 \times N^{0.1}}{CBR^{0.6}}$$

$$Ta = \frac{3.84 \times N^{0.16}}{CBR^{0.3}}$$

where,

H : The total pavement thickness (cm)

Ta : The design thickness (i.e., the thickness of a full depth hot mixed asphalt concrete pavement having an equivalent strength (cm))

N : The number of equivalent five-ton wheel-loads in one direction to be expected during the ten year period following construction

CBR: The California bearing ratio of subgrade materials

(2) Considerations for the calculation of pavement thickness

Considerations for the calculation of pavement structure thickness are as follows;

a) Traffic Volume

The future traffic volumes in 1995, 2005 and 2015 on the approach road were forecasted in the previous section. The traffic volumes used for calculation of pavement structure thickness are those expected during the ten year period following construction.

According to the results of the future traffic forecast, the traffic volumes in both directions in 1995 and 2005 were expected to be 29,000 V/D and 56,000 V/D respectively, and vehicle composition ratio of passenger car, pick up and trucks are expected to be 72.0 %, 20.0 % and 8.0 % respectively.

b) CBR

According to the results of soil investigation on side borrow pits for embankment materials, the CBR was presented as 2.0 to 2.5 % . When these materials are used for the subgrade material of the pavement, some soil improvement of the subgrade material will be required. However, the CBR of the main borrow area which is located at about 4.0 km south of the project site is expected to be over 8.0%.

As the results of a pavement construction cost comparison study between 8.0 % and 2.5 % CBR, the construction costs of asphalt concrete pavement with 8.0 % CBR are about 20.0 % less than of pavement with 2.5 %. Taking into account economic aspects, 8.0 % CBR is adopted for the strength of subgrade material.

(3) Pavement Thickness Requirement

a) Number of Equivalent Five-Ton Wheel-load

Table 8.7 Equivalent Traffic Volume

	Wheel Load	Number of Wheels	Damage Factor	Traffic Volume
Pass. car	0.5	41,760*1	0.0001	4
Pick Up	1.5	2,900*2	0.008	23
Truck	3.5	3,480*3	0.25	870

Total 897 (N_5)

*1 ; 29,000/2 x 0.72 x 4 axle =41,760

*2 ; 29,000/2 x 0.20 x 1 axle = 2,900

*3 ; 29,000/2 x 0.08 x 3 axle = 3,480

b) The ten year Total of Equivalent Five Ton Wheel load

$N = N_5 \times A \times 10 \text{ (year)} \times 365 \text{ (days)}$

where,

- N : Ten year total of equivalent five ton wheel-load
- N_5 : Five ton equivalent traffic volume
- A : Annual Growth Rate

$N = 897 \times 1.93 \times 10 \times 365 = 6.30 \times 10^6$

c) Thickness

$$H = \frac{28.0 \times N^{0.1}}{CBR^{0.6}} = 38.5 \text{ cm}$$

$$Ta = \frac{3.84 \times N^{0.16}}{CBR^{0.3}} = 25.1 \text{ cm}$$

d) Proposed Thickness

Considering the asphalt concrete pavement materials, construction cost and requirement of thickness, the following pavement structures are proposed;

*	Surface Course	t = 5.0 cm
*	Binder Course	t = 5.0 cm
*	Base Course (asphalt)	t =10.0 cm
*	Base Course (crushed stone)	t =15.0 cm
*	Sub-base course	t =20.0 cm
	Total Thickness	t =55.0 cm > H =38.5 cm

and the design thickness is checked as follows;

*	Surface Course	5.0 x 1.0 =	5.00 cm
*	Binder Course	5.0 x 1.0 =	5.00 cm
*	Base Course	10.0 x 0.55=	5.50 cm
*	Base Course	15.0 x 0.35=	5.25 cm
*	Sub-base Course	20.0 x 0.25=	5.00 cm
	Total Thickness	t =25.75 cm >	T_a =25.1 cm

8.7 DRAINAGE

8.7.1 General

Greater Khartoum has an annual rainfall of 150 mm and 90 % or more takes place in the four months, from June to September. Rainy days with rainfall more than 0.1 mm are only 22 days in a year.

Considering the above-mentioned climate in Greater Khartoum, road drainages might not be required. However, the results of careful site reconnaissance and discussions with inhabitants revealed that seasonally the river flows parallel to the boundary fence on the southeast side of the military area during the rainy season and appropriate drainage would be required for this area. In addition, carriageway drainage (so-called gutter drainage) might be required on both the carriageway sides as well.

8.7.2 Drainage System

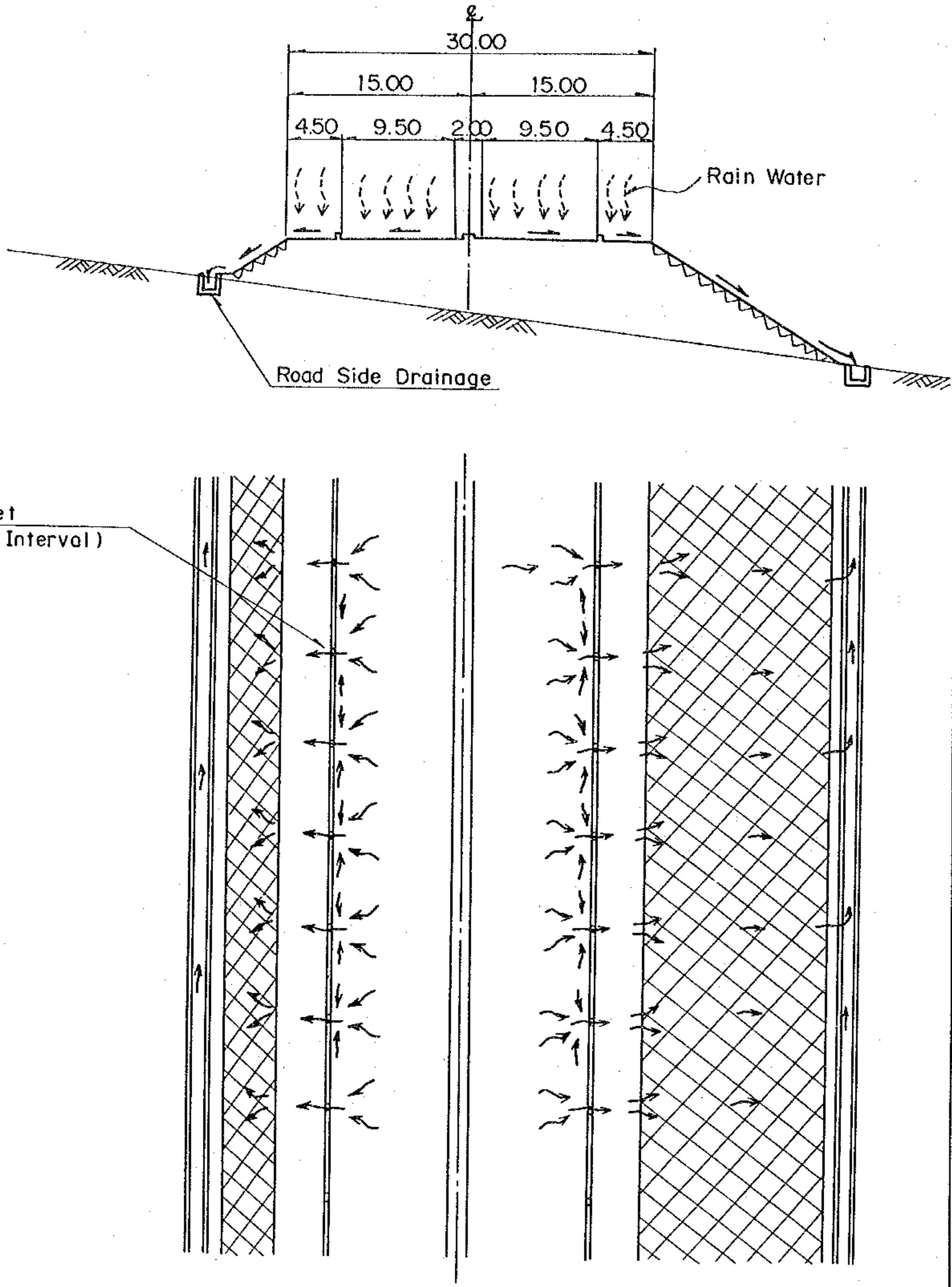
(1) Drainage System for Carriageway

In general, open drains or covered drains are usually provided on each side of the carriageway of the existing roads in Greater Khartoum. However, it should be noted that most of the existing drains have not been operating well due to accumulation of wind-blown soils or sands by dust-storms or 'Habab'.

The following drainage system is recommended, at present, for the project road taking into consideration the existing drainage conditions of Greater Khartoum and Figure8.14 shows its configuration.

a) No drains such as U-type concrete gutters or pipes will be provided longitudinally.

b) Rainwater will be collected by in-let for drains, which will be provided at longitudinal intervals under the curb stone, and then led to roadside drains through the surface of the slope.



Drainge System for Carriageway

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	**Fig.** 8.12	DRAINAGE SYSTEM FOR CARRIAGE WAY
	JAPAN INTERNATIONAL COOPERATION AGENCY	

(2) Drainage System for Road Side

The following drainage system is proposed for the project road and with the configuration as shown in Figure 8.15.

a) Road side drains are provided longitudinally along both the bottom edges of the embankment.

b) Rainwater collected by the above-mentioned carriage-way drainage be led to the White Nile by the road side drains.

c) U-type concrete drains be provided as road side drains except for the inundation-prone area where earth drains will be provided.

d) Pipe culverts be provided as cross drains.

e) As a result of a reconnaissance survey of existing drains,an open channel drain of about 5.0-meter width be provided on the right side toe of the embankment from Station No.9 to No.14, where there is a seasonal river course.

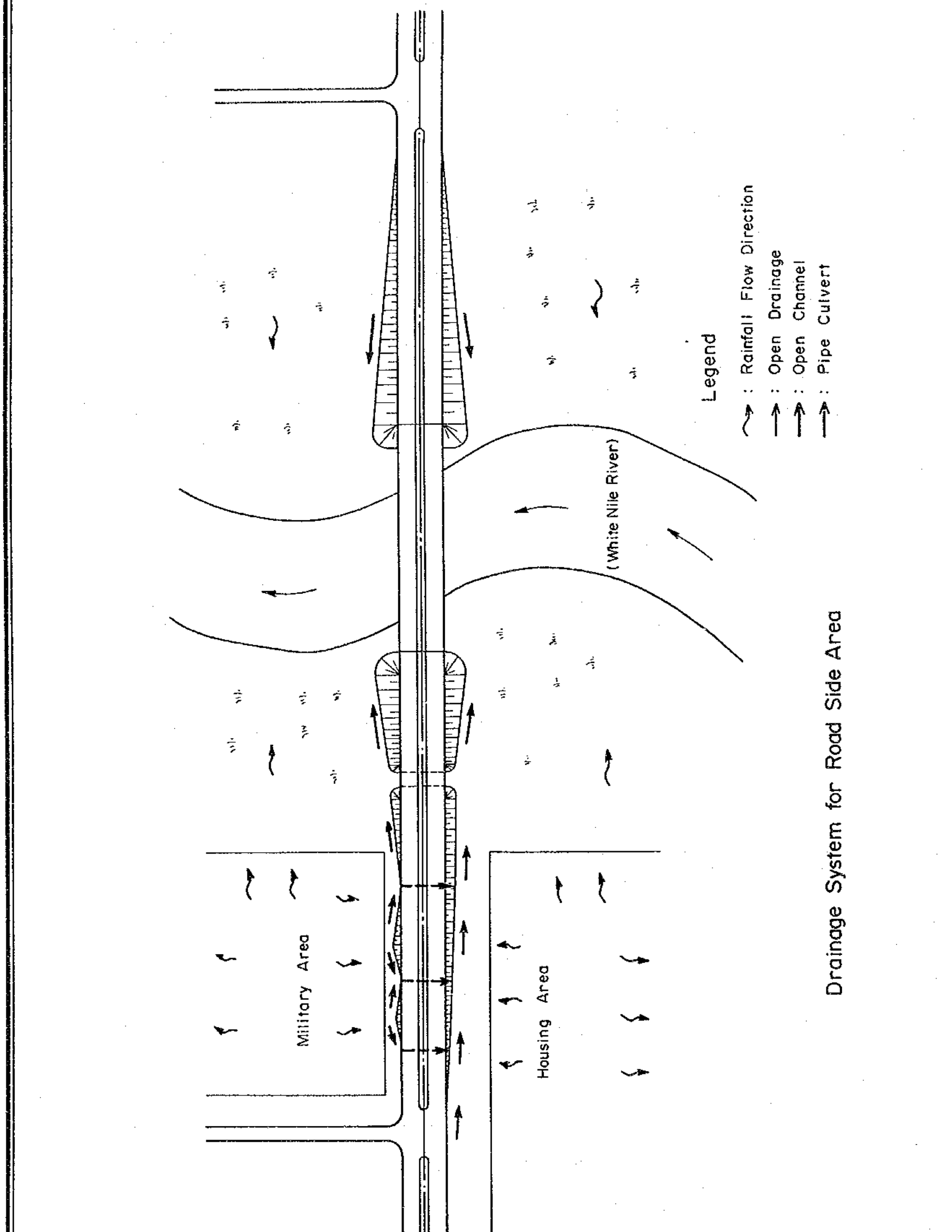
8.7.3 Drainage Structures

Based on the full reconnaissance survey, the rainfall condition of the Greater Khartoum Area and the drainage system previous mentioned, the main drainage structural design is carried out as mentioned below;

(1) Opening in Curb Stone

The longitudinal gradient of the project road adopted was 0.24 5 or 0.00 % and the superelevation adopted is 2.00 %. This means that rain water on the carriageway could not flow in the longitudinal direction but could flow in the transverse direction.

The curb stone should provide an opening for rainwater from the carriageway to the outside of the road embankment across the sidewalk. The opening in the curb stone is required at an interval of about 5.0 meters to 7.50 meters.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	**Fig.** 8.13	DRAINAGE SYSTEM FOR ROAD SIDE AREA
	JAPAN INTERNATIONAL COOPERATION AGENCY	

(2) Pipe Culvert

In the section from station No. 1 + 0.00 to station No. 15 + 0.00, rain water on the existing ground flows from north to south. The existing rain water is flows obstructed by the project road as the project road runs at east west in this area.

Based on a full reconnaissance survey, six pipe culverts should be provided for control of the above mentioned rain water streams.

The diameter of the pipe culvert at station No. 2 + 0.00 and No. 6 + 0.00 is 300 mm considering the small cover to the pipe culvert. The diameter of the other four pipe culverts is 600 mm considering easy maintenance.

The pipe culverts provided are as follows;

a)	No. 2 + 0.00	D 300 x 2	(Reinforced Concrete)
b)	No. 6 + 0.00	D 300 x 2	(Reinforced Concrete)
c)	No. 9 + 45.00	D 600	(Reinforced Concrete)
d)	No. 11 + 30.00	D 600	(Reinforced Concrete)
e)	No. 12 + 25.00	D 600	(Reinforced Concrete)
f)	No. 13 + 35.00	D 600	(reinforced Concrete)

The detailed designs of the above mentioned pipe culverts are presented in the "Drawing".

