

# **CHAPTER 4**

## **ROAD DESIGN**

## 4. ROAD DESIGN

### 4.1 General

The project road is a 5 km-long bypass running on the west side of Neelum and Jhelum Rivers, linking the north and south of Muzaffarabad.

The road commences from the Kohala-Muzaffarabad Road in front of Supreme Court, crossing Jhelum River and traverses along the Naluchi Road on river terrace. It is then linked to Muzaffarabad-Balakot Road, which is the highest point in the project road, and diverges near the long-way bus terminal near Alama Iqbal Bridge. The route continues to the existing road along Neelum River, and ends at its intersection with the Neelum Valley Road at Chela Bandi.

The route selected in the preliminary design in October and November 2006 is reviewed and refined based on supplemental topographic survey from the basic design and the detailed design. The route is carefully examined and optimized considering the control points such as schools, grid station and grave yards, locations of bridge, culvert, and drainage structures to minimize adverse environmental effects.

A few horizontal curves at the vicinity of intersections and at some sections utilizing the existing road, are substandard. However, they can be maintained as horizontal elements to minimize construction and environmental cost aspects, provided safety facilities such as traffic signs and guardrails are installed at appropriate locations to promote road safety.

The implementation of the Project is divided into two packages<sup>1</sup>: Package I (approximately 1 km-long which includes Naluchi Bridge and viaducts at bridge ends), and Package II (the remaining 4 km-long section of the road). Drawings and quantity calculations are prepared separately by package.

For design purposes, the two packages are further sub-divided into nine sections according to intersection area, new construction section, improvement of the existing road section, bridge section, etc. These sections are shown in **Figure 4.1.1** and **Table 4.1.1**.

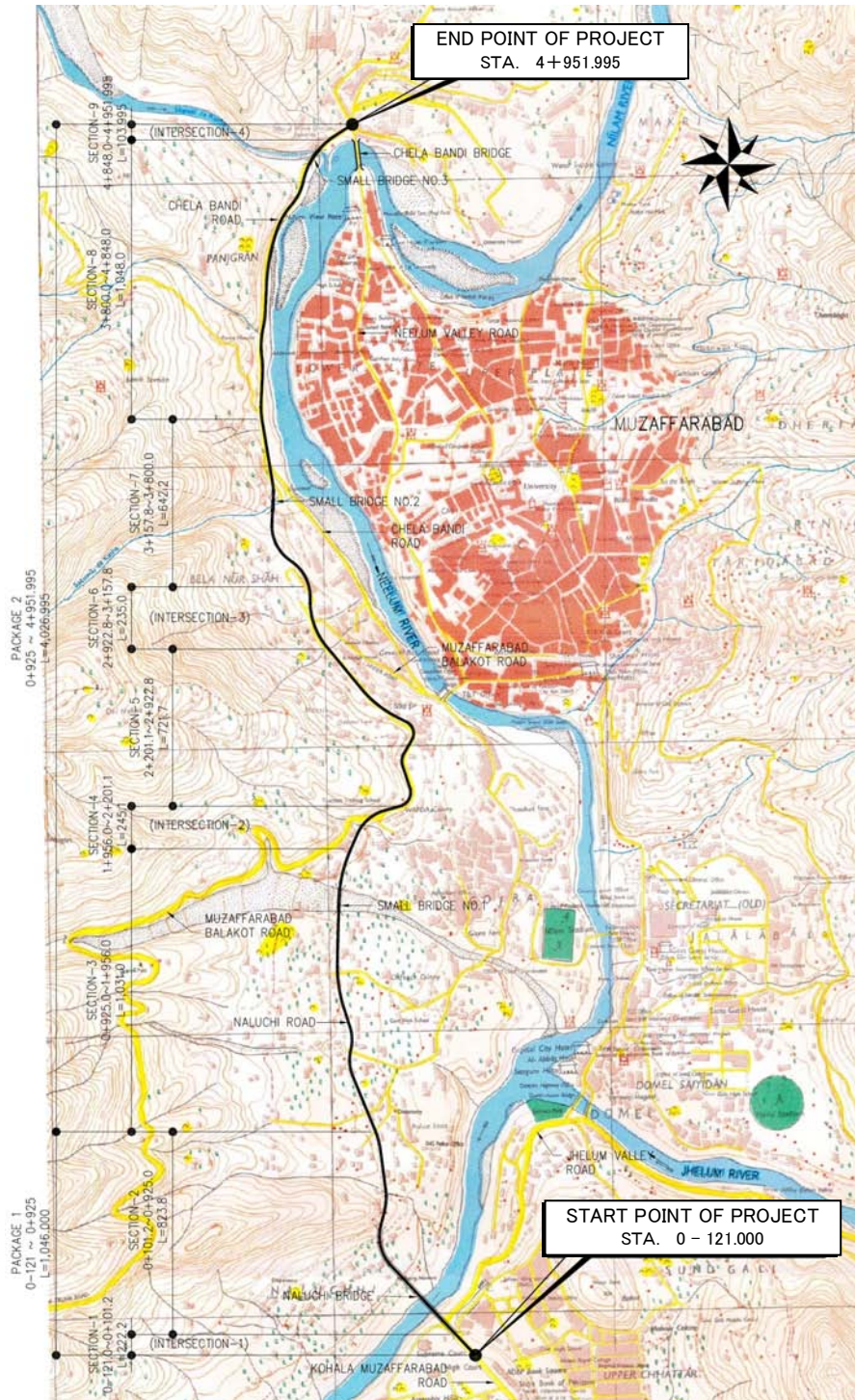
The alignment has been studied and finalized using computer software. Various alternatives for the alignment are superimposed on the digital topographic map of the project area, to identify the influence on control points which are visible on the map.

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<sup>1</sup>/ Study on Contract Packaging is described in subchapter 9.3 in Chapter 9.

**Table 4.1.1 Division of the Entire Project Route by Sections**

Package I		Package II						
Section-1	Section-2	Section-3	Section-4	Section-5	Section-6	Section-7	Section-8	Section-9
Intersection No. A, 1	Naluchi Bridge and Viaduct	Improvement of Naluchi road	Intersection No.2	Improvement of Muzaffarabad-Balakot road	Intersection No.3	New construction	Improvement of Neelum Road	Intersection No.4



**Figure 4.1.1 Sub-divided sections of the Project**

## 4.2 Applicable Design Standard and Design Criteria

The Design Standards applied in the Study are as follows:

- Standards For Roads In Pakistan by National Highway Authority (NHA)
- A Policy On Geometric Design Of Highways And Streets (2004) by AASHTO

In addition to the above, Japan Road Structure Ordinance (2004) by JRSO is also applied for special cases.

Referring to the above standards, the geometric design criteria applicable to the Study are established as shown in **Table 4.2.1**, taking into account function of the road, including future traffic volume and existing conditions at the project site such as topography, geology and hydrology.

The applicable design speed is generally 50 km/hr. However for Section-5, design speed to be considered is 40 km/hr due to topographic condition of the connecting Muzaffarabad-Balakot Road. Furthermore, at intersection areas (Sections 1, 4, 6, 9), 40 km/hr design speed is also considered due to constraints in the design as compared to basic freeway segments. This ensures further safety at said locations.

The topography of Muzaffarabad is mountainous. It is steep and has limited flat plains, which is similar to that of Japan. Thus, the geometric criteria of Stopping Sight Distance were set in accordance with the Japan Road Structure Ordinance (JRSO) discussed in Section 5.

**Table 4.2.1 Geometric Design Standard of the Project Road**

Design Items		Unit	Standard		Value Applied			
			Value	Reference				
Basic Conditions	Administrative Classification	-	Provincial Road		NHA			
	Functional Classification	-	Primary Road		NHA			
	Design Speed	Km/h	50	40		50	40 <sup>2</sup>	
	Design Vehicles					Truck with Trailer		
Cross Section Elements	Total Width	m	11.3			11.3	11.3	
	Number of Lanes	-	2		NHA	2	2	
	Lane Width	m	3.65		NHA	3.65	3.65	
	Shoulder Width	Shoulder	m	1.0		NHA	1.0	1.0
		Soft Shoulder (for ditch)	M	1.0		NHA	1.0	1.0
	Slope of Embankment	-	V:H=1:1.5-1.8			V:H=1:1.5	V:H=1:1.5	
	Slope of Cutting		V:H=1:0.8-1.2			V:H=1:1.0	V:H=1:1.0	
	Clearances	Lateral Clearance	M	All Paved Width				
		Vertical Clearance	M	5.1(3.0)			5.1	5.1
Cross Slope	Normal Cross Slope	%	2.0			2.0	2.0	
Horizontal Alignment	Minimum Radius	Max. super elevation= 6%	M	79	43	AASHTO	150	45,50,55
		5%	M	156	88	AASHTO	170,180	150
		4%	M	261	155	AASHTO	250,300	250
		3%	M	443	300	AASHTO	500,600	400
		2%	M	750	525	AASHTO	—	—
Sight Distance	Stopping Distance	M	65	40	AASHTO	65	50(40 <sup>3</sup> )	
	Length of passing sight distance	M	345	270	AASHTO	345	270	
Vertical Alignment	Maximum Gradient	%	14	15	AASHTO	6	6	
	Vertical Curve: Radius	Crest	%	7	4	AASHTO	10	11
		Sag	%	13	9	AASHTO	14	11

NHA: National Highway Authority(Standards for Road in Pakistan)

AASHTO: A Policy on Geometric Design of Highways and Streets (2004)

Geometric design criteria established above are further elaborated hereunder:

### (1) Horizontal Alignment

The minimum radius of curve for sections with design speed of 50 km/hr and 40 km/hr is 79 m and 43 m, respectively. No transition curve is applied since the design speed is relatively low for the wide road width.

The maximum superelevation is small at 6% due to many access roads and at-grade intersections along the route. Based on AASHTO, transition ratio is set to be less than 1/154 for design speed of 50 km/h and less than 1/143 for 40km/h.

<sup>2</sup> Design speed 40 km/h is applicable to Section 5 and all Intersections.

<sup>3</sup> Stopping Site Distance for Design Speed 40km/h in JRSO is applied for curve radius of 45 m and 50 m in Section 5.

The lanes are widened at sections where horizontal radius of curve is less than 99 m, to accommodate semi-trailer traffic.

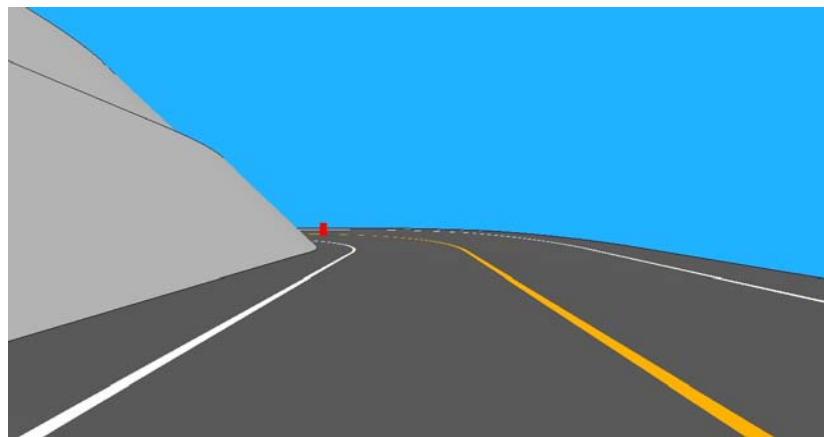
## (2) Vertical Alignment

The maximum gradient is controlled up to 6% considering the heavy vehicles in Pakistan as suggested by the local counterpart. The vertical alignment is designed for heavy trucks to pass more than a half of the design speed throughout the bypass. The speed of heavy trucks is checked using the speed gradient diagram based on uprising performance curve. This is based on the design approach of JRSO.

## (3) Sight Distance

### Stopping Sight Distance

To ensure stopping sight distance for cutting section having a small radius of curve, traveling simulation is carried out. **Figure 4.2.1** is one scene from the computer simulation used to check stopping sight distance. Stopping sight distance required for design speed of 40 km/hr is 40 m in accordance with JRSO.



**Figure 4.2.1 Computer Graphic for Stopping Sight Distance**

### Passing Sight Distance

Since the Project road is two-lane, speeding small vehicles can overtake slow heavy vehicles. Thus, the alignment is designed to ensure passing sight distance for one passing per minute.

## (4) Vertical Clearance

The vertical clearance of at grade-separation over Intersection No.1 is 5.1 m. However, 3 m is applicable for local roads where heavy vehicles are not expected to pass. This was

also considered to reduce cost of raising the embankment to meet required vertical gradient.

#### **(5) Typical Cross Section**

The width of the Project road is 11.3 m having 7.3 m-wide carriageway (3.65 m x 2), 1.0 m shoulder and 1.0 m soft shoulder on each side. Side ditch and retaining wall are installed at the sides of the soft shoulder.

At intersection areas, a lane width is shortened to 3.0 m, to add right-turn lanes.

In residential areas between Sta.0+905 and Sta.1+510, the shoulder is widened to 1.5 m to be used as parking space and to ensure access to residents at the roadside

The cross slope is 2% for carriageway as well as for asphalt-paved shoulder.

Side slope is 1.5 : 1 (H:V) for embankment and 1 : 1 (H:V) for cutting.

**Figure 4.2.2** shows the typical cross section, while **Figure 4.2.3** and **Figure 4.2.4** shows typical cross section with sidewalk. The flat type is selected for sidewalk to provide access to roadside, and also to allow surface water flow to roadside ditch. The side walk at intersection areas is elevated by 20 cm to protect pedestrians from vehicle traffic. Interlocking blocks are installed on the sidewalk surface.

Land acquisition is limited to the area required for widening, since houses are built relatively close to the Project road. The set back is 1.5 m from the edge of cutting and embankment. The Right of Way (ROW) ranges from 15 m to 39 m, and the average is approximately 25 m.

