No.

THE DEPARTMENT OF ROADS,
MINISTRY OF PHYSICAL PLANNING AND WORKS
NEPAL

THE PREPARATORY SURVEY ON THE PROJECT FOR COUNTERMEASURE CONSTRUCTION FOR THE LANDSLIDES ON SINDHULI ROAD (SECTION II)

March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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Volume I

Main Report

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COMPOSITION OF REPORTS

Volume	Report Name	Language
Volume I	MAIN REPORT	English
Volume II	DRAWING	English

PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey and entrust the survey to Nippon Koei Co., Led.

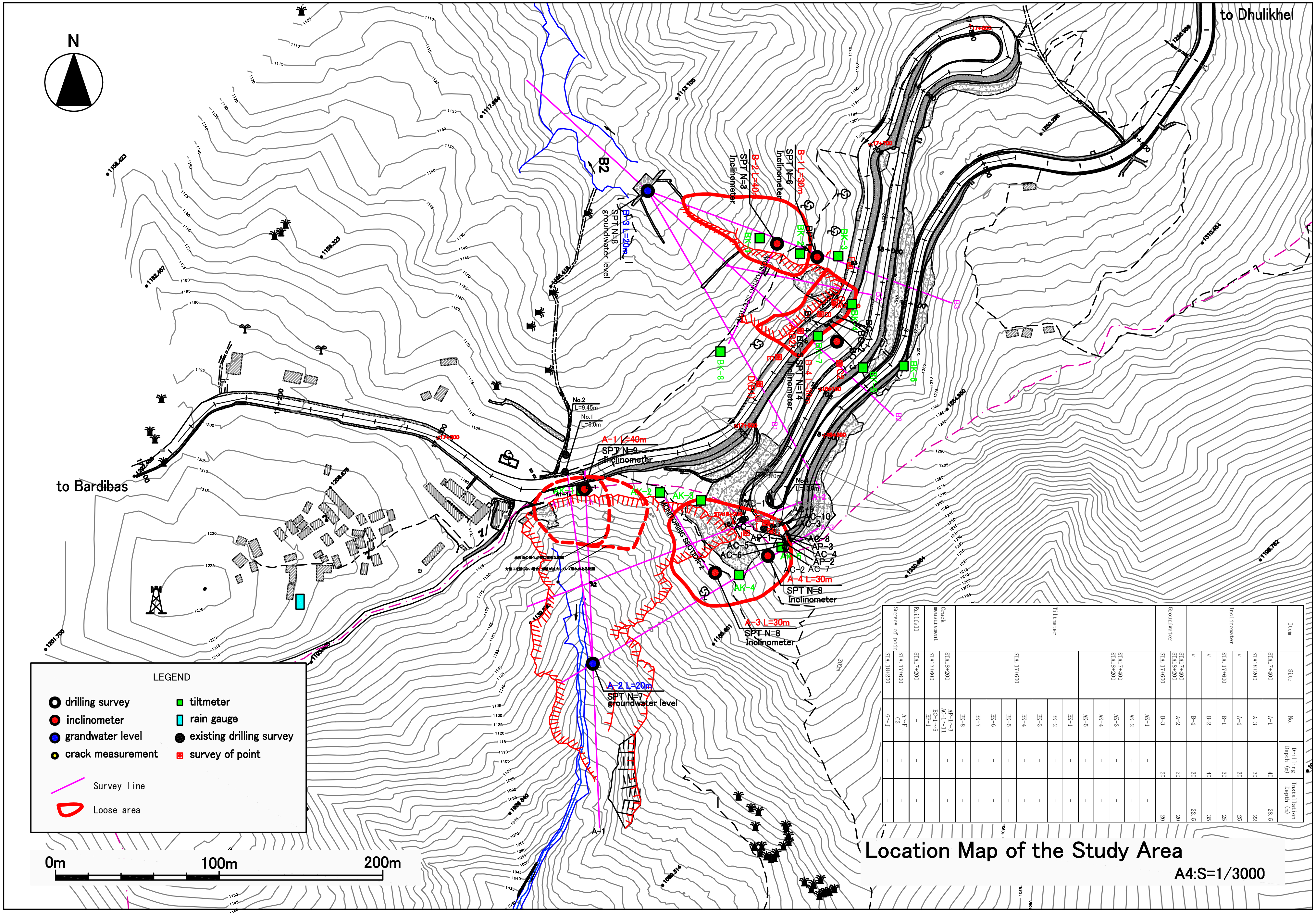
The survey team held a series of discussions with the officials concerned of the Government of Nepal, and conducted field investigations. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Nepal for their close cooperation extended to the survey team.

March, 2011

Kiyofumi KONISHI
Director General,
Economic Infrastructure Department
Japan International Cooperation Agency



Item	Site	No.	Drilling Depth (m)	Installation Depth (m)
Inclinomater	STA17+400	A-1	40	28.5
	STA18+200	A-3	30	22
	〃	A-4	30	25
	STA.17+600	B-1	30	25
	〃	B-2	40	35
	〃	B-4	30	22.5
Groundwater	STA17+400 STA18+200	A-2	20	20
	STA.17+600	B-3	20	20
Tiltmeter	STA17+400 STA18+200	AK-1	-	-
		AK-2	-	-
		AK-3	-	-
		AK-4	-	-
		AK-5	-	-
	STA.17+600	BK-1	-	-
		BK-2	-	-
		BK-3	-	-
		BK-4	-	-
		BK-5	-	-
		BK-6	-	-
		BK-7	-	-
		BK-8	-	-
Crack measurement	STA18+200	AP-1~3 AC-1~11	-	-
	STA17+600	BC-1~5 BP-1	-	-
Railfall	STA17+200	-	-	-
Survey of poin	STA.17+600	A~F C2	-	-
	STA.18+200	G~J	-	-

Location Map of the Study Area

LIST OF ACRONYMS AND ABBREVIATIONS

A

AADT	Annual Average Daily Traffic
ASTM	American Society for Testing and Materials
ALp	Potential Annual Loss of a Site

B

Bill. or Bil.	Billion

D

DL	Detour Loss
DoR	Department of Road
Dr	Reopening duration
DRO	District Road Office
DWIDP	Department of Water Induced Disaster Prevention

E

EIA	Environmental Impact Assessment

F

FRCD	Frequency of Road Closure Disaster of a Site
FRCDp	Potential Frequency of Road Closure Disaster of a Site
Fs	Factor of Safety

G

GoJ	Government of Japan
GoN	Government of Nepal

H

hr	Hour

I

IEE	Initial Environment Examination

J

JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards

K

km	Kilometer

L

Lp	Potential Loss of a RCD

M

m	Meter
m^2	Square meter
m^3/s	Cubic meter per second
MBT	Main Boundary Trust
MCT	Main Central Trust
Mill. or Mil.	Million

N

Nos.	Numbers
NRs	Nepalese Rupee

O

OD	Origin and Destination

P

PR	Postal Road

R

REC	(Core) Recovery
RCD	Road Closure Disaster
ROW	Right of Way
RQD	Rock Quality Designation

S

Sta.	Station
S.N.	Serial Number
SPT	Standard Penetration Test

U

UVOC	Unit Vehicle Operation
S.N.	Serial Number

V

VAT	Value Added Tax
VDC	Village Development Committee
VOC	Vehicle Operation Cost

SUMMARY

1. INTRODUCTION

1.1 BACKGROUND OF STUDY

In response to the request of the Government of Nepal, the Japanese International Cooperation Agency (JICA) implemented a brief study on strengthening the maintenance system for the Sindhuli Road in August 2009. During the study, the current road maintenance system for strategic roads of Nepal was examined and the present condition of the completed Sections I, II and IV of Sindhuli Road was inspected. In this study, the following major issues were pointed out in relation to the sustainable operation and maintenance of Sindhuli Road, after fully opening in 2014:

A) Necessity of improving and strengthening the organization, budgetary preparation, and technology for road maintenance,

B) Necessity of implementing permanent preventive works for the critical sections which require sufficient repairs in Sections I, II and IV of the road.

For issue B above, most of the identified sites required to be repaired were judged to be improvable through the methods commonly adopted in Nepal. However, among the slope failures along the road, those at Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Section II were found to be the most serious, since such failures could cause fatal impacts to the road's function in the future. It is judged in the study that permanent countermeasures for these three sites should be implemented by introducing advanced technologies for sustainable operation and maintenance to ensure safe road traffic.

This study is prepared and implemented by JICA to plan the countermeasure construction project for the three sites as indicated above.

The study area covers the surrounding areas of Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Sindhuli Road, Section II. (See location map in the beginning of this report)

1.2 OBJECTIVES OF THE STUDY AND MAJOR OUTPUT

The study is focused on the target sites, namely: Sta. 17+400, Sta. 17+600, and Sta. 18+200. The objectives of the study are to:

1. Analyze the slope failure mechanism and assess the risk on road closure disasters,

2. Design reasonable permanent countermeasures to prevent disaster occurrence, and

3. Plan the countermeasure construction project.

The major outputs of the study are shown in Table 1.1.

Table 1.1 Major Work Items in the Study

Objective	Major Output
1. Analysis of Failure Mechanism and Risk Assessment on Road Closure Disasters	➢ Failure mechanism ➢ Magnitude of disaster ➢ Impact of disaster occurrence and necessity of countermeasure implementation
2.Countermeasure Design	➢ Countermeasure alternatives ➢ Cost estimation of all alternatives and comparison to select proposed plan
3. Planning Countermeasure Project	➢ Plan of countermeasure construction project

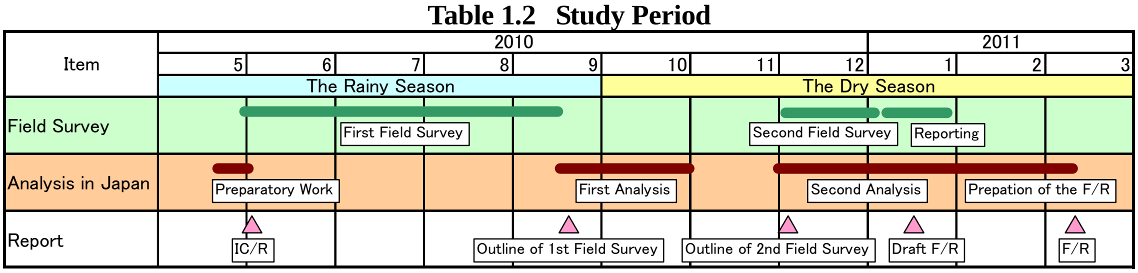
To achieve the objectives of the study, a series of topographical and geological surveys, slope movement/deformation monitoring and data collection necessary for construction have been conducted.

1.3 PROCESS OF THE STUDY

The study has been carried out by a team composed of six engineers specializing on slope disaster technology and one bridge engineer.

The study started on May 27, 2010 and will be completed on March 31, 2011 as shown in Table 1.2.

Table 1.2 Study Period



2. RISK ASSESSMENT OF PROJECT SITE

The risk of landslides causing traffic disturbance in each slope, Sta. 17+400, Sta. 17+600 and Sta. 18+200, has been evaluated based on the results of topographical/geological surveys, slope movement/deformation monitoring carried out in the field, and correlation analysis between past rainfall intensities and landslide occurrences.

2.1 RISK ASSESSMENT OF TARGET SITES

2.1.1 RISK ASSESSMENT OF STA. 17+400

(1) History of Disaster Occurrences

After the first failure in June 2003, another failure occurred on the south-facing slope of Sta. 17+400 in July 2004, followed by still another in August 2005. The series of failures eroded the ridge on which the road section was constructed by 15 m. Consequently, the road shoulder of this section was brought to a condition to be damaged (eroded) by further slope failures. Therefore, the road section was realigned to the northern side of the ridge in 2006. The surface of the collapsed slope was protected with shotcrete, but the shotcrete has been broken completely by the subsequent slope collapses that frequently occurred during the rainy seasons.

(2) Topographic and Geological Condition and Failure Mechanism

The road is situated on top of a narrow ridge extending almost along the east-west direction.

Failure type of the slope around Sta. 17+400 is 'collapse' of steep slope (40 to 70 degrees) and around 40 m in height. This slope is composed of mica schist, green schist and gneiss with geological structure almost orthogonal to the slope surface. Distinct defects (discontinuities and/or geologically weak zones) are not found in the slope. The monitoring results with the two tilt meters and one borehole inclinometer on the ridge suggested no significant movements/deformations in each device.

However, schist and gneiss are severely weathered and intermittently eroded by collapsing every rainy season. The lower valley under the steep slope is likewise being scoured during the rainy season, which affects the stability of the upper slope.

It is therefore judged that the erosion front, which captures the road shoulder, will reach the road in the future.

(3) Probability of Disaster Occurrence

The slope collapses in this section tend to occur when the hourly rainfall exceeds 30 mm and continuous rainfall exceeds 150 mm.

According to the correlation between past rainfalls and occurrence of slope collapses, the slide back of the slope is estimated at 10 cm by 1-year probable rainfall and 60 cm by 5-year probable rainfall. It is judged, therefore, that the collapsing front will reach the road section in 30 years.

2.1.2 RISK ASSESSMENT OF STA. 17+600

(1) History of Disaster Occurrences

The first slope failure occurred just under the road approximately 70 m wide and 90 m long in August 2007, which deformed and damaged the road. Cracks occurred on the road surface and the retaining wall on the mountain side in September of that year. Moreover, hair cracks on the road surface occurred again in July 2009.

(2) Topographic and Geological Condition and Failure Mechanism

The following four unstable zones were identified in the surrounding area of Sta. 17+600:

a) Scarp just under the road at Sta. 17+600

Quartzite and sandy schist are distributed around Sta. 17+600. On the whole, it is hard and dense, but the high-angle schistosity oblique to the slope and the sheeting joint parallel to the slope dipping valley side have developed. Considering these geological conditions, the slope has the potential for planar or wedge failures to likely occur. It was judged that the cracks/deformations on the road surface have been caused by such type of failure mechanism.

b) Loosened zone below Sta. 17+620

A mass composed of fractured and loosened rocks is distributed below the road at Sta. 17+620. Slope monitoring suggests that this part will possibly be unstable under heavy rains.

c) Landslide landform below Sta. 17+500

A typical landslide landform was observed on the lower slope under Sta. 17+500. It was identified in the field observation that this zone was composed of clay, sand, gravel and boulders brought by old landslide. No evidences were found that this zone is creeping or deforming currently, but judging from geological and topographical conditions, this zone has a potential for landslide to be triggered by heavy rains or earthquakes.

d) Upper slope of Sta. 17+600

It has often been observed that groundwater springs out from the retaining wall and the mountain side slope around Sta. 17+500 during the rainy seasons. These phenomena will possibly affect the stability of the upper slope of Sta. 17+500.

(3) Probability of Disaster Occurrence

a) Scarp just under the road of Sta. 17+600

A small expansion tendency was observed in the measurement of cracks on the road and the retaining wall above the scarp crack. Also, a small accumulative tendency was observed during monitoring with the tilt meters. Although there were no significant displacements found during the study, it is judged that this part is in a temporary balanced state after slope failure occurred in 2007.

The failure type is a wedge or planar failure in rock slope. It is difficult to predict the time of further slope failure of this type, but deformation of the slope is considered to be in progress due to gravity and/or rainfall, which will possibly break the balance of slope stability in the near future.

It is a realistic and practical judgment for planning the road maintenance project to consider that rock slide will possibly occur in ten years.

b) Loosened zone below Sta. 17+620

Only a small amount of tilting of the slope was observed by the tilt meter monitoring. It is judged that the slope is in a state of balance at present. However, considering geological conditions of the slope which are similar to those where the large collapse occurred in 2007, the slope will possibly collapse/slide under heavy rainfall in the future.

c) Landslide on the foot of slope

Although the footslope zone is assumed to be in a state of balance at present judging from the conditions of the slope, this zone also has a landslide potential.

d) Upper slope of Sta. 17+600

This site is being deteriorated by intermittent spring flow through open cracks. This slope has a potential for rock fall.

As mentioned above, the monitoring result did not suggest any significant deformations of the site. However, the rock mass in the slope has already been displaced along the joints and is considered to be in a temporary balanced state. It is judged that the slope is likely to slide due to such events as heavy rainfall or earthquakes. Considering the importance of this section in the road, earlier implementation of preventive work on the slope, including the whole unstable zone, is recommended.

2.1.3 RISK ASSESSMENT OF STA. 18+200

(1) History of Disaster Occurrences

The cracks occurred on the slope just below the road in 2003 and appeared on the road in

2005. In 2006, the road was realigned to about 6 m toward the mountain side. Loosening of the rock slope and cracks on the retaining wall have occurred after the realignment. The slope protection by shotcrete applied to the slope below the existing road shoulder had been broken by successive slope failures and left unrepaired at present.

(2) Topographic and Geological Condition and Failure Mechanism

The site is located on the toe of the ridge which consists of quartzite schist. As the schistosity of the rock is parallel to the slope face with the dip to the mountain side, toppling slope failure is likely to occur in this site.

(3) Probability of Disaster Occurrence

During monitoring of cracks on the retaining wall, the tilt meters and inclinometers in the slope during the rainy season indicated that deformation was taking place in an area around 50 m by 50 m, including the half lane of the road section.

The collapses have occurred frequently in the slope just under the road when hourly rainfall exceeded 30 mm and continuous rainfall exceeded 150 mm. A large collapse occurred when the continuous rainfall exceeded 500 mm, which corresponds to ten years successive rainfall probability. As continuous rainfall, approximately 300 mm, is observed every year, frequent collapses in the lower slope will occur every year.

It is judged that landslide disaster with a scale that could disturb the traffic will possibly occur in the near future in Sta. 18+200 if no preventive measures would be implemented.

2.2 ECONOMIC LOSS INDUCED BY SLOPE DISASTERS

2.2.1 METHODOLOGY OF ESTIMATION OF ECONOMIC LOSS

Road slope disaster risk was evaluated using the following two risk indicators:

$$\underline{ALp = FRCDp \times (Cr + Lt)}$$

Where:

ALp: Potential annual economic loss induced by road slope disaster (NRs/year)

FRCDp: Frequency of road closure disaster of a site in a year

Cr: Reopening cost (NRs)

Lt: Traffic loss (NRs); Economic loss induced by road closure disaster; only detouring cost is considered in this estimation

2.2.2 ESTIMATION OF ECONOMIC LOSS INDUCED BY SLOPE DISASTERS

Potential annual loss induced by road closure disaster is estimated through the equation above and shown in Table 2.2.1. Conditions for the estimation were decided based on the survey result described in the previous section and traffic data in existing reports such as “Study on Disaster Risk Management for Narayangharh-Mugling Highway, JICA 2009” and “The Basic Design for Sindhuli Road (Section III), JICA 2008”.

Table 2.2.1 Potential Annual Loss of a Site (Alp)

Site	Potential Loss of RCD （million NRs）	Potential Frequency of Road Closure Disaster of a Site (FRCDp)	Potential Annual Loss of a Site（ALp） （million NRs/year）
Sta. 17＋400	1,411	0.033	47
Sta. 17＋600	3,925	0.1	393
Sta. 18＋200	1,519	0.2	304

As shown in the table, annual economic losses induced by road closure disasters at Sta. 17+400, Sta. 17+600 and Sta. 18+200 are estimated at NRs 47 million/year, NRs 393 million/year and NRs 304 million/year, respectively.

3. PLANNING OF COUNTERMEASURES

3.1 POLICY ON PLANNING COUNTERMEASURE FOR TARGET SLOPES

The results of the risk evaluation on slope disasters in Sta. 17+400, Sta. 17+600 and Sta. 18+200 indicate that road traffic is considered to be disturbed seriously if these sections are left without protection and adequate preventive measures. Countermeasure alternatives have been planned in consistency with the following policies considering the importance of these sections for sustainable traffic function of the road:

A) Permanent countermeasures shall be designed introducing advanced technology which can protect the target sections for a long term,

B) Application of common construction methods in Nepal shall be applied as far as possible,

C) Impact on environment shall be minimized in countermeasure planning, and

D) Proposed countermeasure plan shall be selected considering the following viewpoints:

- Level of effectiveness
- Construction cost
- Difficulty of construction
- Safety level of construction
- Difficulty of maintenance
- Impact on environment

Considering results of risk assessment described in the previous section, countermeasure alternatives were planned as follows.