(3) Box Culvert

In the flood area, two box culverts are provided for the existing traffic which crosses under the project road and for treatment of flood water in the rainy season. The box culverts provided are as follows;

a)	No. 15 + 50.00	6.00 x 4.50
b)	No. 35 + 50.00	6.00 x 4.00

Details of the above mentioned box culverts are presented in the " Drawing ".

8.8 INTERSECTIONS

8.8.1 Location of Intersections

Two intersections are scheduled on the project road: one is at the starting point on the Omdurman side (hereinafter referred to as "A" intersection), and the other is at the ending point on the Khartoum side (hereinafter referred to as "B" intersection). The locations of the start and end points are referred to in the preceding Subsection 8.1.1.

8.8.2 Traffic Volume

Generally, intersections are planned based on the 5-year future traffic volume considering the following:

a) Traffic flows and volumes at intersections are likely to change according to traffic conditions on the related roads. It is very difficult to forecast the future traffic volumes at intersections over the long term. Therefore, the 5-year future traffic volume is usually adopted for design of new intersections.

b) When the 5-year future traffic volume is adopted, the intersection shape should be re-examined every five years according to traffic flow and volume at that time and improvement work should follow if required to cope with the traffic flow and volume. Such improvement work might require only small changes to the intersection at a relatively low cost.

Accordingly, intersection planning was done on the basis of the traffic volumes in 1995 (opening year) and 2005 (5 years after opening).

Peak hour traffic was observed twice a day, i.e. morning peak hour and afternoon peak hour. Traffic flows and volumes of these two peak hours differ from each other remarkably. So, the intersection capacity was examined for the following cases:

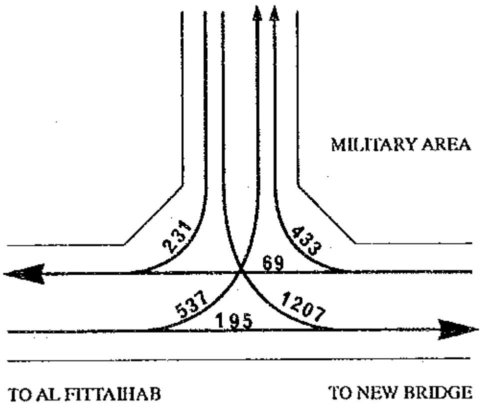
a) Traffic volume at morning peak hour in 1995 and 2005

b) Traffic volume at afternoon peak hour in 1995 and 2005

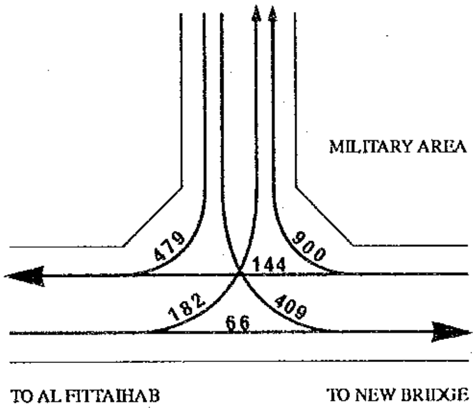
The above-mentioned traffic volumes are shown in Figures 8.14 and 8.15.

TRAFFIC VOLUME IN 1995

(1) MORNING PEAK IN 1995 (V/H)

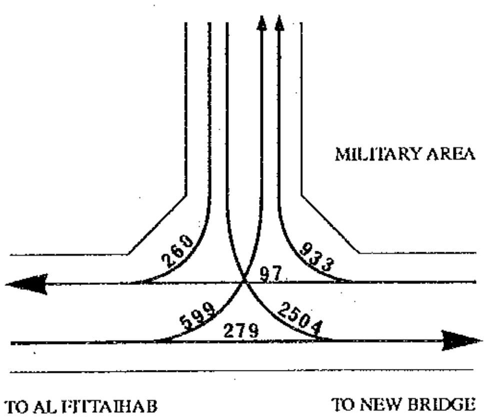


(2) AFTERNOON PEAK IN 1995 (V/H)

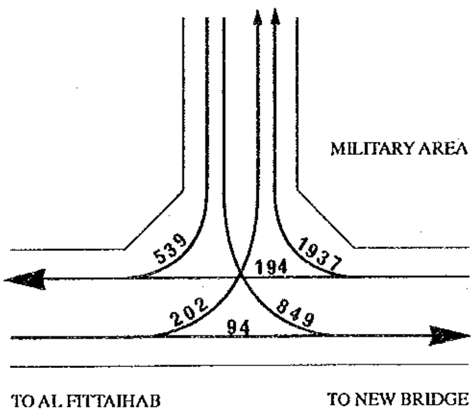


TRAFFIC VOLUME IN 2005

(1) MORNING PEAK IN 2005 (V/H)



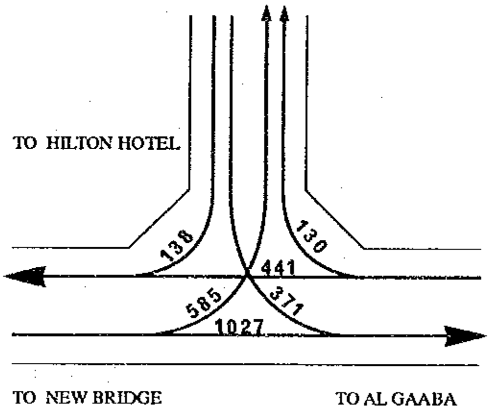
(2) AFTERNOON PEAK IN 2005 (V/H)



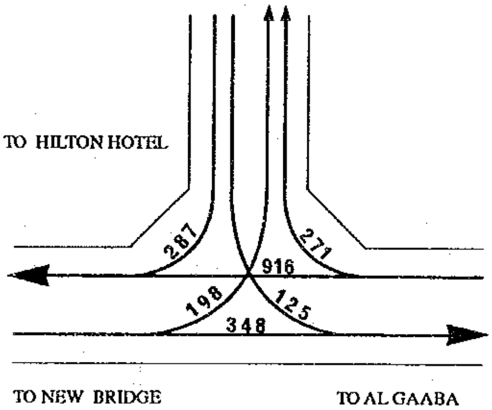
THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.14	FUTURE TRAFFIC VOLUME ON A INTERSECTION (OMDURMAN SIDE)
	JAPAN INTERNATIONAL COOPERATION AGENCY	

TRAFFIC VOLUME IN 1995

(1) MORNING PEAK IN 1995 (V/H)

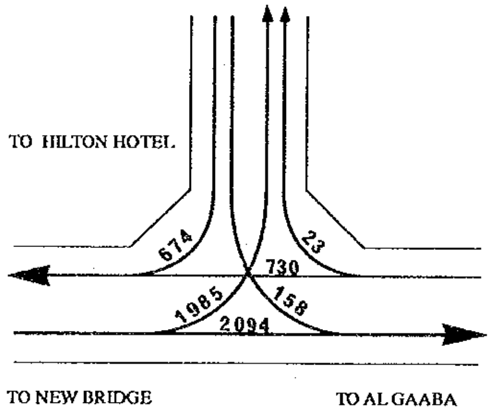


(2) AFTERNOON PEAK IN 1995 (V/H)

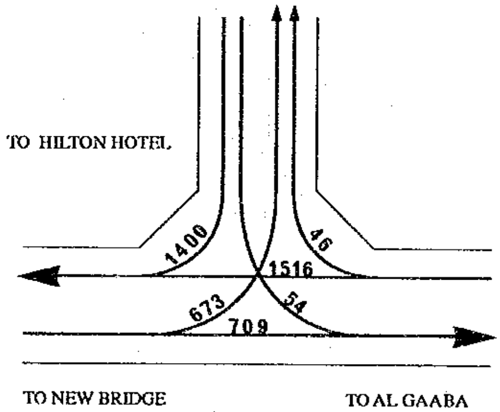


TRAFFIC VOLUME IN 2005

(1) MORNING PEAK IN 2005 (V/H)



(2) AFTERNOON PEAK IN 2005 (V/H)



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.15	FUTURE TRAFFIC VOLUME ON B INTERSECTION (KHARTOUM SIDE)
	JAPAN INTERNATIONAL COOPERATION AGENCY	

8.8.3 Intersection Types

(1) Type of Intersection

There are three types of intersection as described below;

* Grade Separated Intersection
* Signalized At-Grade Intersection
* Non Signalized At- Grade Intersection

The selection of intersection type from the above three is based on the saturation degree of an intersection and road network configuration.

a) From the Viewpoint of Saturation Degree

The saturation degree of Omdurman and Khartoum side intersections are calculated based on signal phasing as shown in "appendix 8". From an analysis of saturation degree in 1995 and 2005, the saturation degree will not exceed 1.00 at either in intersections which means that At-Grade Intersection type is appropriate to both the intersections.

$$\text{Saturation degree} = \frac{\text{Traffic Volume}}{\text{Intersection capacity}}$$

b) From the Viewpoint of the Road Network

Generally, an intersection is planed in accordance with the road functions and characteristics as shown in Table 8.8. The project road is classified as a Primary Distributor, and the existing AL Gaaba and Abu Syaid road can be classified as District Distributors or Local Distributor.

Both intersections are junctions between a Primary Distributor and a District Distributor or Local Distributor. Therefore, these intersections can be provided as At-Grade Intersection.

Table 8.8 Road classification and Intersection Type

TABLE 8.8 ROAD CLASSIFICATION AND INTERSECTION TYPE

FUNCTIONAL CLASSIFICATION	PRIMARY DISTRIBUTOR	DISTRICT DISTRIBUTOR	LOCAL DISTRIBUTOR	ACCESS
PRIMARY DISTRIBUTOR	◎	◎○	○	—
DISTRICT DISTRIBUTOR	◎○	○	○△	—
LOCAL DISTRIBUTOR	○	○△	○△	○△
ACCESS ROAD	—	—	○△	○△

NOTES

◎ ; GRADE SEPARATED INTERSECTION

○ ; SIGNALIZED AT-GRADE INTERSFCTION

△ ; NON SIGNALIZED AT-GRADE INTERSECTION

— ; NON ACCESS

c) From Viewpoint of Traffic Volume

Judging from the viewpoint of saturation degree and road network configuration, Omdurman and Khartoum side intersections are designed as At-Grade Intersection type.

The projected traffic volume in both directions in 1995 and 2005 on both intersections is about 1,300 to 1,600 V/D and 2,400 to 2,600 V/D. In addition, the traffic volumes in 1995 and 2005 on the existing roads to be joined at the intersections are forecasted at over 500V/D and 800 V/D respectively.

Generally, intersection capacity at a Non-Signalized At-Grade Intersection is very small as shown in Table 8.9. Judging from this table, Omdurman and Khartoum side intersections should be provided as Signalized At-Grade Intersections.

Table 8.9 Limited Capacity on Non Signal Intersection

Main Road (2-lane)	Main Road Traffic Volume(V/D)	400	500	600
	Sub Road Traffic Volume(V/D)	250	200	100
Main Road (4-lane)	Main Road Traffic Volume(V/D)	1,000	1,500	2,000
	Sub Road Traffic Volume(V/D)	100	50	25

d) Conclusion

Judging from the viewpoints of saturation degree and road network configuration, both intersections are designed Signalized At-Grade Intersections.

8.8.4 Alternative Plans

(1) Formation of Alternative Plans

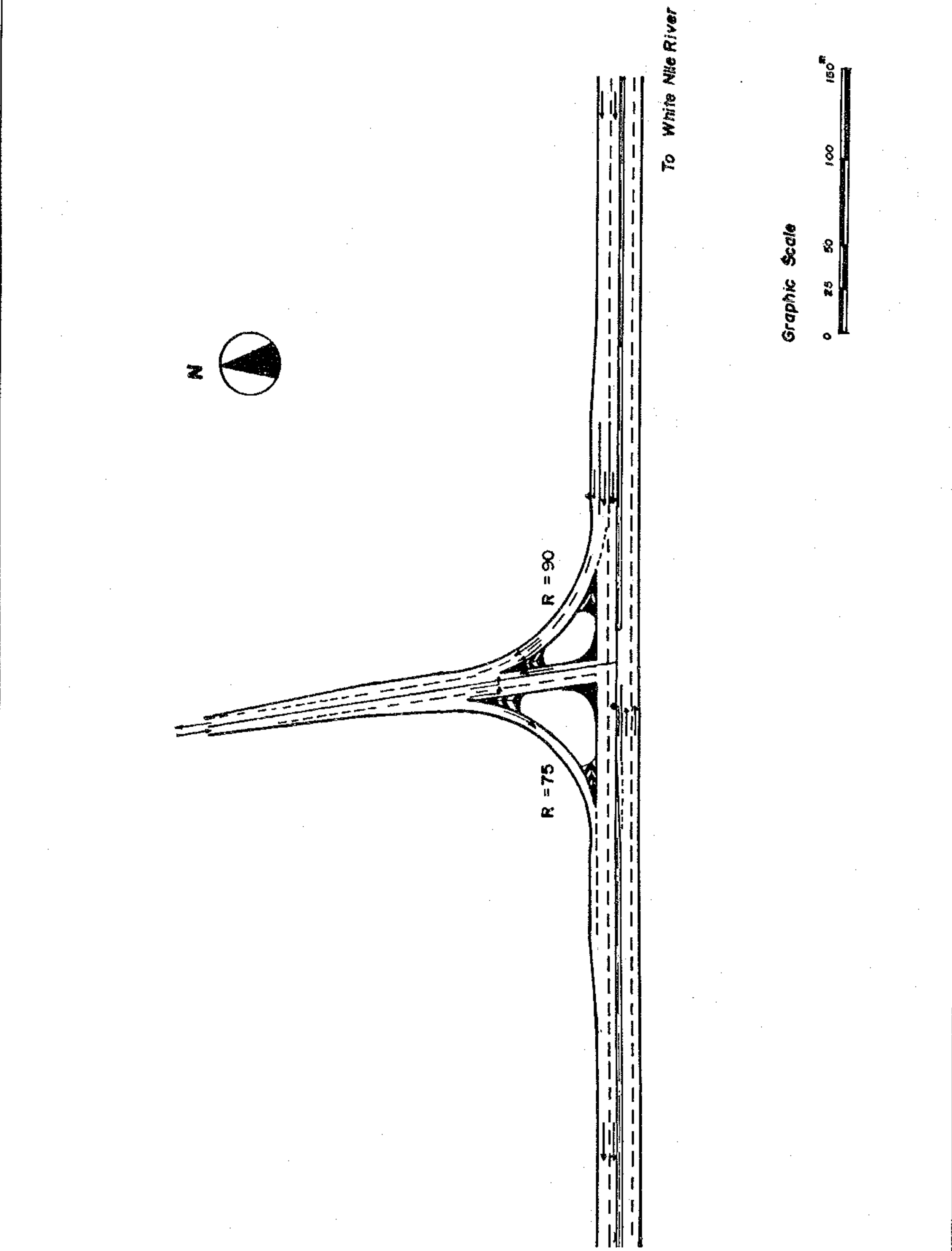
Taking into account the full reconnaissance survey, traffic flow directions and road network configuration, three alternative plans for the Omdurman side intersection and two alternative plans for the Khartoum side intersection are prepared as described below;

