2.4 ROAD DESIGN CRITERIA AND METHOD

2.4.1 Right of Way

The road design will be carried out with Right of Way (ROW) width and land acquisition width as shown below:

- The right of way width will be 50m.
- The boundary of land acquisition is 15m or the width adding 3m clearance on the construction width for both sides from the road centreline

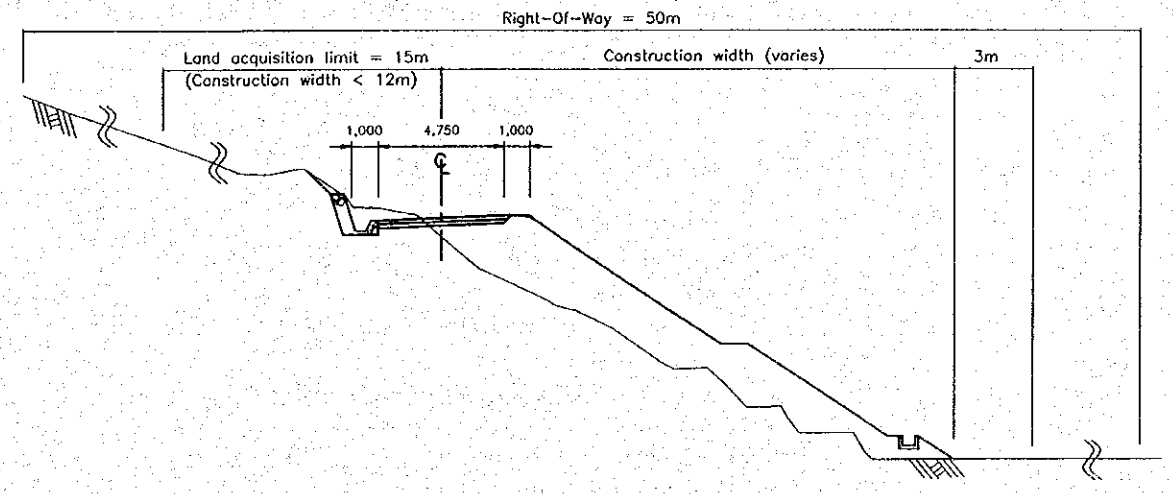


Figure 2.4.1 Right of Way and Land Acquisition Boundary

2.4.2 Road Design

(1) Design Criteria

The following design criteria based on the National Road Standards (NRS) No. 2027, Classification and Design Standards for Feeder Roads (Second Revision), February 1994 and Japan Road Standard (JRS) will be adopted in the Section II Road design.

Right of way	:	50m
Design speed	:	20kmph
Formation width	:	4.75 m (Exceptional 4.00m)
Cross-fall	:	4%(Gravel), 2.5%(Double surface treatment)
Minimum curvature	:	15m
Widening on curves	:	To be widened by adequate width for semi-trailer
Minimum vertical curve radius	:	300m
Maximum grade	:	10%
Limit length of the maximum grade	:	300m (Recover section (4%, 150m) will be followed)

Interval of passing place : To be constructed by adequate interval according to the site conditions

The section from end point of the Section I to the downtown of Sindhuli Bazar, about 2.5km length, will be constructed by dual lane.

(2) Super-elevation

The normal road cross section has camber slope always towards mountainside for full width of road (4 % for gravel surface and 2.5% for DBST). The road sections where the curvature is less than 25m will have appropriate super-elevation as shown in Table 2.4.1. For curvature with radius less than 25m, the following relationship is used to calculate the value of super-elevation.

$$R_{min} = \frac{V^2}{127(e+f)}$$

where, R = radius of horizontal curvature (m)
V = design speed (20 km/hr)
e = super-elevation
f = side frictional factor (0.15)

Table 2.4.1 Radius and Super-elevation

Radius (m)	Super-elevation	remarks
>25m	4.0 % towards mountain side	
20m	4 %	
15m	6 %	6 % (max)

(3) Widening on Horizontal Curve

The geometry of road will be designed and widened with consideration that semi-trailer can possibly pass through the road with minimum requirements. Widening on curve will be done on inner side of the curve. Japan Road Standards (JRS) recommends the following expression for calculating extra widening of roadway width on horizontal curvature for semi-trailer,

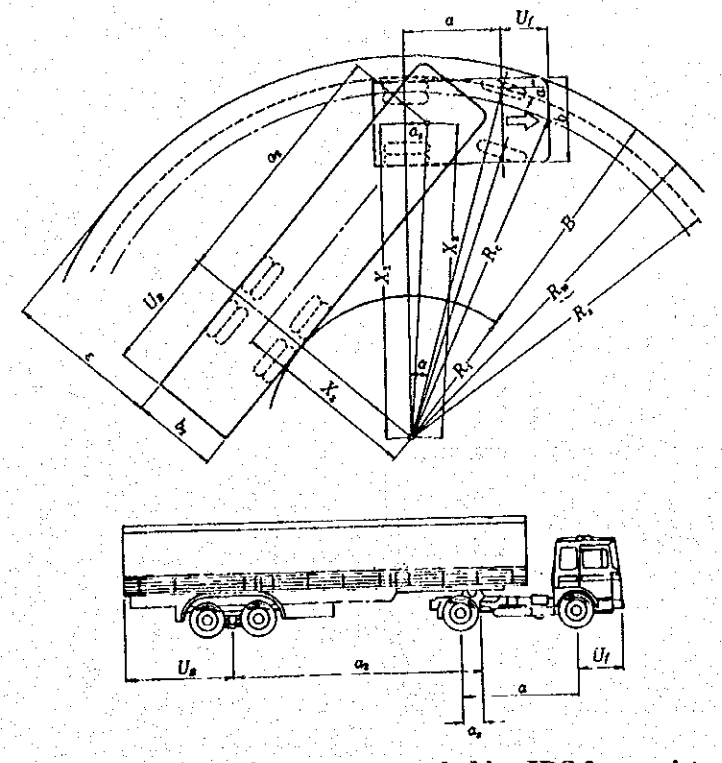


Figure 2.4.2 Dimensions recommended by JRS for semi-trailer

$$B = R_w + \frac{b}{2} - \sqrt{R_c^2 - \left(a + U_f\right)^2 - a_2^2 + a_s^2}$$

$$R_w = \sqrt{\left(\sqrt{R_c^2 - \left(a + U_f\right)^2} + \frac{b}{2}\right)^2 + \left(a + U_f\right)^2}$$

The dimensions recommended by JRS for semi-trailer are,

a	=	4.0m
b	=	2.5m
U_f	=	1.3m
a_2	=	9.0m
a_s	=	0m

$$\therefore\ B = R_w + 1.25 - \sqrt{R_c^2 - 109.09}$$

and, $$R_w = \sqrt{\left(\sqrt{R_c^2 - 28.09} + 1.25\right)^2 + 28.09}$$

JRS normally considers a road width of 3.5m whereas, the total road width on normal tangent section is 4.75m for the Project road. Hence a balance of 0.625m (2.375-1.75) is added in the radius of curve to use those relationships.

For radius of 30m,

R_c	=	30 + 0.625 = 30.625m
R_w	=	31.86m

B = 4.32m

In addition to this, 0.5m on inner side of vehicle is given for lateral clearance. Thus, total width required: 4.32 + 0.5 = 4.82m

For radius of 25m,

R_c = 25.625m
R_w = 26.85m
B = 4.70m
Total width required = 4.70 + 0.50 = 5.20m

Minimum of 0.5m will be widened.

For radius of 20 m,

R_c = 20625m
R_w = 21.84m
B = 5.31m
Total width required = 5.31 + 0.50 = 5.81m

Minimum of 0.5m will be widened.

For radius of 15m,

R_c = 15.625m
R_w = 16.81 m
B = 6.44 m
Total width required = 6.44 + 0.50 = 6.94m

The extra widening on the inner side of the curvature of radius 25m, 20m and 15m are shown in Table 2.4.2.

Table 2.4.2 Widening on Curve

Radius of Curve (m)	Widening (m)
30	0.00
25	0.50
20	1.00
15	2.25

Widening on horizontal curves are introduced as shown in Figure 2.4.3 in conformity to JRS. Widening has been provided only for the inside of the curve.

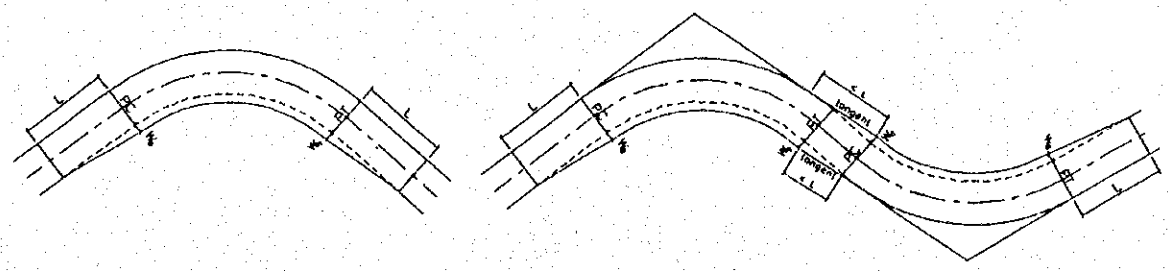


Figure 2.4.3 Attaining Widening

where ; L = We x n (n = 10 for Design Speed 20kmph)

The attaining of super-elevation is as shown in Figure 2.4.4 for various cases.

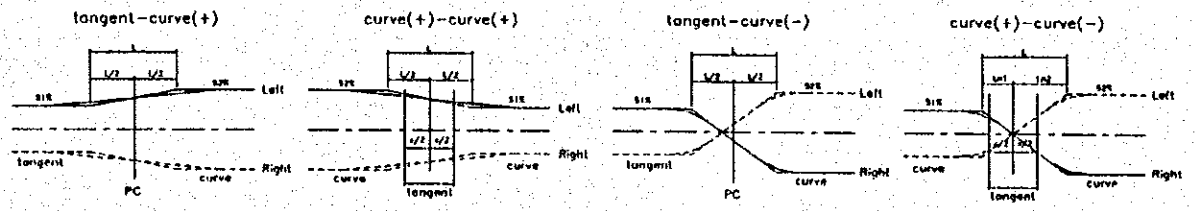


Figure 2.4.4 Attaining Super-elevation

where ; L = 0.01 (S2 - S1) x n x roadway width (n = 50 for Design Speed 20kmph)

(4) Sight Distance

Basically, the alignment design will be done to secure the sight distance of 40m as single lane road with design speed of 20kmph. However, in case it is difficalt to keep the sight distance of 40m by severe geographical and topographical conditions, the sight distance of 20m as minimum will be applied with provision of the double traffic warning signs at both sides of curvature.

(5) Hairpin Curve

The vertical alignment at hairpin bend sections applied minimum radius of 15m will be designed as less than 5% excepting exceptional cases.

2.4.3 Earthworks

Cut and embankment slopes will be selected from the following table according to the Earthworks Manual, Japan Road Association.

[Cut slope]

		Range
Rock		1:0.3 – 1:0.8
Soft Rock		1:0.5 – 1:1.2
Sandy Soil	Dense	1:0.8 – 1:1.0
	Loose	1:1.0 – 1:1.2
Gravel, Soil	Dense	1:0.8 – 1:1.0
	Loose	1:1.0 – 1:1.2

[Embankment slope]

	Height	Range
Good grading sand, Gravel	<5 m	1:1.5 – 1:1.8
Poor grading sand	5 – 15 m	1:1.8 – 1:2.0
Poor grading sand	<10 m	1:1.8 – 1:2.0
Crushed Rock	<10 m	1:1.5 – 1:1.8
	10 – 20 m	1:1.8 – 1:2.0
Sandy Soil	<5 m	1:1.5 – 1:1.8
	5 – 10 m	1:1.8 – 1:2.0

2.4.4 Revegetation Works

(1) Natural Conditions

a) Topography and land use

The road alignment of the Section II is located in mountainous region of Mahabharat Range with total length of 40 km. The road connects Sindhuli Bazar (Elevation; 500m) and Khurkot (Elevation; 500m) passing though Sindhuli Gadhi (Elevation; 1350m) which is the highest elevation. The average grade of natural slope along the alignment is 28 degree and the maximum is 57 degree

The land use along the route can be divided into four types, i.e., residential areas, cultivated lands, shrub areas and wastelands, and forest areas. About thirty percent of the road alignment pass through forest areas and about forty percent of it go though cultivated areas.

b) Vegetation along the route

Vegetation around cultivated areas consists of grass. On shrub areas and wastelands grass and shrubs are mixed. Forest areas are classified into four types, which are Sal, Chilaune, Uttis and Rani Salla forests.

(2) Slope Conditions

a) Height and gradient

The cross-sectional feature of the road are formed depending on the conditions

of natural slope and geology as shown in Figure 2.4.5. The height and gradient of slopes to be done in revegetation works are as follows.

