Feasibility Study

Chapter 15
Design Standards

15 Design Standards

15.1 General

In the previous Pre-Feasibility Study, the design concept, methodology and design standard were established. Subsequently, applying these criteria, preliminary design was carried out for ten bypasses, and finally drawings were developed and design quantities were calculated.

Two bypasses, Bareilly Bypass and Gwalior Bypass, were selected as the highest priority for this Feasibility Study based on the gained score by the JICA Study Team. The selection was agreed between the JICA Study Team and MoST.

The features of two bypasses in the Feasibility Study are shown in Table 15-1. Distances in the table are derived from the result of the alignment design in this phase.

Table 15-1 Two Bypasses in Feasibility Study

No.	Name of Bypass	Distance (km)	State	National Highway to be Connected
1	Bareilly	29.98	Uttar Pradesh	NH24
2	Gwalior	26.50	Madhya Pradesh	NH3

After the review of design standard applied in Pre-Feasibility Study, revised and detailed design standards was established. Subsequently, the preliminary design was carried out based on the updated design standards.

15.2 Changes and Modifications

Changes and modification were derived from 1) the further study of each value referring to AASHTO/JRSO to satisfy requirements of the proposed bypasses; 2) the further study of road drainage system in India; and 3) results of natural conditions survey.

- Crossfall of outer shoulder was changed to 3 % from 2.5%, according to "IRC Special Publication 42, Guidelines on Road Drainage, 1994";
- Minimum radius of horizontal curve was changed to 410 m from 360 m by referring the value of coefficient of side friction in AASHTO for safety side;
- Maximum superelevation was changed to five (5) % from seven (7) % take into account of the stability of heavy commercial vehicles; and

- Minimum longitudinal gradient for drainage was changed into 0.30 % from 0.50 % referring AASHTO/JRSO.

15.3 Vertical Controls

(1) General

Generally there are three types of crossing structures: i.e. 1) for highways/ roads, 2) for railways, and 3) for channels/waterways. The structures shall be planned to have appropriate lateral/vertical clearance, or a flow capacity. The maximum interval for foot/cattle path which cross the proposed bypass was proposed as one kilometre.

(2) Required Vertical Clearance as Vertical Controls

There are three types of bridges, three types of culvert box for road and three types of culvert box for water channels were proposed in the project. Taking into account required internal clearance, structural depth, coverage depth and pavement depth, the general features and relevant requirements were summarised in Table 15-2.

Table 15-2 Required Clearance of Crossing Structures

Existing Crossing Facilities		Structure Type Applied	Required Internal Clearance		Other Requirement	Required Vertical Clearance	Remarks
			Horizontal (m)	Vertical (m)	(m)	(m)	
Rail-way	Bareilly	ROB	20.0	5.1	1.7	6.8	
	Gwalior	ROB	25.0	5.1	2.0	7.1	Skew 70d
Road	State Highway (SH 33)	RDBR	12.0	5.0	1.7	6.7	
	State Highway (SH 37)	RDBR	12.0	5.0	2.0	7.0	
	Interchange Bridge	ICBR	12.0	5.0	2.0	7.0	
	Major District Road	RDBR	9.0	5.0	1.6	6.6	
		RDCBL	5.0	4.0	1.6	5.6	
	Major Village Road	RDCBL	5.0	4.0	1.6	5.6	
		RDCBM	4.0	3.5	1.5	5.0	
	Village Road	RDCBM	4.0	3.5	1.5	5.0	
		RDCBS	2.5	2.5	1.4	3.9	
	Cart Truck/Foot Path	RDCBS	2.5	2.5	1.4	3.9	
		WCBR	9.0	0.9	1.2	2.1	
Water Channels	Natural River	WCBR	19.0	1.2	2.4	3.6	Deonarain(Bareilly)
		WCBR	19.0	1.2	2.4	3.6	Nakatia(Bareilly)
		WCBR	25.0	0.6	2.0	2.6	Bandha Nala(Gwalior)
		WCBR	19.0	1.2	2.4	3.6	Raikapur(Gwalior)
		WCBR	9.0	0.9	1.2	2.1	Raipur Tighara(Gwalior)
		WCCBL	3.5	3.5	1.5	5.0	
	Major Canal	WCBR	9.0	0.9	1.2	2.1	
		WCCBM	2.5	2.5	1.4	3.9	
	Minar Canal	WCCBS	1.5	1.5	1.3	2.8	
	Drain	WCCBS	1.5	1.5	1.3	2.8	
		WCCP	1.5	1.5	1.3	2.8	

15.4 Service Roads

(1) General

The project bypasses will carry the through traffic, banning the entry of slow traffic such as three-wheelers, bicycles, animal-drawn-cart, and etc. In order to facilitate the new access for such slow traffic, the service road along the bypass was proposed.

The service road was proposed to be located along ROW, with an offset of two metres. The area between the throughway and the service road should be graded properly to drain the surface water of the road towards outside of the roadway.

(2) Basic Concepts

- Secure local traffic along/crossing the proposed bypass as much as possible by installing service road and crossing structures properly, for the short trip for cultivation and medium trip between villages;
- Install crossing foot/cattle path at maximum one kilometre interval;
- Utilise existing village roads as a part of the service road as much as possible; and
- Study alternatives of relocation possibility of existing road to reduce the earthwork volume of the throughway.

(3) Dimension of Service Road

The service road will be a dual lane with the following cross-sectional elements:

Carriageway width	5.50 m (2 @ 2.75 m)
Inner-shoulder width	1.50 m
Inner-side-ditch width	1.50 m
Outer-shoulder width	1.50 m
Total roadway width	10.00 m
Clearance	Lateral 5.50 m, Vertical 3.50 m

15.5 Geometric Design Standards for Interchange

The geometric standards for the interchange were established based on the AASHTO standards, and referring to the Japanese standards (JRSO).

15.5.1 Design Speed for Interchange Ramps

The design speed of interchange ramps is normally determined by the classification of the throughway and the intersecting road and the respective design speeds, and traffic volume, vehicular compositions and terrain conditions at the interchange.

Reference was made to the JRSO standard together with the interchange design standards of the Japan Highway Public Corporation. The throughway design speed is 100 km/hr. The intersecting highways at the interchange locations are the existing SH37 and SH33, whose design speeds were assumed to be 80 km/hr.

According to JRSO standard, the applicable range of the design speed of interchange ramps for the above combination is 35 to 50 km/hr. Referring to it, a 40 km/hr design speed was selected.

15.5.2 Geometric Design Standards

Table 15-3 shows the geometric design standards for interchange ramps based on a 40 km/hr design speed, together with the requirements of the throughway. The required widening on curves of interchange ramps is shown in Table 15-4.

15.5.3 Typical Cross Sections

Figure 15-1 shows the typical cross sections of the interchange ramps.

Table 15-3 Geometric Design Standards for Interchange Ramps

Design Speed Of Throughway (Km/Hr)		100
Throughway Alignment Between Interchange		
Minimum Radius Of Curve (M)		410
Maximum Grade (%)		3.3
Minimum Vertical Curve Radius (M)	(Summit)	10000
	(Valley)	4500
Design Speed Of Ramp(Km/Hr)		40
Ramp Type & Width		
Carriageway Width (M)		3.50
Shoulder Width (M)		
Single Carriageway	(Left)	1.00
	(Right)	2.50
Dual Carriageway	(Right)	2.50
Median Width (M)		2.50
Clearance Limit (M)		5.00
Minimum Radius Of Curve (M)		50
Minimum Parameter Of Transition(M)		35
Minimum Radius Without Transition(M)		140
Sight Distance(M)		40
Maximum Grade(%)		6.0
Vertical Curve		
Min. Radius (M)	(Summit)	450
	(Valley)	450
Min. Length M)		35
Geometry At Nose		
Minimum Radius(M)		200
Minimum Transition(M)		70
Deceleration Lane		
Type		Parallel
Length Of Deceleration Lane (M)		90
Tapered Lane(M)		60
Acceleration Lane		
Type		Parallel
Length Of Acceleration Lane (M)		180
Tapered Lane(M)		60

Table 15-4 Curve Widening of Interchange Ramps

RADIUS	WIDENING (m)
15m≦R<21m	2.75
21m≦R<23m	2.50
23m≦R<25m	2.25
25m≦R<27m	2.00
27m≦R<29m	1.75
29m≦R<32m	1.50
32m≦R<36m	1.25
36m≦R<42m	1.00
42m≦R<48m	0.75
48m≦R<58m	0.50
58m≦R<72m	0.25
72m≦R	0

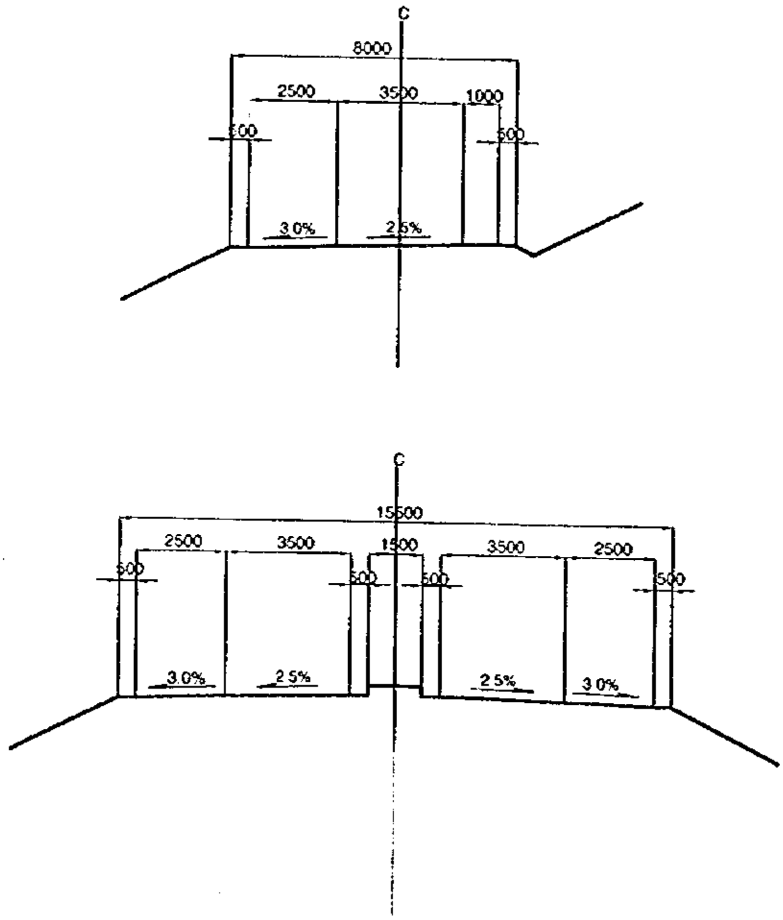


Figure 15-1 Typical Cross Section of Interchange Ramps

15.6 Geometric Design of At-Grade Intersection

15.6.1 General

For the design criteria of at grade intersection, following standard were referred to

a) IRC Special Publication 41, "Guidelines on Design of At-Grade Intersections in Rural & Urban Areas, 1994"

b) AASHTO, "A Policy on Geometric Design of Highways and Streets, 1994"

c) JRA, "Japan Road Structure Ordinance (JRSO), 1983"

15.6.2 Design speed

Design speed of the bypass is 100km/hr, described in former section. However the design speed at the approach section of the bypass to the intersection was applied as 50km/hr. National Highways connected with bypass are assumed as 80km/hr. design speed.

15.6.3 Design Vehicle for the width of turning path

In the IRC standard, "Guidelines on Design of At-Grade Intersection in Rural & Urban Areas, 1994", design vehicles of AASHTO are quoted. Therefore, semi-truck trailer (WB-15) in AASHTO is used for design vehicles to determine the width of width of turning path. Truck trailer was not taken into consideration. The dimension of design vehicle is shown in Figure 15-2.

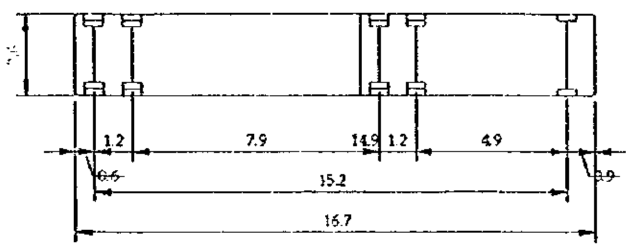


Figure 15-2 Design vehicle WB-15

15.6.4 Storage lane/right turning lane

Provision of storage lane/right turning lane increase the capacity of intersection and improve safety. Thus, in the intersection between bypass and National Highway the provision of storage lane/right turning lane was judged as essential to secure the smooth and safe traffic movement.

In general, storage lane length is based on 1.5 times the average number of vehicles which would be stored in turning lane at peak hour. For the study, length of the storage lane recommended by IRC standard was applied. Table 15-5 shows the IRC recommendation.

Table 15-5 Length of Storage/Right turning lane

Design Speed(km/hr.)	Length of Storage/Right turning lane including taper
120	200
100	160
80	130
60	110
50	90

Source : IRC Guidelines for the design of at-grade intersection in rural and urban areas

15.6.5 Taper

At the transition section between the existing NH and the bypass, increase/decrease of lanes(from one lane in one direction of NH to two lanes in one direction of bypass) will be necessitated. An appropriate taper shall be provided to enable this. Required taper length to increase/decrease the number of throughways/lanes was estimated based on JRSO recommendation. The recommended formula by JRSO is as follows:

L=(Taper rate) x (Width of lane)

Applying the design speed of 80km, the length of 175m was designed as a taper. Taper rate is shown in Table 15-6.

Taper to add storage lanes/right turning lanes, was applied IRC standard, which is shown in Figure 15-3.

Table 15-6 Taper Rate

Design speed(km/hr)	Taper rate	
	Rural area	Urban area
120	1/70	-
100	1/60	-
80	1/50	1/40
60	1/40	1/30
50	1/30	1/25
40	1/25	1/20
30	1/20	1/15
20	1/15	1/10

Resource : JRSO

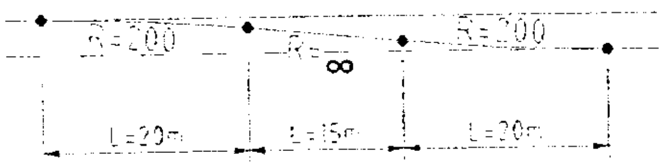


Figure 15-3 Method of transition curves at Points of storage/turning lanes

15.6.6 Re-alignment

Intersections are points of conflict and potentially hazardous. The alignment, therefore, should permit users to discern and perform readily the manoeuvres necessary to pass through the intersection safely.

Site conditions generally establish definite alignment on intersecting roads. However, it is often possible to modify the alignment and improve traffic conditions and reduce hazards, particularly on rural roads. Regardless of the type of intersection, for safety and economy, intersecting roads should meet at or nearly at right angles. Roads intersecting at acute angles require extensive turning roadway areas and tend to limit visibility, particularly for drivers of trucks. Acute angle intersections increase the exposure time of the vehicles crossing the main traffic flow and may increase the accident potential. The practice of re-aligning roads intersecting at acute angles in the manner shown in Figure 15-4 has proved to be beneficial. Although a right angle crossing normally is desired, some deviation is permissible. Angles above approximately 60 degrees produce only a small reduction in visibility, which often does no warrant re-alignment closer to 90 degrees.

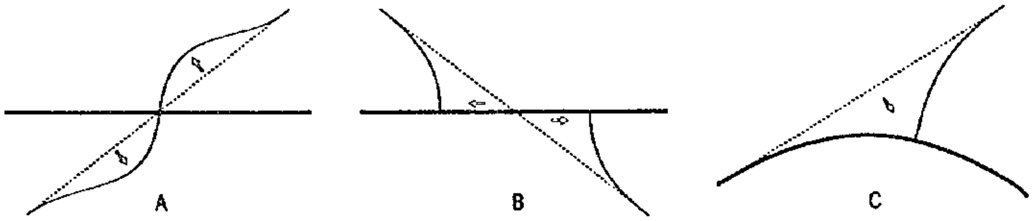


Figure 15-4 Re-alignment variations at intersections

15.6.7 Geometric standard of at-grade intersection

Geometric standard of at-grade intersection was proposed as shown in Table 15-7.