3.2 COUNTERMEASURES FOR STA. 17+400

3.2.1 PLANNING AND SELECTION OF COUNTERMEASURE ALTERNATIVES

Considering the above hazardous situation of the site, it is necessary to protect not only the upper steep slope but also the lower valley. Countermeasure alternatives for this site are proposed as below.

- Plan I Shotcrete with rock bolt works + gravity-type retaining wall (for upper steep slope) + check dams and open ditches / underdrainage (for lower valley)

- Plan II Retaining wall + rock bolt works with shotcrete (for upper steep slope) + check dams and open ditches / underdrainage (for lower valley)

- Plan III Gabion wall + masonry retaining wall (for upper steep slope) + check dams and open ditches / underdrainage (for lower valley)

- Plan II is very difficult due to sharp/rugged undulation of surface in the site. Thus, Plan II is eliminated from the comparison below.

Plan I is better than Plan III in view of direct cost, construction difficulty and construction safety. But these works were judged difficult to be implemented with the present Nepalese construction technology due to shortage of construction machinery and experiences for shotcrete with rock bolt works. It was also considered to be difficult to rehabilitate these structures during maintenance stage when the structures would be deteriorated.

Plan III is slightly but not significantly expensive compared with Plan I. Generally, it is not easy to construct high gabion walls in steep and high slopes. But many gabion walls in steep slopes had been constructed successfully during the construction of Section II. This construction experience can be applied for Plan III not only for construction but also for maintenance of the structure.

Plan III is therefore recommended as the most suitable countermeasure for Sta. 17+400.

3.2.2 OUTLINE OF THE COUNTERMEASURE FOR STA. 17+400

Proposed countermeasure (Plan III) is composed of two parts, namely, (1) countermeasure for the upper slopes between EL. 1,140 m to 1,180 m and (2) countermeasure for below EL. 1,140 m.

Table 3.2.1 Outline of Countermeasures for Sta. 17+400 Area

Method	Unit	Quantity	Specification
For upper steep slope			
Gravity-type retaining wall	m	18	h＝5.0 m
Gabion wall	m^3	2,290	h＝5.0 m＊6 steps
Masonry retaining wall	m^2	1,090	t= 50 cm, 2 steps
Guard fence	m	72	h＝2.0 m
For lower valley			
Check dams by gabion	m^3	500	h＝5.0 m
Open ditch	m	120	
Underdrainage	m	113	φ＝600 mm
Catch basin	no.	1	
Planting cuttings	m^2	1,700	

3.3 COUNTERMEASURES FOR STA. 17+600

3.3.1 PLANNING AND SELECTION OF COUNTERMEASURE FOR STA. 17+600

Considering the importance of this site for maintaining the traffic function, three countermeasure alternatives have been planned covering all four unstable zones (a, b, c, d).

- Plan I Two steps of high reinforced counterweight fill to protect Zone b and lower part of Zone c + anchor works for Zone a + shotcrete for Zone d.

- Plan II One step of high reinforced counterweight fill to protect Zone b and lower part of Zone c + anchor works for full area of Zone a + shotcrete for Zone d.

- Plan III One step of low reinforced counterweight fill to protect Zones a and b and lower part of Zone a + anchor for extended area of Zone c + shotcrete for Zone d.

Due to severe topography and road alignment conditions, there was no other choice but to apply advanced technologies on landslide protection such as high reinforced counterweight fill or anchor works.

In planning the countermeasures of these alternatives, sufficient and necessary design conditions have been introduced for long term protection of the road. With the implementation of one of the above alternatives, the environment of the surrounding area will have marked improvement.

Plan I has been selected for the proposed countermeasures because it is the cheapest and most convenient for the maintenance stage.

3.3.2 OUTLINE OF COUNTERMEASURES (PLAN I)

Countermeasures for the surrounding area of Sta. 17+600 are composed of three units, as follows:

- Two steps of high reinforced counterweight fill for lower slopes, Zones a and b;
- Anchor works, tie rod anchor works, rock bolt works for deformed slope just below the road;
- Protection by shotcrete for mountain side slope;

Table 3.3.1 Outline of Countermeasures for Sta. 17+600 Area

Method	Unit	Quantity	Specification
For deformed slope just below the road; Zone c			
Tie rod anchor works	m	619	F20UA, @3.0 m, 2 steps, L=13.5~14.0 m,
Plastering concrete work (1)	m^2	663	t=40 cm
Anchor works	m	525	F70UA, @3.0 m, 2 steps, L=12~13.0 m
Plastering concrete work (2)	m^2	391	t=60 cm
Rock bolt works	m	861	D=19, @2.0 m, L=3.0 m
Shotcrete	m^2	1,148	t=10 cm
Scaffolding	m^2	7,368	W=4.5 m
For lower slopes; Zones a and b			
Counterweight fill (1) from Sta. 18+200	m^3	36,100	
Counterweight fill (2) from borrow site	m^3	20,000	
Planting works	m^2	5,610	
Gravity-type retaining wall	m	30	H=5.0 m
Gabion wall	m	3,370	H=2.0 m
Check dam	m	30	H=3.0 m
Underdrainage	m	200	ϕ=600 mm
Open ditch	m	1,400	W=300 mm
For protection of mountain side slope; Zone d			
Shotcrete	m^2	2,145	t=10 cm
Road for construction	m	686	W=4.0 m

3.4 COUNTERMEASURES FOR STA. 18+200

3.4.1 PLANNING AND SELECTION OF COUNTERMEASURE FOR STA. 18+200

Three countermeasure alternatives for this site have been planned as below.

- Plan I Shift the road to the mountain side by around 10 m.

- Plan II Stabilize the unstable slope by anchor works.

- Plan III Stabilize the unstable slope by caisson piles.

Countermeasures by structures such as anchor works or caisson piles can keep the existing road alignment unchanged. However, it is required to remove the unstable zone in the slope before implementing any type of structure and thereafter, careful monitoring of slope deformation shall be done during the construction. Consequently, construction costs of Plans II and III are more expensive than that of Plan I. In selecting Plan I, the area of the cutting slope for road shifting is in a national land underlined by sandy quartzite and sandy schist. Produced materials from the cutting slope will be utilized for the counterweight fill in Sta. 17+600.

Plan I, road shifting, has been evaluated as the most reasonable plan for the countermeasure for Sta. 18+200.

3.4.2 OUTLINE OF COUNTERMEASURES

- The road section is shifted by around 10 m to the mountain side that is considered to be around 5 m outside the presumed unstable area.
- The cutting slope of 37,000 m^3 includes minimum cutting for road shifting of 20,000 m^3 and the materials of the additional cutting to be used as counterweight fill material in Sta. 17+600.
- The newly-made roadside slope is protected by shotcrete and the slope formed by additional cutting is covered by rock net for safety.
- The cutting slope is part of the works of the high counterweight fill in Sta. 17+600. Therefore, the work plan of cutting shall be finalized considering the construction plan of Sta. 17+600.

Major works and facilities for Sta. 18+200 are shown in Table 3.4.1.

Table 3.4.1 Outline of Countermeasures for Sta. 18+200 Area

Method	Unit	Quantity	Specification
Earth removal work on rock slope	m^3	37,600	
Rock net	m^2	920	
Masonry retaining wall	m	125	h=5.0 m, t=50 cm
Tentative protection fence	m	192	h=5 m
Slope shaping	m^2	2,820	
Shotcrete (1); slope	m^2	1,070	t=10 cm
Shotcrete (2); valley	m^2	130	t=10 cm
Open ditch	m	600	
Planting cuttings	m^2	920	
Road realignment	m	142	

4. PROJECT IMPLEMENTATION PLAN

4.1 GENERAL OUTLINE OF THE PROJECT

The general outlines of the countermeasures for each site are shown in Table 4.1.1. Based on the Minutes of Discussion (Explanation of Draft Final Report) on Jan. 20, 2011, the Nepalese side intended to implement the countermeasure works at Sta. 17+400 with their own expenses.

Table 4.1.1 General Outline of the Countermeasure

Section	Outline of Countermeasure	Note
Sta. 17+400	・Check dam, gravity-type wall and planting cuttings ・Gabion wall and masonry retaining wall (upper side) ・Guard fence	(Implemented by GoN)
Sta. 17+600	・Check dam and gravity-type retaining wall ・Reinforced counterweight fill, gabion wall and sheet sodding works for slope protection ・Shotcrete and anchor works	Cutting disposal at Sta. 18+200 are used for the counterweight fill.
Sta. 18+200	・Earth removal work, shotcrete, masonry retaining wall and planting cuttings ・Road realignment to mountain side	Minimize the quantity for earth removal

4.2 IMPLEMENTATION POLICY

The policies for the implementation of the Project are summarized as follows:

- Maximize use of local labor and construction materials for the Project,
- Minimize negative impacts of the Project against public transportation services,
- Minimize negative impacts on the surrounding environment,

4.3 IMPLEMENTATION CONDITIONS

4.3.1 CONSTRUCTION PLAN

(1) Construction Methodology

The common construction method and technology in Nepal should be adopted, except in such cases where traffic safety is difficult to secure without applying Japanese technology, to reduce the burden during the maintenance stage.

Considering the general design criterion and experience of construction for landslide protection in Nepal, Japanese technology should be adopted for the design criterion for slope protection, construction experience such as reinforced soil wall, high counterweight fill work and anchor work.

(2) Location of Construction Yard

The following locations are proposed sites for the necessary construction yard (including borrow pit):

- Camp / Stockyard / Crushing plant / Concrete plant: Sta. 3+000
- Local / Security camp yard (near the site): Sta. 17+200
- Material yard (temporary, near the site): Sta. 17+200
- Embankment test site: Sta. 16+800
- Borrow site: Sta. 29+000 (Section I, Kamara River)

4.3.2 PROCUREMENT PLAN

(1) Labor procurement

Some of the skilled (rigger, rebar worker, form worker, mason, etc.) and unskilled laborers can be possibly procured near the site considering the recent increase of population and construction scale. However, particular and advanced skilled laborers (foreman, plant operator, survey/supervisor specialist, etc.) should be procured from Katmandu area.

(2) Material and equipment procurement

Natural construction materials (aggregate, stone, embankment material, timber) and cement are available in Nepal. Reinforcing bars are also available in the local market. Particular or advanced items not available in the local market, such as reinforced embankment and anchoring materials, and equipment, should be imported from Japan. In addition, materials and equipment which require maintenance of quality should also be procured from Japan.

(3) Transportation path

Construction materials and equipment that are procured from Japan will be shipped to Kolkata Port. The distance from Kolkata to the construction site via Pathalaiya (southern direction from Hetauda, Narayangadh and Muglin) is about 750 km.

The good condition of the road enables the equipment to be transported within three days. (This transportation path is shown in red-orange line in Figure 4.3.2.)

Furthermore, the transportation path from Katmandu to the site takes within two days.

4.4 IMPLEMENTATION SCHEDULE

As the preparatory survey for the Project will be completed by the end of March 2011, basic study is required before implementing the financial arrangement of the Project. In case that Japan's grant aid will be the source of financing, the detailed design and preparation of the tender documents will be carried out by the Consultant after signing of the E/N and G/A between GoN and GoJ. Consulting services for the detailed design and preparation of the tender documents will be completed within seven months. The tendering process for construction works, which includes prequalification, tender opening and evaluation, and subsequent negotiations to conclude the contract between the DoR and the successful tenderer, will take about four months.

Considering the rainy season and mobilization/demobilization at the site, construction works will be completed within approximately 27 months.

4.5 OBLIGATION OF RECIPIENT COUNTRY

For the smooth implementation of the Project, the government of the recipient country shall fulfill the undertakings as stated in Table 4.5.1.

4.6 PROJECT COST ESTIMATION

The project costs required for the undertakings by the GoN is estimated around 9 million NRs. (10million yen).

5. CONCLUSION AND RECOMMENDATION

5.1 RISK LEVEL OF TARGET SITE

The results of the risk evaluation on slope disasters occurring in Sta. 17+400, Sta. 17+600 and Sta. 18+200 indicate that road traffic will be seriously affected if these sections were left without adequate preventive protection measures. It is recommended that these sections be protected by permanent countermeasures before full opening of the Sindhuli Road in 2014. Earlier implementation of adequate preventive works for these sites will avert huge economic loss during the operation stage.

5.2 PROPOSED COUNTERMEASURES AND IMPLEMENTATION

(1) Proposed Countermeasures

In planning the countermeasures for each site, sufficient and necessary design conditions have been introduced to keep the long term traffic function of the road as follows.

- Sta. 17+400: Slope protection for the upper slope by a series of gravity-type retaining wall, gabion wall, and masonry retaining wall, and slope stabilization method for the lower valley by checks dam by gabion, underdrainage, open ditch and planting cuttings;
- Sta. 17+600: Anchor works for just below the road, stabilization by high reinforced counterweight fill for the lower two slopes and shotcrete for the upper slope;
- Sta. 18+200: Road realignment to the mountain side by slope cutting.

(2) Countermeasure Implementation for Sta. 17+600 and Sta. 18+200

Considering the topographical and landslide situations at Sta. 17+600, advanced methods such as anchor works and high reinforced counterweight fill works are introduced for planning countermeasures. Materials produced in Sta. 18+200 are utilized for the high counterweight fill in Sta. 17+600. Therefore, these two work units shall be implemented together as one project.

(3) Countermeasure Implementation for Sta. 17+400

On the other hand, slope protection works for Sta. 17+400 could be implemented by DoR utilizing the experience of construction of Section II in which many gabion walls in steep slope had been constructed safely

The proposed countermeasures works, which are based mainly on design condition and economical effects will be expected to be suitable for landslide stabilizaiton. In addition, because unexpected rainfalls frequently occur around the project area it is suggested to make effort to mitigate the damage due to the unexpected rainfall through appropriate maintenance of Department of Road and to establish early restoration system.

THE PREPARATORY SURVEY
ON
THE PROJECT
FOR
COUNTERMEASURE CONSTRUCTION
FOR
THE LANDSLIDES
ON
SINDHULI ROAD (SECTION II)

Main Report

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROJECT

The Sindhuli Road (Banepa-Bardibas Highway), with a total length of around 160 km, is being constructed through grant assistance from the Government of Japan since November 1996. Construction history of the road is briefly described as follows:

- 1986 - 1988: Feasibility Study on the Sindhuli Road Construction Project,
- 1996 - 1998: Section I, Bardibas to Sindhulimadi (37 km), including nine bridges and 17 causeways,
- 1998 - 2002: Section IV, Nepaltok to Dhulikhel (50 km)

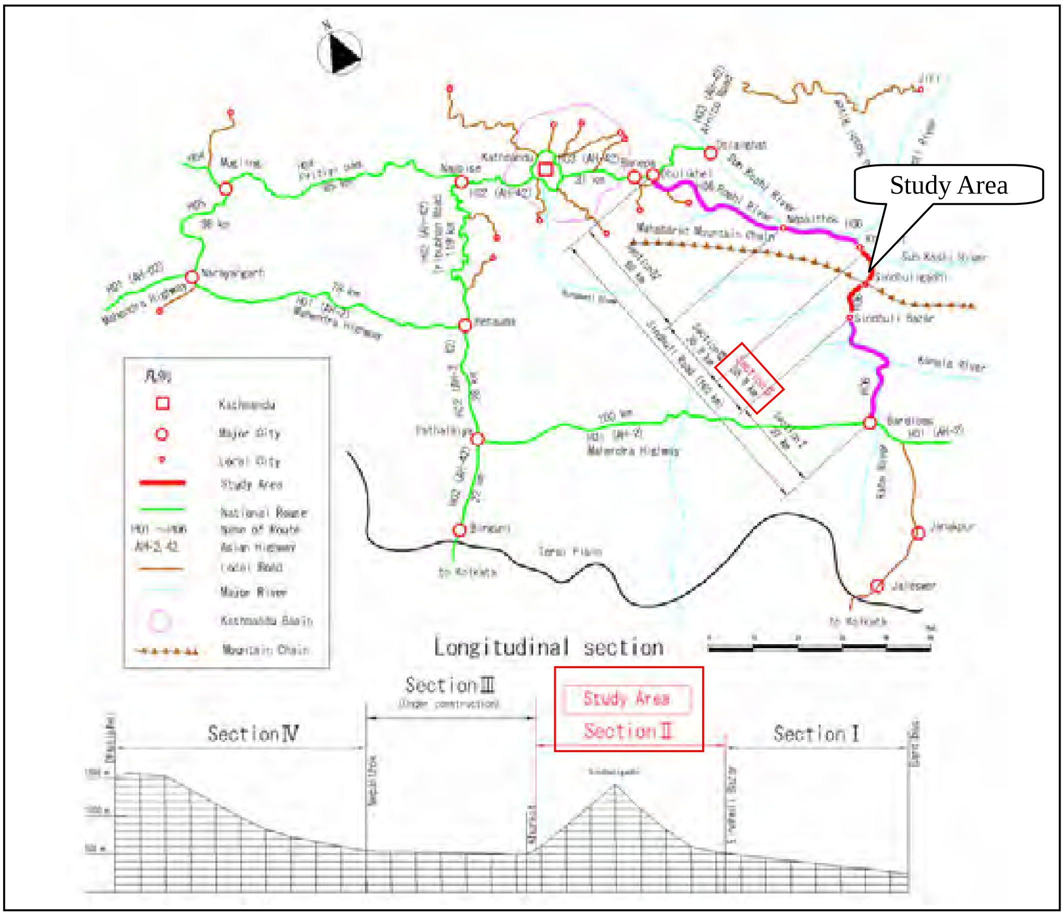


Figure 1.1.1 Location of Study Area

- 2001 – 2009: Section II, Sindhulimadi to Khurkot (36 km)
- 2009: Commencement of Construction of Section III, Khurkot to Nepaltok (37 km)

The construction is scheduled to be completed in 2014. Consequently, the entire section of this road will be fully opened as an important alternative highway connecting the capital city of Katmandu to the Terai Plain.

The Sindhuli Road has been planned in an area of adverse topographical and severely weathered geological conditions that are inherent natural conditions to cause landslides during construction. Therefore, the Sindhuli Road has been and is being constructed carefully coping with such possible landslide occurrences. However, during and after the construction, the road will remain in natural conditions where landslides may occur. Although most of its sections damaged by landslides have been suitably rehabilitated, some sections have not yet been repaired sufficiently, partly because the implementation capacity of the road maintenance system has not yet been sufficiently developed. Therefore, full traffic operation may not be sustained even after the full opening of the road.

To improve the above mentioned situations for the sustainable operation and maintenance of the Sindhuli Road to be fully opened in 2014, the Government of Nepal requested the Government of Japan to grant technical assistance projects. In response to the request, the Japanese International Cooperation Agency (JICA) implemented a brief study on strengthening the road maintenance system for the Sindhuli Road in August 2009. During the study, the current road maintenance system for strategic roads of Nepal was examined and the present condition of the completed Sections I, II and IV of Sindhuli Road were inspected. Based on the study above, the following major issues were pointed out in relation to the sustainable operation and maintenance of the Sindhuli Road after its full opening in 2014:

A) Necessity of improving and strengthening the organization, budgetary preparation, and technology for road maintenance,

B) Necessity of implementing permanent preventive works for the critical sections which include repairing works on Sections I, II and IV of the road.

For issue B above, disaster records were reviewed and general field inspection was carried out for the completed Sections I, II, and IV. This was intended to identify the portions which shall be improved before the full opening. Most of the identified sites were judged to be improvable through the methods commonly adopted in Nepal. However, among the slope failures along the road, Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Section II were found to be most serious where slope failures could cause fatal impacts on road traffic in the future. It was judged in the study that permanent countermeasures for these three sites should be initiated by introducing advanced technologies that are necessary for sustainable operation and maintenance for safe road traffic.

Based on the conclusions and recommendations of the abovementioned brief August 2009 study, this present study was prepared and implemented by JICA to formulate the countermeasure construction project for the three sites above.