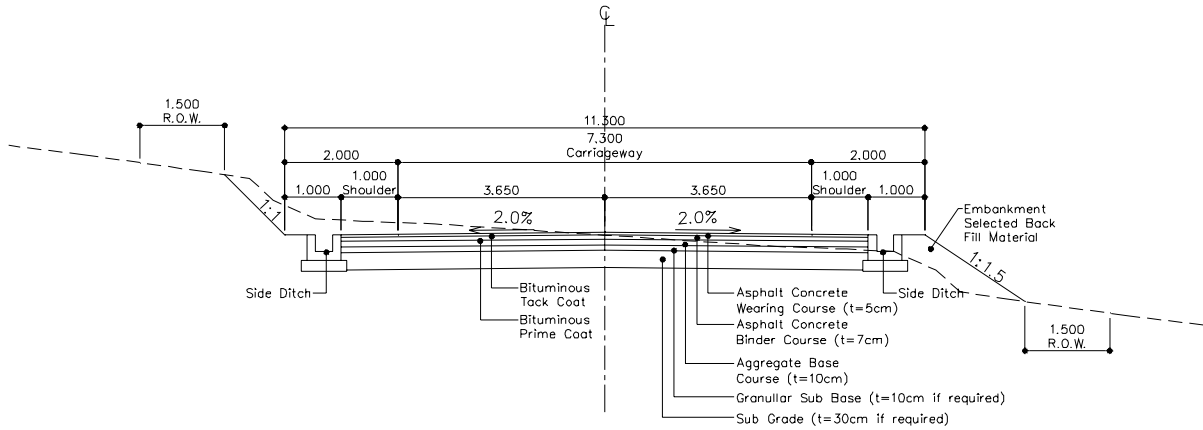


Figure 4.2.2 Typical Cross Section

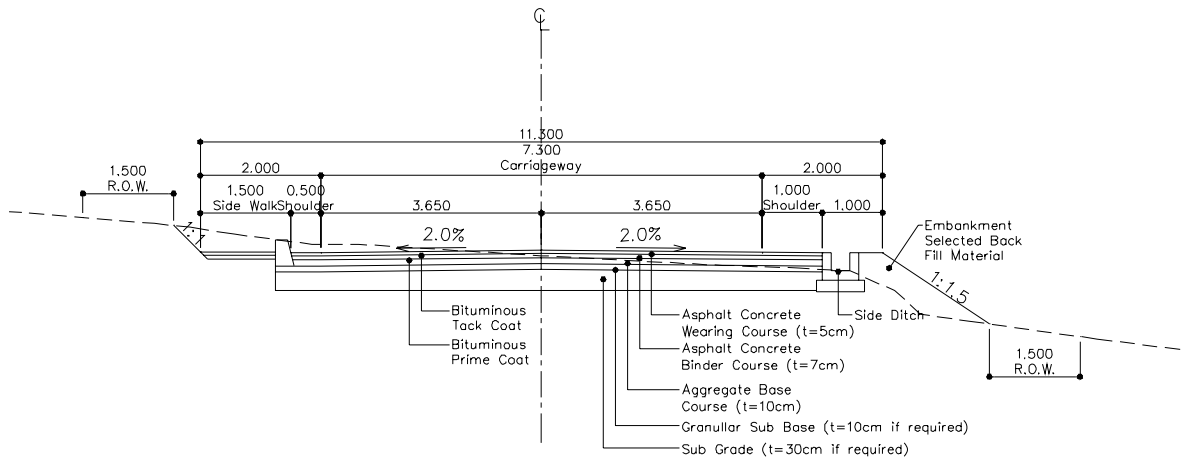


Figure 4.2.3 Typical Cross Section with Side Walk (Flat Type)

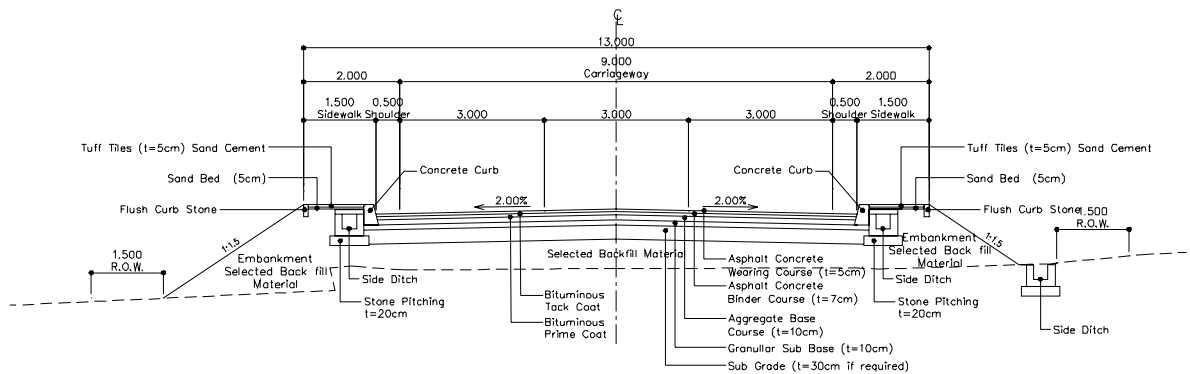


Figure 4.2.4 Typical Cross Section with Side Walk (Mount Up Type)

### 4.3 Refinement of Alignment Design

The alignment was refined and finalized after a series of detailed discussions were held with ERRA, NHA and AJK government.

Schools, hospitals, graveyards, and steel towers were established as the control points, to determine the alignment and minimize social and environmental impact. The AJK government strongly suggested avoiding the graveyards. Therefore, the alignment is refined to avoid every graveyard in the Project area.

Control points, applied minimum horizontal radius of curve, maximum vertical gradient, and major structures for each section in each package are summarized in **Table 4.3.1**.

The total road length of the proposed West Bank Bypass Project is 5,072.995m (Sta.0+121 - Sta.4+951.995); the new construction section is 1,170.0 m (Sta.0+160 - Sta0+630, Sta.3+050 - Sta.3+750), and the improvement section is 4005.6 m.

**Table 4.3.1 Applied Design and Site Description for Each Section for Package 1**

	PACKAGE I		PACKAGE II
	SECTION-1	SECTION-2	SECTION-3
Intersection	Intersection No.A,1		
Length (Station ~ Station)	222.2 m (0-121 ~ 0+101.1)	823.8m(new const.:470m) (0+101.2 ~ 0+925.0)	1031.0m (0+925.0 ~ 1+956.0)
Road condition	Existing Road (Kohara Muzafarabad Road)+New Bridge	New Bridges + Existing Road (Naluchi Road)	Existing Road (Naluchi Road)
Traffic Volume(2019) (pcu/day)		18,229	9,894
Design Speed	40km/h	50km/h	50km/h
Min. Radius	R= $\infty$	R=150m	R=150m
Max. Gradient	i=3.5%	i=5.6%	i=3.9%
Max. Super elevation		M=5.2%	M=5.2%
Bridge	Approach Bridge	Naluchi Bridge + Viaduct	Bridge
Box Culvert		Box Culvert (1)	Box Culvert (3)
Control Points	Grave Yard	Mobile Tower(2) Grave Yard	Grave Yard
Intersection Type	Four-leg Signalized Intersection and Three-leg Intersection		

	PACKAGE II		
	SECTION-4	SECTION-5	SECTION-6
Intersection	Intersection No.2		Intersection No.3
Length (Station ~ Station)	245.1m (1+956 ~ 2+201.1)	721.7m(new const.:700m) (2+201.1 ~ 2+922.8)	235.0m (2+922.8 ~ 3+157.8)
Road condition	Existing Road (Naluchi Road- Muzafarabad Balakot Road)	Existing Road (Muzafarabad Balakot Road)	Existing Road (Muzafarabad Balakot Road)
Traffic Volume (2019) (pcu/day)		9,991	
Design Speed	40km/h	40km/h	40km/h
Min .Radius	R=150m	R=45m	R=250m
Max. Gradient	i=3.6%	I=6%	I=3.75%
Max. Super elevation	m=4.2%	M=6%	m=3.4%
Bridge			
Box Culvert	Box Culvert (1)	Box Culvert (1)	Box Culvert(2)
Control Points		Grave yard	Grave yard, Grid Station, Pylon
Intersection Type	Three-leg Intersection		Three-leg Intersection

	PACKAGE II		
	SECTION-7	SECTION-8	SECTION-9
Intersection			Intersection No.4
Length (Station ~ Station)	642.2m (3+157.8 ~ 3+800.0)	1048.0m (3+800.0 ~ 4+848.0)	103.995m (4+848.0 ~ 4+951.995)
Road condition	New Alignment	Existing Road	Existing Road
Traffic Volume (2019) (pcu/day)	4,831	5,583	
Design Speed	50km/h	50km/h	40km/h
Min .Radius	R=150m	R=170m	R= $\infty$
Max. Gradient	i=6%	i=4.4%	i=4.0%
Max. Super elevation	m=5.2%	M=5.0%	m=2.0%
Bridge	Bridge	Bridge	
Box Culvert(2)	Box Culvert(1)	Box Culvert(3)	Box Culvert(1)
Control Points	Grave yard	Flood water (Neelum River)	
Intersection Type			Four-leg Signalized Intersection

The results of the alignment study are as follows:

### (1) Section-1 : Package I

In the preliminary design, at-grade intersection was planned in front of the Supreme Court; however, during this study, grade separation is identified as the more appropriate alternative for this intersection. The result of the Study on Intersection No.1 is presented in the next section, Section 4.4. Because of the design change, the start point of the Project is shifted to Kohara side by 121 m.

### (2) Section-2 (From Naluchi Approach Bridge to Sta.0+925) : Package I

The horizontal alignment is a straight line from Naluchi Approach Bridge to viaduct. The gradient is 3.5% for the approach bridge, 2% for Naluchi Bridge and 5.6% for the 168-m viaduct.

After the viaduct, the alignment follows the existing Naluchi Road on the west bank terrace, but with some improvement, i.e, the existing horizontal radius of 50 m to 100 m is improved to 200 m. The vertical gradient is adjusted to 6% to match the existing road elevation.

### (3) Section-3 : Package II

The horizontal alignment follows and improves the existing Naluchi Road. The existing horizontal radius of curve of 50 m to 100 m is improved to 150 m. The gradient is close to the existing road by 2%.

A bridge crosses a river near Sta.1+750. However, because of the low bridge height and narrow width, a new bridge with a length of 30 m is planned downstream of the river. During construction of the new bridge, the existing bridge will be utilized as diversion, thus the current traffic flow will not be affected.

**(4) Section-4 : Package II**

Intersection No.2 is planned where Muzaffarabad-Balakot Road connects to the Project road. Since the horizontal curve at the approach from Muzaffarabad-Balakot Road is small, the alignment is shifted to riverside to improve the curve. This also results in the widening of the riverside.

**(5) Section-5 (Muzaffarabad-Balakot Road) : Package II**

The existing road in Section-5 has three small continuous curves. To examine possibility of improving the continuous curves, a comparative study was conducted, identifying three alternatives.

**a. Alternative-1**

Alternative-1 is to follow the existing road with continuous curves. The radius of curve is between 45 m and 55 m, which is the least among all the alternatives. Further, the gradient is between 3.9% and 5.9%, which is low and thus, better than the other alternatives. In addition, the volume of earthwork and number of affected houses are also minimal. This is considered as the most economical alternative. Since the middle curve is on the hillside, there are no issues of sight distance which is normally an issue for three continuous curves.

**b. Alternative-2**

Alternative-2 eliminates the middle curve and connects the remaining two curves with a straight line. The radius of curve is between 50 m and 55 m, and the gradient is between 3.9% and 6.2%. The 45 m radius is improved to 55 m, but the shortened road length increases the vertical gradient. The volume of earthwork and number of affected houses also increases, and construction cost increase significantly. The cost for this alternative is estimated to be three times that of Alternative-1.

**c. Alternative-3**

Alternative-3 eliminates two curves. The radius of curve is between 50 m and 400 m, and the gradient is between 3.9% and 6.6%. The 45 m radius is improved forming almost a straight line, however, gradient increases from 5.9% to 6.6% because the road length is shortened. The volume of earthwork is considerably large, and the number of affected houses is significant. The construction cost of Alternative-3 is 20 times than Alternative-1.

The result of study is summarized in **Table 4.3.2**.

Based on the above, Alternative 1 is identified as the most appropriate alignment for Section-5.

In the detailed design, the horizontal alignment of selected Alternative-1 is improved to ensure the passing sight distance. The improvement is carried out by increasing the radius of curve and creating sufficient space inside the curve. Stopping sight distance required in AASHTO is 50 m for this section, however, applying this requires considerable amount of cutting volume. Since it is in a mountainous site, a stopping sight distance of 40 m per JRSO standard is more applicable based on the topographic condition.

**Table 4.3.2 Result of Comparative Study on Section-5**

	Alternative-1			Alternative-2			Alternative-3
	To follow the existing road			To shift alignment on river side			To shift alignment on mountain side
Layout							
Description	Alignment with three continuous curves			Removing one curve in the middle and connecting two curves with a straight line			Removing two curves out of three
Alignment	R= 50m	R= 55m	R= 45m	R= 50m		R= 55m	R = 50 m~ R = 400m
Gradient	I=3.9%	i=5.9%	i=4.3%	i=3.9%	<b>I=6.2%</b>	i=4.3%	i=3.9% ~ <b>i=6.6%</b>
Volume of Cut and Fill	Cut: 0 Fill: 7,500 m3			Cut: 0 Fill: 20,000 m3			Cut: 96,400 m3 Fill: 0
Affected Houses	4 houses			9 houses			16 houses
Construction Cost	<b>1</b>			<b>2.7</b>			<b>20</b>
Advantage	<ul style="list-style-type: none"> <li>- The alignment is the most economical.</li> <li>- The number of affected houses is the least.</li> </ul> (Since the middle curve is on hill side, there are no issues of visibility which is normally an issue for three continuous curves).			<ul style="list-style-type: none"> <li>- Horizontal alignment is improved by removing one curve.</li> </ul>			<ul style="list-style-type: none"> <li>- Horizontal alignment is improved by removing two curves.</li> </ul>
Disadvantage				<ul style="list-style-type: none"> <li>- Removing one curve shortens the road length, resulting in increase in, vertical gradient.</li> <li>- Construction cost increases significantly (2.7 times than Alternative-1)</li> </ul>			<ul style="list-style-type: none"> <li>- Removing two curves shortens the road length, resulting in increase in, vertical gradient.</li> <li>- Construction cost increases significantly (20 times than the Alternative-1)</li> </ul>
Evaluation	Good and Reasonable			Poor			Very Poor

**(6) Section-6 : Package II**

Intersection No.3 is planned as three-legged at the U-turn section near the bus terminal of Muzaffarabad-Balakot Road. The horizontal radius of curve is 150 m, and gradient is 3.75%.