Table 15-7 Geometric Standard of At-grade Intersection

( ) absolute value

DESIGN SPEED OF BYPASS AT INTERSECTON (km/hr)	80
BYPASS ALIGNMENT	
MINIMUM RADIUS OF CURVE (m)	700(360)
MAXIMUM GRADE (%) AT INTERSECTION	2.5
TAPERED LANE FOR ADDITIONAL LANE	1/50
DESIGN SPEED OF NATIONAL HIWAY(km/hr)	80
NATIONAL HIWAY ALIGNMENT	
MINIMUM RADIUS OF CURVE (m)	230(60 at intersection)
DECELERATION LANE	
LENGTH OF DECELERATION LANE (m)	70
TAPERED LANE	55
ACCELERATION LANE	
LENGTH OF ACCELERATION LANE (m)	50
TAPERED LANE	55
STORAGE/RIGHT TURNING LANE	
TOTAL LENGTH OF STORAGE/RIGHT TURNING LANE	130
TAPERED LANE	55
STORAGE/RIGHT TURNING LANE	75

15.7 Pavement Design Criteria

Vehicle Damage Factor (VDF) was revised based on the recent "Study on spectrum of Axle Loads on National Highways, July 1992" which was carried out for MoST by the Central Road Research Institute (CRRI), and the "Faridabad - NOIDA - Ghaziabad Expressway Final Report, March 1995" and the actual axle-load surveys conducted during the traffic survey.

However the number of samples of actual survey was not sufficient for Light Commercial Vehicle (LCV) and Multi Axle Vehicle (MAV) and no sample for buses which may have higher VDF than LCV.

Considering the actual traffic conditions, the values to be applied to the pavement design was proposed as shown in Table 15-8.

Table 15-8 Vehicle Damage Factor (VDF)

Vehicle Type	VDF Value					
	MOST	F-N-G Expressway	Actual Survey		Proposed	
			Bareilly	Gwalior	Bareilly	Gwalior
Buses	0.3560	0.561	-----	-----	0.561	
LCV	0.0530	0.090	0.189(34)	1.069(13)	0.09	
HCV	1.9540	4.164	4.440(250)	6.690(161)	4.440	6.690
MAV	2.2870	3.372	3.720(7)	9.000(3)	3.372	

LCV: Light Commercial Vehicle
HCV: Heavy Commercial Vehicle
MAV: Multi Axle Vehicle
( ) Number Vehicles weighed

15.8 Drainage Design Criteria

15.8.1 Categorisation and Data required

There are four aspects of drainage design in which the road engineer is particularly interested:

- Road surface drainage;
- Surrounding area drainage including slope of road;
- Cross drainage; and
- Sub-surface drainage.

Following factors should be studied in depth in order to design above mentioned drainage system for the project.

- Rainfall
- Topography and present drainage system of the project area
- Crossfall and longitudinal profile of the proposed road
- Internal drainage of pavement layers

15.8.2 Road Structure relating Drainage System

(1) Longitudinal Gradient

Based on the above IRC concept, the following criteria were adopted in the drainage design:

- Kerbs should be installed at fill section higher than 3 metres;
- Longitudinal gradient shall be steeper than 0.3 percent in section with kerbs; and
- Longitudinal gradient shall be steeper than 0.3 percent in cut section.

(2) Pavement Crossfall/Camber

According to "IRC:73-1980, Geometric Design Standard for Rural (on-urban) Highways", and as described in above 7.2.2 Cross-sectional Elements, the Study Team proposed to adopt a uni-direction crossfall of 2.5 percent as a normal crossfall for the carriageway including median shoulder downward to the outer edge.

(3) Shoulder

There are three types of shoulder in the proposed cross-section, median shoulder 0.70 m wide, paved shoulder 2.50m wide, and earth shoulder 1.00 m wide.

The Study Team proposes the following consideration for the shoulder drainage.

<u>Median Shoulder</u>

Rainwater on the median shoulder should be drained towards the pavement surface in normal crossfall section. In the case the carriageway is superelevated, catch-basin/inlet at the median and transversal drain under the pavement should be provided and the water should be drained into it.

Pavement Shoulder

At tangent section of the horizontal alignment, 3.0 percent outwards gradient should be provided. At curved section, the Study Team proposes the method of "Roll-Over" to avoid too great a cross slope break. The algebraic difference in the carriageway and shoulder grades at the high edge-of-carriageway should not exceed 8 percent.

Earth Shoulder

Gradient of 4.0 percent shall be provided.

15.8.3 Proposed Drainage System

(1) General

The drainage system of the project was categorised as follows:

a) Longitudinal drainage,
b) Cross-sectional drainage, and
c) Structural drainage

Regarding the drainage categorised as a) and b) in the above, the application details are described below. Structural drainage will be described in Structure section in this report.

(2) Longitudinal drainage

Figure 15-1 illustrates longitudinal drainage system to be applied in the project. The drainage includes following facilities:

- Side ditch (1), locates along the top of the cut section SD(1)
- Side ditch (2), locates in cut section SD(2)
- Side ditch (3), locates along the Service Road SD(3)
- Berm ditch (1), locates at cut slope BD(1)
- Berm ditch (2), locates at fill slope BD(2)
- Kerb ditch (1), locates at the median KD(1)
- Kerb ditch (2), locates at the edge of paved shoulder KD(2)

Water collected by the longitudinal drainage should be channelised properly by the combination of the catch-basin/inlets and transversal/vertical drain.

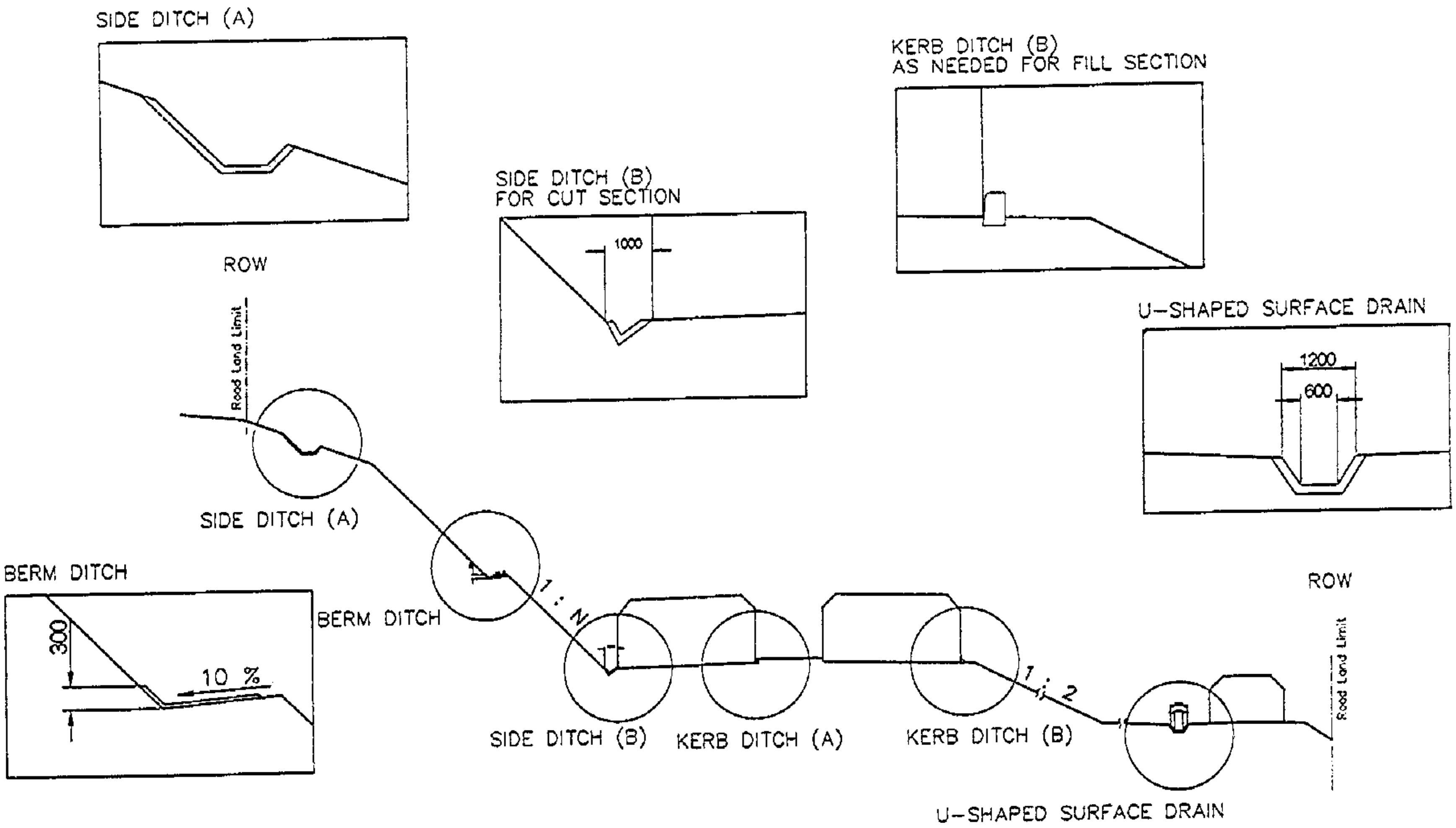


Figure 15-5 Type of Longitudinal Drainage

(3) Cross-sectional drainage

Figure 15-6 illustrates cross-sectional drainage system to be applied in the project. The drainage includes following facilities:

- Vertical drain (1), locates at cut slope VD(1)
- Vertical drain (2), locates at fill section VD(2)
- Transversal drain, locates at superelevated section TD

These cross-sectional drainage should be properly connected with the longitudinal drainage by the catch-basin/inlets and to drain rainwater out of roadway. The intervals of the drainage shall be determined by the hydraulic design as described below.

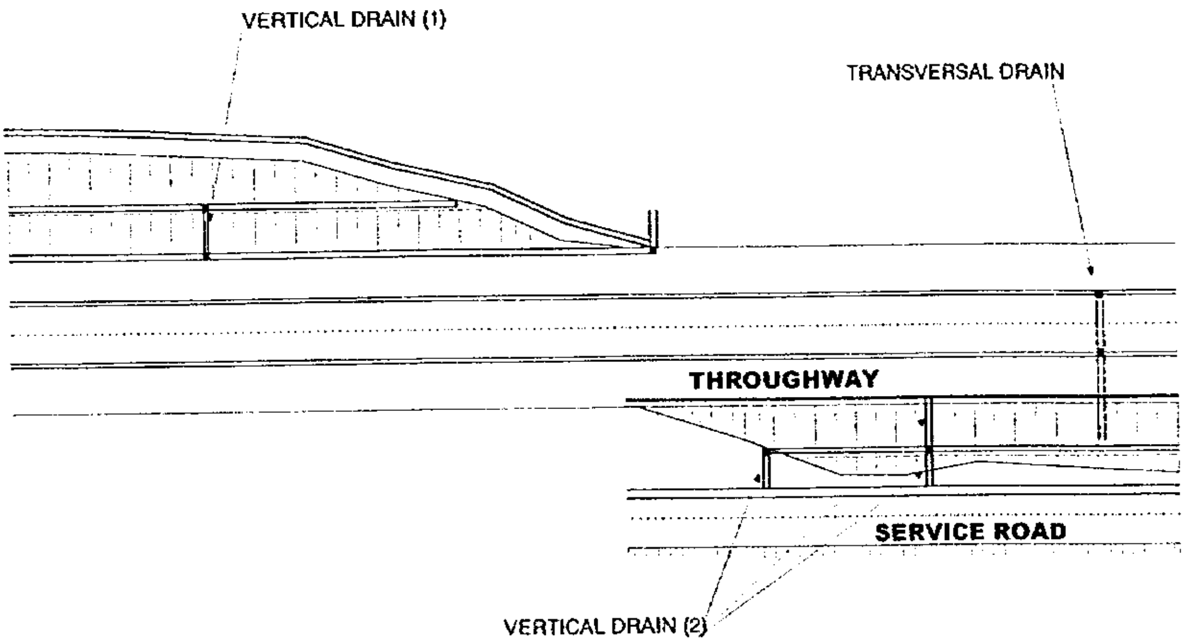


Figure 15-6 Type of Cross-sectional Drainage

15.9 Hydrological and Hydraulic Design

(1) Design Return Period

As IRC standard is not specified design return period for each drainage facility, the Study Team proposed it referring to "Japan Highway Public Corporation Design Manual Volume 1, Drainage Design" as shown in Table 15-9.

Table 15-9 Return Period for Drainage Design

	Type of Drainage Facilities		
	Road Surface Drainage	Surrounding Area Drainage	Cross Drainage
Return Period	3	10	50

(2) Rational Method

The Study Team proposed to adopt the Rational Method which indicated in the IRC standards.

(3) Open Channel Designs

The Study Team proposed to apply the Manning's Formula for open channel design according to the IRC standards.

15.10 Utilities Relocation Criteria

15.10.1 General

The proposed bypasses are expected to run suburban area of the cities. Bareilly Bypass will traverse the suburban area of Bareilly city in its whole stretch. Gwalior Bypass will traverse the suburban area of Gwalior city at the beginning and the end of proposed alignment. Hamlets sporadically locate in these suburban areas.

To properly carry out the construction of the bypass it will be necessary to relocate existing utilities within the Right -of-Way.

Potential utilities to be affected by the project are:

1) Electric pylon (for Main Power Lines);
2) Electric poles (for Distribution Lines);
3) Telecommunication poles;
4) Water supply pipes;
5) Water supply wells; and
6) Irrigation canals

"IRC: 32-1969, Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads" have been guided road construction and the related utilities relocation in India.

As Water supply pipes/wells and irrigation canal are not covered by the IRC standard, these relocation concepts and procedures were discussed and confirmed with the State PWD.

15.10.2 Definitions of Clearances

(1) Vertical Clearance

Vertical clearance is the clear vertical distance between carriageway crown and the lowest point of any overhead conductor installation which includes the conductor wire, bearer wire, guard wire, stay wire, guard cradle, or screen. The lowest point should be determined after accounting for the maximum possible sag in the lowest member of the conductor installation.

(2) Horizontal Clearance

Horizontal clearance is the horizontal distance, measured at right angles to road alignment between roadway or carriageway edge and a pole carrying an overhead utility line, or any pole-supporting structure.

15.10.3 Vertical Clearance Required

Minimum vertical clearances for different categories of overhead conductor installation shall be as shown in Table 15-10 and Figure 15-7. These clearance have been fixed taking into consideration the overall height of vehicles and the statutory provisions of the Indian Electricity Rules.

Table 15-10 Minimum Vertical Clearance

Category	Clearance Required (m)
Up to 110 Volts[1]	5.5
110 - 650 Volts	6.0
Exceeding 650 Volts	6.5
1) Includes Telecommunication lines	

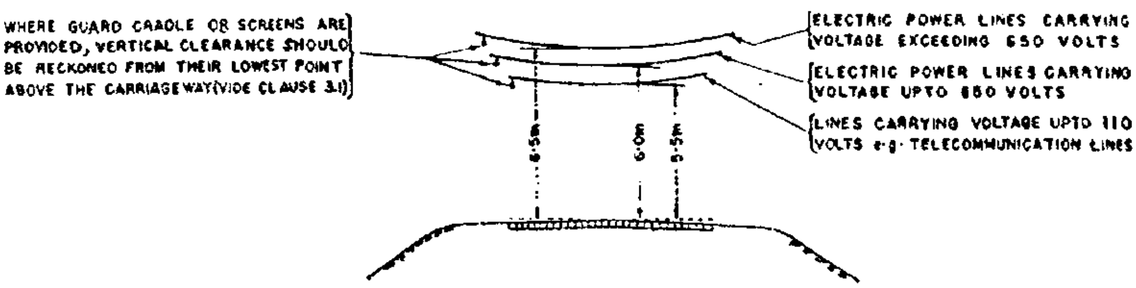


FIG-1 MINIMUM VERTICAL CLEARANCES

Figure 15-7 Minimum Vertical Clearance

15.10.4 Horizontal Clearance Required

In this project, the Right-of-Way (ROW) will be a eighty (80) metres and utility lines crossing the ROW will be relocated properly. Figure 15-8 and 15-9 shows the required horizontal clearance.