1.2 STUDY AREA

The study area covers the surrounding areas of Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Section II of the Sindhuli Road. (See location map at the beginning of this report).

1.3 OBJECTIVES OF THE STUDY AND MAJOR WORK ITEMS

The objectives of the study are to:

1. Analyze the slope failure mechanism and risk assessment on slope disasters for the target sites.
2. Design reasonable permanent countermeasures to prevent disaster occurrence which will affect sustainable and safe traffic along the Sindhuli Road.
3. Formulate the countermeasure construction project, considering socio-environmental aspects, technical situation of construction industry in Nepal, and the implementation capability of the Nepalese government.

The major work items necessary to achieve the above objectives are shown in Table 1.3.1.

Table 1.3.1 Major Work Items in the Study

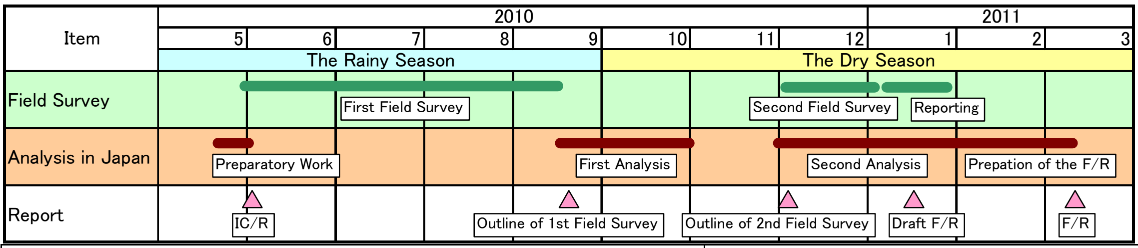
Work Category	Work Item	Output
1. Analysis of Slope Failure Mechanism and Risk Assessment	1.1 Geological inspection 1.2 Topographical /geological survey 1.3 Slope monitoring 1.4 Assessment of disaster impact	➢ Slope Failure mechanism ➢ Magnitude of disaster ➢ Impact of disasters and necessity of countermeasure implementation
2.Countermeasure Design	2.1 Countermeasure alternatives for Sta. 17+400, Sta. 17+600 and Sta. 18+200 2.2 Unit cost arrangement 2.3 Cost estimation for all alternatives	➢ Countermeasure alternatives ➢ Cost estimation of all alternatives

3. Planning Countermeasure Project	3.1 Designing of countermeasures 3.2 Temporary work plan 3.3 Socio-environmental consideration 3.4 Laws on construction and labor 3.5 Survey on construction industry 3.7 Survey on procurement 3.7 Planning countermeasure project	➢ Plan of countermeasure construction project

1.4 PROCESS OF THE STUDY

The study started on May 27, 2010 and will be completed on March 31, 2011 as scheduled, as shown in Table 1.4.1.

Table 1.4.1 Study Period



Work Item		Output
(1) Preparation in Japan (end of May 2010 to beginning of June 2010)		
	1) Understanding of the project	➢ Inception Report
	2) Preparation of Inception Report	
	3) Preparation of monitoring equipment and devices	
(2) First Field Work in Nepal (beginning of June 2010 to middle of September 2010)		
	1) Explanation of and discussion on Inception Report	➢ Consensus with counterpart on plan of study ➢ Topographical map, geological condition ➢ Mechanism of disaster occurrence ➢ Preliminary plan on countermeasure alternatives
	2) Confirmation of background, purpose and contents of the project	
	3) Topographical and geological survey and laboratory test	
	4) Monitoring of slopes	
	5) Study on environmental and social consideration	➢ Preliminary plan on social/natural environment considerations ➢ Current situation of the DOR in terms of road maintenance
	6) Investigation of management and maintenance system of Department of Roads (DOR)	
(3) First Work in Japan (beginning of July 2010 to end of October 2010)		
	1) Analysis and data arrangement of the first work in Nepal	➢ Risk assessment for three sites ➢ Preliminary plan of countermeasure alternatives ➢ Plan of social and environment considerations ➢ Plan of the second work in Nepal
	2) Explanation of result of first work in Nepal	
	3) Preparation for second field work	
(4) Second Field Work in Nepal (beginning of November to beginning of December 2010)		
	1) Field survey	➢ Data necessary to design countermeasures ➢ Confirming the rules and regulations
	2) Planning of temporary works	

	3) Investigation of procurement circumstance	➢ Execution plan ➢ Unit price of countermeasures ➢ Information on procurement
	4) Data collection	
(5) Second Work in Japan (beginning of December 2010 to early March 2011)		
	1) Explanation of outline of second work result in Nepal	➢ Decision on countermeasures ➢ Plan for the countermeasures construction project
	2) Preparation of draft Preparatory Study Report	
(6)Explanation and Conference with Counterpart on the Draft Preparatory Study Report (end of Jan. 2011)		➢ Agreement on survey results
(7) Finalize Preparatory Study Report (March 15, 2011)		➢ Final Report

1.5 STUDY TEAM

The study team was composed of six engineers specializing in slope disaster prevention engineering and one bridge engineer as shown in Table 1.5.1.

Table 1.5.1 Study Team Members and Their Roles

Name	Position/Expertise	Roles
Masatoshi Eto	Team leader/ Slope Countermeasures/ Evaluation of Environmental Effect	1. General management of the Study 2. Coordination with the C/P and related organization 3. First and second field survey 4. Evaluation of environmental effect 5. Investigation of management and maintenance department 6. Explanation of the field survey result 7. Analysis and examination of the field survey result 8. Preparation and explanation of reports
Fumio Nakamura	Design of Slope Countermeasures	1. First and second field survey 2. Analysis and examination of the field survey result 3. Risk assessment of three slopes 4. Planning countermeasure alternatives 5. Execution plan (slope countermeasures) 6. Planning countermeasure construction project 7. Preparation and explanation of reports
Akira Okawara	Investigation of Natural Features (geographical and geological features)	1. First field survey 2. Slope monitoring and data analysis 3. Analysis of field data 4. Analysis of mechanism of disaster occurrence 5. Risk assessment of three slopes
Tomonori Kawabe	Execution and Procurement Plan/Cost Estimation	1. Execution plan 2. Investigation on procurement circumstances 3. Investigation on construction cost 4. Preparation and explanation of reports
Hiroaki Tauchi	Execution Plan of Slope Countermeasures / Cost Estimation	1. First field survey 2. Implementation plan (slope countermeasures) 3. Procurement circumstances (slope countermeasures) 4. Cost estimation 5. Estimation of economic loss induced by disasters
Naoki Kawahara	Assistance and Coordination (Field survey assistance)	1. Procurement of observation equipment and devices 2. Technical assistance to members 3. Project coordination 4. Field survey during rainy season
Tomoyuki Nishikawa	Assistance and Coordination (Field survey assistance)	1. Field survey during rainy season 2. Technical assistance to members 3. Project coordination

CHAPTER 2

RISK ASSESSMENT OF PROJECT SITE

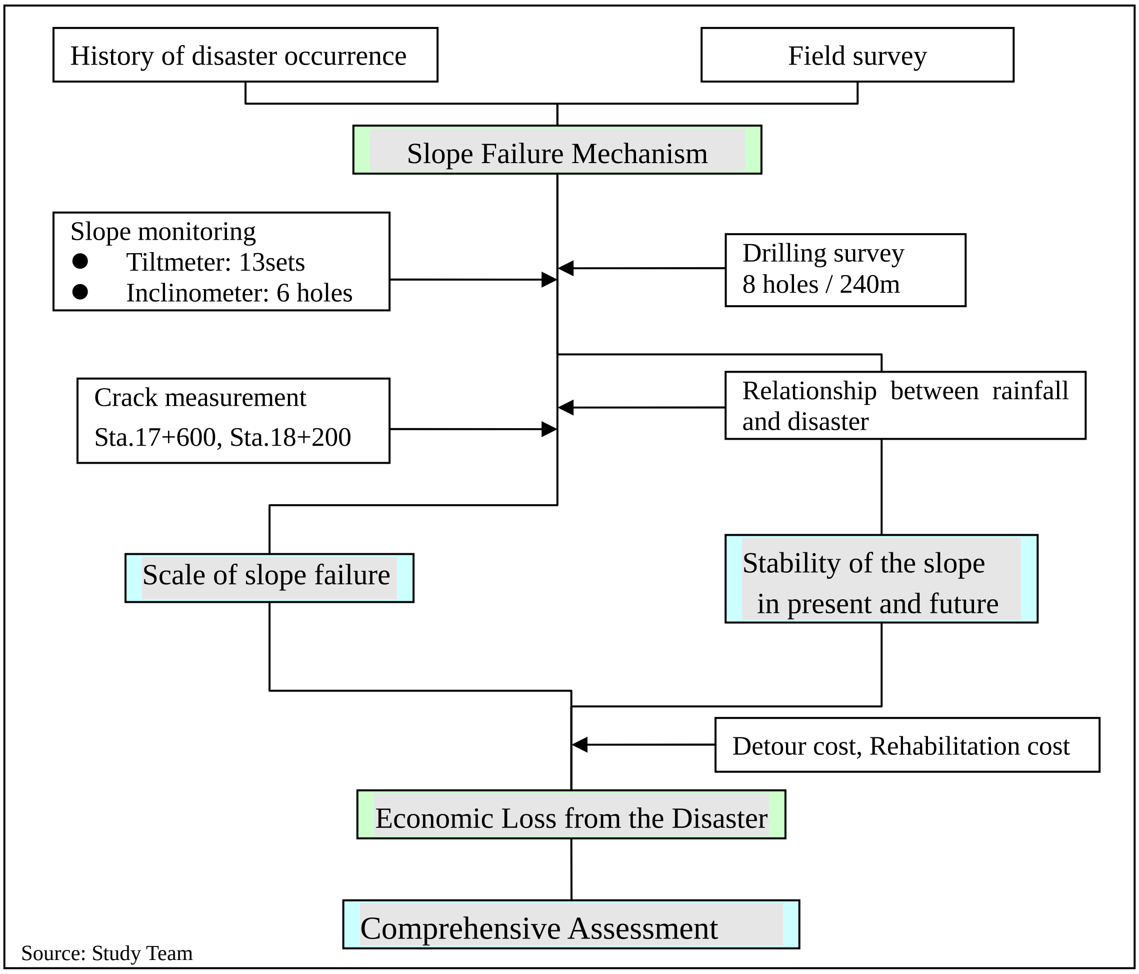
2.1 METHODOLOGY FOR RISK EVALUATION

Risk is defined as the cost to be incurred if landslides should occur at identified sections where preventive countermeasures against landslides are not implemented.

The risk for each slope, Sta.17+400, Sta.17+600 and Sta.18+200, was assessed with the procedure as will be briefly described below and shown in Figure 2.1.1.

First of all, preliminary survey and assessment were carried out such as the field surveys including slope monitoring, geological and topographical surveys; and compilation of the existing information on past slope failures; thereafter primary causes and mechanisms of the past slope failures were examined for planning the subsequent detailed field investigations to be conducted for the Study such as core drilling investigations, slope movement monitoring, crack measurements, topographical surveys and others. Based on the results of these investigations together with an analysis on the correlation between past rainfall and slope failure occurrences, the scale/size and stability of slope failures were comprehensively assessed.

Finally, based on the results of the abovementioned investigations and assessments, risk expressed as “economic loss” was estimated, which consisted of the (1) detour cost and (2) rehabilitation cost.



Source: Study Team

Figurer 2.1.1 Flow of Risk Assessment

2.2 RISK ASSESSMENT FOR TARGET SLOPES

Slope failure mechanism and risk for the studied slopes were assessed as shown in Table 2.2.1.

Table 2.1.1 Risk Assessment for Each Slope

Location		Sta.17+400	Sta.17+600 (a)Failed upper slope	Sta.17+600 (b)Lower slope On end side	Sta.18+200
Failure Mechanism	Topography	Col on narrow ridge	Scarp on head of catch basin	Creeping-deformed slope (flank is steep)	Toe of ridge
	Geology	Highly weathered mica schist /green schist /gneiss	Quartzite schist with dip joints	Quartzite schist with schistosity of opposite dip	Mica and quartzite schist with schistosity of opposite dip
	Disaster type	Intermissive surface collapse	Planar failure and wedge failure /Deformation of the road embankment	Toppling failure	Toppling failure(including partial surface failures)
History of the disaster that occurred		Since June 2003	September 2007 July 2009	September 2007	After November 2003
Result of Monitoring	Tilt-meter	No displacement	Slightly significant accumulated displacement (Rank B)	Small accumulated displacement (Rank C)	Significant accumulated displacement (Rank A,B)
	Inclinometer	No displacement	-	No significant displacement	Accumulated displacement
	Crack	-	Small expansion tendency	-	Significant expansion tendency
Slope Stability		When rain, small-scale surface collapses occur intermittently.	Deformation of the road structure gives signs of destabilization.	Creep is in progress. The failure is likely to occur on the road part.	Expansion of failure and cracks due to rainfall are confirmed.
Predicted failure in the future		If velocity of surface failures is 10cm under one year probable rainfall and 60cm under 5-years probable rainfall, the failure will erode 6 m of the slope and damage the road shoulder in 30 years.	It's difficult to predict the timing of the failure occurrence because accumulated rainfall of over 500mm or earthquake can lead the failure to occur suddenly.	Accumulated rainfall of over 500mm or earthquake might lead the failure as large as that in September 2007 to occur. It's difficult to predict the timing of the failure occurrence.	Cracks expanded about 10mm/month in this rainy season, Therefore, the failure is expected to worsen within a few years.
Impact on traffic		The impact on the road will not start in recent years. The progress of the surface collapse causes the disaster which would block the road for around 1 month in the future.	The progress of deformation affects the road and the road structure directly. The road would be closed around 2monthes.	In case the landslide occurrence forms scarps under the road, the road would be unstable by loosening.	The failure will block the passage for around 1 month.
Priority		C	B	C	A

Source: Study Team

2.2.1 RISK ASSESSMENT OF STA.17+400

(1) History of Disaster Occurrences

After the first failure on June 2003, subsequent failures occurred in July 2004 and August 2005 at the south-facing slope on narrow ridge where Sta.17+400 of the road is located.. The ridge width has narrowed from around 15 m to about 10 m due to these intermittent collapses. Moreover, the road shoulder is likely to be further damaged by future failures. Therefore, the road section was realigned to the north side (mountain side) in 2006. Refer to the Appendix I for details.

(2) Topographic and Geological Condition and Failure Mechanism

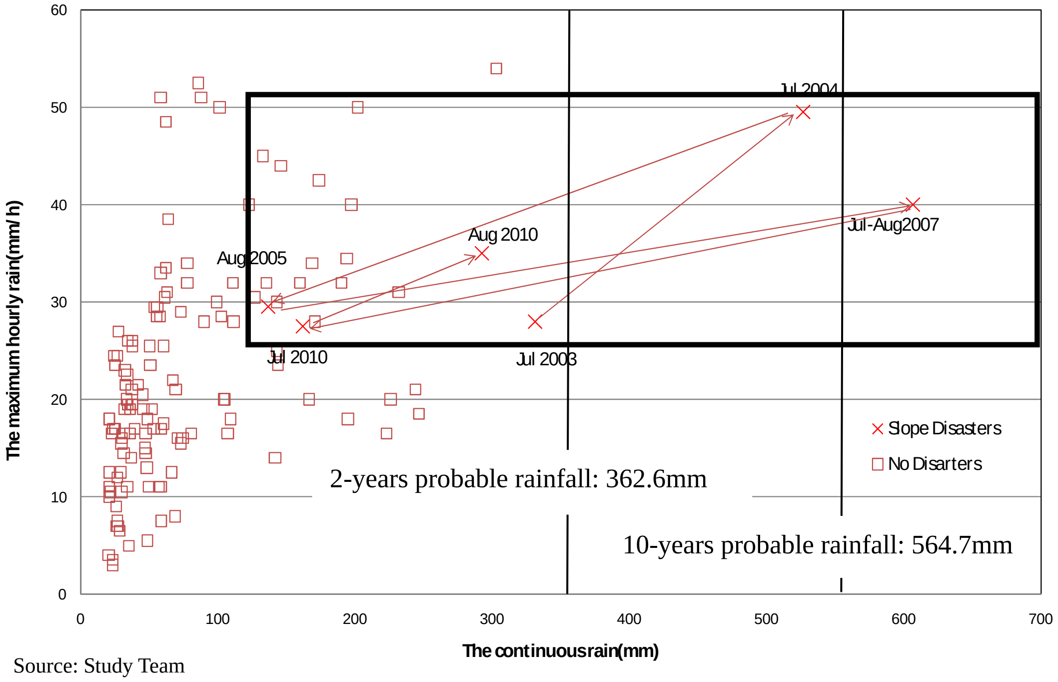
Talus deposit of maximum 10 m in depth is distributed in the lower part of the slope while weathered schist rocks are exposed in the upper part of the slope just below the road. Talus deposit was accumulated due several past failures and surface denudation of highly weathered rocks of the upper part of the slope. Significantly weathered green schist and gneiss are distributed in the area, except for quartzite schist at approximately 10 m stretch of Terai plain side of this section.

(3) Correlation between Disaster Occurrences and Rainfall Intensity

It was observed that: (a) the continuous rainfall of approximately 300 mm recorded every year; (b) when the hourly and continuous rainfalls exceeded 30 mm and 150 mm, respectively, collapses seem to occur; (c) although approximately 50 mm of hourly rainfall has occurred eight times, large-scale collapses occur only when continuous rainfall exceeded 500 mm; (d) the correlation between the hourly rainfall and the collapses was not clearly identified.

Based on the analyses of the correlation between the past rainfalls and velocities of failure, the latter was estimated to be 10 cm/year and 60 cm/year under the condition of one-year probable rainfall and five-years probable rainfall, respectively. In other words, it will take 30 years for the failure to erode approximately 6 m of the slope, consequently reaching and damaging the road section. (Refer to the Appendix III for details)

Figure shows the correlation between disaster occurrences and rainfall intensity.



Source: Study Team

Figure 2.2.1 Correlation between Disaster Occurrences and Rainfall Intensity (Sta.17+400)

(4) Slope Monitoring – Slope Failure Mechanism

The monitoring on slope movement was conducted using two tilt-meters and one borehole inclinometer. Significant displacements were not clearly observed with the devices. However, surface failures have often occurred in rainy seasons (Refer to the Appendix IV for details). It is judged that the failure mechanism is an intermittent surface failure triggered by rainfall.

(5) Scale and Area of Slope Disaster

Because the dip of the schistosity is almost normal to the slope, and low-angle discontinuity planes were not observed on the slope, a large-scale slope failure is not likely to occur. The observation results based on both tilt-meter and inclinometer showed no significant displacements. However, as the rocks of green schist and gneiss are susceptible to weathering, small-scale surface failures are considered to continuously occur with every heavy rainfall.

Table 2.2.1 shows the outline of the site while Figure 2.2.2, Figure 2.2.3 and Figure 2.2.4 present the route map and geological profiles.