**(7) Section-7 : Package II**

Section-7 is a new construction area. One 30m-length bridge is planned at Sta.3+515. Two alternatives are studied to determine the alignment. Alternative-1 is on the mountainside, while Alternative-2 is to go through an army camp. Alternative-2 is better with respect to horizontal alignment, and also the number of affected houses for Alternative-2 is less than Alternative-1. However, the volume of earthwork for Alternative-2 is more. As a result, the construction cost is almost twice as Alternative-1. Another point to be noted is that it could be uncomfortable for road users to go through the army camp. Therefore, Alternative-1 is selected as the appropriate alignment for Section-7.

The result of comparative study is summarized in **Table 4.3.3**.

**Table 4.3.3 Result of Comparative Study on Section-7**

	<b>Alternative-1</b>	<b>Alternative-2</b>
	Mountainside	Through Army Camp
Layout		
Alignment	R = 150 m ~ 150 m ~ 250 m	R = 150 m ~ 300m ~ 200 m
Vertical Gradient	i = Level ~ 6.0% ~ 0.27%	i = -3.25% ~ -5.5% ~ -6.0% ~ -0.48%
Cut and Fill Volume	Cut: 25,000m <sup>3</sup> Fill: 47,000 m <sup>3</sup>	Cut: 4,000 m <sup>3</sup> Fill: 80,000 m <sup>3</sup>
Affected Houses	11	5 (excluding Army Camp Facilities)
Construction Cost	<b>1</b>	<b>1.9</b>
Advantage	- Construction cost for earthwork is low as a half of Alternative-2	- Affected number of houses is less.
Disadvantage		- It could be uncomfortable for people to go through army camp. - Retaining walls are continuously required, so the access to the bypass could be difficult.
Evaluation	Good	Poor

**(8) Section-8 (Chela Bandi Bridge – Alama Iqbal Bridge Road) : Package II**

The alignment follows the existing road along Neelum River. The horizontal radius of curve starts with 80 m and shifted to 150m.

The minimum elevation of the existing road was 677 m, and it was under water during the flood in 1992. The vertical alignment is determined considering floods in the past. The elevation at Sta.4+000 is set as higher than 681 m, which is based on the hydrological study results discussed in Chapter 3.

A truss bridge crosses the river near Sta.4+750. In the design, a new bridge having the length of 60 m is planned downstream of the river. During construction of the new bridge, the existing bridge is utilized as a diversion without affecting the current flow of traffic.

The alignment between the bridge and Intersection No. 4 follows the existing road to minimize adverse effects on the surroundings.

### **(9) Section-9 : Package II**

The existing intersection in Section-9 is congested. There are many pedestrians crossing the road because it is a commercial area. Poor pavement condition is another reason for the congestion. To examine the alignment and avoid passing through the intersection, a comparative study is conducted with two alternatives.

#### **a. Alternative-1**

Alternative-1 is to follow the existing road and improve Intersection No.4. From its topography, the intersection is complicated with 4 legs.

The radius of curve is 250 m, and the gradient is in between 3.9% and 4.4%. The volume of earthwork is approximately 30,000 m<sup>3</sup>. The bridge length on the alignment is 50 m. The affected area is strip along the existing road. The commercial area will be affected, and compensation for commercial areas is higher than for residential area.

Improving Intersection No.4 improves access to shops on the roadside.

#### **b. Alternative-2**

Alternative-2 requires shifting of alignment to the mountainside, avoiding Intersection No.4.

The radius of curve is between 150 m and 250 m, and the gradient is between 3.5% and 6%. The volume of earthwork is approximately 67,000 m<sup>3</sup>. The bridge length on the alignment is 80 m. Although only the residential areas are affected, the entire Right of Way width is targeted for land acquisition since it is a new construction.

The result of study is summarized in **Table 4.3.4**.

In Alternative-2, the gradient is high at 6%, and construction and land acquisition cost is also high. It requires high volume of cut, so there are no spaces on roadside to be utilized. On the other hand, construction and land acquisition cost of Alternative-1 is relatively low

because the affected area is only a strip along the existing road instead of the entire ROW. Access to shops on the roadside is also improved with Alternative-1. From the aspects of social, environmental impact, and construction cost, Alternative-1 is the recommended alternative for Section-9.

**Table 4.3.4 Result of Comparative Study on Section-9**

	Alternative-1		Alternative-2	
	To follow the existing road and improve Intersection No.4		To shift alignment on mountainside avoiding Intersection No.4	
Layout				
Alignment	R = 250 m	R = 250 m	R = 250 m	R = 150 m
Vertical Gradient	i = 4.4%	i = 3.9%	i = 6%	i = 3.5 %
Cut and Fill Volume	Cut: 0      Fill: 30,000 m <sup>3</sup>		Cut: 67,000 m <sup>3</sup>	Fill: 0
Bridge Length	L = 50 m		L = 80 m	
Affected Area	Strip along the existing road: 1,750 m <sup>2</sup> (Commercial + Residential Area)		New construction area: 12,500 m <sup>2</sup> (Residential Area)	
Land Acquisition and Compensation Cost	<b>1</b>		<b>3</b>	
Construction Cost	<b>1</b>		<b>2.3</b>	
Advantage	<ul style="list-style-type: none"> <li>- Construction cost is relatively low.</li> <li>- Access to shops on roadside is improved.</li> </ul>		<ul style="list-style-type: none"> <li>- The traffic from bypass can avoid Intersection No.4, which is currently congested.</li> </ul>	
Disadvantage	<ul style="list-style-type: none"> <li>- From its topography, Intersection No.5 is rather complicated intersection with 4 legs.</li> </ul>		<ul style="list-style-type: none"> <li>- Vertical gradient is high as 6%.</li> <li>- Construction cost and land acquisition cost is very high.</li> <li>- It requires high volume of cut, so there are no spaces on roadside to be utilized.</li> <li>- Even after the bypass is opened, the traffic to Muzaffarabad City has to go through the current congested intersection.</li> </ul>	
Evaluation	Good		Poor	

**(10) Intersection with Minor Roads**

Minor access roads intersecting with the bypass are listed in the **Table 4.3.5**.

The road width is either 4 m or 6 m depending on the existing road width. The vertical gradient is intended to be as low as possible. Pavement design is discussed in Section 4.5 of this report, where aggregate base course of 17 cm is applied.

**Table 4.3.5 Minor Road List**

	<b>Station</b>	<b>Width</b>	<b>Side</b>		<b>Station</b>	<b>Width</b>	<b>Side</b>
1	0+630	6m	Left	7	1+515	4m	Both
2	0+910	4m	Both	8	1+820	4m	Left
3	1+060	4m	Right	9	3+720	6m	Right
4	1+175	4m	Left	10	3+780	4m	Left
5-1	1+220	4m	Left	11	3+850	6m	Left
5-2	1+225	4m	Right	12	4+685	6m	Left
6-1	1+330	4m	Right	13	4+860	4m	Left
6-2	!+338	4m	Left				

## 4.4 Intersection Design

### 4.4.1 Site Condition of Proposed Intersection

There are four intersections planned in the Project with respective stations as follows. One intersection is close to Intersection No.1, which is designed simultaneously with Intersection No.1 as Intersection-A.

- Intersection No.1: Underpass & Intersection-A: Sta.0+000
- Intersection No.2: Sta.2+081
- Intersection No.3: Sta.3+038
- Intersection No.4: Sta.4+952

The respective conditions and key issues of each proposed intersection site is as follows:

#### **Intersection No.1**

The existing Intersection No.1 is three-leg intersection at Sta.0+150. The Supreme Court of AJK is located in one corner of the intersection. This intersection can be considered as an entrance to Muzaffarabad by motorists coming from Islamabad.

After construction of Naluchi Bridge, the intersection will be located at the edge of the bridge, and becomes a four-leg intersection. Having an intersection at the end of a bridge is not preferred in intersection design, however, the topography of the river side limits the location of the bridge abutment. This is one of the special issues considered in the design.

A steep cliff exists along the road to the center of Muzaffarabad, thus, the alignment of the approach road should be designed to avoid the large cut of this cliff.

#### **Intersection No.2**

Intersection No. 2 is located at Sta. 2+081, where Muzaffarabad-Balakot Road approaches. It is designed to be T-shaped intersection. The traffic volume from start point to this intersection is the highest among the rest of the bypass sections. The existing approach road from Balakot has steep vertical gradient at more than 10%.

#### **Intersection No.3**

Intersection No. 3 is located at Sta. 3+038 near the long-way bus terminal of the Muzaffarabad-Balakot Road. It is designed to be a T-shaped intersection. The existing approach road has steep vertical gradient of 10%.

#### **Intersection No.4**

Intersection No. 4 is located at Sta. 4+952 where the proposed road alignment ends. There are many shops on roadside of this intersection. The pavement is deteriorated and the surface

condition is rough and bumpy. No drainage systems are observed. The traffic is congested because of pedestrians. The traffic flow is erratic, making it difficult for motorists to go through the intersection. Its vertical gradient is 6%. Traffic safety should be carefully considered in this intersection. The satellite photo of the intersection site is shown in **Figure 4.4.1**.



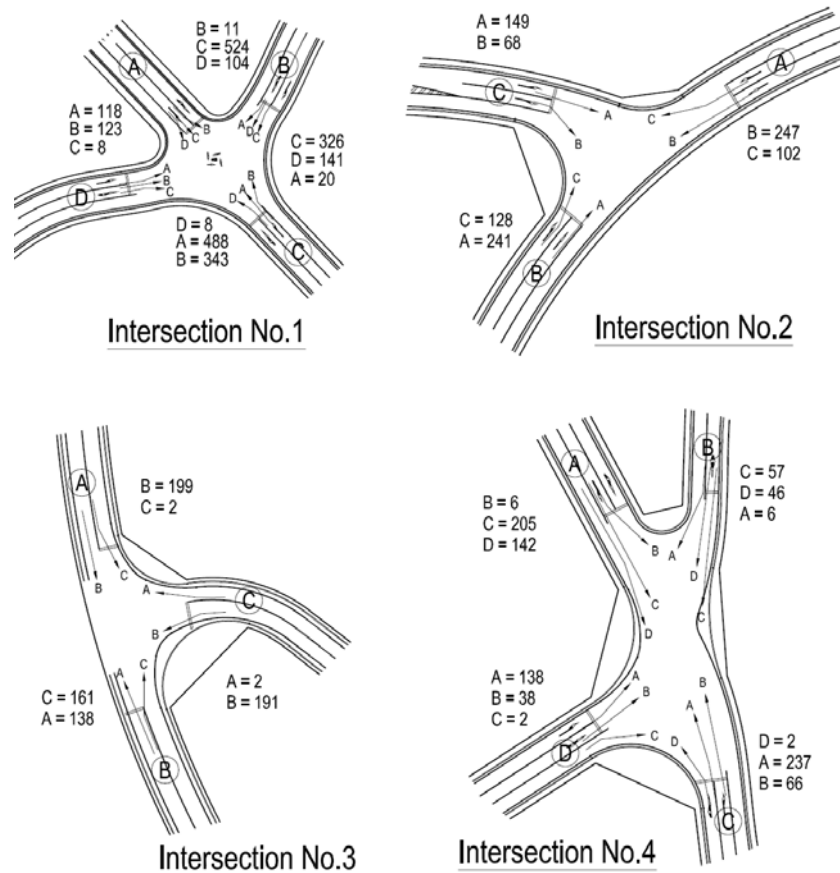
**Figure 4.4.1 Site of Intersection No.4**

#### **4.4.2 Traffic Demand at Intersections**

The target year of the traffic demand forecast applied to intersection design is 2019, which is 10 years after the opening of the West Bank Bypass. The traffic demands at intersections are estimated based on traffic survey in the preliminary study conducted in November, 2006.

The result of traffic demand forecast for each intersection is shown in **Figure 4.4.2**. The number shown in the figure is hourly traffic volume in peak hour in terms of pcu, which is applied to design. The peak hour ratio is 8.5%. Based on the preliminary design, the peak hour is continuous from 8 am to 5 pm. There are also no significant changes in traffic volume by directions throughout the peak hours. These facts are confirmed by supplemental traffic counts carried out in this study.

The share of heavy vehicles is estimated to be 7.4% based on the traffic count at the sites.



**Figure 4.4.2 Hourly Traffic Volume of Each Direction**

### 4.4.3 Comparative Study and Design Result

The lane width is designed as 3 m for approach to intersections, which is narrower than the basic freeway segment. This is intended since vehicles are supposed to slow down when approaching intersections. Sight clearance is ensured at every corner, and three-centered compound curve radius is applied as much as possible. The vertical gradient is set to be less than 4% for intersection of the bypass.

Traffic safety is considered carefully in the design. Right-turn lane is added to the approach of almost every intersecting leg. Sidewalk and pedestrian crossings are installed. The level of sidewalk at the intersection area is 20 cm higher than the carriage way. Lane marks such as arrows and zebra are designed for smooth traffic flow. Lane marks help a driver identify channels at the intersection area.

Signal system is examined for every intersection using estimated traffic volume. Based on calculations, signal systems need to be installed at Intersections A and No. 4.

Traffic signs are also installed at appropriate locations specifying design speed, direction and other warnings.

**(1) Intersection No.1**

For Intersection No. 1, a comparative study was conducted with three alternatives. There is one intersection close to Intersection No. 1, which is defined as Intersection-A in the study. Intersection No. 1 cannot be designed without considering the effect of Intersection-A. Therefore, these two intersections are designed jointly, in consideration of each other.