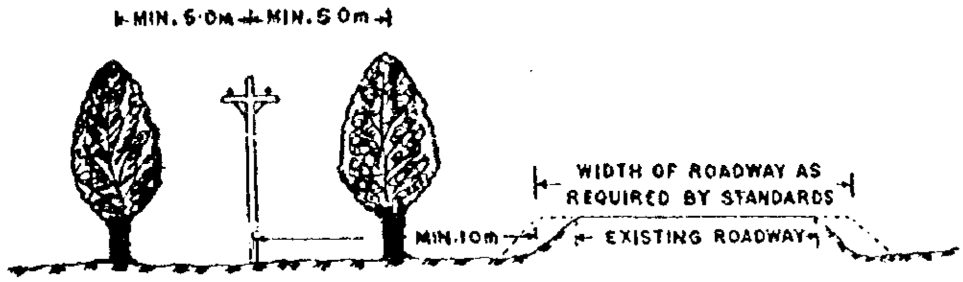


FIG-2 MINIMUM HORIZONTAL CLEARANCE FOR POWER AND TELECOMMUNICATION LINES ON RURAL ROADS, EXCEPT (i) FOR POLES ERECTED FOR STREET LIGHTING AND (ii) FOR POLES ERECTED IN MOUNTAINOUS COUNTRY

Figure 15-8 Minimum Horizontal Clearance (1)

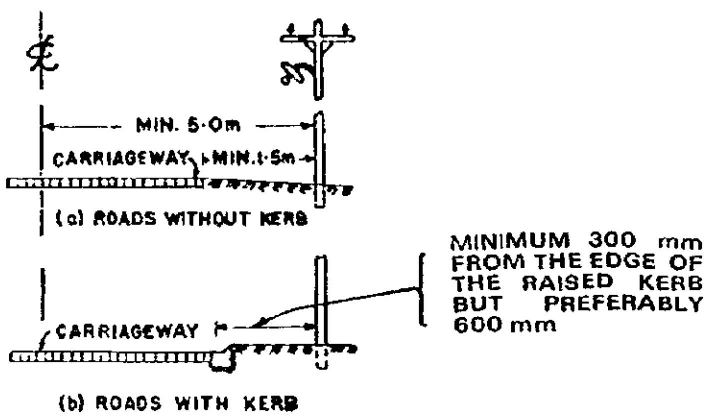


FIG-3 MINIMUM HORIZONTAL CLEARANCES FOR STREET LIGHTING POLES ON RURAL ROADS AND FOR TELECOMMUNICATION, ELECTRIC POWER OR STREET LIGHTING POLES ON URBAN ROADS

Figure 15-9 Minimum Horizontal Clearance (2)

15.11 Design Standard and Criteria of Structures

15.11.1 Design Concept and Methodology of Structure Design

Structural design was carried out basically followed the procedure described in Chapter 4 of Pre-Feasibility Study.

However, the additional detailed data obtained from the field investigation for the two bypasses to be studied, i.e., hydrological, geological, and topographic survey, was incorporated into the design.

Crossing facilities, they are, roads, railways, and water channel, were classified again, and required clearances were confirmed. At the same time, the design parameters of natural conditions were studied and determined for each structural class. Subsequently on the each classified facilities basis, applicable structures were studied and identified.

Major structures were studied carefully and applicable structural types were individually designed. For the minor structures such as culvert-box, the standard types were applied.

15.11.2Design Condition

15.11.2.1 General

Two category of design condition can be reviewed with additional detailed data obtained from field investigation, i.e., hydrology and geology.

Hydrological survey was carried out to analyse the hydrological design parameters for individual crossing facility of water channel identified.

Geotechnical survey was carried out to acquire geotechnical design parameters for structure design, and depth of the bearing layer, N-values distribution, depth of ground water level were identified. With applying these data, general soil/rock properties were determined as the design parameters for subsequent structure design.

Table 15-11 Shows item of analysis of these two surveys.

Table 15-11 Item of analysis of field investigation

Field Investigation	Item of Analysis or Survey
Hydrology	- Maximum Design Discharge (M.D.D.) - Design Highest Flood Level(D.H.F.L.) - Afflux - Minimum Vertical Clearance - Maximum Depth of Scour (M.D.S.)
Geology	- Depth of bearing layer - N-values distribution - Depth of Ground Water Level

In the following sections, detailed data mentioned above is explained.

15.11.2.2 Hydrology

(1) Maximum Design Discharge (M.D.D.)

Maximum design discharge is the principal design parameter from hydrological viewpoint. Method to estimate M.D.D. is described in IRC;5-1985, Clause 103. "Determination of Design Discharge", and IRC Special Publication 13, Article 7, "Fixing Design Discharge".

In this study, two formula which was mentioned in IRC;5-1985, Clause 103, was employed to estimate M.D.D. for rivers. They are "Dieken's formula" and "Rational formula".

For canal of which design discharge was already defined by irrigation department, M.D.D. can be assigned same value.

For rivers, other design conditions such as below were also taken into account for rivers.

- Other hydrological information
  - Record of flood in spate over cross section of water channel
  - Record of flood level at vicinity
  - Throughout area or span arrangement of existing structures placed in vicinity of same water channel with applied structure of proposed bypass
- Alignment of the proposed bypass
- Local traffic secured

(2) Design Highest Flood Level (D.H.F.L.)

D.H.F.L. is defined in IRC:5-1985, Clause 101.5., as the level of the highest flood ever recorded or the calculated level for the highest possible flood.

Estimate method is shown below:

- estimate by applying Manning's Formula to M.D.D.

  (calculated level for the highest possible flood)

- compare estimated H.F.L. with reported H.F.L.

  (highest flood ever recorded)

- determine D.H.F.L. from either of two H.F.L.

(3) Afflux

Afflux is the height by which the natural flood level of the river is raised at any point due to constriction and/or obstruction.

In case that afflux arise, its height is necessary to add to estimated H.F.L..

The type of bed and bank material and the type of bridge crossing influences the extent of afflux, and afflux will arise in the following cases:

- flashy floods
- constriction of channel flow due to provision of piers and guide bunds
- provision of embankments preventing spill flow

Afflux is approximately calculated using Orifice Formula which is referred to IRC Special Publication No.13, Article 18, Afflux.

(4) Minimum Vertical Clearance

Required vertical clearance of water channel is defined above highest flood level (H.F.L.) with afflux, and in IRC5-1985, Clause 106. Relation of minimum vertical clearance and design discharge is shown in chapter 4.

(5) Maximum Depth of Scour (M.D.S.)

Top of footings of bridge over water channel is defined to be placed below maximum depth of scour.

M.D.S. is the depth below highest flood level upto the estimated scoured river bed level.

Method to estimate M.D.S. is described in Clause 104.~110 of IRC:5-1985.

15.11.2.3 Geology

(1) General

Geotechnical Survey was carried out in this Feasibility Study to acquire geotechnical design parameters for structure design. The study results was summarised in Chapter 14.

In this section, the survey result was reviewed based on the field investigation, and depth of the bearing layer, N-values distribution, depth of ground water level. General soil/rock properties are determined as the design parameters for subsequent structure design phase.

(2) Definition of the Bearing Strata

Japanese Standard was applied to define the bearing strata. When the strata satisfy following conditions of N-values, the strata was assumed as the bearing strata, according to Clause 7.3, Part IV of Japanese Specification of Highway Bridge.

Table 15-12 Definition of Bearing Strata

Type of Strata		N-value
Soil	Clay/Silt	Equal or more than 20
	Sand/Gravel	Equal or more than 30
Rock		Regard as bearing strata

15.11.3 Classification of Crossing Facilities

15.11.3.1 General

Objective of classification of crossing facilities is to assign adequate clearance to individual crossing facility, and to make clear the design concept about each crossing facility. Based on the site reconnaissance Results, three main categories, "Road", "Railway", and "Water Channel", were classified as the existing facilities.

15.11.3.2 Classification of Existing Crossing Facilities

In the pre-feasibility stage, crossing facilities were classified with utilising topographic map of 1:50,000 published by Survey of India. After site survey in this phase, classification of crossing facilities was reviewed, and summarised as shown in Table 15-13:

Table 15-13 Classification of Crossing Structures

Crossing Facility	Classification		Remarks
(1) Roads (RD)	a) Highway (HW)	National and State Highway	Same classification with IRC:73-1980
	b) Major District Road (MDR)	Major and Other District Road	
	c) Major Village Road (MVR)	Village Road	
	d) Village Road (VR)		
	e)Cart Track / Foot Path (CT)	Track or Path available to passage Carriage or Pedestrian	Required clearance was defined with considering traffic condition of site.
(2)Railways (R)	Individually defined with following conditions: - Traction (Electrified or Non-Electrified) - Number of track - width of gauge (Broad, Meter, Narrow)		Need to certify future programme of each railway which cross bypass
(3)Water Channels (WC)	a)Natural River (River) b)Major Canal (Major Canal) c)Minor Canal (Minor Canal)		Basically, classified with Maximum Design Discharge

Note: *Character in ( ) indicates code of crossing facility which is employed in the next chapter, 16.

15.11.3.3 Roads

Roads were categorised into four (4) classes as HW, MDR, MVR, VR, and CT.

Only change from that of Pre-F/S is shown in Table 15-14.

Table 15-14 Comparison of Classification (Road)

Class in Pre-F/S	Class in F/S
Road-HW	HW
Road-DR	MDR
Road-VR	MVR
	VR
Road-CT	CT
Road-PT	
Road-FP	

Class for village road was divided into MVR and VR. This is because during the field investigation, it was observed that there are two types of village roads. One was paved and functioned as an arterial roads connecting villages and the other was unpaved and used for local cultivation activities

Regarding tracks and path, classification was not required based on the field investigation.

15.11.3.4 Railway

Based on these future scheme, railways expected to cross the proposed bypass was studied individually.

15.11.3.5 Water Channel

Water channels were categorised into three (3) classes, River, Major Canal, Minor Canal. River is the class for natural river. Major canal is the class for canal with wide water surface and motorable road alongside. Minor Canal is the class for canal with narrow water surface and without motorable road.

15.11.4 Required Clearance

15.11.4.1 Road

In the pre-feasibility stage, required clearance was defined referring to the IRC:73-1980 and IRC:54-1974, and actual traffic condition at the sites.

In this phase, more detail survey was conducted to review the traffic condition at the project area. Table 15-15 shows the applied clearance to each road category.

Table 15-15 Clearance of Classified Road

<table>
<tr><th colspan="3">Classification & Clearance of Previous Phase</th><th colspan="3">Classification & Clearance of This Phase</th><th rowspan="2">Remarks</th></tr>
<tr><th>Class in Project</th><th>Lateral Clearance</th><th>Vertical Clearance</th><th>Class in Project</th><th>Lateral Clearance</th><th>Vertical Clearance</th></tr>
<tr><td>RD-HW</td><td>12.0m</td><td>5.0m</td><td>RD-HW</td><td>12.0m</td><td>5.0m</td><td rowspan="2">Same as IRC</td></tr>
<tr><td>RD-DR</td><td>9.0m</td><td>5.0m</td><td>RD-MDR</td><td>9.0m</td><td>5.0m</td></tr>
<tr><td rowspan="3">RD-VR</td><td>*1
7.5m</td><td>*1
5.0m</td><td rowspan="2">RD-MVR</td><td>7.5m</td><td>5.0m</td><td rowspan="4">Defined with consideration of the present condition</td></tr>
<tr><td rowspan="2">*2
4.0m</td><td rowspan="2">*2
3.5m</td><td>5.0m</td><td>4.0m</td></tr>
<tr><td>RD-VR</td><td>4.0m</td><td>3.5m</td></tr>
<tr><td>Road-CT, PT, FP</td><td>2.5m</td><td>2.5m</td><td>Road-CT</td><td>2.5m</td><td>2.5m</td></tr>
</table>

* Minimum Lateral Clearance = Roadway Width IRC:73-1980
* Vertical Clearance in Rural Area = 5.0m IRC:54-1974
*1 (RD - VR) : Individual Road which has possibility of upgrading in future
*2 (RD - VR) : Individual Road which does not have possibility of upgrading in future

"RD - HW" and "RD - DR" are classified as major road categories, (detailed description is in IRC : 73-1980). Required clearances for these are defined to have the same figures as the IRC specification.

In the previous, from the viewpoint of cost savings, the reduced clearance for "RD - VR" was proposed by the Study Team and approved by the MOST, as the clearance of exceptional case.

Domestic traffic was reviewed in this phase, and larger clearance is judged to be desirable for RD-MVR as shown in Table 15-15.

"Road - CT" is generally not supposed to cater the vehicle traffic. The clearance for this road category is not defined in the IRC specification. Judging from the findings from the site reconnaissance, lateral and vertical clearance were proposed as 2.5m, respectively.

15.11.4.2 Railway

Required clearance of individual railway was defined with the application of the same length and width confirmed by Ministry of Railway.

15.11.4.3 Water Channel

The required clearance for water channel is classified by the applicable structure, bridge or culvert. For bridge structure, required clearance was assigned the value described in previous section, 7.3.1.4. For culvert structure, required vertical clearance is not mentioned in IRC Specification.

In this study, 600mm of vertical clearance was considered to accommodate the flow obstruction caused by sediment.

15.11.5 Application of Structures

15.11.5.1 Classification of Applicable Structures

Application of structures for the proposed bypasses are summarised in Table 15-16, Table 15-17, and Table 15-18. Viaduct and Bridge were designed for individual crossing facility. For Culvert Box, typical structures were designed with considering features and conditions of whole crossing facilities. For combination of multiple crossing facilities, applicable structure was individually designed at each point.

Table 15-16 Classification of Applicable Structures (Roads)

Crossing Facility		Structure	Composition
Roads (RD)	RD-HW	Over Bridge (RDBR)	Superstructure: RC - T beam Substructure: Inverse T - Type Abutment, Wall Type Pier Foundation: Individually Designed
	RD-MDR	Over Bridge (RDBR)	Superstructure: RC - T beam Substructure: Inverse T - Type Abutment Foundation: Individually Designed
	RD-MVR	Culvert - Box (RDCBL)	Internal width = 5.0m Internal height = 4.0m
		Culvert - Box (RDCBM)	Internal width = 4.0m Internal height = 3.5m
	RD-VR	Culvert - Box (RDCBM)	Internal width = 4.0m Internal height = 3.5m
		Culvert - Box (RDCBS)	Internal width = 2.5m Internal height = 2.5m
	RD-CT	Culvert - Box (RDCBS)	Internal width = 2.5m Internal height = 2.5m

Note: *Characters in ( ) of Structure column indicate code of each structure.

Table 15-17 Classification of Applicable Structures (Railways)

Crossing Facility		Structure	Composition
Railway	(R)	Over Bridge (ROB)	Superstructure: PC Hollow Slab Substructure: Inverse T - Type Abutment Foundation: Individually Designed

Note: * Characters in ( ) of Structure column indicate code of each structure.

Table 15-18 Classification of Applicable Structures (Water Channels)

Crossing Facility		Structure	Composition
Water Channels	Natural River (River)	Bridge (WCBR)	Superstructure: Individually Designed Substructure: Inverse T - Type Abutment, Wall Type Pier Foundation: Individually Designed * Pile foundation is not available for Pier placed in waterway
		Culvert - Box (WCCBL)	Internal width = 3.5m Internal height = 3.5m
	Major Canal	Bridge (WCBR)	Superstructure: Individually Designed Substructure: Inverse T - Type Abutment, Wall Type Pier Foundation: Individually Designed * Pile foundation is not available for Pier placed in waterway
		Culvert - Box (WCCBM)	Internal width = 2.5m Internal height = 2.5m
	Minor Canal	Culvert - Box (WCCBS)	Internal width = 1.5m Internal height = 1.5m

Note: * Characters in ( ) of Structure column indicate code of each structure.
* Number of inner cell of Culvert - Box is designed with considering maximum design discharge.

15.11.5.2 Application of Structures to Classified Crossing Facilities

Applied structures to classified crossing facilities in the project is described in the next chapter 16, based on design standard and criteria described above.

Feasibility Study

Chapter 16
Design for the Feasibility Study

16 Design for the Feasibility Study

16.1 Throughway of Bareilly Bypass

16.1.1 Review of Pre-F/S Alignment

16.1.1.1 Detailed Field Investigation

The Study Team carried out detailed field investigation along the Pre-F/S alignment between 24 and 29 October 1997, at early stage of the Feasibility Study, to review the Pre-F/S alignment and re-identify major controls for establishment of survey corridor. A complete photo album was prepared by taking shots of all necessary objects in the fields.