Classification	Height	Slope gradient
Filling slope	Below 15m	1: 1.5 – 1: 1.8
Cutting slope	Below 15m	1: 0.3 – 1: 1.2

Along the alignment, 38 hairpin curves are planned. In the zigzag sections which have continuos hairpin curve and reform the natural slope to stairs, the road construction works will fell existing vegetation widely and establish the large scale of cutting and embankment slopes.

b) Geology

Geology along the route consists of terrace sediment, alluvial corn, river sediment, sand stone of Middle Shiwalik layer of the Miocene to Pleistocene, pelitic schist and calcareous schist of Nuwakot group of Paleozoic to Pre-Cambrian and granitic schist, gneiss, psamitic schist and pelitic schist of Bimpedy group of Pre-Cambrian.

Table 2.4.3 shows the condition of cutting slopes and slope grade range to be applied.

In the geology of cut slope as listed above, hardly weathered granitic schist and hardly weathered gneiss have an erosive character. Therefore, it is necessary to take measures against erosion properly taking into consideration of the slope scale and the magnitude of affect for the upper natural slope.

c) Climate

At Sindhuli Gadhi Station, which is the highest point of the route, the annual average maximum temperature is 28.3℃ and the minimum is 16℃. The monthly average temperature is above 0℃. Annual average rainfall depth is 2320mm. The monthly average rainfall depth is above 100mm in May to October. The monthly average rainfall depth is 25 in dry season (from November to April) and 360mm in rainy season (from May to October).

The intensity of rainfall in one hour duration is calculated at about 140mm/hr for five years return period. It is presumed about 300mm/hr rainfall will be suffered in a short time in the area.

Therefore, in revegetation works, it is necessary to consider these conditions on selection of the type of plant, the foundation structure for planting and the revegetation method.

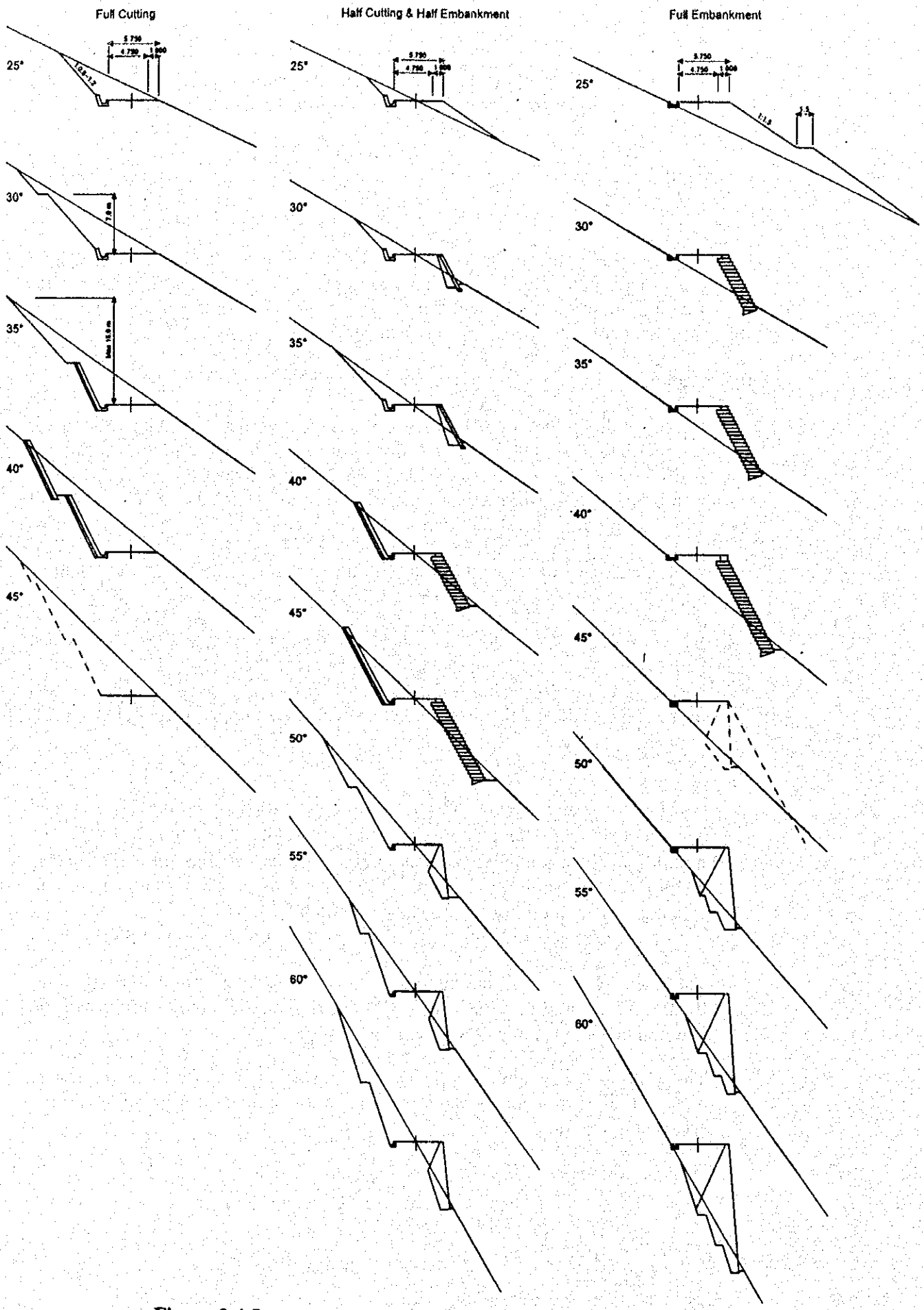


Figure 2.4.5 Natural Slope Gradients and Road Cross Sections

Table 2.4.3 Geological Condition and Slope Grade Range

Type	Geology of slope	Adopted slope grade	Remarks
A	Alluvial fan talus and colluvial deposit	1:0.8 – 1:1.2	There is a possibility of trouble on cut slope treatment due to the existence of big boulder.
B	Conglomerate	1:0.5 – 1:0.8	
C	Sandstone	1:0.5 – 1:0.8	
D	Hardly weathered granitic schist	1:0.8 – 1:1.0	This type of soil has to be taken care against erosion.
E	Weathered and joint developed granitic schist	1:0.5 – 1:0.8	In case of possible rock falling, appropriate countermeasures will be installed. There is a possibility of trouble on cut slope treatment due to existence of big boulder.
F	Granitic schist	1:0.3 – 1:0.5	
G	Weathered and joint developed pelitic schist and calcareous schist	1:0.5 – 1:0.8	In case of possible rock falling, appropriate countermeasures will be installed.
H	Pelitic schist and calcareous schist	1: 0.3 – 1: 0.5	
I	Hardly weathered gneiss	1: 0.8 – 1: 1.0	
J	Weathered and join developed gneiss	1: 0.5 – 1: 0.8	In case of possible rock falling, appropriate countermeasures will be installed.
K	Gneiss	1: 0.3 – 1: 0.5	
L	Terrace deposit	1: 0.8 – 1: 1.2	There is a possibility of trouble on cut slope treatment due to existence of big boulder.
M	General earth and sand else	1: 0.8 – 1: 1.2	

(3) The Policy on Introducing Revegetation Works

a) The objectives of revegetation

It is the primary objective to protect surface of slope from erosion in view of maintaining the Sindhuli Road, security of users and prevention against disasters.

Presently in Nepal, preservation and maintenance of forest is a urgent theme because area of forest has decreased to 29% (1998) of country area. On the other hand, the road alignment pass through the area of which has plentiful nature as about 30% of area along the route are forest area. Therefore, it is the second objective to preserve the natural environment and to improve the landscape.

b) Policy on making targets for final feature of revegetation

The final feature of revegetation has to harmonize with surrounding circumstances and the process to the target should be sustainable. Therefore, the final feature of the revegetation has to be determined in accordance with the surrounding environment and the conditions of sites especially slope grade

on which plants are grown up.

[Revegetation and surrounding environment]

The surrounding environment along the alignment differ by land use and it is classified as follows. The planting target is instituted by land use.

- City area
- Cultivated area
- Shrub and waste area
- Special area

The special area is the area on which require special consideration for maintaining slopes and to be adopted reliable revegetation method.

- The areas of that magnitude runs the risk to suffer from slope failures is high and the failure can cause serious and extensive damage on the road due to the broad destruction on existing vegetation, heavy cutting and establishment of the large scale artificial slopes by road construction and concentration of road like zigzag section.

- The area of the slope failure caused by erosion will seriously extend to the destruction of upper natural slope because of soil characteristic eroding rapidly like hardly weathered granitic schist.

On the stable rock cut slope, revegetation is not done expecting the natural phenomena which is a common metod in Nepal.

[Slope grade and possible revegetation type]

As the vegetation type on cut slope, the forest type of revegetation should be selected taking into consideration the ecological preservation , disaster prevention and landscape and in view of reducing the maintenance cost by function and life of trees. The tree type of revegetation will be classified into two types, i.e., tree type and shrub type.

In the revegetation plan for the Section II, the target of revegetation on each slopes are instituted, referring the following guidelines.

Gradient	Types of Revegetation			Remarks
	Tree type	Shrub type	Grass type	
More gentle than 1: 1.4	Applicable	Applicable	Applicable	This grade is critical grade that is possible to grow the plant community on naked slope naturally.
1: 1.4 - 1: 1.0	Applicable	Applicable	Applicable	This grade is critical grade that is possible to introduce trees by planting method.
1: 1.0 - 1: 0.6	Requiring examination	Applicable	Applicable	The target introducing of the shrub and grass community is recommendable.
More steep than 1: 0.6	Requiring examination	Applicable	Inapplicable	It is recommendable to introduce shrubs expecting penetration of roots into the joint of rock.

The source: Yamadera, Anbo and Yoshida, '93, "Design for Green to Rebirth Natural Environment" (a part of them is revised)

c) The policy on selection of plants

The kind of plants will be selected based on the policies as follows:

- To select from native species of plants in view of environment.

- To select the plants suitable to target of revegetation.

- To select plural suitable plants so as to avoid simple target plant community.

The plant community consisting of simple composition is extremely weak against environmental pressure such as wind, rain, landslide, undernourishment, damage by blight and insects, and it is difficult to sustain under bad condition. The standard composition of target plant community is shown as follows.

[The standard composition of target plant community]

Classification	Purpose to use
Main plants	It is main plants in the target community.
Supporting plants	It prepares the suitable conditions for growth of the main plants.
Grasses	It prevents erosion of surface soil especially in initial stage.

d) The policy on selection of planting method

The locally available methods have to be selected primarily taking into account the easy repair in maintenance stage. The selection of revegetation method for the special areas will be given special consideration for establishing stable vegetation quickly and extensively.

(4) Target of Revegetation

The planting target for the areas classified by land use along the route is initiated considering condition of the slope grade as shown in Table 2.4.4.

Table 2.4.4 Classified Areas and Revegetation Target

Classification	Revegetation Target
City area	To establish plant community consisting of grasses with shrubs expecting assimilating surrounding environment without care selecting suitable kind of plants for the slope grade and geology on sites.
Cultivated area	To establish plant community consisting of grasses with shrubs expecting assimilating surrounding environment without care selecting suitable kind of plants for the slope grade and geology on sites.
Shrub and waste area	To establish plant community consisting of grasses with trees and shrubs expecting assimilating surrounding environment without care selecting suitable kind plants for the slope grade and geology on sites.
Forest area	To establish plant community consisting of trees, shrubs and grasses almost same as the surrounding revegetation within several year without care selecting suitable kind plants for the slope grade and geology on sites.
Special area	To establish plant community consisting of trees, shrubs and grasses to prevent erosion and restoration of forest within few year without care expecting assimilating surrounding environment in future.

(5) Selection of plants

The native plants are adopted for revegetation to assimilate surrounding environment. The plants recommended in Bio-Engineering Information, Second edition, Department of Roads, December 1997, as suitable plants for slope for altitude of between 500m and 1500 will be used considering the availability along the route.

(6) Revegetation Method

[Revegetation technique in Nepal]

a) Planting technique of DOR

The revegetation technique has been introduced from Dharan - Dhankuta road construction implemented under British Aid. The Jiri road construction project under Swiss Aid also used the technique. Then it is transferred to Geo-Environmental Unit of DOR. The technique is summarized in Bio-Engineering Information, Second edition, December 1997, which consists the standard production rate, standard specification, list for adopted plants and outline of supervision. Nepal's major revegetation method are listed in Table 2.4.5

The revegetation technique in Nepal aims at (i) concentrating manpower, (ii) self-subsistence in the field (iii) low cost. The effect of the technique is

recognized by the present situation of the Dharan - Dhankuta road and the Jiri road, of which slopes are covered with plenty of plants and excellent forest at roadside.