Table 2.2.1 Slope Failure Mechanism (Sta.17+400)

Failure Mechanism	Repeat of surface failures on high-weathered part
Geology / Geological structure	・ Mica schist, green schist and quartzite schist. ・ The dip of Schistosity of 40~50-degree eastward is almost normal to the slope in this section.
Primary causes	・Weathered schist is distributed on the arete-like col. ⇒ Schist rocks are erodible and brittle. ・Severely weathered mica schist around the boundary with green schist. ⇒ Green schist is hard and low-permeable; mica schist on the green schist is thus likely to be weathered. ・Topographically, the failure slope is located on the valley head, that is, on the erosion front.
Triggers	・Erosion on the slope surface caused by rainfall ・Earthquake
Full view	

Source: Study Team

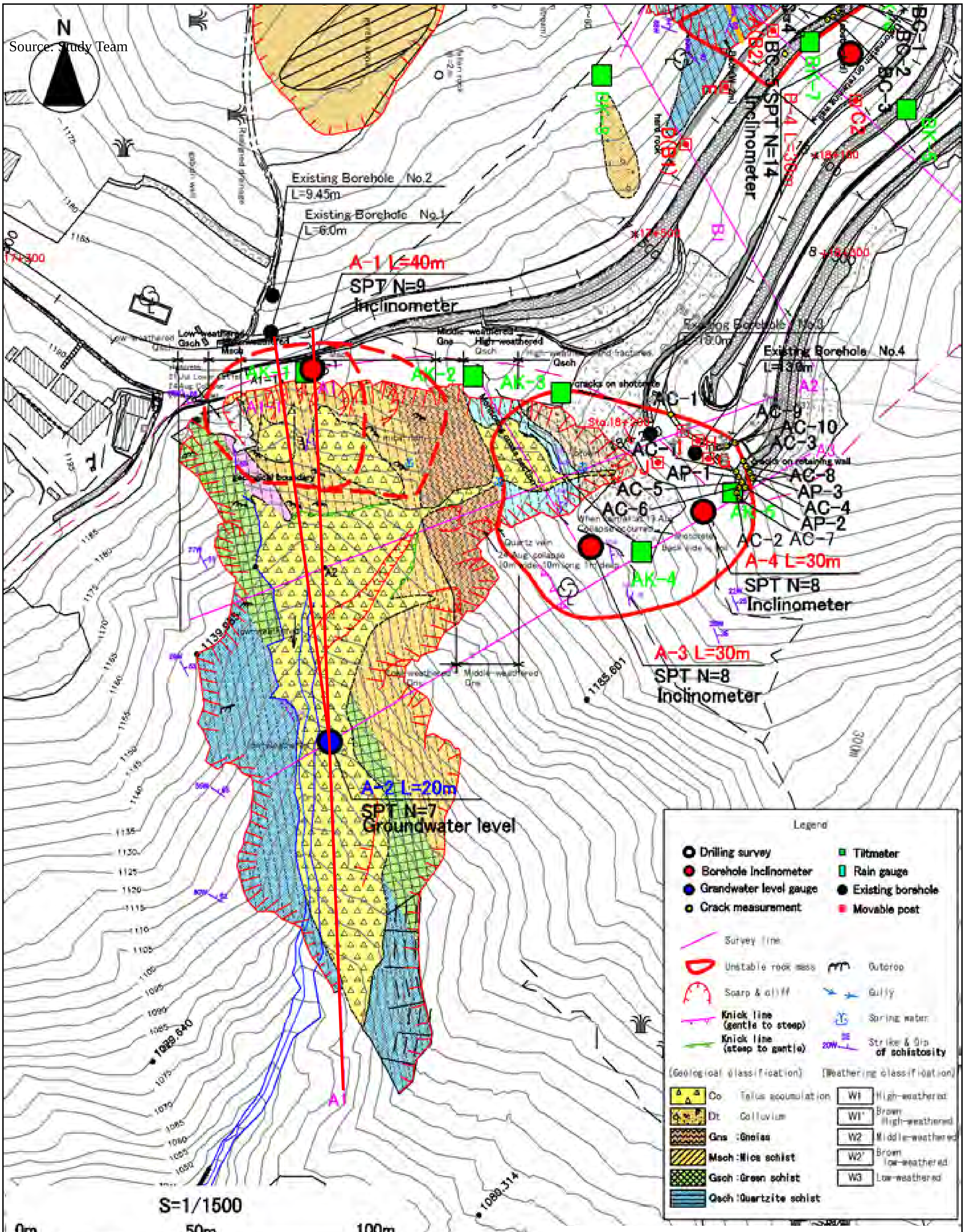


Figure 2.2.2 Route Map of Sta.17+400

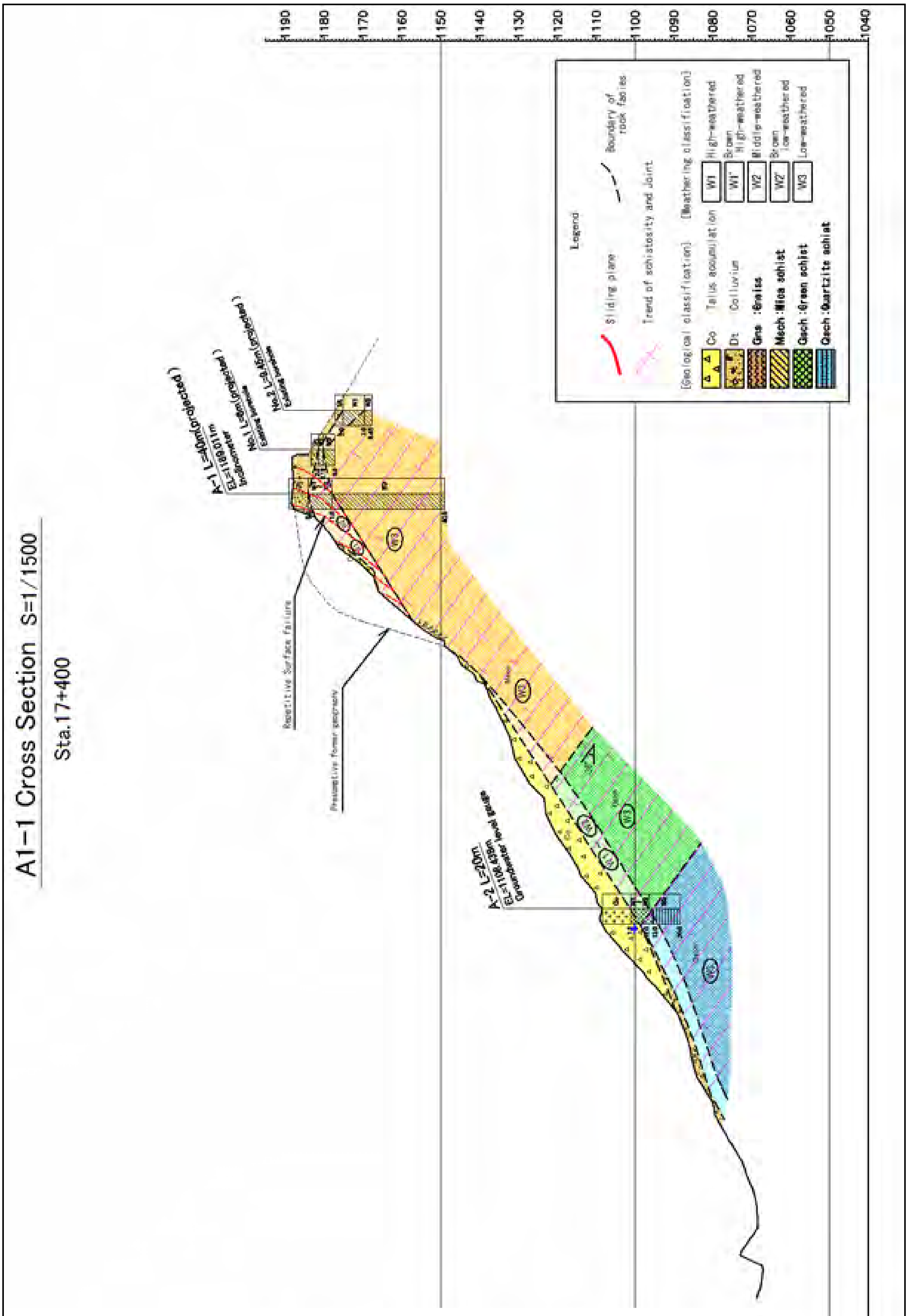


Figure 2.2.3 Geological Profile of Sta.17+400 (A1-1 cross section)

Source: Study Team

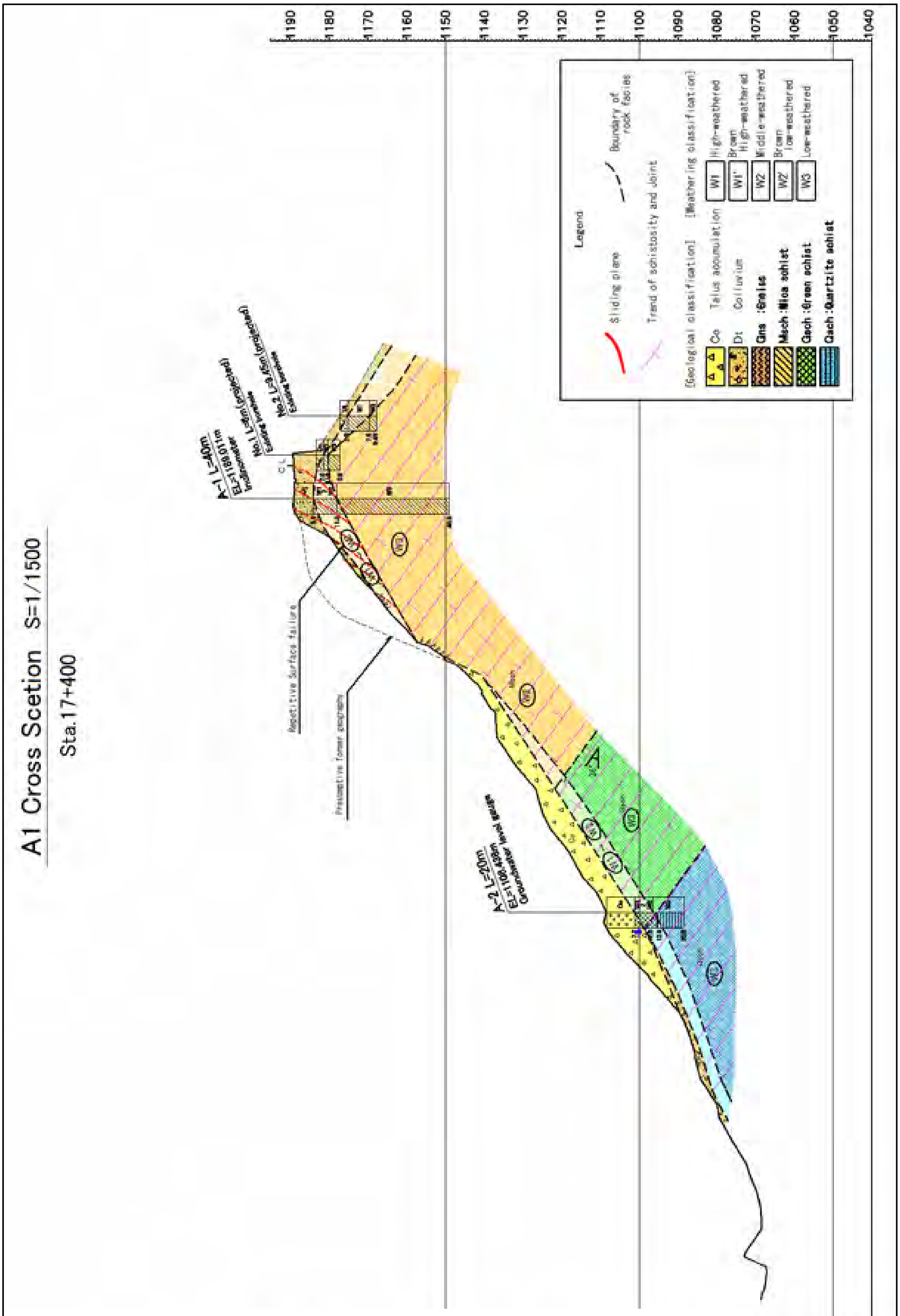


Figure 2.2.4 Geological Profile of Sta.17+400 (A1 cross section)

Source: Study Team

(6) Probability of Disaster Occurrence

The expansion pace of the slope failure is considered to be sluggish and will not totally block the transportation system of the road in the immediate future. However, the failures will eventually reach the road in the future if no countermeasures are implemented. Thus, monitoring of the slope movement/deformation during rainy seasons should be continued and countermeasures against the slope failures should be implemented.

Implementation of countermeasures is also preferable for the purpose of environmental improvement because the slope has been totally deforested and deserted, which has lessened its durability against erosions.

Therefore, the priority of countermeasures is considered as Rank “C”.

2.2.2 RISK ASSESSMENT OF STA.17+600

Unstable areas around Sta.17+600 were confirmed as described below, and shown in Figure 2.2.5.

a) A scarp just below Sta.17+600 of the road, including related structures such as road surface and retaining wall,
b) A loosened zone consisting of weathered and bended rocks below the road on Kathmandu side,
c) A landslide on the foot of the slope below the road next to the slope failure,
d) Upper slope of Sta.17+600.

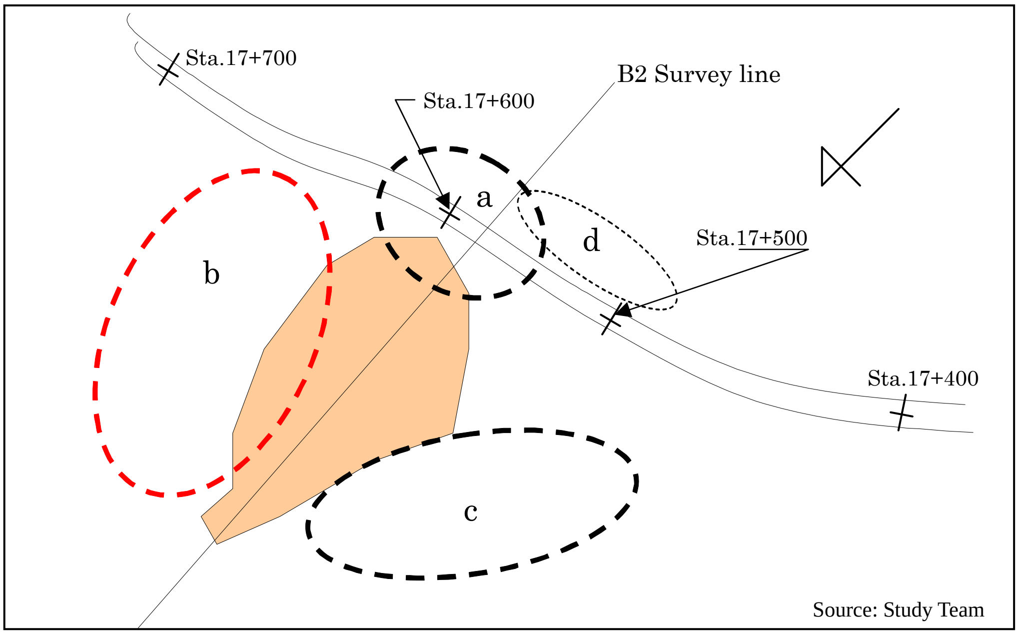


Figure 2.2.5 Schematic View of Sta.17+600

(1) History of Disaster Occurrences

A failure with a scale of approximately 70 m wide and 90 m long has first occurred below said area of the road in August 2007. Other failures affected the road in September of the same year, when cracks appeared on the road surface and the retaining wall built on the mountain side. Thereafter, hair cracks were observed in July 2009 in the same section. (Refer to the Appendix I for details.)

(2) Topographic and Geological Condition, and Failure Mechanism

a) Scarp just below the road of Sta.17+600

Quartzite and sandy schist are distributed around Sta.17+600. On the whole, it is hard and dense, but the high-angle schistosity oblique to the slope, and the sheeting joints parallel to the slope have developed. For this reason, the slope is characterized by a structure where planar and wedge failures are likely to occur. This pair of schistosity and joint has caused the occurrence of cracks on the road surface.

b) Loosened zone below Sta.17+620.

The loosened zone of the schist has been creeping due to toppling phenomenon, moving towards Terai plain side and valley direction. It resulted in progressive weakening and therefore has become unstable. On the other hand, this part serves as counterweight against possible landslide of the rock slope overlying this loosened zone.

c) Landslide landform below Sta.17+500.

The obvious landslide-mass is distributed on the lower slope below the road section at Sta.17+500. The slope is gentle in the head of the landslide while the ridge along its centre terminates at the gentle slope. Although detailed geological surveys such as drilling survey and movement monitoring were not carried out, it appears that the landslide consists of soil and rocks as its topography is relatively gentle.

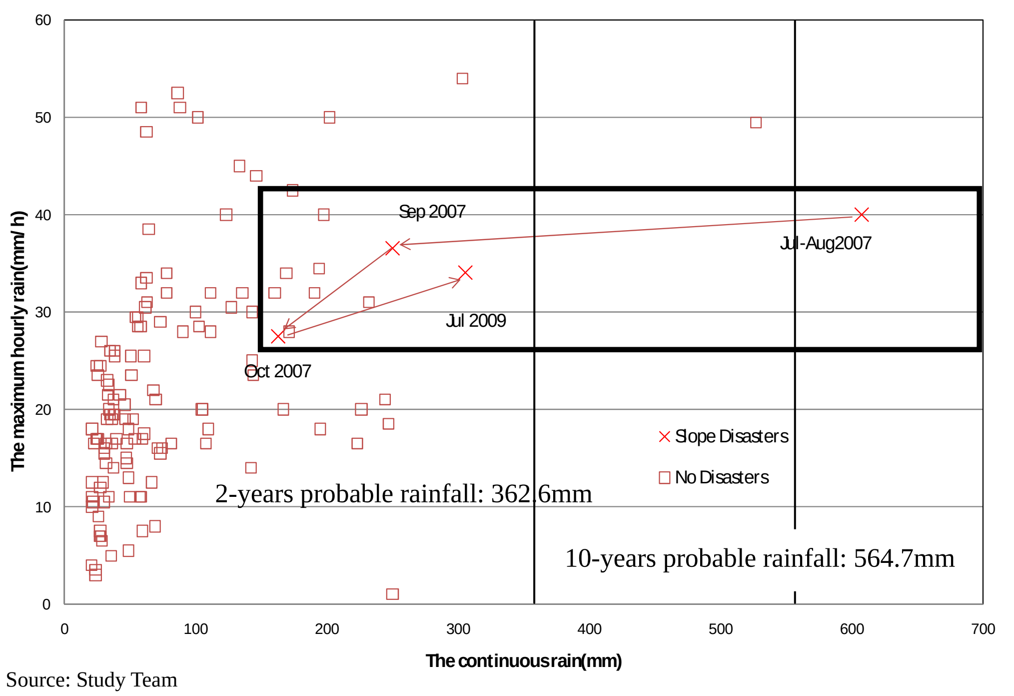
d) Upper slope of Sta.17+600.

It has been observed that ground water is springing out of the retaining wall and the mountain side slope at the vicinity of Sta.17+500 in rainy seasons. These phenomena will possibly affect the stability of the upper slope of Sta.17+600.

(3) Correlation between Disaster Occurrences and Rainfall Intensity

Between July and August 2007 when the continuous total rainfall reached 607 mm, the first large collapse occurred. Subsequently, small collapses occurred with continuous rainfall of approximately 150 to 300 mm. Although an hourly rainfall of around 50 mm took place eight times, no collapse occurred. The correlation between the hourly rainfall and the collapses was not clearly understood. It is also noted that there were no incidents of collapse during this study period.

Figure 2.2.6 shows the Correlation between disaster occurrences and rainfall intensity.



Source: Study Team

Figure 2.2.6 Correlation between Disaster Occurrences and Rainfall Intensity (Sta.17+600)

(4) Slope Monitoring

a) Scarp just under Sta.17+600 of the road

No significant displacements were observed using all the monitoring devices. On the other hand, a significant tendency of expansion was confirmed based on the measurements of cracks on the road and the retaining wall above the scarp. A significant accumulative tendency was also confirmed during the monitoring with tiltmeter. Considering these observations, signs of instability are confirmed. (Refer to the Appendix IV for details).

The failure type is considered to be that of a wedge failure in rock slope, where micro-deformation by gravity will continue and accumulate. Consequently, this may result in sudden occurrences of slope failures, particularly triggered by heavy rainfalls or larger scale earthquakes.

b) Loosened zone below Sta.17+620.

No significant expansion tendencies of tension cracks on the head of the loosened zone were confirmed from the field observations. However, a slight accumulative displacement was confirmed with the tilt meter. Therefore, it is considered that destabilization of the whole slope will become significant, which may lead to large scale failures. (Refer to the Appendix IV for details.)

In case the slope collapses, a cliff will appear just below the road, similar to the case of the failure that occurred in September 2007. This will result in an unstable condition of the road due to further loosening of the newly formed cliff.

c) Landslide landform below Sta.17+500.

