IV

FIELD SURVEY FOR LANDSLIDE

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IV. FIELD SURVEY FOR FEASIBILITY STUDY

4.1 General

The study team carried out the topographic and geological survey for the sites having high potential of slope hazards to affect the Narayangharh-Mugling Highway, and the Marsyangdi Power House.

The results were to use for the Feasibility Study in Phase II, which is to review and plan countermeasures for slope hazards, especially slides.

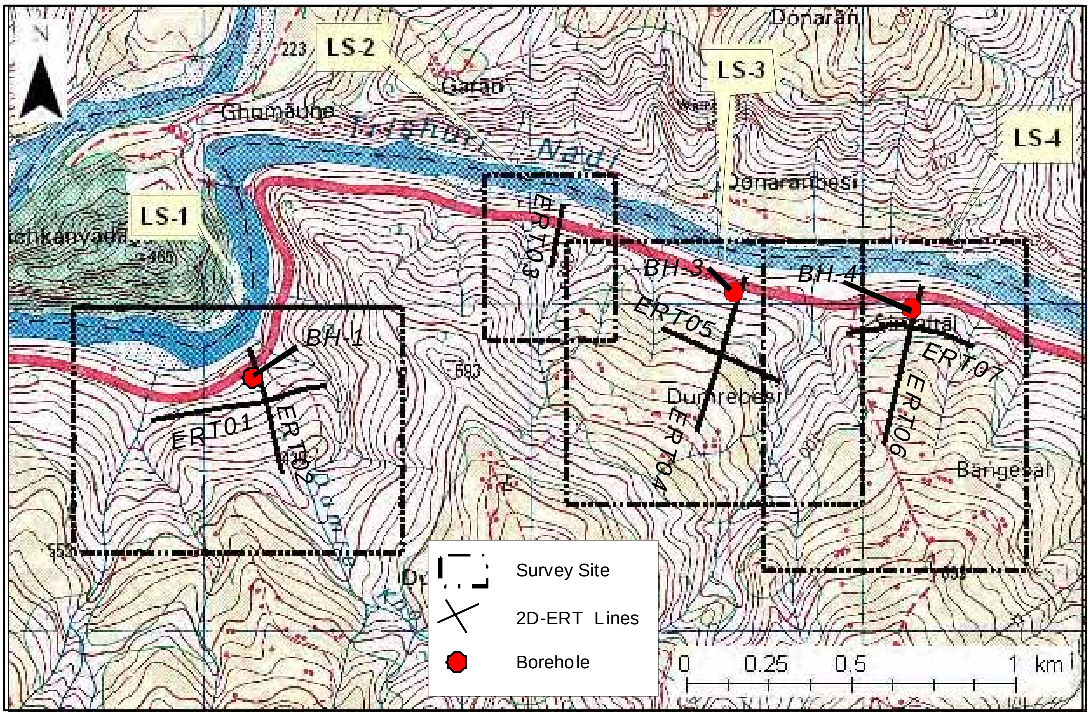


Figure 4.1.1 Location of selected survey sites for Narayangharh-Mugling Highway

The team selected four (4) sites that are recognized as dangerous slides for the highway. Figure 4.1.1 shows the location of the selected four (4) slopes sites. In addition to the four (4) slopes, the team also selected four (4) streams which are crossing the road and have potential of debris flow, and one (1) stream area next to the Marsyangdi Power House. The sites were initially identified by preliminary field reconnaissance carried out by the DWIDP and the study team on August 2 and August 3, 2007.

After the preliminary field reconnaissance, the team planned the following survey items and quantities of the work to be commenced by a Nepalese local consultant firm (hereinafter referred to as the Contractor).

4.1.1 Topographic Survey

Survey for topographic maps with a scale of 1:1000:

Four (4) selected slopes along the highway, and the Marsyangdi Power House site

Survey for cross sections with a scale of 1:1000:

Four (4) streams crossing the Highway

4.1.2 Geological Survey

1) Geo-tomography Survey (two dimensional electrical resistivity tomography survey; 2D-ERT) for:

Four (4) selected slopes (SL-1, SL-2, SL-3 and SL-4)

2) Drilling Survey for:

All-core/non-core drilling on three (3) slopes (SL-1, SL-3 and SL-4)

Standard Penetration Test (SL-1, SL-3 and SL-4)

Installation of perforated PVC pipes with strain gauges (SL-1, SL-3 and SL-4)

3) Engineering geological mapping/profiling for:

Engineering geological maps with a scale of 1:1000 for SL-1, SL-2, SL-3 and SL-4

Engineering geological profiles with a scale of 1:1000 for SL-1, SL-2, SL-3 and SL-4

Through the tender process above, METCON GROUP Pvt. Ltd. (METCON Consultants) was nominated as the contractor for the work. Both the team and the contractor made a joint inspection to confirm the site condition and locations of the work on August 27, 2007.