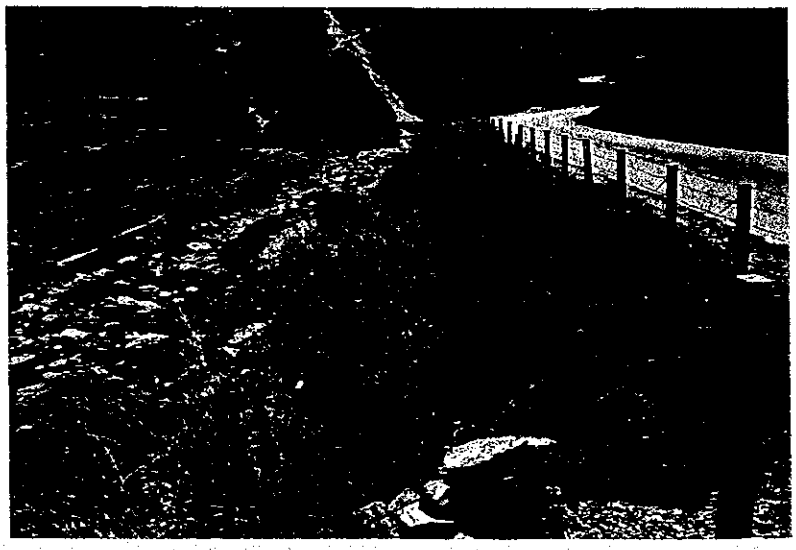
Now Nepal's revegetation method is spreading in road construction and maintenance project, and the reason of it's effectiveness is stability of slope and low cost.

Nepal's revegetation techniques will also be applied in the Sindhuli road project in the following manner.

[The application standard of planting techniques in Nepal]

- To apply on the stable slopes.
- To apply on the stabilized slopes by appropriate slope protection measures.

Photograph 2.4.1 Vegetation in Jiri Road



Photograph 2.4.1 Vegetation in Kodari Road

Table 2.4.5 Nepal's Revegetation Method

Description	Method name	contents	application
Revegetation works	Direct seeding on site	Direct seeding. Cover with a layer of mulch or mulch with jute net also to be used. Tree seeds will be pushed into a small dug hole.	It may take a long time to get an erosion prevention effect. So this method should be applied to the site stable to the erosion or with other supporting method.
	Planting grass cutting on site	Planting root cut plant in lines on the slope. Lines can be configured in contour line, down slope line diagonal line, etc.	Effective for stabilizing slope from the erosion. Apply to filling and cut slope with suitable soil for vegetation. Low possibility in success when applied on the hard and less fertile soil.
	Planting shrub and tree seedlings and cuttings on site.	Planting shrub and tree seedlings and cuttings. Including auxiliary works such as mulching.	Effective for stabilizing slope from the erosion. Apply to filling and cut slope with suitable soil for revegetation. Usually, used with other grass planting method. Low possibility in success when applied to the hard and less fertile soil.
Foundation for vegetation	Brush layering, palisades and fascines	Same as Japanese weave fence method. Set on the slope like stair to prevent from flowing of surface water and moving of surface soil by a strong wind and supporting the plant by keeping soil.	Set up on relatively moderate slope of detritus, etc. as a foundation for planting
	Jute netting works	Cover the slope with jute net. Using one of the foundation for planting.	Set up on relatively steep cut slope. Less effective than mulch mat for erosion.
	Gabion wire bolsters	Set gabions (about 30cm diameter) in strip.	Set up on relatively moderate slope of detritus, etc. in strip as a foundation for planting

b) Revegetation works in the Section I and the Section IV Project

The Sindhuli Road Section I Project area coveres Siwalik layer which is easily affected by erosion. Hence, slope-protection by crib work was used on the cut slope basically, and shot soil work will also be applied on some parts of the cut slope. Grass strips work and plant grass cutting and tree seedling that are Nepalese technique will be used for filling slopes.

In the Section IV site, straw mat mulching method and stepped sodding method were used to cut slope experimentally, and Grass strips work used to filling slope.

The revegetation methods used in the Projects Section I and IV are summarized in Table 2.4.6.

Table 2.4.6 The Revegetation Methods used in the Projects Section I and IV

Description	Method name	Contents/Effect	Application
	Grass striping	Plant about 50cm width sod with 50cm vertical interval or whole place. After planting, its roots grow into earth in a few days, and become effective for against the surface erosion.	Apply to filling slope that is easily be affected by erosion.
	Sodding with straw mat	Scattering seeds and fertilizer on the slope and cover by straw mat.	Tested during Lot-4 constructing. It can be observed that this method effected to the spillage of fertilizer.
	Stepped sodding	Make 10cm wide steps with 50cm high interval on the face of cut slope that cut in designated incline, and plant cut lawn on each step.	Effective on preventing from surface erosion. However, since the work accelerating weathering, careful selection is require considering the soil condition of slope.
	Shot soiling	All construction equipment and material has to be import from Japan basically.	Effective on preventing the slope from erosion. The growing speed of trees on slope is fast. Though it is expensive, it is possible to reduce the cost if materials can be localized.
Foundation for planting	Crib work	To make the pre-cast crib utilized in Japan on site. Filled in the frame by grass cutting shrub, cobble and masonry. Adopted to cut and filling slope.	Effective on preventing the slope from erosion. Construction work will be complicated.

Selection of revegetation method is as shown in Table 2.4.7, which has been prepared for the purpose of this study in consideration of Nepalese common planting technique, experiences at the Projects Section I and IV, the selecting procedures prescribed in Bio-Engineering Information; Second Edition, December 1997 and the available selecting procedures in Japan.

In the zigzag sections classified as the special area, the construction activities will widely destruct forest and make large scale of naked artificial slopes. Taking into consideration of the importance to reserve the forest in Nepal and location of the Section II site, where it is heavy rainfall affected area, the special slope stabilization measures, to restore the forest and to prevent acceleration and expansion of slope failure triggered by naked heavy cut slopes, have to be considered in the zigzag sections. In this line, application of high-grade revegetation method such as the shot soiling method is

recommendable in accordance with the past actual result. Therefore, the shot soiling method will be selected as the revegetation method for the special area.

Table 2.4.7 Slope Conditions and Revegetation Method

Type of slope		Fill slope	Cut slope					
			Common soil		Un-rock			Hard rock
Conditions of slope		Easy to be eroded	Stable to an erosion hardness: 27 or less	Easy to be eroded	Easy to be eroded and weathered	Stable to an erosion and weathering		Stable rock or keeped stable slope
		B1,B2	C1	C2	C3	C4	C5	C6
Geology		Depends on filling material	L M	A D	E I	B C	E G J	F H K
Slope incline		1:1.5 to 1:1.8	1:1.0 to 1:1.2	1:1.0 to 1:1.2	1:0.5 to 1:1.0	1:0.5 to 1:0.8	1:0.3 to 1:0.8	1:0.3 to 1:0.8
	Direct seeding	●	●	●				
	Planting grass cutting			●	◎ (*1)	◎		
	Planting shrub and tree seedlings and cuttings	●	●	●				
	Brush layering, palisades and fascines							
	Lawn planting	◎						
	straw mat mulching		◎					
	Stepped sodding							
	Shot soiling(*2)			◎	◎			
	Jute netting							
	Gabion wire bolsters							
	Slope frame		◎(*2)	◎	◎	◎		
	Concrete spreading						◎ (*3)	
	Earth reinforcing						◎	
	Untreated							◎

adopted ◎ use as supporting

(*1) adopted in case of the height of the slope is 5m or less

(*2) choose at special considerable section

(*3) adopted with earth reinforcing work

(7) Timen of Revegetation Work

The revegetation work will be done in the following season as instructed in Bio-Engineering Information, Second edition, December 1997.

Method	Timing
Direct seeding	May – June
Tree seedling	June - July

(8) Revegetation management

One year of revegetation management after the completion of construction works is very important. So that, following measures will be considered in order to keep away from mowing by villagers, eating of cows and sheep, and burning the undergrowth.

a) One year of watching by a guard after a seedling.
b) Construction of barbed wire fence.

2.4.5 Pavement Works

Gravel pavement will be applied in principle, however, surface treatment or other types of pavements will be applied to the specific sections such as steep section.

At hairpin bend sections applied minimum radius of 15m,concrete pavement of 25cm thickness will be applied to avoid the waving of the road surface.

2.4.6 Cross Drain and Side Ditch

(1) Side Ditch

According to the recommendation of "Road Safety Note 2, Designing Safe Side Drains, Traffic Engineering and Safety Unit, Design Branch, Department of Roads, November 1996", side ditches will be designed 45 cm or shallower in depth and bottom width more than 40 cm for the traffic safety.

(2) Cross Drain

Minimum diameter size of cross drainpipe will be 60cm following the design guideline in Classification and Design Standards for Feeder Road (Second Revision), 1994, DOR excepting the drainpipes for agricultural purpose.

In case of the lightweight drainage, structures are required from the view of construction planning, application of corrugated pipes will be considered.

(3) Channel Works

The existing channels crossing the route many times at a zigzag section, and/or its bed soil condition is in danger for erosion at the outlet of discharge will be protected appropriately.

(4) Runoff Calculation

Runoff calculation is carried out for estimation of runoff peak discharge as design value for side ditch, cross drain, causeway, and bridge. The rational formula as given below is applied for runoff calculation.

$$Q = 1/3.6 \times C \times I \times A$$

where,

Q : peak discharge (m^3/sec)
C : runoff coefficient
I : rainfall intensity (mm/hour)
A : catchment area (km^2)

The magnitude of design discharge is given by type of structure as shown in Table 2.4.8.

Table 2.4.8 Magnitude of Design Discharge by Type of Structure

Type of Structure	Return Period (years)
Side Ditch	3
Cross Drain (Culvert)	5
Causeway	50
Bridge	50

According to Road Earthworks and Drainage Design Guideline, JRA, Runoff coefficient of 0.8 and 0.4 are applied for cross drain and side ditch respectively since the catchment areas are mostly located in the steep mountains and considering the importance of the structures. Rainfall intensity is obtained from IDF equations discussed above. Runoff concentration time (equivalent to duration of design rainfall) is calculated as follows.

$$T = T_1 + T_2$$
$$T_1 = 1.445 \times (n \times L / S^{0.5})^{0.467}$$
$$T_2 = 60 \times L / V$$

where,

T : runoff concentration time (minutes)
T_1 : overland flow time (minutes)
T_2 : channel flow time (minutes)
n : Kerby's coefficient of roughness (=0.2)
L : stream length (m)
S : slope
V : flow velocity (m/sec)

According to the recommendation of "Road Safety Note 2, Designing Safe Side Drains, Traffic Engineering and Safety Unit, Design Branch, Department of Roads,

November 1996", side ditches will be designed 45 cm or shallower in depth and bottom width more than 40 cm for the traffic safety.

Minimum diameter size of cross drainpipe will be 60cm following the design guideline in Classification and Design Standards for Feeder Road (Second Revision), 1994, DOR excepting the drainpipes for agricultural purpose.

In case of the lightweight drainage structures are required from the view of construction planning, application of corrugated pipes will be considered.

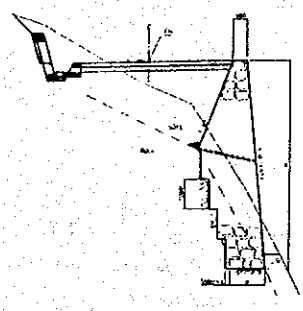
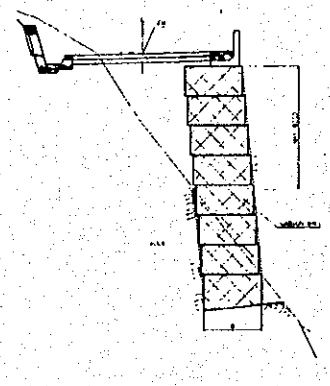
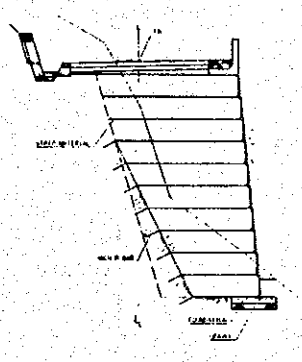
2.4.7 Existing Irrigation Channel Diversion

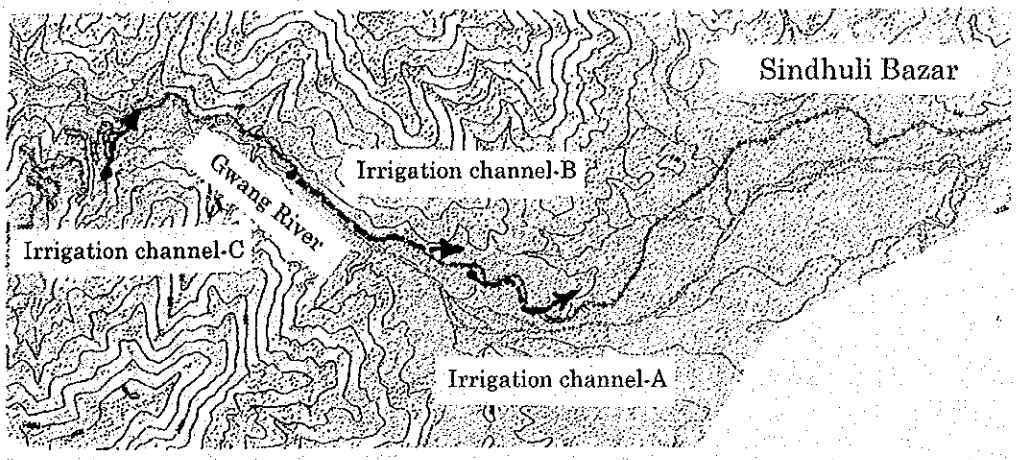
Irrigation channels located along the alignment and distorted by the road construction will be replaced. The locations and typical relocation plan are shown in Figure 2.4.6.

