VIII. Preliminary Design

VIII. Preliminary Design

VIII.1 Road Design

VIII.1.1 General

Preliminary design of the Bypass was carried out on topographical maps (scale = 1:2500) is accordance with the tentative design by JICA team on maps (scale = 1:5000) which were prepared by MOTC.

Geometric design of the Bypass was done in accordance with the Road Design Manual Part 1, Geometric Design of Rural Roads.

The road alignment was designed to enable traffic to pass through the Bypass at high speeds, hence the maximum gradient of vertical alignment adopted was 3.0% except when unavoidable due to topographical conditions.

After the first trial design a discussion was held between MOTC and JICA Team in which it was decided that the maximum gradient would be 5% to reduce earth work volume and construction.

It was recommended to reduce the central reserve according to the Geometrical Design Manual, to 3.5m from 11.0m as Thika Road (A2) to save on construction cost for deep rock cutting section and high embankment section. Therefore, in this preliminary design, the central reserve of the section from Ngong Road junction to Kikuyu junction is recommended to be 3.5m in width.

VIII.1.2 Geometric Design Standard

Geometric design standards depend on the Road Design Manual Part 1 MOTC Kenya as follows:-

Geometric Design Standard for Main Road

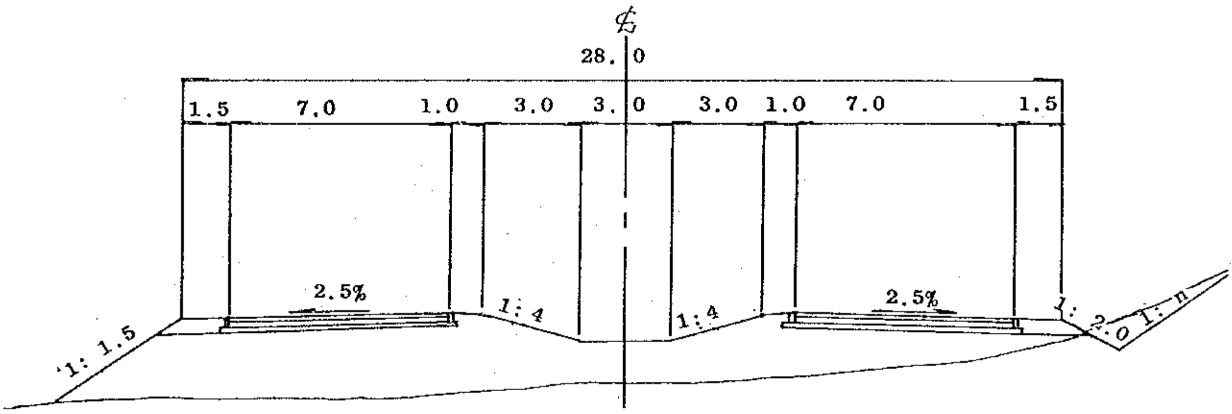
Item	Description
Road Classification	Class A
Design Speed	100 - 70 km/h
Lane width	3.5m
Shoulder width	
Right	1.0m
Left	1.5m
Central Reserve	11.0 - 3.5m
Crossfall	2.5%
Longitudinal Maximum Gradient	
Flat	3.0%
Rolling	4.0%
Mountainous	7.0%
Minimum Horizontal Curve	
Radii	600m
Right of Way	60m

Geometric Design Standard for Intersection

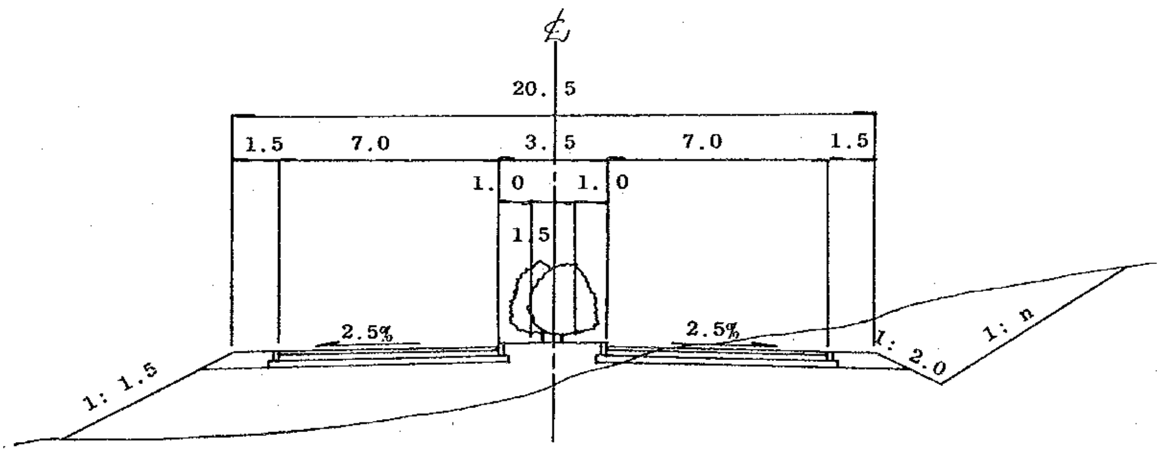
Item	Description
Design Speed	50 km/h - 40 km/h
Lane Width	One way: W = 4.0m
	Two way: W = 6.0m
Shoulder Width	Right : W = 1.0m
	Left : W = 1.5 (for one lane)
	: W = 1.0 (for two lane)
Cross fall	2.5%
Minimum Radius	50.00m
Acceleration lane	240m for design speed 100 km/h
	210m for design speed 80 km/h
Deceleration lane	150m for design speed 100 km/h
	130m for design speed 80 km/h

VIII.1.3 Typical Cross Section of the Bypass

Typical cross section of the Nairobi Bypass has been proposed in accordance with Geometric Design Standard of Kenya (1979) as follows:

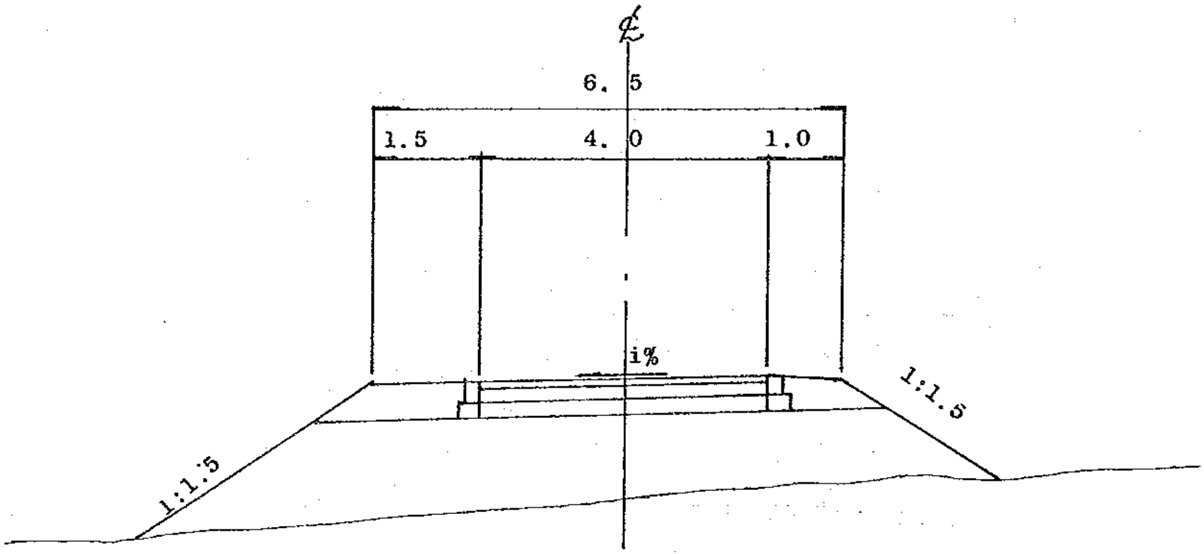


TYPICAL CROSS SECTION (CENTRAL RESERVE, W_c = 11.0m)

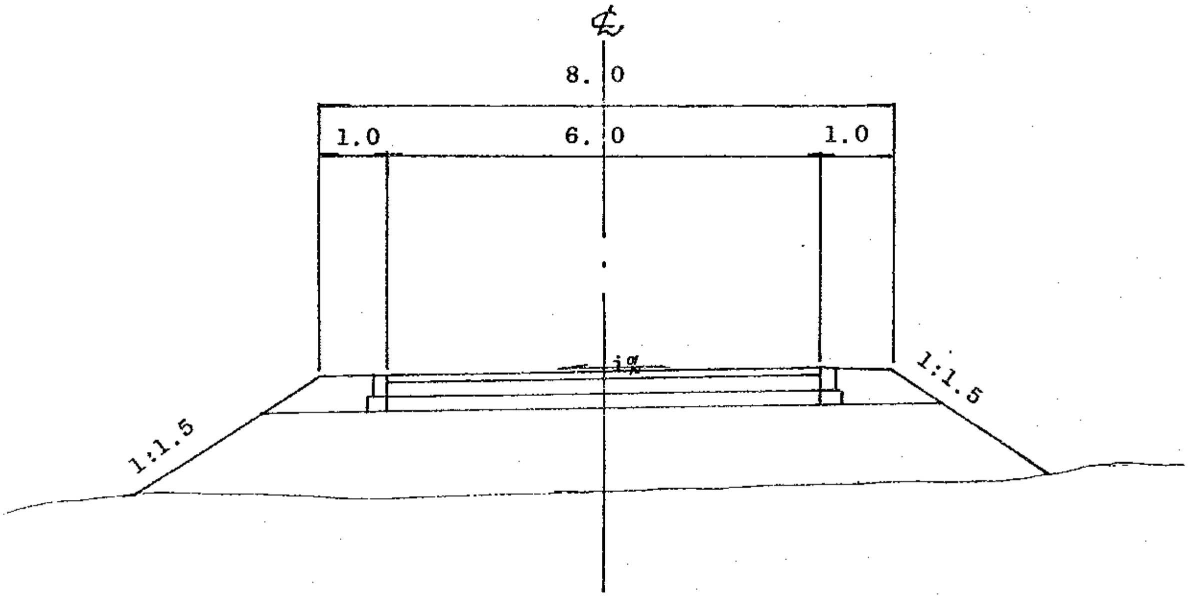


TYPICAL CROSS SECTION (CENTRAL RESERVE, W_c = 3.5m)

Typical Cross Section of Ramps



One - lane



Two - lane

VIII.1.4 Alignment

Nairobi southern Bypass begins on the Mombasa Road A104 at the northeast edge of Nairobi National Park and ends at Kikuyu Junction (A104).

Horizontal alignment from the beginning point to Langata Estate was planned in accordance with the structural plans of Nairobi (Departmental Reference No. 42 - 28 85 - 9) by Department of Physical Planning of the Ministry of Works, Housing and Physical Planning. Then the alignment was planned as much as possible to pass through the Ngong Road Forest and Dagoretti Forest (namely Government land) in view of reducing land acquisition costs.

The outline of the horizontal alignment and vertical alignment is shown on Fig. VIII-1-2 and Fig. VIII-1-3.

(1) MOMBASA Road Junction - UHURU Junction (Langata Road Junction)

Referring to a Nairobi Structure plan by the Ministry of Works, Housing and Physical Planning, the horizontal alignment was designed in the right of way of the proposed Trans African Highway and Railway Reserve and in consideration of UHURU Monument and an existing restaurant.

Vertical alignment was designed slightly rising up over existing ground level to make it easy to drain rain water from the road surface. After passing through the edge of the national park, the vertical alignment rises up to cross over Langata Road (C58).

(2) UHURU Junction - NGONG Road Junction

The Bypass was designed along the right bank of Motoine River avoiding the Housing Estate. After that it stretches along the south edge of Ngong Road Forest and Motoine River. In this section, the proposed route was designed in consideration of the existing housing estates.

(3) NGONG Road Junction - DAGORETTI Road Junction

The Bypass crosses Ngong road and Motoine River and stretches in the Ngong Road Forest on the left hand bank of the Motoine River.

After passing through the forest the route stretches on the top of the left slope of the Motoine River avoiding the forest station and a lot of houses and crosses over Dagoretti Road (C63) at the foot of Dagoretti Forest near the railway.

In this section, it was tried to take an existing road for the Bypass, but there are many houses along the existing road. Moving the people to construct the Bypass would cause much disturbance. So, after a discussion between MOTC and JICA Team at the tentative design, it was decided to have the horizontal alingment along the edge of the left bank of Motoine River.

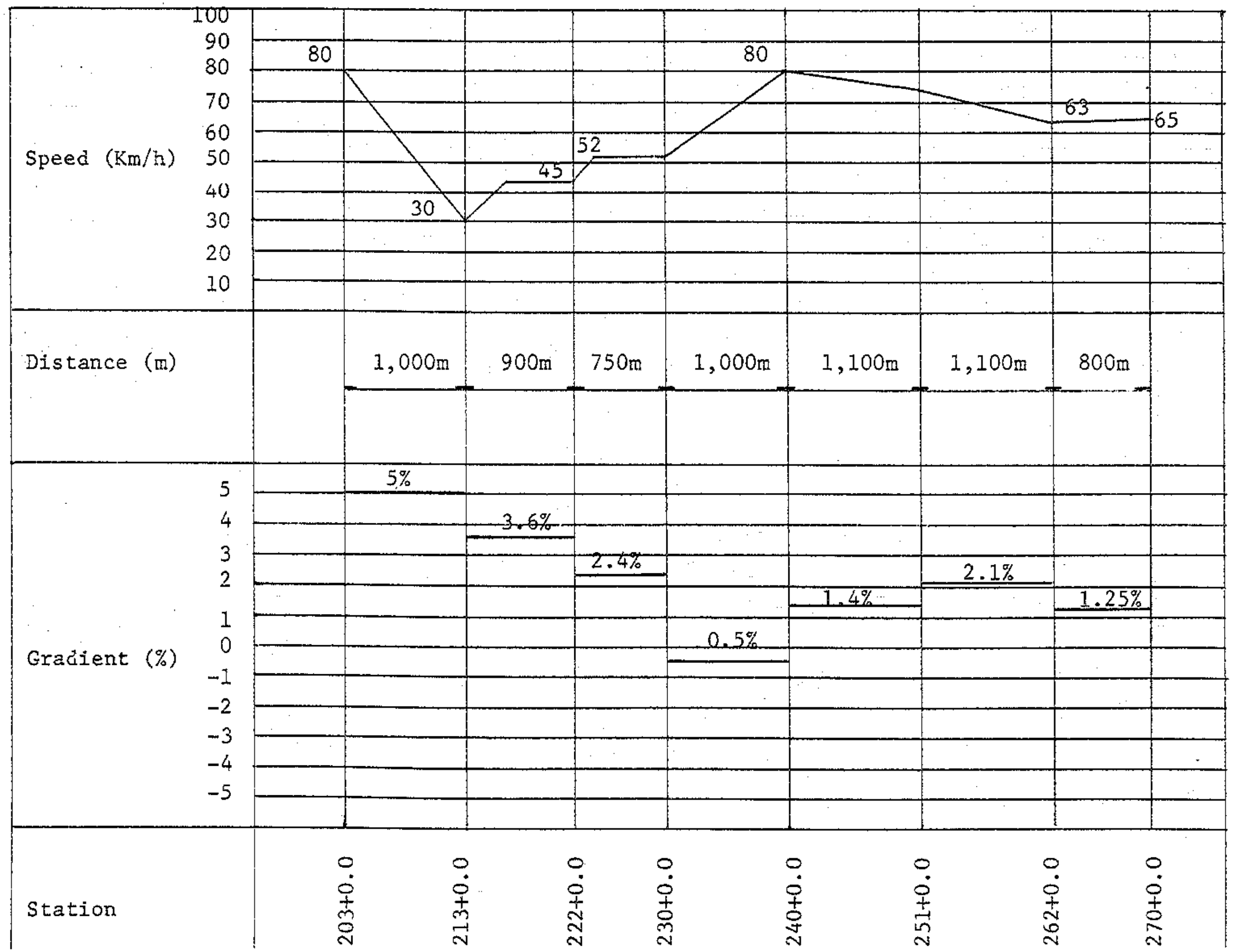
(4) DAGORETTI Junction - KIKUYU Junction

Topography of the beginning point of this section is very steep and the rock below the top soil was found to be hard from geological survey. Therefore a 5% gradient was adopted for vertical alignment so as to reduce the earth volume, especially rock excavation. For reference, running speed of heavy vehicles was studied by making a running speed - Gradient Curve and it is estimated that running speed of heavy vehicle would be to 30 km/hr. (See Fig. VIII-1-1)

The proposed alignment climbs up the Dagoretti forest and passes through the northeast edge of the forest and Thogoto village avoiding a developed area.

After that the Bypass goes around outside both Alliance Boys and Girls High Schools to the west, thus avoiding breaking the school community and destroying a famous church. The Bypass then crosses slightly the Ondiri Swamp with a high embankment and joins the route (C63) avoiding the swamp as much as possible. After that it passes under an existing railway, and reaches Naivasha Road (A104) at Kikuyu Junction.

Fig. VIII-1-1 Running Speed - Gradient Curve



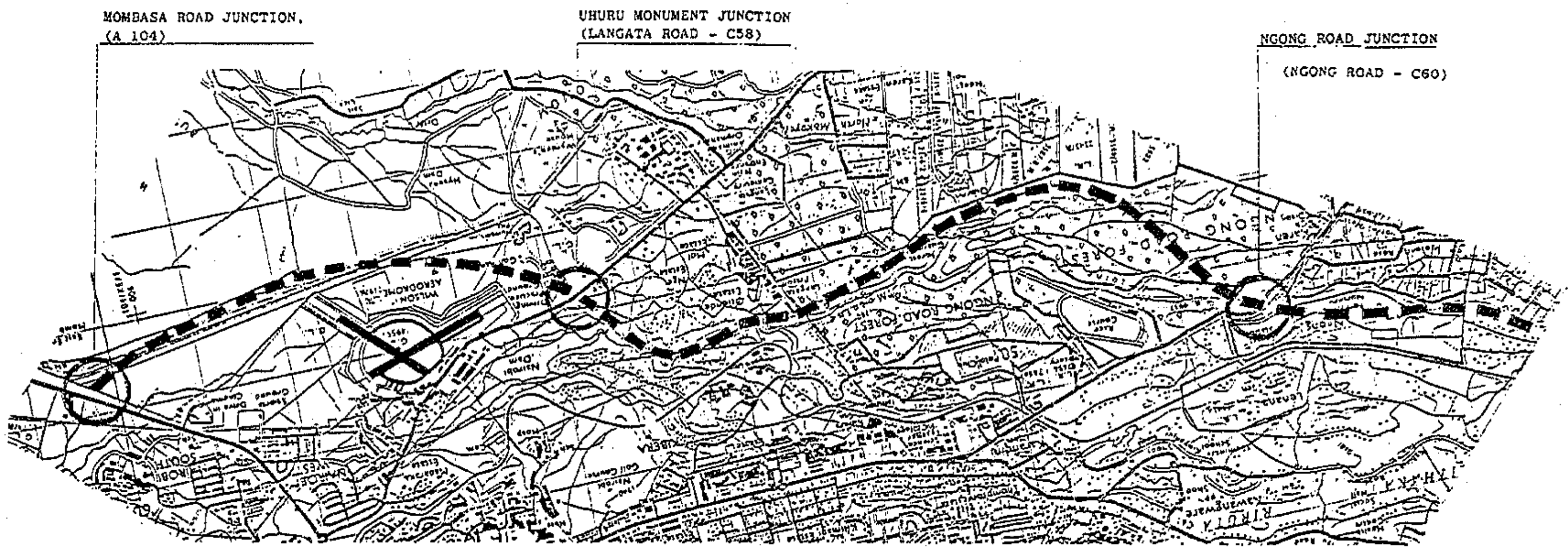


Fig. VIII-1-2 Plan (1)

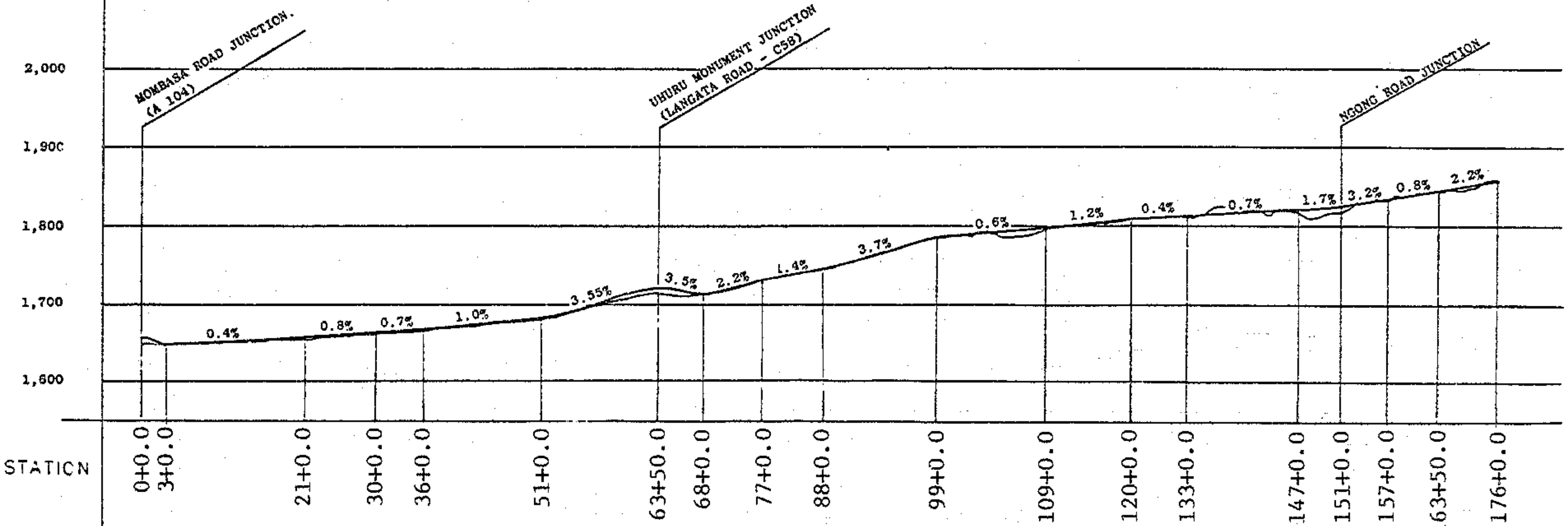


Fig. VIII-1-2 Profile (1)

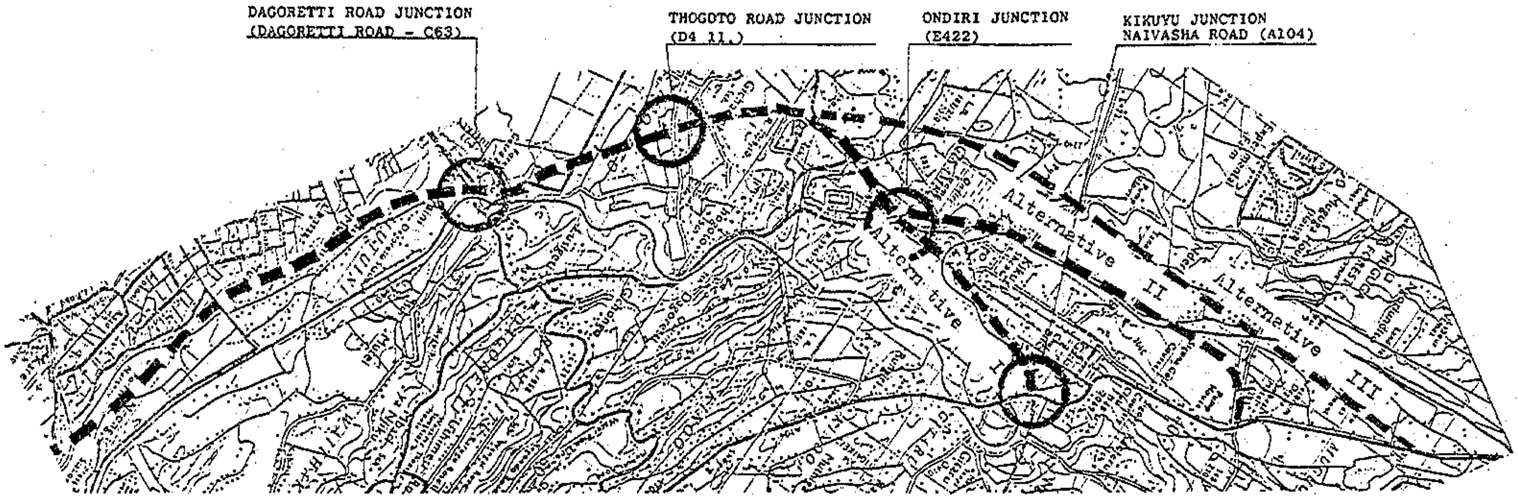


Fig. VIII-1-3 Plan (2)

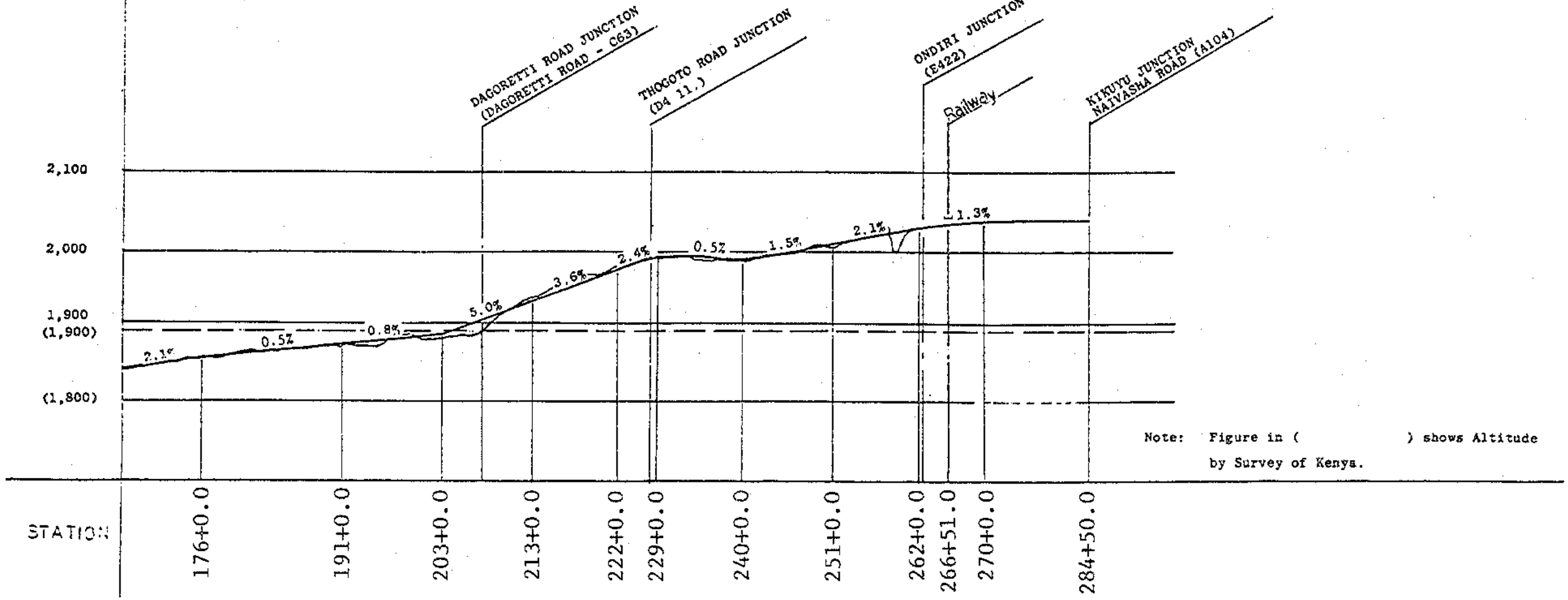


Fig. VIII-1-3 Profile (2)

VIII.1.5 Intersection

Prior to designing junctions, it is considered that all traffic can enter and leave the Bypass at relatively high speeds.