The landslide movement/displacement monitoring was not conducted in this study. Based on field observation of micro landslide topographies, no cracks were identified on the landslide surface. It is therefore assumed that landslide is dormant.

d) Upper slope of Sta.17+600.

The movement/deformation monitoring of the retaining wall was not conducted in this study. However, no cracks and damages of significant sizes were observed from field inspection. Therefore, it is considered that deformation of the retaining wall will not be significant in the future.

(5) Scale and Area of Slope Disaster

The outline of the three sites, except for Site d in Figure 2.2.5 where slope failures are not likely to occur, is shown in Table 2.2.2, Table 2.2.3 and Table 2.2.4.

Meanwhile, Figure 2.2.7, Figure 2.2.8 and Figure 2.2.9 show the route map and geological profiles.

Table 2.2.2 Slope Failure Mechanism (Sta.17+600: Beginning Side)

Failure Mechanism	Planar failure and wedge failure
Geology / Geological Structure	・Schistosity of the quartzite schist is almost normal to the slope. Schistosity dips 40~50-degrees toward eastern direction (Kathmandu direction) ・Sheeting joints dipping out of the slope face
Primary Causes	・Surface water tend to concentrate in the catchment area formed such as the valley as a whole, ・Sheeting joints dipping out of the slope face. ⇒ The slides on slip plane along joints tend to occur.
Triggers	・ Collapses on the foot of the slope and rainfall ・ Continuous gravity action ・ Earthquake
Full View	

Source: Study Team

Table 2.2.3 Slope Failure Mechanism (Sta.17+620: End Side)

Failure Mechanism	Toppling failure
Geology / Geological Structure	・Schistosity of the quartzite schist is almost normal to the slope. Schistosity dips 40~50 degrees toward the eastern direction (Kathmandu direction)
Primary Causes	・The creep deformation by toppling phenomenon in the whole lower slope has become evident. ⇒ Weathering and loosening in rock slope tend to further develop. ・Progress of creep deformation has become evident in the lower slope; rock has been completely fractured at the toe of the slope.
Triggers	・ Rainfall and the collapses on the flank cause destabilization of the loosened zone. ・ Heavy rainfall causes the failure in loosened zone, and the road above this zone also collapses due to the removal of the counterweight at the toe.
Full View	

Source: Study Team

Table 2.2.4 Slope Failure Mechanism (Sta.17+600: Landslide at the Beginning Side)

Failure Mechanism	Landslide
Geology / Geological Structure	Schistosity of quartzite schist is oblique to the slope face. The detailed survey for failure mechanism is necessary
Primary Causes	･The whole slope shows a typical landslide topography. ･The toe of the landslide faces a failure slope which is fractured.
Triggers	･The whole landslide slope becomes unstable during heavy rains. ･A collapse for the flank of the failure slope causes destabilization of the landslide. ･At present, significant deformations are not observed and slope is generally stable against landslides.
Full View	

Source: Study Team

Source: Study Team

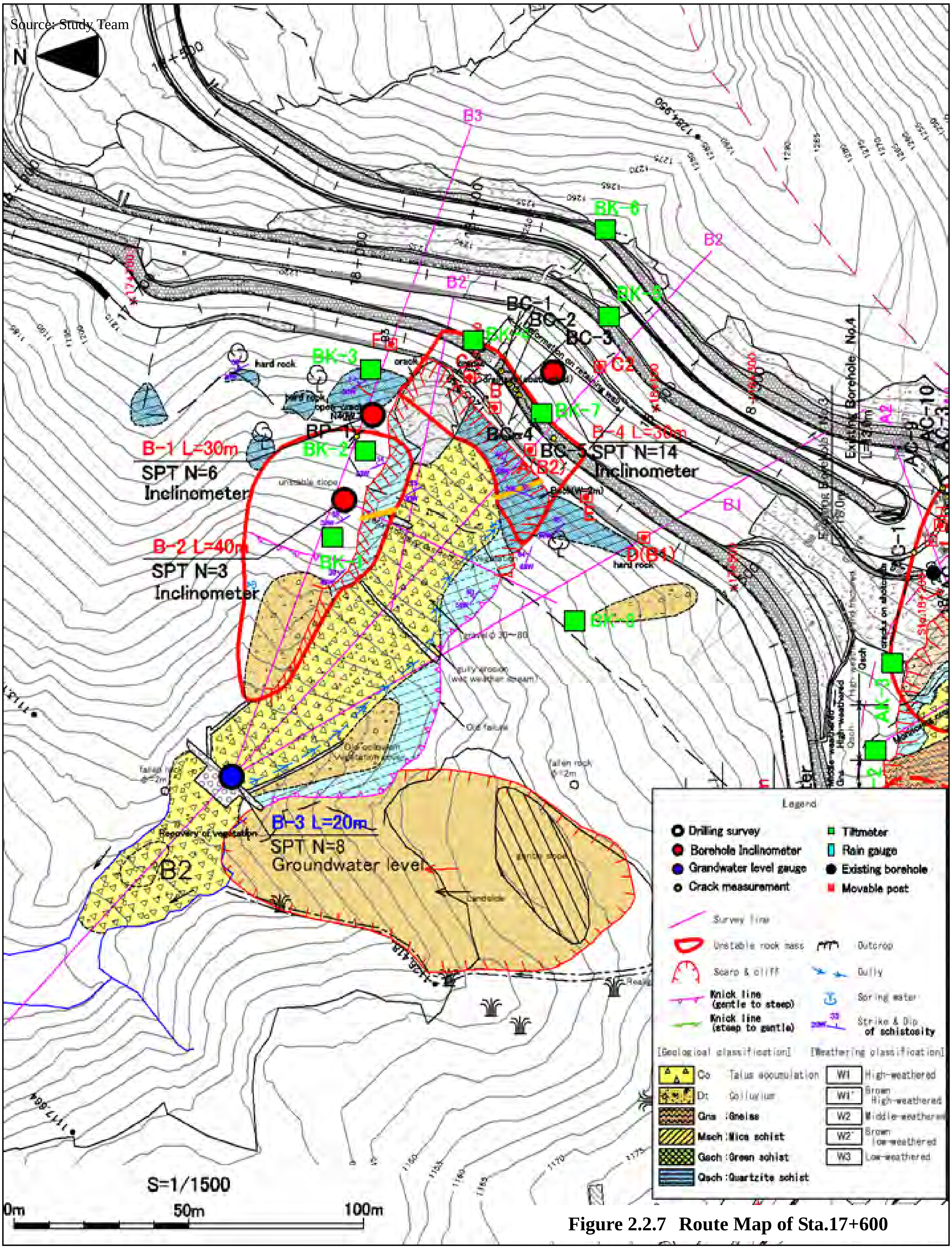
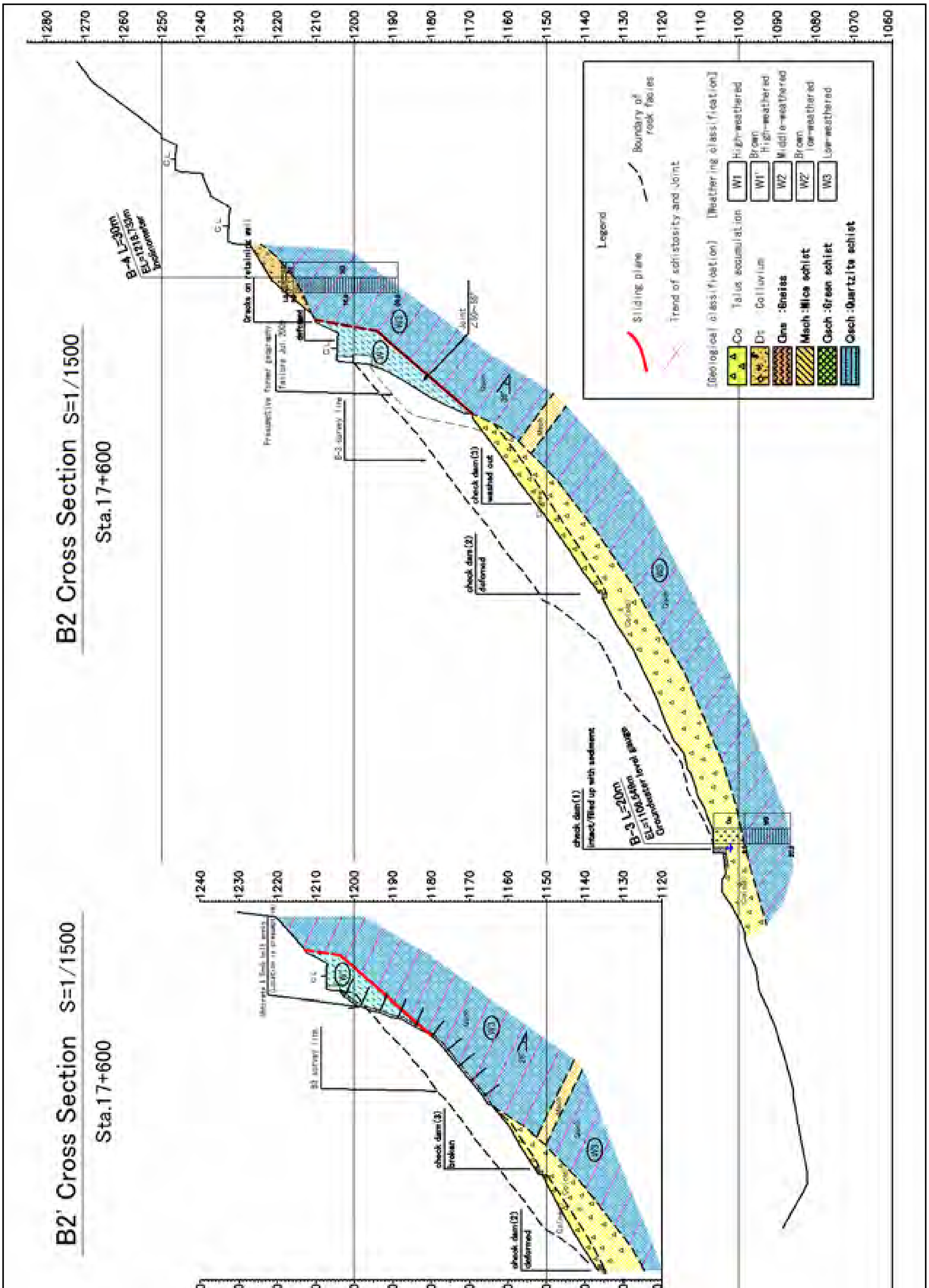


Figure 2.2.7 Route Map of Sta.17+600



Source: Study Team

Figure 2.2.8 Geological Profile (Sta.17+600: Beginning Side)

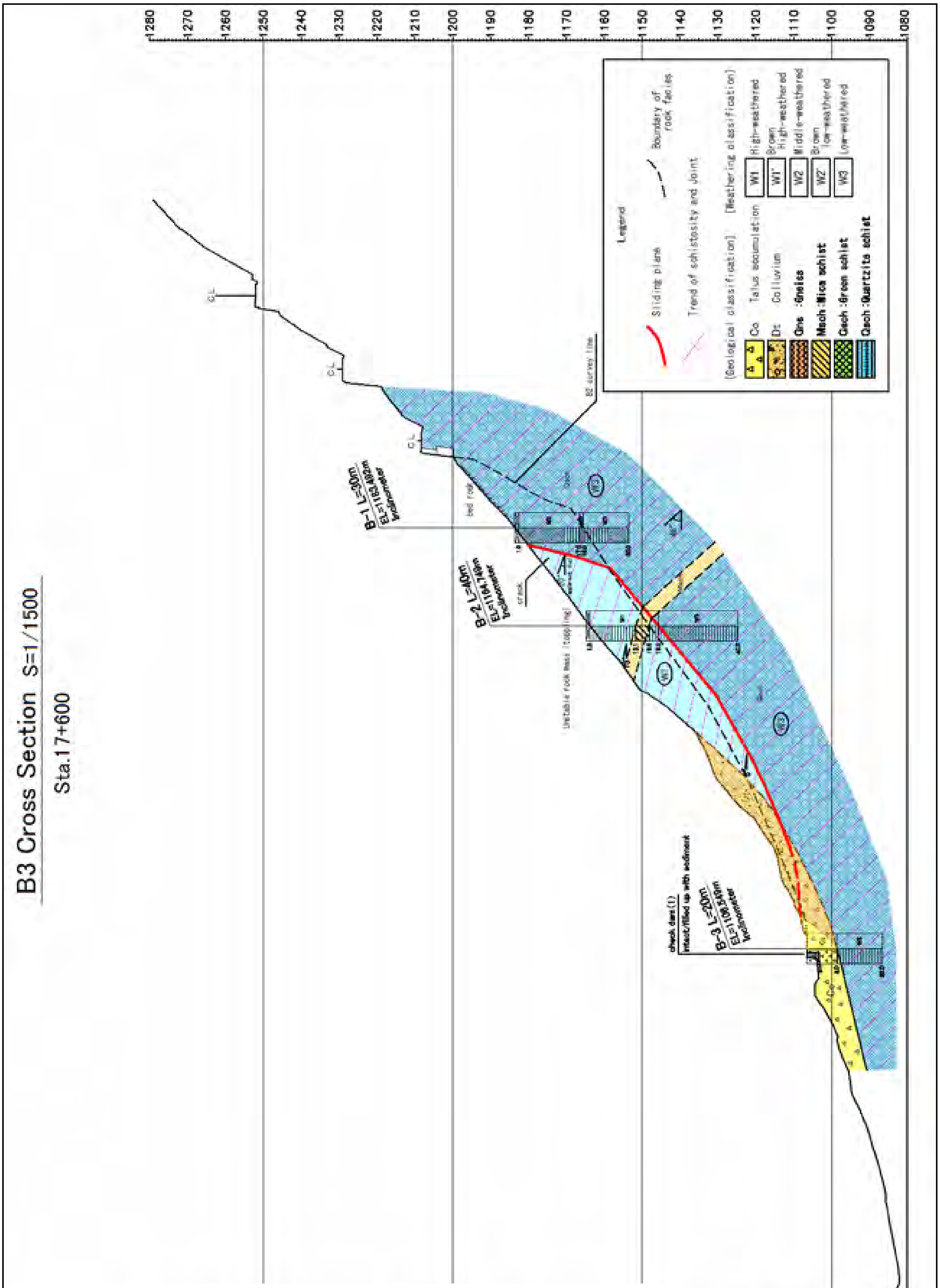


Figure 2.2.9 Geological Profile (Sta.17+600: End Side)

Source: Study Team

(6) Probability of Disaster Occurrence

a) Scarp just under Sta.17+600 of the road

In case that the slope, including the road in the vicinity of Sta.17+600, should collapse, realignment of the road to the mountain side will not be possible since its other section runs through a slope above Sta.17+600. Thus, excavation of the slope for such realignment will reach the other section of the road above. Therefore, stabilization of the landslide itself is necessary without realigning the road at this section.

No significant displacements on the slope were observed in the rainy season experienced during the study period. Thus, it appears that this part is temporarily in a balanced state. However, since the rock slope has become unstable due to past slope failures, heavy rains or earthquake may trigger sudden slope failures in the future.

Therefore, the priority of the countermeasures is assessed as Rank B.

b) Loosened zone below Sta.17+620.

Loosened zone on the lower slope below the road is assumed to be stable at present. A large-scale crack, however, has developed on the head of the zone, and therefore, a heavy rain or earthquake may cause further slope failures. This zone is considered to serve as an important counterweight against landslide of the upper slope, where another section of the road is located. Therefore, stabilization of the loosened zone itself will be necessary.

Therefore, the priority of the countermeasures is assessed as Rank C.

c) Landslide landform below Sta.17+500.

The landslide is also considered to be stable at present. However, in case the landslide should occur at the foot of the slope, another landslide may be triggered at the upper slope overlying the lower slope. Consequently, the road section constructed on the upper slope will be damaged. Therefore, similar to the case of the loosened zone, provision of countermeasures should be executed.

d) Upper slope of Sta.17+600.

The retaining wall has not been damaged totally. However, spring water has been observed through the retaining wall after every rainfall. Considering the long-term stabilization, failure of the retaining wall is likely to occur as the ground water may deteriorate the geological conditions. Therefore, similar to the case of the other sites, provision of countermeasures should be executed.

2.2.3 RISK ASSESSMENT OF STA.18+200

(1) History of Disaster Occurrences

In 2003, cracks appeared on the slope just below the road in 2003, as well as on the road in 2005. In 2006, the road was realigned by about 6 m toward the mountain side. Loss of rock slope and cracks on the retaining wall have occurred after such realignment.

(2) Topographic and Geological Condition and Failure Mechanism

The site is located on the toe of the ridge. The rock slope consists of quartzite schist, which has creep deformation due to toppling. This could possibly cause slope failure triggered by heavy rainfalls or large scale earthquakes.

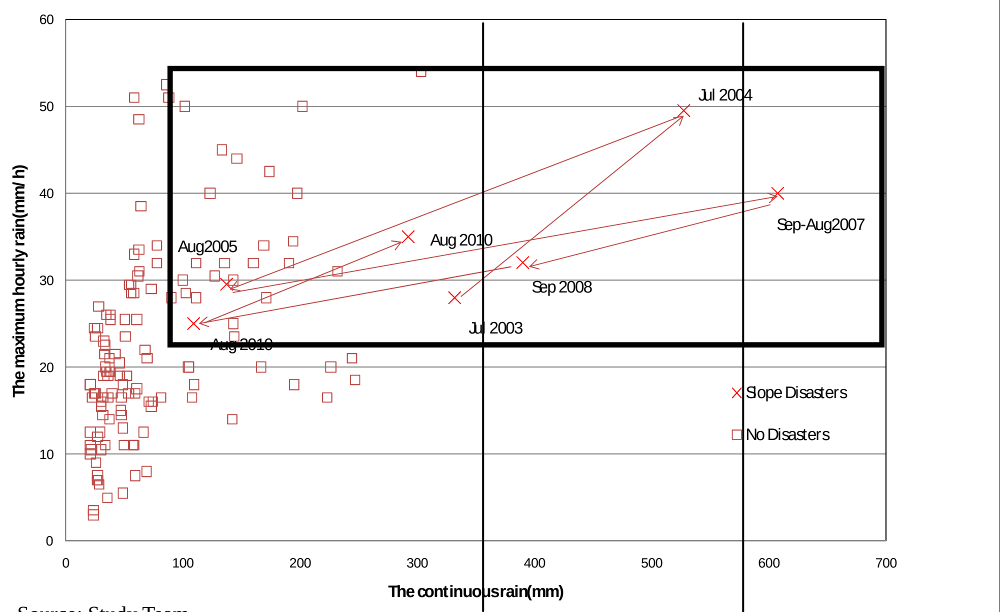
(3) Correlation between Disaster Occurrences and Rainfall Intensity

When hourly and continuous rainfall exceed 30 mm and 150 mm, respectively, collapses tend to occur. In particular, large collapses take place when continuous rainfalls exceed 500 mm.

Approximately 50 mm of the hourly rainfall has occurred eight times. However, collapse occurred only once when the continuous rainfall exceeded 500 mm.

The correlation between the hourly rainfall and the collapse were not clear.

Figure 2.2.10 shows the correlation between disaster occurrences and rainfall intensity.



Source: Study Team

Figure 2.2.10 Correlation between Disaster Occurrences and Rainfall Intensity (Sta.18+200)

(4) Slope Monitoring

Monitoring of crack widths on the retaining wall was conducted using a manual measuring device. Displacement/movement of the slope was measured using tiltmeters and inclinometers. The result of crack monitoring showed a tendency of crack expansions to a maximum of 20 mm, which was identified within two months from June to August. The monitoring results with the tilt meter and inclinometer exhibited significant accumulated displacements of the landslide. (Refer to the Appendix IV for details.)

(5) Scale and Area of Slope Disaster

The area where deformations have become evident is approximately 50 m wide and 50 m long below the road section. It is judged that the slope could likely fail due to heavy rainfalls, in particular. Countermeasures, therefore, should be implemented. The outline of the site is shown in Figure 2.2.11 and Figure 2.2.12. Figure 2.2.13 meanwhile shows the route map and geological profiles.