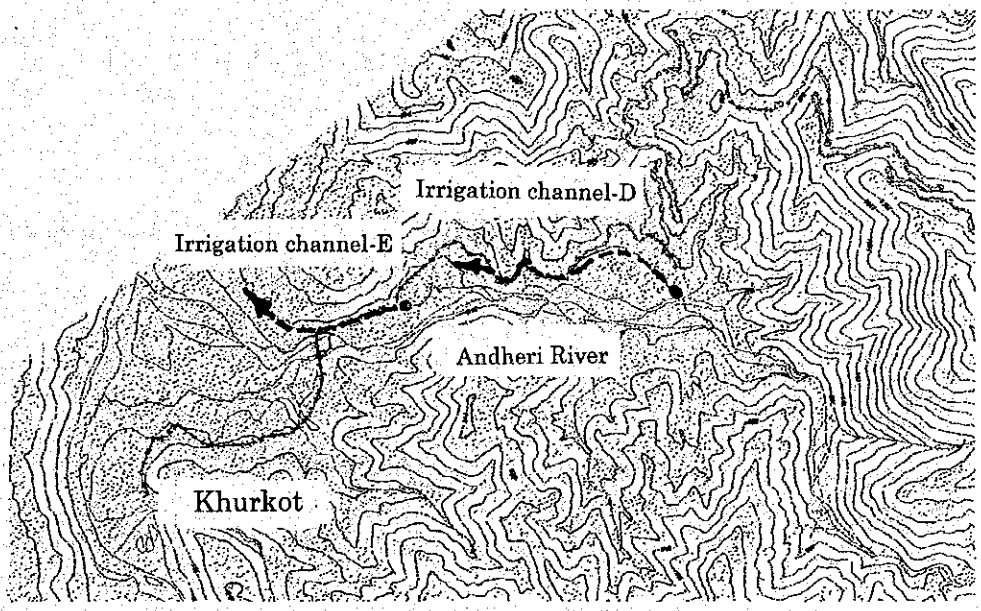
2.4.8 Retaining Wall

The retaining walls using locally available materials and techniques such as gabion and masonry will be adopted in the design mainly. The sections where common types of walls are not applicable, special type of walls as shown in Table 2.4.9 will be adopted based on the site conditions.

Table 2.4.9 Walls to be applied on Steep Slope Section

	Gravity Wall with Replaced Concrete Foundation	Large Gabion Box Wall	Earth Reinforcement Wall
Typical Section			
Working conditions and Workability	- Prompt construction work - Flexible against change of the site conditions - Require concrete mixing place	- Prompt construction work - Flexible against change of the site conditions - Require boulder stock yard	- All material can be carry by man power. - Manual construction - Inflexible against change of the site conditions - Require careful quality control
Cost	15,000-20,000 (Japanese Yen/m2)	15,000-30,000 (Japanese Yen/m2)	25,000-40,000 (Japanese Yen/m2)
Site and Working conditions to be selected	Foundation: Weathered rock or hard rock Workability: Require easy concrete supply Maximum height: 8m	Foundation: Weathered rock or hard rock Workability: Require easy boulder supply Maximum height: 6m	Foundation: Hard rock with anchor Common-hard rock without anchor Workability: Require availability of selected back fill material Maximum height: Tentatively 13m





Location map of irrigation channel to be relocated

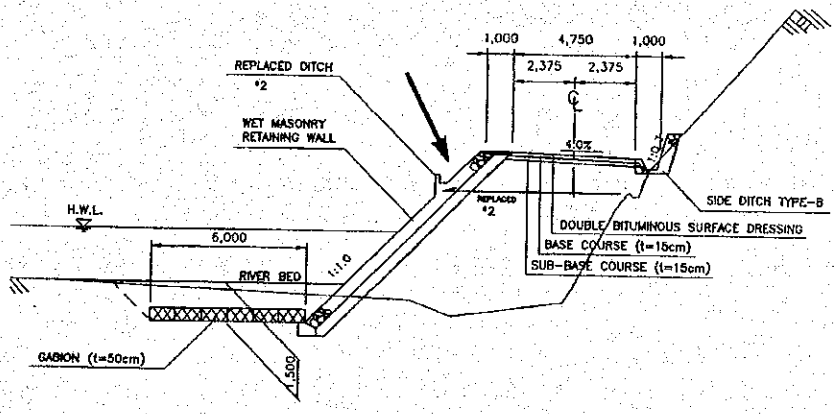


Figure 2.4.6 Location and Typical Relocation Plan of the Existing Irrigation Channel to be Relocated

2.4.9 Countermeasure for Landslide and Slope Failure

For the eight possible landslide and slope failure sections found along the alignment as shown in Figure 2.4.7, inhibition type of countermeasures will be planned at first and countermeasures types against landslides and slope failures will be planned second priority, if necessary. Detailed site conditions and concept on the road design are described below.

(1) Chiyabari Landslide Area

a) Landform and Geological Features

Chiyabari landslide area is located 400 meters north of the Gwang bridge site. It is near the toe of the ridge between Gwang river and rests on the left side tributary. The slope gradient of this portion is 30 to 40 degrees. The geological feature of the area is that it consists of sandstone and partially by mid Siriwaku conglomerate.

b) Magnitude of Landslide

This landslide is 100 meters in length and 40 meters in width. The thickness of landslide mass is estimated at about 8 meters.

c) Cause and Potential Activity of the Landslide

The right side tributary of Gwang river has an acute bend at the foot of this landslide. Debris collapsed from this landslide has deposited across the bend. The erosion of the river bank was caused by the rapid flow of water during the flooding period. Edges of top scarp of this semi-circular landslide is rounded and progression of dissection can be observed. Some gullies have developed into the interior of the landslide due to secondary failures at the toe of the landslide. From these findings, inference can be made that this landslide is old and not active. There is no evidence of landslide formation above this area.

d) Road Construction Issues

Flooding and heavy rain may cause failure at the toe of the landslide. Thus, it is important to plan the alignment and the formation of the road so as to stabilize the landslide and some countermeasures must be provided to prevent erosions at the toe of the landslide.

e) Countermeasure against Potential Landslides

The alignment was planned in the section as shown in Figure 2.4.8 adopting following design concepts.

- Slope cutting on the upper portion and embankment on the lower portion of landslide should be considered for earthworks. Surface drainage system will be installed on the landslide area.
- Countermeasures against river erosion and bank protection against scouring will be provided at the toe of the landslide along the Gwang river.

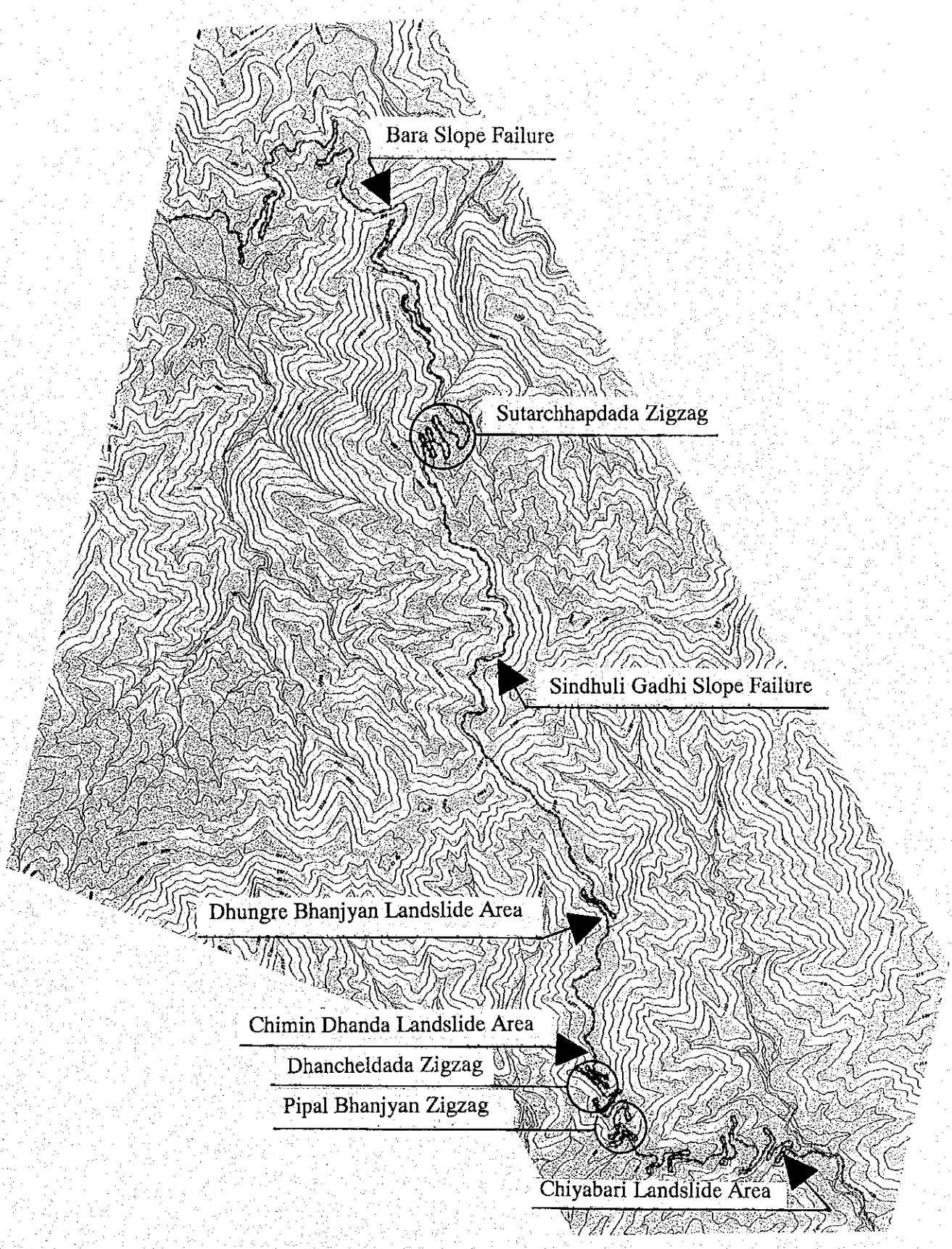


Figure 2.4.7 Location Map of Land Slides and Slope Failures to be considered in the Road Design

Photograph 2.4.5 Chiyabari Landslide Area

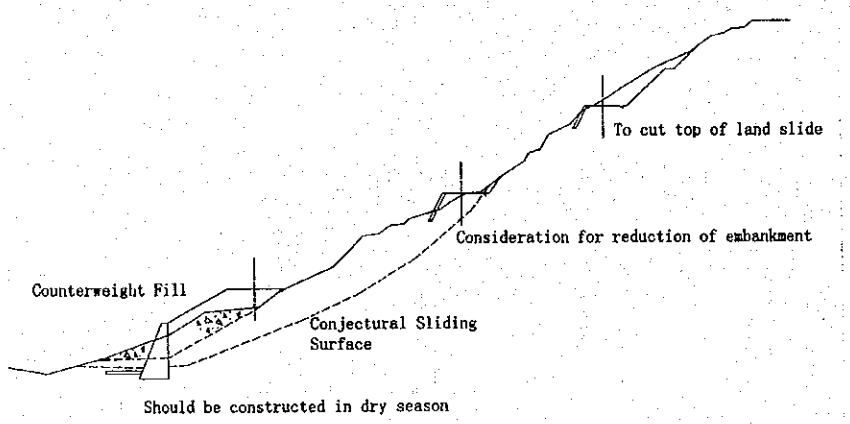


Figure 2.4.8 Road Plan on the Chiyabari Landslide

(2) Pipal Bhanjyan Zigzag

a) Landform and Geological Features

The landform of this area is syncline valley. Slope gradient is very steep, varying from 30 to 40 degrees. There are two landslide areas in this valley. Although one shows a clear landslide feature, the other is obscure. Pelitic schist, partially psamitic schist, is distributed in this valley. The Main Boundary Thrust (MBT) fault exists in the outlet of this valley.

b) Magnitude of Landslide

Magnitude of the landslide is 50 meters in length and 30 meters in width. Thickness of landslide layer is estimated at about 5 meters.

c) Potential Activity of the Landslide

The toe of the landslide is located above the riverbed and edges of the rounded top scarp of the landslide indicates that it is stable.

d) Road Construction Issues

The zigzag curved road is planned to climb the steep slopes of this valley. Since dormant landslides and MBT fault exist near this valley, careful earthwork plan is necessary to stabilize the slopes to prevent potential failures.

e) Countermeasure Policy against Potential Landslides

Since the valley is of limited size and narrow, high embankment with amount of about 190,000m3 in total will be constructed stable with adequate drainage system. The embankment will function as spoil bank as well as countermeasure for the slope failures in the area.