Then all intersections were planned as grade separated junctions. Type of each interchange was selected in accordance with traffic forecast, after which the preliminary design of intersection was done.

Design standard of interchange depends on the Road Design Manual Part 1 Geometric Design of Rural Roads
Chapter 7 Grade Separated Junction.

The scheme of each interchange is herewith attached (Fig. VIII-1-4 and VIII-1-10).

Brief explanations of each junction follow.

(1) Mombasa Road Junction

Referring to the Nairobi South-Structure plan by the Nairobi City Commission, March 1985 and traffic forecast done by JICA Team, Mombasa Road Junction was designed.

Topography of the site is very flat, therefore, this junction was designed as a partial cloverleaf interchange.

This partial cloverleaf interchange employes two loop ramps to accommodate right-turning movements from Bypass to Mombasa Road to Industrial Area.

This interchange services traffic from different directions i.e. Mombasa to Bypass, Mombasa to Industrial Area, Byapss to Mombasa and Industrial Area to Mombasa.

However, as the Nairobi City Commission strongly requested another layout of the junction to serve traffic of all directions, after discussion with MOTC, NCC and the consultants, two layouts (shown in Fig. VIII-1-4A and Fig. VIII-1-4B) were planned as reference. And additional construction costs for Layout A and B were roughly estimated about Kshs 1,539,000 and Kshs 7,763,000 respectivly and the details are shown in appendix VIII.2.

(2) Uhuru Monument Junction (Langata Road Junction)

This junction was designed as a diamond interchange. At the tentative design stage this junction had been designed as a partial clover leaf interchange to serve traffic from four directions with two loop ramps and two other ramps. However, to avoid disturbing a housing estate area and to reduce acquiring land from the Langata cantonment area, a diamond interchange was adopted. Accommodating right turning movements from city centre to Ngong (through Bypass) and from Karen to Mombasa Road could be available by two turning lane on the Langata Road.

(3) Ngong Road Junction

This compound T junction services traffic from four directions with two approach roads to the Bypass (Fig. VIII-1-6). Topography at this point is complicated; Ngong Road is coming down from Karen to Motoine River and climbing up, winding along the topography after crossing Motoine River. Therefore a diamond interchange had been adopted in consideration of topography, future traffic forecast, low construction cost and full directional service for traffic.

Prior to carrying out a preliminary design, the design team considered the design of a lower cost junction in consideration of Nairobi City Commission's plan to when Ngong Road from a single carriage way to a dual carriage way in the future.

(4) Dagoretti Junction

Dagoretti Road lies at the foot of Dagoretti Forest, after crossing over the Dagoretti Road from Ngong Road Forest direction, the Bypass climbs up Dagoretti Forest.

So the proposed profile at the cross point of the Bypass and Dagoretti Road (C63) is steep. Therefore, an interchange is proposed to shit about 400m toward Ngong Road Forest. And a compound T junction was adopted in consideration of future traffic forecast, low construction cost and full directional service for traffic.

(5) Thogoto Junction

The project road crosses Thogoto Road (D411) and traffic volume on this local road is a little, but this road is one route of the bus transport network.

Then an at-grade junction (staggered junction which is recommended in the road design manual of MOTC) was proposed due to a little traffic crossing the Bypass and topographical conditions.

(6) Kikuyu Junction

Prior to design of this junction, it was considered that all traffic can move smoothly between A104 and the Bypass. So the Bypass was proposed to connect route A104 directly and this scheme does not disturb the improvement plan of the existing Kikuyu junction which is now being undertaken by other consultants.

This proposed interchange is most desirable in view of east of traffic movement, not to spoil the present improvement plan of an existing Kikuyu junction and east of construction.