The work in the sites by the Contractor had started on September 1, 2007 and finished on October 15, 2007. The final report of the contracted work was prepared by the end of October, 2007.

The following sections shows a summary of the work results.

4.2 Contents of Field Survey

4.2.1 Work Items for the Contractor

Table 4.2.1 shows the actual quantity of the Contractor's work along the Narayangharh-Mugling Highway, four (4) streams crossing the highway, and the stream area next to the Marsyangdi Power House.

4.2.2 Topographic Survey

Topographic surveys were carried out to provide the following data and outputs.

- Topographic map with a nominal scale of 1:1000, and digital data.
- Cross sections with a nominal scale of 1:1000, and digital data.

The mapping accuracy was nominally specified as below:

- The standard deviation of the horizontal position of all features shall be within 500 mm of the position depicted on the topographic maps and the cross sections.
- The standard deviation of spot heights shown on the topographic maps and cross sections shall be within one third (1/3) of the contour interval (2 m), i.e. within 670 mm.
- The standard deviation of the heights of contours shall be within one half (1/2) of the contour interval (2 m), i.e. within 1.0 meter.
- The horizontal and vertical accuracy of the cross sections shall be within 500 mm.

A brief reconnaissance survey in each topographic survey site was performed in the beginning to explore the site conditions as well as to determine the requirements for ensuring the safety of personnel and equipments. The data collected in the memory of the Total Station Instrument was downloaded to a computer in order to build the DEM., contour maps, location of features, etc. After traversing from different trigonometrically stations established by Survey Department of the Government of Nepal (SDN), the necessary ground reference point in the project area were established and connected with National Grid.

The field survey for detail topographic mapping as well as fixing ground control points, cross sections, and engineering geological profiles plus 2D-ERT profile lines with borehole locations were carried out.

All together 2000 m cross section survey work was performed on the scale of 1:1000 for R-1, R-2, R-3 and R-4 sites.

Table 4.2.1 Quantity of the Work

Work		Unit	Sites															Total
			LS-1	LS-2	LS-3	LS-4	MP-1	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10	
A) Topographic Survey	**A.1) Topographic map with a scale of 1:1000**																	
	A.1.1) Preparation, and mobilization/demobilization	site	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
	A.1.2) Field survey for topographic map	ha	35	9	42	42	15	0	0	0	0	0	0	0	0	0	0	143
	A.1.3) Plotting/compiling the topographic map	set	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	5
	A.2) Cross section(s) with a scale of 1:1000																	
	A.2.1) Preparation, and mobilization/demobilization	site	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	4
	A.2.2) Field survey for cross section(s)	m	0	0	0	0	0	500	700	700	100	0	0	0	0	0	0	2000
	A.2.3) Plotting/compiling the cross section(s)	set	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	4
	A.4) Accommodation and lodging	lump sum	1															1
B) Geological Survey	**B.1) Geo-tomography Survey**																	
	B.1.1) Preparation, mobilization/demobilization	site	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	4
	B.1.2) Two dimensional electrical resistivity tomography (2D-ERT)	m	700	150	900	900	0	0	0	0	0	0	0	0	0	0	0	2650
	B.1.3) Consumables for 2D-ERT (electric cables, electrodes, and PVC tapes, etc.)	m	700	150	900	900	0	0	0	0	0	0	0	0	0	0	0	2650
	B.1.4) Accommodation and lodging	lump sum	1															1
	B.2) Drilling Survey and Relate Investigation																	
	B.2.1) Preparation, mobilization/demobilization	site	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3
	B.2.2) Drilling: All-core 66 mm diameter	m	17.6	0	26.3	20.6	0	0	0	0	0	0	0	0	0	0	0	65
	B.2.3) Drilling: Non-core 66 mm diameter	m	2.4	0	6.7	9.6	0	0	0	0	0	0	0	0	0	0	0	19
	B.2.4) Standard penetration test	number	4	0	7	12	0	0	0	0	0	0	0	0	0	0	0	23
	B.2.5) Preparation of perforated PVC pipes (including material costs)	m	20.0	0.0	33.0	29.0	0	0	0	0	0	0	0	0	0	0	0	82
	B.2.6) Attachment of strain gauges onto perforated PVC pipes (Two (2) gauges with electrical lead wires per one (1) meter)	m	20.0	0.0	33.0	29.0	0	0	0	0	0	0	0	0	0	0	0	82
	B.2.7) Installation of perforated PVC pipes with strain gauges	m	20.0	0.0	33.0	29.0	0	0	0	0	0	0	0	0	0	0	0	82
	B.2.8) Measurement of groundwater level	number	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3
	B.2.9) Measurement of strains on the perforated PVC pipes	number	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3
	B.2.10) Accommodation and lodging	lump sum	1															1
	B.3) Engineering Geological Mapping/Profiling																	
	B.3.1) Engineering geological map with a scale of 1:1000	ha	12	4	20	20	0	0	0	0	0	0	0	0	0	0	0	56
	B.3.2) Engineering geological profile(s) with a scale of 1:1000	m	700	200	900	900	0	0	0	0	0	0	0	0	0	0	0	2700
C) Reporting	**C1) Reports and Maps** (as specified in the Section III of this tender document)	lump sum	1															1