Photograph 2.4.6 Pipal Bhanjyan Zigzag

(3) Dhancheldada Zigzag

a) Landform and Geological Features

This area is located on the west of the moderate gradient ridge at the elevation of 1100m. The slope gradient is about 40 degrees. As a whole, the area is the remains of an old landslide where some long dormant landslide block is evident. Geologically, the slope consists of pelitic schist.

b) Magnitude of Landslide

Unstable soil mass from the collapsed landslide is approximately 200 meters in length and 40 meters in width.

c) Potential Activity of the Landslide

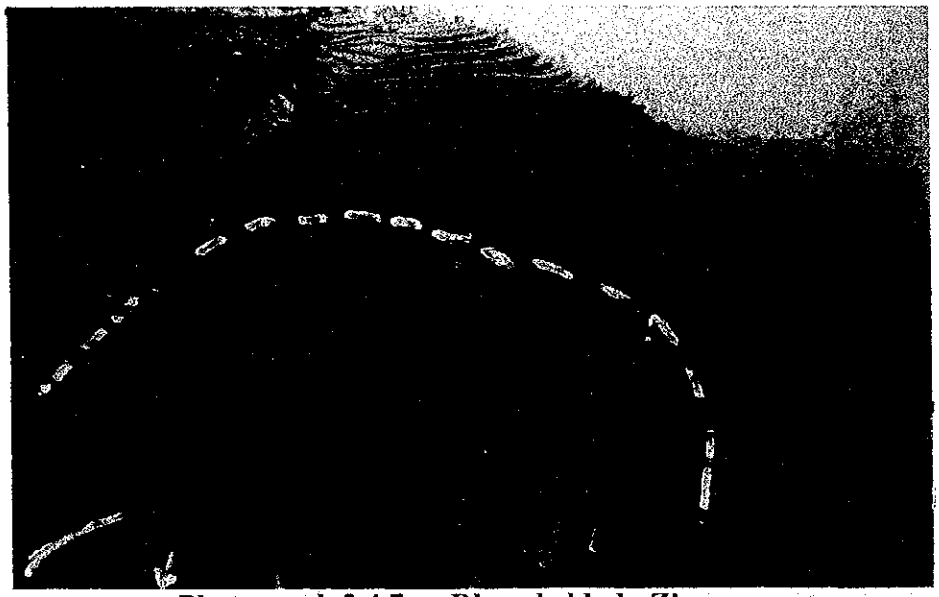
Traces of a huge landslide that occurred in the past is evident in this area. The top scarp of landslide is obscure. Since the slope gradient of the top scarp is equivalent to the slopes below, it can be inferred that the landslide is very old. Also it can be inferred that the existing landslide is composed of the remains of sliding mass. However, the site reconnaissance confirmed that currently there is no evidence of landslide activity.

d) Road Construction Issues

The road alignment is planned to pass through slopes having a 40 degrees gradient and where thin layer of landslide exists.

e) Countermeasure Policy against Potential Landslides

Road sections with balanced cut and fill features as shown in Figure2.4.9, and an adequate slope protection measures is required in this area. The road construction should commence from the upper portion of the slope in order to prevent reactivation of potential failures.



Photograph 2.4.7 Dhancheldada Zigzag

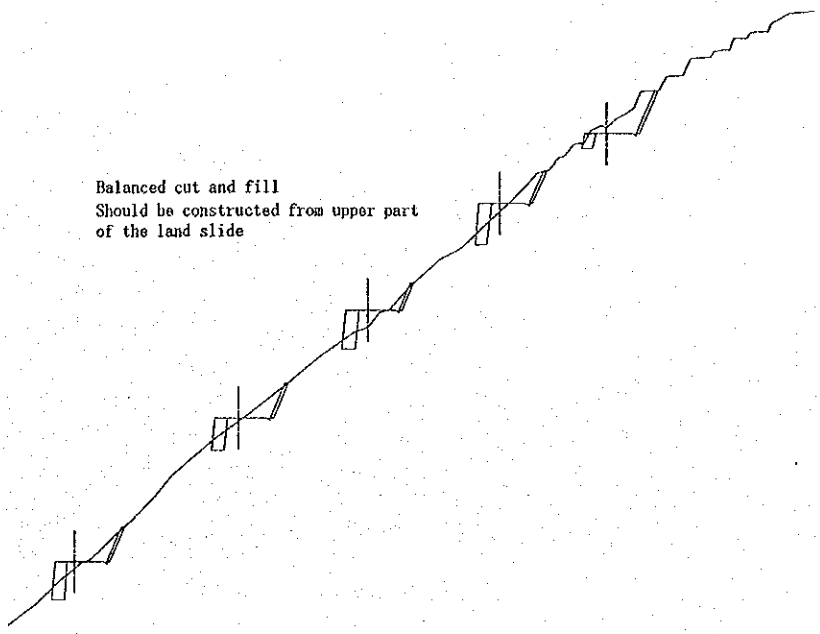


Figure 2.4.9 Road Plan in Dhancheldada Zigzag Section

(4) Chimin Dada Landslide Area

a) Landform and Geological Features

The landslide is located on the west ridge at an elevation of 1100m. The slope gradient is about 40 degrees. The landform feature of this area shows traces of a massive landslide. However, an active landslide exists in the interior portion of this massive landslide. Geologically, the landslide is composed of calcareous schist.

b) Magnitude of Landslide

The magnitude of the landslide is approximately 250 meters in length, 100 meters in width, and 20 meters thick. Mass volume of this landslide is estimated to be approximately 300,000m3.

c) Potential Activity of the Landslide

The landslide was caused by the heavy rain of July 1993 which eroded the foot of the slope, areas along the stream, and ravine failure down stream. Since the vegetation on top scarp of this landslide has not yet recovered and edges of the top scarp are still sharp, it can be inferred that this landslide is active.

d) Road Construction Issues

The road alignment will completely avoid this landslide.

Photograph 2.4.8 Chimin Dada Landslide Area

(5) Dhungre Bhanjyan Landslide Area

a) Landform and Geological Features

This landslide area is located on the north slope having a moderate gradient, and is at an elevation of 1200 meters. Slope gradient is 20 to 30 degrees. The area is composed of Pelitic Schist, Calcareous Schist, and Psamitic Schist.

b) Magnitude of Landslide

In this area, three dormant landslides exist. The magnitude of each are as follows:

i) Landslide A Length 200m, Width 100m, Estimated thickness 13m
ii) Landslide B Length 100m, Width 100m, Estimated thickness 13m
iii) Landslide C Length 80m, Width 50m, Estimated thickness 6m

c) Potential Activity of the Landslide

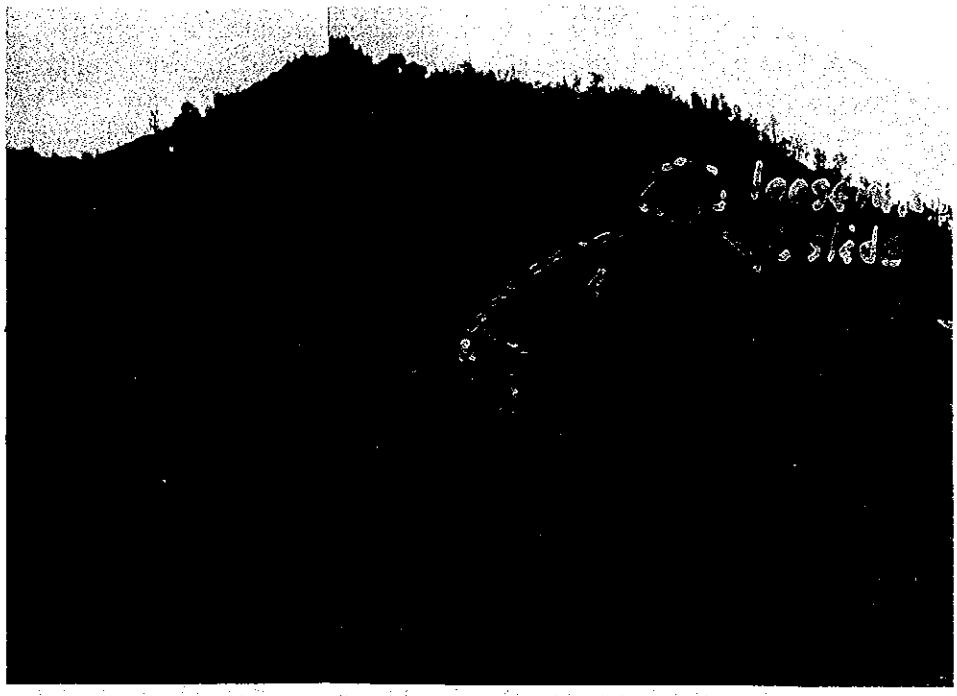
Of the three, landslide A and B are presumed not active since the landform features indicate that top scarps and the side boundaries of both landslides are obscure. Among the three, only C collapsed due to the heavy rain of July 1993. The estimated magnitude of landslide is 80 meters long, 50 meters wide, and 6 meters thick. A triangle block of 30 meters in length, 50 meters in width, and a thickness of 4 meters remained on the south side of C.

d) Road Construction Issues

The road alignment was planned to pass through the landslide by three layers of zigzags. The road will pass through the upper portion of A and B by cut at the heel of the landslide making it stable situation. However, the road alignment will pass the toe of C.

e) Countermeasure Policy Against Potential Landslides

For the road alignment passing through landslide, the principle policy is to take out the top of landslide block by cut as shown in Figure 2.4.10. Removal and cutting of loose soil at the upper part of the landslide is also considered. Since psamitic schist is observed around this area, influence due to cutting to upper slope is minimal.



Photograph 2.4.9 Dhungre Bhanjyan Landslide Area

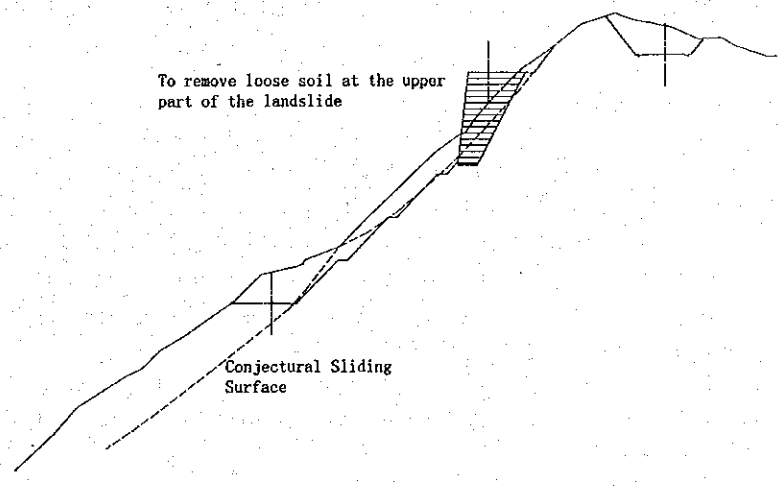


Figure 2.4.10 Road Plan in Dhungre Bhanjyan Landslide Area

(6) Sindhuli Gadhi Slope Failure

a) Landform and Geological Features

This massive failure is located on the southern wing of the convex slope that originates at the backbone of the Mahabharat Range. The top edge of this failure positions 20 meters below the ridge at the elevation of 1540 m and stretches down towards the northeast slope at the elevation of 1340m. The toe of the landslide is 20 meters wide and continues to the gully. The distinct feature of the landslide is that the upper part has a wider range of the failure compared to the bottom. Two gullies converge at the lower part of the failure and active top scarps on the left tributary reaches the summit of the mountain. The right tributary terminates at the interior of the failure where surface failures, with fist-to-head size rock debris scattered at 50 meters width and 70 meters length, are observed. Gneiss of the Binphedi stratum is dispersed in the area.

b) Magnitude of Failure

The failure covers an area approximately 200 meters in length, from an elevation of 1450m to 1300m, 170 meters in width, and 60 meters thick. The deposit volume of the failure is estimated about 900,000m^3.

c) Cause and Potential Activity of Failure

Photographic evidence taken in 1986 and in 1994 shows the failure of the top scarp on the right slope has progressed 20 to 30 meters wider due to the extraordinary heavy rain of July 1993. Despite the rain equivalent to the stochastic precipitation of once in 50 years (maximum daily precipitation 403mm, monthly precipitation 193mm), no major failures disrupting area of the planned road was observed. Inference can be made that this area will withstand the stochastic precipitation of once in 50 years. The origin of the failure was presumed to be due to the DamQuta earthquake of 1934 (M8.6). This hypothesis is supported by the interview results with the inhabitants of the area.

d) Road Construction Issues

The road alignment is planned to pass through the existing footpath. An alternative route detouring this failure around the saddle of Sindhuli Gadhi is not a realistic plan considering the fact that the route has to pass through the dense forest area with the same landform and geological condition. Furthermore, the length of this alternative route is an additional 8 kilometers extension to the design and would cost extra.

The following two issues must be addressed for the road alignment passing through the area:

- During construction period: Since, compression pressure movements due to failure is dormant along the ridges, earthworks in the area may trigger potential failure.

- During maintenance period: Boulder and debris fall over the road due to heavy rain may cause damage to road structures disrupting the traffic.