16.1.1.2 Three Major Controls Newly Identified

Three major controls were newly identified during the detailed field investigation as described below:

1) Borrow Pits (STA. 11+300 - 12+700)

Two borrow pits were observed to exist near Saidpur village. One is 100 m wide and 200 m long at STA. 11+300, the other is 220 m wide in maximum and 900 m long between STA. 11+800 and STA. 12+700. The Pre-F/S alignment passes at the centre of these large borrow pits.

2) Major Water Distributary: Faridpur Branch (Approximate STA. 15+000)

The Pre-F/S alignment crosses the major water distributary (Faridpur Branch) which is 10 m wide water course with 4 m wide paved road alongside, near Kumra village.

3) Main Power Line (Approximate STA. 14+500 - 20+500)

Three main power lines (say A, B, C-line) run in parallel at the north of the proposed bypass. Two of them (A and B-line) are deviated to the South-east direction from near Singhal village. Then there two lines change their running direction independently, A-line runs towards South-south-east, B-line runs the Southeast. The Pre-F/S alignment crosses both of A-line and B-line.

16.1.1.3 Summary of Major Controls

Including the above mentioned new controls, the wide-area controls, approximate 1 km either side, were summarised in Table 16-1. There are 34 villages, six(6) major roads including NH24 at the beginning and end point of the proposed bypass, one(1) railway, four(4) watercourse including two(2) natural rivers, and other two(2) special areas in the project. In addition, High Tension Lines (HTL) are located at STA. 2 - 8 and STA. 14 - 20. An airforce aerodrome is located at STA. 10 - 12, in approximately 500 m south of the project corridor.

Table 16-1 Major Controls

No.	STA	Side	Description
1	0	—	NH24
2	1.5	Left	Village(Tihulla)
3	3.2	Left	Pond and Trees
4	2.8	Left	Village(Hamipur)
5	2.8	Right	Village(Khana Gauntiya)
6	4.2	Right	Village(Pardhauli)
7	5.5	Left	Village(Bibiapur Kasimnagar)
8	6	Right	Village(Bibiapur)
9	6.5	Left	Village(Ata)
10	7.9	—	Deonarain River
11	8.5	Right	Village(Belwa)
12	9	—	SH 37
13	9.1	—	Railway
14	10.2	Right	Village(Bhura)
15	10.2	Left	Village(Didar Patti)
16	10.3	Left	Village(Gauntiya)
17	11.5	Left	Village(Saidpur)
18	12	Right	Borrow pit
19	13.6	—	SH33
20	13.7	Right	Village(Khera)
21	14.3	—	Nakatia River
22	14.4	Left	Village(Aspur Khubchan)
23	15	Right	Village(Kumura)
24	15	Left	Major Canal
25	17.2	Left	Village(Ahladpur)
26	16.8	Right	Village(Rupapur)
27	18	Right	Village(Kalari)
28	18.7	Right	Village(Lalpur)
29	20	Right	Village(Itaua)
30	20.5	Right	Village(Ramunagar)
31	21	Left	Village(Kachhauli)
32	21.5	Right	Village(Ramunagar Gauntya)
33	22.9	—	MDR
34	23	Right	Village(Nawadia Jhada)
35	24.5	Left	Village(Bithri Chainpur)
36	25	Right	Village(Bhimpur)
37	25.3	—	Major Village Road
38	25.6	Right	Village(Kishapur)
39	26	Left	Village(Alampur)
40	26.4	—	Major Canal
41	26.9	Right	Village(Undia)
42	27.4	Right	Village(Gauntiya Shamnagar)
43	27.5	Left	Village(Tahtajpur)
44	28	Right	Village(Jarathpur)
45	28.5	Left	Village(Nagaria)
46	29.5	Right	Village(No Name)
47	30		NH24

16.1.2 Alignment Designed

16.1.2.1 Basic Data

The following basic data were obtained and/or prepared by the Study Team for the alignment design of Bareilly Bypass:

1) Topographic Map of Survey of India (Scale 1:50,000/250,000)

These maps were used to identify the name of villages and to obtain wide area information such as locations of major rivers, main roads and railways.

2) Topographic Map prepared in the F/S

Topographic map prepared in the F/S was submitted to the Study Team at the end of February 1998. All controls were identified and work quantities were estimated based on this map.

3) Digital ASCII data of topographic survey

Digital ASCII data of topographic survey was also submitted from the entrusted local subcontractor. Digital Terrain Model (DTM) was established from the data in order to make the earthwork volume calculation.

4) Satellite Photographs

Satellite photographs obtained from National Remote Sensing Agency (NRSA) were utilised for identification of the controls.

5) Photographs

During the detailed site investigation by the Study Team, a complete photo album was prepared by taking shots of all necessary objects in the fields. This was referred while the horizontal alignment was being prepared and finally verified.

16.1.2.2 Designed Alignment

(1) Horizontal Alignment

Horizontal alignment was formulated applying radii of 1,800 - 4,000 m. Fifty-two (52) percent of the alignment is curve elements and the other forty-eight (48) percent is tangent elements. Spiral and Superelevation is not required because all curves are large enough to omit the transition and the superelevation.

Figure 16-1 shows the relationship between the PWD alignment and JICA alignment. Figure 16-2 shows design element of the bypass .

Table 16-2 Summary of Horizontal Alignment

Design Element	Length (m)	Ratio (%)
Tangent	14,250.5	48
Curve	15,725.8	52
Spiral (Clothoide)	0.0	0
	29,976.3	100

(2) Vertical Alignment

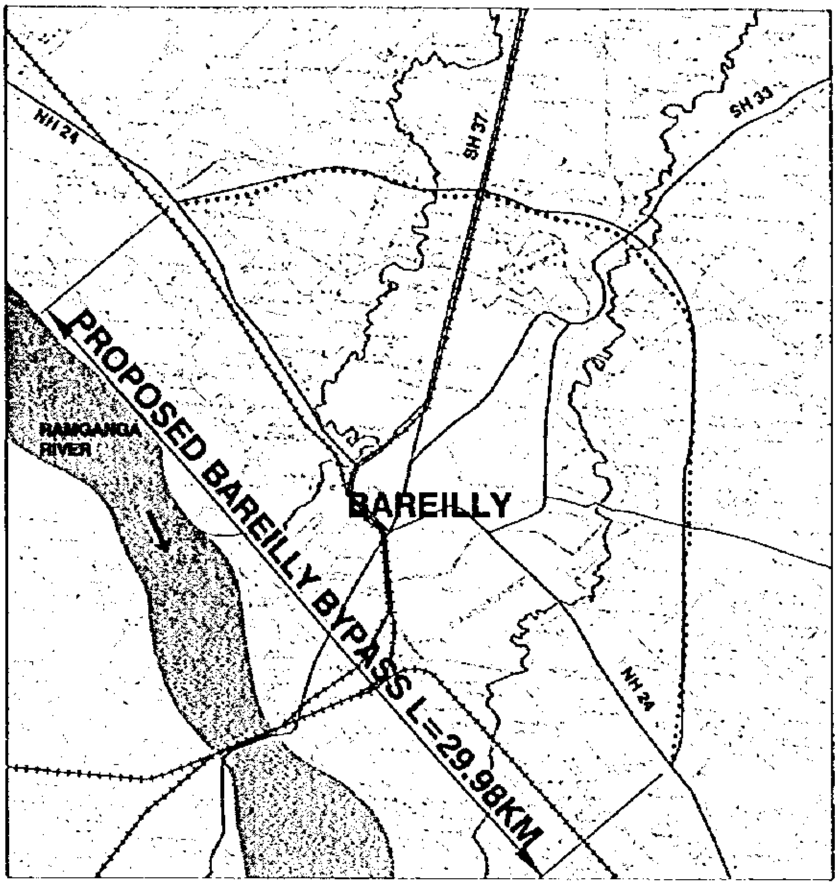
The project area is very flat terrain and therefore fill structures were applied for whole stretch of Bareilly Bypass. As the bypass intended to full control of access, all crossing with the main existing roads were designed as the grade separated intersections.

Maximum grade of 2.5 percent was applied for the vertical alignment and level grade was allowed where the height of filling is lower than 3 m.

Table 16-3 Summary of Vertical Alignment

Grade (%)	Length (m)	Ratio (%)
G = 0.0	4,026.3	13.4
0.0 < G <= 0.3	4,750	15.8
0.3 < G <=1.0	3,400	11.3
1.0 < G <= 2.0	17,200	57.4
2.0 < G	600	2.0
(Max. = 2.5)	(350)	(1.2)
Total	29,976.3	100

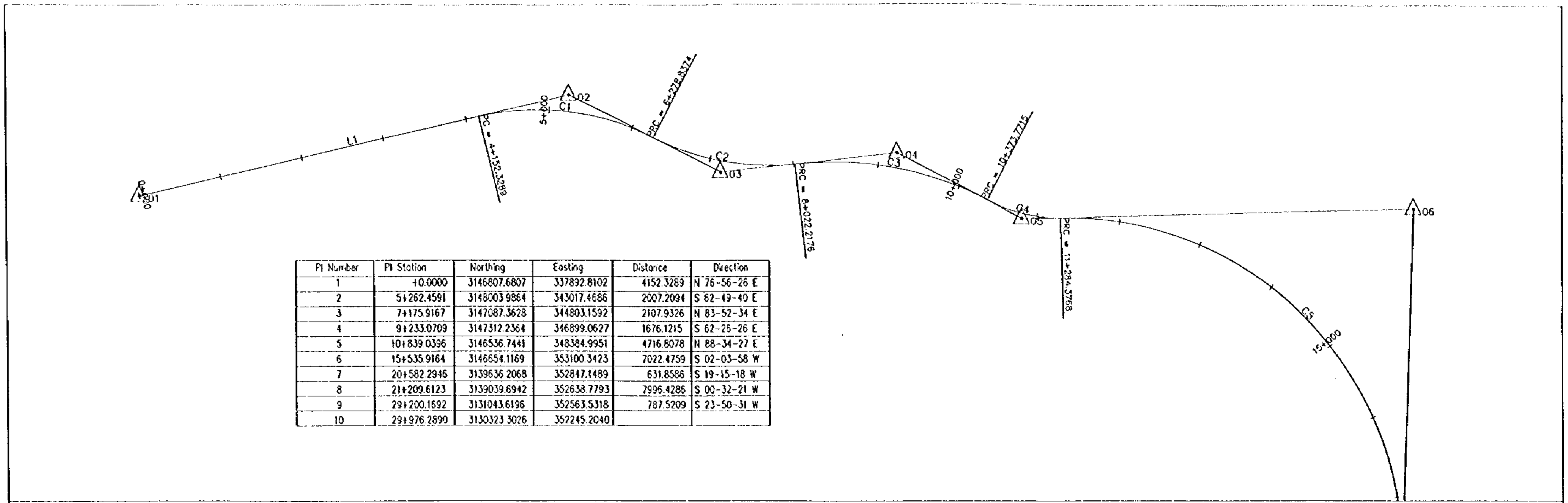
ROUTE MAP OF BAREILLY BYPASS



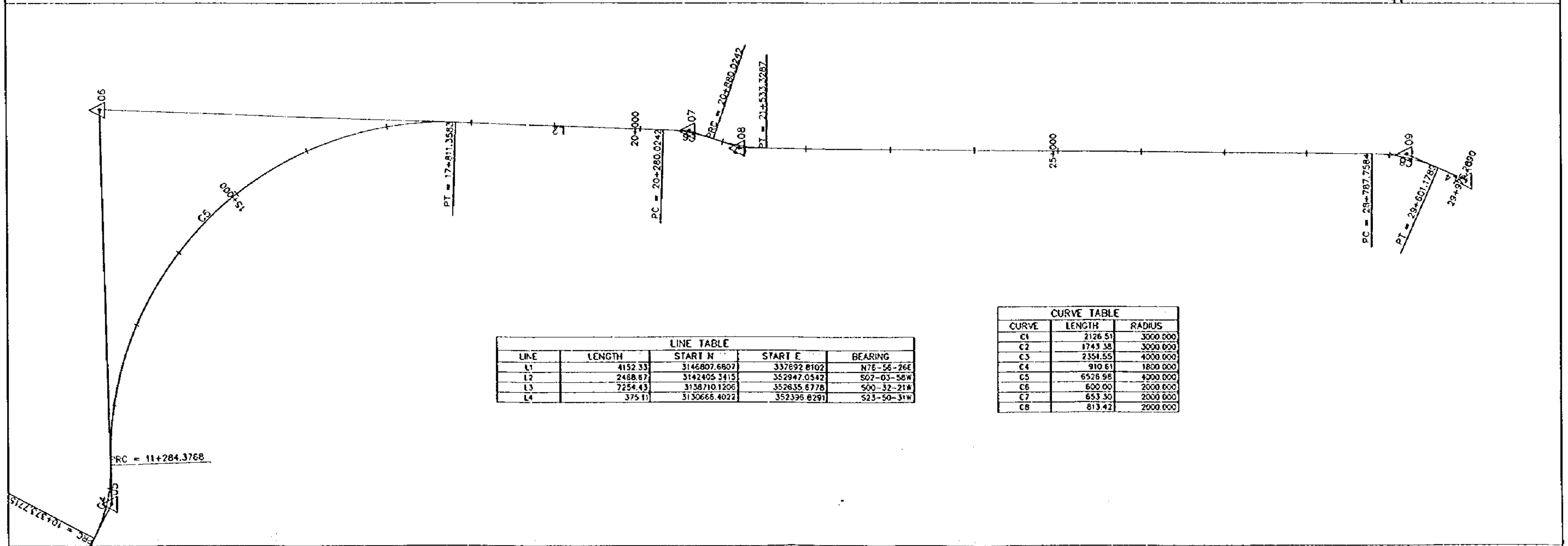
LEGEND

————————	PROPOSED BY JICA STUDY TEAM
················	PROPOSED BY STATE PWD
NH24/SH33/SH37	NATIONAL/STATE HIGHWAY
————————	OTHER ROAD
┼┼┼┼┼┼┼┼┼	RAILWAY
	RIVER

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) THE FEASIBILITY STUDY ON NATIONAL HIGHWAY BYPASSES IN INDIA	DWG TITLE : Figure 16-1 Route map of Bareilly Bypass



PI Number	PI Station	Northing	Easting	Distance	Direction
1	+0.0000	3146807.6807	337892.8102	4152.3289	N 76-56-26 E
2	5+262.4591	3148003.9864	343017.4686	2007.2094	S 62-49-40 E
3	7+175.9167	3147087.3628	344803.1592	2107.9326	N 83-52-34 E
4	9+233.0709	3147312.2364	346899.0627	1676.1215	S 62-26-26 E
5	10+839.0396	3146536.7441	348384.9951	4716.8078	N 88-34-27 E
6	15+535.9164	3146654.1169	353100.3423	7022.4759	S 02-03-58 W
7	20+582.2946	3139636.2068	352847.1489	631.8586	S 19-15-18 W
8	21+209.6123	3139039.6942	352638.7793	7996.4285	S 00-32-21 W
9	29+200.1692	3131043.6196	352563.5318	787.5209	S 23-50-31 W
10	29+976.2890	3130323.3026	352245.2040		



LINE TABLE				
LINE	LENGTH	START N	START E	BEARING
L1	4152.33	3146807.6807	337892.8102	N76-56-26E
L2	2468.67	3142405.3415	352947.0542	S02-03-58W
L3	7254.43	3138710.1206	352635.6778	S00-32-21W
L4	375.11	3130666.4022	352396.8291	S23-50-31W

CURVE TABLE		
CURVE	LENGTH	RADIUS
C1	2126.51	3000.000
C2	1743.38	3000.000
C3	2351.55	4000.000
C4	910.61	1800.000
C5	6526.98	4000.000
C6	600.00	2000.000
C7	653.30	2000.000
C8	813.42	2000.000

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) THE FEASIBILITY STUDY ON NATIONAL HIGHWAY BYPASSES IN INDIA	DWG TITLE : DESIGN ELEMENTS OF HORIZONTAL ALIGNMNET	DWG SCALE : H = 1 : 50,000	DWG NO. : B-2

Figure 16-2 Horizontal Design Element of Bareilly Bypass

16.1.3 Pavement Design Criteria

16.1.3.1 Traffic Analysis and Determination of Design MSAL

As category of truck was not sub-divided in to LCV, HCV and MAV in the traffic forecast, all volume was assumed as HCV, considering the current proportion (LCV: 15%, HCV: 83%, MAV: 2%) in to account, in order to estimate appropriate damage incurred by the vehicles. Table 16-4 shows the future traffic projection for commercial vehicles for Bareilly Bypass.