Table 2.2.5 Slope Failure Mechanism (Sta.18+200)

Failure Mechanism	Toppling failure
Geology/Geological Structure	• Quartzite schist・Gneiss • Stratum of opposite dip
Primary Causes	・Located on the toe of the ridge ⇒ Weak against weathering and deformation by gravity. ・Toppling failure on whole schist slope with schistosity dipping steeply in to the slope. ⇒ Susceptible to weathering and loosening of rock slope. ・Quartzite schist on the steep cliff has been severely weathered by the past failure along the cracks; on the highest part it has decomposed into soil. ・Weathering and creep deformation have progressed at the southern slope next to the past failure .
Triggers	・Destabilization of the rock slope by loosening of materials caused by rainfall. ⇒ Collapses occurred on the lower shotcrete slope due to heavy rains ・Earthquake
Full View	

Source: Study Team

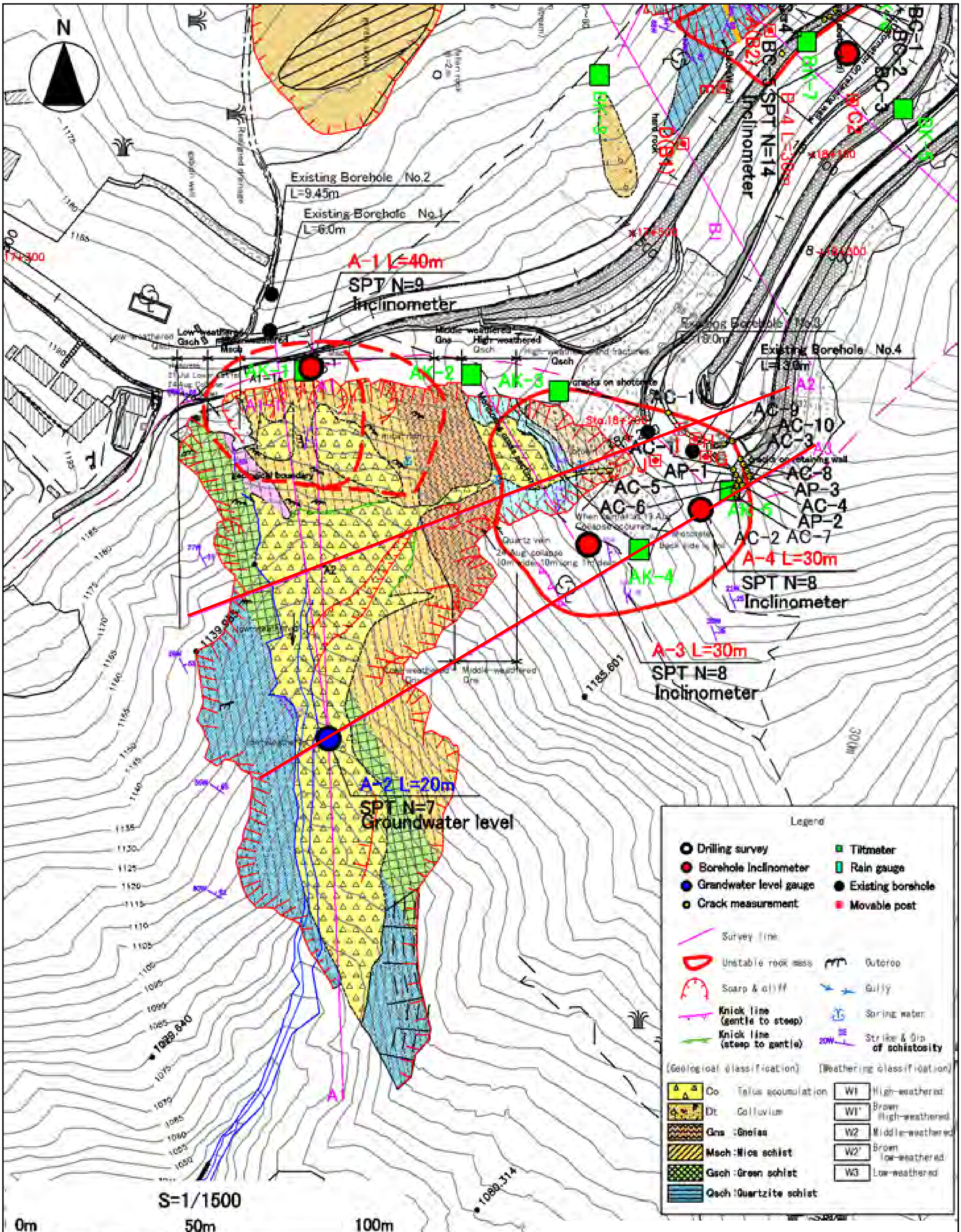


Figure 2.2.11 Route Map of Sta.18+200

Source: Study Team

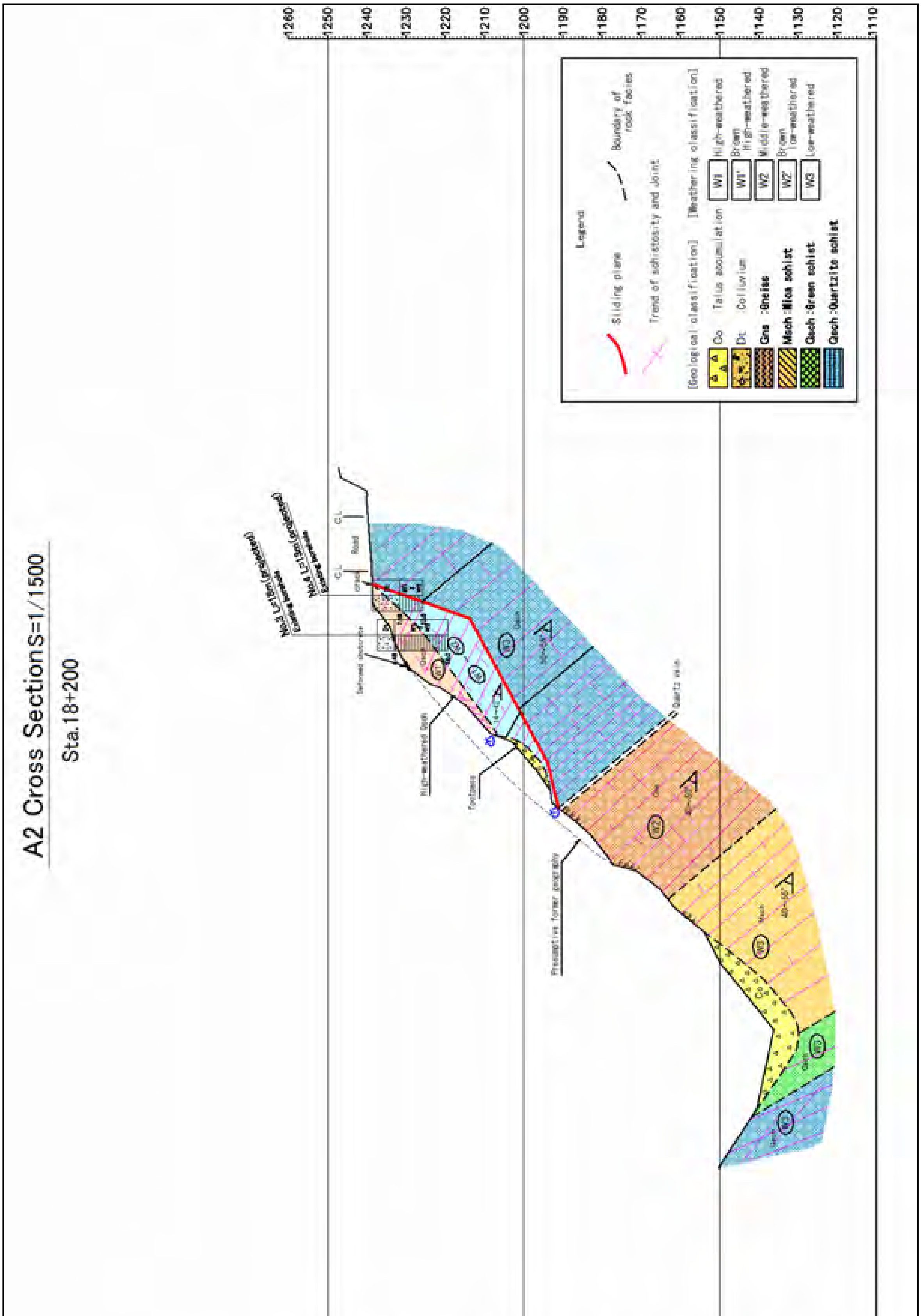


Figure 2.2.12 Route Map and Geological Profile of Sta.18+200 (A2 cross section)

Source: Study Team

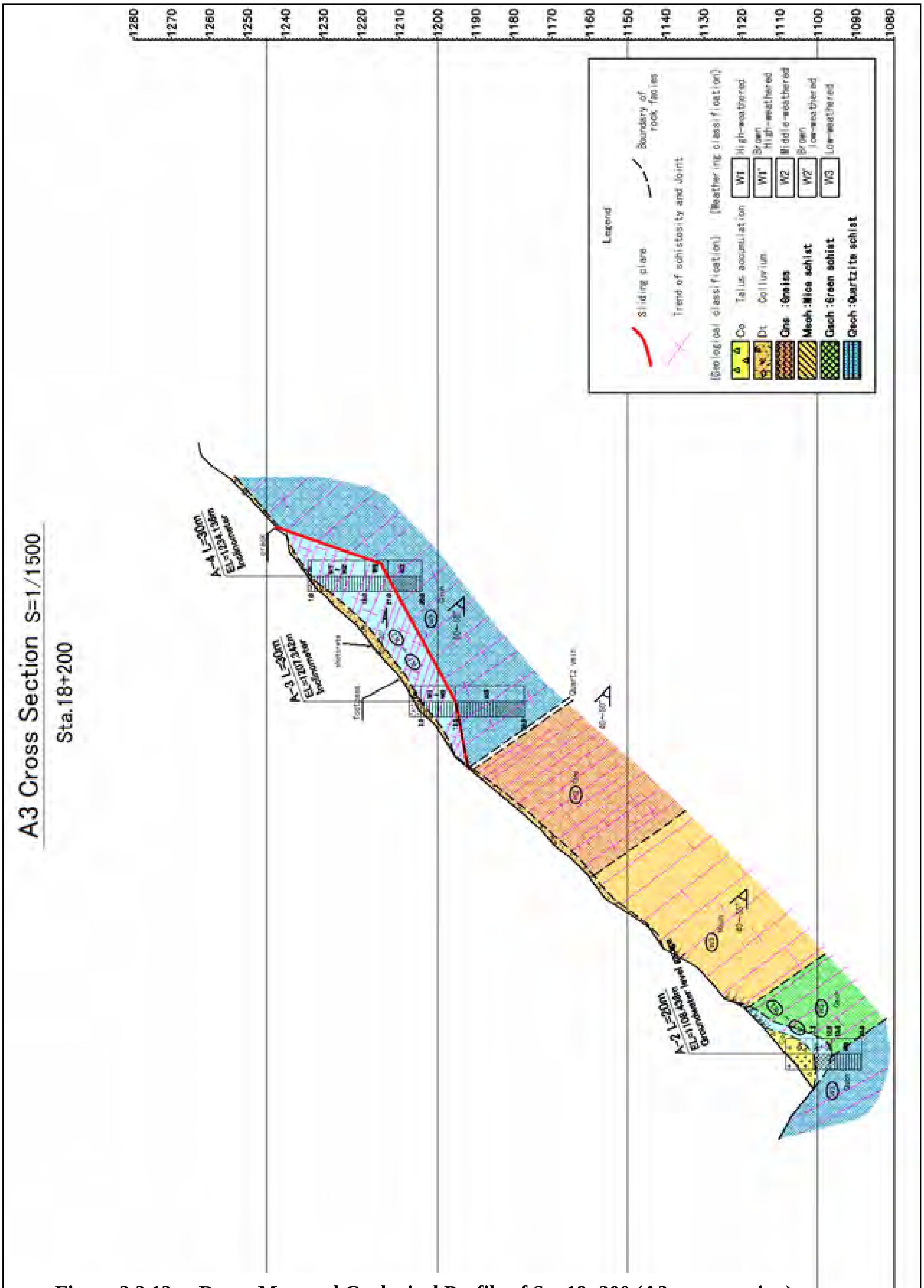


Figure 2.2.13 Route Map and Geological Profile of Sta.18+200 (A3 cross section)

Source: Study Team

(6) Probability of Disaster Occurrence

The toppling failure of Sta.18+200 has become evident. Displacements measured using monitoring devices (tilt meter and inclinometer) were not confirmed in the dry season. while expansion of cracks after rainfall was confirmed during the rainy season. It is judged therefore that the slope has become unstable and countermeasures against slope failure should be constructed immediately.

Therefore, the priority of countermeasures is considered as Rank A.

2.3 RISK ASSESSMENT OF ROAD SLOPE DISASTERS

2.3.1 OUTLINE OF RISK ASSESSMENT

Road slope disaster risk is evaluated in this report using risk indicators to determine potential annual loss of a site (ALp). In general, risk is considered as the product of frequency and magnitude. Potential Frequency of Road Closure Disaster (FRCDp) is an index which shows the frequency element of risk while potential loss of a site (Lp) is an index showing the magnitude element of risk.

Relation of the indicators is shown in Figure 2.3.1 below.

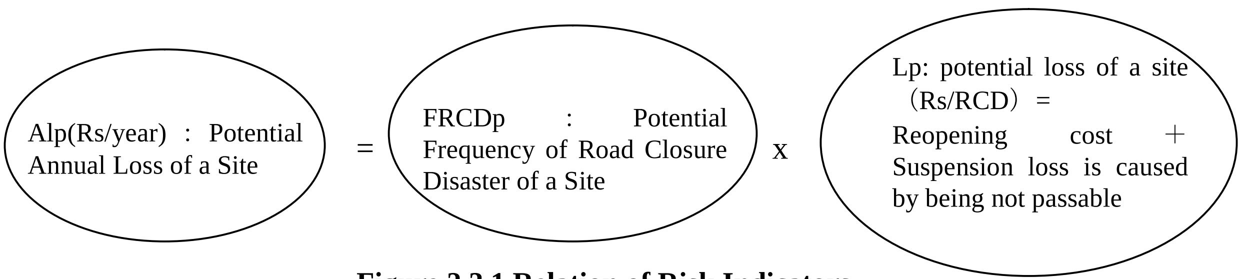


Figure 2.3.1 Relation of Risk Indicators

(1) FRCDp

FRCDp of the sites are as follows based on the analysis of rainfall return period and past disaster occurrence:

Table2.3.1 Frequency of Disaster at the Sites

Site	Probability Year of Disaster	FRCDp (1/year)
Sta.17+400	30 years	0.033
Sta.17+600	10 years	0.1
Sta.18+200	5 years	0.2

Source :Study Team

(2) Lp

Lp is composed of two elements namely, reopening cost (RC) and detour loss (DL).

(3) Estimation of the Reopening Cost

The scales of landslide are evaluated based on the result of field survey and the monitoring.

The evaluated scales of landslides are shown in Table 2.3.2.

Table 2.3.2 The Scale of the Landslides

Station	width	length	depth
Sta.17+400	40	40	15
Sta.17+600	55	20	10
Sta.18+200	65	70	20

Source: Study Team

The reopening works are as follows:

・Sta.17+400 : Because failure surface is gentle and the road damage is assumed partially, a reinforced soil wall, which is often used along the Sindhuli Road, is installed.

・Sta.17+600 : The failure surface slide is steep and the reopening using the reinforced soil wall is difficult. Alternative plan by providing embankment on the valley side requires an enormous volume, consequently extending the reopening period. Therefore, provision of bridge is applied as the reopening method.

・Sta.18+200 : the road is realigned on the mountain side.

The reopening periods and the roughly estimated reopening costs are shown in Table 2.3.3.

Table 2.3.3 Reopening Costs and Periods

Station	Unit	Quantity	Unit Price	Reopening Period	Reopening Cost (Million Rs)*1	Remarks*2
Sta.17+400	m^3	2,400	5,000	30	12	L= 40m, W=4m, H=15m
Sta.17+600	m^2	560	350,000	60	196	L=70m, W=8m
Sta.18+200	m^3	30,000	4,000	30	120	L=50m, W=20m, H=30m

*1: It is makeshift reopening cost.
*2 : L: Length W: width H: height

Source: Study Team

(4) Detour Loss of a Road Closure Disaster

The detour loss of a road closure disaster was estimated using the following equation.

DL＝VOC× （L1-L2） ×AADT×Dr

Where:

DL: Detour Loss

UVOC: Unit Vehicle Operation Cost of a Vehicle per km (Rs/vehicle/km)

L1：Distance（Kathmandu～Narayangadh～Hetauda～Bardibas） 350km

L2：Distance（Kathmandu～Dhulikhel～Khurkot～Bardibas） 195km

AADT：Average Annual daily traffic（vehicles/day）

Dr；The reopening period（days）

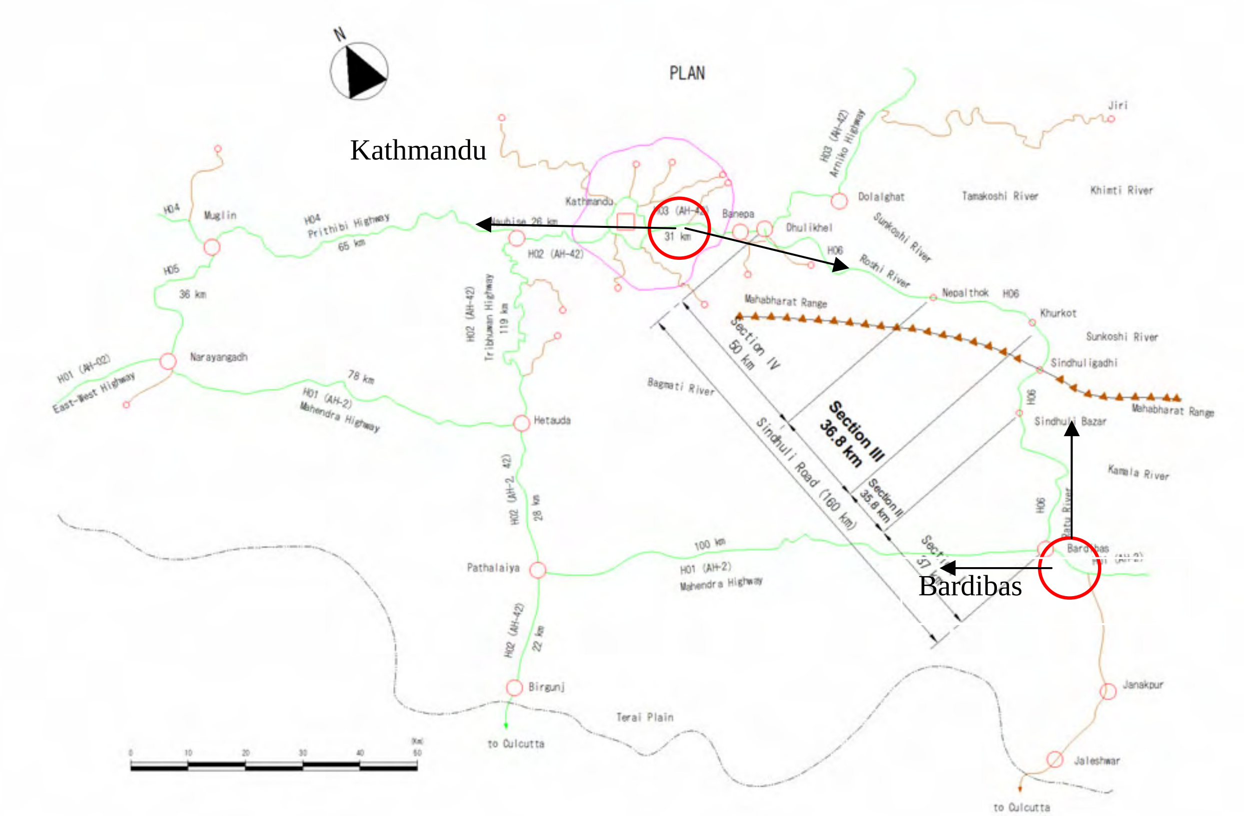


Figure 2.3.2 Location Map Source: Study Team

Unit vehicle operation cost (UVOC) is referred from The Study on Disaster Risk Management for Narayagharh-Muguling Highway Final Report, Feb. 2009. The UVOC adopted was set with due consideration of inflation rate. which is 30Rs/km/ vehicle as shown in Table 2.3.5.