4.2.3 Geo-tomography Survey

The basic method of conducting the resistivity survey is to inject electrical current in the round using two metal stakes driven into the ground. The resulting voltage or the response is measured using other two metal stakes which are also driven into the ground. The positions and distances between the metal stakes depend on the type of array used. There are many arrangements of these four electrodes, and these are named as Wenner, Schlumberger, Dipole-Dipole, Pole Dipole, Two Pole etc. Each arrangement has its own advantages and disadvantages. Some arrangements are good in some situation while other arrangement is good in other situation. The purpose of the survey plays deciding role in selecting Electrode arrangement to be used during the survey.

In the present field survey, Dipole-Dipole array was used. The Dipole length was 5 m and spacing factor between the pair of Dipoles was employed varying from 1 to 7. To gather information from deeper part, the dipole length was changed to 10 m and then to 20 m, while the dipole separation was maintained from 4 to 7 in both cases.

The instrument used was the ABEM TERRAMETER SAS 300B. It has electric current selecting capability to use either 5, 10 or 20 milli Amps (mA). The current range can be increased to 50 or 100 mA with the external booster. It has also in-built averaging capacity to select 4, 16, 32, or 64 cycles. It has input impedance of 20 Mega Ohm, which is far more from required impedance in the present field condition.

The preliminary data processing of the field data were made in the field site and unexpected anomalous data were filtered in the site itself. The detailed processing was made in Kathmandu. The field data with unrealistic look were either corrected or removed. The field data were finally prepared in the format acceptable for the data inversion software. The ERT field data were grouped together with the topographic elevation data of survey points of the respective ER profile.

The software used in analyzing the processed field data was RES2DINV, Geotomo. This software is able to handle large number of field data. It has many options to select during the data to handle large number of field data. It has many options to select during the data inversion process, which gives user to choose right parameter suitable to the field condition and local geology. The final product is in the form of colored Electrical Resistivity Tomograms. Each Tomograms represent local subsurface geological condition. The tomograms of each profile are presented separately.

Based on the Tomograms, representative lithological sections were prepared for each ER profile.

The overburden generally consists of rock fragments of different sizes and types, soils, etc. They are present in different proportions and are in different state and thickness. Such disturbed mass are represented by discontinuous, patchy tomograms. Continuous tomograms are the result of presence of uniform lithology or geology which may represent bed rock. High values of resistivity tomograms suggest hard, compact bedrock, while lower values suggest fractured, jointed, soft bedrock.

4.2.4 Drilling Survey

Exploratory core drilling was performed by using a KOKEN (KS-5) drill rig at different locations, which are SL-1/BH-1, SL-3/BH-3, and SL-4/BH-4 to the depths of 20 m, 33 m, and 30 m respectively as per the ASTM Designation D 2113-83 standard procedure using a conventional type DCDMA/Craelius metric standard core barrel and other accessories. The drilling work was commenced by using NX size DCDMA standard core-barrel. Drilling process was carried out telescopically with the largest HW size standard casing at the top. The sizes of the boreholes were reduced telescopically wherever frequent side fall and caving occurred in the holes. The subsequent size of HW and NX casing were installed in the hole to protect the drill hole wall from caving. Various sizes of crown set, surface set as well as impregnated casing shoe bits; core bits and reamer shells were used during drilling operation. Long tube core barrels with a length of 1.5 m were used to retrieve core samples from the holes.