Table 16-4 Future Traffic Projection for Commercial Vehicles

Section	Year 2002		Total (A)	Saturate Year			Total (B)	Growth Rate(%/yr)
	Bus	Truck			Bus	Truck		
1	1,053	2,974	4,027	2016	3,842	10,915	14,757	9.72%
2	1,238	4,550	5,788	2014	2,957	11,689	14,646	8.04%
3	639	3,317	3,956	2020	56	2,151	9,757	5.14%

Section 1: STA.0 – 8+700(8.7km)
Section 2: STA.8+700 – 13+300(4.6km)
Section 3: STA. 13+300 – 29+976(16.676km)

The design traffic volume recalculated as shown in Table 16-5.

Table 16-5 Design Traffic Volume

No.	Bypass	Year 2002		Total (A)	Design Traffic (B:75% of A)	Directional Traffic (C)
		Bus	Truck			
1	Section 1	1,053	2,974	4,027	3,020	1,510
2	Section 2	1,238	4,550	5,788	4,341	2,171
3	Section 3	639	3,317	3,956	2,967	1,484

On the basis of the traffic projection and the Vehicle Damage Factor, 4.44 was assigned, cumulative equivalent standard Axle Loads in Millions (MSAL) for Bareilly Bypass was calculated in following table.

Table 16-6 Million Equivalent Standard Axle Loads (MSAL)

No.	Bypass	Directional Traffic (C)	Growth Rate(%/yr)	Design Life	VDF	MSAL
1	Section 1	1,510	25.60%	10	4.44	83
2	Section 2	2,171	21.04%	10	4.44	95
3	Section 3	1,484	4.05%	10	4.44	29

The design MSAL value is determined as 90 for the feasibility study.

16.1.3.2 Composition of the Pavement

The total thickness of the pavement to be applied was determined as 800 mm. Following table shows the composition of the structural design of pavement.

Table 16-7 Pavement Composition in Bareilly Bypass

No.	Depth (mm)	Acc. Depth (mm)	Sign	Description
1	40	40	AC	Asphalt Concrete
2	160	200	DBM	Dense Bituminous
3	300	500	WMM	Wet Mix Macadam
4	300	800	GSB	Granular Sub-Base

16.1.4 Drainage Design

1) Longitudinal Drainage

Following longitudinal drainage was installed:

0 Kerb ditch at the fill height is higher than 3 m and

Necessary locations to install above drainage were identified based on the result of the alignment design.

2) Cross-sectional Drainage

Vertical drain for side slope of road embankment is the only cross-sectional drainage in the bypass. This drain was allocated at fill section higher than 3 m, at 20 m interval and lead the surface runoff to the side ditch alongside of the service road.

16.1.5 Utility Relocation

All utilities which have a potential to be affected by ROW were identified using the topographic map in a scale of 1:5,000.

High Tension Lines (HTL) is the biggest utilities when it is required the relocation. HTL will cross the proposed alignment at seven places, STA. 1+475, STA. 4+910, STA. 4+995, STA. 5+870, STA. 15+300, STA. 20+415, STA. 20+565.

16.1.6 Work Quantities

Overall work quantities derived from the preliminary design of throughway was summarised in Table 16-8.

Table 16-8 Quantities of Throughway Works

Item	Unit	Amount
Bypass Length	Km	29.976
Earthwork Section	Km	29.623(98.8%)
Structure Section	Km	0.353(1.2%)
Earthwork Balance		-2,584,340
Fill	M^3	2,584,340
Cut	M^3	0
Pavement		
AC	M^3	24,305
DBM	M^3	97,219
WMM	M^3	182,286
GSB	M^3	182,286
Service Road	Km	60,41
Slope Protection	M^2	424,200
Drainage		
Kerb	M	31,500
Berm	M	3,400
Side Ditch	M	31,980
Vertical Drain	M	24,000
Utility Relocation		
HTL	M	900
Power Line	M	3,510
Telecom. Line	M	920
Well/Pump	M	28

16.2 Design of Interchanges in Bareilly Bypass

16.2.1 General

The Bareilly Bypass has two link points with the existing NH24 at the beginning point (BP) and end point (EP) of the throughway. In addition to these link points, Bareilly Bypass was intended to have interchanges at the cross points with SH37 and SH33 to enable the access between the bypass and these SHs. The interchange is required to secure the smooth and safe traffic flow to the driver as much as possible, under the fully access-control policy.

16.2.2 Intersection at the Beginning Point

16.2.2.1 Characteristics of Traffic Flow

Traffic Flow between NH24 (Delhi side) and the Bypass

The design speed of the section between the tollgate and BP does not need the same design speed of the throughway because this section is required as a part of intersection, or the transition section between NH24 and the bypass. Consequently, the geometric design of the horizontal alignment does not require the adoption of a large curvature as required for the throughway.

Traffic Flow on NH24, between Delhi side and Bareilly side

The flow from Bareilly side to Delhi side may utilise the existing NH24 as it is. However, this directional flow will receive the traffic flow which runs from the bypass to NH24 (Delhi side). Therefore, this traffic flow will require an appropriate merging section, which may necessitate an additional lane, to secure the smooth and safe traffic.

Traffic Flow between NH24 (Bareilly side) and the Bypass

Based on the simulation conducted for the future traffic demand forecast, this directional traffic flow showed very small amount compared to other traffic flows. However, the traffic which tried to enter the bypass from NH24 (Bareilly side) is to cross the through traffic on NH24. Intersection layout design shall be carried out carefully, taking into account this traffic movement, to minimise the adverse influence to the overall traffic management in this intersection.

16.2.2.2 Selection of Intersection Type of BP

Four alternative layouts were prepared for the intersection design as illustrated below.

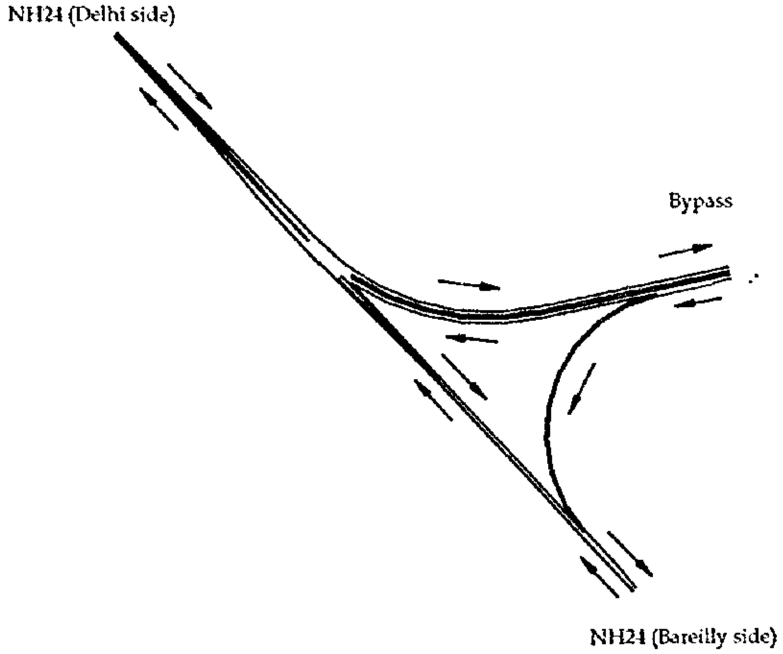


Figure 16-3 Intersection Type of Alternative 1

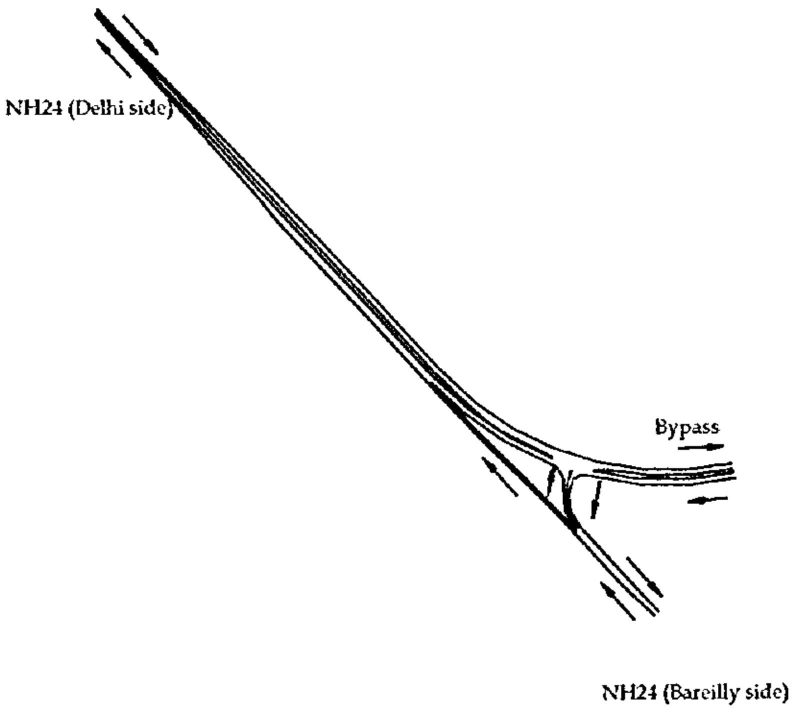


Figure 16-4 Intersection Type of Alternative 2

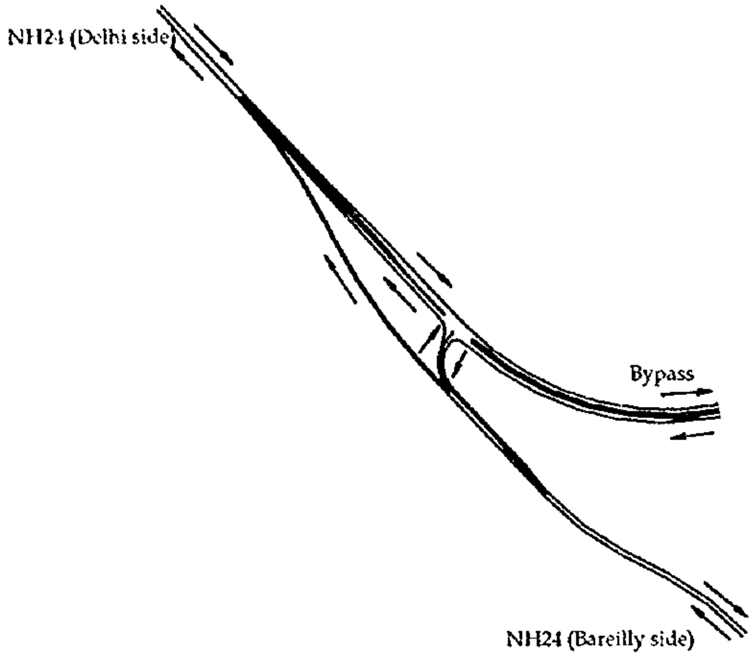


Figure 16-5 Intersection Type of Alternative 3

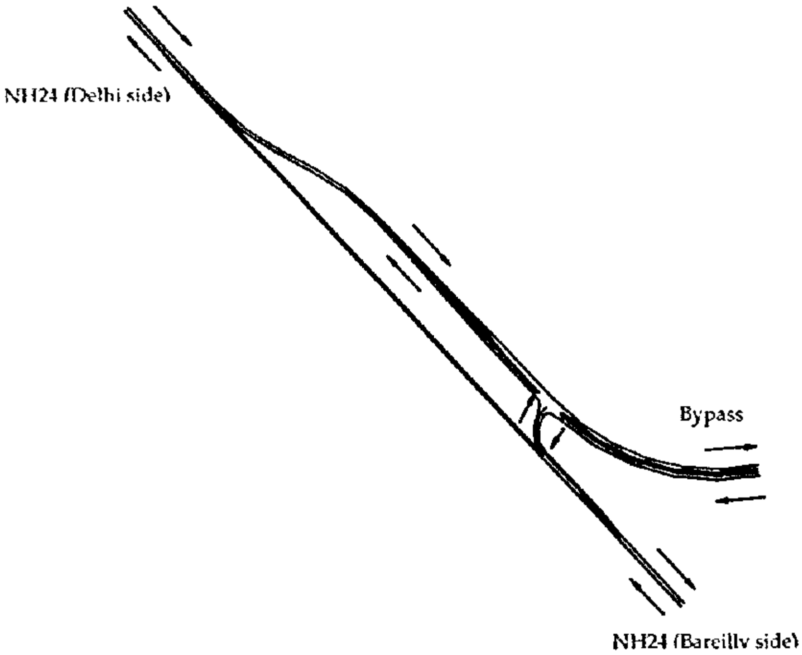


Figure 16-6 Intersection Type of Alternative 4

Table 16-9 Alternative of Intersection Type

	Merit	Demerit
Alternative 1	• Less civil work will be required for the existing NH.	• Large additional land will be required.
Alternative 2	• Less additional land will be required. • Less civil work will be required for the existing NH. • Intersection angle between Bypass and the approach from NH is 90 degrees.	• Intersection between Bypass and the approach from NH is located on the curve
Alternative 3	• Intersection angle between Bypass and the approach from NH is 90 degrees. • Intersection between the bypass and the approach from the NH is located on the tangent section of the bypass alignment.	• Additional land will be required for relocation of NH. • Alignment of NH will be worse than the present.
Alternative 4	• Less affection to NH during the construction. • Intersection angle between Bypass and the approach from NH is 90 degrees. • Intersection between the bypass and the approach from the NH is located on the tangent section of the bypass alignment.	• Alignment of bypass is worse than other alternatives. • Additional land will be required for the bypass.

16.2.2.3 Proposed Intersection type at BP of Bareilly Bypass

Based on the consideration described in the previous sections, the JICA Study Team recommends to apply the Alternative 2 as the proposed intersection layout for the project.

16.2.3 Intersection at the End Point

16.2.3.1 Characteristics of Traffic Flow

Based on the future traffic demand forecast, the majority of traffic flow at this intersection will be given by the movement between the bypass and NH24 (Lucknow side), 28,200 pcu/day in 2012. The second traffic volume was given by the traffic movement on NH24 between Bareilly side and Lucknow side. The third (the smallest) traffic is the one between the bypass and NH24 (Bareilly side). The Study Team gave the priority to the traffic movement between the bypass and NH24 (Lucknow side).

16.2.3.2 Proposed Intersection type of EP of Bareilly Bypass

The alternative study of this intersection layout was quite similar to that of beginning point as the site situation is in mirror symmetry.

Accordingly, the Alternative 2 type as illustrated in Figure 16-4 was judged as the most appropriate layout for the intersection at this location. Figure 16-7 shows the recommend layout of the intersection at EP of Bareilly Bypass.

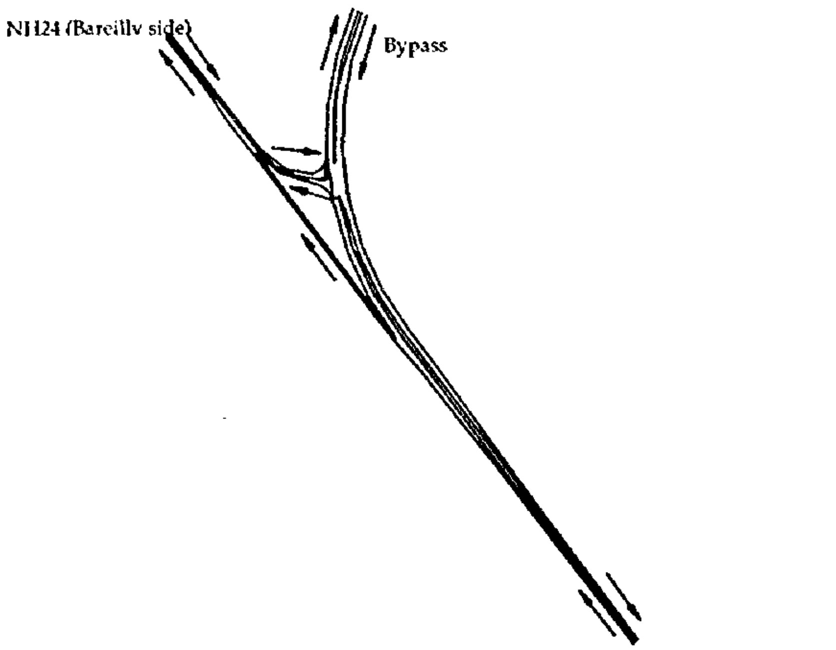


Figure 16-7 Layout of the Intersection at the End Point of Bareilly Bypass

16.2.4 Design of SH37 Interchange

The function of this interchange is to provide the link point for the traffic demand between the bypass and the existing SH37. Within the area where the proposed bypass crosses SH37, a metre gauge railway, which will be upgraded to a broad gauge in future, runs parallel to SH37. A small village, Belwa, is located on the southwestern side of the crossing point.