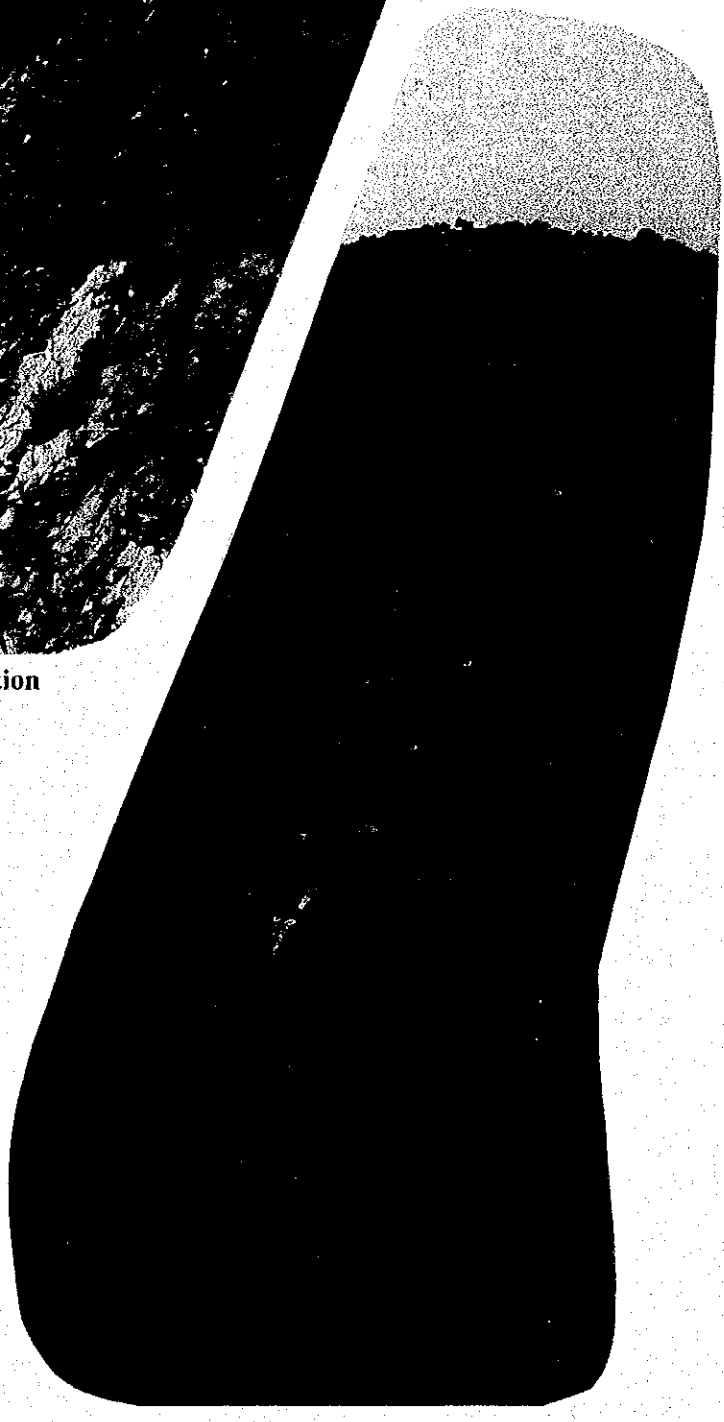
e) Countermeasure Policy against Potential Failure

In order to cope with the potential failures, removal of one-third of the soil on the upper portion of the failure is recommended. However, it is not realistic solution to carry out the removal works of landslide mass amounting to several hundred-thousand cubic meter on a steep slope where access of construction equipment is restrictive. The following are the most feasible countermeasures:

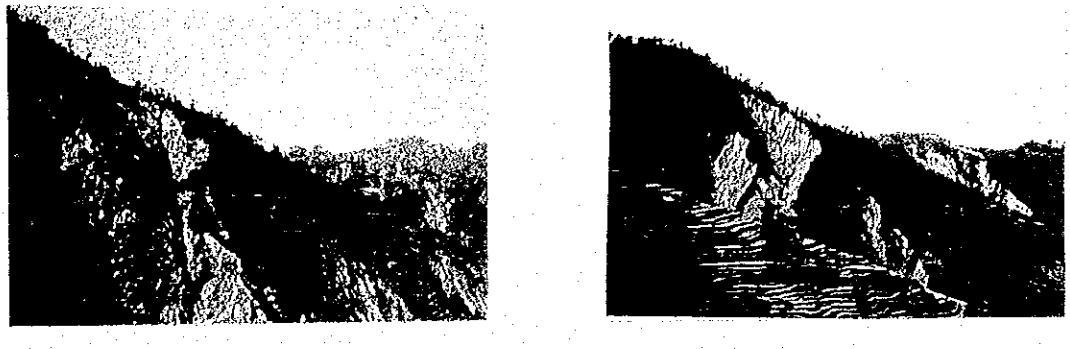
i) Cutting works on the failure is restricted to prevent potential failure, particularly the removal of mass between the two gullies is not allowed.
ii) The road structure should be constructed by gabion retaining walls having its foundation on the fresh base rock at the foot of the failure as shown in Figure 2.4.11.
iii) Pocket walls and other retaining structures should be provided at gully crossing areas.
iv) Considering the three countermeasures above, the road alignment should be designed at low design speed standards as exceptional section.

Photograph 2.4.10 Sindhuli Gadhi Slope Failure

Photograph 2.4.11 Gully Portion



Photograph 2.4.12 Aerial Photograph of Sindhuli Gadhi Slope Failure



Photograph taken in 1986　　Photograph taken in 1994

Photograph 2.4.13　Situation of the Slope Failure in 1986 and 1994

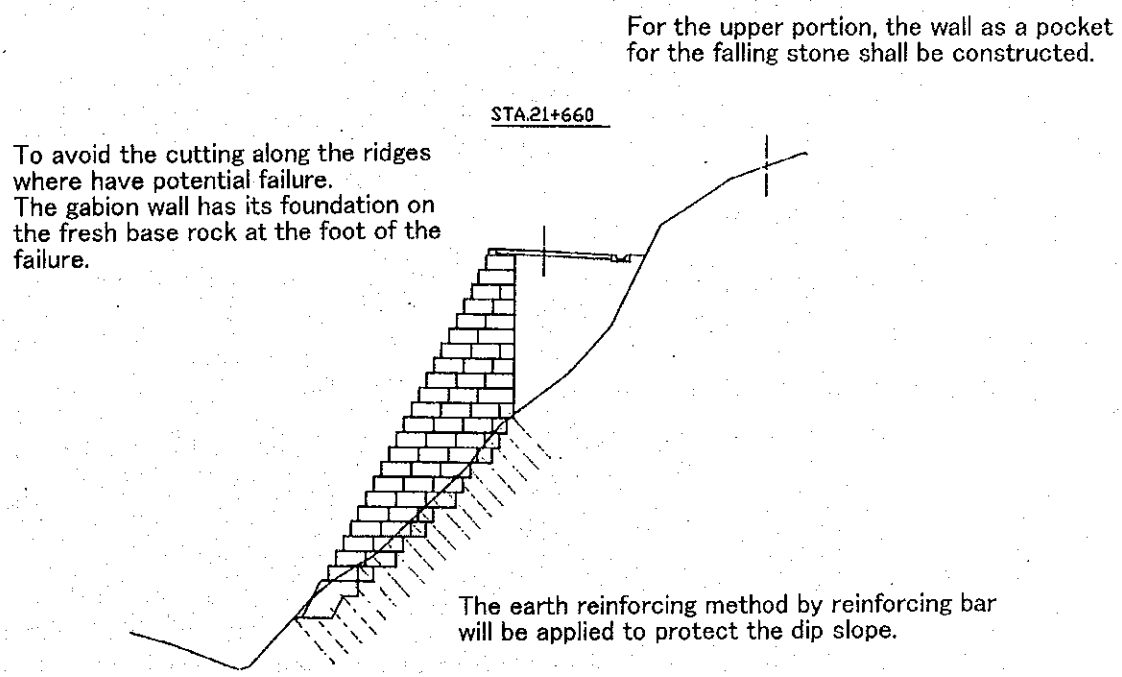


Figure 2.4.11　Typical Cross Section in the Sindhuli Gadhi Slope Failure Area

(7)　Sutarchhapdada Zigzag

a)　Landform and Geological Features

This massive landslide is located on the upper part of the terrace having progressive dissection and faces the southeast at the elevation of 1400m. The feature of this landslide is that its shape forms a typical landform of a landslide with obscure horse-shoe shape profile and a mound at the toe. Gneiss can be observed in this area.

b)　Magnitude of Landslide

The size of this massive landslide is about 500 meters in width, about 600 meters in length. This landslide is composed of thirteen to fourteen dormant landslides.

c) Potential Activity of the Landslide

The site reconnaissance revealed the following features of the huge landslide:

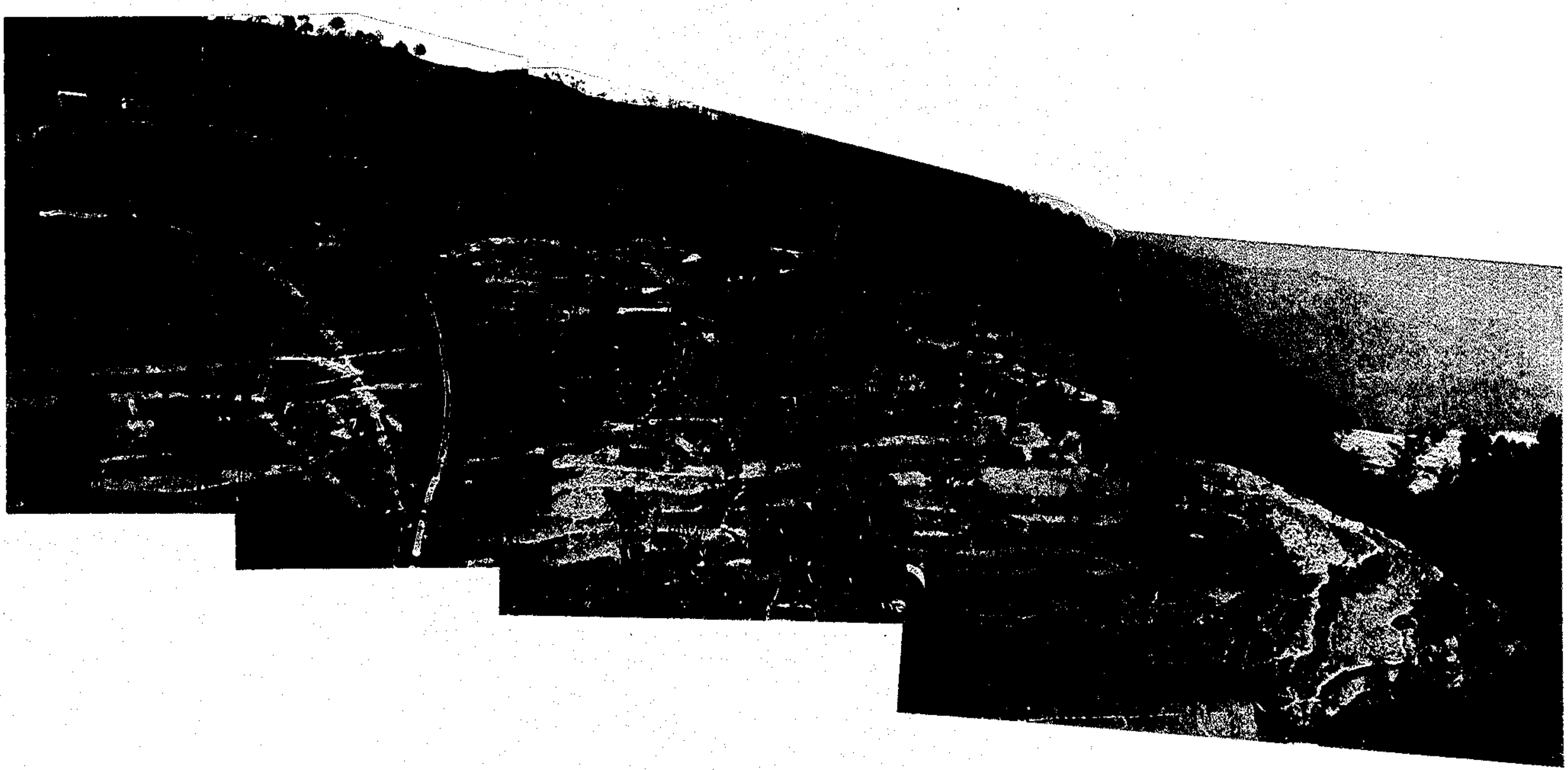
- Progressive dissection of top scarp by several small gullies is observed.
- The edges of the upper portion of the top scarp is rounded due to erosion.
- Progressive erosion on the lower portion of top scarp is observed and the step profile is obscure due to the deposits of the eroded debris.
- Progressive erosion of the gully that divides the landslide is observed.
- Interviews of the residents who live on the landslide concluded that the cracks observed on the walls of residence that stand on the landslide was due to the tremors of the Dalang earthquake (M6.6) of 1988, not due to landslide activity.
- Linden trees over 50 years of age grow along the streams at the foot of the landslide where no signs of erosion was imminent.
- Minor scale surface landslides presumably due to ground water were observed. Although, secondary minor landslides located at old top scarp were observed, as a whole the landslide can be considered stable.

d) Road Construction Issues

The road alignment is planned to descend by a zigzag formation along the moderate gradient of the landslide.

e) Countermeasure Policy against Potential Landslides

- The landslide is considered primitive and stable, and influence due to earthworks is minimal. However, since minor scale landslides exists locally at the lower block, three particular locations have to carry out attentive alignment planning to minimize embankment.
- It is required to stabilize and prevent the progression of erosion at the foot and side of the landslide by providing structures or backfilling soil from earthworks along the stream. Therefore, a spoil bank will be prepared functioning as counterweight.
- Sufficient drainage system is required on the landslide prone area to effectively drain surface and spring water that flow in from the road and slope surface.