A) Omdurman Side Intersection

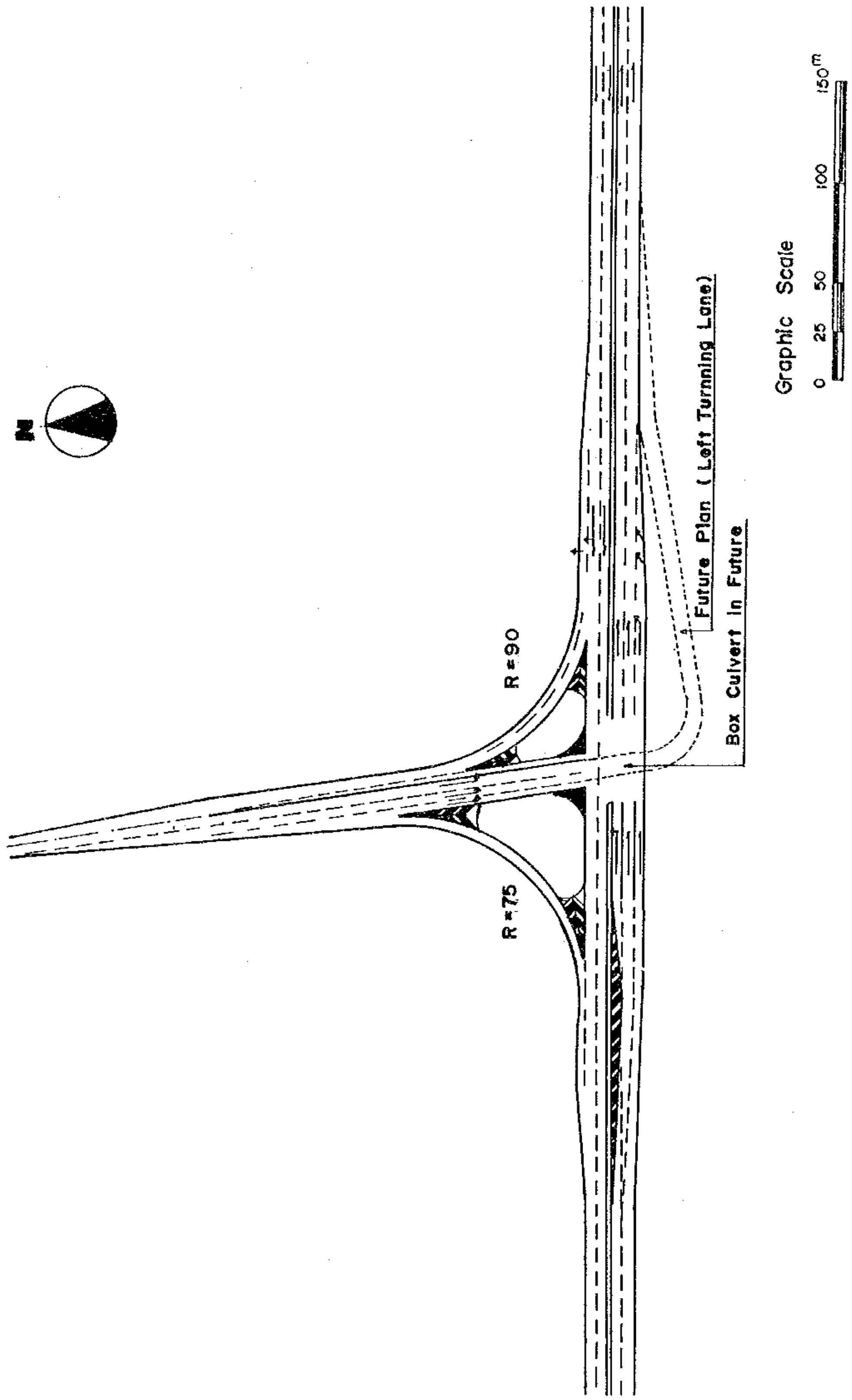
a) Alternative Plan A-A (See Figure 8.16)
b) Alternative Plan A-B (See Figure 8.17)
c) Alternative Plan A-C (See Figure 8.18)

B) Khartoum Side Intersection

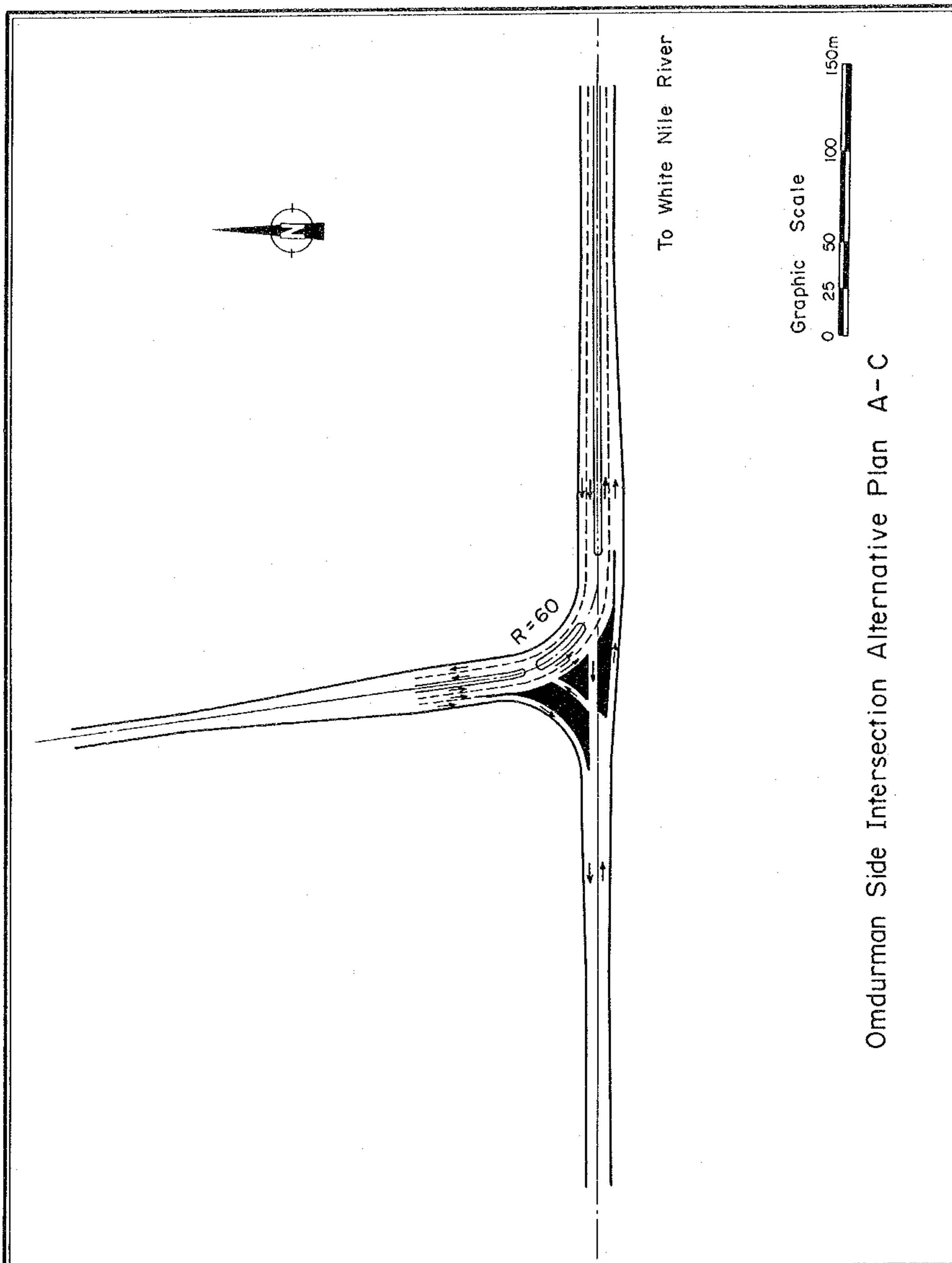
a) Alternative Plan B-A (See Figure 8.19)
b) Alternative Plan B-B (See Figure 8.20)



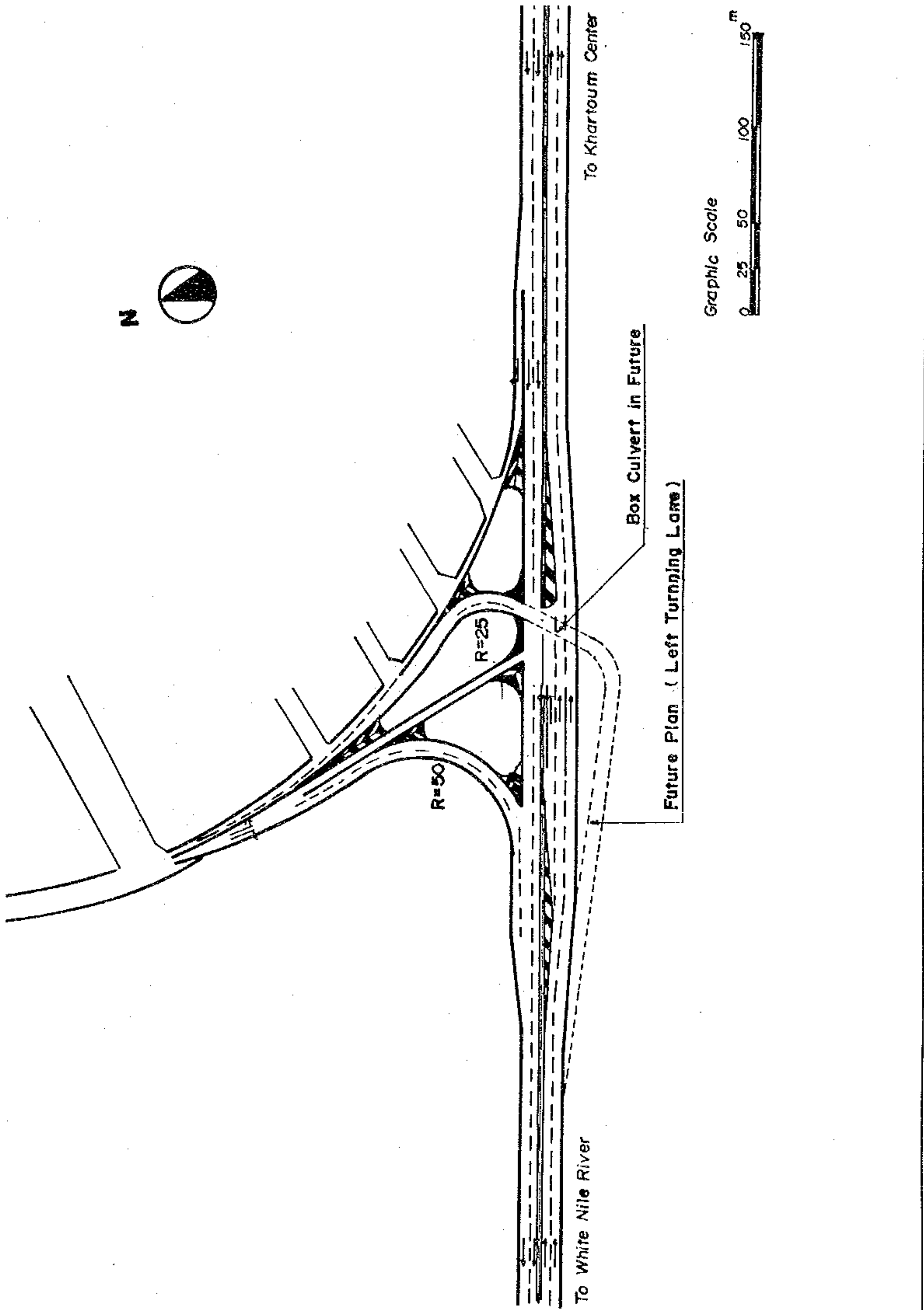
THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	**Fig.** 8.16	OMDURMAN SIDE INTERSECTION ALTERNATIVE PLAN A-A
	JAPAN INTERNATIONAL COOPERATION AGENCY	



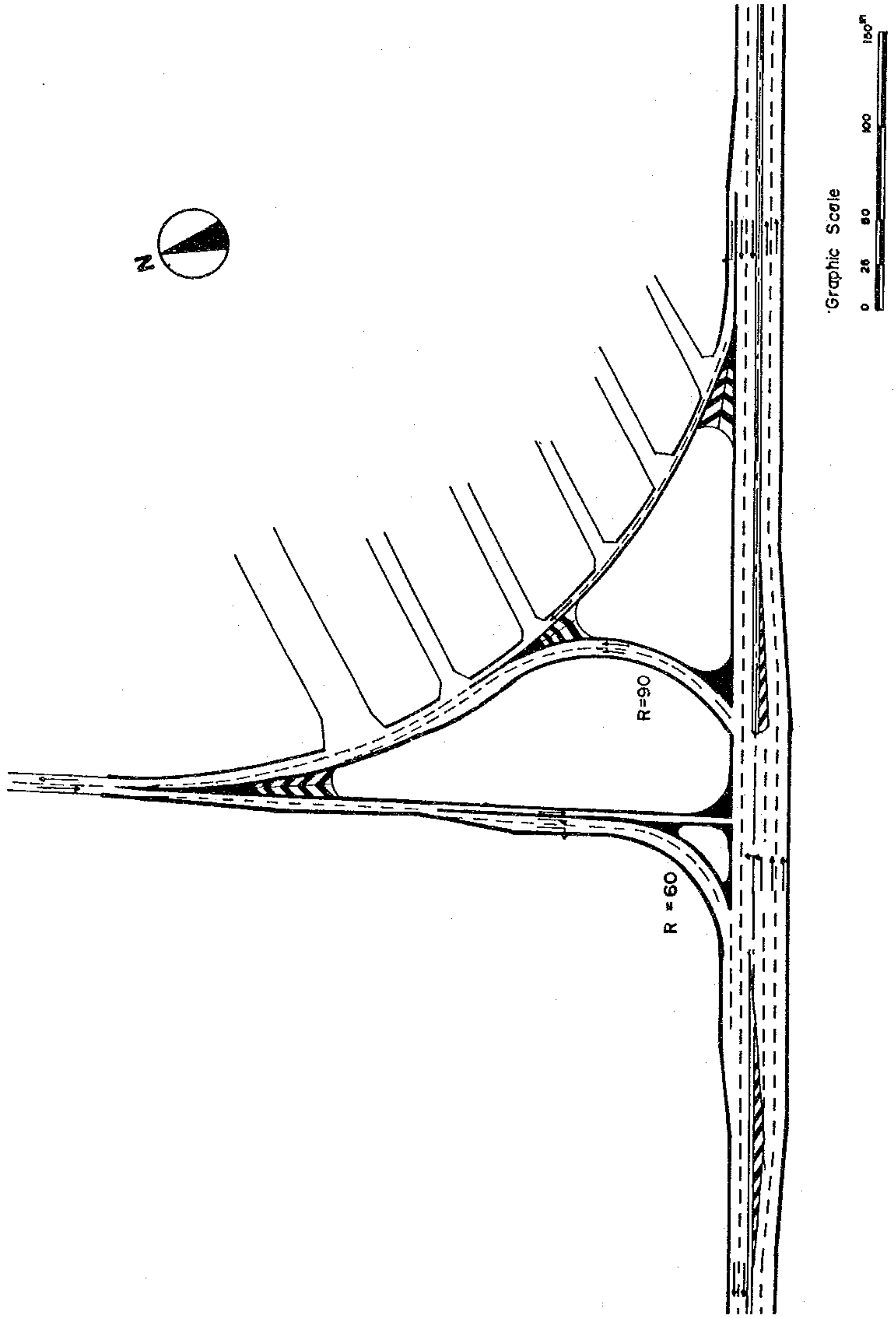
THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.17	OMDURMAN SIDE INTERSECTION ALTERNATIVE PLAN A-B
	JAPAN INTERNATIONAL COOPERATION AGENCY	



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.18	OMDURMAN SIDE INTERSECTION ALTERNATIVE PLAN A-C
	JAPAN INTERNATIONAL COOPERATION AGENCY	



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.19	KHARTOUM SIDE INTERSECTION ALTERNATIVE PLAN B-A
	JAPAN INTERNATIONAL COOPERATION AGENCY	



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 8.20	KHARTOUM SIDE INTERSECTION ALTERNATIVE PLAN B-B
	JAPAN INTERNATIONAL COOPERATION AGENCY	

(2) Selection of Alternative Plan

A) Omdurman Side Intersection

The saturation degrees for the respective alternative plans are as shown in Table 8.11. The detailed calculations of the saturation degrees are shown in "Appendix 8.