The comparative study result is summarized in **Table 4.4.1**.

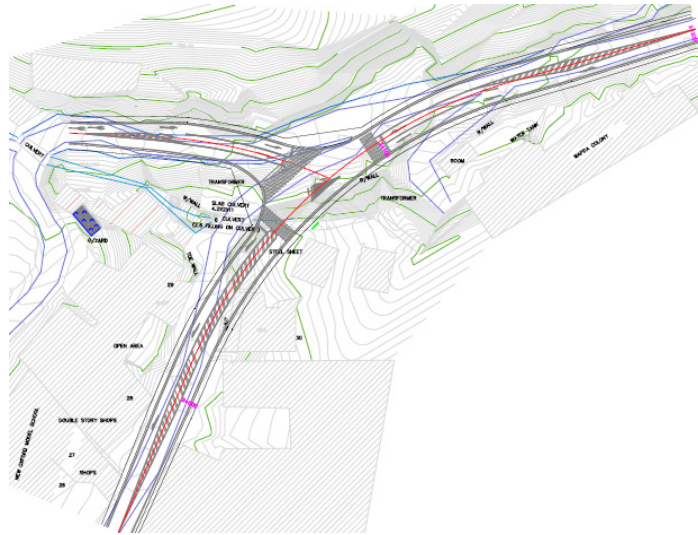
From the aspects of safety, convenience for users and future capacity, Alternative-3 for Intersection No. 1 is selected as an optimum scheme. Although the construction cost is higher than others, tolerance of traffic capacity against unexpected future growth and traffic safety of Alternative 3 supersedes its high cost. Taking that into account, it is concluded that Alternative 3 with an underpass is the most appropriate scheme for Intersection No. 1.

**Table 4.4.1 Comparative Study Table for Intersection No.1&A**

	<b>Alternative I</b>	<b>Alternative II</b>	<b>Alternative III</b>
	To convert the current three-legs intersection into four-legs intersection by adding one leg from Naluchi Bridge	To connect the road from Lower Chatter to Intersection-A and convert Intersection-A with 3 legs to 4 legs. To design Intersection No.1 as 3-legs intersection	To design grade separation and extend Naluchi Bridge with overpass and connect directly to Intersection-A. To convert Intersection-A with 3 legs to 4 legs
<b>Intersection Type</b>	Intersection No.1: 4 legs with signal system Intersection-A (Upper Chhattar):3 legs	Intersection No.1: 3 legs with signal system Intersection-A (Upper Chhattar): 4 legs with signal system	Intersection No.1: overpass +3 legs Intersection-A (Upper Chhattar): 4 legs with signal system
<b>Layout</b>			
<b>Capacity (Service Level)</b>	Intersection No.1 : degree of saturation $\lambda=0.67$ Intersection-A : degree of saturation $\lambda=0.46$ Service Level (cycle length) : less than 70 seconds	Intersection No.1 : degree of saturation $\lambda=0.60$ Intersection-A : degree of saturation $\lambda=0.72$ Service Level (cycle length) : less than 70 seconds	Intersection No.1 : degree of saturation $\lambda=0.26$ Intersection-A : degree of saturation $\lambda=0.47$ Service Level (cycle length) : less than 70 seconds
<b>Gradient</b>	$i = 3\% - 6\%$	$i = 3\% - 6\%$	$i = 3.5\% - 2\% - 5.6\%$
<b>Construction Cost Ratio</b>	<b>1.00</b>	<b>1.36</b> Additional Factor: New construction of the road from Lower Chatter (L=250m)	<b>17.7</b> Additional Factor: Extension of Naluchi Bridge (L=110m)
<b>Advantage</b>	The design is <b>most economical</b> .	<b>Service Level:</b> The service level increases at Intersection No.1 because the road from Lower Chatter is disconnected from Intersection No.1 and connected to Intersection-A.	<b>Capacity:</b> the capacity of intersections is highest. <b>Structural Benefit:</b> The gradient of Naluchi Bridge becomes 2%. It is structurally and architecturally preferable for the bridge. <b>Safety &amp; Convenience for Users is good:</b> Sufficient radius of curves and visibility at intersections are ensured <b>Tolerance for Future Traffic Demand is sufficient:</b> The design tolerates the future demand by unexpected growth.
<b>Disadvantage</b>	<b>Safety &amp; Convenience for Users is poor:</b> A steep cliff toward Muzaffarabad prevents widening of the road, so the radius of curve for left turn from Naluchi Bridge becomes small. A heavy truck has to use a part of opposing lane to turn left.	<b>Safety &amp; Convenience for Users is poor:</b> A steep cliff toward Muzaffarabad prevents widening of the road, so the radius of curve for left turn from Naluchi Bridge becomes small. A heavy truck has to use a part of opposing lane to turn left.	Construction cost is <b>the highest</b> .
<b>Evaluation</b>	<b>Fair</b>	<b>Fair</b>	<b>Good</b>

**(2) Intersection No.2**

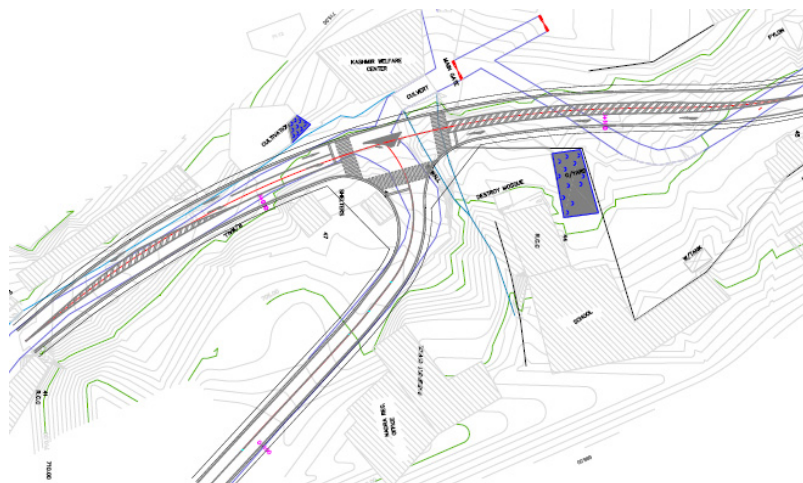
The layout of Intersection No. 2 is shown in **Figure 4.4.3**. Intersection No. 2 is planned where Muzaffarabad-Balakot Road links to the Project road. It is T-shaped, and right-turn lane is added to two legs. A signal system is not required for the estimated traffic demand.



**Figure 4.4.3 Layout of Intersection No.2**

**(3) Intersection No.3**

The layout of Intersection No. 3 is shown in **Figure 4.4.4**. Intersection No. 3 is T-shaped, and one lane is added on the bypass road from south for right turn. No lanes are added for other two legs because of their traffic demand. A signal system is not required for the estimated traffic volume.



**Figure 4.4.4 Layout of Intersection No.3**

**(4) Intersection No.4**

The existing intersection is five-leg. The number of intersection legs at an at-grade intersection should not exceed four in principle because the number of conflicting, merging and diverging points increases rapidly as the number of intersection legs increases. All the alternatives are planned based on this design approach.

The alternative study of the alignment in Section 9 concludes that improvement of the existing intersection is more appropriate, than shifting the alignment toward the mountain side. Following this result and considering present issues in the existing intersection, an alternative study of Intersection No 4 was conducted to determine an optimum improvement scheme.

Two alternatives of at-grade intersection<sup>4</sup>, Alternative-A and B, are shown in **Table 4.4.2**, which were prepared considering the above design approach. Alternative A utilizes the existing road to the maximum. The construction cost is the least among these. However, there is one road intersecting with an acute angle of 35 degrees, which will consequently create blind areas, leading to traffic hazards. Therefore, Alternative-A is not recommendable considering its traffic safety level.

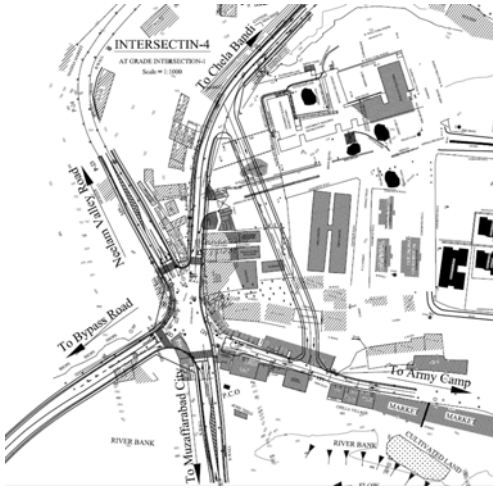
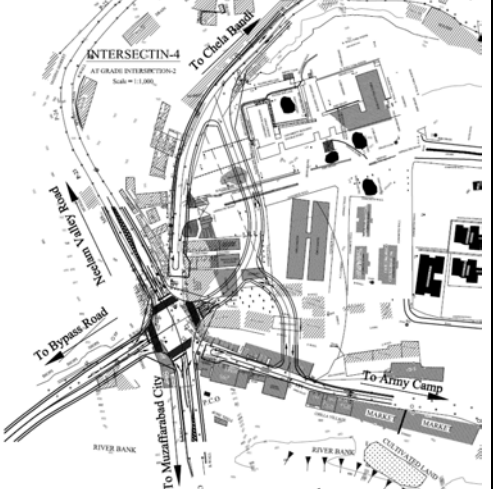
The acute angle is improved in Alternative B. The new road is planned to intersect at an almost right angle. Improving the angle shortens the crossing distances, minimizing intersection area and also provides easy discernment to drivers. The level of traffic safety is significantly improved, and the number of traffic accidents is expected to be low.

Therefore, it is concluded that Alternative B is the most optimum design for Intersection No. 4.

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<sup>4</sup> Alternatives of grade separation were presented and evaluated as per ERRRA's special request. However, these alternatives were discarded since all of them are over-designed and too costly.

**Table 4.4.2 Comparison Study on At-Grade Alternatives**

Items		Alternative A	Alternative B
Layout			
Road Composition & Geometric Design		<ul style="list-style-type: none"> <li>- One leg is closed to reduce the number of conflicting, merging and diverging points. Diversion is added to access to the closed road.</li> <li>- The new road is approx. 150 m.</li> <li>- There is one road intersecting with an angle of 35 degree. (Intersecting roads should meet at or nearly at right angles to ensure sight clearance.)</li> <li>- The crossing distance is 60 m in average.</li> <li>- Vertical gradient of intersection area is less than 4% for every direction.</li> </ul>	<ul style="list-style-type: none"> <li>- Two existing legs are closed to reduce the number of conflicting, merging and diverging points.</li> <li>- The new road is added to meet at almost right angle. It is connected to the roads closed.</li> <li>- The new road is approx. 210 m.</li> <li>- The crossing distance is 36 m in average.</li> <li>- Vertical gradient of intersection area is less than 4% for every direction.</li> </ul>
		<b>Comments</b>	<b>Rating</b>
Safety Level		<ul style="list-style-type: none"> <li>- The crossing distance is relatively long, so the crossing traffic flows are more complicated, and guiding the traffic is difficult. This may induce higher traffic accident ratio compared with Alt-B.</li> <li>- It is difficult for drivers to judge instantly which signal to follow because two signals facing the same direction could show different signs.</li> <li>- The intersecting angle of 35 degree creates blind area, which threatens traffic safety.</li> </ul>	<ul style="list-style-type: none"> <li>- The crossing distance is the minimum, which provides a safe intersection.</li> <li>- The traffic flow is simple. It provides easy discernment to drivers.</li> </ul>
Service Level		<ul style="list-style-type: none"> <li>- Cycle time: <b>70 s</b></li> <li>- Average time of delay: <b>23.5 s/vehicle</b></li> </ul>	<ul style="list-style-type: none"> <li>- Cycle time: <b>60 s</b></li> <li>- Average time of delay: <b>15.8 s/vehicle</b> with higher serviceability</li> </ul>
Traffic Capacity		- Demand Rate in 2019 (demand/capacity): <b>41.7%</b>	- Demand Rate in 2019 (demand/capacity): <b>33.4%</b> It has better tolerance for future traffic demand.
Effect on Social Environment	Traffic Safety & Convenience	<ul style="list-style-type: none"> <li>- It creates inconvenience for users of closed road. They have to travel more than 200 m to reach the intersection.</li> <li>- The long crossing distance, poor sight clearance and complicated traffic flows of this design can be causes for traffic accident.</li> </ul>	<ul style="list-style-type: none"> <li>- The level of traffic safety is significantly improved by minimizing crossing distance, ensuring enough sight clearance and simplifying traffic flows, and the number of traffic accidents is expected to be reduced.</li> <li>- Inconvenience for users of closed roads is less than Alternative A.</li> </ul>
	Affected Commercial Area	<b>Approx. 484 m<sup>2</sup></b>	<b>Approx. 766 m<sup>2</sup></b>
Additional Construction Cost		<b>PKR1,900,000</b> It is the most economical alternative.	<b>PKR2,600,000</b>
Evaluation		<b>Discarded</b>	<b>Selected</b>
		Total 18 pt.	Total 25 pt.

A: Excellent (5 points)    B: Good (4 points)    C: Fair (3 points)    D: Poor (2 points)    F: Bad (0 points)

#### 4.4.4 Signal System

Signal system is designed for Intersection A and No. 4. For every other intersection, the capacity is checked considering no provision of signal system for traffic demand in 2019. This checking was carried out using the following method: It is ensured that other intersections have enough capacity without signal system.

1. Estimate maximum traffic capacity of each minor road by using Equation-1 below.
2. Check if the result of 1 is more than estimated traffic demand of target year. If maximum traffic capacity of minor road,  $q'$  is more than the demand for every traffic flow from minor road, then the intersection has enough capacity without a signal system.