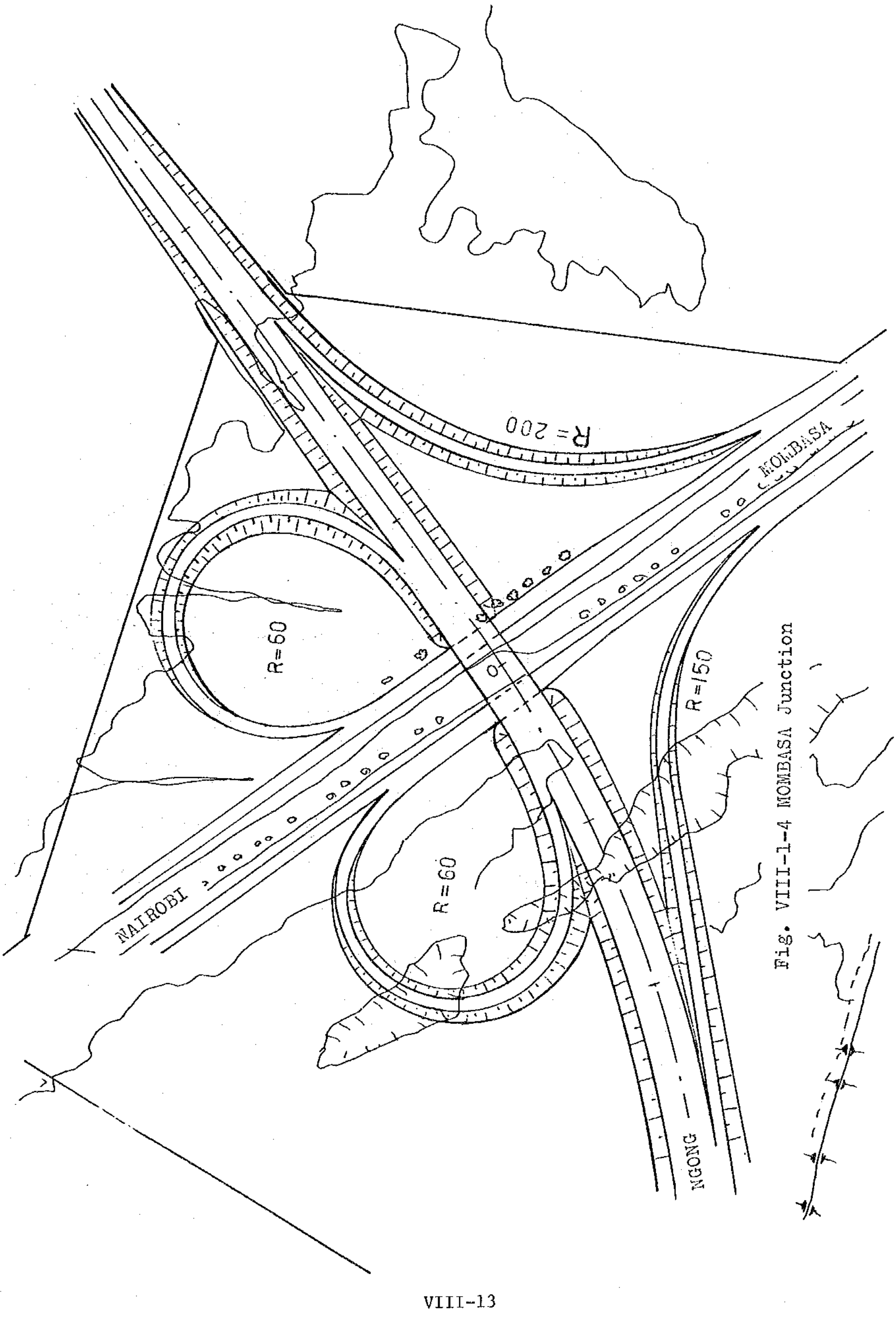


Fig. VIII-1-4 MOMBASA Junction

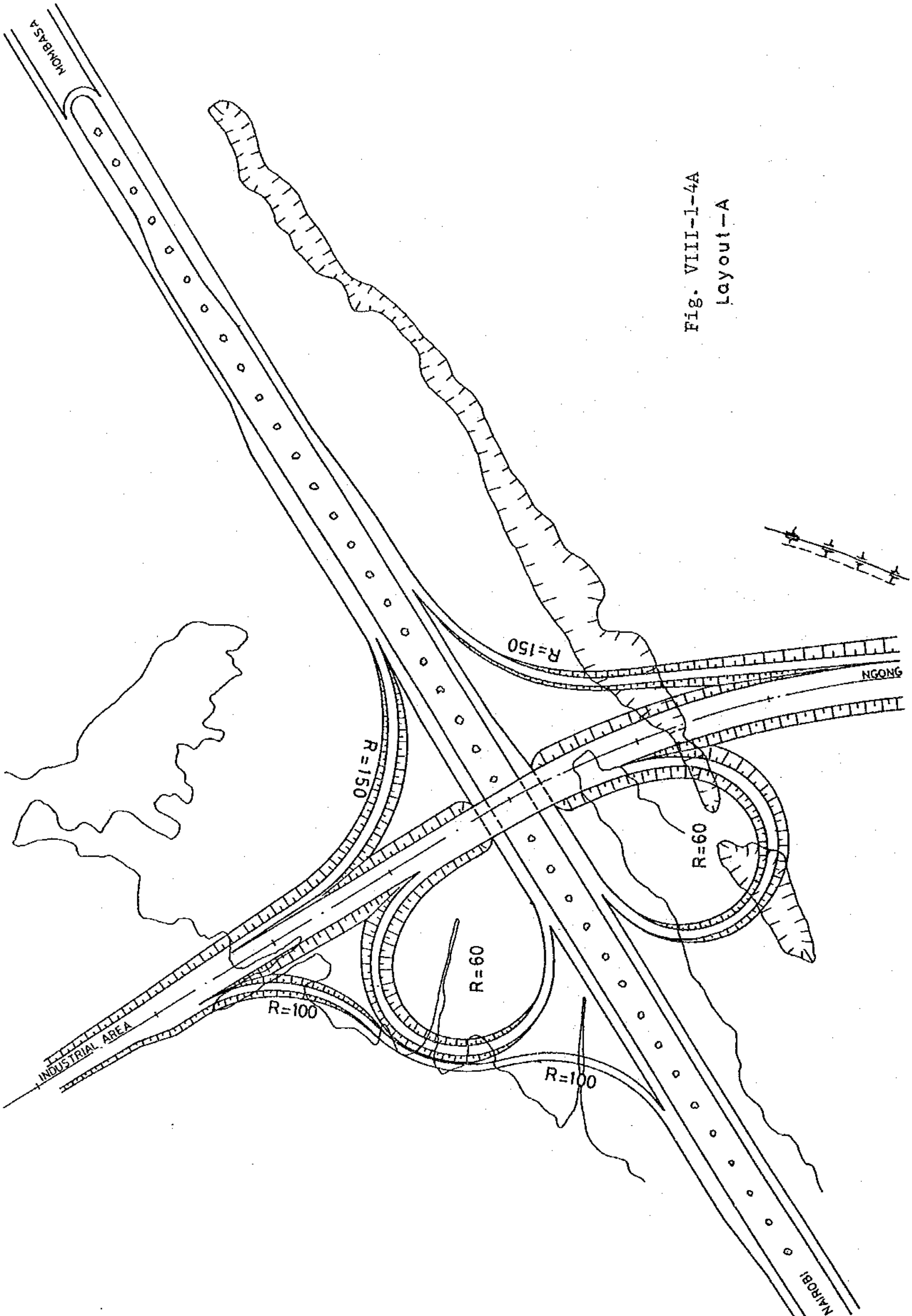


Fig. VIII-1-4A
Layout-A

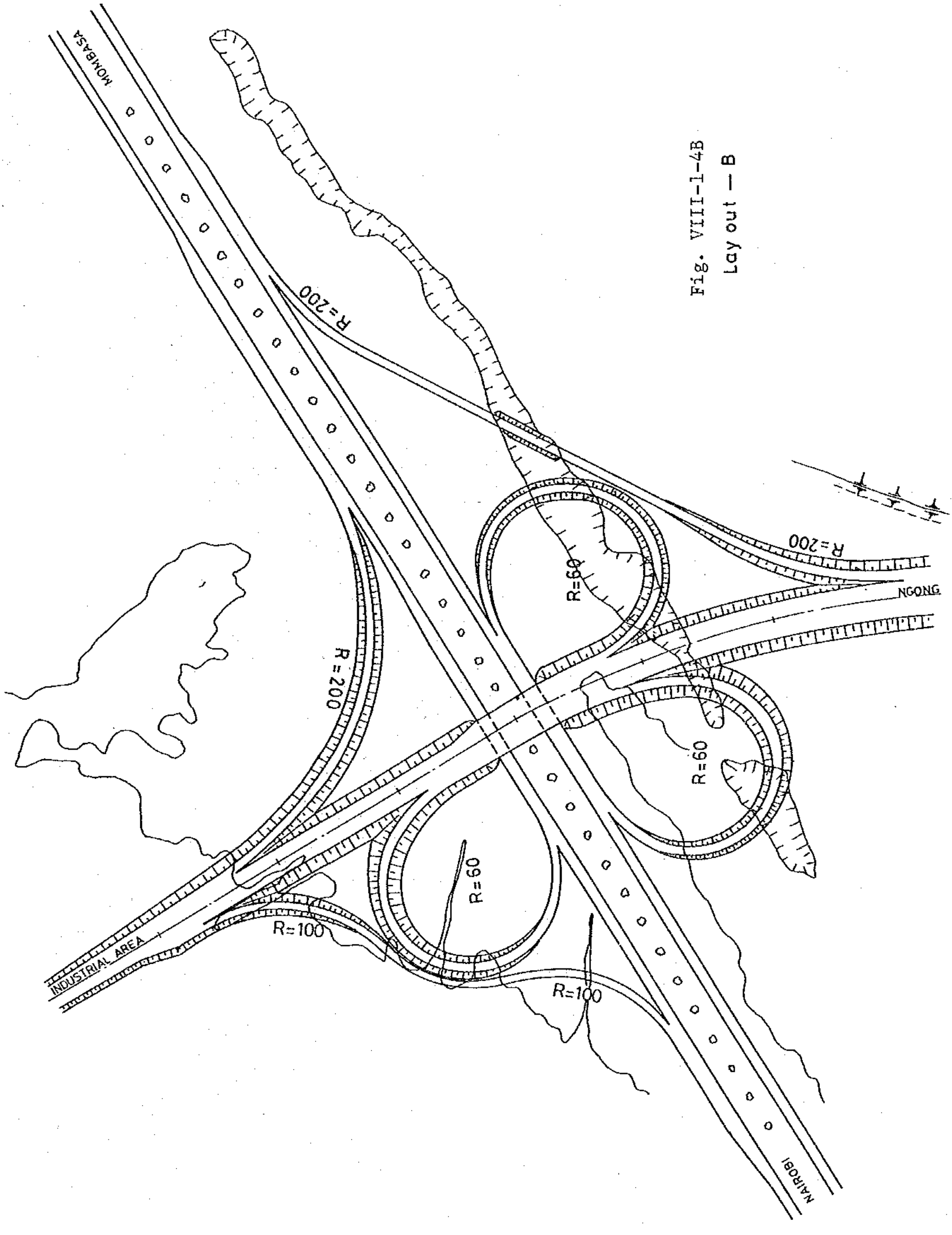


Fig. VIII-1-4B
Layout — B

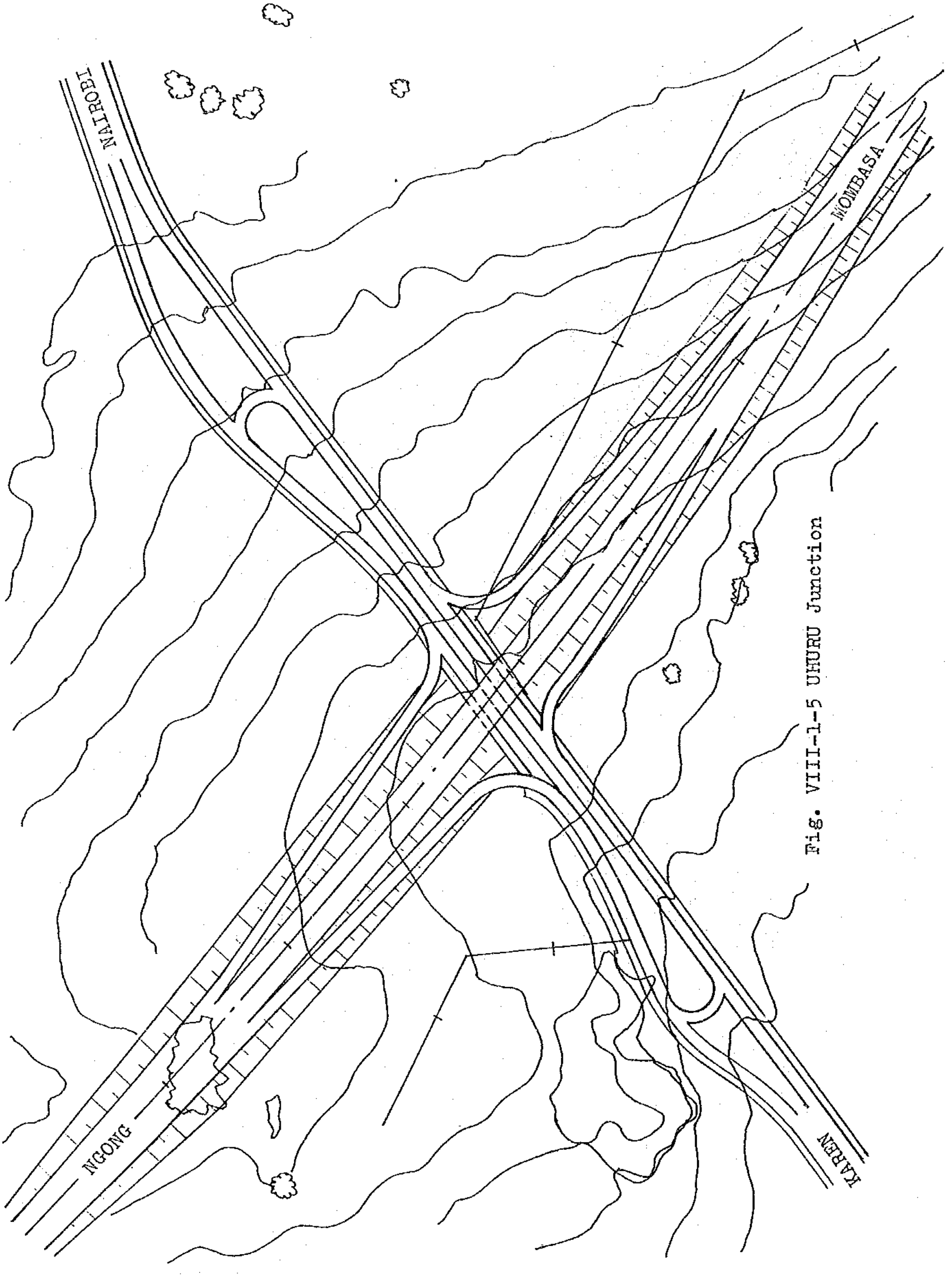


Fig. VIII-1-5 UHURU Junction

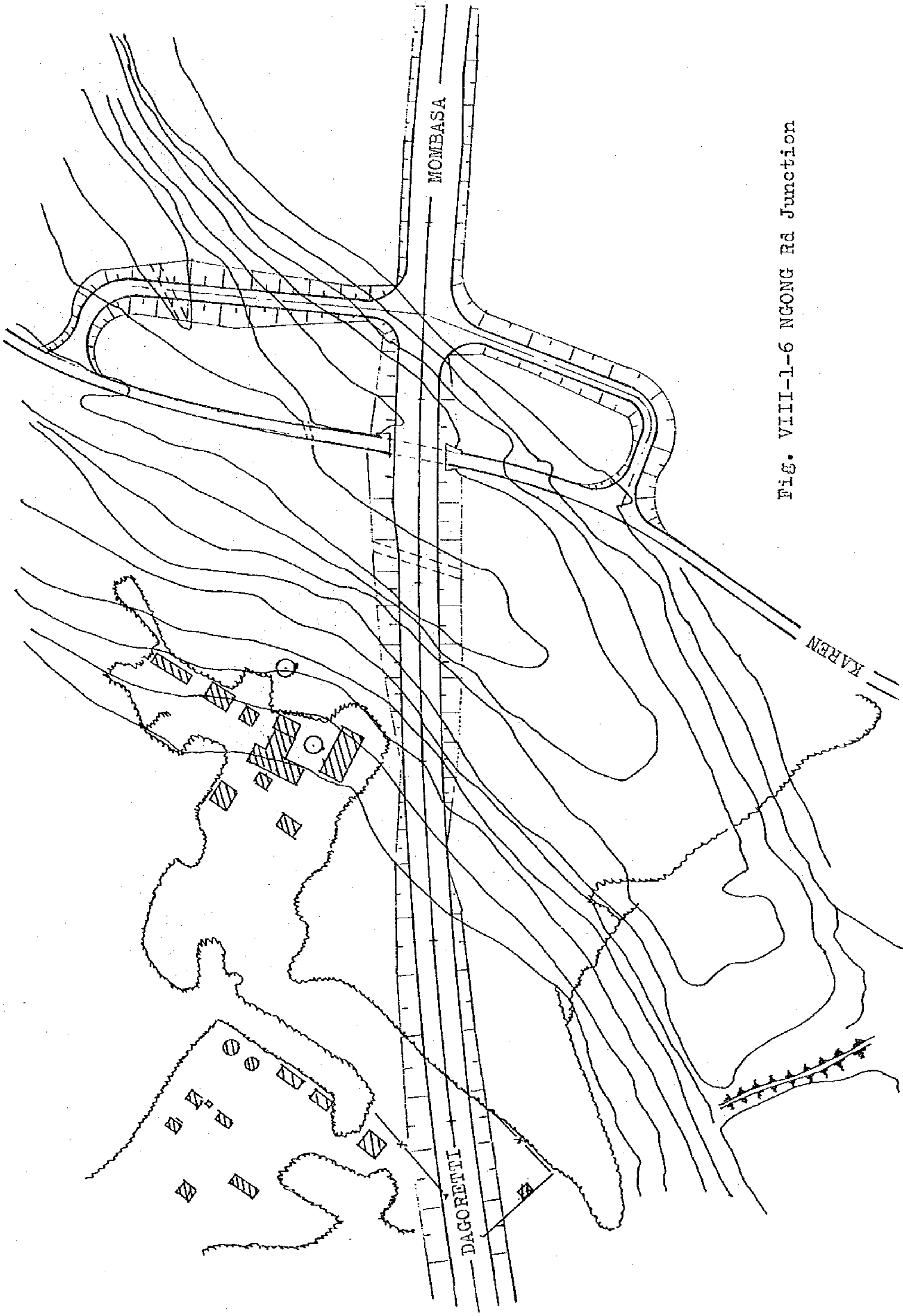


Fig. VIII-1-6 NGONG Rd Junction

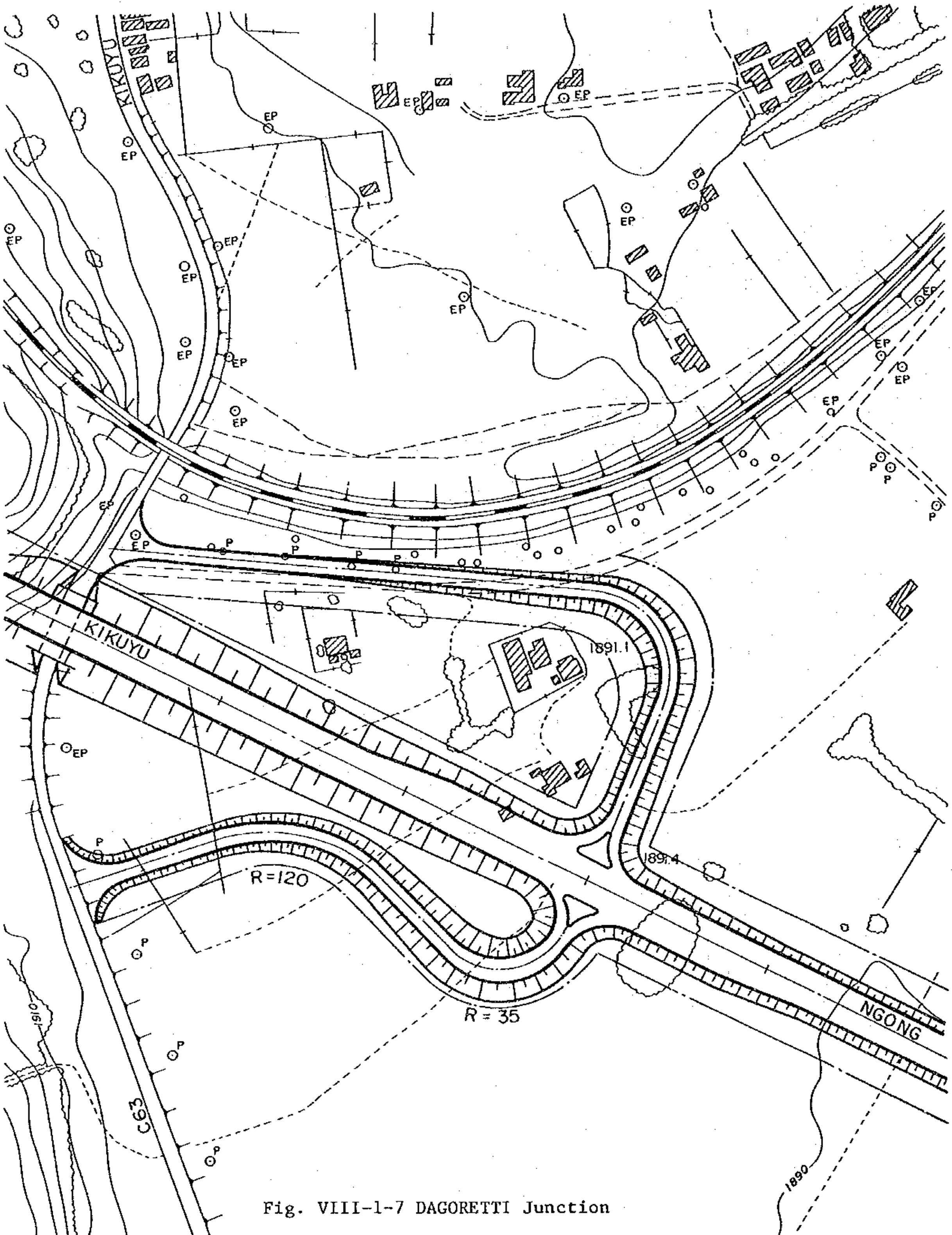


Fig. VIII-1-7 DAGORETTI Junction

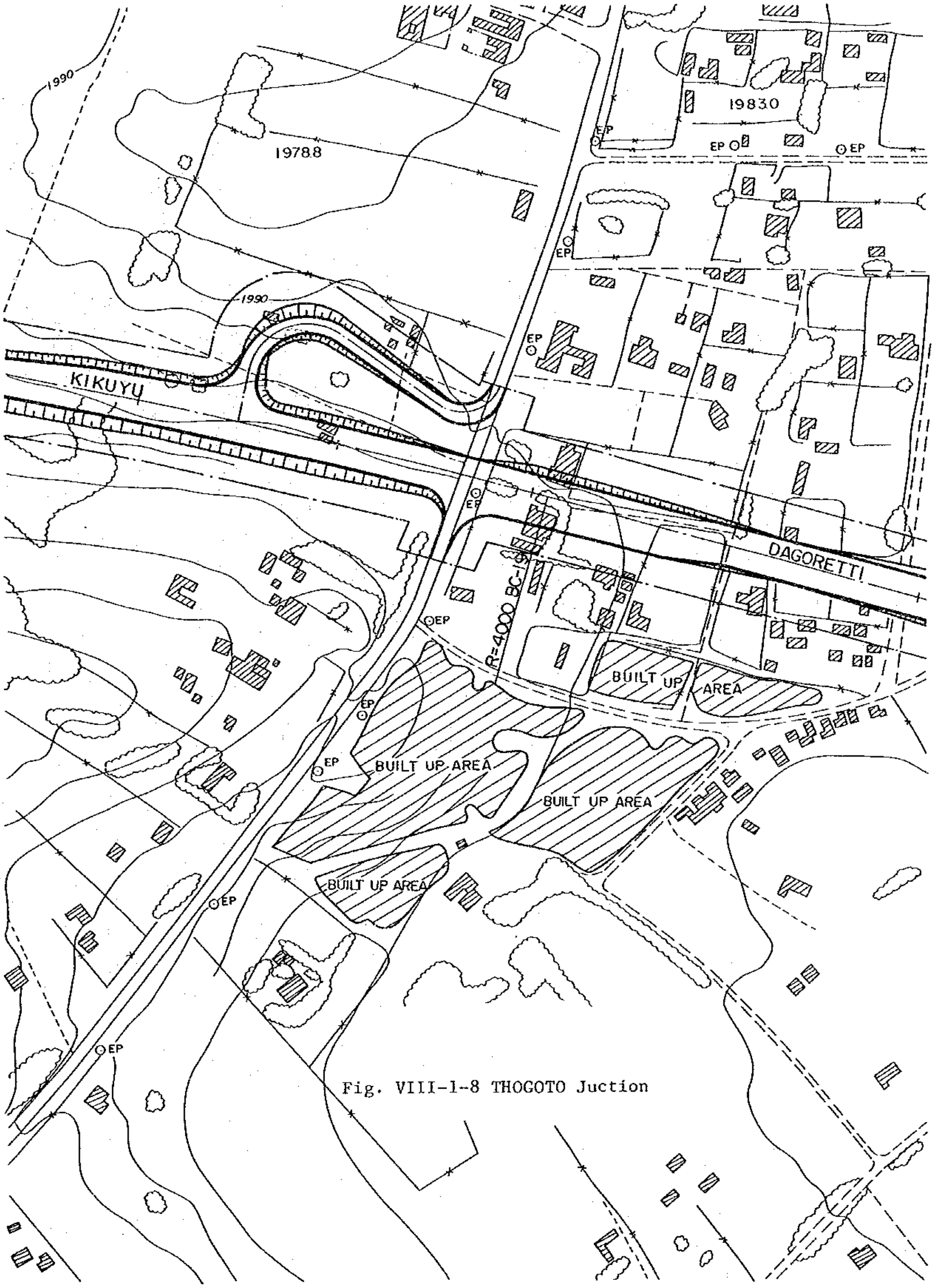


Fig. VIII-1-8 THOGOTO Juction

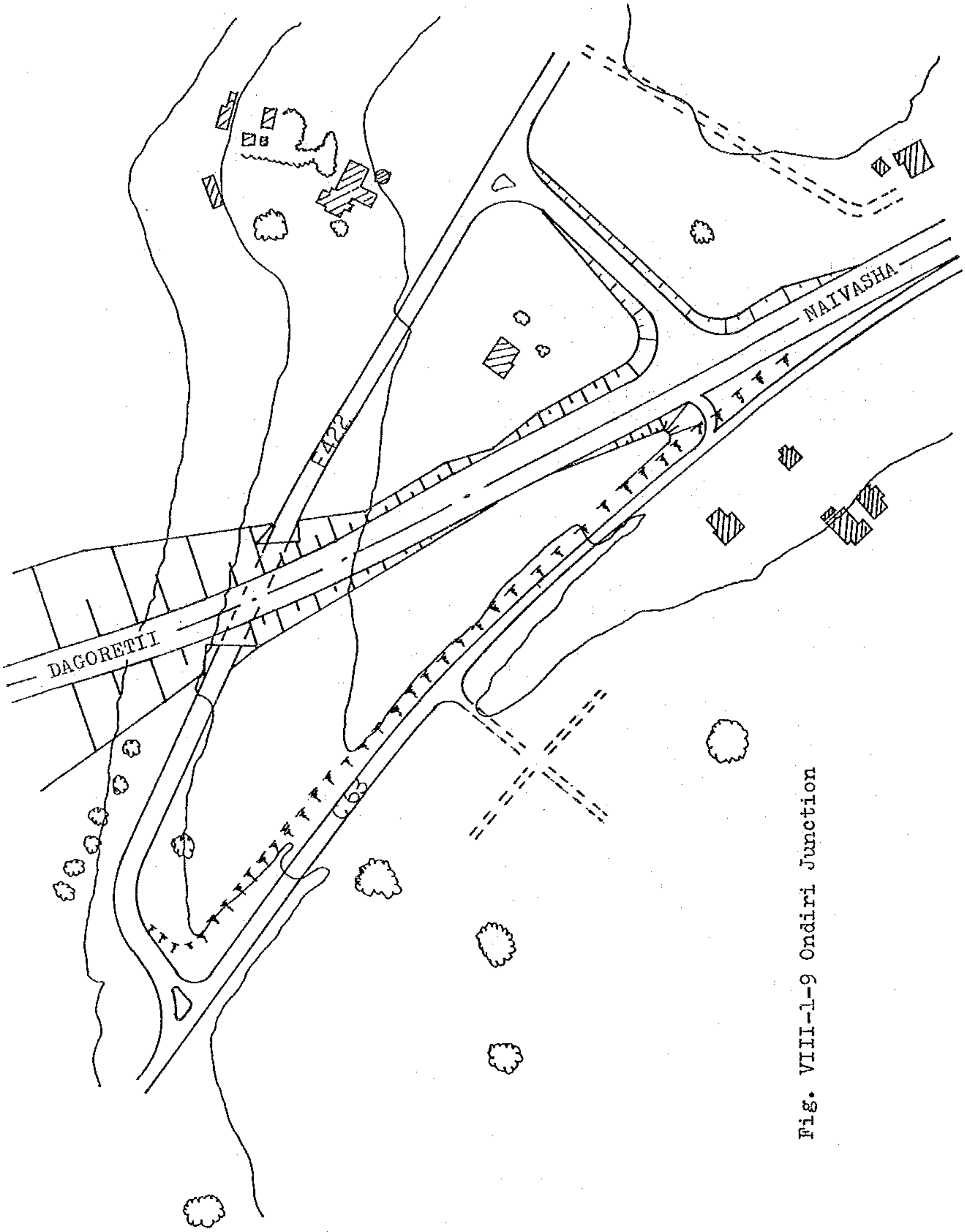


Fig. VIII-1-9 Ondiri Junction

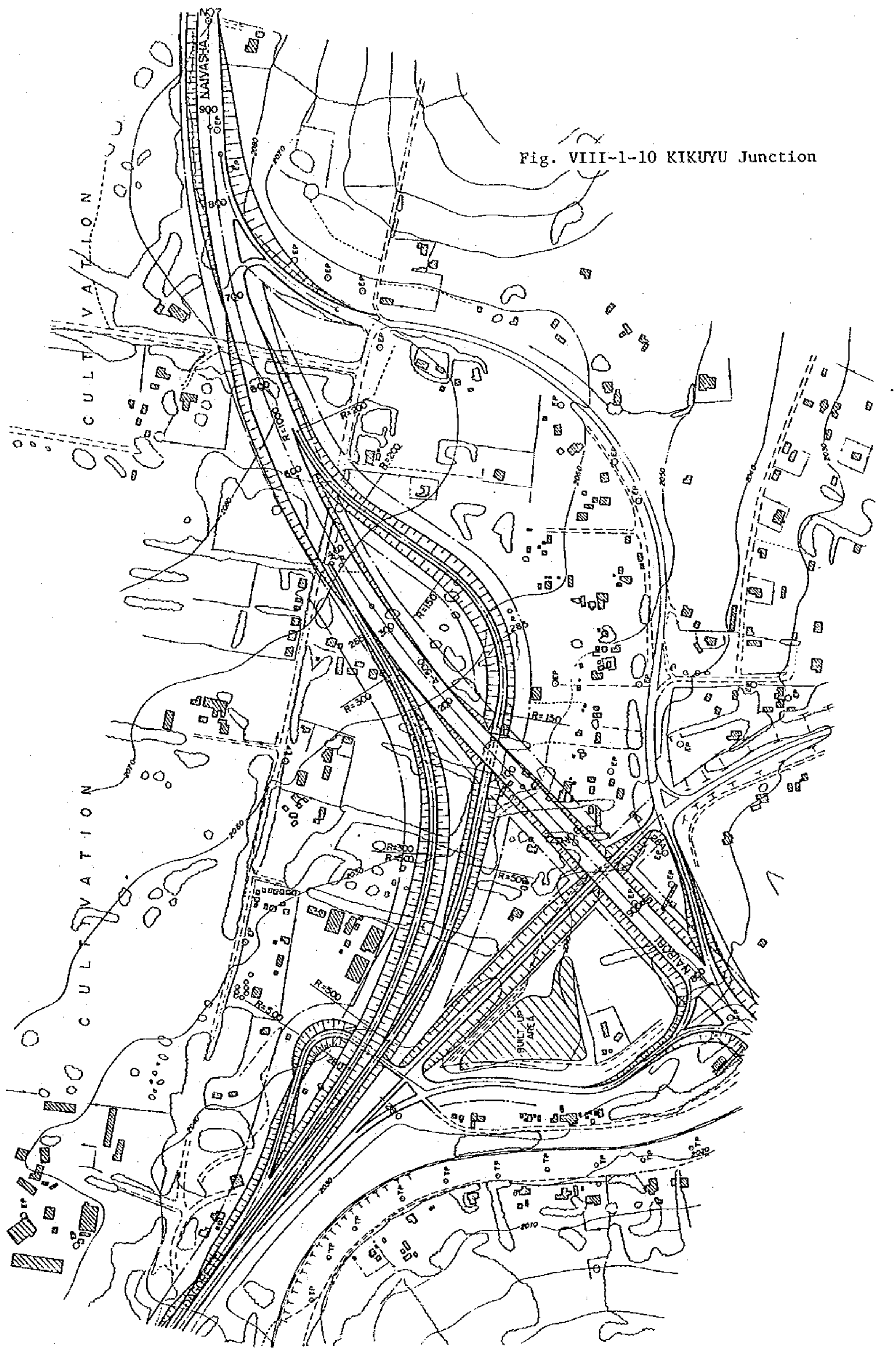


Fig. VIII-1-10 KIKUYU Junction

VIII.2 Pavement Design

Pavement design was carried out in accordance with the Road Design Manual Part III by MOTC Kenya, comparing with the Japan Asphalt Pavement Manual.

VIII.2.2 Traffic

(1) Initial Daily Number of Standard Axles in Opening Year 1991.

Initial daily number of standard axles in opening year were obtained from the number of medium goods vehiles, heavy goods vehiles and buses on the Table VI-4-4 "Future Traffic Growth of the Bypass by Link" by using "Average Vehicle Equivalence Factors (Table 2. 3. 1, Road Design Manual Part III, MOTC)

Daily Number of Standard Axles = $t \times (1 + i)^n$

Where

- t = The average daily number of standard axles in the basic year (= 1986)
- i = Annual growth rate
- n = Years

Section	t	i (%)	n	ESA/day in Year one (1991)
1	5,811	14.0	5	11,189
2	5,397	10.7	5	8,972
3	4,068	7.2	5	5,760
4	4,527	6.5	5	6,202

(2) Cumulative Number of Standard Axles in Design Period.

Cumulative number of standard axles in design period obtained by MOTC Method as follows: -

$$T = 365 \times t_1 \frac{(1 + i)^n - 1}{i}$$

Where:

t_1 : the average daily number of standard axles in the first year after opening

i : the annual growth rate expressed as a decimal fraction

n : design period 15 years.

Cumulative Number of Standard Axles by Links

Section	t_i	i (%)	T	T/2 (one direction)
1	11,189	14.0	179,051,588	89,525,588
2	8,972	10.7	110,003,432	55,001,716
3	5,760	7.2	53,652,312	26,826,156
4	6,202	6.2	54,741,902	27,370,951

Then traffic class is defined T_1

VIII.2.2 Bearing Strength of Subgrade

In accordance with the geological and soil survey, bearing strengths of subgrades are defined in accordance with the Road Design Manual Part III, MOTC Kenya as follows: -

Bearing Strength of Subgrade

Section	Soil Class	Design CBR	Remarks
STA 0 + 0 - 52 + 0.0	S5	20	Improved Subgrade
STA 52 + 0.0 - 90 + 0.0	S5	20	Natural Subgrade
STA 90 + 0.0 - End	S4	13	Except STA 207-220
STA 207 + 0.0 212 + 0.0	S6	30	Rock Cut Section
STA 214 + 0.0 - 220 + 0.0	S6	30	Rock Cut Section

VIII.2.3 Proposed Pavement Structure

Pavement type was studied and selected in view of reduction of cost (especially of foreign components) and availability of local material.

Pavement structures were designed in accordance with the Road Design Manual Part III as follows:

Table VIII-2-1

Proposed Pavement Structure by Section

Section	Traffic	Subgrade	Proposed	Pavement Structure
STA 0 + 0.0 -STA 90 + 0.0	T_1	S5	100mm	Surface
			200mm	Cement Stabilized Material
			175mm	Cement improved Material (or crushed stone
STA 90 + 0.0 -End	T_1	S4	100mm	Surface
			200mm	Cement Stabilized Material
			225mm	Cement improved Material (or crushed stone)
STA 207 + 0.0 -STA 212 + 0.0	T_1	S6	100mm	Surface
STA 214 + 0.0 -STA 220 + 0.0	T_1	S6	200mm	Cement Stabilized Material

Note: Detailed soil investigation should be carried out at the detailed design stage to design suitable pavement structures in every section.

Crushed stone for subbase course would be imported from quarries in Eastland. Base course is not cement stabilized gravel but cement stabilized material (crushed stone, sand, local material and cement). Cement stabilized material in this case is similar to lean concrete.

VIII.2.4 Pavement Design By Japan Asphalt Pavement Manual

It is respected that pavement structure of the Bypass was designed by Road Design Manual Part III (Pavement and Material), M.O.T.C. For trial, however, pavement structure was reviewed by Asphalt Pavement Manual of Japan Road Association. This pavement method is based on the daily heavy goods traffic at five years after opening.

(1) Traffic volume of heavy vehicles in five years after opening is classified as follows:-

Table VIII-2-2

Classification of Traffic

Class	Heavy goods traffic / day / one direction
A	Less 250
B	250 - 1,000
C	1,000 - 3,000
D	Over 3,000

The traffic volume of heavy goods vehicles (including bus, medium goods, truck) was estimated at 1,143 / day / one direction in 1996, 5 years after opening year which was expected to be 1991. Therefore the traffic class in 1996 is C by Table VIII-2-2.

Target value of equivalent layer thickness (TA) and total pavement thickness are shown as follows:-

Table VIII-2-3

Target Value of TA and Total Thickness (cm)

Design CBR	Traffic Class A		B		C		D	
	TA	Total Thickness	TA	Total Thickness	TA	Total Thickness	TA	Total Thickness
2	21	62	29	74	39	90	51	105
3	18	49	25.5	58	34	70	45	82
4	17	41	23.5	50	31	61	42	70
5	15.5	35	22	43	29.5	54	39	60
6	14.5	30	21	38	28	48	36	53
8	13.5	27	19	33	26	40	33	47
Over 10	12.5	23	17.5	29	24	34	31	40

Coefficient of relative strength for TA calculation are as follows:-

Table VIII-2-4

Coefficient of Relative Strength for TA Calculation

	Material	Condition	Coefficient of Relative Strength
Surface Course	Asphalt Misture		1.0
Base Course	Bitumimous Stabilization	Stability 350Kg -	0.8
		Stability 250 - 350kg	0.65
	Cement Stabilization	Unconfined strength 30kg / cm^2	0.55
	Mechanical Stabilization	Modified CBR Over 80	0.35
	Penetration		0.55
	Macadam		0.35
Subbase Course	Crusher run, Gravel and Sand	Modified CBR Over 30	0.25
		Modified CBR 20 - 30	0.20
	Cement Stabilized	Unconfined Strength (7 days) Over $10kg/cm^2$	0.25

Review of the proposed pavement structure is as follows:

	Thickness (cm)	TA Value
Surface Course	10	1.0 x 10 = 10
Cement Stabilized Base	20	0.55 x 20 = 11
Cement Stabilized Sub-base (or Crusher-run CBR over 30)	17.5	0.25 x 17.5 = 4.3
Total	$47.5^{cm} > 34^{cm}$	$25.3^{cm} > 24^{cm}$

Each value is more than each target value. Therefore, the proposed pavement is applied.

VIII.3 Climate and Hydrology

VIII.3.1 Climate

This section describes the outline of the climate in the Project area.

Proposed route of the Bypass will be a section of the Trans-African Highway, and it is located almost at the equator.

The project area is located on a highland in the central area of Kenya at altitude ranging from 1,700 to 2,000m. And as it is about 500 km from the eastern coast of Kenya which faces the Indian Ocean, the project area is not affected by the trade wind, then it is dry and calm except for two rainy seasons from March to June and from the end of October to December.

(1) Temperature

Change of the temperature has been minimal over the years. The past average temperatures by records at four meteorological stations in the project area are as follows: -

	TEMPERATURE MEANS		
STATION NAME	MAX.	MIN.	ALTITUDE
NAIROBI (J.K.A.)	25.4·C	12.3·C	1,624m
WILSON AIRPORT	24.8·C	13.1·C	1,683m
DAGORETTI	23.4·C	11.9·C	1,798m
MUGUGA K.A.R.I.	20.9·C	10.8·C	2,096m

Average, maximum and minimum temperature at each four meteorological stations are shown on Table A-VIII-3(1), (2), (3), (4).

(3) Wind

Generally, wind blows calmly in the project area throughout the year. From May to September, wind blows calmly very much, and from October to April wind at noon blows comparatively stronger than in the morning. The past maximum wind speed is around 6.5m/sec.

The average wind speeds at the four meteorological stations are as follows: -

STATION NAME	WIND SPEED	
	0600 G.M.T.	1200 G.M.T.
NAIROBI (J.K.A.)	6 Knots	10 Knots
WILSON AIRPORT	6 Knots	10 Knots
DAGORETTI	5 Knots	9 Knots
MUGUGA (K.A.R.I.)	-	-

Average, Maximum and Minimum wind speeds at the four meteorological stations are shown on Table A-VIII-3(1), (2), (3), (4).

Precipitation

Annual rainfall in this project area ranges from 800mm to 1,100mm. Most rain falls in the big rainy season (March to June) and the small rainy season (October to December) as well as in other areas of Kenya.

Precipitation records (1976 - 1986) at Meteorological Stations, Wilson Airport and Dagoretti are shown Table A-VIII-3(5), (6).

VIII.3.2 Hydrological Analysis

In this section hydrological analysis for structural design is mentioned as follows:-

(1) River

Three river, Ruora River, Motoine River and Ondiri River cross the Nairobi Southern Bypass. Water flows in these rivers only in the rainy season and hence there is no need to construct a big structure but a box culvert.

The following data is available for reference for design purposes:-

(a) Rainfall Frequency Atlas of KENYA
(for durations of 10 minutes to 24 hours)
January, 1978
Master planning section
Water Development
Ministry of Water Development

(b) Rainfall and Rainfall Intensity

Rainfall Record (mm/hour, mm/day, mm/month, mm/year, 1976 and 1986)

Climate Section

Meteorological Department of M.O.T.C.

Maximum rainfall inensity in the Project site is shown on the Table VIII-3-1 and rainfall intensity at Dagoretti and Wilson Airport are shown as Fig. VIII-3-1, 2. designing drainage structures.

Rainfall Records were used to study the construction schedule of the Bypass.