Table 8.10 Saturation Degree

		Alt. A-A	Alt. A-B	Alt. A-C
1995	M	0.712	0.590	0.619
	A	0.315	0.292	0.292
2005	M	1.175	0.901	0.968
	A	0.634	0.504	0.417

Notes M : Morning Peak Hour

A : Afternoon Peak Hour

The alternative plan A-C is selected for the Omdurman side intersection and its reasons are described below;

a) The saturation degree of Alternative Plan A-A exceeds 1.00. So, the future traffic volume in 2005 will not be controlled at the intersection.

b) The saturation degree of Alternative Plan A-B and A-C does not exceed 1.00. So, the future traffic volume in 2005 can be controlled at the intersection.

c) Considering the main traffic flow directions, Alternative Plan A-C is better traffic control than Alternative Plan A-B.

d) However the main traffic flow directions will be changed when the Beltway will be constructed. It is required that the intersection type will be improved as Plan A-B or other appropriate one.

B) Khartoum Side Intersection

The saturation degrees of Alternative Plans B-A and B-B do not exceed 1.00 as shown in Table 8.12. Alternative Plans B-A and B-B are both applicable in terms of the saturation degrees, which are below 1.00. Alternative B-B is selected from the viewpoint of lower construction costs and easy control of traffic movements.

Table 8.11 Saturation Degrees on Khartoum Intersection

		Alt. B-A	Alt. B-B
1995	M	0.578	0.578
	A	0.411	0.411
2005	M	0.885	0.885
	A	0.754	0.754

Notes M : Morning Peak Hour

A : Afternoon Peak Hour

(3) Future Intersection Type

Sometime, after the year 2005, both intersections will start to become congested and some improvement works will be required.

The saturation degrees after the above-mentioned improvements will be significantly decreased. In the Study, the future intersection types will not be studied for the reasons described in Subsection 8.8.3. However, a right of way plan will be prepared taking into account the future possibilities as anticipated.

The following factors should be examined for the further improvement plan:

a) Traffic movement and its characteristics

b) Construction method including traffic diversion

c) Construction cost and its economic feasibility

d) Sub-surface water level and flood conditions

e) Box culvert drainage system (including pumping up)

f) Electric conditions

g) Maintenance and its organization

8.8.5 Design Criteria

(1) Design Speed

In principal, the design speed should be the same at the intersections as a part of the approach roads where traffic flow is not interrupted by signals or stop signs. However, when the traffic is controlled by traffic signals, the design speed may not be set at a slower speed than for the road section taking into consideration such factors as stop, start, acceleration and deceleration of the vehicles.

Considering the above-mentioned matters, the design speed of at-grade intersections is adopted as 40 to 60 km/h.

(2) Design Vehicles

The project road is classified as a primary distributor. Therefore, the intersections should be so designed that all kinds of vehicles can be operated there.

(3) Design Standards

There is no authorized standard for intersection design in Sudan at present. Since the present vehicle conditions in Greater Khartoum are very similar to those in Japan, JRA (Japan Road Association) standards will be basically adopted and AASHTO or BSI standards will be used to supplement JRA standards.

(4) Intersection Type

As previously mentioned, Omdurman and Khartoum side intersections are designed as Signalized At-Grade Intersections.

8.8.6. Results of Preliminary Design

On the basis of the selected intersection type and design criteria, the preliminary designs of both intersections were carried out. The design used the topographic maps at a scale of 1 to 500 which were produced by the Study Team in July 1989.

The drawings of the preliminary designs are presented in the "Drawing".

The design elements to be adopted are described as follows:

a) Lane Width

The lane widths of through lane and right turn or left turn lanes are adopted as 3.50 meters and 3.00 meters respectively considering vehicle running speeds and economic aspects.

b) Acceleration Length

The acceleration lengths for a one lane road and a two lane road are adopted as 60.0 meters and 120.0 meters respectively considering a 40.0 km/h design speed.

c) Deceleration Length

The deceleration length for a one lane road is adopted as 45.0 meters.

d) Storage Length

The storage length depends on the number of stored vehicles, however, in this study, 20.0 meters storage length is adopted assuming four vehicles are stored.

e) Channel Width

Channel width adopted depends on the radius of channel. The relationship between channel width and radius is shown below;

Radius(m)		Channel Width
13 or more	14 less	8.5
14	15	8.0
15	16	7.5
16	17	7.0
17	19	6.5
19	21	6.0
21	25	5.5
25	30	5.0
30	40	4.5
40	60	4.0
60	-	3.5

f) Taper Length

The minimum taper length for a speed changing lane, which are acceleration and deceleration lanes, is calculated from the following formula.

$$TL = \frac{V \times W}{6}$$

where,

TL : Taper Length (m)
V : Design Speed (km/h)
W : Width of Shift to be Required (m)

The minimum taper length for a through traffic lane to be shifted is calculated using the following formulation.

$$TLL = \frac{V \times W}{3}$$

where,

TLL : Taper Length (m)
V : Design Speed (km/h)
W : Width of Shift Required (m).

8.9 RIGHT OF WAY

The right of way plan was made based on the Drawings of preliminary design of approach road.

The right of way consists of road embankment structure width, frontage roads width, drainage structure width and construction or camp yard width.

The planned width of right of way is shown in Table 8.12 and comments of Table 8.12 are given below:

a) The left side of right of way at station No.1 to No.14 is from the center line to the military fence located at the end of the military area.

b) The right side of right of way at the station No.1 to No.5 is adopted as 50.0 m considering future improvement of the "A" intersection.

c) The total right of way width at the station No.20+50 to No.23 is adopted as 200.0 m considering the construction yard.

d) The left side of right of way width at the station No.35 to No. 39 is adopted as 105.0 m considering the camp yard.

Table 8.12 Right Of Way

R.O.W (m) Left Side (From Center)	No. Of Station	R.O.W (m) Right Side (From Center)	:	R.O.W (m) Left Side (From Center)	No. Of Station	R.O.W (m) Right Side (From Center)
45.0	No.20	45.0	:	-	No.40	40.0
45.0	NO.19	45.0	:	105.0	No.39	40.0
45.0	No.18	45.0	:	105.0	No.38	40.0
45.0	NO.17	45.0	:	105.0	No.37	40.0
45.0	NO.16	45.0	:	105.0	NO.36	40.0
45.0,33.0	NO.15+50	33.0,45.0	:	105.0,40.0	No.35	40.0
33.0	No.15	33.0	:	42.0	No.34	40.0
Until Fence	No.14	33.0	:	42.0	No.33	40.0
"	No.13	33.0	:	42.0	No.32	42.0
"	No.12	33.0	:	42.0	No.31	42.0
"	No.11	33.0	:	River	No.30	River
"	No.10	33.0	:	River	No.29	River
"	No. 9	22.0,33.0	:	River	No.28	River
"	No. 8	22.0	:	River	No.27	River
"	No. 7	22.0	:	River	No.26	River
"	No. 6	22.0	:	River	No.25	River
"	No. 5	50.0	:	River	No.24	River
"	No. 4	50.0	:	100.0	No.23	100.0
"	No. 3	50.0	:	100.0	No.22	100.0
"	No. 2	50.0	:	100.0	No.21	100.0
Until Fence	No. 1	50.0	:	100.0,45.0	No.20+50	45.0,100.0

8.10 SUMMARY OF QUANTITIES

The quantities of approach roads were computed based on the preliminary design drawings as shown in the "Drawings" in this report and the main construction quantities of the approach roads are summarized in Table 8.13.

Table 8.13 Construction Quantities of Approach Roads

Main Working Items	Unit	Quantities
Road Embankment	CM	605,236
Road Excavation	CM	7,863
Surface for carriageway	SM	60,019
Base coarse for carriageway	CM	17,557
Sub-Base coarse for carriageway	CM	14,478
Sidewalk Pavement	SM	30,340
Box Culvert	M	67
Pipe Culvert	M	206
Slop Protection	SM	41,769
Concrete Drainage	M	3,000
Central Reserve	M	3,053
Concrete Curb	M	7,191
Wave Protection	M	1,656
Guardrail	M	3,525
Road Lighting	NO	279

CHAPTER - XI

PROJECT EVALUATION

CHAPTER-IX CONSTRUCTION PLANS

9.1 GENERAL

Construction planning for the New White Nile bridge is based on the optimum scale of the proposed bridge established in CHAPTER-VII and VIII. The time schedule is based on an assessment of the required periods for detailed design and tendering, site conditions, possible construction methods and expected production rate for the selected plant and equipment. It is assumed that the construction works would be undertaken under one main contractor by a mechanized method to minimize the construction period. Recommendations concerning the procurement of construction materials and equipment are offered and requirements for provision of construction facilities also considered.

9.2 CONSTRUCTION TIME SCHEDULE

The total period for construction is planned to be 3.5 years (42 months) considering the difficult construction sequence of a bridge over a 500m wide river, an inundated site (Aug. to Oct.) and workable days of the calendar year.

The construction time schedule is prepared on the following assumptions.

a) The construction will be started at the beginning of October, 1991, shortly after the flood season.

b) Mobilization and preparatory works will be completed within 7 months and foundation works of P14 Pier would be commenced the beginning of May, 1992.

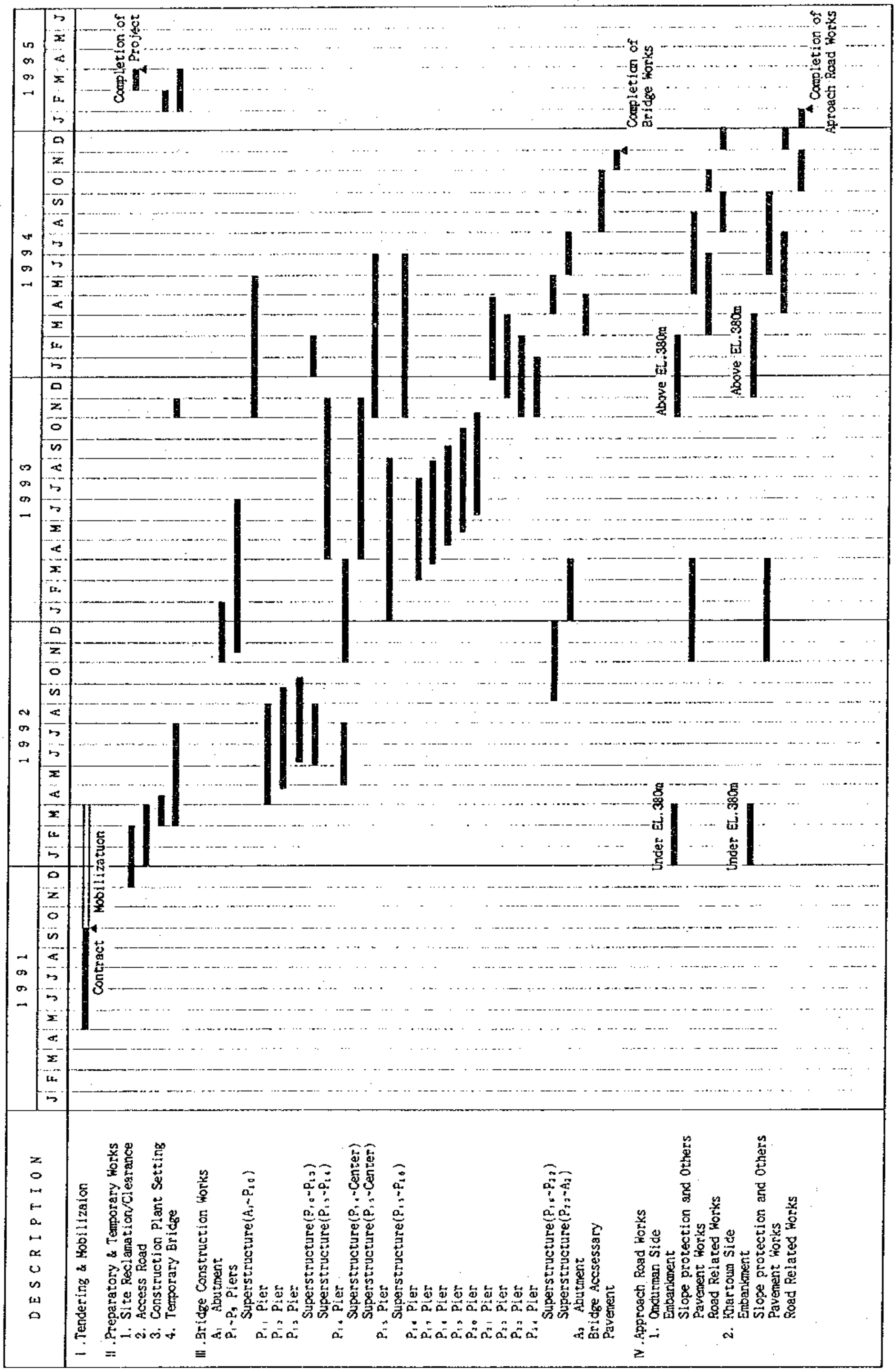
c) Structures of foundations and piers under E.L 381m would be completed before the flood season.

d) Construction of PC box girders will be carried out in parallel with construction of PC-I-Girders and will follow slab bridges.

e) All construction of the bridge would be completed by the end of November, 1994 (32 months in total)

f) After demobilization of the site, the project would be completed by the end of March, 1995.

In compliance with the above assumed conditions, a construction time schedule is worked out as shown in Figure 9.1.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 9.1	TENTATIVE IMPLEMENTATION SCHEDULE FOR THE NEW WHITE NILE BRIDGE PROJECT
	JAPAN INTERNATIONAL COOPERATION AGENCY	

9.3 CONSTRUCTION MATERIALS REQUIRED

Construction materials were firstly surveyed by conducting interviews at the Government Offices and laboratory and local contractors and then determining whether these materials would be available in the Sudan or would have to be imported from other countries. The required quantities of main materials were estimated based on the results of the preliminary design for the construction of the New White Nile bridge and are summarized in Tables 9.1 and 9.2.