Table 2.3.4 Vehicle Operation Cost

Road section No.	Road section name	Road section length:		Unit vehicle operation cost	
		Symbol	(km)	Symbol	(Rs/km)
1	Mugling - Narayangharh	RSL_1	38.0	$UVOC_1$	24.19
2	Mugling - Naubise	RSL_2	94.8	$UVOC_2$	22.37
3	Naubise - Hetauda	RSL_3	106.5	$UVOC_3$	28.49
4	Hetauda - Narayangharh	RSL_4	76.8	$UVOC_4$	21.07
5	Mugling-Pokhara	RSL_5	90.5	$UVOC_5$	22.37
6	Pokhara-Butawal	RSL_6	159.1	$UVOC_6$	28.49
7	Butawal-Narayangharh	RSL_7	113.7	$UVOC_7$	22.03

source: The Study on Disaster Risk Management for Narayagharh-Muguling Highway Final Report Volume Ⅲ, Feb 2009

Table 2.3.5 Inflation Rate and UVOC adopted

Year	domestic	oversea	AVE	UVOC
2007	100	100	100	24
2008	108	103	106	26
2009	122	100	111	25
2010	136	101	119	30

Source: Study Team

The numerical data used in the estimation is as follow:

Table 2.3.6 Average Annual Daily Traffic (AADT)

Item	Numerical number (vehicle/day)	Remarks
AADT	Bardibas traffic intersection（to Sindhuli）3229	The transport demand forecasting in 2018*1
	Dhulikhel traffic intersection（to Sindhuli）7232	The transport demand forecasting in 2018

Source Preliminary study report on the project for construction of Sindhuli Road (Section III) in Nepal Dec 2007

Potential losses due to a road closer disaster (RCD) are calculated as shown in Table 2.3.7.

Table 2.3.7 Potential Losses of a RCD

site	Detour Loss of a RCD（million Rs）	Reopening cost of a RCD（million Rs）	Potential Loss of a RCD（million Rs）
Sta.17＋400	1,399	12	1,411
Sta.17＋600	3,729	196	3,925
Sta.18＋200	1,399	120	1,519

Source: Study Team

(5) Alp

Values of Alp, which is the product of FRCDp and Lp is shown Table 2.3.8.

Table 2.3.8 Potential Annual Loss of a Site (Alp)

site	Potential Loss of a RCD（LP）（million Rs）	Potential Frequency of Road Closure Disaster of a site (FRCDp)	Potential Annual Loss of a Site（ALp）（million Rs）
Sta.17＋400	1,411	0.033	47
Sta.17＋600	3,925	0.1	393
Sta.18＋200	1,519	0.2	304

Source: Study Team

CHAPTER 3

PLANNING OF COUNTERMEASURE

3.1 POLICY ON PLANNING COUNTERMEASURES FOR TARGET SLOPES

Risk evaluation of the slope disasters around Sta. 17+400, Sta. 17+600 and Sta. 18+200 indicated that road traffic functions would be seriously affected if these slope disasters were left uncontrolled or unprotected with adequate preventive measures. Countermeasure alternatives have been examined to maintain sustainable road traffic function with the following policies:

A) Level of effectiveness: Permanent countermeasures will be introduced to keep long-term stability of the target road sections or slopes;

B) Application of preventive methods or works commonly used in Nepal: Preventive methods that are technically feasible in Nepal will be applied as much as possible;

C) Environmental consideration: The planned countermeasures are implemented to improve road slope hazards. However, the construction of these countermeasures may also have some impact on the natural and social environment especially during construction. These environment impacts should be minimized and mitigated in planning and selecting countermeasures; and

D) Economics and safety of countermeasure construction: Countermeasures should be selected and planned in view of costs of construction and maintenance as well as safety and difficulty of construction.

3.2 COUNTERMEASURES FOR STA. 17+400 AREA

3.2.1 PRESENT SLOPE CONDITION

The road slope hazard around Sta. 17+400 is due to a 40 m high steep slope of 40 to 70 degrees. The slope is composed of mica schist whose bedding schistosity is almost orthogonal to slope surface. The mica schist was strongly weathered. In addition, no adverse geological structures which are likely to cause large-scale slope failure were observed. It was thus considered that the road slope hazard was surface collapse mainly due to weathering and subsequent erosion.

The lower part of the target road slope seems to be more highly susceptible to erosion and collapse especially under the influence of heavy rainfall. This would in turn affect the stability of its upper slope, consequently damaging the stability of the road slope or section (refer to 2.2.1: Risk Assessment of Sta. 17+400).

3.2.2 STUDY ON ALTERNATIVE COUNTERMEASURES

Based on the hazard and risk assessment around Sta. 17+400 stated above, it is necessary to protect the road slope from further instability, including its steep upper part and lower part. In order to secure safe operation of the road, the following three alternatives were conceivable as protective countermeasures for Sta. 17+400 (see Volume II: Figures 2 to 8):

- Plan I: Shotcrete with rock bolt and gravity-type retaining wall for the steep upper slope; and check dams, open ditch and underdrainage for the lower slope.

Table 3.2.1 Outline of Countermeasures for Sta.17+400 Area; Plan I

Method	Unit	Quantity	Specification
A) For the upper steep slope			
Shotcrete	m^2	1,490	t=10mm
Rock bolt works	m	1,119	ϕ =28.5,L=3.0m
Scaffolding	m^3	261	W=1.0m
Guard fence	m	63	H=5.0m
Gravity-type retaining wall	m	14	H=5.0m Foot of Shotcrete
Gabion wall	m^3	24	H=2.0m base of Gravity-type retaining wall
B) For the lower slope			
Check dam	m^3	500	H=5.0m
Open ditch	m	10	
Underdrainage	m	113	ϕ =600mm
Catch basin	No.	1	
Tree Planting	m^2	2,010	

- Plan II: Retaining wall and shotcrete with rock bolt works for the steep upper slope; and check dams, open ditch and underdrainage for the lower slope.

Table 3.2.2 Outline of Countermeasures for Sta.17+400 Area; Plan II

Method	Unit	Quantity	Specification
A) For the upper steep slope			
Shotcrete	m^2	1,580	t=10cm
Rock bolt works	m	1,185	D=19.L=3.0m
Scaffolding	m^3	5,390	W=4.5m
Gravity-type retaining wall	m	51	H=5.0m Middle area of the upper steep slope
Guard fence	m	70	H=2.0m
B) For the lower slope			
Check dam	m^3	470	H=5.0m
Open ditch	m	351	
Underdrainage	m	17	

Catch basin	Nos	11	
Vegetation mat	m^2	1,600	
Tree Planting	m^2	1,770	

- Plan III: Gabion wall and masonry retaining wall for the steep upper slope; and check dams, open ditch and underdrainage for the lower slope.

Table 3.2.3 Outline of Countermeasures for Sta.17+400 Area; Plan III

Method	Unit	Quantity	Specification
A) For the upper steep slope			
Gravity-type retaining wall	m	18	H=5.0m , Foot of Gabion wall
Gabion wall	m^3	2,290	H=5.0m∗6steps
Mortar masonry wall	m^2	1,090	t=50cm, 2 steps
Guard fence	m	72	H=2.0m
B) For the lower slope			
Check dam	m^3	500	H=5.0m
Open ditch	m	120	Including longitudinal drainage(110m)
Underdrainage	m	113	ϕ =600mm
Catch basin	No.	1	
Tree Planting	m^2	1,700	

Based on the site inspection conducted after planning of countermeasures, the construction of gravity-type retaining wall under Plan II was considered very difficult because surface undulation of the wall construction line was sharp. Plan II was thus excluded from comparison with the other plans.

The layout and standard section for each plan is shown in Volume II: Figures 2 to 9. The technical and economical comparison is explained below and summarized in Table 3.2.4.

Table 3.2.4 Comparison of Countermeasure Alternatives for Sta. 17+400

Evaluation Item	Plan I	Plan II	Plan III
1) Effectiveness	3	-	3
2) Direct Cost	2	-	3
3) Construction Difficulty	3	-	2
4) Construction Safety	3	-	2
5) Maintenance Difficulty	1	-	2
6) Application of Nepal Methods	1		3
7) Environmental Impact	1		2
Total Points	14	-	17

Judgment point: Excellent: 3, Good: 2, Fair: 1

Plan I was more preferable than Plan III in terms of direct cost, construction difficulty and construction safety. However, the construction of countermeasures in Plan I seemed to have more environmental impacts than in Plan III. Besides, Nepal has limited experience in the construction of shotcrete with rock bolts as in Plan I.

As a result of comparative evaluation, Plan III is technically and economically recommended for Sta.17+400.

3.2.3 OUTLINE OF COUNTERMEASURES

The planned countermeasures (Plan III) for Sta. 17+400 included two parts, namely, the countermeasures for the steep upper slope between elevations 1,140 m and 1,180 m, and the countermeasures for the lower slope below elevation 1,140 m. These are summarized in Table 3.2.2. (see Volume II: Structural Drawing Figures 7 to 9).

A) Countermeasures for the upper slope

The planned countermeasures for the upper slope are as follows:

- Gravity-type retaining wall: H=5 m, L=18 m, constructed around EL=1,140 m. This wall was planned to stabilize the lowest part of gabion walls;
- Six steps of gabion walls from EL 1,145 m to 1,175 m. These walls were applied to protect the main part of the steep upper slope; and
- Two steps of masonry retaining walls from EL 1,175 m to 1,188 m. These walls were planned to protect the most critical part of the upper slope just below the target section.

Because of steep slope and fragile foundation condition, these structures should be constructed carefully under strict construction supervision.

B) Countermeasures for the lower slope or valley

Since the lower slope was covered with thick unstable talus deposits, the countermeasures for the lower slope was mainly planned to protect the foot area of the steep upper slope. The planned countermeasures for the lower slope are as follows:

- Underdrainage and open ditch (169 m + 6 m): The underdrainage is connected to the existing outlet of the road side ditch. The underdrainage was planned for the removal of surface water collected around the road and for the reduction of the underground water table of the steep upper slope.
- Two gabion check dams (32 m + 18 m): The gabion check dams were planned to control the unstable colluvial deposits.

- Planting works: 1,700 m^2 is planed to reduce erosion of surface and improve environment of the valley.

3.3 COUNTERMEASURES FOR STA. 17+600 AREA

3.3.1 PRESENT SLOPE CONDITION

Sta. 17+ 600 area was subdivided into four unstable zones in terms of their hazards as shown in Figure 2.2.5 (refer to Clause 2.2.2 Risk Assessment of Sta. 17+600).

- Zone a: Just below the road, the collapse area occurred in 2007.

- Zone b: Below the road at the east of Sta. 17+600, potential unstable mass composed of loosened and fractured rocks, and loose deposits due to toppling. The zone functions as a counterweight of the upper slope.

- Zone c: Below the road at the west of Sta. 17+600, potential landslide mass is stable at present. Once the zone becomes active, the northern slope of Sta. 17+400 would become unstable and subsequently slide down.

- Zone d: Above the road from Sta. 17+520 to Sta. 17+600, numerous sprint spots were observed in this zone.

3.3.2 STUDY ON ALTERNATIVE COUNTERMEASURES

Once the road section around Sta. 17+600 is damaged by slope failure, it is very difficult to realign the road towards the mountainside because Sta. 17+600 is located at the lowest section of the ascending zigzag route to Sta. 18 +200.

In order to maintain the traffic operation on the road, countermeasures for Sta. 17+600 area have been planned to cover all four unstable zones (a, b, c and d).

The following three alternatives are conceived as protective countermeasures for Sta. 17+600 (refer to Volume II: Figures 10 to 18).

- Plan I: Two steps of high reinforced counterweight fill to protect zone (b) and the lower part of zone (c), anchor works for zone (a), and shotcrete for zone (d).

Table 3.3.1 Outline of Countermeasures for Sta.17+600 Area; Plan I

Method	Unit	Quantity	Specification
A) For the deformed slope of zone (a) just below the road			
Anchor works (1)	m	619	F20UA,@3.0m,2steps,L=13.5~14.0m,
Plastering Concrete work (1)	m^2	663	t=40cm
Anchor works(2)	m	525	F70UA,@3.0m,2steps,L=12~13.0m

Plastering Concrete work (2)	m^2	391	t=60cm
Rock bolt works	m	861	D=19,@2.0m,L=3.0m
Shotcrete	m^2	1,148	t=10cm
Scaffolding	m^3	7,368	W=4.5m
B) For the lower slopes of zones (b) and (c)			
Counterweight fill (1) from 18+200	m^3	36,100	
Counterweight fill (2) from borrow site	m^3	20,000	
Vegetation mat works	m^2	5,610	
Gravity-type retaining wall	m	30	H=5.0m
Gabion wall	m	3,370	H=2.0m
Check dam	m^3	30	H=3.0m
Underdrainage	m	200	ϕ=600mm
Open ditch	m	1,400	W=300mm
C) For the mountain side slope of the road, zone (d)			
Shotcrete	m^2	2,145	t=10cm
Road for construction	m	686	W=4.0m

- Plan II: One step of high reinforced counterweight fill to protect zone (b) and the lower part of zone (c), anchor works for zone (a), and shotcrete for zone (d).

Table 3.3.2 Outline of Countermeasures for Sta.17+600 Area; Plan II

Method	Unit	Quantity	Specification
A) For the deformed slope of zone (a) just below the road			
Anchor works (1)	m	619	F20UA,@3.0m,2steps,L=13.5~14.0m,
Plastering Concrete work (1)	m^2	663	t=40cm
Anchor works(2)	m	966	F100UA,@3.0m,4steps,L=10~13.0m
Plastering Concrete work (2)	m^2	731	t=60cm
Rock bolt works	m	1,320	D=19,@2.0m,L=3.0m
Shotcrete	m^2	1,759	t=10cm
Scaffolding	m^3	9,940	W=4.5m
B) For the lower slopes of zones (b) and (c)			
Counterweight fill (1) from 18+200	m^3	37,000	
Counterweight fill (2) from borrow site	m^3	20,000	
Vegetation mat works	m^2	6,760	
Gravity-type retaining wall	m	30	H=5.0m
Gabion wall	m	3,370	H=2.0m
Check dam	m	30	H=3.0m
Underdrainage	m	200	ϕ=600mm
Open ditch	m	1,250	W=300mm
C) For the mountain side slope of the road, zone (d)			
Shotcrete	m^2	2,145	t=10cm
Road for construction	m	686	W=4.0m

- Plan III: One step of low reinforced counterweight fill to protect zones (b) and (c), anchor works for zone (a), anchor works for extended area of zone (c), and shotcrete for zone (d).

Table 3.3.3 Plan III -Outline of Countermeasures for Sta.17+600 Area

Method	Unit	Quantity	Specification
A) For the deformed slope of zone (a) just below the road			
Anchor works (1)	m	619	F20UA,@3.0m,2steps,L=13.5~14.0m,
Plastering Concrete work (1)	m^2	663	t=40cm
Anchor works(2)	m	966	F100UA,@3.0m,4steps,L=10~13.0m
Plastering Concrete work (2)	m^2	731	t=60cm
Anchor works(3)	m	1,540	F100UA,@3.0m,8steps,L=13.5~21.0m
Plastering Concrete work (3)	m^2	740	t=60cm
Rock bolt works	m	1,320	D=19,@2.0m,L=3.0m
Shotcrete	m^2	1,760	t=10cm
Scaffolding	m^3	12,240	W=4.5m
B) For the lower slopes of zones (b) and (c)			
Counterweight fill (1) from 18+200	m^3	3,000	
Counterweight fill (2) from borrow site	m^3	20,000	
Vegetation mat works	m^2	2,720	
Gravity-type retaining wall	m	30	H=5.0m
Gabion wall	m	2,290	H=2.0m
Check dam	m^3	30	H=3.0m
Underdrainage	m	190	ϕ=600mm
Open ditch	m	650	W=300mm
C) For the mountain side slope of the road, zone (d)			
Shotcrete	m^2	2,145	t=10cm
Road for construction	m	686	W=4.0m

The layout and standard section for each plan are shown in Volume II: Figures 10 to 18. The technical and economical comparison is explained below and summarized in Table 3.3.4.

Table 3.3.4 Comparison of Countermeasure Alternatives for Sta. 17+600

Evaluation Item	Plan I	Plan II	Plan III
1) Effectiveness	3	3	3
2) Direct Cost	3	2	1
3) Construction Difficulty	3	2	1
4) Construction Safety	3	2	2
5) Maintenance Difficulty	2	2	1
6) Application of Nepal Methods	1	1	1
7) Environmental Impact	3	2	1
Total Points	18	14	10

Judgment point: Excellent: 3, Good: 2, Fair: 1

Because of steep slope and space constraints, advanced methods of landslide protection, such as high reinforced counterweight fill or anchor works, were introduced as primary countermeasures for Sta. 17+600.

As a result of comparative evaluation as shown in Table 3.3.4 above, Plan I was technically and economically recommended. In addition, considering the lack of construction experience in

Nepal, these works should be executed by an experienced international construction company.

3.3.3 OUTLINE OF COUNTERMEASURES

The planned countermeasures (Plan I) for Sta. 17+600 are summarized in Table 3.3.2 and explained as follows:

- Anchor works, including ground anchor and rock bolt, for the deformed slope of zone a just below the road: The ground anchor works were planned to strengthen the exiting road structure and road embankment, while the rock bolt works were used to protect the foot part of the anchored areas.
- There are two steps of high reinforced counterweight fill for zones a and b. This work was planned to stabilize the lower part of zone a just below the road and the lower slope of zone b. The materials to be excavated from the cut slope were suggested to be used as embankment material.
- The counterweight fill is strengthened by reinforcement materials in every 2m. And, under drainages are laid on the base of the fill.
- A gravity type concrete wall is constructed to stabilize the foot of the fill.
- Protection by shotcrete for the mountain side slope.

3.4 COUNTERMEASURES FOR STA. 18+200 AREA

3.4.1 PRESENT SLOPE CONDITION

The road slope hazard around Sta. 18+200 is due to a steep slope of the ridge which is underlain by quartzite schist. The road slope hazard started from topping failure in 2003 and then developed into a large-scale slope failure involving the originally constructed road in 2005. Accordingly, the road was shifted toward the mountainside about 6 m in 2006. Moreover, slope monitoring during the rainy season of 2010 showed that a potentially unstable area around Sta. 18+200, approximately 50 m wide and 50 m long, including the existing road center, was still active (refer to 2.2.3 Risk Assessment of Sta. 18 +200).

The road slope hazard was the most critical section within the survey area. The early implementation of suitable preventive works was required in order to maintain safe operation of the road.

3.4.2 STUDY ON ALTERNATIVE COUNTERMEASURES

Based on the risk assessment of Sta. 18+200, the following three alternatives are conceived as protective countermeasures for Sta. 18+200 (see Volume II: Figures 19 to 25):

- Plan I: Realignment of the existing road towards the mountainside at around 10 m.

Table 3.4.1 Outlines of Countermeasures for Sta.18+200 Area; Plan I

Method	Unit	Quantity	Specification
Earth removal works of road slope	m^3	37,6 00	
Rock net	m^2	920	
Masonry retaining wall	m	125	H=5.0m, t=50cm
Tentative protection fence	m	192	H=5m
Slope shaping	m^2	2,820	
Shotcrete (1) at slope	m^2	1,070	t=10cm
Shotcrete (2) at valley	m^2	130	t=10cm
Open ditch	m	600	
Tree Planting	m^2	920	
Road realignment	m	142	

- Plan II: Stabilization of the unstable slope using anchor works.