Table VIII-3-1

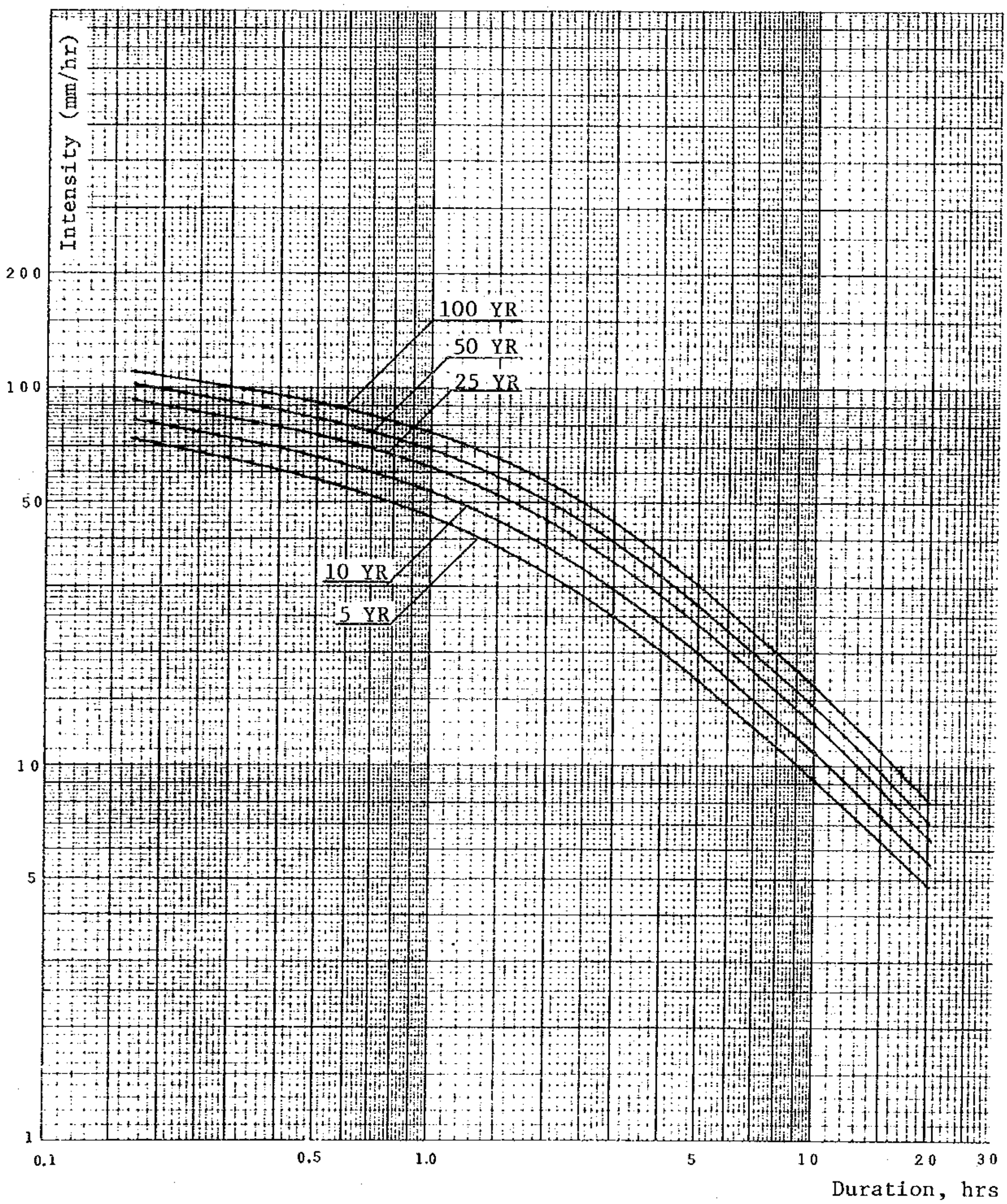
Maximum Rainfall Intensity

Period / Duration	5 Years	10 Years	25 Years	50 Years	100 Years
10 Minutes	110 mm/hr	120 mm/hr	130 mm/hr	140 mm/hr	220 mm/hr
30 Minutes	60	80	90	100	120
1 Hour	50	60	70	80	90
2 Hours	30	40	45	54	60
3 Hours	26	30	36	40	45
6 Hours	15	18	22	26	29
12 Hours	9	10	13	15	17
24 Hours	5	6	8	9	10

AUTHORITY: RAINFALL FREQUENCY ATLAS OF KENYA
MASTER PLANNING SECTION
WATER DEVELOPMENT
MINISTRY OF WATER DEVELOPMENT

AUTHORITY: RAINFALL FREQUENCY ATLAS OF KENYA
MASTER PLANNING SECTION
WATER DEVELOPMENT
MINISTRY OF WATER DEVELOPMENT

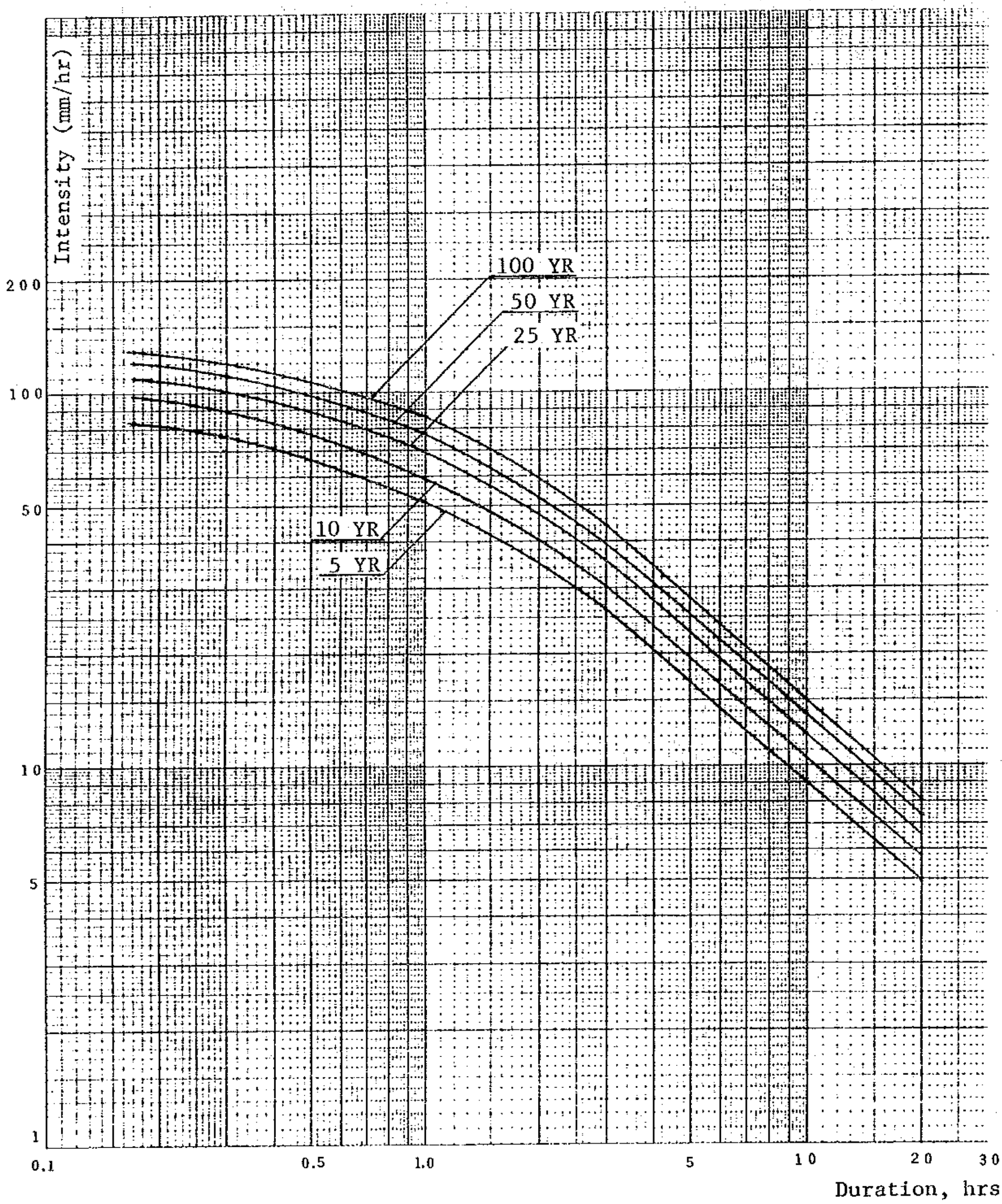
Fig. VIII-3-1



Rainfall Intensity - Duration - Frequency
Relationships for Nairobi Wilson Airport

AUTHORITY: RAINFALL FREQUENCY ATLAS OF KENYA
MASTER PLANNING SECTION
WATER DEVELOPMENT
MINISTRY OF WATER DEVELOPMENT

Fig. VIII-3-2



Rainfall Intensity - Duration - Frequency
Relationships for Dagoretti, Nairobi, E.A.M.D.

VIII.3.3 Drainage Design

The design peak flow for a drainage structure that will drain a related 5 km^2.

The runoff coefficient for the catch area is estimated as 0.3 from tables in hydrology books, and the time of concentration is determinated as 0.5 hour by employing the length and slope of the water course in related formula. The design return period is specified as 10 years. In an area of this type the rational formula is applicable.

This project area is extending from nearby Nairobi Wilson Airport to Dagoretti, Nairobi, so the Rainfall Intensity-Duration-Frequency Relationships for Nairobi Wilson Airport and Dagoretti, Nairobi E.A.M.D. were used as attached.

10 years Return period, 0.5 hour

Nairobi Wilson Airport	65 mm
Dagoretti, Nairobi E.A.M.D.	76 mm

The time of concentration:

$$\frac{h}{L} = 30 \quad 500 = 0.06$$

based on the diagram with 6% gradient

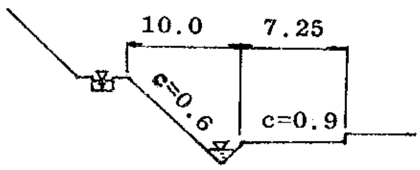
$$t_1 = 30 \text{ min.}$$

The rational formula in meter units

$$Q_2 = \frac{1}{3.6 \times 10^6 \text{ c.r.a.}}$$

$$= \frac{1}{3.6 \times 10^6} (0.9 \times 76 \times 130 \times 7.25 + 0.6 \times 76 \times 10 \times 130)$$

$$= \frac{123.747}{3,600,000} = 0.034^3/\text{sec.}$$



$Q_2 = \frac{1}{3.6}$ c.r.a. $= \frac{1}{3.6}$ x 0.3 x 76 x 0.4 = 2.5^3m/sec.

$Q_1 + Q_2 = 2.53^3$m/sec.

Therefore D = 900 mm is preferred for drainage pipe.

VIII.4 Structures

VIII.4.1 Design Criteria

There are proposed three bridges, five Road Box Culverts and five box culverts for drainage.

Design Criteria for structural design have been refered to Road Earthwork Manual and Road Bridge Design Manual by Japan Road Association. Live load for preliminary design of bridge was adopted TL-20, and earthquake load was not considered.

Width of road and clearance were referred to Road Design Manual Part I by Ministry of Transport and Communications as follows: -

Item		Descriptions
Road Class		A
Lane Width		3.5m
Shoulder Width		-
	Right	1.0m
	Left	1.5m
Clearance		
Vertical	Class-A	5.25m
	Class-C	4.75m
Horizontal		1.5m

Probabilily of Rainfall:	
Box Culvert	5 Years for less than $5m^2$
	25 Years for more than $5m^2$
Bridges	25 Years

VIII.4.2 Type, Size and Location of Major Structures

Type of major structures, their location and scale on Project Route of Nairobi By-Pass are as follows :

TYPE		NO	SITE	LENGTH (m)	WIDTH (m)
BRIDGES		1	Starting point of By-Pass (Mombasa Road Junction)	72.0	25.2
		2	Crossing of C58 Road (Uhuru Monument Juction)	33.0	21.7
		3	Crossing of Rail Way (Near Kikuyu Station)	15.4	6.0
CULVERTS	FOR ROAD	1	Crossing of C60 Road (Ngong Road Junction)	24.0	9.0
		2	Crossing of C63 Road (Dagoretti Forest Junction)	43.0	9.0
		3	Crossing of E422 Road Ondiri Junction)	37.0	9.0
		4-1	Crossing of A104 Road (Kikuyu Junction)	33.0	7.0
		4-2	Crossing of C63 Road (Kikuyu Junction)	26.0	7.0
	FOR DRAINAGE	1	Ruora River (Sta. NO.131 +45.0) (Ngong Road Forest)	58.0	3.5 x 3.0
		2	Motoine River (Sta. NO.142 + 25) (Ngong Road Forest)	63.0	2.0 x 1.5
		3-1	Motoine River (Sta. NO.151 + 85) (Ngong Road Junction)	62.0	4.0 x 3.5
		3-2	Motoine River (Ngong Road J.) (Ngong Road Forest)	37.0	4.0 x 3.5
		4	Ondiri River (Sta. NO.259 + 80)	119.0	3.5 x 3.5

VIII.4.4 Selection of Structure Type

Types of structure are studied and selected with due consideration to low construction cost and especially the following items:

1. Easy construction work by Kenya Contractors
2. Construction by using local material and easily imported material in Kenya
3. Easy maintenance work after construction
4. Beauty (Not to interfere with natural beautiful sights).

As there exists a Kenyan standard design of bridges up to a span length of 10.0m, all bridges over 10 meters long would be newly designed. And box - culverts also would be newly designed due to lack of Kenya design standards.

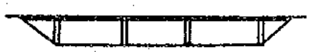
Planning and design of structures were carried out after detailed survey and study of existing structures.

Selected types of structures and reasons for the selection are as follows: -

(1) Bridges No. 1 (Mombasa Road Junction):

This bridge is located at the beginning point of the Bypass. It has a long span due to crossing over the existing A104 with a proposed acceleration lane and declaration lane in the newly designed interchange.

Two types of bridges, type (I) 

Type (II)  were studied and Type II was adopted in view of construction costs.

Piers were designed as circular in shape for aesthetic reasons.

(2) Bridge No. 2 (Uhuru Monument Junction):

This bridge is located at the cross point of the Bypass and C58 (Langata Road).

As the Nairobi City Commission has the idea to improve the existing road to a dual carriage way in the near future, the Bypass bridge was designed in consideration of the width of a dual carriage way.

Both the super and substructure are the same type as Bridge No. 1. However, due to the lack of detail design of the C58 improvement plan. it was assumed that the fourth path would be set at both sides of C58. Then at the detailed design stage of the Bypass, detailed discussion should be done between MOTC and Nairobi City Commission.

(3) Box Culvert for Road No. 1 (Ngong Road Junction):

This culvert is located at the cross point of the Bypass and C60 (Ngong Road). In consideration of an improvement plan to expand the existing road to dual carriage way by the Nairobi City Commission, a Box culvert was designed for C60 to underpass the Bypass. There is enough space to build an additional box culvert for a dual carriage way in future.

As it is uneconomic to construct a long bridge for an indefinite improvement plan of dual carriage way for C60, a box culvert is proposed.

(4) Box Culvert for Road No. 2 (Dagoretti Forest Junction):

This culvert is located at the cross point of the Bypass and C63 (Dagoretti Road). In the case of a bridge, it will have a tall substructure due to a steep vertical alignment. Then the box culvert is superior from the construction cost point of view. Shape of this culvert is the same as the culvert passing under a railway which crosses C63. This shape is superior to typical box shape in view of construction cost.

(5) Box Culvert for Road No. 3 (Ondiri Junction):

This culvert is located at a cross point of the Bypass and E422 which diverts from C63.

A box culvert is proposed for ease of construction and lower construction cost than bridge construction.

(6) Box Culvert for Road No. 4-1 and 2 (Kikuyu Junction):

Two box culverts were designed at a cross point of Bypass slip road and A104 under design by other consultants, and at another cross point of Bypass slip road and C63. Both the slip roads are single lane and it makes span short, then box culvert was adopted instead of a bridge in view of lower cost.

(7) Bridge No. 3 (Near Kikuyu Station):

As the Bypass was proposed to pass under the existing railway in combination with C63, a similar type of bridge as for the existing railway bridge was designed. Steel bridge was proposed for the following reasons: -

1) The existing bridge is a steel bridge and a Kenya constructor has experience in such work.
2) Construction is easy and safe.
3) Construction work is speedy.

In deciding the span length of the bridge, a side walk for the Bypass was considered.

(8) Box Culvert for Drainage No. 1 (Ruora River) STA No. 131 + 45.0

This box culvert is located for a steam in the Ngong Road Forest. Discharge area is 5.59 km^2 and necessary run off sectional area of the culvert is 8.4 m^2, but the sectional area of culvert was required to 10.5 m^2 (3.5m x 3.0m) for safety.

(9) Box Culvert for Drainage No. 2 (Motoine River) STA No. 142 + 25.0

This box culvert is also located in the Ngong Road Forest. Discharge area is 0.7 km^2 and necessary run off sectional area of the culvert is 2.1 m^2, but proposed sectional area of culvert is 3.0 m^2 (2.0m x 1.5m) due to the fact that the box culvert is 60m long and easy to maintain.

(10) Box Culvert for Drainage No. 3-1 and 2 (Ngong Road Junctions):

This culvert is located at the cross point of the Bypass and Motoine River. Discharge area is 9.41 km^2 and necessary sectional area of the culvert is 12.0 m^2, but the proposed sectional area of the culvert is 14.0 m^2 (4.0m x 3.5m) for safety.

Hence, an existing box culvert passing under the existing C60 has about 7.5 m^2 sectional area. This is not capable of handling maximum capacity, and it is said that flood flew over the existing road at the last big flood time in 1985.

(11) Box Culvert for Drainage No. 4 (Ondiri River) STA No. 259 + 80:

This culvert is located under a high embankment at the cross point of the Bypass and Ondiri Swamp, and the length of culvert is 110m long. Discharge area is 6.64 km^2 and the necessary sectional area of the culvert is 10.7 m^2, but proposed sectional area of the culvert is 14.0 m^2 (4.0m x 3.5m) for safety.

VIII.4.4 Type and size of box culvert for waterway.

The type and size of box culvert for the waterway were planned in accordance with the Road Drainage Work Manual of Japan Road Association.

Rainfall intensity was referenced to "RAINFALL FREQUENCY ATLAS OF KENYA (June 1978)" by Ministry of Water Development, and the five year frequency was adopted in calculating discharge.

(1) Calculation of run-off

a) Rational Formula

$$Q = \frac{1}{3.6} \ C.I.A.$$

Where: Q : Runoff (m^3/sec)
C : Coefficient of run-off
I : Rainfall Intensity (mm/hr)
A : Drainage Area (Km^2)

Coefficent Run-off

Ruora River)
Motoine River) C = 0.3(Rolling area)
Ondiri River)

Reaching Time

$$t = t1 + t2$$

Where:

t1 : Inlet Time (min)
t2 : Run off time through culvert (min)

b) Inlet Time (min)

$$t1 = \left(\frac{2}{3} \times 3.28 \times L \times \frac{nd}{\sqrt{s}}\right)^{0.467}$$

Where:

t1 : Inlet time (min)
L : Discharge distance (m)
S : Mean gradient of discharge area
nd : Coefficient of delay

c) Run off Time Through Culvert (min)

$$t2 = \frac{L}{60V} \ (min)$$

Where:

t2 : Run off time through culvert (min)
L : Length of waterway (m)
V : Mean Velocity (m/sec)

$$V = \frac{1}{n} R^{2/3} i^{\frac{1}{2}} (m/sec)$$

Where:

V : Mean Velocity
R : Hydraulic Mean Depth

R : $\frac{A}{P}$ A : Section Area (m^2)
P : Length of Watted Perimeter

i : Hydraulic Gradient
n : Coefficient of Roughness

d) Section Area

$$A = \frac{Q}{V}$$

Where:

A : Section Area
Q : Runoff
V : Mean Velocity

(2) Calculation

Discharge capacities of each culvert were calculated by the above mentioned formula and are shown in the following table.

Culvert No.	Site	Drainage Area	Duration Time	Rain-fall Inten-sity	Run-off	Velocity	Section Area
		km^2	min	mm/h	m^3/sec	m/esc	m^2
C-1	Ruora R. Ngong	5.59	66.9	45.5	21.2	2.6	8.4
C-2	Motoine R. Ngong	0.70	417	56.0	3.3	1.6	2.1
C-3-1 -2	Motine R . Ngong	9.41	76.8	42.5	34.1	2.9	12.0
C-4	Ondiri River	6.64	59.7	50.0	27.7	2.7	10.7

Fig. VIII-4-1

DRAINAGE AREA S = 1 50,000

CULVERT NO.1 (RUOHA RIVER STA.NO. 131+45)

A = 5.59 km^2

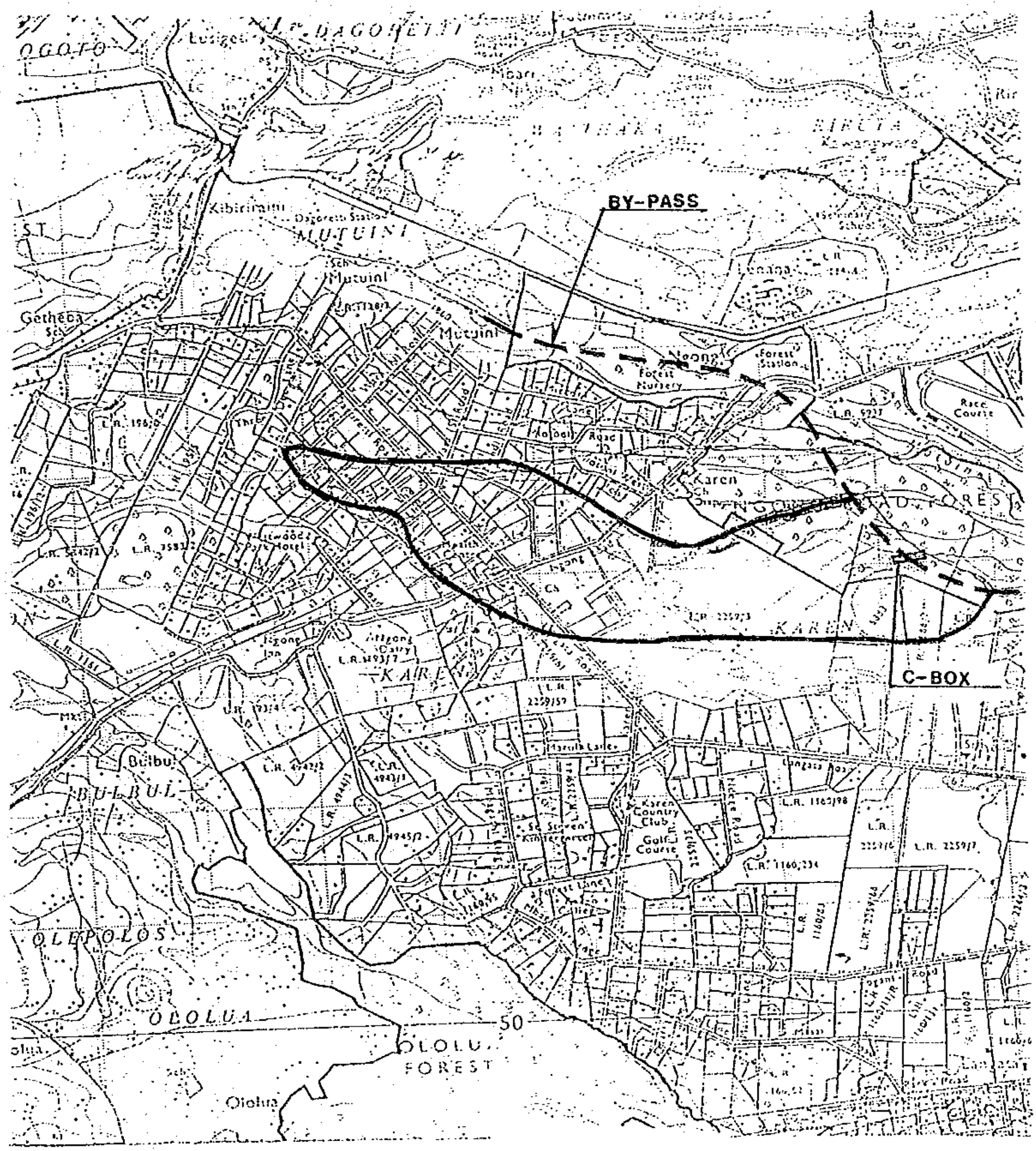


Fig. VIII-4-2

DRAINAGE AREA S=1:10000

CULVERT NO.2 (MOTOINE RIVER STA. NO.142+25)