Core samples collected from the holes were laid in standard 1.0 m long core boxes having five (5) rows of channels. Wooden separators were used to separate each run of the core sample. Depth of each run was clearly marked on top of the wooden strips of the core boxes. Weather proof marking pens were used to mention details of each hole like project name, site name, hole number, box number, depth of the hole and drill date, etc. on the outer and inner side of the core box cover. In addition to that core loggings as well as photography of core samples were performed at the site. Essential precautions measures, such as packing of core boxes with straw and tightening of the lids, were performed carefully, before these were transported to Kathmandu.

4.2.5 Standard Penetration Test

Standard Penetration Test (SPT) was carried out on overburden material wherever possible. The test consists of driving a split tube sampler, with an outside diameter of 50 mm, into the soil at bottom of the drill hole. Driving is accomplished by a trip hammer, weighting 63.5 kg that fall freely through a distance of 750 mm onto the drive head, which is fitted at the top of the drill rods. At first the split tube is driven 150 mm into the soil at the bottom of the drill hole. The split spoon is driven a further 300 mm and the number of blows required to drive the distance was recorded.

The test was carried out in accordance with ASTM D 1586-99.

4.2.6 Installation of PVC Pipes with Strain Gauges

The perforated PVC pipes with strain gauge were installed within the borehole. The pipe at ground surface level was fixed onto the borehole with concrete and a lockable iron box was covered on the top of the pipe for protection. The box had written the borehole number and depth.

4.3 Result of Filed Survey

4.3.1 Site SL-1

(1) Site Condition of SL-1

SL-1 site is occupied by the hillside slopes of Narayangarh-Mugling Highway approximately in between Morray Khola in the west (about 21.5 km) and Dumre Khola in the east (about 22 km). Below the road Trisuli River makes a sharp bend forming a concave slope. The concavity indicates that the material in this particular slope is comparatively more erodible than on the other side of the river. At a first glance, the slope presents various nature of the topographic feature showing steep slope in the higher part in the south with some old and new rock fall scars, whereas the middle part of the slope is hummocky in nature probably composed mainly of the material rolled down from the steep terrain above. In general the area is wet and at the road level and below considerable amount of water outflow was noticed during the field investigation (September – October, 2007).

Figure 4.3.1 SL-1 Site showing the concavity of slope and Trisuli River bend

The type of bedrocks exposed within the area is mainly intercalated phyllite and carbonate in the eastern part whereas the western part is occupied by brown to purple brown phyllite. On both the locations the bedrock dips north to northeast at an angle of 40 degrees and more. In the middle part of the slope basic intrusive rock was exposed which pushed aside the rocks of Nourpul Formation and accommodated during the time of its intrusion. This intrusive rock is still to be properly named after petrographical analysis. However, the exposed rock and the floats mainly observed on the traverse along Murray Khola provided the opportunity to examine the rock in broader sense. Although from the observation of minerals on hand specimen, and the nature of exposed outcrops the rock was expected to be Diorite or Granodiorite.

A transverse fault was observed running north-south across the slope almost from the confluence of Dumre Khola and Trisuli river in the north to the sharp bend of Dumre Khola in the south. The significance of the fault is that the basic rock is appearing only in the western part of the fault. It was revealed from the field observation that the bedrock exposed in the eastern part of the fault was much stronger and stable in nature in comparison to the bedrock exposed to the west.

Signatures of slope distress were also noted specially on the support walls of the road in the form of cracks on the walls and bulging of the gabions (Figure 4.3.2). From stability point of view in general the slope above the road in between Dumre Khola and the Murray Khola is quite vulnerable. Faulting in the eastern part, the wedge shaped phyllitic bedrock of the middle part of the slope and the thick deposit of colluvial soil above the road made the area quite vulnerable. It is also possible to differentiate the stretch of road into less and more vulnerable in comparison to each other. The stretch of road from Dumre Khola to the boundary of basic rock can be termed as highly vulnerable to slope failure in every monsoon season, whereas the rest can be termed as less vulnerable in comparison to the former. However, the later part of the slope also is at high risk due to the presence of loose debris and considerable amount of ground water above the road.