16.2.4.1 Comparison of Interchange Types

<u>Diamond Type</u>

The Diamond Type is the simplest and commonly used type for small scale interchange. A full diamond interchange is formed with a one-way diagonal-type ramp in each quadrant. The ramps are generally aligned with free-flow terminals on the major highway, and the right turns at grade are confined to the crossroad. The merits and demerits will be compared as list below:

Merits:

- Required area is small
- Only one viaduct is required over the existing road
- Construction cost is inexpensive
- Identification of entry point may be simpler for the user on existing road

Demerits:

- In case of Closed Toll System, tollgates are required on each four ramps
- The right turns at grade are confined on the existing road
- The gradient of ramp road is generally not gentle

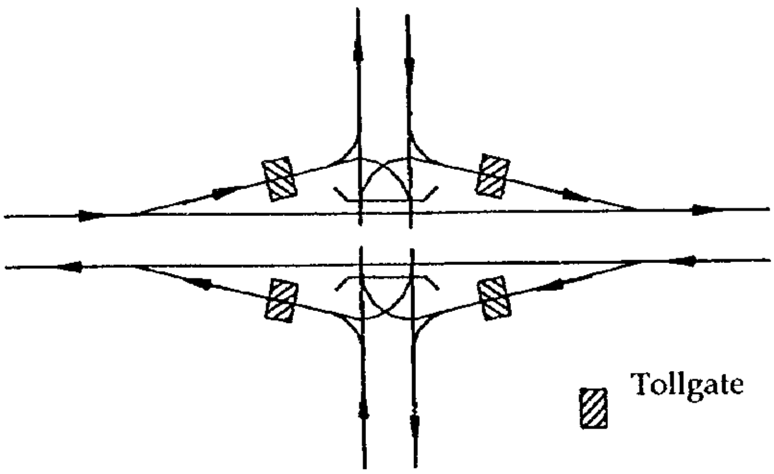


Figure 16-8 Diamond Type Interchange

Trumpet Type

The Trumpet Type is the most common type of interchange. The merits and demerits are will be listed as follows:

Merits:

- Toll collection is easy at the point of entry/exit
- Only one merging point to the existing road is required for the traffic flows
- The gradient of rampway is generally gentle

Demerits:

- Large-scale area is required
- Two viaducts over the existing road and rampway are required
- Construction cost of the structure is expensive than Diamond Type

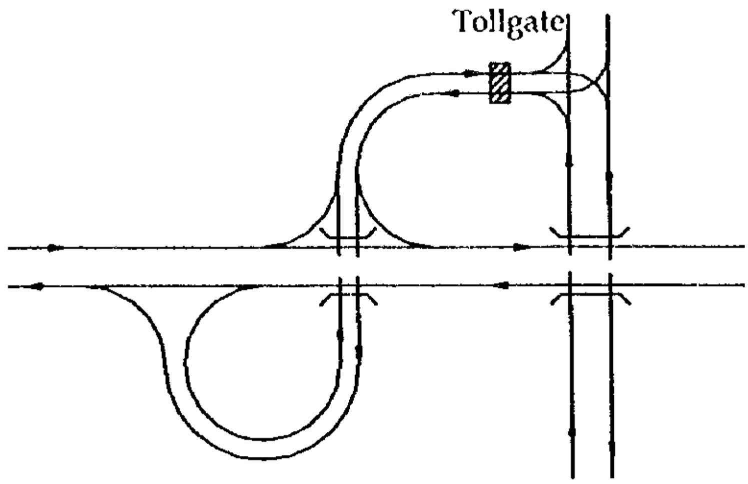


Figure 16-9 Trumpet Type Interchange

Y-shape Type (with at-grade intersection)

Y-shape Type is one of the popular types of interchanges. However, a typical Y-Type interchange will require several structures for crossing the throughway/rampway. Therefore, in this project case, Y-Type, with at grade intersection on the ramps, was proposed for the alternatives.

Merits:

- Required area is comparatively small
- Toll collection is easy at the point of entry/exit
- Only one merging point of the existing road is required for the traffic flows

Demerits:

- Two viaducts over the existing road and rampway are required
- Construction cost of the structure is expensive than Diamond Type
- The at-grade crossing of two traffic flows occurs on the rampway

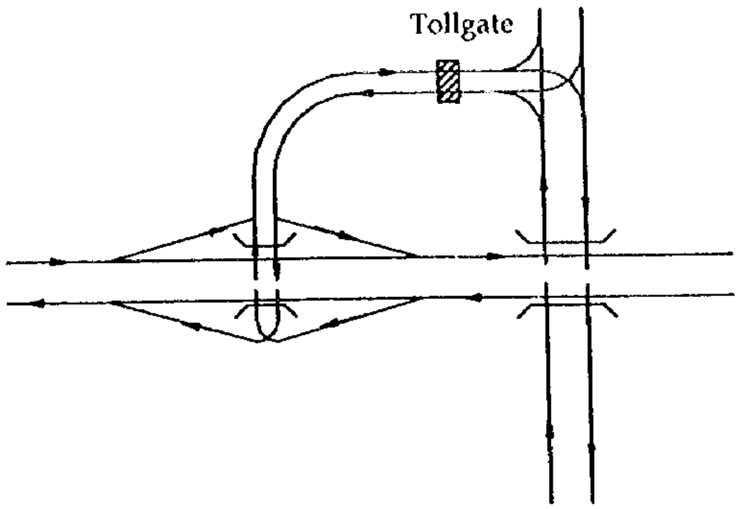


Figure 16-10 Y-shape Type (with at-grade intersection) Interchange

16.2.4.2 Proposed Interchange Type

For SH37 IC, the JICA Study Team proposed the Y-Type Interchange, with at-grade intersection. Hence this Y-type of interchange with at-grade intersection was judged as the most suitable from the viewpoints of cost minimum and fulfilment of required function. The application of Diamond Type at this location is not recommended due to the existence of railways.

16.2.4.3 Design Conditions

The following conditions were taken into account and reviewed for the design of interchange.

1) Traffic Volume

The projections of directional traffic volume in the design year of 2012 in terms of Design Hourly Volume (DHV) of SH37 are shown in Table 16-10 and Figure 16-11.

Table 16-10 Traffic Volume of Ramps on SH37IC

SH37	Traffic Survey Data			ADT	DHV
Bypass	Delhi	8847	SH37		
	SH37	8999	Delhi	17800	1070
	SH37	10498	SH33		
	SH33	10726	SH37	21200	1270
Ramp-B & Ramp-D	Nainital	1549	Lucknow		
	Bareilly	3856	Lucknow	5400	320
	Lucknow	1593	Nainital		
	Lucknow	4242	Bareilly	5800	350
	Sub total	11240		11200	670
Ramp-A & Ramp-C	Nainital	239	Delhi		
	Bareilly	3869	Delhi	4100	250
	Delhi	70	Nainital		
	Delhi	3684	Bareilly	3700	220
	Sub total	7862		7800	470

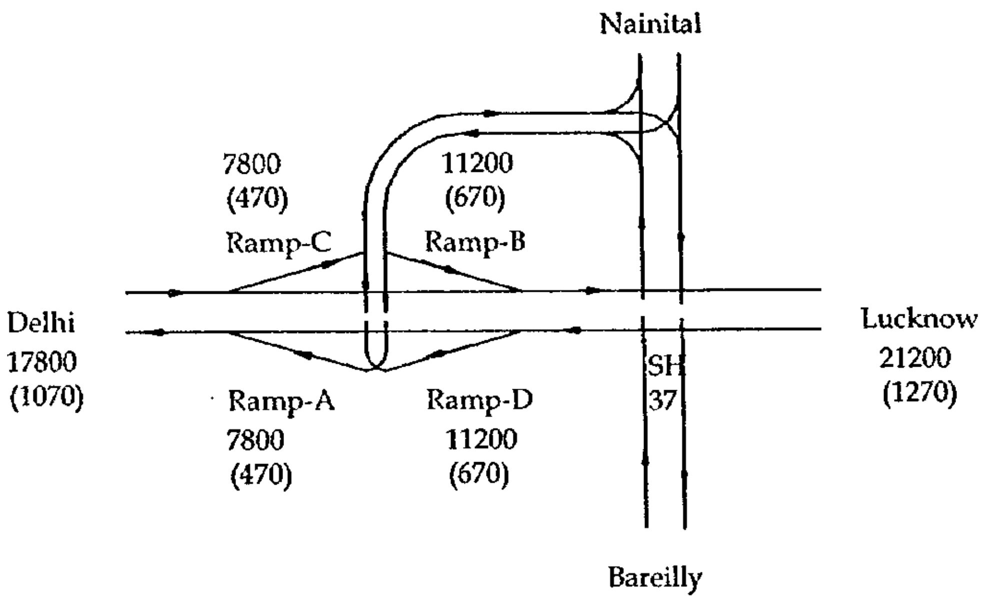


Figure 16-11 Traffic Volume of Ramps on SH37IC

16.2.4.4 Plan of SH37 IC

1) Horizontal Alignment Plan

The horizontal alignment plan of the interchange was made with the following considerations.

0 The layout of interchange is Y-shape Type with at-grade intersection.

1 The ramp alignment under the throughway is to be a straight line and crosses at right angle with throughway in order to minimise the viaduct span.

2) Vertical Alignment Plan

The approach section to the existing SH37 was designed in a gentle grade to secure smooth and safe traffic flow.

3) Cross Sectional Plan

Judging from the required capacity for the directional traffic volume, the number of lanes of all four ramps were applied as one lane.

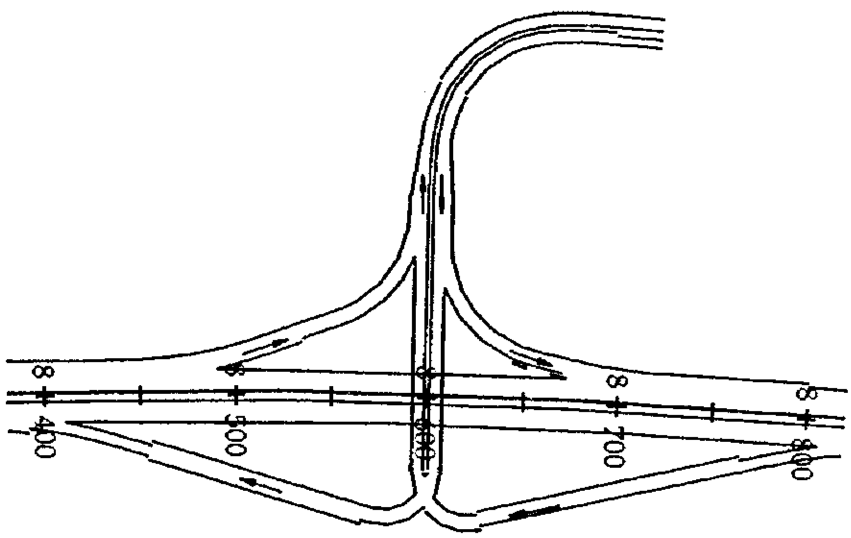


Figure 16-12 Layout of SH37IC

16.2.5 Design of SH33 Interchange

This Interchange connects the bypass and SH33, and serves the traffic to link between the bypass and the city centre of Bareilly or Pilibhit through SH33. The proposed SH33 IC was designed to locate approximately 700 m south from the existing Nakatia River Bridge on SH33.

16.2.5.1 Proposed Interchange Type

Y-Type Interchange with at-grade intersection was proposed with the same consideration for the SH37 IC. Regarding the Toll System, this interchange type is applicable to manage the toll collection under the Closed Toll System.

The traffic control to prevent the entry of rogue vehicles will be conducted on the approach road from the existing SH to the rampway.

16.2.5.2 Design Conditions

1) Traffic Volume

The projections of directional traffic volume in the design year of 2012 in terms of DHV of SH33 are shown in Table 16-11 and Figure 16-13.

Table 16-11 Traffic Volume of Ramps on SH33IC

SH33	Traffic Survey Data			ADT	DHV
Bypass	SH37	10498	SH33		
	SH33	10726	SH37	21200	1270
	SH33	6660	Lucknow		
	Lucknow	6687	SH33	13300	800
Ramp-B & Ramp-D	Pilibhit	129	Lucknow		
	Bareilly	2387	Lucknow	2500	150
	Lucknow	160	Pilibhit		
	Lucknow	2564	Bareilly	2700	160
	Sub total	5240		5200	310
Ramp-A & Ramp-C	Pilibhit	3412	Delhi		
	Bareilly	3351	Delhi	6800	410
	Delhi	2973	Pilibhit		
	Delhi	3381	Bareilly	6400	380
	Sub total	13117		13100	790

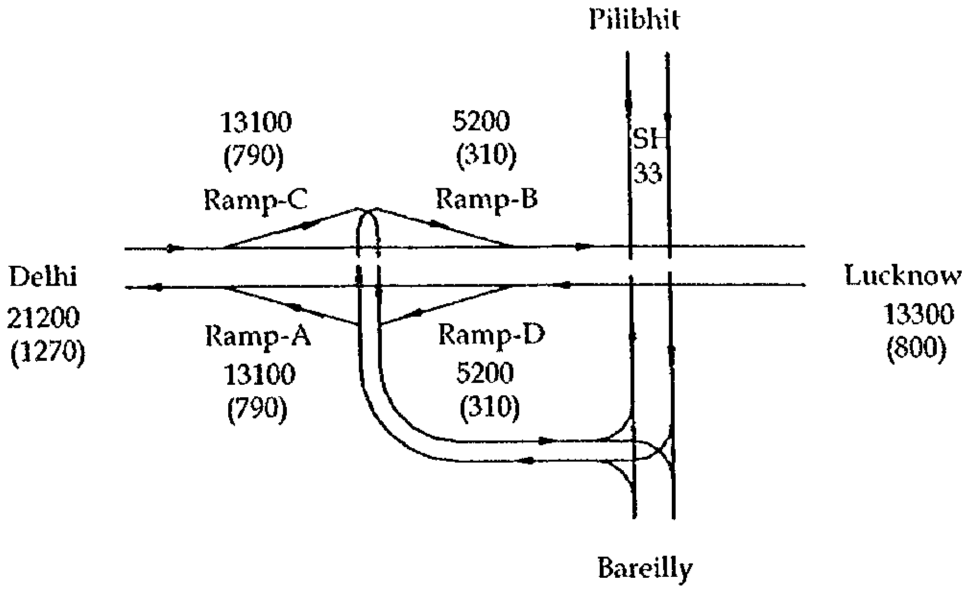


Figure 16-13 Traffic Volume of Ramps on SH33IC

16.2.5.3 Plan of SH33 IC

Through the several site reconnaissance by the Study Team, it was judged that there are no physical restrictions or major controls at the proposed location for the SH33 IC. Taking into account the said site condition and future traffic demand at this location, the Y-Type IC with at-grade intersection was recommended. This Y-Type IC will achieve the least cost construction with minimum structures.

The layout of SH33 IC was designed based on the following criteria:

0 The design speed of 40 km/hr for the ramp design.
1 The IC will locate at the southwest side of SH to minimise the scale of IC.
2 The tollgate will be installed on the rampway

1) Horizontal Alignment Plan

The ramp under the throughway was designed to cross at right angle to minimise the viaduct span over the rampway.

2) Vertical Alignment Plan

Vertical grade of 3% was applied to the slope section of on/off ramps.

3) Cross Sectional Plan

Based on the required capacity of the estimated four directional traffic volume by the future traffic demand forecast, one-lane ramp was applied to the IC.

Figure 16-14 shows the recommended layout of the SH33 IC, estimated by the above design policy.