##### Maximum Traffic Capacity of Minor Road

$$q' = \frac{3600qe^{-qt_c}}{1-e^{-qhr}} \quad (\text{Equation-1})$$

- where,
- $q'$  : Traffic capacity of minor road (pcu/hr)
  - $q$  : Total two-way traffic volume of preference road (pcu/hr)
  - $t_c$  : Critical Gap for minor traffic to flow into the intersection (s). (It is time headway. Half of drivers flow into the intersection less than  $t_c$ .)
  - $e$  : Base of natural logarithm ( $\approx 2.7$ )
  - $hr$  : Car-following time headway. (s) (It is time headway for minor traffic to flow into intersection successively.  $hr < t_c$ , but  $hr \approx t_c$  when visibility is bad.)

The examples in Highway Capacity Manual (HCM) 2000 are applied for critical gap and car-following time headway.

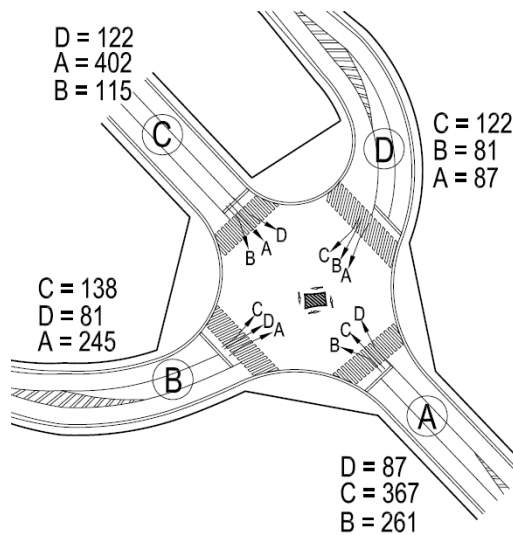
Traffic Flow	Basic Critical Gap (s) Two-lane preference road	Basic Car-Following Time Headway (s)
Right-turn from preference road	4.1	2.2
Left-turn from minor road	6.2	3.3
Straight from minor road	6.5	4.0
Right-turn form minor road	7.1	3.5

Note: Examples in HCM2000

##### (1) Signal Phase for Intersection A

Signal Phase is designed for Intersection A. The detailed calculation is in **Appendix A-2**.

Only main calculation results are shown in this section. Traffic volume applied is shown below.



**a. Signal Phase Pattern**

	A	B	C	D
1φ	Green	Red	Green	Red
2φ	Red	Green	Red	Green

**b. Time of Signal Phase and Cycle Length**

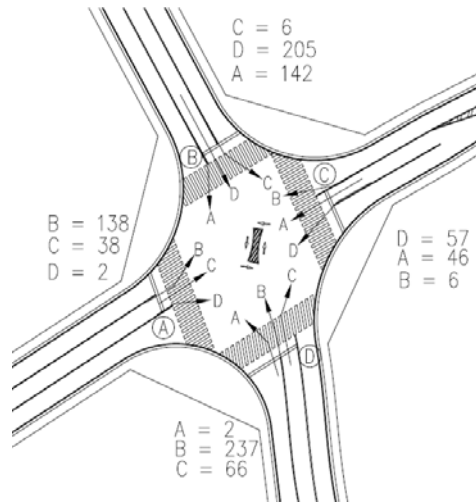
Phase	Green (s)	Yellow (s)	Red (s)	Clearance Time (s)	Loss Time (s)
1φ	43	3	3	6	5
2φ	15	3	3	6	5
Total	58	6	6	12	10
Cycle Length = 70s					

**c. Traffic Capacity**

Inflow	Lane	Traffic Volume q	Traffic Capacity Ci	q/Ci
A	Left & Through	628	1,057	0.594
	Right-Turn	87	550	0.158
B	Left & Through	219	386	0.567
	Right-Turn	245	294	0.833
C	Left & Through	524	1,148	0.456
	Right-Turn	115	621	0.185
D	Left & Through	168	407	0.413
	Right-Turn	122	307	0.397

**(2) Signal Phase for Intersection No.4**

Signal Phase is designed for Intersection No. 4. The detailed calculation is in **Appendix A-2**. Only main calculation results are shown in this section. Traffic volume applied is shown below.



**a. Signal Phase Pattern**

	A	B	C	D
1φ	Green	Red	Green	Red
2φ	Red	Green	Red	Green
3φ	Red	Right-turn only	Red	Right-turn only

**b. Time of Signal Phase and Cycle Length**

Phase	Green (s)	Yellow (s)	Red (s)	Clearance Time (s)	Loss Time (s)
1φ	16	3	3	6	5
2φ	18	3	0	3	2
3φ	12	2	3	5	4
Total	46	8	6	14	11
Cycle Length = 60s					

**c. Traffic Capacity**

Inflow	Lane	Traffic Volume q	Traffic Capacity Ci	q/Ci
A	Left & Through	176	422	0.417
	Right-Turn	2	371	0.005
B	Left & Through	211	594	0.355
	Right-Turn	142	367	0.387
C	Left & Through	103	493	0.209
	Right-Turn	6	431	0.014
D	Left & Through	239	572	0.418
	Right-Turn	66	352	0.188

## 4.5 Pavement Structure Design

The pavement structure is designed based on AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURE 1993.

### 4.5.1 Traffic Volume and Equivalent Single Axle Load (ESAL)

The traffic volume by vehicle type applied to the pavement design is based on the traffic survey conducted in November 2006 at the Preliminary Design stage.

The traffic volume in Section 1-6 (Sta.0+120 to Sta.3+157.8, from the begging point to Intersection No.3) is significantly different from that of Section 7-9 (Sta.3+157.8 to Sta.4+951.995, from Intersection No.3 to the end point). Therefore, the pavement is designed separately for those two sections.

To avoid insufficient or excessive design, the design period is defined to be 15 years from year 2010 which is the opening year of the Project road. The light weight vehicle such as the rickshaw and motorcycle are neglected in the analysis since their impacts on the pavement is very small.

Traffic Equivalency Factor is determined referring to other projects in Pakistan.

**Table 4.5.1 The Accumulated Traffic Volumes and its ESAL for 15 years from the Opening Year of 2010**

		Traffic Volume 2010~2024			Design Traffic	Traffic Equivalency Factor	ESAL two way	Design ESAL(W <sub>18</sub> )
		2010	2014	2024				2010-2024
Section 1~6	Passenger Car	1921	2256	3674	14,677,396	0.001	14,677	
	Small Bus	1063	1248	2033	8,122,288	0.01	81,223	
	Small Truck	1022	1201	1956	7,812,034	0.01	78,120	
	Large Bus	95	111	181	723,926	0.1	72,393	
	Truck(2 axle)	296	347	566	2,259,285	1.0	2,259,285	
	Truck(3 axle)	5	6	10	39,776	1.5	59,664	
	Tractor	46	54	88	350,030	1.5	525,045	
							3,090,407	1,545,204
Section 7~9	Passenger Car	497	869	1709	5,911,240	0.001	5,911	
	Small Bus	275	481	946	3,270,339	0.01	32,703	
	Small Truck	265	463	910	3,147,188	0.01	31,472	
	Large Bus	24	42	83	287,352	0.1	28,735	
	Truck(2 axle)	77	135	265	916,790	1.0	916,790	
	Truck(3 axle)	1	2	4	13,683	1.5	20,525	
	Tractor	12	20	40	136,834	1.5	205,251	
							1,241,387	620,693

Source: JICA Study Team, quoted from Table 9.2.1

### 4.5.2 Design Condition

#### (1) Design Criteria

The design criteria are summarized in **Table 4.5.2**.

**Table 4.5.2 Summary of Pavement Design Criteria by AASHTO Method**

Design Input Requirements			Value
1	Design Variables	Performance Period (years)	15
		Traffic	
		Equivalent Single Axle Load (ton-f)	8.2
		Directional Distribution Factor, $D_D$	0.5
		Lane Distribution Factor, $D_L$	1.0
		Reliability % (ZR)	90%(-1.282)
		Overall Standard Deviation, $S_O$	0.45
2	Performance Criteria	Initial Serviceability Index, $p_o$	4.2
		Terminal Serviceability Index, $p_t$	2.5
		Design Serviceability Loss, $PSI$	1.7
3	Material Properties	Effective Roadbed Soil Resilient Modulus, MR (psi)	1500 x CBR
		Layer Coefficient for Asphalt Concrete Surface coarse, $a_1$	0.42
		Layer Coefficient for Asphalt Concrete Binder corce, $a_2$	0.37
		Layer Coefficient for Base Course, $a_3$ (CBR>80)	0.132
		Layer Coefficient for Sub base Course, $a_4$ (CBR>30)	0.109
4	Pavement Characteristics	Drainage Coefficients for Base Course and Sub base Course, $m^2, m^3$	1.0

**(2) ESAL (W18)**

The accumulated ESAL for the pavement design is 1.55 million for Section 1~6 and 0.62 million for Section 7~9.

**(3) Subgrade Strength**

The effective road soil resilient modulus, MR is computed from the CBR value of the subgrade material.

The results of the CBR test are listed in **Table 4.5.3**. The values of the CBR are fluctuated from 18.9 to 36.0. The design CBR in the existing road section is defined as 15% for safety design. The design CBR on new embankment section is also defined as 15%. The subgrade is ignored in cut section which is expected to have soft rock with 15% CBR or higher.

The thickness of the subgrade is defined as 30cm.

**Table 4.5.3 Summary of Existing Road CBR**

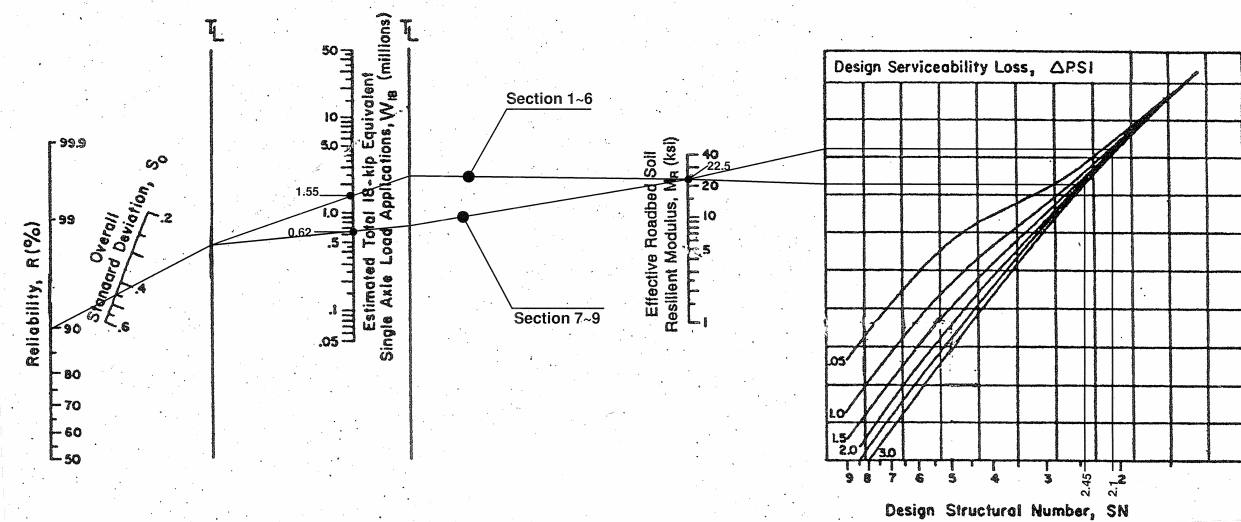
	Station	Existing Sub grade CBR%
TP2	0+800	19.8
TP3	1+430	18.9
TP4	1+850	22.5
TP5	2+100	34.4
TP6	4+800	36.0

### 4.5.3 Required Structural Number (SN)

A set of design variables such as performance criteria and effective roadbed soil resilient modulus, the required Structural Number (SN) is estimated from the following equation or the AASHTO Nomograph.

$$\log_{10} W_{18} = Z_R S_0 + 9.36 \log_{10} (SN + 1) - 0.20 + \frac{\log_{10} (\Delta PSI / (4.2 - 1.5))}{0.40 + 1094 / (SN + 1)^{5.19}} + 2.32 \log_{10} M_R - 8.07$$

Where W18=Number of 18,000 ESAL (Equivalent Single Axle Load)



	ZR	S0	W18 Millions	MR	PSI	SN(inch)
Section 1-6	90%	0.45	1.55	22.5	1.7	2.45
Section 7-9	90%	0.62	0.62	22.5	1.7	2.10

Figure 4.5.1 Design Chart for Flexible Pavement.

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

Where,

a1, a2, a3 = Layer coefficients representative of surface (binder), base and subbase courses, respectively.

D1, D2, D3 = Actual Thickness (in inches) of surface (binder), base and subbase courses, respectively.

m2, m3 = Drainage coefficients for base and subbase layers, respectively.

### 4.5.4 Thickness design

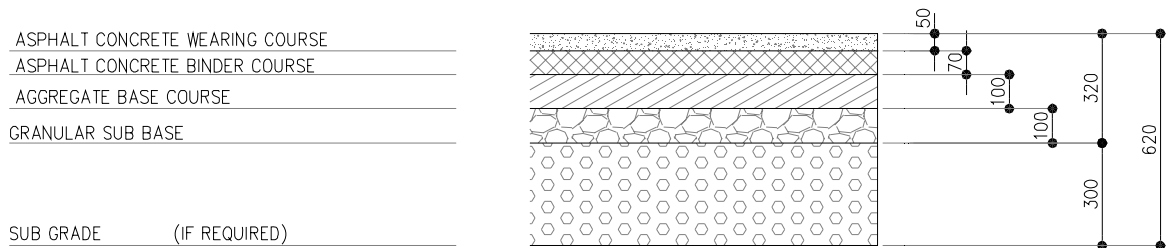
#### (1) Pavement Structure on Bypass Road

The calculated thickness for various layers is summarized in **Table 4.5.4**.