Photograph 2.4.13 Sutarchhapdada Zigzag

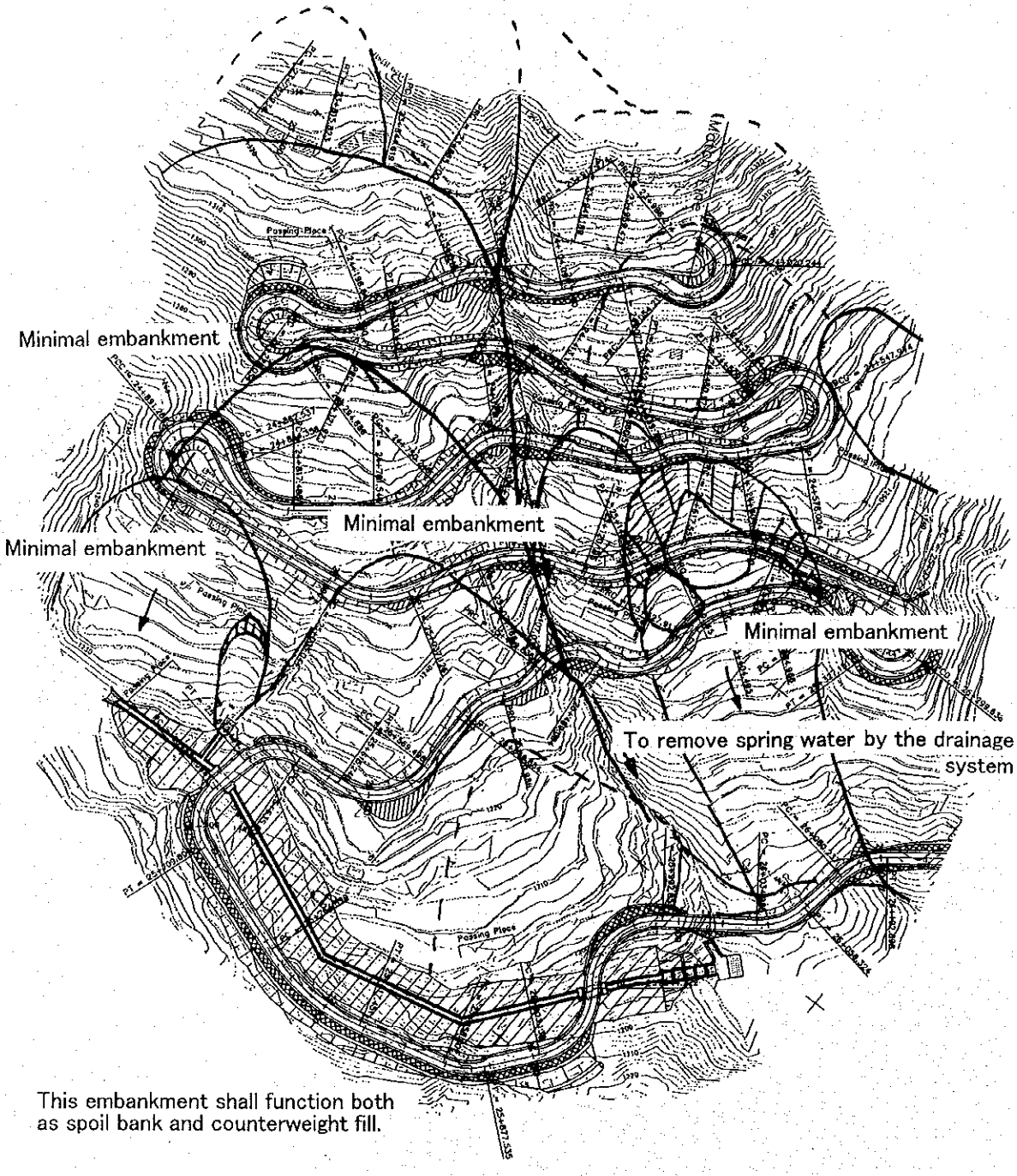


Figure 2.4.12 Road Plan in Sutarchhapdada Area

(8) Bara Slope Failure

a) Landform and Geological Features

This failure is located on the north-side slope near the ridge and stands at an elevation of 910 meters. The slope gradient is very steep and ranges from 45 to 50 degrees. The area is composed of Granitic Schist.

b) Magnitude of Slope Failure

The failure originates at the ridge and the magnitude is about 50 meters in length, 30 meters in width, and 5 meters thick. The shape of this failure is circular at the heel and contracts into ravine at the toe, and resembling the shape of a fig.

c) Potential Activity of Failure

The cause of the failure is presumed to be due to ground and surface water erosion. However, since fresh granite base rock protrudes, it is unlikely that a massive failure will occur.

d) Road Construction Issues

Road alignment is planned to pass through the toe of the gully. There is possibility of collapsing rocks and debris which may cause obstruction during the road works and after the handover of the road.

e) Countermeasure Policy Against Potential Failures

Pocket walls will be constructed to prevent collapsing rocks falling onto the road and disturbing the traffic.

Photograph 2.4.14 The Head of the Bara Slope Failure

Photograph 2.4.15 Bara Slope Failure

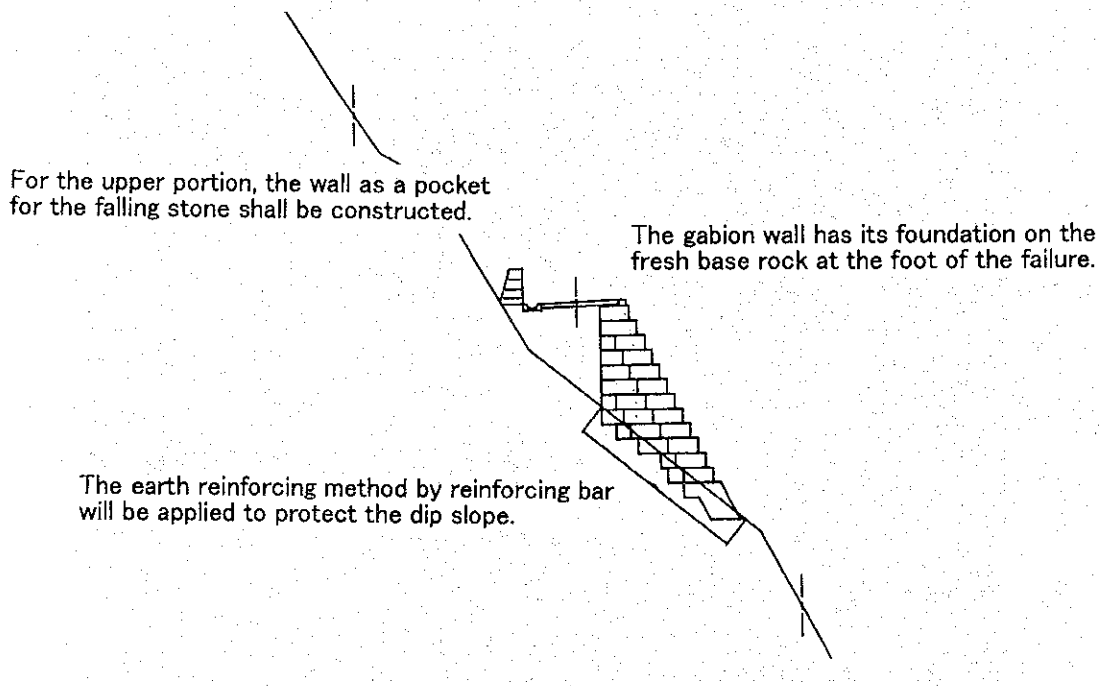


Figure 2.4.13 Road Plan in Bara Slope Failure

2.4.10 High Embankment Section

The Pipal Bhanjyan Zigzag section formed on high embankment established in the narrow valley with 22 steps and 110m height. To stabilize the high embankment, adequate drainage system such as ditch on each steps, vertical drain on each edge of embankment slopes and main centre drain will be installed. Furthermore, subsurface drain will also be placed as shown in Figure 2.4.14.

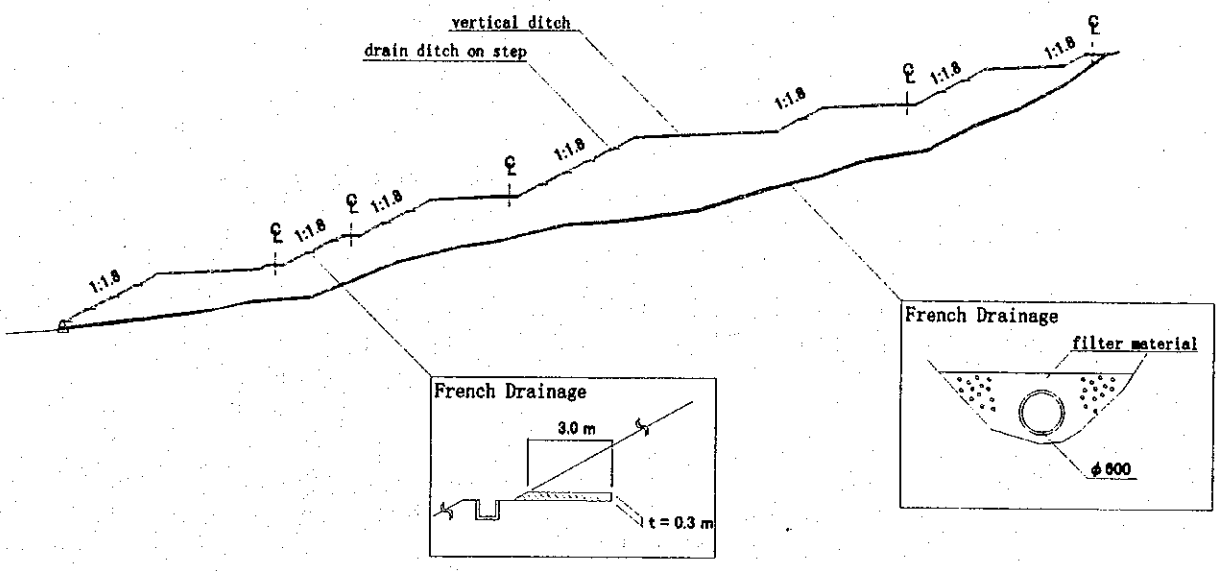


Figure 2.4.14 Subsurface Drains to be installed in the High Embankment

2.4.11 High Cutting Section

At hairpin curve section, high cuttings slope (1V; 0.3H and/or 1V: 0.5H) of which height is more than 30m will appear by the construction. The geology of the slope will be covered pelitic schist, calcareous schist, granitic schist gneiss, psamitic schist and pelitic schist of Pre-Cambrian to Paleozoic. These rocks commonly have joints and affected by weathering. Therefore, earth reinforcing method by reinforcing bar will be applied to prevent for small scale slope failure caused by weathering. The surface of the slope adopted the earth reinforcing method will be covered by shotcrete.