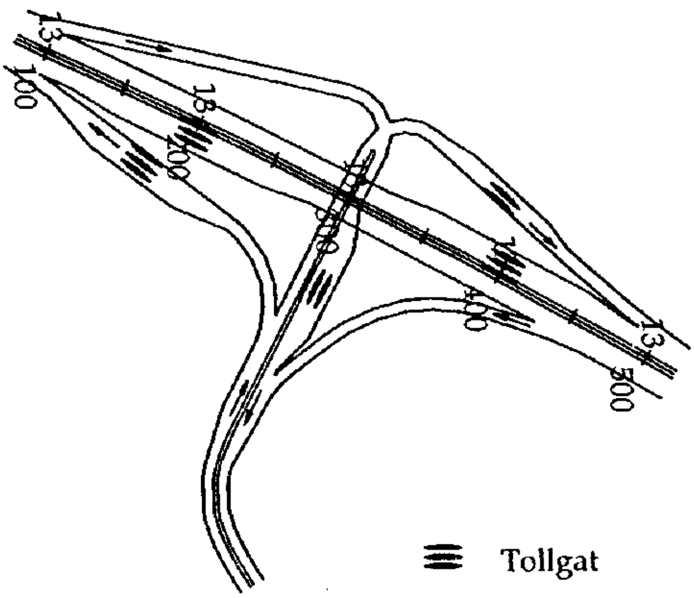


Figure 16-14 Layout of SH33IC

16.2.6 Work Quantities

16.2.6.1 Work Quantities of BP Intersection

Work quantities of proposed intersection at the BP of Bareilly Bypass is summarised in table below.

Item	Unit	Amount
2 Lane Approach Road	m	210
Earth filling	m3	3570
Pavement	m2	2730

Work quantities of toll barrier at BP is as followings:

Item	Unit	Amount
Toll barrier	Each	1
Earth filling	m3	880
Pavement	m2	440
Toll booth	Each	3

16.2.6.2 Work Quantities of EP Intersection

Work quantities of the intersection at the EP is shown in the table below.

Item	Unit	Amount
2 Lane Approach Road	m	180
Earth filling	m3	3060
Pavement	m2	2340

Work quantities of toll barrier at EP is as followings:

Item	Unit	Amount
Toll barrier	Each	1
Earth filling	m3	880
Pavement	m2	440
Toll booth	Each	3

16.2.6.3 Work Quantities of SH37 IC

Work quantities of the proposed interchange of SH37 is summarised in Table below.

Item	Unit	Amount
1 Lane Rampway	m	1320
Earth filling	m3	33120
Pavement	m2	9660
2 Lane Approach Road	m	750
Earth filling	m3	12750
Pavement	m2	9750

16.2.6.4 Work Quantities of SH33 IC

Work quantities of the interchange of SH33 is shown in following table.

Item	Unit	Amount
1 Lane Rampway	m	1390
Earth filling	m3	33360
Pavement	m2	9730
2 Lane Approach Road	m	510
Earth filling	m3	8670
Pavement	m2	6630

Work quantities of tollgate/toll barrier at SH33IC is as followings:

Item	Unit	Amount
Tollgate/Toll barrier	Each	5
Earth filling	m3	10200
Pavement	m2	2930
Toll booth	Each	14

16.3 Structure Design of Bareilly Bypass

16.3.1 General

Methodology of structure planning and design was described in Chapter 15.11, "Design Standard and Criteria of Structure".

16.3.2 Crossing Facilities

16.3.2.1 Roads(RD)

There are two highways of State Highway(RD-HW) 33 and 37, and one major district road(-DR) which cross the proposed bypass. 25 village roads(-VR) and 4 cart tracks(-CT) were identified to cross the proposed bypass.

16.3.2.2 Railways

One railway line crosses the bypass at near State Highway 33. The current feature is single track, meter gauge, non-electrified. However, according to

Ministry of Railway, it will be upgraded to double track, broad gauge, non-electrified in near future.

16.3.2.3 Water Channels(WC)

3major rivers of Deonarain and Nakatia River cross the proposed bypass. 7 canals were identified to cross the proposed bypass. Some of their hydrological feature were investigated and analysed.

16.3.2.4 Summary of Crossing Facilities

Crossing facilities are summarised as shown in the following Table 16-12.

Table 16-12 Major Crossing Facilities in Bareilly Bypass (1/3)

No.	STA	Type and Class	Present Condition	Remarks
1	1+180	RD - VR	Width : 5.0m (Paved) C.W. : 3.0m Height: 0.7m	
2	1+990	RD – VR	Width : 2.5m (Non-paved) Height : 0.7m	Crossing with bypass at same point
3	1+990	WC – Major Canal	Width : 4.5m Depth : 0.9m	Mundia Minor
4	3+230	RD – VR		
5	3+810	RD – VR		
6	3+920	RD – VR		
7	4+020	RD – VR		
8	5+150	RD – VR		
9	5+750	RD – VR		
10	6+280	WC – Major Canal		Bhojipura Distributary Crossing with bypass at same point
11	6+280	RD – VR		
12	6+500	RD – CT		
13	7+900	WC - River	Width : 20.0m Depth : 3.0m	Deonarain River Submergible bridge in vicinity of upstream
14	8+450	RD – VR		
15	9+040	RD – HW		State Highway 37
16	9+090	Railway	Meter Gauge Single Track Non-electrified	*Future Programme is confirmed by Ministry of Railway. (Broad Gauge, 2 Track, Non-electrified)

Note: Present Condition
RD: Height is measured from existing ground level.
WC: Width is distance between inside top of embankments.
G.L.: Present Ground Level

Table 16-12 Major Crossing Facilities in Bareilly Bypass (2/3)

No.	STA	Type and Class	Present Condition	Remarks
17	9+110	RD - CT	Width : 3.7m Height : 2.0m	
18	9+450	WC - Minor Canal		
19	10+350	RD - VR		
20	10+660	RD - VR		
21	11+600	RD - VR		
22	12+970	WC - Major Canal	Width : 3.0m Height : 0.7m	Bareilly Distributary
23	12+970	RD - VR		Crossing with bypass at same point
24	13+610	RD - HW	Width : 12.0m(Paved) C.W. : 7.0m Height : 1.5m	State Highway No.33
25	14+270	WC - River	Width : 20.0m Depth : 3.0m	Nakatia River *Bridge in vicinity of upstream
26	15+200	WC - Minor Canal		
27	15+200	RD - VR		
28	16+200	RD - VR		
29	17+250	RD - VR		
30	19+180	RD - VR		
31	20+250	RD - VR		
32	21+310	RD - VR		
33	21+670	RD - VR		
34	22+900	RD - DR	Width : 10.4m(Paved) C.W.: 4.0m Height : 1.0m	
35	23+920	RD - CT		
36	25+200	RD - VR		
37	25+200	WC - Minor Canal		
38	25+290	RD - VR	Width : 10.4m(Paved) C.W.: 4.5m Height : 1.0m	
39	25+910	RD - VR		

Note: Present Condition
RD: Height is measured from existing ground level.
WC: Width is distance between inside top of embankments.
G.L.: Present Ground Level

Table 16-12 Major Crossing Facilities in Bareilly Bypass (3/3)

No.	STA	Type and Class	Present Condition	Remarks
40	26+360	WC - Major Canal		Rajau Distributary Crossing with bypass at same point
41	26+360	RD - VR		
42	27+270	RD - VR		

Note: Present Condition RD: Height is measured from existing ground level.

WC: Width is distance between inside top of embankments.

G.L.: Present Ground Level

16.3.3 Design Condition (1), Hydrology

16.3.3.1 General

Hydrological analysis was carried out for individual crossing facility of water channel identified.

Scope of work and applied formula of hydrological analysis were described in Chapter 15.11, "Design Standard and Criteria of Structure".

16.3.3.2 Summary of Hydrological Analysis

Results of hydrological analysis were summarised in the following tables.

(1) Maximum Design Discharge

a) River

Table 16-13 Maximum Design Discharge of Rivers

No. of Crossing Facility	River	Catchment Area	Rational formula for peak run-off from catchment				Dieken's formula		Design Discharge
		A (hectare)	f	p	Ic	Q (m3/sec)	Cd	Q (m3/sec)	Q (m3/sec)
13	Deonarain River	20,000	0.65	0.30	10.17	1,110.6	6	319.2	478.8
25	Nakatia River	11,000	0.69	0.30	10.17	648.4	6	203.8	305.7

b) Canal

Table 16-14 Design Discharge of Canal

No. of Crossing Facility	Design Discharge (m^3/sec)	Name of Canal	Other Additional Information
3	0.8	Mundia Minor	village road or cart track along with canal
10	20	Bhojipura Distributary	
22	4.1	Bareilly Distributary	

(2) Design Highest Flood Level (DHFL) of River

Table 16-15 Estimated Highest Flood Level

River	No. of Crossing Facility	M.D.D. Qd (m^3/sec)	Application of Manning's Formula					Estimated H.F.L. (m)
			R (m)	S	n	V (m/sec)	A (m^2)	
Deonarain River	13	478.8	4.7	1/1493	0.040	1.8	275.5	7.5
Nakatia River	25	305.7	3.7	1/1587	0.040	1.5	212.2	5.5

Note: R: hydraulic mean depth S: bed slope n: rugosity co-efficient
V: velocity considered uniform throughout the cross-section
A: available throughout area Estimated H.F.L.: from deepest bed

a) Deonarain River

Reported H.F.L. is approximately 173m from M.S.L. which is 1m above existing submersible bridge in vicinity, and estimated H.F.L. is approximately 2m.

Estimated H.F.L. is calculated based on the river cross section with where proposed bypass crosses. It may represent the concentrated water flow of flood at only one opening. However the Study Team judged that the provision of culvert box in adjust? area for local with function as the conduit at the time of flood, and the actual H.F.L will be returned in the height of reported H.F.L.

With this reason, reported H.F.L. is selected as DHFL. (approximately, 171 from mean sea level)

b) Nakatia River

Reported H.F.L. is approximately 171m from M.S.L., which is 2.5m above water bed level. Reported H.F.L. is determined as DHFL with the same reason with Deonarain River.

(3) Minimum Vertical Clearance

a) River

Table 16-16 Minimum Vertical Clearance

River	No. of A.S.	Applicable Type of Structure	M.D.D. Qd (m^3/sec)	Minimum Vertical Clearance (mm)
Deonarain River	9	WC-BR	478.8	1,200
Nakatia River	20	WC-BR	305.7	1,200

Note: No. of A.S.: Number of Applied Structures

b) Canal

Major Canal

Applied structure is bridge type structure, and minimum required clearance is defined with M.D.D. of each canal. However in most case, vertical clearance was controlled by the village road or cart track running along the canal.

Minor Canal

Applicable structure is Culvert Box (WCCBS), and 600mm of vertical clearance was applied for flow obstruction caused by sediment in the future.

(4) Afflux

Afflux is required to consider for river and stream at which the bridge structure was proposed.

Table 16-17 Afflux

No. of C.S.	River	M.D.D. Qd (m^3/sec)	Orifice Formula				H (m)	Obstructions
			L (m)	W (m)	e	C_0		
13	Deonarain	478.8	46.0	49.0	0.16	0.950	0.420	2 piers
25	Nakatia	305.7	43.0	49.0	0.37	0.913	0.850	2 piers

Note: L: Sum of bridge spans
W: Unobstrudted width of stream
e: Coefficient of Orifice Formula (Defined by L / W)
C_0: Coefficient of Orifice Formula (Defined by L / W)

(5) Maximum Depth of Scour

Maximum depth of scour is also required to consider for river and stream at which the bridge structure was proposed.

Table 16-18 Maximum Depth of Scour

No. of C.S.	River	M.D.D. Qd (m^3/sec)	E.L.W. (m)	D_b (m^2/sec)	K_{sf}	d_{sm} (m)	M.D.S. (m)
13	Deonarain	478.8	46.0	10.4	1.75	5.3	Abut: 6.7 Pier: 10.6
25	Nakatia	305.7	43.0	7.1	1.75	4.1	Abut: 5.2 Pier: 8.2

Note: L.W.: Linear waterway
D_b: Discharge divided by E.L.W.
d_{sm}: Mean depth of Scour
E.L.W.: Effective linear waterway
K_{sf}: Silt factor of bed material
M.D.S: Maximum depth of scour

(6) Summary of Hydrological Condition for Structure Design

Summary of hydrological condition is tabulated in Table 16-19.

Table 16-19 Summary of Hydrological Condition of Bareilly

STA	No.	River	A.S.	M.D.D. (m^3/sec)	DHFL (m)	M.V.C. (m)	Afflux (m)	M.D.S. (m)
7+900	13	Deonarain River	WC-BR	478.8	173	1.2	0.42	Abut:6.7 Pier: 10.6
14+270	25	Nakatia River	WC-BR	305.7	171	1.2	0.85	Abut:5.2 Pier: 8.2

Note: DHFL: from Mean Sea Level

16.3.4 Design Condition (2), Geology

(1) Geological Feature of Bareilly Bypass

Bareilly is situated in the Indo-gangetic alluvial plains and is about 100km from the lower Siwalik mountain ranges. The strata at different locations in Bareilly are in general alluvium of up to 35m thickness. The alluvium is categorised as the Bhangar or old alluvium, which corresponds in age with the Middle Pleistocene. The alluvium consists of silt, sand, clay or silt-clay mixture. The alluvium sometimes exhibit presence of calcareous matter.

The soils have developed on alluvium washing from inner or outer Himalayas transported by Ganges and its tributaries.

All of 16 boring points show the similar feature and composition of soils. Most of the portion of soil is occupied with coarse grained alluvium like silty sand or fine sand, and some clay strata is identified. Depth of clay strata depends on each boring point. Apparently, portion of clay is more in the boring points near the two major rivers than other points.

Principally, silty or fine sand of which N value is equal or more than 30 is determined as bearing strata. Those bearing strata were found in approximately 25m below the ground surface.

(2) Ground Water Level

Ground water level was measured when the bore holes were drilled. Throughout the bypass area, the ground water level was observed approximately 2 to 5.5 m deep.

This level will rise up during heavy rainy season or go down during dry season.

16.3.5 Applied Structures

16.3.5.1 General

Proposed locations of each structure was determined based on the site investigation and prepared topographic map of 1:5,000. There are some new crossing structures that planned their location to secure the current local traffic. As the major structures, there are tow interchange bridge, three road over bridge, one road/railway over bridges, and two bridges over rivers. Summary of applied structure for individual crossing facility is shown in the Table 16-20.

Table 16-20 Summary of Applied Structures (1/2)

No. of A.S.	No. of C.F.	STA	Applied Structure	Type and Class of Crossing Facility	Remarks
1	1	1+180	RDCBM	RD - VR	L = 33.4m
2	2	1+990	WCBR	RD – VR	Foundation: Abut: Pile
	3	1+990	(RC-Slab, 2 @ 9.0 = 18.0m)	WC – Major Canal	Pier: Pile
3	4	3+230	RDCBM	RD – VR	L = 33.4m
4	5	3+810	RDCBM	RD – VR	L = 33.4m
	6	3+920	(Detoured)	RD – VR	
	7	4+020	(Detoured)	RD – VR	
5	8	5+150	RDCBM	RD – VR	L = 33.4m
6	9	5+750	RDCBM	RD – VR	L = 33.4m
7	10	6+280	WCBR	WC – Major Canal	Foundation: Abut: Pile
	11	6+280	(RC-Slab, 2 @ 9.0 = 18.0m)	RD – VR	Pier: Well
8	12	6+500	RDCBS	RD – CT	L = 33.4m
9	13	7+900	WCBR (RC-T beam, 15.0+ 19.0+15.0 = 49.0m)	WC – River (Deonarain River)	Foundation: Abut: Pile Pier: Well
10	14	8+450	RDCBM	RD – VR	
11		8+700	ICBR (RC-T beam, 2 @ 15.0 = 30.0m)	(New)	For Interchange
12	15	9+040	RDBR	RD – HW (SH37)	Foundation: Abut: Pile
	16	9+090	(PC Hollow,	Railway	Pier: Pile
	17	9+110	22.0+25.0+22.0 = 69.0m)	RD – CT	
13	18	9+450	WCCBS (cell x 2)	WC – Minor Canal	L = 33.4m
14	19	10+350	RDCBM	RD – VR	L = 33.4m
15	20	10+660	RDCBM	RD – VR	L = 33.4m
16	21	11+600	RDCBM	RD – VR	L = 33.4m
17	22	12+970	WCBR	WC – Major Canal	Foundation: Abut: Pile
	23	12+970	(RC-Slab, 2 @ 9.0 = 18.0m)	RD – VR	Pier: Pile

Note: Number of C.F.: Number of Crossing Facility
Number of A.S.: Number of Applied Structure
Code of Applied Structure is summarised and described in Part 1: General.