**Table 4.5.4 Designed Pavement Thickness for Bypass Road**

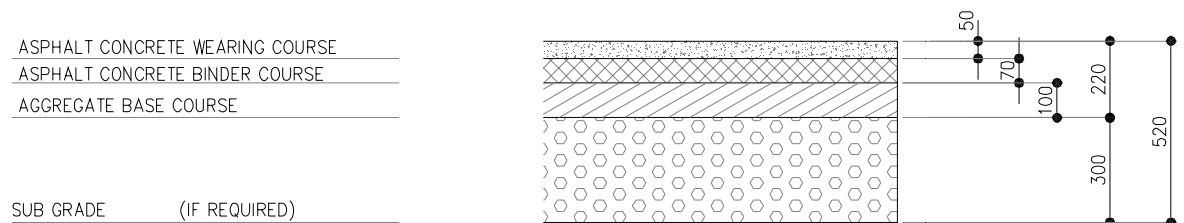
	Design CBR	ESAL (million)	SN (inch)	SN (cm)	Designed Thickness(cm)				Designed SN(cm)
					Surface Course	Binder Course	Base Course	Sub base Course	
Section 1~6	15%	1.55	2.45	6.21	5	7	10	10	2.10+2.59 +1.32+1.09 =7.10>6.22
					5x0.42 =2.10	7x0.37 =2.59	10x0.132 =1.32	10x0.109 =1.09	
Section 7~9	15%	0.62	2.10	5.34	5	7	10		2.10+2.59 +1.32 =6.01>5.41
					5x0.42 =2.10	7x0.37 =2.59	10x0.132 =1.32		

The pavement composition for Section 1-6 is shown in **Figure 4.5.2**, which has higher traffic volume than in Section 7-9. The thickness of each layer is; Wearing Course (5cm), Binder Course (5cm), Aggregate Base Course (10cm), Granular Sub Base Course (10cm).



**Figure 4.5.2 Pavement composition for Section 1 ~ 6 (Sta.0-121.0 ~ Sta3+157.8)**

The pavement composition in Section 7-9 is shown in **Figure 4.5.3**. Subbase course is ignored due to low traffic volume. The thickness of each layer is; Wearing Course (4cm), Binder Course (5cm), Aggregate Base Course (15cm).



**Figure 4.5.3 Pavement composition for Section 7 ~ 9 (Sta.3+157.8 ~ Sta4+951.995)**

The same pavement composition is applied to shoulder as carriage way. The shoulder of most of the section is narrow. The shoulder having a width of 1.5 m is expected to be used as parking space and to ensure access to residents at the roadside.

**(2) Pavement Structure on Access Road to the Bypass**

**a. Vehicle Pass**

The pavement composition of the access road to the bypass with low traffic which is listed below is determined as Wearing Course (5cm) and Aggregate Base Course (17cm) considering the pavement composition of the neighbor bypass.

- Access road to Naluchi Road (Sta.0+600)
- Access road to Chela Bandi Road (Sta.3+700)
- Access road to Hoidra Bandi Road (Sta.3+860)



**b. Small Track**

There is little traffic volume on other small tracks. Therefore, the asphalt mix layer is eliminated, and the pavement composition is only Aggregate Base Course (17cm) as follows.



**(3) Side Walk**

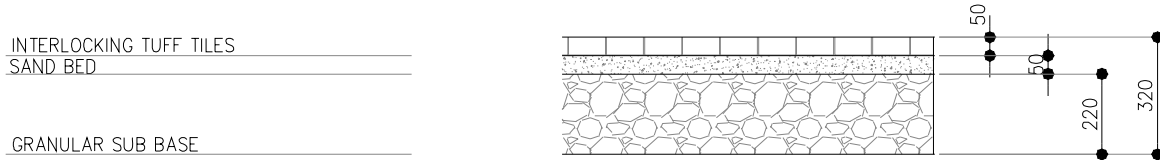
**a. Flat Type Side Walk**

The formation height of side walk in the normal section is the same as that of carriageway (flat type). The pavement composition is Wearing Course (5cm) and Aggregate Base Course (10cm) as follows.



**b. Elevated Side Walk**

The side walk at intersection is elevated by 20 cm, and its pavement composition is; Interlocking Tuff Tile (5cm), Sand Bed (5cm), Granular Sub Base (22cm).



**4.6 Drainage Design (Side Ditch)**

**4.6.1 Design Criteria**

The existing side ditches along the existing road is not sufficient. Due to this, it was observed that surface water stream and stagnant water are present on the roads during rainy season. From the viewpoint of traffic safety and keeping road life as long as possible, provision of side ditch with sufficient capacity is requisite to immediately drain surface water to the nearest discharge point. This can be achieved using a culvert or bridge.

The project road passes through the hilly area which is ascending on the left side of the road. From its topographical condition, the surface water from the hillside should be collected by the side drain on the left side of the road or mountain side, and drained to adjacent cross drainage provided by culverts and bridges.

The design policies for side ditches are as follows;

- Both left and right side ditches are provided in residential and commercial areas considering cross fall of the road.
- Minimization of required land acquisition is essential.

The rainfall intensities for specific design storm duration and return period are calculated in Section 3.4. The design criteria are as shown in **Table 4.6.1**.

**Table 4.6.1 Design Criteria for Side Ditch**

Catchment Area	As calculated from the Topographical Survey Map
Runoff Coefficient :	Road Surface : 0.95 Cut Slope Surface : 0.60
Return Period	3 years
Design Storm Duration	10 minutes
Rainfall Intensity	72mm/h (10minutes) at 3years' return period
Roughness Values	Concrete : 0.015

#### **4.6.2 Drainage Design**

The design discharge is estimated using the Rational formula below:

$$Q_{req} = (1/3.6*106)*C*I*A$$

$Q_{req}$  : Peak Runoff Rate (m<sup>3</sup>/s)

C : Runoff Coefficient

I : Rainfall Intensity (mm/hr)

A : Catchments Area (m<sup>2</sup>)

Flow Velocities are calculated from the Manning equation as follows:.

$$Q = B*H*0.8*v$$

$$v = (1/n)*R^{2/3}*(I/100)^{1/2}$$

Q : Capacity of Drain Discharge (m<sup>3</sup>/s)

v : Average Flow Velocity (m/s)

B : Drainage Width (m)

H : Drainage Height (m)

n : Roughness Values

R : Hydraulic Radius (m)

I : Slope (%)

The design discharge and required drainage capacity of each catchment area is calculated, and the results are shown in **Table 4.6.2** and **Table 4.6.3**.

**Table 4.6.2 Design Discharge and Required Drainage Capacity of Each Catchment Area (Left side Drainage)**

		Leftside Drainage														
Start	End	Discharge Estimate						Drain Capacity								
		Slope			Road			Qreq Part	Qreq Section	Form	B	H	A	I	v	Q
		c	I	A	c	I	A									
mm/hr	m2	mm/hr	m2	m3/s	m3/s	m	m	m2	%	m/s	m3/s					
-0+120	0+000			0	0.95	72	780	0.015		U	0.300	0.300	0.072	3.333	2.486	0.179
0+000	0+101			0	0.95	72	657	0.012		U	0.300	0.300	0.072	3.333	2.486	0.179
0+101	0+574	Naluchi Bridge														
0+574	0+723	0.60	72	5,839	0.95	72	1,367	0.096	0.314	U	0.400	0.400	0.128	5.564	3.891	0.498
0+723	0+910	0.60	72	15,949	0.95	72	1,396	0.218		U	0.400	0.400	0.128	5.564	3.891	0.498
0+910	0+990	0.60	72	3,190	0.95	72	565	0.049		U	0.300	0.300	0.072	3.100	2.397	0.173
0+990	1+160	0.60	72	104,500	0.95	72	791	1.269		U	0.900	0.900	0.648	2.857	4.787	3.102
1+160	1+460	0.60	72	184,425	0.95	72	339	2.220		U	0.900	0.900	0.648	1.500	3.469	2.248
1+460	1+600	0.60	72	86,075	0.95	72	283	1.038		U	0.900	0.900	0.648	2.000	4.006	2.596
1+600	1+733	0.60	72	8,530	0.95	72	751	0.117		U	0.400	0.400	0.128	0.909	1.573	0.201
1+733	1+763	No.1 Bridge														
1+763	1+810			0			0	0.000	0.205	U	0.400	0.400	0.128	7.000	4.364	0.559
1+810	2+063	0.60	72	16,606	0.95	72	325	0.205		U	0.400	0.400	0.128	3.000	2.857	0.366
2+063	2+130	0.60	72	2,459			0	0.030		U	0.400	0.400	0.128	3.636	3.145	0.403
2+130	2+680	0.60	72	77,307	0.95	72	3,051	0.986		U	0.600	0.600	0.288	4.333	4.499	1.296
2+680	2+925	0.60	72	88,050	0.95	72	989	1.075		U	0.600	0.600	0.288	3.750	4.186	1.205
2+925	3+053	0.60	72	7,376			0	0.089		U	0.400	0.400	0.128	1.000	1.650	0.211
3+053	3+200	0.60	72	14,977	0.95	72	1,017	0.199	0.394	U	0.400	0.400	0.128	3.000	2.857	0.366
3+200	3+300	0.60	72	14,977	0.95	72	791	0.195		U	0.400	0.400	0.128	5.000	3.688	0.472
3+300	3+500	0.60	72	14,875	0.95	72	339	0.185		U	0.400	0.400	0.128	6.000	4.041	0.517
3+500	3+530	No.2 Bridge														
3+530	3+794	0.60	72	48,000	0.95	72	1,752	0.609		U	0.600	0.600	0.288	1.000	2.161	0.623
3+794	3+869	0.60	72	21,809	0.95	72	51	0.263		U	0.500	0.500	0.200	2.200	2.839	0.568
3+869	3+900	0.60	72	6	0.95	72	175	0.003	0.405	U	0.500	0.500	0.200	3.330	3.493	0.699
3+900	4+100	0.60	72	9,937	0.95	72	1,017	0.139		U	0.500	0.500	0.200	0.240	0.938	0.188
4+100	4+289	0.60	72	12,520	0.95	72	1,243	0.174		U	0.500	0.500	0.200	0.240	0.938	0.188
4+289	4+435	0.60	72	57,566			0	0.691		U	0.900	0.900	0.648	0.240	1.388	0.899
4+435	4+511	0.60	72	12,602			0	0.151		U	0.500	0.500	0.200	0.240	0.938	0.188
4+511	4+544	0.60	72	5,472			0	0.066		U	0.500	0.500	0.200	0.240	0.938	0.188
4+544	4+581	0.60	72	6,135	0.95	72	124	0.076		U	0.500	0.500	0.200	0.240	0.938	0.188
4+581	4+661	0.60	72	13,265	0.95	72	904	0.176	0.178	U	0.500	0.500	0.200	0.240	0.938	0.188
4+661	4+715			0	0.95	72	102	0.002		U	0.500	0.500	0.200	0.240	0.938	0.188
4+715	4+775	No.3 Bridge														
4+775	4+870	0.60	72	10,298			0	0.124		U	0.300	0.300	0.072	4.350	2.840	0.204
4+870	4+992	0.60	72	3,496	0.95	72	689	0.055		U	0.600	0.600	0.288	3.970	4.307	1.240

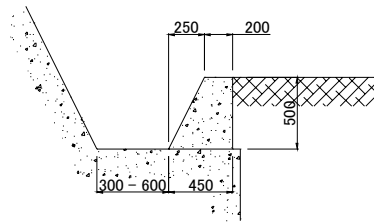
**Table 4.6.3 Design Discharge and Required Drainage Capacity of Each Catchment Area (Right side Drainage)**

Start	End	Rightside Drainage														
		Discharge Estimate						Drain Capacity								
		Slope			Road			Qreq Part	Qreq Section	Form	B	H	A	I	v	Q
		c	I	A	c	I	A									
	mm/hr	m2		mm/hr	m2	m3/s	m3/s		m	m	m2	%	m/s	m3/s		
-0+120	0+000			0	0.95	72	780	0.015		U	0.300	0.300	0.072	3.333	2.486	0.179
0+000	0+101			0	0.95	72	657	0.012		U	0.300	0.300	0.072	3.333	2.486	0.179
0+101	0+574	Naluchi Bridge														
0+574	0+723	0.60	72	1,171	0.95	72	316	0.020	0.040	U	0.300	0.300	0.072	5.564	3.212	0.231
0+723	0+910	0.60	72	561	0.95	72	718	0.020		U	0.300	0.300	0.072	5.564	3.212	0.231
0+910	0+990			0	0.95	72	339	0.006		U	0.300	0.300	0.072	0.500	0.963	0.069
0+990	1+160			0	0.95	72	1,130	0.021		U	0.400	0.400	0.128	0.500	1.166	0.149
1+160	1+460			0	0.95	72	2,034	0.039	0.085	U	0.400	0.400	0.128	0.500	1.166	0.149
								1.038		U	0.900	0.900	0.648	2.000	4.006	2.596
1+460	1+600			0	0.95	72	1,300	0.025		U	0.400	0.400	0.128	0.500	1.166	0.149
1+600	1+733	0.60	72	405	0.95	72	751	0.019		U	0.300	0.300	0.072	0.909	1.298	0.093
1+733	1+763	No.1 Bridge														
1+763	1+810			0	0.95	72	531	0.010	0.117	U	0.300	0.300	0.072	7.000	3.603	0.259
1+810	2+063	0.60	72	2,825	0.95	72	2,964	0.090		U	0.300	0.300	0.072	3.000	2.358	0.170
2+063	2+130			0	0.95	72	871	0.017		U	0.300	0.300	0.072	3.000	2.358	0.170
2+130	2+680	0.60	72	0	0.95	72	3,164	0.060		U	0.300	0.300	0.072	4.333	2.834	0.204
2+680	2+925	0.60	72	2,825	0.95	72	1,780	0.068	0.099	U	0.300	0.300	0.072	3.750	2.637	0.190
2+925	3+053	0.60	72		0.95	72	1,664	0.032		U	0.300	0.300	0.072	3.750	2.637	0.190
3+053	3+200	0.60	72	400	0.95	72	741	0.019		U	0.300	0.300	0.072	3.000	2.358	0.170
3+200	3+300	0.60	72	700	0.95	72	339	0.015		U	0.300	0.300	0.072	3.000	2.358	0.170
3+300	3+500	0.60	72	800	0.95	72	1,921	0.046		U	0.300	0.300	0.072	6.000	3.335	0.240
3+500	3+530	No.2 Bridge														
3+530	3+794			0	0.95	72	1,232	0.023	0.039	U	0.300	0.300	0.072	1.000	1.362	0.098
3+794	3+869			0	0.95	72	797	0.015		U	0.300	0.300	0.072	1.000	1.362	0.098
3+869	3+900			0	0.95	72	175	0.003	0.027	U	0.300	0.300	0.072	0.240	0.667	0.048
3+900	4+100			0	0.95	72	1,243	0.024		U	0.300	0.300	0.072	0.240	0.667	0.048
4+100	4+289			0	0.95	72	893	0.017		U	0.300	0.300	0.072	0.240	0.667	0.048
4+289	4+435			0	0.95	72	1,650	0.031		U	0.300	0.300	0.072	0.240	0.667	0.048
4+435	4+511			0	0.95	72	859	0.016		U	0.300	0.300	0.072	0.240	0.667	0.048
4+511	4+544			0	0.95	72	373	0.007		U	0.300	0.300	0.072	0.240	0.667	0.048
4+544	4+581			0	0.95	72	294	0.006		U	0.300	0.300	0.072	0.240	0.667	0.048
4+581	4+661			0			0	0.000	0.010	U	0.300	0.300	0.072	0.240	0.667	0.048
4+661	4+715			0	0.95	72	509	0.010		U	0.300	0.300	0.072	0.240	0.667	0.048
4+715	4+775	No.3 Bridge														
4+775	4+870			0	0.95	72	1,074	0.020		U	0.300	0.300	0.072	4.350	2.840	0.204
4+870	4+992			0	0.95	72	689	0.013		U	0.300	0.300	0.072	3.970	2.713	0.195