Table 9.1 Major Materials Required for Bridge

No.	Material Description	Required Quantities	Source Supplied
1	Cement	11,000 t	Imported
2	Reinforcing bar	2,300 t	Imported
3	Admixture	330 t	Imported
4	Prestressing steel bar	15 t	Imported
5	Prestressing steel wire	670 t	Imported
6	PC anchor	8,500 No	Imported
7	Steel sheet pile	780 t	Imported
8	Shaped steel beam	4,000 t	Imported
9	Coarse aggregate	58,000 Cu.m	Domestic
10	Fine aggregate (sand)	85,000 Cu.m	Domestic

Table 9.2 Major Materials Required for Approach Road

No.	Material Description	Required Quantities	Source Supplied
1	Embankment soil	510,000 m3	Domestic
2	Sub-base course	14,500 m3	Domestic
3	Base course	17,500 m3	Domestic
4	Asphalt	3,200 t	Imported
5	Rip rap	9,000 m3	Domestic
6	Diesel oil	1,000,000 gal	Domestic
7	Lubricant	5,000 gal	Domestic

9.4 PROCUREMENT OF THE MATERIALS AND EQUIPMENT

9.4.1 Imported Materials and Equipment

Local cement factories are producing Portland cement (400ton/day) at Atbara and (160ton/day) at Rabak but there is still a shortage of supply in meeting increasing demand. The price of local cement is Ls 1,700/ton which is costly in comparison with that of imported cement including ocean freight. Consequently, it is recommended that the cement be imported from a foreign country. The other major construction materials except aggregate, sand, soil, riprap, diesel oil and lubricants are not sufficiently available in the Sudan market.

It is assumed that these unavailable materials will be imported from Japan. However, it will be advantageous if cement, shaped steel beams and soil moving equipment are imported from Italy in consideration of the following points.

a) Distance of country and good accessibility
b) Surplus of production capacity over domestic demand
c) Low price even including ocean freight and inland transportation cost
d) Social-economic condition is stable now

Where the construction materials and equipment would be procured in Japan or Italy, a period of 4.0 months or 2.0 months has been allowed for purchasing, shipping, and transporting them to the construction site respectively.

9.4.2 Local Materials

(1) Coarse Aggregate

Rocks for coarse aggregate will be obtained from the quarry site located at Jabal Torya, approximately 7 km south-west of the proposed bridge site. This rock is of basalt and sand stone and exists at ground level. It is assumed that light blasting will be required to excavate the basalt and sandstone by bench-cut method. Drilling will be done by a crawler drill powered by a portable air compressor. Explosive will be AN-FO and dynamite. The quantity of coarse aggregate is approximately 58,000 cu.m. The blasted rock will be transported by dump trucks to the construction site and conveyed directly to the crushing plant. This plant can produce all the concrete and asphalt aggregates and riprap stone.

Coarse aggregate will also be obtained from the quarry site on Jabal Seletate. This source is approximately 37 km north-east of the construction site, and entails a hauling distance of 40 km. A private firm is licensed to quarry a granite stone for concrete aggregate and has installed a crushing plant (Cone crusher) with a rated output of approximately 60 t/hour. This crushed stone would be high strength and available for the PC bridge, but workability of the concrete is considered to be bad because the crushed shape is flat.

Natural gravel obtained from the gravel deposit on Jabal Seletate would also be suitable for concrete aggregate. However, the mixed portion of natural gravel and sandy soil will be 4 to 6. Primary screening of the natural gravel is necessary in order to select the gravel stone on the borrow site. This source is near the Jabal Seletate quarry site, approximately 40km north-east of the construction site, and entails a hauling distance of 50 km. Secondary screening is carried out to wash and screen the natural gravel which contains silt and clay on the construction site. A scrubber can be installed near the entrance end of the screen in order that the natural gravel is agitated in water.

Costs of above three types of coarse aggregate at the construction site are estimated and compared in Table 9.3.

Table 9.3 Approximate Cost of Coarse Aggregate

No.	Description	Source	Hauling Distance(km)	Cost/m3 (Ls)
1.	Crushed stone	Jabal Seletate	40	530
2.	Natural Gravel	Jabal Seletate	50	340
3.	Crushed stone	Jabal Torya	7	250

It is proposed that the crushed stone obtained from Jabal Torya be utilized for concrete and asphalt aggregate, but a detailed survey such as a boring test, and quality tests must be conducted in the detailed design stage.

(2) Fine aggregate (Sand)

The required fine aggregate is approximately 85,000 cu.m. The fine aggregate will be produced by a rod mill installed at the final crushing stage of the plant which produces coarse aggregate. The material source will be the same quarry as for the coarse aggregate at Jabal Torya.

Fine aggregate (Sand) would also be obtained from the desert located 10 km south-west of the construction site (4 km west of Jabal Torya).

The desert sand is distributed in a wide area but in a thin layer (approximately 20- 30 cm). This sand contains silt and very fine sand passing 0.300 mm (No.50 Sieve). The contained portion of sand and silt is considered to be 4 to 6. Consequently, a portable vibrating screening (single deck screen) plant is required for selecting sand over 0.15mm (No. 100 Sieve). The volume required of desert sand is roughly estimated at 30 ton/day in total, but the quantity is uncertain.

Costs of the above fine aggregate at the construction site are estimated and compared in Table 9.4.

Table 9.4 Approximate Cost of Fine Aggregate

No.	Description	Source	Hauling Distance(km)	Cost/m3 (Ls)
1.	Natural sand	Desert	10	185
2.	Crushed sand	Jabal Torya	7	260

It is proposed that crushed sand produced from the same crushing plant as the coarse aggregate be used for concrete fine aggregate. Natural sand obtained from the desert has disadvantages in regard to both quantity and gradation.

(3) Embankment soil

Embankment soil for the approach road and construction yard-1 will be obtained from the borrow area located approximately 2 km south of the proposed bridge site on the Omdurman side. This embankment soil is a decomposed soil derived from weathered mudstone and sandstone which is used for road embankments and is deposited in a thickness of 1.5 - 2.0 m. The volume of embankment is approximately 460,000 cu.m (approach road 350,000 cu.m and construction yard-1 110,000cu.m), and 340,000 sq.m of borrow area is required.

The embankment soil on the Khartoum side will be obtained from the borrow area located in the Sunt Wood, approximately 500 m south of the construction site on the Khartoum side. The quantity obtained from the borrow area is roughly estimated at 152,000 cu.m and 60,000 sq.,m of borrow area is required.

(4) Rock for Riprup

The rock for riprap is obtainable from the same quarry site as for concrete aggregate located at Jabal Torya. The over 200mm size of the rock blasted at the quarry site is removed ahead of a crusher by grizzly feeder to reduce the load on the crusher. The removed rock will be stockpiled at the construction yard and used for riprap. The quantity of riprap stone required is approximately 8,500 cu.m.

9.5 TRANSPORTATION METHOD

9.5.1 Facilities of Port Sudan

Port Sudan, which is the only international port in the Sudan, has two (2) quays, namely Main and South quay. Construction plant, equipment and materials imported from Japan, Italy or other countries during the construction will be unloaded on the Main quay. The south quay is used only for oil tankers. An outline of the two quays is shown in Table 9.5.

Table 9.5 Main and South Quays of Port Sudan

No.	Description	Quay Main	Quay South
1.	No. of berths	11	5
2.	Maximum ship tonnage (t)	25,000	50,000
3.	Maximum Depth (m)	9	12
4.	Unloading crane(t)	5 -75	--
5.	Class of cargo	General cargo	oil

Several 5 -75 ton rail-mounted gantry cranes are operating on the Main quay but unloading capacity is estimated at about 750 -1000 t/day by each berth. It is recommended that heavy plant or equipment be transported by cargo ship with a loading/unloading crane of sufficient capacity.

9.5.2 Inland Transportation

Inland transportation for construction plant, equipment and materials mainly depends on road transportation by the Khartoum - Port Sudan highway about 1,200 km in distance. Railway transportation is now under repair and river transportation is not available because dams and waterfalls exist on the Nile river.

The Khartoum- Port Sudan highway, which has a 2-lane carriageway paved in asphaltic concrete, is generally in good condition except in the following road sections:

- Where the highway passes a mountainous area between Port Sudan and Sinkat (120 km), the gradient of over 7 % is continuous for 10 km.
- Many pot holes were observed on the pavement surface between Haya and Kasala.

There are many transportation companies in Khartoum and Port Sudan, of which 5 -7 companies are large and undertake transport and forwarding services for major development and construction projects in the Sudan.

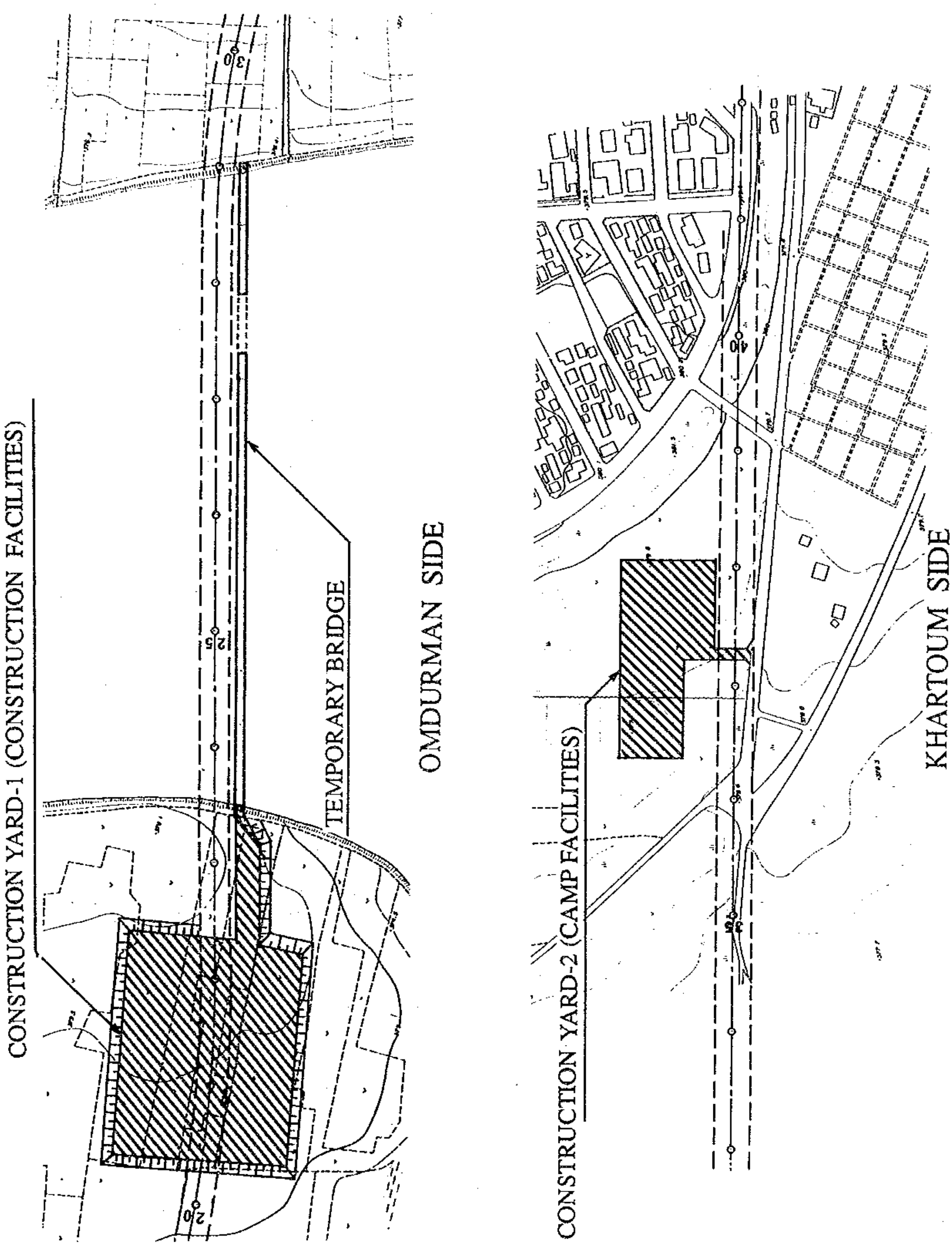
Typical vehicles used for transportation between Port Sudan and Khartoum are;

- Heavy trucks of 50 ton loading capacity
- Lowbed trailers of 60 -80 ton capacity
- Fork-lift trucks of 5 -10 ton capacity

The maximum capacity of a transporting unit is considered to be 200 ton (3.50m wide and 22.0m long) on an 8 axle hydraulic trailer. As far as length is concerned, steel pipes to 35.0 m long have been transported by the Khartoum - Port Sudan highway.

9.6 CONSTRUCTION FACILITIES

Construction facilities would be developed on two separate construction yards as shown in Figure 9.2. Construction facilities such as a concrete batching plant, a crushing and screening plant, a fabrication yard for precast PC T-girders etc., would be constructed in Construction Yard-1 with an embankment up to the high water level near the White Nile river on the Omdurman side. Camp facilities such as the Engineer's office, Contractor's office, Contractor's camp, etc., would be developed in Construction Yard-2 near the end of the approach road on the Khartoum side. This area is not subject to inundation during the flood season. Land and building floor areas required for the construction facilities are estimated in Tables 9.6 and 9.7.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 9.2	CONSTRUCTION FACILITIES
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 9.6 Construction Yard - 1

No.	Construction Facility	Required Land Area (m2)	Required Floor Area (m2)
1.	Concrete Batching Plant	1,000	--
2.	Crushing & screening Plant	2,000	--
3.	Fabrication Yard for Precast PC T-girder	3,000	1,000
4.	Stock Yard (Cement)	2,000	1,000
5.	Warehouse (Spare Parts)	1,500	500
6.	Stock Yard (Aggregate & riprap)	4,000	--
7.	Stock Yard (Rebar,H-beam)	3,000	--
8.	Mortar Pool	2,000	--
9.	Repair Shop	500	200
10.	Access Road and Others	10,500	--
	Total	19,000	2,700

Table 9.7 Construction Yard - 2

No.	Construction Facility	Required Land Area (m2)	Required Floor area (m2)
1.	Engineer's Office	800	250
2.	Contractor's Office	1,500	500
3.	Contractor's Camp	1,500	400
4.	Labour Camp (Skilled Labour)	5,000	1,500
5.	Laboratory	200	50
6.	Guard House	200	50
	Total	9,200	2,750

9.6.1 Embankment for Construction Yard - 1

To expedite the installation of the various construction facilities, an extensive embankment (Approximately 110,000 cu.m at a level of 380.0 m) for Construction Yard - 1 will be required at least 3 months before the construction plant and equipment arrive on the site. Therefore, earth moving equipment such as bulldozers, dump trucks, and wheel loaders will have to be rented from the local market or a Contractor. It is expected that the embankment for Construction Yard - 1 could be sublet to local contractors who have enough earth moving equipment. Construction Yard-1 will be utilized as a counter weight for the approach road because the height of the embankment is over 10 m.

9.6.2 Construction Yard - 2 (Camp Area)

It is expected that between 600 and 800 personnel will be employed on the construction of the New White Nile bridge. The camp area would be developed near the end of the approach road on the Khartoum side and used for the Engineer's and Contractor's offices, Contractor's accommodation (Approximately for Approximately 20 personnel), labour camp (for Approximately 300 personnel), laboratory and guard house. It is considered that the labour camp facilities should be prepared for half of required Labour, the remaining Labour being recruited in Khartoum.

9.6.3 Access Road

The access road to the borrow area and the hauling road from the existing road to the bridge construction site on both the Khartoum and Omdurman sides will be constructed for the bridge construction at a level of 380.0 m. It is proposed that the hauling roads follow the same alignment as the approach roads because the embankment of the access roads can be used as a part of the approach road.

An access road to the quarry site at Jabal Torya from the existing road should be constructed for hauling the rock for concrete and asphalt aggregate and riprap stone. The access roads required are shown in Table 9.8.