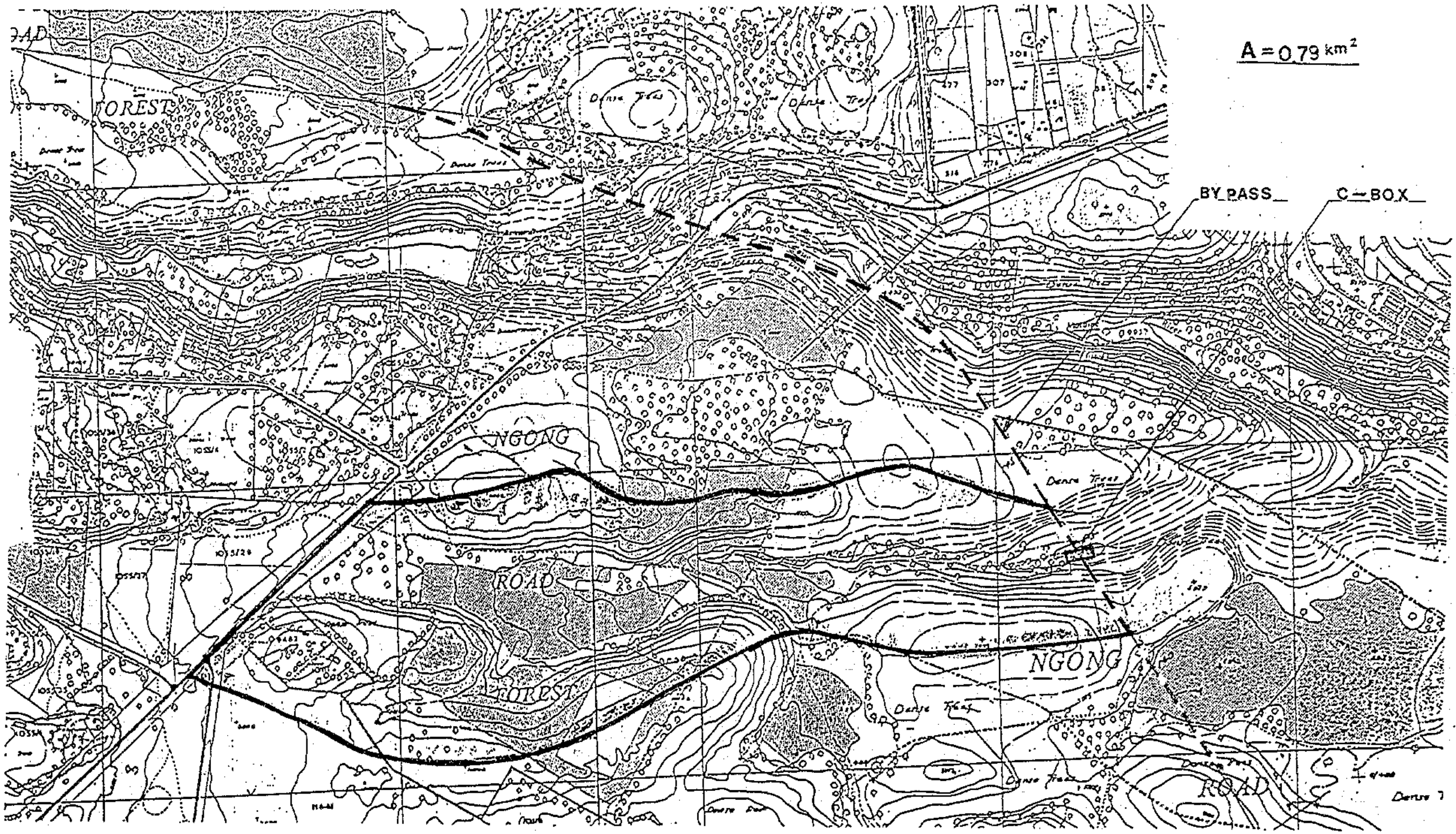
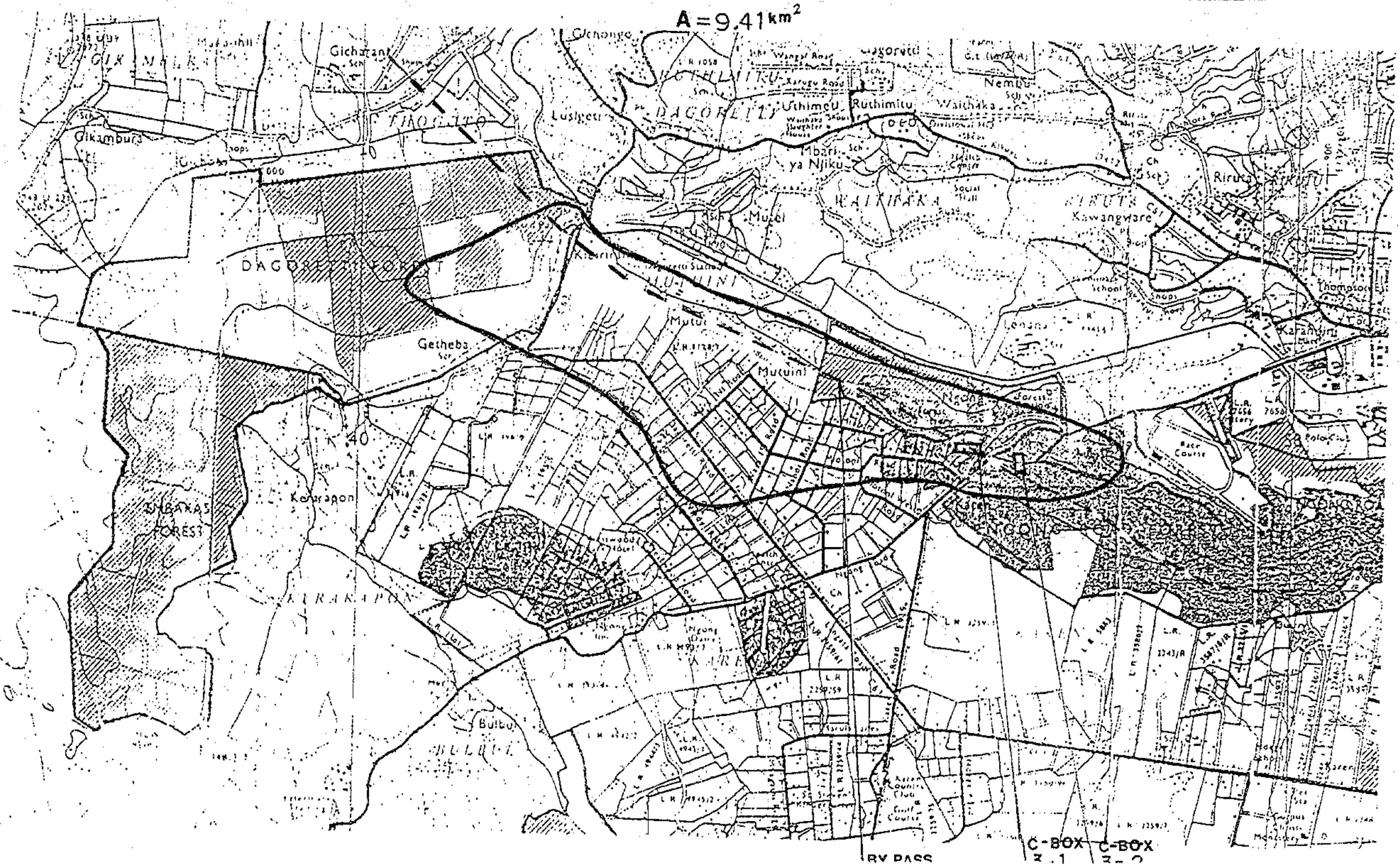


Fig. VIII-4-3

DRINAGE AREA S= 1:50000

CULVERT NO. 3-1~2 (MOTOINE RIVER STA.NO. 151+85 & UNDER THE SLIP ROAD)

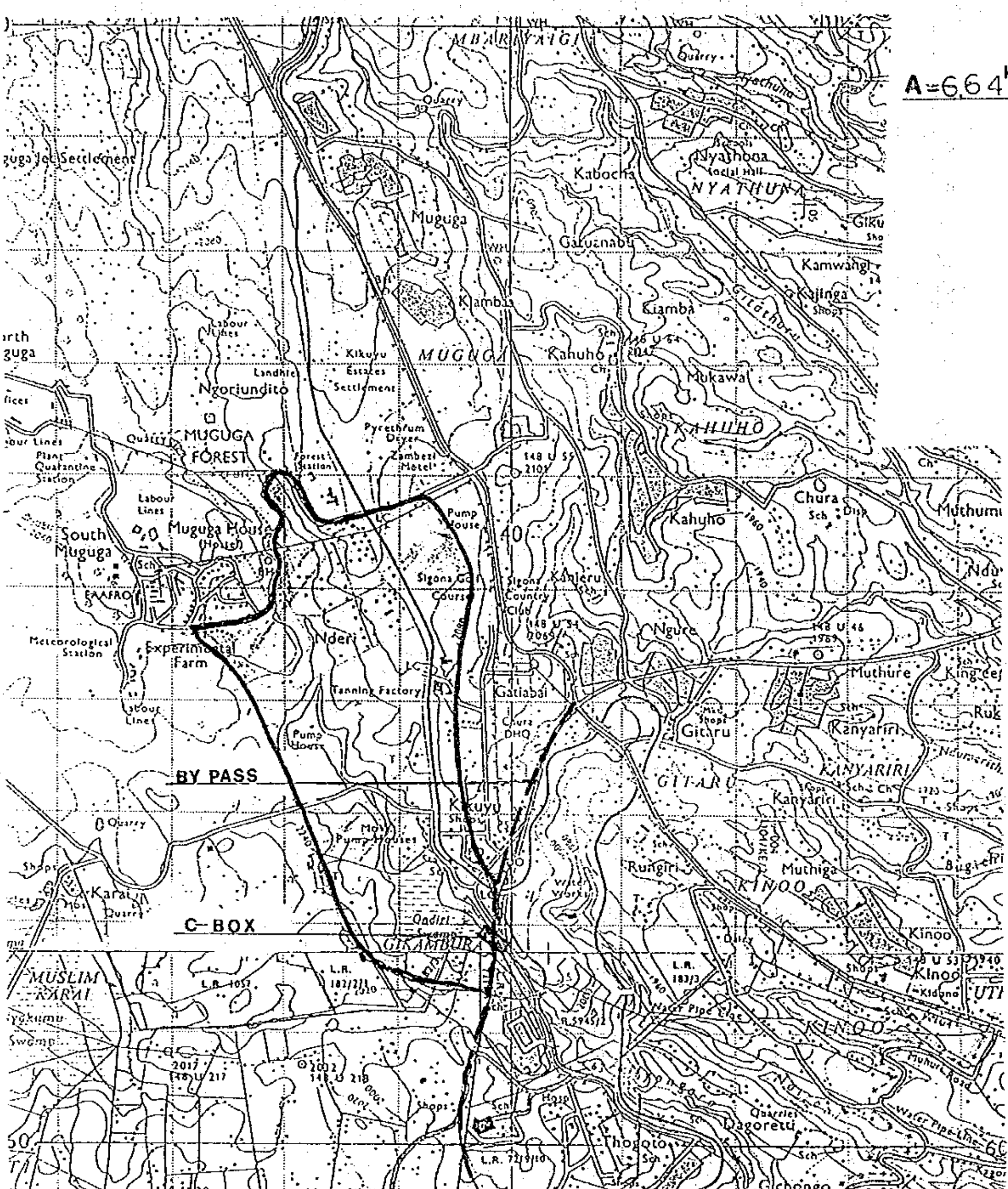
A=9.41 km^2



DRAINAGE AREA S=1:50,000 Fig. VIII-4-4

CULVERT NO.4 (ONDIRI RIVER STA.NO 25°+80)

A=6.64 ^{kr}



VIII.4.5 Preliminary Design of Structures

Preliminary design of the following structures were done in accordance with the design criteria and discussions with M.O.T.C. engineers.

NO.1	BRIDGE NO.1 (Mombasa Road Junction)
NO.2	BRIDGE NO.2 (Uhuru Monument Junction)
NO.3	BRIDGE NO.3 (Crossing of Railway - Near Kikuyu Station)
NO.4	CULVERT (FOR ROAD) NO.1 (Crossing of Ngong Road)
NO.5	CULVERT (FOR ROAD) NO.2 (Crossing of C63-Dagoretti Road)
NO.6	CULVERT (FOR ROAD) NO.3 (Crossing of E422 Road)
NO.7	CULVERT (FOR ROAD) NO.4-1 (Kikuyu Junction)
NO.8	CULVERT (FOR ROAD) NO.4-2 (Kikuyu Junction)
NO.9	CULVERT (FOR DRAINAGE NO.1 (Ruora River)
NO.10	CULVERT (FOR DRAINAGE NO.2 (Motoine River)
NO.11	CULVERT (FOR DRAINAGE NO.3-1 (Motoine River)
NO.12	CULVERT (FOR DRAINAGE NO.3-2 (Ngong Road J-Motoine River)
NO.13	CULVERT (FOR DRAINAGE NO.4 (Ondiri River)

Drawings of the above-mentioned structures are shown in the Appendix.

VIII.5 Construction Program

VIII.5.1 General

This section describes the construction plan including method, sequence and period for the implementation of the Nairobi Bypass Project. The project will be implemented by the Ministry of Transport and Communication (MOTC). Also, the construction works will be carried out by a contractor selected by a process of international competitive bidding in accordance with standard international guidelines. As for the engineering services including detailed design and construction supervision, the international consulting engineer will be selected.

For the implementation of the project, the stage construction is not adopted in this construction programme, considering the urgent bypass requirement. The construction will be executed as one single construction package, considering the volume of earthwork and pavement work and the total construction cost. This will also be controlled by the size of general financial package applied by international financing agencies.

For the convenience of preparing the detailed implementation schedule and construction cost estimate, the Bypass Project of 29.22km in length will be tentatively divided into four construction sections as below. However, these construction sections are not contract packages.

Section I : Mombasa Road Junction - Uhuru Monument Junction
STA. 4-400 to STA. 63+25, L = 6,725m

Section II : Uhuru Monument Junction - Ngong Road Junction
STA. 63+25 to STA. 150+50, L = 8,725m

Section III : Ngong Road Junction - Dagoretti Forest Junction
STA. 150+50 to STA. 203+00, L = 5,250m

Section IV : Dagoretti Forest Junction-Kikuyu Junction
STA. 203+00 to STA. 288+20, L = 8,520m

VIII.5.2 Construction Schedule

(1) Construction Period and Time Target

The construction period of the Nairobi Bypass Project is scheduled to extend over about 4.5 years. The first 2 years are required for such pre-construction works as detailed engineering design, land acquisition, tendering and contractual events. The later 2.5 years are required for the construction work of the project.

- Detailed engineering design will require 12 months and will be completed in the 1st year.

- Prequalification of contractors will require 3 months before the tender call. The tender and contract will be performed for 10 months by the 25-month in the 3rd year.

- Main construction work is scheduled to be performed for 2.5 years from month 26 in the 3rd year to month 55 in the 5th year.

(2) Construction Schedule

The construction schedule is shown in Fig. VIII-5-1 by bar chart. The total construction period including four construction sections is scheduled to be 30 months. The construction works of each construction section will be made by staggering procedures, taking into account the transfering of the construction equipment and plant. Especially, the pavement works will be performed in relation with each construction section. Each work item and construction period are as follows: -

Fig. VIII-5-1
Construction Schedule (1/2)

Fig.VIII-5-1 Construction Schedule (1/2)

DESCRIPTION	UNIT	QUANTITY
Detailed design		
Land acquisition		
Tender and contract		
Construction Work		
1. Mobilization, Preparatory work		L.S
2. Section I		
Clearing and grubbing	ha	37.5
Excavation	m^3	36,150
Embankment	m^3	325,070
Subgrade	m^3	209,100
Crusher-run subbase	m^3	24,190
Cement stabilized base	m^3	21,990
Asphalt surface course	m^3	10,990
Drainage work		L.S
Bridge No.1	m^3	72
Road furniture		L.S
3. Section II		
Clearing and grubbing	ha	42.3
Excavation	m^3	43,180
Embankment	m^3	371,510
Subgrade	m^3	268,700
Crusher-run subbase	m^3	33,910
Cement stabilized base	m^3	25,690
Asphalt surface course	m^3	12,840
Drainage work		L.S
Box culvert No1 drain.	m	58
Box culvert No2 for drain.	m	63
Bridge No2	m	33
Road furniture		L.S

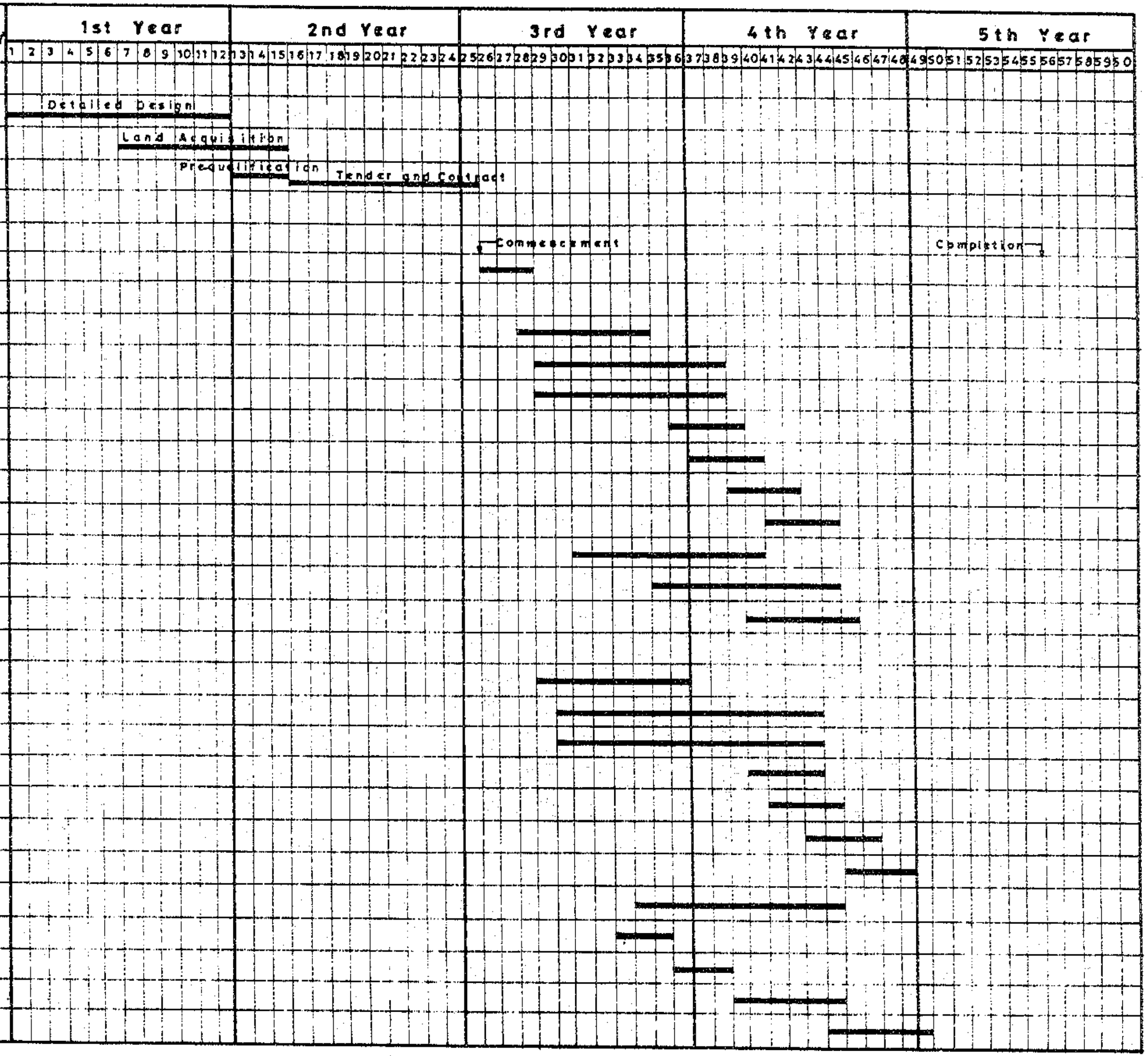
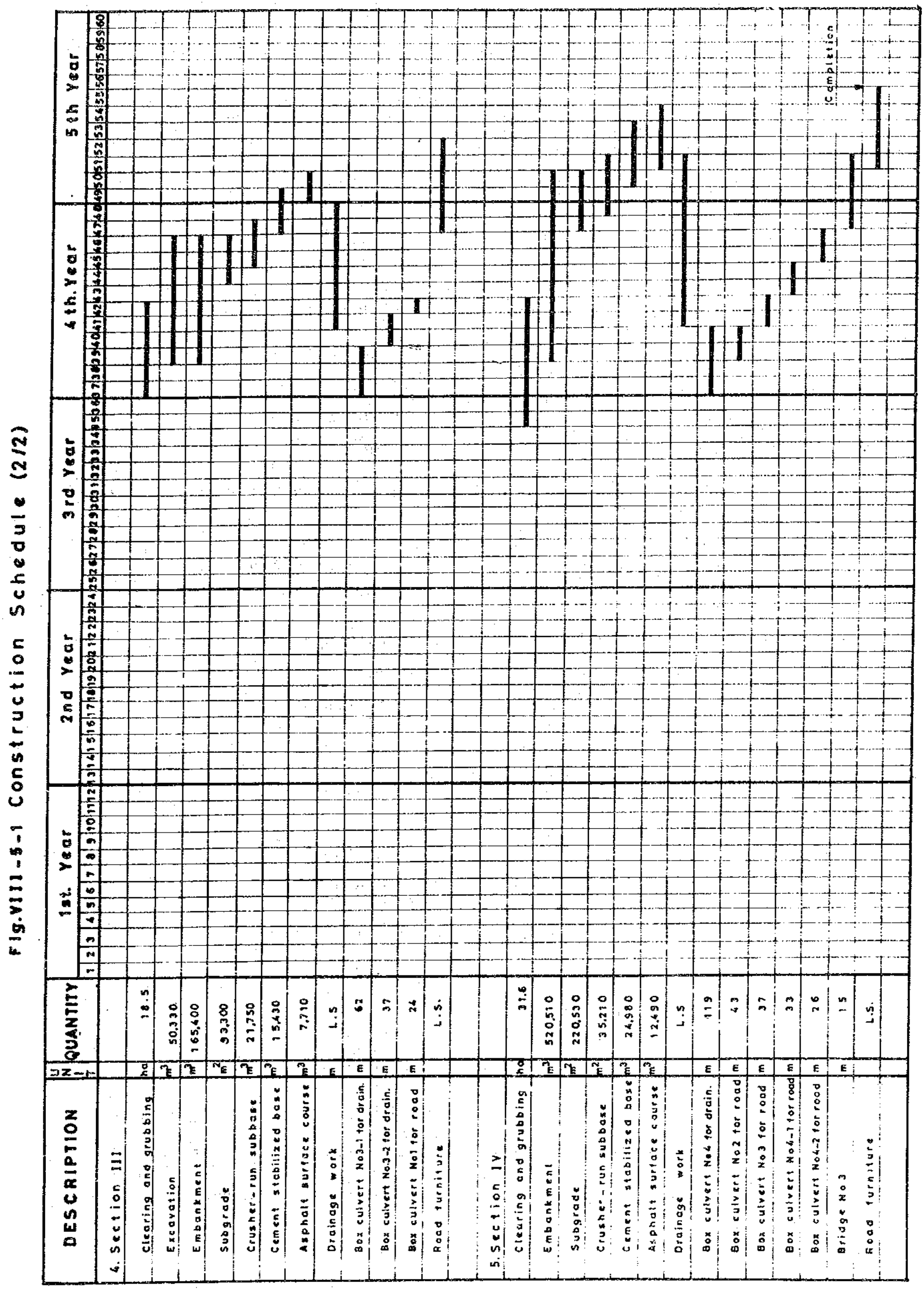


Fig. VIII-5-1

Construction Schedule (2/2)



a. Mobilization and preparatory works : 3rd year, 3 months

b. Clearing and grubbing, removal of topsoil : 3rd year to 4th year

Section	I	: 7 months
Section	II	: 8 months
Section	III	: 6 months
Section	IV	: 8 monhts

c. Excavation and embankment : 3rd year to 5th year

Section	I	: 10 months
Section	II	: 14 months
Section	III	: 8 months
Section	IV	: 12 months

d. Preparation of subgrade : 4th year to 5th year , 15 months

e. Crusher-run subbase : 4th year to 5th year

Section	I	: 4 months
Section	II	: 4 months
Section	III	: 3 months
Section	IV	: 4 months

f. Cement Stabilized base : 4th year to 5th year

Section	I	: 4 months
Section	II	: 4 months
Section	III	: 3 months
Section	IV	: 4 months

g. Asphalt surface course : 4th year to 5th year

Section	I	: 4 months
Section	II	: 4 months
Section	III	: 2 months
Section	IV	: 4 months

h. Drainage : 3rd year to 5th year

i. Box culvert and bridge : 3rd year to 5th year

j. Road furniture : 4th year to 5th year

VIII.5.3 Construction Plan and Method

(1) Workable Day and Hours for the Construction Works

Two short rainy seasons from April to May and from November to December are observed in the Nairobi area. The workable day for construction works is estimated on the basis of the rainfall data and monthly rainy days, which were reported at Dagoretti Forest and Wilson Airport between 1976 and 1986.

The workable days for earthwork are estimated at 21 days on the average, in considering suspended days due to rainfall, Sunday and holidays (as shown in Table VII-5-1). The suspended days due to rainfall are as follows:

Daily Rainfall	Suspended Day
3 - 10 mm	0.5 days
10 - 30 mm	1.0 "
30 - 50 mm	1.5 "
more 50 mm	2.0 "

Table VIII-5-1 Workable Day

Month	Rainly Days						
	(1) Less than 3 mm	(2) 3-10mm	(3) 10-30mm	(4) 30-50mm	(5) More than 50mm	Sunday & National Holidays	Working Days
Jan	2.4	1.2	0.5	0.1	o.2	5	24
Feb	2.3	1.9	1.3	0.2	0.2	4	21
Mar	5.0	1.9	1.7	0.4	0.4	5	22
Apr	6.6	5.1	4.1	1.4	1.4	6	12
May	7.1	3.4	3.1	1.0	0.9	6	17
Jun	5.0	1.1	0.7	0	0	5	24
Jul	3.5	0.9	0.5	0.1	0	4	26
Aug	4.1	0.8	0.5	0	0	5	25
Sep	3.5	1.1	0.5	0.2	0	4	25
Oct	5.1	3.0	1.7	0.3	0	5	22
Nov	6.7	5.0	3.1	0.6	0.3	5	18
Dec	4.6	2.6	2.0	0.8	0.3	7	19
Total	55.9	28.0	19.7	5.1	3.7	61	255

Note: Average monthly rainy days (1976-1986) at Dagoretti Forest Station

The workable day for concrete and pavement works is planned to be the same as days for earthwork.
Daily working hours are planned to be 7 hours out of 8-working hours per one shift.

(2) Preparatory Works

- Access Road

The national highway of Route A104 and other city roads with asphalt pavement road are available to access to each proposed junctions. The transportation of construction materials and equipment is no problem by using existing highways and city roads.

The temporary accss road for cutting and filling works is planned to be provided within the road alignment area.

- Power Supply

The electric power supply for construction is planned to be taken from diesel generator sets. A 200 KVA generator for an asphalt plant and two 80 KVA generators for a soil plant and a batcher plant will be installed at each plant site. The electric supply for a contractor's office, labor camp and other temporary buildings will be taken from the existing distribution line conducted by the Kenya Power and Lighting Company Ltd.

- Telecommunication System

The telecommunication between Government office including engineer's office and Contractor's office will be carried out by utilizing the public telephone.

- Water Supply

The water required for the construction use, office and camp use is planned to be taken from the existing domestic water supply system.

- Temporary building and office

The temporary buildings required for the construction consist of the contractor's quarters, repair shop, warehouse and labour quartere, and will be provided by a contractor in and near the project site.

(3) Earthworks

The earthwork of each construction section will be carried out in advance of the pavement work. The works are scheduled to be performed for 22 months from month 28 in the 3rd year. The distribution of earth materials is planned based on the mass curve and volume calculation data. The required work quantity is as follows:-

Removal of topsoil	Section I	75,000m^3
	Section II	84,600m^3
	Section III	37,000m^3
	Section IV	63,160m^3
	Total	259,760m^3
Excavation		
Unsuitable soil and Surplus soil	Section I	36,150m^3
	Section II	43,180m^3
	Section III	50,330m^3
	Total	129,660m^3
Embankment		
Cross fill	Section I	9,810m^3
	Section II	58,230m^3
	Section III	27,450m^3
	Section IV	34,200m^3
	Total	129,690m^3
Cutting and filling	Section I	25,750m^3
	Section II	313,280m^3
	Section III	137,950m^3
	Section IV	486,310m^3
	Total	963,290m^3
Borrow filling	Section I	289,510m^3
	Total	289,510m^3

The topsoil excavation will be done by using a 21 ton bulldozer and the material will be spoiled and spreaded along the road alignment. The unsuitable material of black cotton soil in Section I and surplus material will be spoiled along the road alignment.

The cross filling (side borrow) of 129,690m^3 will be done by bulldozer dozing work and the cutting and filling work will be carried out by a shovel-dump truck method. The cutting and filling works are planned with the hauling distance upto 1,000m and 2,000m. The soil material will be excavated and hauled to the embankment area by using a 21 ton bulldozer, a 2.3m^3 tractor shovel and an 11 ton dump truck. The soil material will be spread by an 11 ton bulldozer and compacted by a 20 ton tire roller.