Table 16-20 Summary of Applied Structures (2/2)

No. of A.S.	No. of C.F.	STA	Applied Structure	Type and Class of Crossing Facility	Remarks
18		13+300	ICBR (RC-T beam, 2 @ 15.0 = 30.0m)	(New)	For Interchange
19	24	13+610	RDBR (RC-T beam, 2 @ 15.0 = 30.0m)	RD – HW (SH33)	Foundation: Abut: Pile Pier: Pile
20	25	14+270	WCBR (RC-T beam, 15.0+19.0+15.0 = 49.0m)	WC – River (Nakatia River)	Foundation: Abut: Pile Pier: Well
21	26	15+200	WCBR	WC – Major Canal	Foundation: Abut: Pile
	27	15+200	(RC-Slab, 2 @ 9.0 = 18.0m)	Road – CT	Pier: Pile
22	28	16+200	RDCBM	RD - VR	L = 33.4m
23	29	17+250	RDCBM	RD - VR	L = 33.4m
24		18+100	RDCBS	(New)	L = 33.4m
25		18+600	RDCBS	(New)	L = 33.4m
26	30	19+180	RDCBM	RD – VR	L = 33.4m
27	31	20+250	RDCBM	RD – VR	L = 33.4m
28		20+800	RDCBS	(New)	L = 33.4m
29	32	21+310	RDCBM	RD – VR	L = 33.4m
30	33	21+670	RDCBM	RD – VR	L = 33.4m
31		22+300	RDCBS	(New)	L = 33.4m
32	34	22+900	RDBR (RC-T beam, 1 @ 13.0 =13.0m)	RD – DR	Foundation: Abut: Pile
33	35	23+920	RDCBS	RD – CT	L = 33.4m
34		24+500	RDCBS	(New)	L = 33.4m
35	36	25+200	WCBR	RD – VR	Foundation: Abut: Pile
	37	25+200	(RC-Slab, 2 @ 9.0 = 18.0m)	WC – Major Canal	Pier: Pile
36	38	25+290	RDCBL	RD – VR	L = 33.4m
37	39	25+910	RDCBM	RD – VR	L = 33.4m
38	40	26+360	WCBR	WC - Major Canal	Foundation: Abut: Pile
	41	26+360	(RC-Slab, 2 @ 9.0 = 18.0m)	RD – VR	Pier: Pile
39	42	27+270	RDCBM	RD – VR	L = 33.4m
40		28+000	RDCBS	(New)	L = 33.4m
41		28+700	RDCBS	(New)	L = 33.4m
42		29+400	RDCBS	(New)	L = 33.4m

Note: Number of C.F.: Number of Crossing Facility
Number of A.S.: Number of Applied Structure
Code of Applied Structure is summarised and described in Part 1: General.

16.3.5.2 Interchange Bridge (ICBR) (STA. 8+700)

This is over bridge planned for interchange. Design conditions are summarised in Table 16-21.

Composition of applied ICBR is summarised in Table 16-22.

Table 16-21 Design Condition of Interchange bridge (STA. 8+700)

Item		Condition
Throughway Alignment	Vertical Alignment	i = 0.7%
	Horizontal Alignment	R = 4,000m
	Cross Section	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	RD-HW (State Highway No.37) (New)
	Lateral Clearance	12.0m
	Vertical Clearance	5.0m
	Other Information	
Geology	Depth of Bearing Strata	20.0m from G.L.
	Type of Bearing Strata	Sand (N>30)

Table 16-22 Applied Road Over bridge (STA. 8+700)

Item	Conditions	
AS. No.	No. 11	
Superstructure	RC – T beam	Total Length 27.0m 2 @ 13.0m = 30.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 12.0m Width of Footing: 7.5m x 26.5m
	Pier: Wall type (2 piers for one supporting point)	Height of Pier: 10.0m Width of Footing: 6.0m x 7.5m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 18.0m Diameter 1.0m 3x 6 for each abutment
	Pier	Cast-in-Situ Pile Foundation Length: 18.0m Diameter 1.0m 2x 3 x 2 for each

16.3.5.3 Road and Railway Over Bridge (RDBR) (STA 9+090)

This over bridge is planned and designed to cross over State Highway 37, Railway, and village road. Total bridge length and span arrangement was planned with the consideration of the feature and required clearances.

Design conditions are summarised in Table 16-23.

Composition of applied RDOB is summarised in Table 16-24.

Table 16-23 Design Condition of Over bridge (STA. 9+090)

Item		Condition
Throughway Alignment	Vertical Alignment	i = 0.7%
	Horizontal Alignment	R = 4,000
	Cross Section	Type – I of Bridge Section (L<100m)
Crossing Facility-1	Classification of Project	RD-HW (State Highway No.37), (CF No.15)
	Lateral Clearance	12.0m (for Future Programme)
	Vertical Clearance	5.0m
	Other Information	
Crossing Facility-2	Classification of Project	Railway (CF No.16)
	Present Condition	Broad Gauge, Single Track, Non-electrified
	Future Programme	Broad Gauge, Double Track, Non-electrified
	Lateral Clearance	9.445m (for Future Programme)
	Vertical Clearance	5.030m
	Other Information	
Crossing Facility-3	Classification of Project	RD-CT (CF No.17)
	Lateral Clearance	2.5m
	Vertical Clearance	2.5m
	Other Information	Non – paved
Geology	Depth of Bearing Strata	17.0m~20.0m from G.L.
	Type of Bearing Strata	Sand (N>30)

Table 16-24 Applied Road Over bridge (STA. 9+090)

Item	Conditions	
AS. No.	No. 12	
Superstructure	PC – Hollow	Total Length 70.0m, 22.0 + 25.0 + 22.0 = 69.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 14.5m Width of Footing: 10.0m x 26.5m
	Pier: Wall type 2piers for one supporting point	Height of Pier: 12.0m Width of Footing: 7.5m x 7.5m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 14.0m for A1 18.0m for A2 Diameter 1.0m 4x 6 for each abutment
	Pier	Cast-in-Situ Pile Foundation Length: 16.0m for P1 18.0m for P2 Diameter 1.0m 3x 3 x 2 for each

16.3.5.4 Interchange Bridge (ICBR) (STA. 13+300)

This is the new over bridge planned for interchange. Design conditions are summarised in Table 16-25.

Composition of applied ICBR is summarised in Table 16-26.

Table 16-25 Design Condition of Over bridge (STA. 13+300)

Item		Condition
Throughway Alignment	Vertical Alignment	i = 0.7%
	Horizontal Alignment	R = 4,000
	Cross Section	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	RD-HW (State Highway No.37) (New)
	Lateral Clearance	12.0m
	Vertical Clearance	5.0m
	Other Information	
Geology	Depth of Bearing Strata	20.0m from G.L.
	Type of Bearing Strata	Sand (N>30)

Table 16-26 Applied Road Over bridge (STA. 13+300)

Item	Conditions	
AS. No.	No. 18	
Superstructure	RC – T beam	Total Length 27.0m, 2 @ 13.0m = 30.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 12.0m Width of Footing: 7.5m x 26.5m
	Pier: Wall type (2 piers for one supporting point)	Height of Pier: 10.0m Width of Footing: 6.0m x 7.5m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 18.0m Diameter 1.0m 3x 6 for each abutment
	Pier	Cast-in-Situ Pile Foundation Length: 18.0m Diameter 1.0m 2x 3 x 2 for each

16.3.5.5 Road Over Bridge (RDBR) (STA. 13+610)

Road over bridge for State highway 33 is planned and designed with the condition summarised in Table 16-27.

Table 16-27 Design Condition of Over bridge (STA. 13+610)

Item		Condition
Throughway Alignment	Vertical Alignment	i = -2.0%
	Horizontal Alignment	R = 4,000
	Cross Section	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	RD-HW (State Highway No.33) (CF No.24)
	Lateral Clearance	12.0mfor Future Programme
	Vertical Clearance	5.0m
	Other Information	
Geology	Depth of Bearing Strata	20.0m from G.L.
	Type of Bearing Strata	Sand (N>30)

Composition of applied over bridge is shown in Table 16-28.

Table 16-28 Applied Road Over bridge (STA. 13+610)

Item	Conditions	
AS. No.	No. 19	
Superstructure	RC – T beam	Total Length 27.0m, 2 @ 13.0m = 26.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 12.0m Width of Footing: 7.5m x 26.5m
	Pier: Wall type (2 piers for one supporting point)	Height of Pier: 10.0m Width of Footing: 6.0m x 7.5m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 16.0m for A1 18.0m for A2 Diameter 1.0m 3x 6 for each abutment
	Pier	Cast-in-Situ Pile Foundation Length: 17.0m Diameter 1.0m 2x 3 x 2 for each

16.3.5.6 Road Over Bridge (RDBR) (STA. 22+900)

Crossing facility of this over bridge is for major district road. Design condition is tabulated in Table 16-29.

Table 16-29 Design Condition of Over bridge (STA. 22+900)

Item		Condition
Throughway Alignment	Vertical Alignment	i = -2.0% ~ 2.0%
	Horizontal Alignment	R = ∞
	Cross Section	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	RD-DR (C.F. No.34)
	Lateral Clearance	9.0m
	Vertical Clearance	5.0m
	Other Information	
Geology	Depth of Bearing Strata	23.0m from G.L.
	Type of Bearing Strata	Sand (N>30)

Composition of applied over bridge is shown in Table 16-30.

Table 16-30 Applied Road Over bridge (STA. 22+900)

Item	Conditions	
AS. No.	No. 32	
Superstructure	RC – T beam	Total Length 12.0m, 1 @ 11.0m = 11.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 12.0m Width of Footing: 7.5m x 26.5m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 21.0m Diameter 1.0m 3x 6 for each abutment

16.3.5.7 Bridge Over Deonarain River (WCBR) (STA. 7+900)

Bridge over Deonarain River was planned and designed under the condition summarised in Table 16-31.

Table 16-31 Design Condition of Bridge (STA. 7+900)

Item		Condition
Throughway Alignment	Vertical Alignment	i = 0.0%
	Horizontal Alignment	R = 3,000
	Cross section of Throughway	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	Water Channel, River (C.F. No.13)
	M.D.D.	478.8 m³/sec
	DHFL	173.0
	Afflux	0.42m above H.F.L.
	Vertical Clearance	1.2m from H.F.L. + Afflux
	Maximum Depth of Scour	Abutment: 6.7m Pier: 10.6m below DHFL
	Other Additional information	
Geology	Depth of Bearing Strata	25.0m from G.L.
	Type of Bearing Strata	Sand (N>30)
	Other Additional Information	

Composition of applied bridge is summarised in following Table 16-32.

Table 16-32 Applied Bridge (STA. 7+900)

Item		Composition
AS No.	No.9	
Superstructure	RC – T beam	Total Length 50.0m, 15.0 + 19.0 + 15.0 = 49.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 13.0m Width of Footing: 9.5m x 26.5m
	Pier: Wall type (2 piers for one supporting point)	Height of Pier: 14.0m Width of Footing 6.0m x 6.0m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 14.0m Diameter 1.0m 4 x 6 for each abutment
	Pier	Well Foundation: Length: 12.5m Diameter: 6.0m x 2 for each

Protection of embankment in front of abutment is required against scouring caused by the flood flow in rainy season.

16.3.5.8 Bridge Over Nakatia River (WCBR) (STA. 14+270)

Bridge over Nakatia River is planned and designed under the condition summarised in Table 16-33.

Table 16-33 Design Condition of Bridge (STA. 14+270)

Item		Condition
Throughway Alignment	Vertical Alignment	i = 0.3%
	Horizontal Alignment	R = 4,000
	Cross section of Throughway	Type – I of Bridge Section (L<100m)
Crossing Facility	Classification of Project	Water Channel, River (C.F. No.25)
	M.D.D.	305.7 m³/sec
	DHFL	171.0
	Afflux	0.85m above H.F.L.
	Vertical Clearance	1.2m from H.F.L. + Afflux
	Maximum Depth of Scour	Abutment: 5.2m Pier: 8.2m below DHFL
	Other Additional information	
Geology	Depth of Bearing Strata	25.0m from G.L
	Type of Bearing Strata	Sand (N>30)
	Other Additional Information	

Composition of applied bridge is summarised in following Table 16-34.

Table 16-34 Applied Bridge (STA. 14+270)

Item		Composition
AS No.	No.20	
Superstructure	RC – T beam	Total Length 50.0m, 15.0 + 19.0 + 15.0 = 49.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 13.0m Width of Footing: 9.5m x 26.5m
	Pier: Wall type (2 piers for one supporting point)	Height of Pier: 12.0m Width of Footing 6.0m x 6.0m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 14.0m Diameter 1.0m 4 x 6 for each abutment
	Pier	Well Foundation: Length: 17.0m Diameter: 6.0m x 2 for each

Protection of embankment in front of abutment is required against scouring caused by the flood flow in rainy season.

16.3.5.9 Bridge Over Major Canal

At 5 crossing points, Minor Bridge which is 2 @ 9.0m, RC-Slab were applied.

Table 16-35 Summary of Minor Bridge over Major Canal

No. of AS.	No. of CF	STA	Name of Canal	M.D.D. (m^3/sec)
2	2 & 3	1+990	-	0.8
7	10 & 11	6+280	Bhojipura Distributary	20
17	22 & 23	12+970	Bareilly Distributary	4.1
21	26 & 27	15+200		
35	36 & 37	25+200	-	-
38	40 & 41	26+360	Rajau Distributary	-

Minor bridge was applied for major canal having village road or cart track is always located along the canal.

Composition of Minor bridge is summarised in following Table 16-36.

Table 16-36 Minor Bridge

Item		Composition
AS No.	No.2,7,17,21,35,38	
Superstructure	RC-Slab (2 x simple span)	Total Length 19.0m, 2 @ 9.0m = 18.0m
Substructure	Abutment : Inversed T – type	Height of Abutment: 8.5m Width of Footing: 5.0m x 26.5m
	Pier: Wall type	Height of Pier: 7.0m Width of Footing: 5.0m x 5.0m
Foundation	Abutment	Cast-in-Situ Pile Foundation Length: 20.0m Diameter 1.0m 3x 6 for each abutment
	Pier	Cast-in-Situ Pile Foundation Length: 20.0m Diameter 1.0m 2x 3 for each pier

16.3.5.10 Culvert Box for Roads (RDCBL,RDCBM and RDCBS)

At 31 crossing points, Culvert Box for road were applied. Summary is shown in Table 16-37.

Table 16-37 Summary of Culvert Box for Road

Type of Culvert	No. of AS.	STA	Remarks	Type of Culvert	No. of AS.	STA	Remarks
RDCBL	36	25+290	L = 33.4m	RDCBS	8	6+500	L = 33.4m
RDCBM	1	1+180	L = 33.4m		24	18+100	L = 33.4m
	3	3+230	L = 33.4m		25	18+600	L = 33.4m
	4	3+810	L = 33.4m		28	20+800	L = 33.4m
	5	5+150	L = 33.4m		31	22+300	L = 33.4m
	6	5+750	L = 33.4m		33	23+920	L = 33.4m
	10	8+450	L = 33.4m		34	24+500	L = 33.4m
	14	10+350	L = 33.4m		40	28+000	L = 33.4m
	15	10+660	L = 33.4m		41	28+700	L = 33.4m
	16	11+600	L = 33.4m		42	29+400	L = 33.4m
	22	16+200	L = 33.4m		Total Length		L = 334.0m
	23	17+250	L = 33.4m				
	26	19+180	L = 33.4m				
	27	20+250	L = 33.4m				
	29	21+310	L = 33.4m				
	30	21+670	L = 33.4m				
	37	25+910	L = 33.4m				
	39	27+270	L = 33.4m				
	Total Length		L = 567.8m				

16.3.5.11 Culvert Box for Water Channel (WCBR for major Canal, and WCCBS)

Culvert Box was applied for one.

Type of culvert and number of cell was defined with M.D.D. of the canal.

Table 16-38 Summary of Culvert Box for Water Channel

	No. of AS.	STA	No. of Cell	Length (m)	Remarks
WCCBS	13	9+450	2	L = 33.4m	