Table 9.8 Required Access Roads

No.	Location	Required Length (km)
1.	Existing road to construction site on the Khartoum side	1.0
2.	Existing road to construction site on the Omdurman side	2.0
3.	Borrow area to approach road on the Omdurman side	2.0
4.	Borrow area to approach road on the Khartoum side	1.0
5.	Quarry site to existing road	3.0
	Total	9.0

9.6.4 Water Supply

Water can be drawn from the White Nile river and pumped up to storage tanks to provide a reserve supply which should be purified by a purifier and will need chlorinating before use.

Construction water supplies required for washing concrete aggregate, concrete production and general workshop use can be obtained from the White Nile river. When the White Nile river water may carry a sediment contained in the flood season, the water will require filtering before use. It is considered that a water cooling system should be installed near the concrete batching plant for cooling water and concrete aggregate.

9.6.5 Power Supply

National Electric Corporation (NEC) is a government organization in charge of supplying electricity in the Sudan. The NEC supplies at three (3) different voltages; 11,000, 415, 240 volts. In the vicinity of the proposed New White Nile bridge site, there exist two distributions; one is located near the water supply Corporation on the Khartoum side having transformers of 11,000/415 volts and the other near the military camp on the Omdurman side, having transformers of 415/240 volts. The unit rates for electric power are shown in Table 9.9.

Table 9.9 Power Supply by National Electric Corporation

No.	Supplied Voltage	Unit	Unit Rate(Ls)
1.	11,000	1 kw.h	0.23
2.	415	1 kw.h	0.26
3.	240	1 kw.h	0.30

(As of June 1989)

However, interruption of electric power often takes place in Greater Khartoum because of the recent shortage of electric power supply. It is proposed that the Contractor install generators to supply sufficient power for camp and construction facilities because a large supply will be required.

The power supply required for camp and construction facilities is estimated in Table 9.10.

Table 9.10 Required Power Supply

No.	Description	Required Power Supply (kw)
1.	Engineer's Office	30
2.	Contractor's Office	30
3.	Contractor's camp	50
4.	Labour camp	150
5.	Concrete batching plant	75
6.	Crushing &screening plant	100
7.	Other construction use	165
	Total	600 kw

9.7 WORKING CONDITIONS

9.7.1 Workable Days

Monthly workable days were calculated through the past rainfall records in Great Khartoum. Total workable days through the year are 276 days, average monthly workable days are 23 days, 19 days in the rainy season and 24 days in the dry season respectively. The detailed monthly workable days are shown in Table 9.11.

Table 9.11 Workable Days

Month	Day	Friday & Holiday	Rainy & Habub day	Workable Day
Jan.	31	5	0	25
Feb.	28	4	0	24
Mar.	31	6	0	25
Apr.	30	5	0	25
May	31	7	1	23
Jun.	30	5	2	23
July	31	9	6	16
Aug.	31	5	7	19
Sep.	30	5	4	21
Oct.	31	6	1	24
Nov.	30	4	0	21
Dec.	31	6	0	25
	365	67	22	276

Remarks; 1) Rainy days and Habub days as calculated below.

Rainy days = (Rainy days over 10mm) + (Rainy days under 10mm X 1/2)

Habub days = Total rainy days X 1/2

9.7.2 Night Work

Maximum monthly temperature in the daytime is 47.7°C in June to 40.1°C in January. Construction is obliged to be carried out in high temperatures throughout the year. It is proposed that concrete placing work be carried out as night work in the interests of quality.

9.7.3 Water Level and River Depth

Based on the annual high and low water level record at Mogran, the variation of the water level is illustrated in Appendix 9.1, and can be described as below.

a) Maximum variation from the highest to the lowest water throughout the year is 7.18 m in 1946 and the average variation is about 4.8 m (1978 - 1987).

b) The highest water level is 379.96 m recorded in September 1946 and the lowest water level is 372.62 m recorded in May 1945. The high water level for a 5-year return period is about 379.06 m. It is assumed that the level of the temporary bridge and camp yard will be constructed at 380.0 m considering the high water level of a 5-year return period plus 1.0 m allowance.

c) The average low water level is about 373.30 m at Mogran while the riverbed elevation at the proposed bridge site is about 372.10 m. Consequently, the water depth at low water level is about 1.2 m and such shallow depth will be continued for 9 months through the dry season. It is proposed that the temporary bridge be extended from both sides for construction of the bridge. Tug boats and barges are only available through the rainy season (August - November).

9.7.4 Technical Level of Skilled Labour

It is expected that approximately 250 skilled labour as listed in Table 9.12 will be employed on the construction of the bridge.

Table 9.12 Required Skilled Labour

No.	Description	Number
1.	Civil foreman	50
2.	Equipment operator	40
3.	Surveyor	5
4.	Mechanic	5
5.	Electrician	5
6.	Rigger (Bridge worker)	60
7.	Barbender	30
8.	Welder	30
9.	Carpenter	35
10.	Fitter	10
	Total	250

This skilled labour can be recruited in Great Khartoum but the following points should be considered.

a) The skilled labour has experience of road construction projects but little experience of a large bridge construction project. It is recommended that sufficient foreign expatriates such as crane operators, blasting operators and foremen (bridge workers) are required for supervising and training local skilled labour.

b) There are fifty (50) contractors registered in Khartoum city. Several contractors employ enough skilled labour and are widely undertaking road and building projects.

9.8 CONSTRUCTION METHODS

9.8.1 Construction Method for Sub-structure and Foundations

The sub-structure of the bridge has 13 piers in the river and 11 piers and 2 abutments in the inundated area, which are supported by the cast-in-place R.C piles of 1.2m in diameter. The construction of these piers (P11 to P23) in the river will use steel sheet piles for cofferdams. Construction materials and equipment are transported between piers and the sites on banks through the temporary bridge. The construction methods and sequence of the works are illustrated in Figure 9.3.

9.8.2 Construction Method for Superstructure

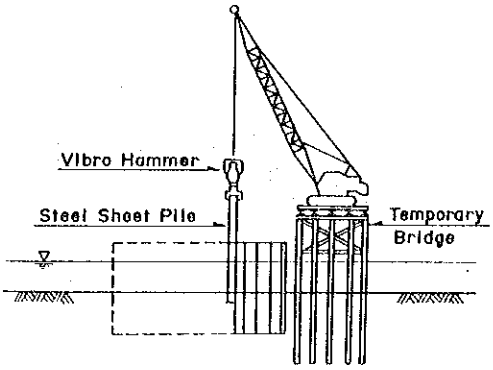
The superstructure of the bridge consists of a cantilever box girder bridge, a P.C I-beam bridge and a hollow slab bridge.

a) PC Box Girder Bridge

The construction of the PC Box Girder Bridge is divided into 4 phases from the view point of construction method; 1) Pier top block, 2) Cantilever girder blocks, 3) End girder block and 4) Keying segment at center. The construction methods and sequences of the works are illustrated in Figure 9.4 (A) and 9.4 (B).

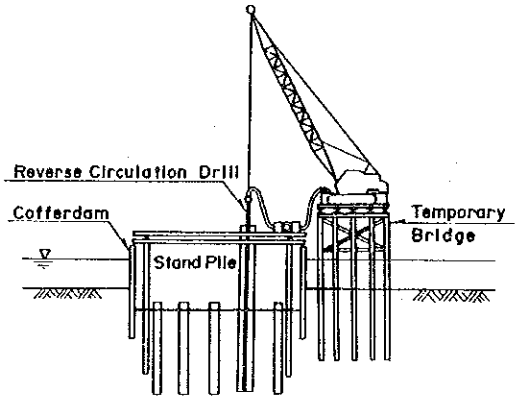
c) Hollow Slab Bridge

Hollow slab bridges will be constructed on the bitty stagings in the low water season.



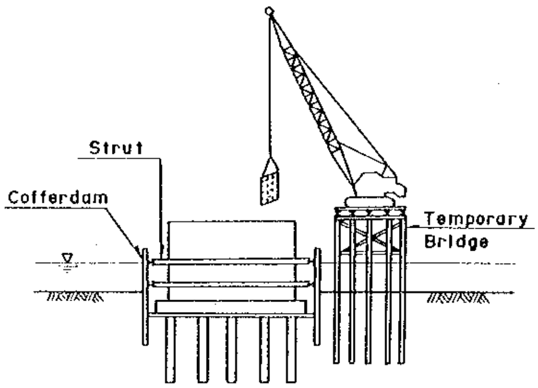
1. **Steel Sheet Pile Cofferdam**

The construction of the pier requires a rectangular steel sheet pile cofferdam. The steel sheet piles are driven by a 50 ton crawler crane on the temporary bridge. The cofferdam is reinforced by a bracing system with two levels to resist the external forces.



2. **Reverse Circulation Drill Piles**

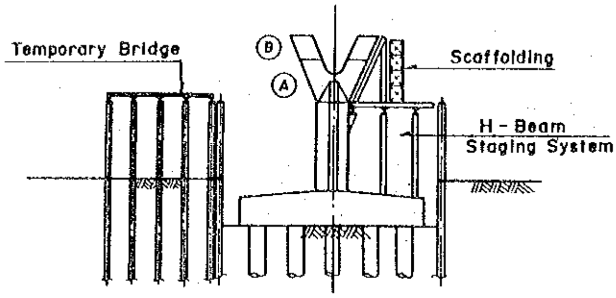
Holes in the cast-in-place concrete piles are drilled down to bearing strata through stand pipes by a reverse circulation drill from the staging in the cofferdam. Reinforcing cages are set by a 50 ton crawler crane and then concrete is poured by tremie pipe.



3. **Construction of Pier**

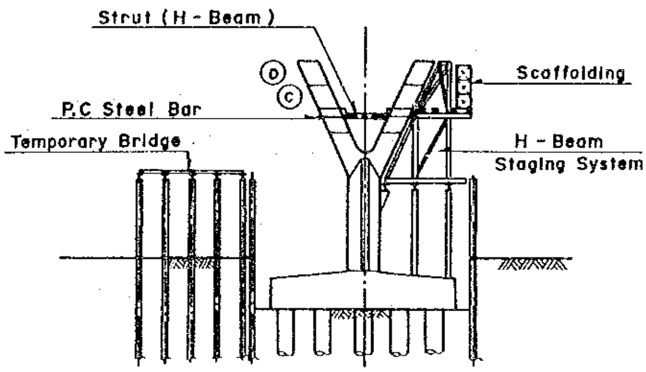
After the preparation of the pile top, footing , pier under WL.380m are constructed within dry season. Formwork and reinforcing bar are installed by a crawler crane. Concrete is placed directly by concrete pump with a boom.

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 9.3	CONSTRUCTION METHOD OF SUBSTRUCTURE AND FOUNDATION
	JAPAN INTERNATIONAL COOPERATION AGENCY	



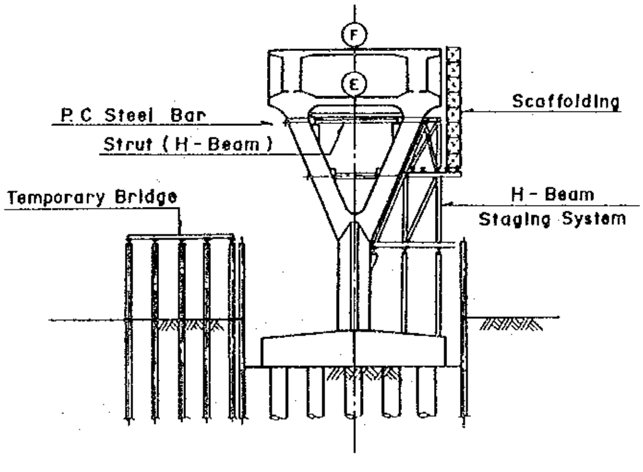
1. **Block A and B of V-type Pier**

Formworks A and B of V-type pier would be supported by the stagings of H-beams which are anchored on the top of the footings. Concrete would be placed separately by concrete pump with boom.



2. **Block C and D of V-type Pier**

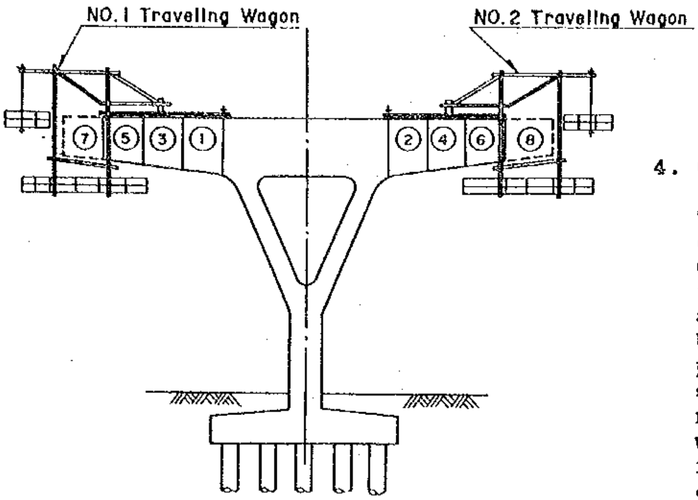
Lower strut would be set and prestressed between both sides of the strut as a counter-measure to increase stress in the V-type piers. Blocks C and D would be constructed by the same method as blocks A and B.



3. **Pier Top Block**

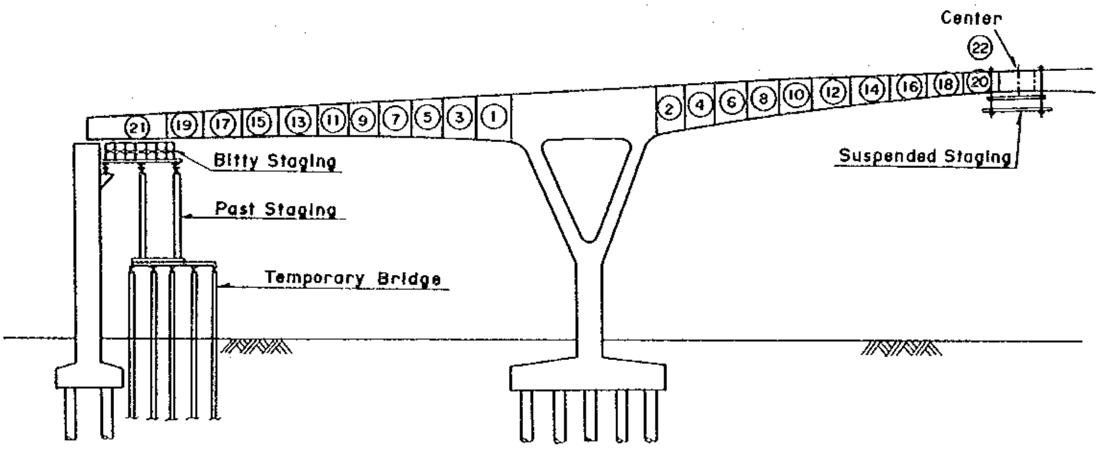
Upper strut would be set and prestressed between both sides of upper strut. Subsequently, the lower strut would be removed. Block E would be constructed on the bitty staging supported by H-beams. The H-beams are arranged on the brackets provided at completed block C.

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 9.4 (A)	CONSTRUCTION METHOD OF SUPERSTRUCTURE
	JAPAN INTERNATIONAL COOPERATION AGENCY	



4. **Cantilever Method**

The main box girder would be constructed with the Cantilever Method using two traveling wagons. The No. 1 and No. 2 wagons are set up on both sides of the V-type pier. The wagons travel one segment forward with alternation of No.1 wagon and No.2 wagon, after forming formwork, reinforcing bar installation, concreting and prestressing.