The weathered rock and rock material are obtained Section IV. The weathered rock will be excavated by a 21 ton bulldozer with ripper. The rock will be drilled by 10m^3/min crawler drill and 13.5m^3/min air compressor and gathered by a 21 ton bulldozer. These materials will be loaded by a 2.3m^3 tractor shovel into an 11 ton dump truck. The material will be spread by an 11 ton bulldozer and compacted by a 10 ton vibrating roller.

As for the Section I embankment, about 90% of total volume is planned to be borrowed filling. The borrow area is planned to be located at Ngong Forest. The average haulage distance is to be 7,000m. The excavation and embankment works will be performed by the same method applied for the soil cutting and filling works.

(4) Subbase

The subbase course is planned to be a crusher-run subbase. The subbase course will be made for 15 months from month 7 in the 4th year, in parallel with the subgrade preparation and base course construction. The required quantity is as follows:

Section I	24,190 m^3
Section II	33,910 m^3
Section III	21,750 m^3
Section IV	35,210 m^3
Total	115,060 m^3

The subbase material will be obtained from private quarry companies located near Dooonholm Estate. The crusher-run will be hauled from the quarry site to the project site by using existing city roads. After the completion of subgrade preparation, the crusher-run material will be dumped from an 8 to an 11 ton dump truck and spreaded by 3.7m motor grader. The rolling compaction of subbase course will be carried out by using a 20 ton tire roller and a 10 ton macadam roller.

(5) Base Course

The base course construction is planned to be applied by a cement stabilization method. The base course will be constructed for 15 months from month 39 in the 4th year, in parallel with subbase course and asphalt surface course construction.
The required quantity is as follows: -

Seciton I	21,990 m^3
Section II	25,690 m^3
Section III	15,430 m^3
Section IV	24,980 m^3
Total	88,090 m^3

The base material will be combined by mixing sand, crusher-run and cement. The combined material will be produced by 120 ton/h in capacity portable mechanical stabilization plant. The crusher-run is planned to be a quarried material from the same material source of subbase course.

While, the said is sourced from the Machakos area located 90 km from the project site. A quantity of Machakos sand is available during the rainy season, and it is easy to gather and collect after rain as a deposited sand. About 23,000 m^3 of sand is required to be stocked periodically at the project site for smoth construction.

The mixed product will be delivered by 8 to 11 ton dump trucks to the site, spread and levelled by a 3.7m motor grader. The material will be compacted by a 20 ton tire roller and a 10 ton macadam roller.

Prime coating of 528 klit in total will be applied immediately after the base course is finished. The prime coating will be made by using 4 klit distributor and 600 lit emulsion sprayer.

(6) Aspahlt Surface Course

Asphalt surface is planned to be a binder course and a surface course. Course graded asphalt concrete is used for the binder course and dense graded asphalt concrete is used for the surface course. The asphalt pavement work is scheduled to be performed for 14 months from month 41 in the 4th year, in parallel with base course construction. The required quantity is as follows: -

Section I	10,990 m^3
Section II	12,840 m^3
Section III	7,710 m^3
Section IV	12,490 m^3
Total	44,030 m^3

The asphalt mix material is composed of a special sealing aggregate, sand, stone dust and asphalt. The asphalt will be obtained from bitumen suppliers at the Industrial Area. The special sealing aggregate and stone dust will be transported from the same material source as the subbase and base course. The sand will be transported from the Machakos area.

An about 15,000 m^3 of sand in total for the pavement work is required to be stocked periodically at the project site so as not to restrict the construction progress.

The asphalt mix will be produced by a 60 t/h batch type asphalt mixing plant installed within the project site. The asphalt mix will be transported by an 8 ton dump truck to the site. The hot mix will be spread and levelled by a 3-5 m class asphalt finisher, and compacted by a 10 ton macadam roller and 15-20 ton pneumatic tire roller. For tack coating, a 4 klit distributor and 600 lit emulsion sprayer will be used.

(7) Box Culverts and Bridges

Ten box culverts of 502m in total length and three bridges of 120m in total length area planned. The concrete volume is estimated at 13,290 m^3. The construction period is scheduled to be 19 months in parallel with earthwork and pavement work.

The daily concrete placing requirement is estimated at 40 m^3/day on the average and the peak concrete placement is assumed to be 60 m^3/day. The concrete is planned to be produced by a portable concrete batching plant with 0.5 m^3 mixer. The coarse aggregate will be transported from the quarry companies near Doonhold Estate, and the fine aggregate will be delivered from the Machakos area. To secure the daily concrete placement, the sand is planned to be stocked periodically at the batching plant area. The concrete will be transported from the central plant to the site by 3.2 m^3 agitator truck and handled by 0.75 m^3 concrete bucket with a 20 ton truck crane.

After completion of construction of box culverts and bridge abutments, the embankment and backfilling works will be performed. The material is planned to be selected and obtained from the suitable excavated material and borrowed material.

(8) Construction Plant and Equipment

The major Construction Plant and Equipment to be used for the Construction are summarized in Table VIII-5-2.

Table VIII-5-2

Major Construction Plant and Equipment

Description	Spec.	Required Number
Bulldozer	21 ton	9
Bulldoezer W/Hpper	21 ton	2
Bulldozer	11 ton	3
Tractor Shovel	2.3 m^3	8
Dump Truck	11 ton	36
Dump Truck	8 ton	4
Tire Roller	20 ton	9
Vibrating Roller	8 ton	1
Macadam Roller	10 ton	3
Motor Grader	3.7 m	3
Asphalt Finisher	3-5 m	1
Distributor	4 K Lit	1
Asphalt Plant	60 t/hr	1
Soil Plant	120 t/hr	1
Concrete Plant	20 m^3/hr	1
Agitator Truck	3.2 m^3	3
Backhoe	0.2 m^3	2
Vibrating Roller	1 ton	4
Tamper, Rammer	100 kg	20
Crawler Drill	10 m^3/min	4
Air Compressor	13.5 m^3/min	4

VIII.6 Project Cost Estimate

VIII.6.1 Construction Cost

The construction cost for the Nairobi Bypass Project is estimated on the basis of the preliminary design and construction plan and schedule. For the cost estimate, the local conditions, available equipment and materials, suitability of construction method, etc. are taken into account. The foreign currency portion and local currency portion of the project cost are estimated in Kenya shillings.

The cost estimates are prepared on the following basic assumptions and conditions.

Price level	:	The prices based on the current price for labor, materials and equipment as of August, 1987.
Exchange Rate	:	The exchange rate used in this estimate is 1.0 US Dollar = 16 Kenya shilling = 150 Japanese Yen.
Work Quantity	:	The work quantities are calculated from the preliminary design.

The project cost consists of direct construction costs (contract price), engineering services, land aquisition and compensation, physical contingency and price escalation. The cost for each work item is estimated as described below:

(1) Direct Construction Cost

The direct cost of main civil works are estimated by adopting unit rates. The cost estimate is based on the expense of labor, materials and construction equipment and plants. In addition to the direct cost, the contractor's overhead expenses and profit are included in each work item. The main components of the costs are described as follows:

a) Labor Cost

The direct daily wages in an 8-hour shift of labor applied to the cost estimate are based on the wages obtained in Nairobi. The applied labor costs are shown in Table VIII-6-1.

b) Material Cost

Most construction materials are supplied from local markets. The local prices on materials used for the cost estimate are canvassed from Nairobi and are considered as foreign and local portion. The local protion is classified into local net price, tax and duties. The material cost is shown in Table VIII-6-2.

c) Equipment Cost

The prices of construction equipment are the prevailing prices in Japan as of August, 1987. The equipment cost is divided into foreign and local portion. The foreign currency portion includes depreciation cost, spare parts and consumable cost, while the local portion includes the cost of mechanic labor, cost for the repair and administration expenses, and duties. The equipment cost is listed in Table VIII-6-3.

d) Contractor's Indirect Cost (Overhead Expenses and Profit)

The overhead expenses and profit is contributed to the unit rate of each work item. These expenses are estimated at 15 percent of the direct cost including labor cost, material cost and equipment cost.

e) Unit Price

The unit price for various work items is estimated in accordance with the above conditions. The unit prices are listed in Table VIII-6-4.

Table VIII-6-1

Labor Cost (Wage Rate)

Description	Unit	Wage Rate (Kshs.)
Foreman	M.D.	72.00
Skilled labor III	M.D.	52.30
II	M.D.	57.80
I	M.D.	69.50
Unskilled labor	M.D.	30.80
Operator, light	M.D.	59.80
Operator, heavy	M.D.	69.50
Assist operator	M.D.	48.60
Driver, truck	M.D.	52.30
Driver, vehicle	M.D.	41.60
Electrician	M.D.	72.00
Assist electrician	M.D.	48.00
Mechanic	M.D.	72.00
Assist mechanic	M.D.	48.00
Carpenter, formworker III	M.D.	52.30
II	M.D.	57.80
I	M.D.	69.50
Concrete worker	M.D.	41.60
Steel wprker	M.D.	41.60
Masonry	M.D.	52.30
Asphalt pavement	M.D.	69.50
Driller	M.D.	41.60
Blaster	M.D.	69.50

Note: At August, 1987 Price Level.

Table VIII-6-2

Construction Material Cost

Unit: kshs.

DESCRIPTION	UNIT	F.C	L.C.	TAX	DUTY	L.C. TOTAL	TOTAL
Cement	Ton	903.00	487.00	237.00	0	724.00	1,627.00
Reinforcement,High Tensil	kg	5.16	2.78	1.35	0	4.13	9.29
Reinforcement, Round	kg	4.97	2.68	1.30	0	3.98	8.95
Fuel, Diesel /3	Lit	3.20	0	1,98	0.44	2.42	5.62
Gasoline, Regular /4	Lit	4.28	0	3.52	0.65	4.17	8.45
Bitumen 80/100	kg	4.05	0	0.69	0.12	0.81	4.86
Bitumen MC 30	Lit	5.82	0	0.99	0.12	1.11	6.93
Bitumen Emulsion,KL 70	Lit	4.90	0	0.83	0.12	0.95	5.85
Explosive	kg	65.79	0	11.18	23.03	34.21	100.00
Detonator	PC.	11.84	0	2.01	4.15	6.16	18.00
Detonator,Delay	PC.	21.05	0	3.58	7.37	10.95	32.00
Timber, Cypress	m^3	0	3,035.00	516.00	0	3,551.00	3,551.00
Timber,Plain Board	m^3	0	3,800.00	646.00	0	4,446.00	4,446.00
Plywood	m^3	0	10,500.00	1,785.00	0	12,285.00	12,285.00
Wire	kg	10.00	5.38	2.62	0	8.00	18.00
Nail	kg	5.22	2.81	1.37	0	4.18	9.40
Channel Steel	Ton	8,093.00	4,357.00	2,177.00	0	6,474.00	14,567.00
Concrete Kerb 10"x5"x36"	PC.	0	33.00	5.61	0	38.61	38.61
Concrete Pipe 610mm	m	0	470.00	79.90	0	549.90	549.90
Concrete Pipe 915mm	m	0	910.00	154.70	0	1,064.70	1,064.70
Sand	m^3	123.20	67.20	-	33.60 /1	100.80	224.00
	Ton	88.00	48.00	-	24.00 /1	72.00	160.00
Aggregate	m^3	166.60	23.80	-	47.60 /2	71.40	238.00
	Ton	119.00	17.00	-	34.00 /2	51.00	170.00
Crusher-run	m^3	155.80	22.40	-	44.80 /2	67.20	224.00
	Ton	112.00	16.00	-	32.00 /2	48.00	160.00
Aggregate For Sealing	m^3	235.20	33.60	-	67.20 /2	100.80	336.00
	Ton	168.00	24.00	-	48.00 /2	72.00	240.00
Stone Dust	m^3	117.60	16.80	-	33.60 /2	50.40	168.00
	Ton	84.00	12.00	-	24.00 /2	36.60	120.00

NOTE: Rate of Duty and Sales Tax is Based on Import Licensing Schedules of July,1984 and Kenya Gazetti Supplement of June,1987. At August, 1987 price level. F.C. (Foreign Currency Portion) L.C. (Local Currency Portion)

/1: Tax and Duty are assumed at 15 percent of Unit Price. /2: Tax and Duty are assumed at 20 percent of Unit Price.

/3: Tax 1.9870 Kshs/Lit, Duty 0.4356 Kshs/Lit. /4: Tax 3.5140 Kshs/Lit, Duty 0.6534 Kshs/Lit.

Table VIII-6-3

Equipment Cost per Hour

Unit: Kshs.

Equipment	F.C.	L.C.	Tax	Duty	L.C. Total	Total
Bulldozer 21 ton	562.5	118.8	0	136.3	255.1	817.6
Bulldozer 11 ton	265.1	58.2	0	64.7	122.9	388.0
Bulldozer rpper 21 ton	645.7	136.4	0	156.4	292.8	938.5
Backhoe 0.2 m^3	200.1	40.5	0	48.1	88.6	288.7
Tractor shovel 2.3 m^3	430.3	90.9	0	104.2	195.1	625.4
Tractor shovel 1.6 m^3	337.8	68.3	0	81.2	149.5	487.3
Dump truck 11 ton	167.4	33.8	0	40.3	74.1	241.5
Dump truck 8 ton	125.5	25.4	0	30.2	55.6	181.1
Truck crane 20 ton	469.4	82.8	0	110.4	193.2	662.6
Crawler drill $10m^3$/min	301.1	54.8	0	71.2	126.0	427.1
Jack hammer 20 kg	101.3	9.3	0	22.1	31.4	132.7 (D)
Motor grader 3.7m	274.2	55.5	0	65.9	121.4	395.6
Macadam roller 10 ton	163.9	28.8	0	38.5	67.3	231.2
Tandem roller 10 ton	146.0	25.6	0	34.3	59.9	205.9
Tire roller 10-20 ton	179.6	31.6	0	42.2	73.8	253.4
Vibrating roller 0.5 ton	51.5	8.4	0	12.0	20.4	71.9
Vibrating roller 8-10 ton	424.8	83.9	0	101.8	185.7	610.5
Rammer, compactor 60-100 kg	126.5	18.2	0	28.9	47.1	173.6 (D)
Concrete plant $20m^3$/Hr	584.6	106.5	0	138.2	244.7	829.3
Agitator truck $3.2m^3$	170.1	34.3	0	40.9	75.2	245.3
Asphalt plant 60 ton/hr	1,911.8	348.7	0	452.1	800.8	2,712.6
Soil plant, 120 ton/hr	667.9	121.6	0	157.9	279.5	947.4
Asphalt finisher 2.4 to 5.0m	778.3	137.3	0	183.1	320.4	1,098.7
Distributor 4 kl	329.2	58.1	0	77.5	135.6	464.8
Engine sprayer 600 lit	666.7	80.1	0	149.4	229.5	896.2
Line marker	15.1	1.9	0	3.4	5.3	20.4
Water sprinkler 5.5 kl	115.1	23.3	0	27.7	51.0	166.1
Air compressor $10m^3$/min	1,247.4	220.1	0	293.5	513.6	1,761.0 (D)
Air compressor $13.5m^3$/min	1,547.0	273.0	0	364.0	637.0	2,184.0 (D)
Vibrating roller 4 ton	140.6	27.8	0	33.7	61.5	202.1
Concrete mixer $0.1m^3$	46.9	8.6	0	11.1	19.7	66.6 (D)
Concrete bucket $0.75m^3$	246.1	40.5	0	57.3	97.8	343.9
Concrete vibrator 50mm	62.5	7.5	0	14.0	21.5	84.0 (D)
Belt conveyor 10m	167.9	25.4	0	38.7	64.1	232.0 (D)

Note: Rate of duty and tax is based on Import Licensing schedule of July, 1984 and Kenya Gazetti Supplement of June, 1987. Duty is 20 percent of C.I.F price and tax is exempt. (D) means Daily cost.

At August, 1987 price level. F.C. (Foreign currency portion), L.C. (Local currency portion),

Table VIII-6-4

Unit Cost for Work Items

Unit: Kshs.

Work Item	Unit	F.C.	L.C.	Duty and Tax	Total
Clearing, grass and bush	ha	2,060.00	60.00	130.00	2,250.00
Clearing, light forest	ha	4,350.00	990.00	1,240.00	6,580.00
Removal of topsoil	m^3	10.00	2.20	2.80	15.00
Excavation, unsuitable soil	m^3	10.00	2.20	2.80	15.00
Excavation, surplus soil	m^3	10.00	2.20	2.80	15.00
Excavation, soil, upto 500m	m^3	24.40	3.70	6.90	35.00
Excavation, rock, upto 500m	m^3	74.20	10.80	25.00	110.00
Cross fill, side borrow	m^3	16.30	4.00	4.60	24.90
Cutting and filling, soil upto 1,000m	m^3	32.80	4.70	9.50	47.00
Cutting and filling, soil 2000m	m^3	39.10	7.40	11.50	58.00
Cutting and filling, weathered rock, upto 1000m	m^3	46.50	10.20	13.30	70.00
Cutting and filling, weathered rock, 2000m	m^3	53.20	11.50	15.30	80.00
Cutting and filling, rock upto 1000m	m^3	83.40	13.00	27.60	124.00
Cutting and filling, rock 2000m	m^3	89.90	14.30	30.80	135.00
Borrow filling, 7,000	m^3	43.90	8.20	12.90	65.00
Preparation of subgrade	m^2	1.90	0.50	0.50	2.90
Backfill	m^3	43.60	8.20	12.80	64.60
Slope protection, cut slope	m^2	0	6.50	0.40	6.90
Slope protection, embankment slope	m^2	3.30	7.10	1.30	11.70
Crusher-run subbase	m^3	262.30	40.40	74.90	377.60
Cement stabilized base	m^3	315.90	58.20	88.10	462.20
Bitumen emulsion prime cost	lit	7.00	1.20	1.40	9.60
Asphalt concrete surface	m^3	1,104.20	145.20	250.60	1,500.00
Concrete pipe, 600mm	m	40.90	610.10	106.30	757.30
Concrete drain pit	No.	1,950.00	2,260.00	730.00	4,940.00
Concrete pipe, 900mm	m	52.80	1,164.50	198.20	1,415.50
Inlet/outlet	No.	15,170.00	34,470.00	8,350.00	57,990.00
Drain ditch	m	91.80	37.90	26.20	155.90
Standard regulatory signs	No.	0	1,600.00	272.00	1,872.00
Standard warning signs	No.	0	1,200.00	204.00	1,404.00
Standard mandatory signs	No.	0	1,200.00	204.00	1,404.00
Standard hazard signs	No.	0	1,100.00	187.00	1,287.00
Permanent informatory signs	No.	0	3,000.00	510.00	3,510.00

Table VIII-6-4(cont'd)

Unit Cost for Work Items

Unit: Kshs.

Work Item	Unit	F.C.	L.C.	Duty and Tax	Total
Guard rails	m	400.00	80.00	188.00	668.00
Road marking lines	m	9.30	0.60	5.10	15.00
Planting	m^2	3.30	7.10	1.30	11.70
Concrete kerb	m	0	28.00	6.40	44.40
Concrete, for culvert	m^3	746.40	314.00	208.60	1,269.00
Concrete bedding	m^3	637.00	269.10	175.10	1,081.20
Formwork	m^2	34.70	120.20	25.60	180.50
Reinforcement	kg	6.30	4.20	1.70	12.20
Structural steel	ton	7,800.00	6,600.00	2,040.00	16,440.00
Supporting	m^3	21.20	11.60	11.10	43.90
Scaffolding	m^2	1.40	27.50	3.40	32.30
Excavation common, for structure	m^3	24.40	3.70	6.90	35.00
Excavation, rock for structure	m^3	74.20	10.80	25.00	110.00
Backfill	m^3	32.80	4.70	9.50	47.00
Joint filler	m^2	113.50	7.30	53.30	174.10
Masonry	m^2	183.90	99.60	56.50	340.00
Foundation concrete for masonry	m^3	637.00	269.10	175.10	1,081.20
Water stop	m	124.40	10.80	58.40	193.60
Concrete, slab for bridge	m^3	810.20	295.70	255.10	1,331.00
Concrete, abutment	m^3	691.40	291.60	197.10	1,180.10
Expanstion joint	m	4,100.00	205.00	1,927.00	6,232.00
Handrail	m	2,900.00	145.00	1,363.00	4,408.00
Rubber shoe	No.	500.00	25.00	235.00	760.00
Steel shoe	No.	12,000.00	600.00	5,640.00	18,240.00
Asphalt pavement, 50mm	m^2	55.20	7.30	12.50	75.00
Temporary steel support	ton	3,900.00	9,300.00	1,020.00	14,220.00

Note: At August, 1987 price level, F.C. (Foreign currency portion)
L.C. (Local currency portion)
Exchange rate 1 U.S. $ = 16 Kshs.

f) Direct Construction Cost

The direct construction costs for site clearing and topsoil stripping, earthwork, pavement work, drainage work, road furniture, box culvert and bridge are estimated based on the above unit prices. The general cost is estimated at 5 percent of the sum of the above work items for the direct cost.

The direct construction cost (contract cost) is estimated at Kshs.338.86 million in total, comprising Kshs.204.39 million for foreign currency (60.3%) and Kshs.134.47 million for local currency (39.7%). The direct construction cost is tabulated in Table VIII-6-5 and VIII-6-6.

(2) Engineering Services

The cost for the engineering services for detailed design and supervision is estimated at 10 percent of the direct construction cost. The cost of engineering services includes the cost of physical contingency.

(3) Land Acquisition and Compensation

All required land acquisition and compensation shall be acquired by the MOTC in accordance with the project implementation schedule. The cost of land acquisition and compensation is estimated at Kshs.22.8 million based on the information from the Ministry of Land.

(4) Contingency

The contingency is provided to cope with unforeseen physical conditions and price escalation due to inflation. The physical contingency amounting to 10 percent of the direct construction cost is applied for both foreign and local portions.

The price escalation is estimated by applying the inflation rate of 2 percent per annum for foreign currency portion and 10 percent per annum for local currency portion. These escalation rates are referred to in "International Financial Statistics 1987", "Economic Survey 1987, Kenya" and "Statistical Abstract 1986, Kenya". The cost of price escalation is estimated over 4.5 years including detailed design and on the basis of expected disbursement schedule.

(5) Construction Cost

The total construction cost is estimated at Kshs.516.43 million, comprising Kshs.263.71 million for foreign currency portion (51.1%) and Kshs.252.72 million for local currency portion (48.9%).

The total construction cost is summarised as follows and is tabulated in Table VIII-6-5 and VIII-6-6.

The detailed construction cost is listed in Table VIII-6-7.

	Description	Foreign Currency (Million Kshs)	Local Currency (Million Kshs)	Total (Million Kshs)
1.	Direct construction Cost	204.39	134.47	338.86
2.	Engineering Services	20.44	13.44	33.88
3.	Land acquisition and compensation	0	22.81	22.81
4.	Physical contingency	20.44	13.44	33.88
	Sub-total (1 to 4)	245.27	184.16	429.43
5.	Price escalation	18.44	68.56	87.00
	Total	263.71	252.72	516.43

The detailed construction cost is attached in Appendix VIII-6.

Table VIII-6-5

Summary of Construction Cost

Unit: 1,000 Kshs.

Description		Foreign Currency	Local Currency	Total
1.	Direct Construction Cost			
1.1	General	0	16,136	16,136
1.2	Site clearing and topsoil stripping	2,962	1,410	4,372
1.3	Earthwork	59,976	31,267	91,243
1.4	Pavement work	110,325	44,956	155,281
1.5	Drainage work	2,802	9,163	11,965
1.6	Road Furniture	6,440	11,026	17,466
1.7	Box Culvert	14,035	12,871	26,906
1.8	Bridge	7,848	7,640	15,488
	Sub-total (1.1 to 1.8)	204,388	134,469	338,857
2.	Engineering Services			
	Detailed design, supervision and administration	20,439	13,447	33,886
3.	Land Acquisition and Compensation	0	22,805	22,805
4.	Physical Contingency	20,439	13,447	33,886
	Total (1 to 4)	245,266	184,168	429,434
5.	Price Escalation	18,443	68,556	86,999
	Grand Total	263,709	252,724	516,433

Table VIII-6-6

Summary of Detailed Construction Cost

Unit: 1000 Kshs.

Description	Foreing Currency	Local Currency			Total
		Local Portion	Duty and Tax	Sub-total	
1. Direct Construction Cost					
1.1 General	0	12,909	3,227	16,136	16,136
1.2 Site clearing and topsoil stripping	2,962	619	791	1,410	4,372
1.3 Earthwork	59,976	13,267	18,000	31,267	91,243
1.4 Pavement	110,325	16,803	28,153	44,956	155,281
1.5 Drainage work	2,802	7,428	1,735	9,163	11,965
1.6 Road furniture	6,440	7,069	3,957	11,026	17,466
1.7 Box culvert	14,035	8,675	4,196	12,871	26,906
1.8 Bridge	7,848	4,948	2,692	7,640	15,488
Sub-total	204,388	71,718	62,751	134,469	338,857
2. Engineering services Detailed design, supervision and administration	20,439	7,172	6,275	13,447	33,886
3. Land Acquisition and Compensation	0	22,805	0	22,805	22,805
4. Physical Contingency	20,439	7,172	6,275	13,447	33,886
Total (1 to 4)	245,266	108,867	75,301	184,168	429,434
5. Price Escalation	18,443	40,526	28,030	68,556	86,999
Grand Total	263,709	149,393	103,331	252,724	516,433

Table VIII-6-7

Breakdown of Direct Construction Cost

Unit: Kshs.