Table 3.4.2 Outlines of Countermeasures for Sta.18+200 Area; Plan II

Method	Unit	Quantity	Specification
Earth removal works	m^3	80,000	
Shotcrete at slope	m^2	490	t=10cm
Vegetation works	m^2	3,130	t=3cm
Anchor works	m	4,080	F50UA
Plastering concrete	m^2	2,070	t=50cm
Scaffolding	m^3	11,010	6,050 m^3+4,960 m^3
Shotcrete	m^2	1,740	t=10cm
Rock bolts	m	2,175	L=5.0m
Road realignment	m	76	
Masonry retaining wall	m	36	H=5.0m

- Plan III: Stabilization of the unstable slope using pile works.

Table 3.4.3 Outlines of Countermeasures for Sta.18+200 Area; Plan III

Method	Unit	Quantity	Specification
Earth removal works	m^3	80,000	
Shotcrete at slope	m^2	490	
Vegetation works	m^2	3,130	T=3cm
Caisson pile	m	255.5	ϕ =4000mm
Road realignment	m	76	
Masonry retaining wall	m	36	H=5.0m

The layout and standard section for each plan is shown in Volume II: Figures 19 to 25. The technical and economical comparison is explained below and summarized in Table 3.4.4.

Table 3.4.4 Comparison of Countermeasure Alternatives for Sta. 18+200

Evaluation Item	Plan I	Plan II	Plan III
1) Effectiveness	3	3	3
2) Direct Cost	3	2	1
3) Construction Difficulty	3	1	1
4) Construction Safety	3	1	1
5) Maintenance Difficulty	3	2	2
6) Application of Nepal Methods	2	1	1
7) Environmental Impact	2	1	3
Total Points	19	11	12

Judgment point: Excellent: 3, Good: 2, Fair: 1

In general, Plans II and III were indented to stabilize the unstable area by using structures in order to maintain the existing road alignment; while Plan I was intended to avoid the road slope hazard by realigning the existing road towards the stable mountainside. In addition, Plans II and III were not only very costly but also required high-level experience for construction of such structures. Furthermore in Plan I, the excavated rock and deposits could be used as embankment materials. This would reduce construction costs and also mitigate environmental impacts.

As a result of the comparative evaluation, Plan I was technically and economically recommended for Sta. 18 + 200.

3.4.3 OUTLINE OF COUNTERMEASURES

The planned countermeasures (Plan I) for Sta.1 8+200 are summarized in Table 3.4.1 and explained as follows:

- The existing road was shifted toward the stable mountainside at around 10 m in order to avoid slope instability.
- Alternative protection fence with steel material to secure the traffic during construction.
- Cut slope is protected by shot crete and rock net.
- Newly road cut slopes are protected by shotcrete and rock net.

CHAPTER 4

PROJECT IMPLEMENTATION PLAN

4.1 GENERAL OUTLINE OF THE PROJECT

The general outlines of the countermeasures for each site are shown in Table 4.1.1. Based on the Minutes of Discussion (Explanation of Draft Final Report) on Jan. 20, 2011, the Nepalese side intended to implement the countermeasure works at Sta. 17+400 with their own expenses (refer to the Appendix VII for details).

Table 4.1.1 General Outlines of the Countermeasures

Section	Outline of Countermeasures	Note
Sta. 17+400	・Check dam, gravity-type wall and planting cuttings ・Gabion wall and masonry retaining wall (upper side) ・Guard fence	(Implemented by GoN)
Sta. 17+600	・Check dam and gravity-type retaining wall ・Reinforced counterweight fill, gabion wall and sheet sodding works for slope protection ・Shotcrete and anchor works	Cutting disposal at Sta. 18+200 are used in this site for the counterweight fill.
Sta. 18+200	・Earth removal work, shotcrete, masonry retaining wall and planting cuttings ・Road realignment to mountainside	Minimize the quantity for earth removal

Source: Study Team

4.2 IMPLEMENTATION POLICY

The policies for the implementation of the Project are summarized as follows:

- Maximize the use of local labor and construction materials for the Project to strengthen the regional economy, generate job opportunities and promote capacity development.

- Avoid traffic accidents caused by construction vehicles, and minimize negative impacts against road users due to the Project.

- Minimize negative impacts such as traffic accidents, noise, vibration, exhaust gas, dust, etc. to the surrounding environment, particularly to the existing villages and cultivated lands along the road.

4.3 IMPLEMENTATION CONDITIONS

4.3.1 CONSTRUCTION PLAN

(1) Labor law

The contractor should manage its laborers properly with an adequate safety control plan and should prevent conflicts with local laborers. In any circumstance, the contractor should abide by the labor laws and regulations of Nepal (e.g., Labor Act 2048 (1992), Labor Rules 2049 (1993), and Bonus Act 2030 (1974)).

(2) Construction methodology

The common method and technology for construction in Nepal should be adopted. However, it is impossible to secure the safety of traffic without Japanese technology in reducing the difficulty during the maintenance stage.

Considering the general design criteria and the experience of construction for landslide protection in Nepal, Japanese technology should be adopted for the items shown in Table 4.3.1.

Table 4.3.1 General Design Criteria and the Experience of Construction

Classification	Item	Condition	Possibility in Nepal
Technology	Design criterion (for slope protection)	Detail design criteria (e.g., condition, methodology, permitted value, etc.) are not specified at “Guide to road slope protection works, 2003”.	×
Experience	Reinforced soil wall	No experience expected for the Sindhuli Road (designed and supervised by Japanese grant aid, including procurement of materials).	×
	High counterweight fill work	Maximum: 20 m (about 80 m required for the Project)	×
	Shotcrete	No experience expected for the Sindhuli Road (Japanese grant aid, including procurement of construction equipment).	×
	Anchor works	Rock bolt works (without installing axial tension at construction) is possible in Nepal.	×

Source: Study Team

(3) Traffic control and safety management during construction

In order to avoid traffic accidents and maintain smooth and safe traffic flow on the existing road during construction, flagmen should be assigned at traffic-controlled locations and near access roads to the site. Also, the contractor needs to plan the schedule for closing the existing road (in order to set the track crane on the existing road, which is expected for a few hours or one day) and discuss the details with the DoR, if necessary.

In addition, the temporary rock-fall prevention works should be installed at the neighboring construction from the existing road at Sta. 18+200.

(4) Consideration for the surrounding environment and residents

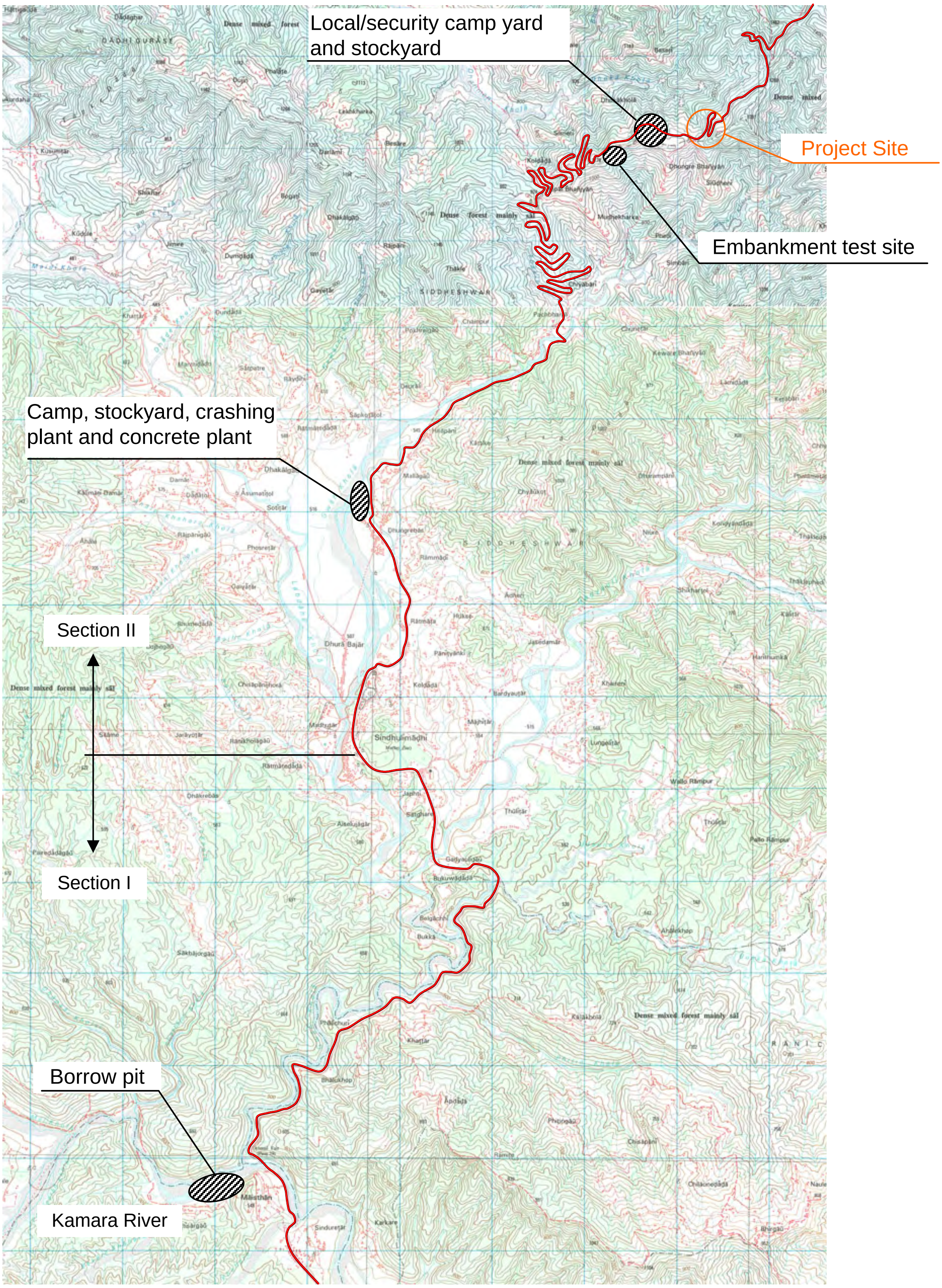
It is required to consider the surrounding environment and residents in minimizing the negative impacts due to construction. The following measures are to be conducted:

- Minimize the quantity for earth removal at Sta. 18+200
- Use cutting disposal at Sta. 18+200 as an embankment material for Sta. 17+600
- Use of low noise and vibration type of generator
- Minimize negative impacts to the existing community road (walkway), vegetation and/or fields located near the site.

(5) Location of construction yard

The following locations are proposed sites for the construction yard (including borrow pit):

- Camp, stockyard, crashing plant, and concrete plant: Sta. 3+000
- Local/security camp yard (near the site): Sta. 17+200
- Stockyard (temporary, near the site): Sta. 17+200
- Embankment test site: Sta. 16+800
- Borrow pit: Sta. 29+000 (Section I, Kamara River).



Source: Nepal map / Survey Dept., Nepal (modified by Study Team)

Figure 4.3.1 Location of Construction Yard

4.3.2 PROCUREMENT PLAN

(1) Labor procurement

Some of the skilled (rigger, rebar worker, form worker, mason, etc.) and unskilled laborers can be possibly procured near the site considering the recent increase of population and construction scale. However, particular and advanced skilled laborers (foreman, plant operator, survey/supervisor specialist, etc.) should be procured from Katmandu area.

(2) Material and equipment procurement

Natural construction materials (aggregate, stone, embankment material, timber) and cement are available in Nepal. Reinforcing bars are also available in the local market. Particular or advanced items not available in the local market, such as reinforced embankment and anchoring materials, and equipment, should be imported from Japan. In addition, materials and equipment which require maintenance of quality should also be procured from Japan.

The procurement of particular materials and equipment are summarized in Table 4.3.2.

Table 4.3.2 Materials and Equipment to be Procured

Item	Procurement Place			Note
	Nepal	India	Japan	
Materials				
Cement	○	○		Nepalese / Indian items available
Aggregates (course and fine)	○			
Concrete Admixture	○			Imported items available
Re-bar	○	○		Nepalese / Indian items available
Bituminous Material	○			Imported items available
Wood / Plywood	○			
Fuel (oil, gasoline)	○			Imported items available
Anchoring Material			○	Quality / durability reason
Reinforced Embankment Material			○	Quality / durability reason
Equipment				
Bulldozer (21 t, with ripper)			○	
Backhoe (0.6 m^3)			○	
Dump Truck (10 t)			○	
Truck Crane (25 t)			○	
Road Roller (10-12 t)	○			DoR lease (for free)
Asphalt Finisher (Wheel 2.4-6 m)	○			DoR lease (for free)
Concrete Spraying Machine (6.0 m^3/hr)			○	
Boring Machine (55 kW)			○	
Concrete plant(30m3/hr)			○	

Aggregate plant（30t/hr,195kVA）			○	

Source: Study Team

(3) Transportation path

Construction materials and equipment that are procured from Japan will be shipped to Kolkata Port. The distance from Kolkata to the construction site via Pathalaiya (southern direction from Hetauda, Narayangadh and Muglin) is about 750 km.

The good condition of the road enables the equipment to be transported within three days. (This transportation path is shown in red-orange line in Figure 4.3.2.)

Furthermore, the transportation path from Katmandu to the site takes within two days. (This transportation path is shown in blue-orange line in Figure 4.3.2.)

Source: India Map / India Tourism Authority (modified by the Study Team)

Figure 4.3.2 Transportation Map

4.4 IMPLEMENTATION SCHEDULE

As the preparatory survey for the Project will be completed by the end of March 2011, basic study is required before implementing the financial arrangement of the Project. In case that Japan’s grant aid will be the source of financing, the detailed design and preparation of the tender documents will be carried out by the Consultant after signing of the E/N and G/A between GoN and GoJ. Consulting services for the detailed design and preparation of the tender documents will be completed within seven months. The tendering process for construction works, which includes prequalification, tender opening and evaluation, and subsequent negotiations to conclude the contract between the DoR and the successful tenderer, will take about four months.

Considering the rainy season and mobilization/demobilization at the site, construction works will be completed within approximately 27 months. The implementation schedule is shown in Table 4.4.1.

Table 4.4.1 Implementation Schedule

	Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Basic design	Basic design		■	■	■	■	■	■																																						
Basic design	Financial arrangement								▽																																					
Basic design	Exchange of notes (E/N)									▼																																				
Basic design	Consultant agreement										▼	▽																																		
Detailed design	Detailed design										■	■	■	■																																
Detailed design	Preparation of tender doc.													■	■	■	■																													
Detailed design	Tender assistance																	■	■	■																										
Detailed design	Contract agreement																				▼	▽																								
Construction	Total schedule																					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Construction	Mobilization																					■																								
Construction	Countermeasure 18+200																						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
Construction	Countermeasure 17+600																						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Construction	Demobilization																																												■	

Source: Study Team, Note: This schedule is tentative and the practical schedule will be determined in the future study.

Obligations of recipient country

For the smooth implementation of the Project, the government of the recipient country shall fulfill the undertakings as stated in Table 4.5.1.

Table 4.5.1 Obligations of the Recipient Country (1)

Item	Content
Common items	・ To provide the necessary data and information for the implementation of the Project ・ To secure the land necessary for the Project site (road, spoil bank, borrow pit, construction yard, and storage of materials and equipment) ・ To clear, level and reclaim the land prior to the commencement of the Project ・ To open a bank account under the Government's name, in a bank in Japan (B/A), and issue the authorization to pay (A/P) ・ To ensure all the expenses for, and prompt execution of, unloading and customs clearance ・ To exempt Japanese nationals from customs duties, local taxes and other fiscal levies imposed in the recipient country, with respect to the supply of the products and services under the verified contracts ・ To accord Japanese nationals, whose services may be required in connection with the supply of the products and services under the verified contracts, such facilities necessary for their entry into the recipient country and stay therein for the performance of their woks ・ To accord Japanese nationals the permission and other competence, if required, for the implementation of the Project ・ To ensure proper maintenance, management and preservation of the facilities ・ To bear all expenses, other than those borne, necessary for the construction of facilities as well as for the transportation and installation of equipment.
Special items	Before construction ・ To complete site clearance following the compensation of private land in the ROW During construction ・ To provide the right to use river gravel for free ・ To lend construction equipment granted by GoJ to the Contractor for free, as long as it does not affect the daily maintenance works of the DoR

Source: Study Team

Table 4.5.1 Obligations of the Recipient Country (2)

Item	Content
Special items	<u>During construction</u> ・ To conduct all procedures regarding the diversion of traffic from the existing road and pedestrian tracks, and to secure land for required diversion ・ To broadcast to the public through mass media the detour road and traffic diversion from the existing road and pedestrian tracks ・ To conduct environmental monitoring through the DoR ・ To maintain partially handed over sections of the road ・ To arbitrate between residents and/or existing road users and the Contractor. <u>After provisional handover</u> ・ To conduct environmental monitoring and inspection through the DoR ・ To advice and recommend the efficient use of the vacant site (beside Sta. 18+200) to the local residents ・ To organize network for O&M of the Project.

Source: Study Team

4.6 PROJECT COST ESTIMATION

The project costs required for the undertakings by the GoN are shown as below:

Table 4.6.1 Project Cost Required for the Undertakings by the GoN

Category	Item	Cost	
		x 1,000 NRs	x 1,000 JPY
Before / During Construction	Compensation and Mitigation	5,868	6,866
	Other Items	1,986	2,324
After Construction	Monitoring / Environmental Auditing	1,174	1,374
Total		9,027	10,562

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 RISK LEVEL OF TARGET SITE

The results of the risk evaluation on slope disasters occurring in Sta. 17+400, Sta. 17+600 and Sta. 18+200 indicate that road traffic will be damaged seriously if these sections were left without adequate preventive protection measures.

Economic loss induced by disasters is estimated at Rs 47 million/year, Rs 393 million/year, and Rs 304 million/year for Sta. 17+400, Sta. 17+600, and Sta.18+200, respectively.

5.2 PROPOSED COUNTERMEASURES AND IMPLEMENTATION

(1) Proposed Countermeasures

Considering the results of the topographical and geological surveys, the proposed countermeasures for each site are summarized as follows:

- Sta. 17+400: Slope protection for the upper slope by a series of gravity-type retaining wall, gabion wall, and masonry retaining wall; and slope stabilization method for the lower valley by check dam, gabion, underdrainage, open ditch and planting cuttings.
- Sta. 17+600: Anchoring works below the road, stabilization by high reinforced counterweight fill work for the lower two slopes, and shotcrete for the upper slope.
- Sta. 18+200: Road realignment to the mountainside by slope cutting.

In planning the countermeasures for each site, sufficient and necessary design conditions have been introduced to keep long-term traffic function of the road.

It is recommended that these sections should be protected by permanent countermeasures before fully opening the Sindhuli Road in 2014. The earlier implementation of adequate preventive works for these sites will save extensive economic loss in the operation stage.

(2) Countermeasure Implementation for Sta. 17+600 and Sta. 18+200

On planning countermeasures for Sta. 17+600, the topographical and landslide situation is too difficult to apply the construction methods that are commonly used in Nepal. Therefore, advanced methods such as anchoring and high reinforced counterweight fill work are introduced for countermeasures in Sta. 17+600. Materials produced in Sta. 18+200 are to be utilized in the high counterweight fill works in Sta. 17+600. Therefore, these two units of work shall be implemented together as one project.

With regards to road realignment at Sta. 18+200, the DoR could independently implement road construction after preparing the site for shifting. However, it is difficult for the DoR to implement anchor works and high counterweight fill work, considering its current lack of experience and capability on these methods in Nepal. Thus, such works would be implemented by an international construction company that is capable of smoothly completing the construction project.

(3) Countermeasure Implementation for Sta. 17+ 400

On the other hand, since many gabion walls at steep slopes had been safely installed in the construction of section II, this experience can be utilized for slope protection works for Sta. 17 + 400. The cost for this implementation appears to fall in the range that the DoR can allocate budget for implementation.

This project could be implemented by the DoR as one of its rehabilitation projects before fully opening the road.

The proposed countermeasures works, which are based mainly on design condition and economical effects will be expected to be suitable for landslide stabilization. In addition, because unexpected rainfalls frequently occur around the project area it is suggested to make effort to mitigate the damage due to the unexpected rainfall through appropriate maintenance of Department of Road and to establish early restoration system.

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