5. **End Girder Block**

The end girder at Pier 13 and Pier 16 would be constructed using bitty staging supported by post staging system, and connected to the main box girder by prestressing.

6. **Keying Segment at Center**

The ends of the main box girder at the center of each span are connected with a keying segment using a suspended staging system. After hardening of concrete of the keying segment, the continuity of the structure will be ensured by prestressing cables.

THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 9.4 (B)	CONSTRUCTION METHOD OF SUPERSTRUCTURE
	JAPAN INTERNATIONAL COOPERATION AGENCY	

CHAPTER - X

PROJECT COST ESTIMATE

CHAPTER-X PROJECT COST ESTIMATE

10.1 BASIS OF PROJECT COST

Project cost consists of Construction cost, Land Acquisition and Compensation cost, Engineering Service cost (Detailed Design and Supervision cost), NCK's Administration cost and Contingency. The basic system of the project cost estimate is shown in Figure 10.1, considering the characteristics of a large scale bridge project and the following assumptions.

a) Project cost is estimated at a price level as at the end of August 1989.

b) The exchange rate is assumed to be :

US$ 1.0 = Ls 4.5

This rate is based on the "Official Rate" controlled by GORS.

c) Materials and equipment, which cannot be procured in Sudan, are assumed to be imported from Japan or Italy. The unit prices are applied to the F.O.B price in the import country. Transportation cost is separately estimated for each country.

d) It is assumed that the project is undertaken by a Japanese contractor selected in a competitive tender under the supervision of a Japanese consultant.

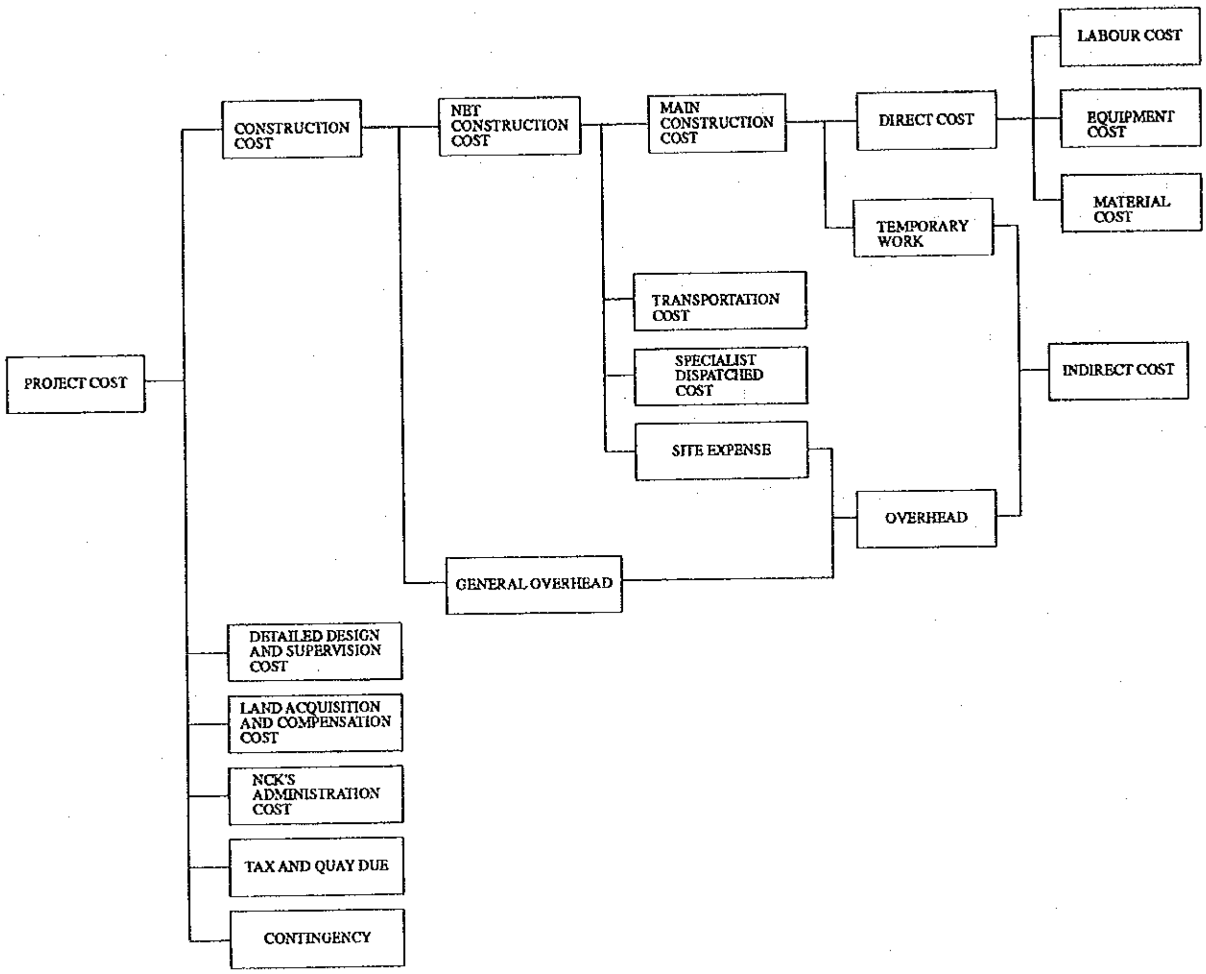
10.2 CONSTRUCTION COST

Construction cost consists of direct cost, cost of temporary works, transportation cost, specialists dispatched cost, site expense and general overheads. Each cost is estimated by items. Net construction cost is all the costs except general overheads while the main construction cost is the direct cost plus the cost of temporary works. The following gives the basic points of each cost item.

(1) Direct Cost

Direct cost consists of labour cost, equipment cost and material cost for each work item.

Labour costs per day were surveyed by interviewing a contractor organized by the Government and private contractors in Khartoum and listed in Appendix 10.1.



THE FEASIBILITY STUDY ON THE CONSTRUCTION OF THE NEW WHITE NILE BRIDGE	Fig. 10.1	BASIC SYSTEM OF COST ESTIMATION
	JAPAN INTERNATIONAL COOPERATION AGENCY	

Equipment costs are estimated based on the depreciation rate used in Japan. Repair costs are assumed to have foreign currency portion (70 %) and a local currency portion (30 %). The equipment costs are listed in Appendix 10.1.

Materials, which cannot be procured in the Sudan, are assumed to be imported from Japan or Italy. The unit prices are applied to the F.O.B price in the import country. Transportation cost is separately estimated for each country. The unit prices of main materials are listed in Appendix 10.2.

(2) Cost of Temporary Works

The cost of temporary works (preparatory works, camp facilities, fences, electric supply, water supply, clearing the site, etc.,) is estimated considering site conditions.

(3) Transportation cost

Transportation cost is estimated in a foreign currency portion for ocean freight and inland transportation. The ocean freight originates in Japan or Italy to Port Sudan. Transportation cost is estimated as only one way for the imported materials and general equipment, but as two ways for special equipment such as 100t lifting capacity crawler crane, cantilever wagon,PC Bridge construction equipment etc.. Transportation cost estimated from Japan and Italy is shown in Appendix 10.3.

(4) Specialists Dispatched Cost

It is expected that specialists for bridge construction (PC bridge Specialists, Foreman, Operator for special equipment) will be dispatched from Japan to train local skilled labour , because the local labour has little experience of a large scale bridge construction project. The specialist dispatched cost is estimated with the planned numbers and periods based on the construction schedule. It is expected that 18 specialists will be dispatched from Japan.

(5) Overhead

Overheads are divided into site expense and general overheads. The site expense such as wages of contractor's staff, operating and maintaining cost of contractor's office etc., are estimated for each item based on the Japanese standard. The general overhead is estimated by the following formula.

General Overhead = (Direct Cost of Main Works and Temporary Works for Main work + Specialist Dispatched Cost) X 10%

10.3 LAND ACQUISITION AND COMPENSATION COST

The proposed bridge site based on the space required for the approach road and contractor's camp sites is possessed by the government, while the farmers use as an agricultural area. A part of a residential area is also an object of compensation. This compensation will be carried out in the following ways.

a) Agricultural area

The government gives the farmers an agricultural area of equivalent value which the government possesses, and compensates for the furniture and plants on the agricultural land.

b) Residential area

The government gives the residents a residential area of equivalent value which the government possesses. The value of the existing buildings is estimated by a discussion of the land committee is compensated by an equivalent amount of money.

Consequently, land acquisition cost is basically estimated as equivalent values in the project cost, while compensation cost is estimated only for the residential buildings.

The equivalent values are estimated adopting the following unit prices.

Description	Unit Price (LS/m^2)
1. Third Class Residential Land	750
2. Farm Land	120

The compensation cost is proposed to be Ls 200,000 / building based on the past results of building compensation.

10.4 ENGINEERING SERVICE COST

Engineering service cost is estimated for the detailed design and supervision works undertaken by a Japanese Consultant team to design in detail, prepare the tender documents and give certification of the Works performed by the Contractor. The costs are estimated with the consultant's staff schedule based on the construction schedule.

10.5 NCK'S ADMINISTRATION COST

A great deal of liaison, co-ordination and administration work will have to be undertaken by NCK (National Capital Khartoum) as the Client in order to expedite the project. At this stage, it is assumed that 4 percent of the detailed design and supervision cost will be allowed for this Project.

10.6 Tax and Quay Due

Tax of construction materials and equipment is levied on the CIF prices when the materials and equipment are imported to Sudan, provided always that the materials and equipment carried out from Sudan after completion of the project are excepted from Tax. The tax ratios of the construction materials and equipment are listed in Appendix 10.4.

Quay due, which is estimated as 2% of CIF value in Port Sudan, is levied on all goods, materials and equipment required for the Project.

10.7 CONTINGENCY

This cost estimate is prepared on information available from the Feasibility study stage. Since it is assumed that bridge construction will be commenced about three years hence. Consequently, allowance must be made for such unknown factors as:

a) Economic changes (Exchange rate, Inflation etc.) in the Sudan, Japan and Italy.

b) Changes in geological condition and quantities which may occur during the detailed design stage.

c) Changes in assumptions regarding the proposed quarry and borrow areas and procurement of materials

From an assessment of the above factors involved, the contingency is assumed to be a maximum of 5 % of the construction cost.

10.8 TOTAL PROJECT COST

The project cost consists of the construction cost, detailed design and supervision cost, land acquisition and compensation cost, NCK's administration cost, tax and quay due and contingency. This cost was estimated by the procedures described in section 10.1. The project cost is summarized in Table 10.1.

Table 10.1 Summary of Project Cost Unit: LS x 10^3

Description	Amount	Components	
		Foreign	Local
1. Construction Cost	288,640	179,760	108,880
2. Detailed Design and Supervision Cost	30,070	16,640	13,430
3. Land Acquisition and Compensation Cost	104,600	-	104,600
4. NCK's Administration Cost	2,340	-	2,340
5. Tax and Quay Due	42,610	-	42,610
6. Contingency	14,430	8,980	5,450
7. Total	482,690	205,380	277,310

($1.0 = Ls4.5 = Y140)

The breakdown of the construction cost is detailed in Appendix 10.5

CHAPTER - IX

CONSTRUCTION PLANS

CHAPTER-XI PROJECT EVALUATION

11.1 GENERAL

In CHAPTER-V 5.4.1, the initial economic evaluation was given to select the most viable bridge route among five alternatives. As a result route B1 showed the highest IRR. Based on this result together with the initial engineering evaluation, route B1 was determined as the most feasible route. In this Chapter, a further comprehensive economic analysis is performed for the selected B1 route project, because the economic analysis made in CHAPTER-V was a tentative analysis just to select the most viable route.

11.2 ECONOMIC EVALUATION

(1) Economic Cost

The construction cost estimated from the engineering side in CHAPTER-X is the financial cost including transfer items such as tax, interest, and so on. Therefore, the financial cost does not represent the real economic cost for use in the economic analysis. In order to give a comprehensive economic analysis the following adjustment was done for the financial cost:

a) Shadow Exchange Rate

At present two foreign exchange rates prevail in Sudan. One is an official rate and the other is a parallel rate. As of 1989 the official rate is \$ 1 = Ls 4.5 and the parallel rate is \$ 1 = Ls 12.2. The former is a fixed official rate determined by the government and the latter is also determined by the government for policy and strategic purposes. In fact, the two rates do not reflect the actual economic situation due to the imperfection of the money market and as a result, a shadow exchange rate has been estimated by the Study Team. Considering the above fact, it is sure that both rates do not represent the correct economic exchange rate. Therefore, apart from the official rate, which is not an economic rate but an artificial rate determined by government strategy, the parallel rate should be converted into the real exchange rate.

According to the report "The Four Year Salvation, Recovery and Development Programme 1988/89 - 1922/92", the following export and import data is listed:

	A Amount (Ls Million)	B Composition Rate (%)	C Tax (Ls Million)	D Ratio (C/A)
Import	1185	67.2	1600	1.350
Export	578	32.8	60	0.104

From the above data the exchange rate is considered to be overestimated 90.72% (67.2 x 1.35) from the import side and 3.41% (32.8 x 0.104) from the export side, respectively. Therefore, the current exchange rate is overestimated about 87.31% (90.72% - 3.41%). As a result, the shadow exchange rate was estimated as follows:

1 dollar = 12.2 x 1.8731
= 22.85 (Ls)

1 Yen = 0.087 x 1.8731
= 0.163 (Ls)

b) Standard Conversion Coefficient

During the past decade the Sudanese economy has not been active due to several negative natural and economic factors like the recent severe drought, long civil war, lots of refugee inflow from neighboring countries, and so on. Reflecting the awful shortage of necessary goods, the domestic business slump, etc., market prices are considered to have been significantly distorted. In this situation market prices never represent the fair and efficient prices. Therefore, the prices of domestic goods and services are converted into fair and efficient prices with the conversion coefficient 0.53 as estimated in CHAPTER-V 5.4.2.

c) Shadow Wage Rate For Unskilled Laborer

According to the official employment statistics, the current unemployment rate is not so high despite the stagnated economy. However, considering the actual current economy, a lot of underemployed workers could be found within Khartoum city. In this economic situation the general wage rate of an unskilled laborer often does not reflect the opportunity cost of unskilled labor. Therefore, the unskilled laborer cost estimated from the engineering side should be converted into the opportunity cost. The Study Team conducted a field survey for this purpose. The survey result is summarized in Appendix 11.1. According to this survey, the opportunity cost of an unskilled laborer was estimated at Ls 17 per day. Since the current wage rate of the unskilled laborer is estimated Ls 25 per day on the engineering side, the shadow wage rate can be calculated with the conversion coefficient 0.68, which was obtained from the following equation:

$$\text{Conversion coefficient} = \frac{\text{Shadow Wage Rate}}{\text{Financial Wage Rate}} = \frac{17}{25}$$

Using the above conversion factors, the financial cost of construction, maintenance, and salvage value were converted into the economic cost.

(A) Construction Cost

The financial construction cost shown in Table 10.1 was converted into the economic cost using the above-mentioned conversion factors, which is summarized in Table 11.1. The Detailed Design and Supervision Cost in Table 10.1 was divided into three parts, that is, material cost, unskilled laborer cost, and skilled laborer cost with a share of 17%, 71%, and 12%, respectively. These shares were calculated in the cost estimation process.