Description		Foreign Currency	Local Currency	Total
1.	General	0	16,136,000	16,136,000
2.	Section I			
2.1	Site clearing and topsoil stripping	827,250	382,125	1,209,375
2.2	Earthwork	14,680,758	7,545,698	22,226,456
2.3	Pavement work	26,350,416	10,699,130	37,049,546
2.4	Drainage work	466,128	1,689,569	2,155,697
2.5	Road furniture	2,193,373	3,082,690	5,276,063
2.6	Box Culvert	0	0	0
2.7	Bridge	4,423,104	3,879,283	8,302,387
	Sub-total (2.1 to 2.7)	48,941,029	27,278,495	76,219,524
3.	Section II			
3.1	Site clearing and topsoil stripping	1,030,005	517,329	1,547,334
3.2	Earthwork	13,422,639	7,152,367	20,575,006
3.3	Pavement work	32,266,902	13,151,080	45,417,982
3.4	Drainage work	860,886	3,026,428	3,887,314
3.5	Road furniture	2,043,713	3,373,298	5,417,011
3.6	Box culvert	947,164	964,542	1,911,706
3.7	Bridge	2,148,182	1,838,457	3,986,639
	Sub-total (3.1 to 3.7)	52,719,491	30,023,501	82,742,992

Table VIII-6-7 (Cont'd)

Breakdown of Direct Construction Cost

Description	Foreign Currency	Local Currency	Total
4. Section III			
4.1 Site clearing and topsoil stripping	408,110	188,515	596,625
4.2 Earthwork	5,818,634	3,115,865	8,934,499
4.3 Pavement work	19,740,734	8,057,484	27,798,218
4.4 Drainage work	572,188	1,931,909	2,504,097
4.5 Road furniture	555,105	1,504,488	2,059,593
4.6 Box Culvert	3,178,327	2,910,371	6,088,698
4.7 Bridge	0	0	0
Sub-total (4.1 to 4.7)	30,273,098	17,708,632	47,981,730
5. Section IV			
5.1 Site clearing and topsoil stripping	696,696	321,804	1,018,500
5.2 Earthwork	26,054,032	13,452,823	39,506,855
5.3 Pavement work	31,967,173	13,047,439	45,014,612
5.4 Drinage work	903,412	2,514,896	3,418,308
5.5 Road furniture	1,647,467	3,066,242	4,713,709
5.6 Box Culvert	9,909,740	8,995,787	18,905,527
5.7 Bridge	1,276,182	1,923,294	3,199,476
Sub-total (5.1 to 5.7)	72,454,702	43,322,285	115,776,987
Total (1 to 5)	204,388,320	134,468,913	338,857,233

VIII.6.2 Annual Disbursement Schedule

The annual disbursement is estimated according to the construction schedule and summarised as follows. The disbursement schedule of the construction cost is taburated in Table VIII-6-8.

Year	Foreign Currency (Million Kshs)	Local Currency (Million Kshs)	Total (Million Kshs)
1st Year	6.60	4.52	11.12
2nd Year	2.95	28.51	31.46
3rd Year	18.54	35.51	54.05
4th Year	147.73	118.27	266.00
5th Year	87.89	65.91	153.80
Total	263.71	252.72	516.43

Table VIII-6-8

Disbursement Schedule

Unit: 1,000 Kshs.

Description	Construction Cost			1st Year		2nd Year		3rd Year		4th Year		5th Year	
	F.C	L.C	Total	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C	F.C	L.C
1. Direct Construction - Cost.	204,388	134,469	338,857	0	0	0	0	14,875	24,394	119,595	73,175	69,918	36,900
2. Engineering-Services	20,439	13,447	33,886	6,541	4,302	2,861	1,883	1,280	843	6,280	4,132	3,477	2,287
3. Land Acquisition-and Compensation	0	22,805	22,805	0	0	0	22,805	0	0	0	0	0	0
4. Physical Contingency	20,439	13,447	33,886	0	0	0	0	1,488	2,439	11,959	7,318	6,992	3,690
Total (1-4)	245,266	184,168	429,434	6,541	4,302	2,861	24,688	17,643	27,676	137,834	84,625	80,387	42,877
5. Price Escalation	18,443	68,556	86,999	65	215	86	3,827	896	7,838	9,896	33,638	7,500	23,038
Total (1-5)	263,709	252,724	516,433	6,606	4,517	2,947	28,515	18,539	35,514	147,730	118,263	87,887	65,915

VIII.6.3 Maintenance Cost

The road maintenance cost is estimated for the following items: Annual routine maintenance cost and periodical maintenance cost. The annual maintenance cost consisting of cleaning cost and repairing cost is estimated based on the "BREAKDOWN OF ROAD MAINTENANCE RATES FOR 1987/88 FINANCIAL YEAR, MOTC". While the periodical maintenance cost for overlays is estimated at intervals of 5 years after the completion of the construction.

- Annual routine maintenance cost: 6,600 Kshs/km/year is adopted for single carriage road. The maintenance rate is reflected by the level of financial allocation from the Treasury (Ministry of Finance). The main road is planned to be a dual carriage road and the ramp is to be a single carriage road. Therefore, the annual routine maintenance cost if estimated below:

  Main road

  6,600 Kshs/km/year x 2 x 29.220km = Kshs.385,700

  Ramp (slipway)

  6,600 Kshs/km/year x 1 x 4.365km = Kshs.28,800

  Sub-total Kshs.414,500/year

- Periodical maintenance cost:

  The periodical maintenance cost is estimated at the overlays cost after 5 years, 10 years and 15 years.

  The overlays are planned to be 35mm thick asphalt pavement at intervals of 5 years. Therefore, each overlay cost is estimated below:

Main Road

$1{,}500$ Kshs/m^3 x 0.035m x 7m x 2 x 29,220m
= Kshs.21,476,700

Ramp (1-lane)

$1{,}500$ Kshs/m^3 x 0.035m x 4m x.3,345m
= Kshs.702,500

Ramp (2-lane)

$1{,}500$ Kshs/m^3 x 0.035m x 6m x 1,020m
= Kshs.321,300

Sub-total Kshs.22,500,500/each

Period	Periodical Maintenance
After 5 years	Kshs.22,500,500
After 10 years	Kshs.22,500,500
After 15 years	Kshs.22,500,500

IX. Economic Assessment

IX. Economic Assessment

The procedure of the Economic Assessment is illustrated in Fig. IX.1.

IX.1 Economic Cost Estimate

IX.1.1 Initial Capital Investment Cost

516,433,000 Shillings as the initial investment cost was estimated including the cost of land acquisition and compensation, based on the preliminary design in the financial term of August 1987 as described in VIII.6.
Approximately 17,670,000 Shillings 1/ per km is considered to be reasonable for a dual-carriage way for 29.22 km long Bypass with grade separation of main junctions having an additional 4.4 km of ramp way, based on financial cost estimate.

As for land acquisition, about 50% of the right of way is either owned by the Government or has already been purchased by the authority concerned, which is ignored in the cost estimate.
15.7 Shillings per m^2 is adopted to estimate the land acquisition cost for the right of way as 60m wide and 32.54 km long, which amounts to 15,310 x 10^3 Shill., while compensation is 7,500 x 10^3 Shill.

Financial cost of 516,433 x 10^3 Shill. is to be converted into economic cost for the economic analysis using the following procedures:

(1) Deduction of land acquisition cost for the right of way

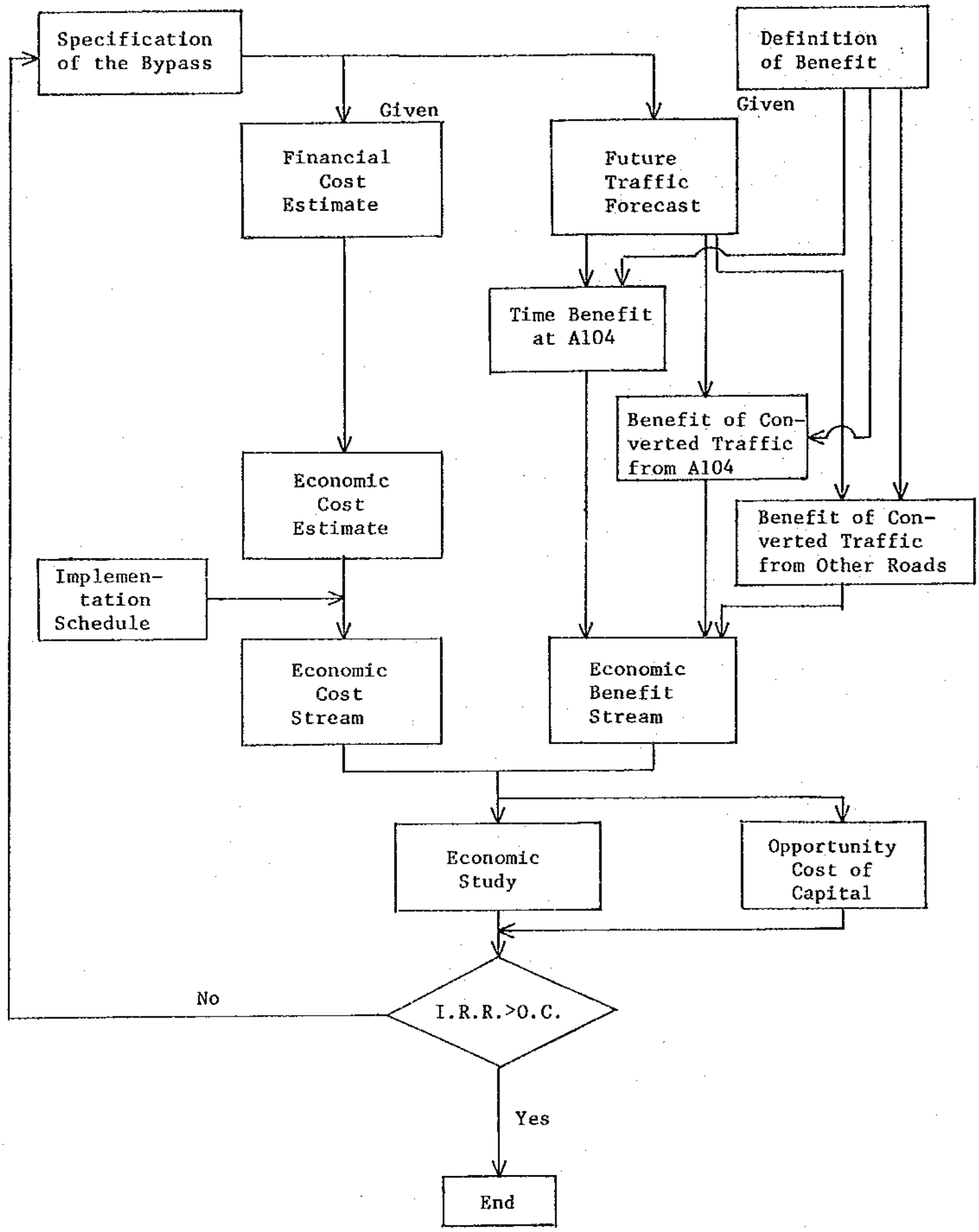
It is generally accepted that the amount of land acquisition cost is not included in the economic cost for the following reasons:

a) After the project life, residual value is calculated, considering the existence of land.

b) Utility of the land, due to the construction of the road will rise with the project and at least the same amount of opportunity benefit of the land will be realized going aside the project road.

1/: length of Bypass plus 1/2 length of ramp way

Fig. IX-1 Flow Chart for Economic Assessment



Thus, it is considered that the portion of land acquisition cost for the right of way belongs to the category of transfer item. $15,310 \times 10^3$ Shill. is included in the financial cost.

Then, initial investment cost becomes $501,123 \times 10^3$ Shill. after the deduction.

(2) Deduction of Tax and Duty

Adjustments are required to be made for sales tax and other indirect taxes. Similarly, licence fees and import duties have to be discounted.

For this purpose $75,300 \times 10^3$ Shill. was estimated, based on cost estimate, which is about 18.5% of direct construction cost, engineering services and physical contingency, and so that appropriate deductions are applied.

Then, adjusted initial investment cost becomes $425,823 \times 10^3$ Shill. after deduction.

(3) Adjustment by the Shadow Price of Unskilled Labour

The economy is still marked by the intensity of unemployment. The real cost of the economy is actually less than the actual wage rate.

This in turn justifies the actual wage payment being more than the calculated cost of unskilled labour.

Based on the cost estimate, the wage bill is estimated as 5% of direct construction cost and 30% of the wage bill is considered as of unskilled labour, which amounts to $3,000 \times 10^3$ Shill. Shadow Price of unskilled labour wage bill is supposed as 15% cheaper than nominal wage bill.

15% was assessed, based on the non-working hour ratio in 8 hour working days.

Then 3,000 x 10^3 Shill. x 0.15 = 450 x 10^3 Shill. .
After deduction, adjusted initial investment cost becomes
425,373 x 10^3 Shill.

(4) Exemption of Price Escalation

Financial cost estimated in VIII.3 includes the price escalation portion during the implementation period with 10% per annum for domestic currency portion and 2% per foreign currency portion.

There is the serious discussion in Transport economics whether price escalation is to be included or not for economic cost.

Here it is adopted that the portion of price escalation is to be exempted for the conversion from financial cost to economic cost, which amounts to 86,999 x 10^3 Shill. However, it should be noted that some amount of price change is to be added in order to offset the discount to the initial year during the implementation period.

After the deduction above, adjusted initial investment cost becomes 338,374 x 10^3 Shill.

Although there is the serious discussion that the official exchange rate does not reflect the scarcity value of foreign currency. As described in II.5, Shadow Price of foreign exchange rate is not adopted in the Study. As the result, 338,374 x 10^3 Shill. is adopted as the economic initial capital investment cost.

IX.1.2 Maintenance Cost

13,200 Shill. per km/ year for dual-carriage way and 6,600 Shill. per km/ year for ramps are adopted in financial term, assessed at cost estimate in VIII.3.

Total financial maintenance cost per year is converted into economic maintenance cost with 65.5% as the rate between financial initial investment cost and economic initial investment cost.

Then, total financial maintenance cost 414,500 Shill. becomes 271,498 Shill. as economic maintenance cost.

Periodical maintenance cost is estimated for the overlay after each 5 years, which amounts to 22,500 x 10^3 Shill..

Financial periodical maintenance cost is to be converted into economic periodical maintenance cost, which amounts to 14,738 x 10^3 Shill.

IX.1.3 Implementation Schedule

The construction of the Bypass is under study. Therefore, the hypothetical implementation schedule was formulated as the construction of Bypass is to start in 1988 with detail design and to finish in 1992 and to start being utilized in 1993, with partial utilization of 42% in 1992.
11,044 x 10^3 Shill. is allocated to detail design in 1988 and 1989, which is 40% of the engineering service.

It is also allocated that the rest of the cost is shared as 0.5% to 2nd project year, 11.5% to 3rd project year, 56.5% to 4th project year and 31.4% to 5th project year, based on cost estimate.

For the construction period, 5% of construction material price change is adopted as the contractor manages properly to mitigate the damage of price escalation, although the price escalation has been more than 10% in previous years.

Herewith, 57,222 x 10^3 Shill. is estimated as the price change during the implementation period, therefore initial capital investment cost in Table IX-1-1 becomes 395,596 x 10^3 Shill. besides the economic initial capital investment cost is 338,374 x 10^3 Shill.

25% of initial capital investment cost in economic term is calculated as the residual value in the Study.

IX.1.4 Economic Cost Stream

The economic cost stream is shown in Table IX-1-1.

Table IX-1-1

Economic Cost Stream

Unit: Economic, mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Initial Capital Investment Cost	Maintenance Cost	Total Cost	Discounted by 12% 1/
1	1988	4,418	0	4,418	4,418
2	89	8,263	0	8,263	7,378
3	90	41,479	0	41,479	33,067
4	91	214,092	0	214,092	152,386
5	92	127,344	0	127,344	80,929
6	93	0	272	272	154
7	94	0	272	272	138
8	95	0	272	272	123
9	96	0	272	272	110
10	97	0	14,738	14,738	5,315
11	98	0	272	272	88
12	99	0	272	272	78
13	2000	0	272	272	70
14	1	0	272	272	62
15	2	0	14,738	14,738	3,016
16	3	0	272	272	50
17	4	0	272	272	44
18	5	0	272	272	40
19	6	0	272	272	35
20	7	0	14,738	14,738	1,711
		△ 84,344 2/		△ 84,344	△ 9,793
Σ	20	311,252 3/	47,478	358,730	279,419

1/ : Opportunity cost of capital, See IX.3.1

2/ : Residual value, △ : Minus

3/ : Included price change

IX.2 Economic Benefit Estate

IX.2.1 Definition of Benefit

The benefit accruing from the construction of the Nairobi Bypass will not only bolster Kenya's economy, but also that of neighbouring countries as the Bypass is part of Trans-African Highway. It will also greatly benefit the inhabitants of Nairobi who are suffering from the traffic congestion on the City's route.

Of the various types of benefits, only the benefits which can be quantified logically from the direct benefits are adopted for the benefit calculation in the Study.

Potential benefits can be considered as follows:

(1) The difference between Vehicle Operating Costs in the case of using A104 and the Bypass.

(2) The difference between required passing times in the case of using A104 and the Bypass.

(3) The difference between of required passing time with and without the Bypass at A104, due to convert the substantial volume of through-traffic to the Bypass.

(4) The deduction of maintenance cost at A104, due to the conversion of the traffic, especially heavy commodity vehicle to the Bypass.

(5) The reduction of cost, based on the difference of using brake, speed change and starting between the traffic using Bypass and that using A104.

(6) The benefit accruing from induced traffic, based on the level of service on the Bypass construction.

(7) The benefit related to the changing traffic pattern of specified O-D, due to the level of service on the Bypass construction.

It should be noted that there exists a substantial amount of benefit in the decrease of traffic accidents, the promotion of comfort, the decrease of driver fatigue and the economization of package cost among the direct cost, however those are to be included in qualitative benefit because of the difficulty of quantification and the lack of data.

Above items, (1), (2) and (3) are adopted for the benefit calculation in the Study.

However, the items from (4) to (7), were neglected, but should be included for the benefit calculation if they can be quantified logically.

IX.2.2. Calculation of Vehicle Operating Cost

Vehicle Operating Cost is the consumption of national resources used when vehicle is run.

V.O.C. consists of fuel cost, lubricating oil cost, tyre cost, maintenance cost, depreciation cost and personnel cost.

In the Study, V.O.C. is to be adjusted by several road factors, based on the figures by standard V.O.C. to calculate the benefit.

Fundamental formula is as follow:

$$V.O.C._j = \sum_{i=1}^{6} C_i$$

whereas,

$V.O.C._j$	:	vehicle operating cost of j type of vehicles
C_1	:	fuel cost
C_2	:	lubricating oil cost
C_3	:	type cost
C_4	:	maintenance cost
C_5	:	depreciation cost
C_6	:	personnel cost

Here, V.O.C. is to be tabulated by types of vehicle, speed, slope of roads and condition of roads with the cost per km in economic term.

Table IX-2-2-1 and IX-2-2-2 are the V.O.C.s to be used for the benefit calculation in the Study, which have been tabulated with the procedures listed in Appendix IX-2-2.

Whereas,

P.V.	:	passenger vehicle
L.P. & C.V. (L.V.)	:	light passenger & commodity vehicle
M.C.V.(M.V.)	:	medium commodity vehicle
H.C.V.(H.V.)	:	heavy commodity vehicle

It is considered that Tables of V.O.C.s before (Table, IX-2-2-1) and after adjustment (Table, IX-2-2-2) identify the differential of service level due to the road surface and road engineering standard, which can not be reflected in the running speed.

The ratios (Table IX-2-1 to Table IX-2-2) are adopted, based on the data of "Survey on direct benefit due to road improvement", Japan's Ministry of Construction, Department of Roads, 1981, which are applied to normal A class road applicable to the Bypass (Table IX-2-1) and below the maintenance A class road applicable to A104 (Table IX-2-2).

Ratios of Adjustment

P.V.	L.V.	Bus	M.V.	H.V.
1.09	1.21	1.18	1.22	1.22

Refer to Appendix A-IX-1, which explains in detail the procedure for estimating V.O.C.

Table IX-2-1

V.O.C. by Types of Vehicle , Slope and Speed

Unit: Cent

Type of Vehicle	Slope	Speed (km/hr)							
		10	20	30	40	50	60	70	80
P.V.	0°	284	273	269	267	266	266	265	265
	1°	292	280	284	282	280	277	277	276
	2°	262	299	306	304	296	294	294	294
	3°	327	314	318	315	312	310	307	306
	4°	343	329	336	333	327	324	322	321
	5°	360	345	355	352	346	340	338	337
L.V.	0°	304	303	298	295	294	292	292	291
	1°	311	311	320	312	308	305	305	304
	2°	333	332	344	335	327	324	324	324
	3°	349	348	357	348	343	339	337	337
	4°	366	365	378	368	362	356	354	353
	5°	384	383	399	389	381	375	371	371
Bus	0°	516	465	448	439	434	430	428	426
	1°	529	476	473	463	456	449	447	445
	2°	566	509	509	499	482	477	476	474
	3°	594	535	528	518	508	499	495	493
	4°	623	561	558	547	534	525	519	517
	5°	653	589	590	579	563	552	545	543
M.C.V.	0°	606	555	539	530	524	521	519	517
	1°	621	569	569	559	551	544	542	540
	2°	664	608	612	602	584	577	577	575
	3°	697	638	636	625	614	604	600	598
	4°	731	669	672	660	646	635	630	627
	5°	765	702	710	698	681	668	661	658
H.C.V.	0°	636	582	563	554	549	545	542	541
	1°	652	596	595	585	676	569	567	565
	2°	697	637	640	630	611	603	603	601
	3°	732	669	665	654	642	632	627	625
	4°	767	701	702	691	676	664	658	656
	5°	804	735	742	730	712	699	691	689

Table IX-2-2

V.O.C. after Service Level Adjustment by Types of Vehicle,Slope and Speed

Unit: Cent

Type of Vehicle	Slope	Speed (km/hr)							
		10	20	30	40	50	60	70	80
P.V.	0°	310	298	293	291	290	290	289	289
	1°	318	305	310	307	305	302	302	301
	2°	286	326	334	331	323	320	320	320
	3°	356	342	347	343	340	338	335	334
	4°	374	359	366	363	356	353	351	350
	5°	392	376	387	384	377	371	368	367
L.P.&.C.V.	0°	386	367	361	257	356	353	353	352
	1°	376	376	387	378	373	369	369	368
	2°	403	402	416	405	396	392	392	392
	3°	422	421	432	421	415	410	408	408
	4°	443	442	457	445	438	431	428	427
	5°	465	463	483	471	461	454	449	449
Bus	0°	609	549	529	518	512	507	505	503
	1°	624	562	558	546	535	530	527	525
	2°	668	601	601	589	569	563	562	559
	3°	701	631	623	611	599	589	584	582
	4°	735	662	658	645	630	620	612	610
	5°	771	695	696	683	664	651	643	641
M.C.V.	0°	739	677	658	647	639	636	633	631
	1°	758	694	694	682	672	664	661	659
	2°	810	742	747	734	712	704	704	702
	3°	850	778	776	763	749	737	732	730
	4°	892	816	820	805	788	775	769	764
	5°	933	856	866	852	831	815	806	803
H.C.V.	0°	776	710	687	676	670	665	661	660
	1°	705	727	726	714	725	794	744	689
	2°	850	777	781	769	745	736	736	733
	3°	893	816	811	798	783	771	765	763
	4°	936	855	856	843	825	810	803	800
	5°	981	897	904	891	869	853	843	841

IX.2.3 Estimation of Time Value

It has been established that the benefit, accruing from time saving due to improvement of the service level of transport infrastructure is the most important component for benefit calculation in terms of estimating incremental value-added if utilizing the saving time for work.

Here, the time values are estimated separately for the passengers of passenger vehicles and the passengers of mass-transit as bus.

The attendants of commodity vehicles and mass-transit are not included for benefit calculation related to the matters as it is reflected in the Vehicle Operating Cost.

Fundamental formula to calculate the time value is as follow:

$$V = \frac{Y}{P \times H} \times S$$

Whereas,

- V: time value
- Y: income
- P: numbers of working persons
- H: working hours
- S: saved time

Time values differ by the type of income groups and trip purpose as follows:

(1) The passenger for passenger vehicle

a) Working hour

Monthly income x 12/ daily working hours x weekly working days x monthly working weeks x yearly working months x 60

$$\frac{6{,}000 \times 12}{8 \times 5 \times 4 \times 11 \times 60} = 68 \text{ cents/minute}$$

whereas, 6,000 shillings is adopted as the highest income group listed in Central Bureau of Statistics, Statistical Abstract.

b) Non-working hours

working time value x 0.6 = 41 cents/minute

whereas, 60% is estimated by the figure of Value time/ Time saving in Coba.

(2) The passenger for mass-transit

a) Working hour

$$\frac{1{,}500 \times 12}{8 \times 5 \times 4 \times 11 \times 60} = 17 \text{ cents/minute}$$

whereas, 1,500 shiilings is adopted as the present mean of Kenya's income group.

b) Non-working hour

$$\frac{189.31 \times 20}{8 \times 5 \times 4 \times 11 \times 60} = 4 \text{ cents/minute}$$

where 189.31 was the GDP/capita, K£ in 1984.

IX.2.4 Economic Benefit Stream

As for the assessment of project viability, economic benefit stream was established, based on the following 3 items discussed on the definition of IX.2.1.

a) The benefit of A104's remaining traffic as the differential of required passing time to pass through the link (hereinafter, required time) with and without project due to speed up accrued from the conversion of through-traffic from A104 to Bypass

b) The benefit of through-traffic as the differential of V.O.C. and required time due to convert from A104 to Bypass.

c) The benefit of converted traffic converting from other routes except A104 to Bypass

In order to calculate the figures of benefit, future traffic forecast described in VI, unit indices for benefit as V.O.C. and time value described in IX.2.1 and IX.2.2 as well as the speeds of vehicles which were assessed, based on design speed, considering the legal speed limit, the quantity·velocity curve and the capacity of superstructure, were adopted.