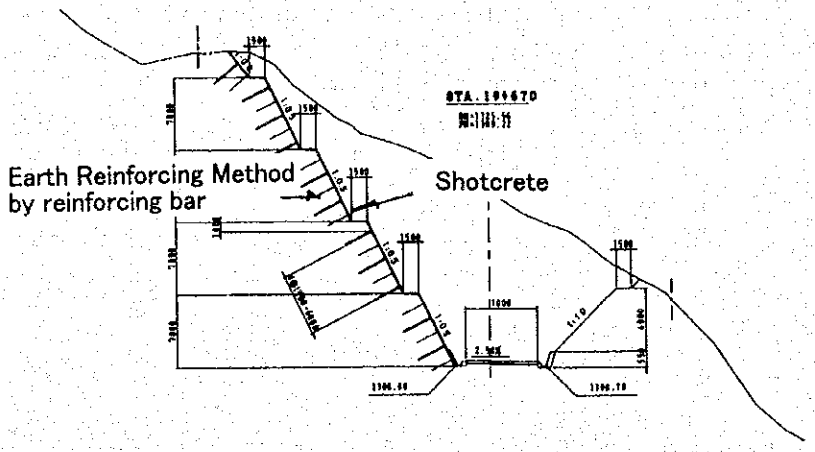


Figure 2.4.15 Slope Protection Works on High Cutting Slope

2.4.12 Revetment

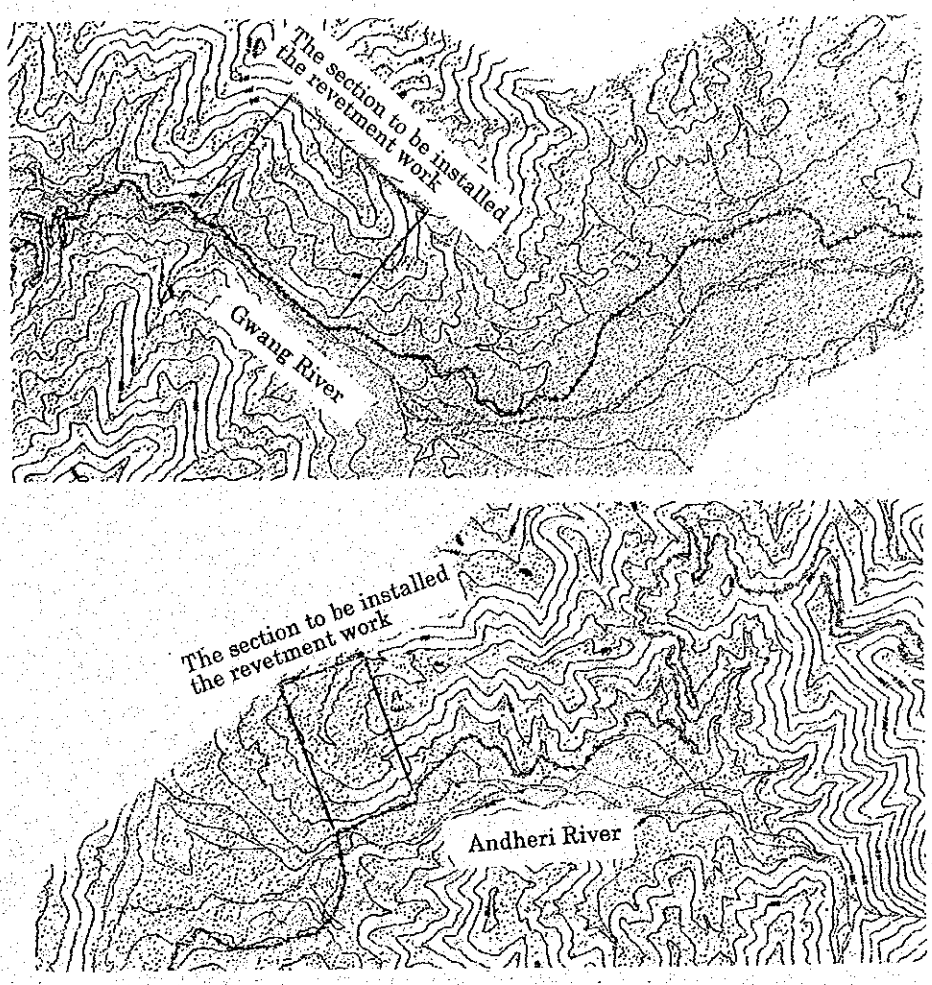
Revetment made by wet masonry with foot protection will be set at sections along the Gwang and Andheri River as shown in Figure 2.4.16.

2.4.13 Spoil Bank

A mass-calculation shows that about 400,000m3 of surplus soil is required to be hauled to spoil banks along the route. As the possible sites for spoil bank, the following four areas were selected taking into consideration of requirement from the mass-hauling balance and the topographical site conditions.

	Name of site	Capacity
Spoil Bank A	Sindhuli Bazar area	173,000m^3
Spoil Bank B	Pipal Bhanjyan area	184,000m^3
Spoil Bank C	Sutarchhapdada area	35,000m^3
Spoil Bank D	Bara area	11,000m^3

The proposed location of sites are as shown in Figure 2.4.17.



Location map of the sections installing the revetment

Figure 2.4.16 Location Revetment

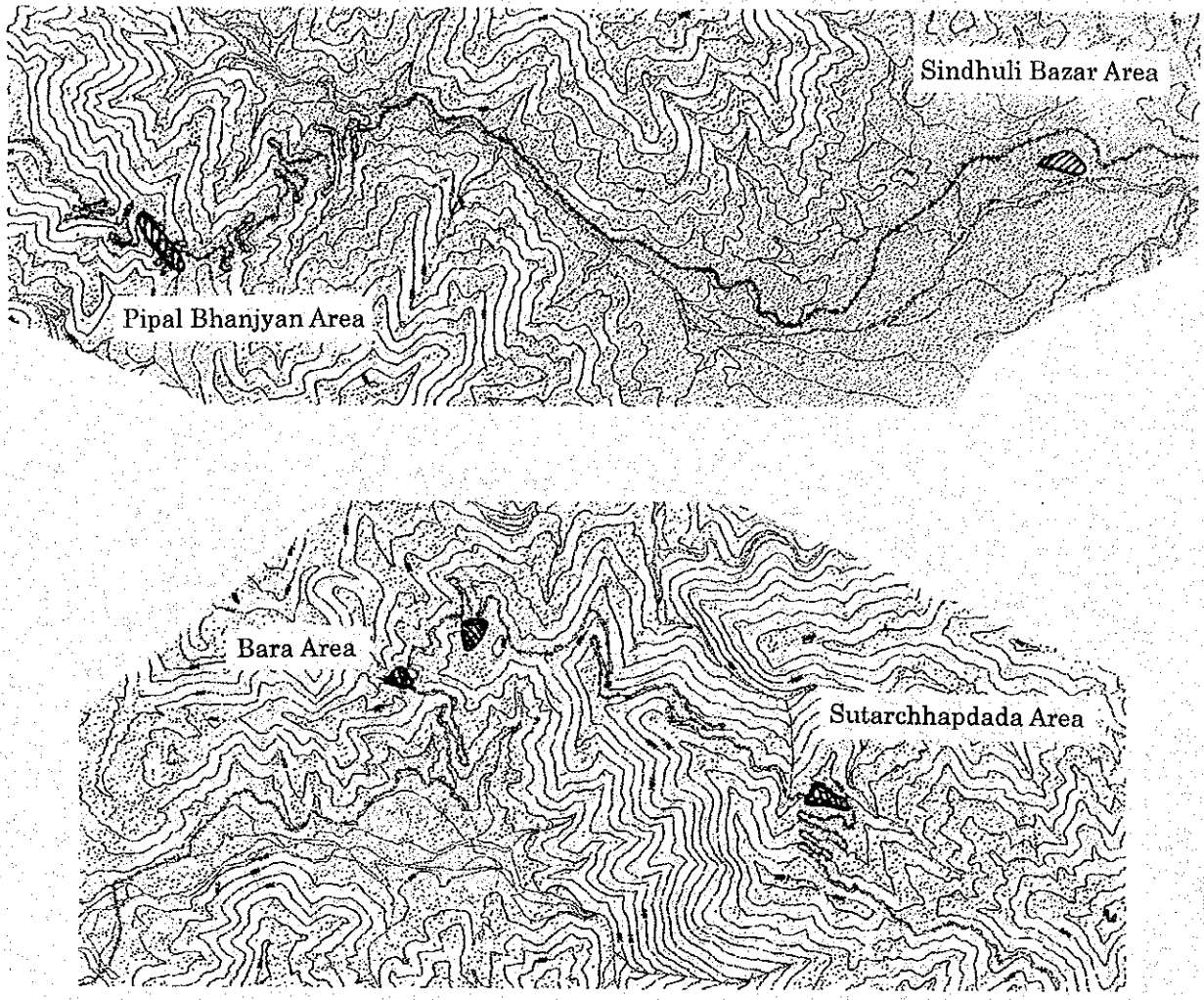


Figure 2.4.17 Proposed Location of Spoil Bank

2.4.14 Traffic Safety Measures

(1) Road Safety Measure

For road safety, the following road side facilities will be installed.

- Normal sections:	Delineator post will be installed according to guideline described in the Traffic Signs Manual, Traffic Engineering and Safety Unit Design Branch, Department of Roads.
- Curve sections where outer side of curve is deep valley and the curvature is small:	L type guard block as shown in the drawing A-9-2 in ANNEX will be installed.
- The sections where road width become narrow by bridge or causeway:	Guard blocks to guide the driver as shown in the drawing A-9-3 in ANNEX will be installed.

(2) Traffic Sign

According to the Traffic Signs Manual, Traffic Engineering and Safety Unit Design Branch, Department of Roads, the following road traffic signs will be installed.

[Direct Sign]

Use of horn	A21 (to be modified)
Maximum speed	A22 (to be 20 km/hr)

[Warning Sign]

Crossroads	B1
Side road right (Left)	B3
Staggered junction	B4
T Junction	B5
Sharp bend to the right (Left)	B10
Hairpin bend to right (Left)	B11
Double bend first left (Right)	B12
Sharp change of direction	B13
Road Narrows on the right (Left)	B15
Steep hill downward	B18
Steep hill upward	B19
Pedestrians in road ahead	B24
Children	B25
Falling rocks	B33
Dangerous dip	B34
Narrow bridge	B35
Delineator post	B48

Inform Sign

Passing place	C4 (to be modified)
Bus-stop	C17

2.4.15 Bus-stop

Twelve (12) bus-stops having 6.5 m width and 30 m length for each directions as one set will be constructed for major villages as shown in Figure 2.4.18.

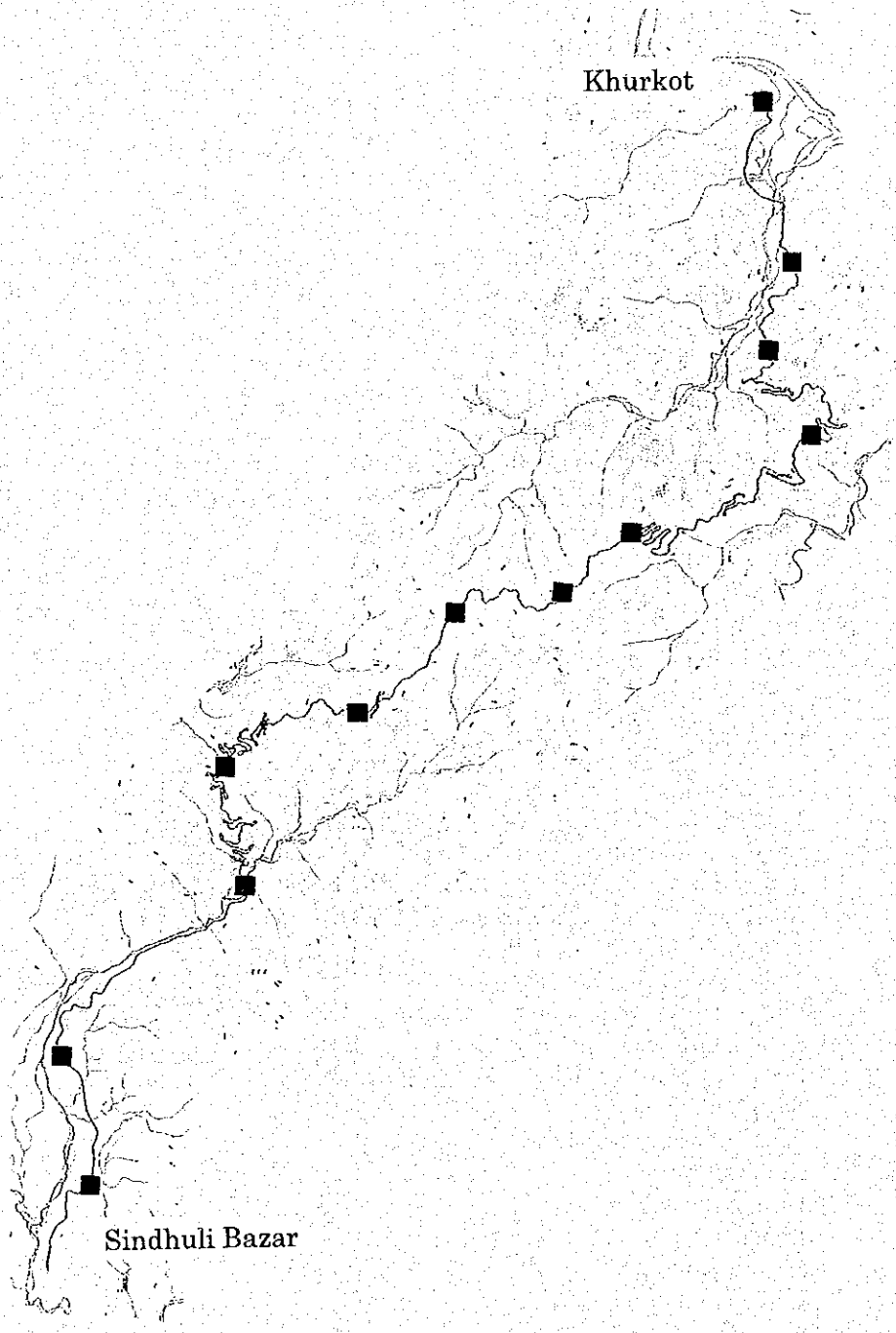


Figure 2.4.18 Location Map of Bus-stop