Table 11.1 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

(B) Maintenance Cost

The maintenance cost was estimated, for the bridge itself and the approach road, separately.

a) Bridge

The asphalt pavement on the bridge surface is assumed to be reconstructed every seven years after completion of the proposed bridge. Therefore, the maintenance cost necessary for every seven years was estimated as follows:

	Financial Cost (Asphalt Pavement)	Economic Cost(*) (Ls 1,000)
Foreign Portion	18,728(Yen 1,000)	3,053
Local Portion	250(Ls 1,000)	133
Total		3,186

* 3,035 = 18,728 x 0.163
133 = 250 x 0.53

b) Approach Road

The maintenance cost of approach roads consists of reconstructing the road surface, cleaning sand and mud caused by the habub, maintaining lights and trees, repainting lane markings, etc. This cost can be separated into the following two parts: maintenance cost required for each year and maintenance cost required for every five years. The former and the latter are assumed to be 1% and 5% of the total construction cost of the approach road, respectively. The following shows the cost of the approach roads and their maintenance cost in terms of Sudan pounds:

	Financial Cost (Approach Road)	Economic Cost(*) (Ls 1,000)
Foreign Portion	774,731(Yen 1,000)	126,281
Local Portion	27,249(Ls 1,000)	14,442
Total		140,723

* 126,281 = 774,731 x 0.163
14,442 = 27,249 x 0.53

Maintenance cost required for every five years

140,723 x 0.05 = 7,036 (Ls 1,000)

Maintenance cost required for every year

140,723 x 0.01 = 1,407 (Ls 1,000)

c) Salvage Value

In this economic analysis the calculation period for the economic indicator is assumed to be 25 years. However, even after the calculation period the facilities of the approach road and bridge can be used. These facilities continue to have the residual value. Therefore, the residual value should be handled as minus cost at the end of calculation period. In this analysis only the superstructure and substructure of the proposed bridge is assumed to have a salvage value since the road facility is considered to be able to use for ever. As the durable years of the bridge superstructure and substructure are assumed to be fifty years, the salvage value of this structure is 50% of its construction cost. The following is the cost of superstructure and substructure of the bridge:

	Financial Cost (Super- and Sub- Structure)	Economic Cost(*) (Ls 1,000)
Foreign Portion	1,747,673(Yen 1,000)	284,871
Local Portion	49,674(Ls 1,000)	26,327
Total		311,198

* 284,871 = 1,747,673 x 0.163
26,327 = 49,674 x 0.53

The salvage value is calculated as follows:

311,198 x 25 years / 50 years = 155,599
(Ls 1,000)

(2) Economic Benefit

The economic quantitative benefit derived from the proposed project is composed of three items: vehicle operating cost saving, time saving, and maintenance cost saving for the existing White Nile Bridge.

a) Vehicle Operating Cost Saving Benefit

As already explained in CHAPTER-V 5.5.2 (1), the vehicle operating cost saving was forecast as follows:

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

b) Time Saving Benefit

The time saving benefit is also shown in CHAPTER-V 5.5.2 (2), however, considering the future prospective economic performance projected by the Sudanese government, the time value of Sudanese people in real term is expected to increase in the future together with the economic growth. Therefore, using the data included in the report " The Four Year Salvation, Recovery and Development Programme 1988/89 - 1991/92 ", the future time value was forecast to increase at the following growth rate:

Economic Growth Rate	5.0% per annum
Population Growth Rate	2.8% per annum

Therefore, the growth rate of time value is calculated in the following equation:

$$\text{Growth Rate} = \frac{(1 + 0.05)^{YEAR}}{(1 + 0.028)^{YEAR}}$$

With the above-mentioned growth rate, the future time saving benefit is estimated as follows:

Year	Time Saving Benefit (Ls 1,000)
1995	68,341 x 1.1355 = 77,599
2005	241,380 x 1.4033 = 338,720
2015	1,245,480 x 1.7342 = 2,159,919

c) Maintenance Cost Saving Benefit

Unless the proposed New White Nile Bridge is realized in the future, much more traffic would use the existing White Nile Bridge, which would cause severe further damage to that bridge. In order to avoid more deterioration of this bridge, a much higher maintenance cost would be needed in the future without the New White Nile Bridge. In addition, as suggested by the British consultant, the existing bridge would be requested to be reconstructed soon for some sections of the bridge structure without a new bridge. Therefore, this benefit is composed of the following three items:

Reconstruction Cost Saving

Reconstruction of some sections of the existing White Nile Bridge is estimated to cost one billion Yen from an engineering analysis. Assuming that 75% of its cost comes from the foreign portion and the rest from the domestic portion, based on the foreign and local cost composition of the superstructure and the substructure for the New White Nile Bridge, this saving benefit is calculated as follows:

	Financial Cost (Reconstruction) (Yen 1,000)	Economic Cost(*) (Ls 1,000)
Foreign Portion	750,000	122,250
Local Portion	250,000	11,528
Total	1,000,000	133,778

* 122,250 = 750,000 x 0.163
11,528 = 250,000 x 0.087 x 0.53

In this Study the partial reconstruction of the existing bridge is assumed to performed in the year 2000 over a four month period.

Time Saving During the Reconstruction Period

During the reconstruction of the existing bridge, any traffic can not be pass through the bridge and should be enforced to detour through another bridges. In this case, it would take much more time for drivers and passengers to go and come between Omdurman and Khartoum. If the New White Nile Bridge is completed, the above-mentioned extra time to detour could be significantly saved. According to the traffic assignment, the time saving of Ls 94,000,000 was estimated 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 much after completion of the New White Nile Bridge. According to the NCK it takes 1,514,500 Yen to repair the road surface on the existing bridge every seven years. As the foreign portion and local portions for repairing the road surface on the bridge are 86.7% and 13.3%, respectively, the benefit from this saving is estimated as follows:

	Financial Cost (Yen 1,000)	Economic Cost(*) (Ls 1,000)
Foreign Portion	1,310	213
Local Portion	205	10
Total		223

* 213 = 1,310 x 0.163
10 = 205 x 0.087 x 0.053

This saving cost depends on the traffic volume, therefore, at present, considering the existing traffic volume (58,000 PCU) Ls 3.8 thousand is necessary per vehicle every seven years. As a result of the traffic assignment, the following cost is calculated as saved:

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

(3) Economic Indicators

The calculation of economic indicators was made with the above-mentioned cost and benefit stream, which is summarized in Table 11.2. With these cost and benefit data the following three economic indicators were calculated:

a) Benefit Cost Ratio (B/C)

B/C is a ratio of the total present value of benefit to the total present value of cost.

$$B/C = \sum B_t /(1+i)^t / \sum C_t/(1+i)^t$$

Here, B : Total present value of benefit
C : Total present value of cost
i : Discount rate
t : Year
T : Calculation period

b) Net Present Value (NPV)

NPV is a difference between the total present value of benefit and the total present value of cost.

$$NPV = \sum B_t/(1+i)^t - \sum C_t/(1+i)^t$$

c) Internal Rate Of Return (IRR)

IRR is the discount rate such that the net present value equals zero.

$$IRR = \sum (B_t - C_t)/(1+i)^t = 0$$

Table 11.3 shows the benefit and cost stream and their discounted value stream with a discount rate of 12%.

Table 11.2 Economic Cost And Benefit

(Unit : Ls 1,000)

Year	Construction Cost	Maintenance Cost Road	Maintenance Cost Bridge	Sulvage Value	Total Cost	Time Saving	VOC Saving	Maintenance Saving	Reconstruction Saving	Avoiding Detour Cost	Total Benefit
1991	60688				60688						0
1992	273995				273995						0
1993	289129				289129						0
1994	280707				280707						0
1995	259601				259601						0
1996		1407			1407	89920	10821				100741
1997		1407			1407	104197	9919				114116
1998		1407			1407	120740	9093				129833
1999		14C7			1407	139910	8335				148245
2000		7036			7036	162124	7640		133778	94003	397546
2001		1407			1407	187866	7004				194869
2002		1407	3186		4593	217694	6420	173			224287
2003		1407			1407	252257	5885				258142
2004		1407			1407	292309	5395				297704
2005		7036			7036	338720	4945				343665
2006		1407			1407	407662	4759				412421
2007		1407			1407	490637	4580				495217
2008		1407			1407	590500	4408				594908
2009		1407	3186		4593	710689	4242	187			715118
2010		7036			7036	855340	4082				859423
2011		1407			1407	1029435	3929				1033363
2012		1407			1407	1238963	3781				1242744
2013		1407			1407	1491139	3639				1494778
2014		1407			1407	1794642	3502				1798144
2015		7036		-155599	-148563	2159919	3370				2163289

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%

As B/C is greater than 1.0 and NPV is positive, the proposed project is feasible. In addition, considering that not only the IRR of 17.7% is a relatively higher value for the big infrastructural project in developing countries, but also a higher value than the interest rate of international lending agencies (12%), the proposed project can be said to be significantly feasible.

The above calculation was made, using the shadow exchange rate, however, for reference, the results for using the parallel rate and the official rate show the IRR values of 23.2% and 31.3% of IRR, respectively. However, keep in mind that these two cases do not represent the real economic analysis in the strict sense of the work. The results of these two cases are shown in Appendix 11.2 and 11.3.

Table 11.3 Summary of Economic Cost And Benefit
(Unit : Ls 1,000)

Year	Benefit	Cost	Benefit (Discounted by 12%)	Cost (Discounted by 12%)
1991	0	59081	0	52751
1992	0	272397	0	217153
1993	0	284738	0	202671
1994	0	275293	0	174954
1995	0	255221	0	144819
1996	100741	1407	51038	713
1997	114116	1407	51620	636
1998	129833	1407	52437	568
1999	148245	1407	53459	507
2000	397546	7036	127999	2265
2001	194869	1407	56020	404
2002	224287	4593	57569	1179
2003	258142	1407	59160	322
2004	297704	1407	60916	288
2005	343665	7036	62786	1285
2006	412421	1407	67275	230
2007	495217	1407	72126	205
2008	594908	1407	77362	183
2009	715118	4593	83030	533
2010	859423	7036	89094	729
2011	1033363	1407	95648	130
2012	1242744	1407	102703	116
2013	1494778	1407	110297	104
2014	1798144	1407	118465	93
2015	2163289	-148563	127252	-8739
Total	13018552	1048159	1576255	794101

(4) Economic Evaluation

Judging from the above three economic indicators, the proposed project is considered to be sufficiently viable. 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

  This type of big project enhances the Sudanese people's spirit and national prestige.

- Economic and Educational Effect

  The various surveys conducted for the proposed project serve as an incentive to private development and private investment. In addition, the advanced technology and experience by the foreign consultant in the process of the study can be transferred to the local staff.

b) During The Construction

- Demand Effect For Construction Materials

  During the construction period the demand for local materials is expected to increase.

- Demand Effect For Employment

  Many skilled and unskilled laborers are hired during construction, which decreases unemployment and underemployment.

- Technology Transfer Effect

  Technology related to the construction work is transferred to the local staff.

- Resource Development Effect

  In the case that some resources are procured from near the construction site, the area with a high potential is encouraged to develop.

c) After Completion Of Project

- Existing Effect

  The New White Nile Bridge can become important symbol for the capital city Khartoum. The New White Nile Bridge forms the main structure of the urban road network.

- User's Effect

  The completion of the project improves the driver's and passenger's comfort and ensures punctuality from origin to destination because of relieving traffic jams.

- Energy Saving Effect

  Gasoline consumption is expected to decrease through the smooth traffic flow.

11.3 SENSITIVITY ANALYSIS

The economic indicators calculated above usually include so-called uncertainty because of the projection errors in traffic demand, the unexpected change of the natural conditions and political situation, the fluctuation of the world economy, and so on. However, generally the probability of the occurrence of uncertainty cannot be known before the project starts. Therefore, in this sensitivity analysis the project cost is assumed to increase by 5%, 10%, 15%, and 20% and also the project benefit is assumed to decrease 5%, 10%, 15%, and 20% in order to examine the project viability from a pessimistic viewpoint. As a result the economic indicators were calculated under the above cost and benefit combination. Table 11.4 shows the result of the sensitivity analysis . Judging from this sensitivity analysis, even in the most pessimistic situation, that is, the project cost increases by 20% and the project benefit decreases by 20%, IRR shows 12.1% which is larger than the interest rate of the World Bank. From this result, the New White Nile Bridge project can be considered to be significantly feasible, even in the considerable unexpected situation.

Table 11.4 Sensitivity Analysis

Benefit \ Cost		0%	5%	10%	15%	20%
0%	B/C	1.985	1.890	1.726	1.527	1.323
	NPV	782154	742449	663039	543923	385103
	IRR	17.7	17.2	16.4	15.2	14.0
-5%	B/C	1.886	1.796	1.640	1.451	1.257
	NPV	703341	663636	584226	465111	306290
	IRR	17.2	16.7	15.9	14.8	13.5
-10%	B/C	1.786	1.701	1.553	1.374	1.191
	NPV	624528	584823	505413	386298	227477
	IRR	16.7	16.2	15.4	14.3	13.1
-15%	B/C	1.687	1.607	1.467	1.298	1.125
	NPV	545716	506010	426600	307485	148665
	IRR	16.2	15.7	14.9	13.8	12.6
-20%	B/C	1.588	1.512	1.381	1.222	1.059
	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 %

11.4 ENVIRONMENTAL CONSIDERATIONS

It was not the purpose of this assessment to modify the basic concept of the Project, nor its design. This work examines whether the project has significant environmental impacts or not; whether such significant impacts are acceptable or not from socioeconomic, cultural and technical points of view; and if not, what kind of countermeasure should be taken to conserve or protect the present environment.

11.4.1 Definition of Impact Area

In this study, the following impact areas are considered:

a) Land which will be acquired for permanent structures such as the bridge, approach road and intersections

b) Land which will be acquired for temporary use or occupation during construction such as construction yard, quarry sites, borrow areas for embankment materials, and so on

c) Land in the vicinity of the project road, where changes in land use are expected as a result of the completion of the Project such as settlement, development and so on

d) Land where water management and agricultural practices will change as a result of the completion of the Project such as navigation and so on.

11.4.2 Environmental Effect during Construction

(1) Noise Nuisance

Any special environmental effects are not expected during the construction period of about 40 months, except the normal construction hazards.

Operation of construction machinery and plant usually causes noise nuisance, especially the "Impact Crusher" to produce coarse aggregates from stones. An impact crusher, which might cause an intensity level of 90 - 95 dB(A), will be furnished about 1.0 kilometer or more away from the residential area on the Omdurman side. Theoretically, the noise level at the nearest point of the residential area can be calculated in the range of 35 - 49 dB(A), which is far below the stipulated value of 85 dB(A) by the Noise Nuisance Regulation of GOJ. Therefore, it can be said that noise caused by construction machinery and plant will be negligibly small.

(2) Water Pollution

During the foundation works, bentonite will be consumed to stabilize bore holes. Such materials will cause water pollution in the White Nile and affect the downstream. However, the required amount of bentonite might be not so much since clayey soil mostly covers the riverbed and bore holes can stand in relatively stable condition. In this regard, severe water pollution is not anticipated.

(3) Air pollution

It is anticipated that dust, which comes from embankment works or spreading subbase/base course materials, will pollute the air. Such dusts are indispensable effects related to highway construction. As for impact crusher, its dust might be less than those of embankment and subbase/base course works. In this regard, air pollution is judged within a range of the normal construction hazards.