Initial average running speeds selected, based on above items

Km/hr

	South - North West		North West - South	
	P.V.	others	P.V.	others
A104	60	50	70	60
Bypass	70	60	80	70

Adjustment Factors

i) Congestion rate

less than 1	0 km/hr
$1 \leqq$ C.R. < 1.2	-10 km/hr
$1.2 \leqq$ C.R. $\leqq 1.5$	-20 km/hr
more than 1.5	-30 km/hr

ii) Degree

less than 1°	0 km/hr
$1° \leqq d \leqq 2°$	-5 km/hr
more than 2°	-15 km/hr

(1) Benefit Calculations are summarized as follows and detailed procedure of calculation is shown in Appendix IX.2.

The benefit of required time differential on A104

a) 1991 year

- $P.V._{1991}$ = 59.09 cent x 1.8 x 365 $\sum T_p \cdot d_i$ = 8,013,392
- Bus_{1991} = 12.71 cent x 55.8 x 365 $\sum T_b ld_i$ = 3,121,389
- $Matatu_{1991}$ = 12.71 cent x 22.5 x 365 $\sum T_m \cdot d_i$ = 1,724,581

Total 12,859 x 10^3 Shill.

whereas, 59.09 : time value of passenger traffic per minutes, considering working trip 2/3, non-working trip 1/3, cent

1.8 : average apasengers per passenger vehicle, person

365 : days a year

T_p : number of traffic, passenger vehicles

d_i : differential of required time with and without Bypass by link

12.71 : time value per person of bus and matatu passenger, considering 2/3 working trip, 1/3 non-working trip cent

55.8 : 90% occupancy rate of 62 seats bus, persons

22.5 : 90% occupancy rate of 25 seats matatu, persons

b) 2000 year

- $P.V._{2000}$ = 59.09 cent x 1.8 x 365 $\sum T_p . d_i$ = 12,421,063
- Bus_{2000} = 12.71 cent x 55.8 x 365 $\sum T_b . d_i$ = 6,700,192
- $Matatu_{2000}$ = 12.71 cent x 22.5 x 365 $\sum T_m . d_i$ = 5,387,932

Total 24,509 x 10^3 Shill.

Differentials of required time are listed in Table IX-2-4. The benefits between 1991 and 2000 are to be extrapolated with average growth rate. After 2000, 4% growth rate is adopted.

(2) The benefit of converted traffic from A104

Due to the construction of the Bypass, through-traffic would possibly divert from A104 to the Bypass, thus the differentials of required time in the case of using A104 and Bypass, and of V.O.C. in the case of using A104 with the V.O.C. listed in by speed, slope and service level and using the Bypass with the V.O.C listed in.

The distance of A104 and the Bypass are 25.4 km and 29.22 km respectively.

a) 1991 year

$$- V.O.C._{1991}^{A104} = 365\ di \sum T_{ij} . V.O.C._i = \begin{pmatrix} 90,230,154 \\ 84,513,560 \end{pmatrix} \text{ Shill.}$$

whereas, T_{ij} : traffic of i type of vehicle at j link

$V.O.C._i$: V.O.C. of i type of vehicle with speed, slope and service level

a_1 : a_1, from South to North West

a_2 : a_2, from North West to South

di : length of link

Total 174,743,714 Shill.

$$- V.O.C.^{Bypass}_{1991} = 365\ di \sum T_{ij}.V.O.C._{i} = \begin{pmatrix} 81,074,202 \\ 80,878,635 \end{pmatrix} \text{ Shill.}$$

Total 161,952,837

- Time $Benefit_{1991}$

$$P.V._{1991} = 59.09 \times 1.8 \times 365 \sum T_p.d_p = \begin{pmatrix} 1,066,710 \\ 261,050 \end{pmatrix} \text{ Shill.}$$

$$Bus_{1991} = 12.71 \times 55.8 \times 365 \sum T_b.d_b = \begin{pmatrix} 274,955 \\ 85,848 \end{pmatrix} \text{ Shill.}$$

whereas, d_p : differential of required time in the case of uisng the Bypass and A104 by passenger vehicle

d_b : differential of required time in the case of using the Bypass and A104 by Bus

Total 1,688,563 Shill.

b) 2000 year

$$- V.O.C.^{A104}_{2000} = 365\ di \sum T_{ij}.V.O.C._{i} = \begin{pmatrix} 139,004,045 \\ 121,886,640 \end{pmatrix} \text{ Shill.}$$

Total 260,890,685 Shill.

$$- V.O.C.^{Bypass}_{2000} = 365\ di \sum T_{ij}.V.O.C._{i} = \begin{pmatrix} 109,997,276 \\ 109,764,917 \end{pmatrix} \text{ Shill.}$$

Total 219,762,193 Shill.

- Time $Benefit_{2000}$

$$P.V._{2000} = 59.09 \times 1.8 \times 365 \sum T_p.d_p = \begin{pmatrix} 3,343,035 \\ 1,360,538 \end{pmatrix} \text{ Shill.}$$

$$Bus_{2000} = 12.71 \times 55.8 \times 365 \sum T_p.d_b = \begin{pmatrix} 558,304 \\ 232,432 \end{pmatrix} \text{ Shill.}$$

Total 5,494,309 Shill.

Therefore, the benefits after the aggregation of the above items of 1991 and 2000 become as follows:

a) 1991 year

	$V.O.C._{1991}^{A104}$	174,743,714	
	$V.O.C._{1991}^{Bypass}$	161,952,837	
−)			
		12,790,877	
	Time Benefit 1991	1,688,563	
+)			
	Total	14,479,440	Shill.

b) 2000 year

	$V.O.C._{2000}^{A104}$	260,890,685	
	$V.O.C._{2000}^{Bypass}$	219,762,193	
−)			
		41,128,492	
	Time Benefit 2000	5,494,309	
+)			
	Total	46,622,801	Shill.

The benefits between 1991 and 2000 are to be extrapolated with average growth rate. After 2000, a 4% growth rate is adopted.

(3) The benefit of converted traffic to Bypass excluding the converted traffic as of (2).

The unit benefits are defined as the same amount of the unit benefits accruing from the converted traffic from A104 to the Bypass, calculated in above (2).

Due to the higher service level of the road (Bypass), compared to other roads, substantial amounts of traffic are supposed to divert to the Bypass expecting the minimum pass, minimum time pass and/or comfort of driving by the driver's choice, which can not be fully assessed as to how the V.O.C. and required time differ with and without the Bypass, thus this method was adopted.

Unit benefit for the converted traffic by types of vehicle per km·vehicle were calculated, based on the benefit of (2) considering 29.22 km of Bypass, which was adopted for both directions, and listed below.

Year	P.V.1/	L.V.	Bus1/	M.V.	H.V.
1991	4.9	29.2	143.8	57.1	61.3
2000	54.3	27.6	264.0	60.4	66.6

1/ : Included time benefit traffics at Bypass by types of vehicle·km (excl. converted traffic as of (2))

$$\text{Benefit}_{1991} = 365 \begin{pmatrix} 124,493 \\ 49,612 \\ 1,106 \\ 2,942 \\ 2,052 \end{pmatrix} (4.9,\ 29.2,\ 143.8\ 57.1,\ 61.3)$$

$$= 9,166,992 \text{ Shill.}$$

$$\text{Benefit}_{2000} = 365 \begin{pmatrix} 245,902 \\ 123,954 \\ 1,733 \\ 5,234 \\ 1,537 \end{pmatrix} (54.3,\ 27.6,\ 264.0,\ 60.4,\ 66.6)$$

$$= 64,421,109 \text{ Shill.}$$

The benefits between 1991 and 2000 are to be extrapolated with the average growth rate. After 2000, a 4% growth rate is adopted.

Benefit calculation has been implemented, based on Table VI-4-4, Future Traffic Forcast of the Bypass by link and the traffic by link at A104.

Table XI-2-3

Economic Benefit Stream

mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Time Benefit at A104	Benefit of Converted Traffic at Bypass from A104	Benefit of Converted Traffic at Bypass from other Roads	Total Benefit	Discounted 1/ by 12% 2/
1	1988	0	0	0	0	0
2	89	0	0	0	0	0
3	90	0	0	0	0	0
4	91	0	0	0	0	0
5	92	5,755	6,033	3,820	15,608	9,919 3/
6	93	14,840	16,760	11,697	43,297	24,568
7	94	15,943	19,399	14,925	50,267	25,467
8	95	17,128	22,455	19,045	58,628	26,520
9	96	18,400	25,991	24,301	68,692	27,744
10	97	19,767	30,085	31,008	80,860	29,159
11	98	21,236	34,824	39,567	95,627	30,789
12	99	22,814	40,309	50,487	113,610	32,660
13	2000	24,509	46,663	64,421	135,593	34,803
14	1	25,489	48,530	66,998	141,017	32,317
15	2	26,509	50,471	69,678	146,658	30,009
16	3	27,569	52,490	72,465	152,524	27,866
17	4	28,672	54,589	75,364	158,625	25,875
18	5	29,819	56,773	78,378	164,970	24,027
19	6	31,012	59,044	81,513	171,569	22,311
20	7	32,252	61,405	84,774	178,431	20,717
Σ	20	361,714	625,821	788,441	1,775,976	424,751

1/ : discounted to initial year, 1988 2/ : 12%, opportunity cost of capital, PLZ refer to IX.3.1
3/ : estimated yearly benefit of 42%, considering partial utilization, based on implementation schedule

Table IX-2-4

Differentials of Required Time with and without Bypass at A104 (1/3)

Link No.	Distance km.	Degree	Capacity PCU per day	Traffic, 1991 4/ without Bypass	Traffic, 1991 4/ with Bypass	Traffic, 2000 without 2/	Traffic, 2000 with	Congestion Rate, 1991 without	Congestion Rate, 1991 with
1	3.6	S - NW 0° [1]	18,000	14,951	10,466	23,194	14,368	0.83	0.58
		NW - S 0°	18,000	14,183	9,928	22,003	13,481	0.79	0.56
2	1.4	S - NW 0°	12,000	12,566	8,796	19,494	15,236	1.05	0.73
		NW - S 0°	12,000	13,519	9,463	20,973	16,965	1.13	0.79
3	1.4	S - NW 0°	12,000	16,748	12,788	25,981	23,467	1.40	0.98
		NW - S 0°	12,000	18,268	11,724	28,340	24,961	1.52	1.07
4	0.9	S - NW 2°	22,000	15,199	10,639	23,578	21,123	0.69	0.48
		NW - S 0°	22,000	15,748	11,024	24,431	21,150	0.72	0.90
5	1.7	S - NW 2°	22,000	15,292	10,704	23,723	23,732	0.70	0.49
		NW - S 0°	22,000	15,936	11,155	24,723	24,156	0.72	0.51
6	1.1	S - NW 0°	20,000	10,005	7,004	15,521	15,533	0.50	0.35
		NW - S 0°	20,000	11,208	7,846	17,231	17,231	0.56	0.39
7	2.0	S - NW 2°	20,000	9,560	6,690	14,836	15,796	0.48	0.33
		NW - S 0°	20,000	10,942	7,659	16,974	17,765	0.55	0.38
8	6.2	S - NW 1°	16,000	7,312	5,118	11,343	13,324	0.46	0.32
		NW - S 0°	16,000	7,413	5,189	11,500	13,263	0.46	0.32
9	7.6	S - NW 1°	20,000	4,378	3,065	6,791	9,972	0.22	0.15
		NW - S 0°	20,000	6,393	4,475	9,917	11,085	0.32	0.23

1/ : S - NW : South to North West, NW - S : North West to South

2/ : without - without Bypass, with - with Bypass

3/ : others - L.V., Bus, M.V., H.V.

4/ : P.C.U.

Table IX-2-4

Differentials of Required Time with and without Bypass at A104 (2/3)

Link No.	Congestion Rate, 2000		Average Running Speed,1991,K/H				Average Running Speed,2000, K/H			
			without 3/		with		without		with	
	without	with	P.V.	others 3	P.V.	others	P.V.	others	P.V.	others
1	1.29 1.22	0.80 0.75	60 70	50 60	60 70	50 60	40 50	30 40	60 70	50 60
2	1.62 1.72	1.27 1.41	50 60	40 50	60 70	50 60	30 40	20 30	40 50	30 40
3	2.17 2.36	1.96 2.08	40 40	30 30	60 60	50 50	30 40	20 30	30 40	20 30
4	1.07 1.11	0.96 0.96	45 70	35 60	45 70	35 60	35 60	25 50	45 70	35 60
5	1.08 1.10	1.08 1.10	45 70	35 60	45 70	35 60	35 60	25 50	35 60	25 50
6	0.78 0.87	0.78 0.87	60 70	50 60	60 70	50 60	60 70	50 60	60 70	50 60
7	0.74 0.85	0.79 0.89	45 70	35 60	45 70	35 60	45 70	35 60	45 70	35 60
8	0.71 0.72	0.83 0.83	55 70	45 60	55 70	45 60	55 70	45 60	55 70	45 60
9	0.34 0.50	0.50 0.55	55 70	45 60	55 70	45 60	55 70	45 60	55 70	45 60

Table IX-2-4

Differentials of Required Time with and without Bypass at A104 (3/3)

Link. No.	Required Time,1991, Min.				Required Time, 2000,Min.				Differentials of Required Time with and without Bypass			
	without		with		without		with		1991		2000	
	P.V.	others	P.V.	others	P.V.	others	P.V.	others	P.V.	others	P.V.	others
1	3.6	4.3	3.6	4.3	5.4	7.2	3.6	4.3	0	0	1.8	2.9
	3.1	3.6	3.1	3.6	4.3	5.4	3.1	3.6	0	0	1.2	1.8
2	1.7	2.1	1.4	1.7	2.8	4.2	2.1	2.8	0.3	0.4	0.7	1.4
	1.4	1.7	1.2	1.4	2.1	2.8	1.7	2.1	0.2	0.3	0.4	0.7
3	2.1	2.8	1.4	1.7	2.8	4.2	2.8	4.2	0.7	1.1	0	0
	2.1	2.8	1.4	1.7	2.1	2.8	2.1	2.8	0.7	1.1	0	0
4	1.2	1.5	1.2	1.5	1.5	2.2	1.2	1.5	0	0	0.3	0.6
	0.8	0.9	0.8	0.9	0.9	1.1	0.8	0.9	0	0	0.1	0.2
5	2.3	2.9	2.3	2.9	1.5	1.5	2.2	2.2	0	0	0	0
	1.5	1.7	1.5	1.7	1.7	2.0	1.7	2.0	0	0	0	0
6	1.1	1.3	1.1	1.3	1.7	2.0	1.7	2.0	0	0	0	0
	0.9	1.1	0.9	1.1	0.9	1.1	0.9	1.1	0	0	0	0
7	2.7	3.4	2.7	3.4	2.7	3.4	2.7	3.4	0	0	0	0
	1.7	2.0	1.7	2.0	1.7	2.0	1.7	2.0	0	0	0	0
8	6.8	8.3	6.8	8.3	6.8	8.3	6.8	8.3	0	0	0	0
	5.3	6.2	5.3	6.2	5.3	6.2	5.3	6.2	0	0	0	0
9	8.3	10.1	8.3	10.1	8.3	10.1	8.3	10.1	0	0	0	0
	6.5	7.6	6.5	7.6	6.5	7.6	6.5	7.6	0	0	0	0

IX.3 Cost·Benefit Analysis

IX.3.1 Opportunity Cost of Capital

It is difficult to assess the exact figure of opportunity cost of capital.

The 1984 National Transport Plan by JICA estimated the Capital output ratio to be between 3 and 6 during the period 1986 to 2000. The Study has therefore adopted a ratio of 4.5.

The gross and net productivity of capital have been estimated at 0.22 and 0.2 respectively.

On the basis of the above and assuming a capital labour split ratio of 50%, the rate of return on capital investment works out to be 10%.

The ratio is close to the generally accepted opportunity cost of capital of 12% adopted by I.B.R.D. for Kenya.

It should be also noted that a marginal rate of return on incremental capital is decreasing all over the world.

The opportunity cost of capital of 12% is adopted in the Study so as to coordinate the rate applied in MOTC.

IX.3.2 Calculation of N.P.V. & Cost/Benefit Ratio

(1) Net Present Value is calculated, based on Table IX-1-1, Economic Cost Stream and Table IX-2-3, Economic Benefit Stream with the discount rate, 12% of opportunity cost of capital to initial project year, 1988.

N.P.V. = total economic benefit discounted by 12% to 1988 – total economic cost discounted by 12% to 1988 =

= $424,751 \times 10^3$ Shill. – $279,419 \times 10^3$ Shill.

= $145,332 \times 10^3$ Shill.

Thus, N.P.V. for the Project has a positive figure.

(2) Cost/Benefit Ratio (B/C ratio) =

total economic benefit discounted by 12% to 1988 ÷ total economic cost discounted by 12% to 1988

= $424,751 \times 10^3$ Shill. ÷ $279,419 \times 10^3$ Shill. = 1.52

Thus, B/C ratio is above the figure of acceptability.

(See Table IX-3-1)

IX.3.3 Calculation of I.R.R.

Economic Internal Rate of Return is calculated, based on Table IX-1-1, Economic Cost Stream and Table IX-2-3, Economic Benefit Stream.

I.R.R. = (Lower discount rate) + (Differential between the 2 discount rates) x (Net Present Value at lower discount rate) ÷ (Absolute differential of the Net Present Values at 2 discount rates)

Therefore,

$$12\% + (19 - 12) \times \frac{424,751 - 279,419}{(424,751 - 279,419) + |(216,509 - 233,589)|}$$

= 18.26%

Thus, I.R.R. 18.26%

(See Table IX-3-1)

Table IX-3-1

Cost and Benefit Stream

Unit: mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Cost: Real	Cost: Discounted by 19%	Cost: Discounted 1/ by 12%	Benefit: Real	Benefit: Discounted by 19%	Benefit: Discounted by 12%
1	1988	4,418	4,418	4,418	0	0	0
2	89	8,263	6,944	7,378	0	0	0
3	90	41,479	29,291	33,067	0	0	0
4	91	214,092	127,046	152,386	0	0	0
5	92	127,344	63,502	80,929	15,608	7,783	9,919
6	93	272	114	154	43,297	18,144	24,568
7	94	272	96	138	50,267	17,701	25,467
8	95	272	80	123	58,628	17,349	26,520
9	96	272	68	110	68,692	17,082	27,744
10	97	14,738	3,080	5,315	80,860	16,897	29,159
11	98	272	48	88	95,627	16,792	30,789
12	99	272	40	78	113,610	16,765	32,660
13	2000	272	34	70	135,593	16,814	34,803
14	1	272	28	62	141,017	14,695	32,317
15	2	14,738	1,291	3,015	146,658	12,842	30,009
16	3	272	20	50	152,524	11,224	27,866
17	4	272	17	44	158,625	9,809	25,875
18	5	272	14	40	164,970	8,572	24,027
19	6	272	12	35	171,569	7,492	22,311
20	7	14,738	541	1,793	178,431	6,548	20,717
		△ 84,344 2/	△ 3,095	△ 9,793			
Σ	20	358,730	233,589	279,419	1,775,976	216,509	424,751

1/ : discounted to initial project year, 1988   2/ : residual value,   △: minus

IX.4 Sensitivity Analysis

In order to assess the feasibility of the Project in more accurate and delicate order, sensitivity analyses are implemented as in the following three cases.

(1) A case study of the cost alternative to IX.1.3 in order to test the feasibility with 20% higher cost, whereas 20% was adopted as the admissable error of the cost based on preliminary design to detail design

(2) A case study of the benefit alternative to IX.2.4 in order to test the feasibility with the benefit decreased by 20%

(3) A case study of the cost alternative as case (1) and the benefit alternative as case (2), jointly occurred.

IX.4.1 A Case Study of Cost Alternative

Economic Internal Rate of Return is calculated, based on the Table IX-2-3, Economic Benefit Stream and a 20% cost increased to the Table IX-1-1, Economic Cost Stream.

Calculation of I.R.R. is as follow:

$$12\% + (17 - 12) \times \frac{424,751 - 335,301}{(424,751 - 335,301) + |(259,723 - 294,928)|}$$

$$= 15.58\%$$

Thus, I.R.R. 15.58%

(See Table IX-4-1)

Table IX-4-1

Cost Alternative and Benefit Stream

Unit: Economic, mid 1987, 10^3 Shill.

Project	Fiscal	Cost			Benefit		
Year	Year	Real	Discounted by 17%	Discounted by 12%	Real	Discounted by 17%	Discounted by 12% 1/
1	1988	5,302	5,302	5,302	0	0	0
2	89	9,916	8,475	8,854	0	0	0
3	90	49,775	36,361	39,680	0	0	0
4	91	256,910	160,407	182,863	0	0	0
5	92	152,813	81,549	97,115	15,608	8,326	9,919
6	93	326	149	185	43,297	19,748	24,568
7	94	326	127	165	50,267	19,596	25,467
8	95	326	109	147	58,628	19,535	26,520
9	96	326	93	132	68,692	19,562	27,744
10	97	17,686	4,305	6,378	80,860	19,682	29,159
11	98	326	68	105	95,627	19,894	30,789
12	99	326	58	94	113,610	20,201	32,660
13	2000	326	50	84	135,593	20,607	34,803
14	1	326	42	75	141,017	18,317	32,317
15	2	17,686	1,963	3,619	146,658	16,282	30,009
16	3	326	31	60	152,524	14,473	27,866
17	4	326	26	53	158,625	12,865	25,875
18	5	326	23	47	164,970	11,435	24,027
19	6	326	19	42	171,569	10,165	23,311
20	7	17,686	896	2,053	178,431	9,035	20,717
		△ 101,213 2/	△ 5,125	△ 11,752			
Σ	20	430,476	294,928	335,301	1,775,976	259,723	424,751

1/ : discounted to initial project year, 1988   2/ : residual value   △ : minus

3/ : partial utilization as 25%

IX.4.2 A Case Study of Benefit Alternative

Economic Internal Rate of Return is calculated, based on the Table IX-1-1, Economic Cost Stream and the benefit having been decreased by 20% against Table IX-2-3, Economic Benefit Stream.

Calculation of I.R.R. is as follow:

$$12\% + (16 - 12) \times \frac{339,803 - 279,419}{(339,803 - 279,419) + |(228,271 - 252,145)|}$$

$$= 14.86\%$$

Thus, I.R.R. 14.86%

(See Table IX-4-2)

Table IX-4-2

Cost and Benefit Alternative Stream

Unit: Economic, mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Cost: Real	Cost: Discounted by 16%	Cost: Discounted by 12%	Benefit: Real	Benefit: Discounted by 16%	Benefit: Discounted by 12% 1/
1	1988	4,418	4,418	4,418	0	0	0
2	89	8,263	7,123	7,378	0	0	0
3	90	41,479	30,826	33,067	0	0	0
4	91	214,092	137,160	152,386	0	0	0
5	92	127,344	70,331	80,929	12,486	6,896	7,935
6	93	272	130	154	34,638	16,492	19,655
7	94	272	112	138	40,214	16,506	20,374
8	95	272	96	123	46,902	16,595	21,216
9	96	272	83	110	54,954	16,762	22,195
10	97	14,738	3,875	5,315	64,688	17,010	23,327
11	98	272	62	88	76,502	17,342	24,632
12	99	272	53	78	90,888	17,761	26,128
13	2000	272	46	70	108,474	18,274	27,843
14	1	272	40	62	112,814	16,384	25,854
15	2	14,738	1,845	3,016	117,326	14,689	24,007
16	3	272	29	50	122,019	13,169	22,292
17	4	272	25	44	126,900	11,807	20,700
18	5	272	22	40	131,976	10,585	19,222
19	6	272	19	35	137,255	9,490	17,849
20	7	14,738	878	1,711	142,745	8,509	16,574
		△ 84,344 2/	△ 5,028	△ 9,793			
Σ	20	358,730	252,145	279,419	1,420,781	228,271	339,803

1/ : discounted to initial project year,1988   2/ : residual value   △ : minus

IX.4.3 A Case Study of Cost Alternative and Benefit Alternative

Economic Internal Rate of Return is calculated, based on the benefit of 20% decreased to the Table IX-2-3,. Economic Benefit Stream and the cost of 20% increased to the Table IX-1-1, Economic Cost Stream.

Calculation of I.R.R. is as follows:

$$12\% + (16 - 12)$$

$$\times \frac{339{,}803 - 335{,}301}{(339{,}803 - 335{,}301) + |(228{,}271 - 302{,}572)|}$$

$$= 12.22\%$$

Thus, I.R.R. 12.22%

(See Table IX-4-3)

Table IX-4-3

Cost Alternative and Benefit Alternative Stream

Economic, mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Cost: Real	Cost: Discounted by 16%	Cost: Discounted by 12%	Benefit: Real	Benefit: Discounted by 16%	Benefit: Discounted by 12% 1/
1	1988	5,302	5,302	5,302	0	0	0
2	89	9,916	8,548	8,854	0	0	0
3	90	49,775	36,991	39,680	0	0	0
4	91	256,910	164,591	182,863	0	0	0
5	92	152,813	84,397	97,115	12,486	6,896	7,935
6	93	326	155	185	34,638	16,492	19,655
7	94	326	134	165	40,214	16,506	20,374
8	95	326	115	147	46,902	16,595	21,216
9	96	326	99	132	54,954	16,762	22,195
10	97	17,686	4,651	6,378	64,688	17,010	23,327
11	98	326		105	76,502	17,342	24,632
12	99	326	64	94	90,888	17,761	26,128
13	2000	326	55	84	108,474	18,274	27,843
14	1	326	47	75	112,814	16,384	25,854
15	2	17,686	2,214	3,619	117,326	14,689	24,007
16	3	326	35	60	122,019	13,169	22,292
17	4	326	30	53	126,960	11,807	20,700
18	5	326	26	47	131,976	10,585	19,222
19	6	326	23	42	137,255	9,490	17,849
20	7	17,686	1,054	2,053	142,745	8,509	16,574
		△101,213 2/	△6,033	△11,752			
Σ	20	430,476	302,572	335,301	1,420,781	228,271	339,803

1/ : discounted to initial project year 1988 2/ : residual value △ : minus