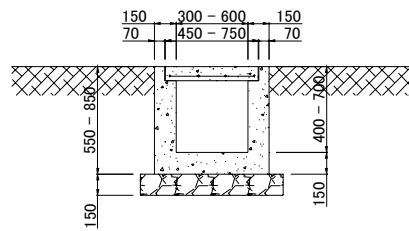
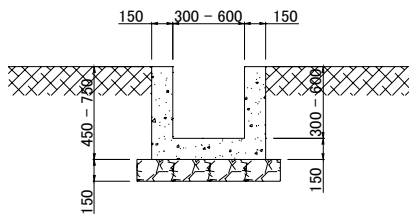
### 4.6.3 Side Ditch Applied

The features of the side ditch such as configuration and material are studied in consideration of drainage capacity, ease of maintenance, available space and cost. Based on these criteria a concrete rectangular-type side ditch was selected. Typical cross sections of the side ditches designed and applied in the project are as shown in **Figure 4.6.1**. Station limit of each type is shown in the Drawings.

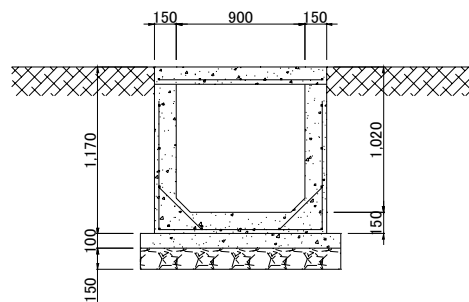
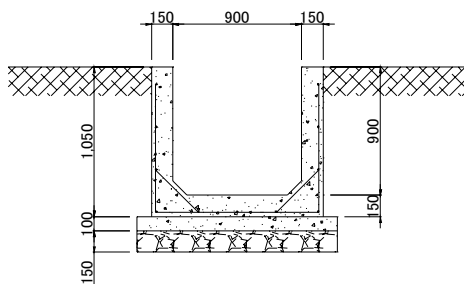
#### Type I



#### Type II-A, B (with cover)



#### Type III-A, B (with cover)



**Figure 4.6.1** Typical Cross Section for Side Drains

## 4.7 Slope Protection Design

### 4.7.1 Applicable Design Criteria and Standards

#### (1) Cut Slopes

Cut slope by construction depends on the characteristics of subsoil and the cut height.

**Table 4.7.1** indicates standard gradients of cut slopes from Japanese Standards.

**Table 4.7.1 Standard Gradients of Cut Slopes from Japanese Standards**

Character of soil or bedrock		Height (m)	Gradient (V:H)
Hard rock			1:0.3 ~ 1:0.8
Soft rock			1:0.5 ~ 1:1.2
Sand	Those are not dense, not solid and of bad grade distribution.		1:1.5 ~
Sandy soil	Dense and solid.	Less than 5 m	1:0.8 ~ 1:1.0
		5~10 m	1:1.0 ~ 1:1.2
	Not dense, not solid.	Less than 5 m	1:1.0 ~ 1:1.2
		5~10 m	1:1.2 ~ 1:1.5
Sandy soil mixed with gravel or rock mass	Those are dense and solid or of good grade distribution.	Less than 10 m	1:0.8 ~ 1:1.0
		10~15 m	1:1.0 ~ 1:1.2
	Those are not dense, not solid or of bad grade distribution.	Less than 10 m	1:1.0 ~ 1:1.2
		10~15 m	1:1.2 ~ 1:1.5
Cohesive soil		Less than 10 m	1:0.8 ~ 1:1.2
Cohesive soil mixed with rock mass or cobble stones		Less than 5 m	1:1.0 ~ 1:1.2
		5~10 m	1:1.2 ~ 1:1.5

(Source: MANUAL FOR SLOPE PROTECTION, by the Japan Road Association, November 1999)

Referring to above **Table 4.7.1**, 1: 1.0 (V:H) of cut slope on earth works is applied in principle, taking into account that the subsoil condition has relatively dense sand with gravel and the height of cut in general along the road.

#### (2) Fill Slopes

Fill slope also depends on fill material used and height of fill. Standard gradients of fill slopes corresponding to fill materials and heights are shown in **Table 4.7.2**.

**Table 4.7.2 Standard Gradients of Slopes Corresponding to Fill Materials and Heights of Fill**

Embankment Materials	Height (m)	Gradient (V:H)
Well graded sand, gravel, and sand or silt mixed with gravel (GW, GP, GM, GC)	Less than 5 m	1:1.5 ~ 1:1.8
	5~15 m	1:1.8 ~ 1:2.0
Poorly graded sand (SP).	Less than 10 m	1:1.8 ~ 1:2.0
Rock masses (with muck inclusions)	Less than 10 m	1:1.5 ~ 1:1.8
	10 ~ 20 m	1:1.8 ~ 1:2.0
Sandy soils (SM, SC), Hard clayey soil and clays (CL, ML)	Less than 5 m	1:1.5 ~ 1:1.8
	5~10 m	1:1.8 ~ 1:2.0
Soft clayey soils	Less than 5 m	1:1.8 ~ 1:2.0

Note) Height of embankment is the vertical height from the toe to the top of embankment.

Source: MANUAL FOR SLOPE PROTECTION, by the Japan Road Association, November 1999

1: 1.5 (V: H) of fill slope in earthwork is applied in principle taking into account the fill materials expected and height of fill.

### (3) Slope Protection

To prevent slope collapse, either the sliding force has to be reduced or sufficient resistance of slope be ensured, to overcome sliding failure. **Table 4.7.3** shows standard countermeasures for safety against slope collapse.

**Table 4.7.3 Preventive Measures against Slope Collapse**

CLASSIFICATION		TYPE OF WORK	
1. Earth Work	Earth Work	Cutting	
		Filling	
2. Vegetation	Seed	Seed Spraying	
		Seed Mud Spraying, etc.	
	Sod	Sodding	
		Sod matting, etc.	
3. Water Drainage	Surface Drainage	Subsoil Drainage Hole	
		Drainage Ditch and Cascade	
	Subsurface Drainage	Culvert	
		Horizontal Drain Hole	
4. Slope Work	Pitching Work	Stone Pitching	
	Shotcrete Work	Shotcrete (mortar)	
	Concrete Crib Work	Shotcrete (concrete)	
5. Anchoring	Anchoring	Crib work (Mortar or Concrete)	
		Soil Nail	
		Rock Bolt	
6. Wall and Resisting Structures	Retaining Wall	Ground Anchor	
		Rock fall Prevention Work	Gabion Wall
			Masonry Wall (Stone, Wet, Dry)
	Concrete Block Wall		
	Concrete Retaining Wall		
	7. Piling Work	Piling Work	Rock fall Prevention Wall
			Rock fall Prevention Fence
Rock fall Prevention Net			
		Steel Pipe Pile	
		Concrete Pile	

Source: JICA Study Team

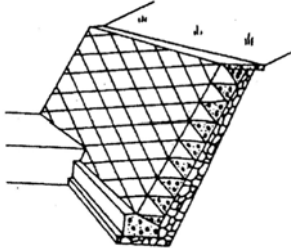
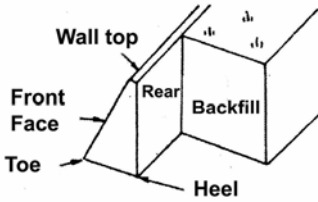
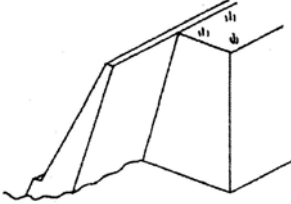
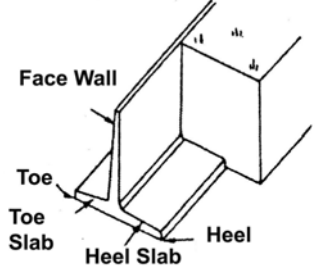
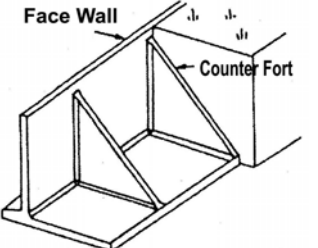
An adequate and effective slope protection measure for preventing slope collapses should be selected in consideration of the anticipated causes, shape, mechanism, and scale of failures, as well as cost-performance. Maximum usage of local materials is also significant criteria in selecting suitable slope protection measure for the project.

### (4) Retaining Walls

Retaining wall structures will be provided at such locations where cut or fill slope affect control points located at road sides or where cut or fill is not appropriate because of steep topography, fragile geology, flooded section, etc. Retaining walls can be generally classified into 5 types in terms of their design criteria, applicability, etc. Selection of the

type of retaining wall shall generally be based on the topographical and geological conditions, location of the wall, work conditions, purpose, elevations, etc. **Table 4.7.4** summarizes retaining wall types and their respective features.

**Table 4.7.4 Retaining Wall Types and Features**

Type	Shape	Height and Gradient	Characteristics	Technical Notes
Block (Stone Masonry)		<ul style="list-style-type: none"> <li>• Normally less than 7.0 m in height.</li> <li>• Up to 15.0 m in height for large block masonry.</li> <li>• Front slope is 1:0.3 to 1:0.6 (V:H)</li> </ul>	<ul style="list-style-type: none"> <li>• Frequently used to prevent small scale collapses at the foot of a slope or to protect the slope.</li> </ul>	<ul style="list-style-type: none"> <li>• Mainly applicable for low earth pressures where the geology of the soil behind the wall is dense or has good soil sediment.</li> <li>• Structurally vulnerable to the effects of earthquakes.</li> </ul>
Gravity Wall		<ul style="list-style-type: none"> <li>• Less than 5.0 m in height.</li> <li>• The width of the wall base is about 0.5 to 0.7 times the height of wall.</li> </ul>	<ul style="list-style-type: none"> <li>• Retains earth pressure with its own deadweight.</li> </ul>	<ul style="list-style-type: none"> <li>• Applicable for foundations on good ground.</li> <li>• Inapplicable for pile foundations.</li> </ul>
Leaning wall		<ul style="list-style-type: none"> <li>• Less than 10.0 m in most cases.</li> <li>• Up to 15.0 m in same cases.</li> <li>• Front slope is 1:0.3 to 1:0.6 (V:H)</li> </ul>	<ul style="list-style-type: none"> <li>• Retains earth pressure with its own deadweight and further supported by the backfill.</li> </ul>	<ul style="list-style-type: none"> <li>• Applicable for widening of existing roads in mountainous terrain.</li> <li>• Frequently used at places with land and topographical constraints.</li> </ul>
Cantilever wall		<ul style="list-style-type: none"> <li>• 3.0 to 10.0 m in height.</li> <li>• The width of the wall base is about 0.5 to 0.8 times the height of the wall.</li> </ul>	<ul style="list-style-type: none"> <li>• Vertical wall resists the lateral load or earth pressure.</li> <li>• The weight of backfill over the heel slab can be used to provide additional resistance against earth pressure.</li> </ul>	<ul style="list-style-type: none"> <li>• Applicable for pile foundations.</li> <li>• Precast concrete is frequently used.</li> </ul>
Counter Fort wall		<ul style="list-style-type: none"> <li>• More than 10.0 m in height.</li> <li>• The width of the wall base is about 0.5 to 0.7 times the height of wall</li> </ul>	<ul style="list-style-type: none"> <li>• Vertical wall and bottom slab are supported at three sides.</li> <li>• Counter fort type is more beneficial than cantilever type for higher walls.</li> </ul>	<ul style="list-style-type: none"> <li>• Fabrication of wall body and backfilling is difficult.</li> <li>• Applicable for pile foundations.</li> </ul>

Source: MANUAL FOR SLOPE PROTECTION, by the Japan Road Association, November 1999

## 4.7.2 Slope Protection Design

### (1) Retaining Walls in Cut/Fill Section

In cross section design, a suitable retaining wall was selected at respective site based on applicable design criteria and standard, space availability, subsoil conditions and construction cost. Through evaluation of these design parameters, concrete leaning retaining wall, concrete L-shaped retaining wall, stone masonry leaning retaining wall were all selected for various cut sections. For fill sections meanwhile, concrete inverted T shaped and stone masonry leaning retaining walls were selected. Detailed station limits of required retaining walls are tabulated in **Table 4.7.5**.

**Table 4.7.5 Station Limit of Respective Retaining Walls Selected**

Section	Type of Retaining Wall	Station Limit	Right or Left
Cut Section	Concrete Leaning Wall (RW-I)	0+610.00~0+710.00	Left
		0+610.00~0+710.00	Right
		2+130.00~2+250.00	Left
		2+710.00~2+770.00	Left
		3+310.00~3+410.00	Left
		4+430.00~4+510.00	Left
	Stone Masonry Leaning Wall (RW-IV)	3+310.00~3+410.00	Right
		0+710.00~0+870.00	Left
		2+830.00~2+890.00	Left
Concrete L shaped Retaining Wall (RW-II)	2+470.00~2+510.00	Left	
Fill Section	Concrete Inverted T shaped Retaining Wall (RW-III)	2+030.00~2+090.00	Right
		3+230.00~3+290.00	Right
	Stone Masonry Leaning Wall (RW-IV)	2+830.00~2+890.00	Left
		3+630.00~3+750.00	Left
		2+150.00~2+290.00	Right
		2+670.00~2+690.00	Right
		2+970.00~3+030.00	Right
		3+530.00~3+550.00	Right
		3+590.00~3+670.00	Right

(Source: Study Team)

It is noted that the applicable slope protection measures are only concrete crib work and stone pitching in the design. The former is studied and designed as countermeasure of rock fall in Chapter 6 (Natural Disaster Hazard Study), while the latter is described in following subsection.

### (2) Bank Protect Wall along the Project Road

#### Comparative Study for Structure Type

Between Sta.3+800 and Sta.4+800, the project road passes on the existing road along the river side. The existing revetment structures made from stone masonry can be seen in some sections but those have been eroded or severely deteriorated.

The alignment on this section is designed in a restrained manner because embankment fill at the river side is susceptible to erosion and will consequently cause reduction of the river width. Accordingly, the retaining wall for river bank should be provided to maintain stability against river flow.

The most optimum and reliable revetment type for this section was determined through a comparative study of four alternatives. The comparative study for the structure is made as shown in the **Figure 4.7.1**. The considerations are summarized as follows:

- Considering fitting to the existing river bank with slope gradient, the application of steep retaining wall will minimize the total construction volume.
- Huge boulders available at the vicinity of the site can be utilized as gravity wall.
- It is assumed that a bearing layer for gravity wall is located at a shallow level in sand gravel or rock layers, based on the geotechnical condition.

From the above points, Stone Pitching & Gravity Wall is selected for design.

Type of Revement	Stone Pitching + Gravity Wall	Reinforced Earth Wall	Gravity Type	Stone Masonry Wall + Gravity Wall
Structural Characteristics	<p>Main structural function of this type wall is to protect against slope erosion and disruption. The design is executed against fluid tractive force.</p> <p>To shorten the height of stone pitching, it is preferable to construct gravity wall at the toe of slope.</p> <p>The careful attention for fine soil suction should be considered.</p>	<p>This type of wall is keeping its stability by the friction between backfill material and strips. Reinforced Earth Wall can be constructed vertically. It also doesn't need high bearing capacity. From these reason, the height of wall can be possibly short.</p> <p>However, there's few application below water level. It is very necessary for design and construction to The careful attention should be paid for selection of backfill material and methods of treatment against fine soil</p>	<p>The soil pressure in back side is supported by self weight of the wall. The reaction force at the wall bottom needs high bearing capacity.</p> <p>The wall height is decided in consideration of freeboard and high water level.</p>	<p>Stone masonry wall of leaning type is generally used up to 5meters height. This mixed type of wall is applied if over 5meters in where the existing back ground is consolidated.</p> <p>The treatment for fine soil suction and dissipation of residual water pressure in back fill is necessary.</p>
Workability	<p>The construction is not difficult.</p>	<p>No considerable difficulties for workability</p>	<p>Easy compaction of back fill material is secured and it is expected to construct stable structures.</p>	<p>The construction is not difficult. However the compaction of granular fill material underneath of stone pitching.</p>
Stability	<p>Once the suction of fine soil arise by flood, the structure lose its stability. The considerable restoration work is anticipated.</p>	<p>The Stability in the flood might be not reliable. There are not many application cases for river reventment. Once the suction of fine soil arise by flood, there's high possibility to lose the structural stability of the wall.</p>	<p>It's the most reliable structure of these alternatives. Even if suction of fine soil arise, the wall retain structural stability and the restoration work will be simple.</p>	<p>Once the suction of fine soil arise by flood, the structure lose its stability. The considerable restoration work is anticipated. The seismic stability is comparatively lower of these alternatives.</p>
Construction Cost	<p>Moderate alternative for the cost(1.07)</p>	<p>Lowest alternative for the construction cost (1.00)</p>	<p>Higher priced alternative (1.29)</p>	<p>Moderate alternative for the cost(1.14)</p>
Judgment	Recommended	Rejected	Conditionally Recommended	Rejected

Source: JICA Study Team

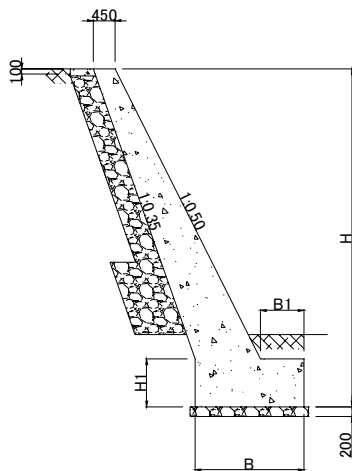
Figure 4.7.1 Study for Structural Type of River Bank Protection

### 4.7.3 Design Results

Stability calculation of each retaining wall selected was initially carried out to determine structural dimensions. Following this, structural analysis was conducted for RC structures to determine amount of reinforcing bars in the structure. The following are detailed design results of each structure.

#### (1) Retaining Wall at Cut Sections

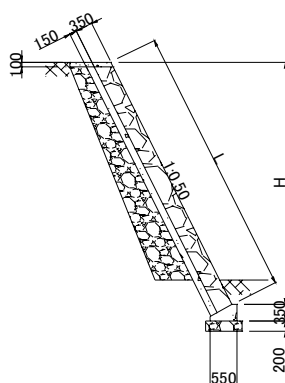
The typical structural details for each type of retaining wall are shown in the following figure.



RC Learning	Unit	B	B1	H1
H=7.00m	mm	2,250	900	1,000
H=6.00m	mm	2,050	840	900
H=5.00m	mm	1,800	720	800
H=4.00m	mm	1,550	610	700

Source: JICA Study Team

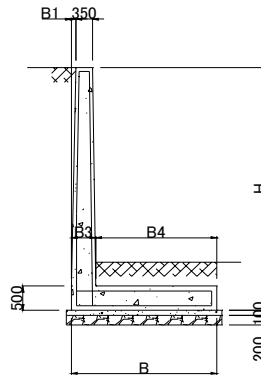
Figure 4.7.2 Typical Structural Detail for Leaning Type Retaining Wall



Stone Masonry (Learning)	Unit	L
H=5.00m	mm	5,590
H=4.50m	mm	5,031
H=4.00m	mm	4,473
H=3.50m	mm	3,913
H=3.00m	mm	3,354

Source: JICA Study Team

Figure 4.7.3 Typical Structural Detail for Stone Masonry (Leaning)



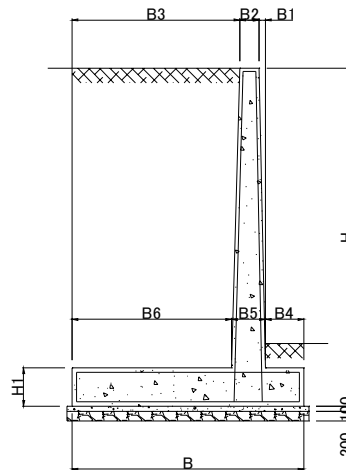
Inversed L-Shaped	Unit	B	B1	B2	B3	B4
H=4.00m	mm	3,400	70	2,980	500	2,900
H=3.00m	mm	1,800	50	1,400	400	1,400

Source: JICA Study Team

**Figure 4.7.4 Typical Structural Detail for Inverted L-Shaped Retaining Wall (Bound Grave)**

**(2) Retaining Wall at Fill Sections**

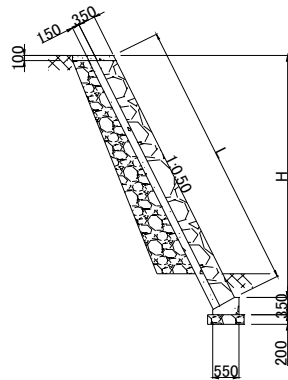
The typical structural details for each type of retaining wall are shown in the following figure.



RC T-Shaped	Unit	B	B1	B2	B3	B4	B5	B6	H1
H=7.00m	mm	4,800	124	400	3,476	800	700	3,300	800
H=6.00m	mm	4,000	106	400	2,894	600	600	2,800	700
H=5.00m	mm	3,400	88	350	2,362	600	500	2,300	600
H=4.00m	mm	2,800	70	350	1,980	400	500	1,900	500

Source: JICA Study Team

**Figure 4.7.5 Typical Structural Detail for T-Shaped Retaining Wall**



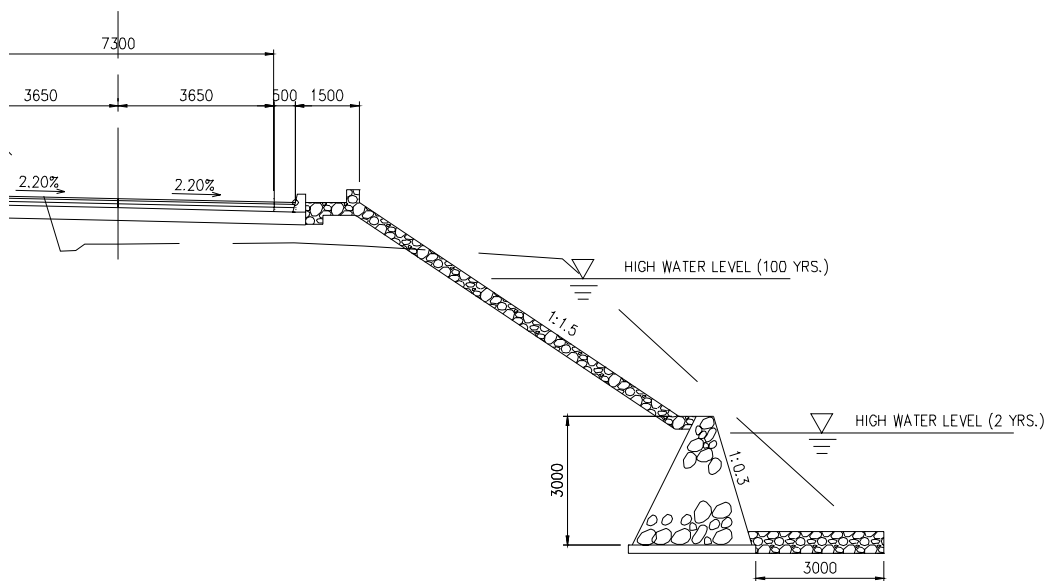
Stone Masonry (Leaning)	Unit	L
H=5.00m	mm	5,590
H=4.50m	mm	5,031
H=4.00m	mm	4,473
H=3.50m	mm	3,913
H=3.00m	mm	3,354

Source: JICA Study Team

**Figure 4.7.6 Typical Structural Detail for Stone Masonry (Leaning)**

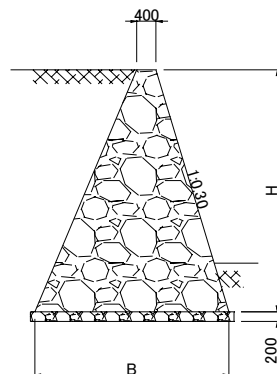
### (3) Bank Protection Wall along the Project Road

The typical cross section for river bank protection is shown in the following figure. For protection against scouring and/or suction, gabion blocks are provided as foot protection.



Source: JICA Study Team

**Figure 4.7.7 Typical Section for River Bank Protection**



Stone Masonry (Gravity)	Unit	B
H=5.00m	mm	4,000
H=4.00m	mm	3,250
H=3.00m	mm	2,400

Source: JICA Study Team

**Figure 4.7.8 Typical Structural Detail for Stone Masonry (Gravity)**

## 4.8 Traffic Safety Facility

Traffic safety facility is designed and planned to be installed at appropriate locations along the Project road.

### 4.8.1 Traffic Signs

Three types of traffic sign are designed in accordance with the NHA standard, “Typical & General Drawings (Highways)”: warning sign, regulatory sign and information sign. Although the detailed design of traffic signs are shown in the Bid Drawings, the design should be finalized after discussion with the executing agency.

#### (1) Warning Sign

Warning signs make drivers aware of any objects or dangers. The warning signs to be installed include Left Reverse Curve Sign, Right Reverse Curve, Bridge, Pedestrian Crossing, Minor Road Crossing at Left Side, Cross Roads, Minor Road Crossing at Right side, Lateral Shift Marker.

#### (2) Regulatory Sign

Regulatory signs inform drivers of traffic regulations to be followed. The regulatory signs designed for this project include speed regulation signs for 30 km/hr, 40 km/hr and 50 km/hr.

#### (3) Information Sign

Information signs lead the drivers to locations and directions of destinations. Information signs are planned to be installed at every major intersection.

#### **4.8.2 Road Marking**

Road marking is designed following the NHA standard, “Typical & General Drawings (Highways)”. The detailed design is shown in the Bid Drawings. The following road markings are designed for this project.

- Lane Marking: Center Line Marking, Edge Line Marking
- Arrow Marking for major intersections
- Zebra Marking for major intersections (for smooth traffic flow)
- Pedestrian Crossing

#### **4.8.3 Guardrails**

Guardrails are designed before and after bridges and box culvert following the NHA standard, “Typical & General Drawings (Highways)”. The detailed design is shown in the Bid Drawings.

#### **4.8.4 Kilometer Posts**

Kilometer posts need to be installed at every 1 km as per the NHA standard, “Typical & General Drawings (Highways)”. The detailed design is shown in the Bid Drawings.

#### **4.8.5 Lighting**

Lighting is designed on Naluchi Bridge and its approach road. The detailed design is shown in the Bid Drawings.