Figure 4.3.2 (a) Deformation of existing structures for countermeasure

Figure 4.3.2 (b) Front view of SL-1

(2) Drilling Survey at BH-1

A borehole named BH-1 was planned on the slope of SL-1 and drilled up to the depth of 20 m. Standard penetration tests were performed four (4) times at depths of 2.0 m, 4.0 m, 6.0 m, and 8.0 m. Water tables during drilling the BH-1 hole were observed at around a depth of 3.6 m.

Table 4.3.1 below summarizes the result of drilling.

Table 4.3.1 Summary of BH-1

Depth	Desrcription	Remarks
0.0 – 8.2 m	Consists of loose deposits of greenish grey to brown clay with pebbles, gravels, cobbles, of phyllite and calcareous quartzite.	N values (blows/cm) 2.0 m: 50 / 30 4.0 m: 50 / 17 6.0 m: 50 / 27 8.0 m: 50 / 4.5
8.2 – 20.0 m	Fresh, medium to strong hard, greenish to dark grey, fine grained, moderately to highly jointed, mica parting and fractured phyllite with quartz veins.	Nourpul Formation
Groundwater	GL -3.1 m (as of October 10, 2007), GL -3.6 m (as of January 25, 2008)	

After finishing the drilling at BH-1, a perforated PVC pipe with strain gauges has been installed for monitoring the movement of anticipated slides.

(3) Geo-tomography Survey

(a) Interpretation of Profile ERT 01 (Lateral Profile)

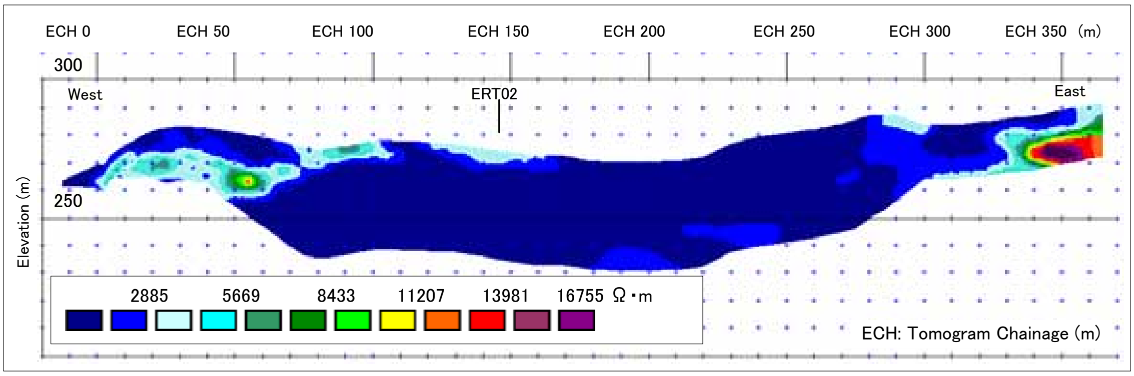


Figure 4.3.3 Colored geo-tomogram along ERT01 line in SL-1

ERT01 line was installed, almost parallel to the major geological structures (foliation and bedding planes) of the bedrock. Therefore many factors seem to have influenced to the geo-tomogram, and the tomogram of the ERT01 line shows a patchy pattern.

Throughout ERT01 line, values of 100 – 2000 Ωm are widely observed on the color tomogram (Figure 4.3.3). Higher value parts consisting of 2000 – 5000Ωm can be recognized at ECH 50, ECH 350 approximately on the tomogram. Values of 2000 – 4000 Ωm are seen around ECH 150, and seem to be loosened/weathered bedrocks, or unconsolidated material.

(b) Interpretation of Profile ERT 02 (Longitudinal Profile)

ERT02 line was installed at almost right angles to the major geological structures (foliations and bedding planes) of the bedrock. The color tomogram of the ERT 02 line seems to represent a layer pattern of the bedrocks well.

Comparatively lower value zone (10 – 500 Ωm) are observed widely on the tomogram. This low value zone comprises of phyllitic rocks.

Within the low value zone, there are some narrow zones of values of 400 Ωm and below. These are recognized at around ECH 0, ECH 50 and ECH 70-200. The zones are considered to comprise of loosened rocks saturated with groundwater.

Higher values of 1500 Ωm and above are recognized around at ECH 330. This high value part coincides with basic rocks, which are usually very hard.

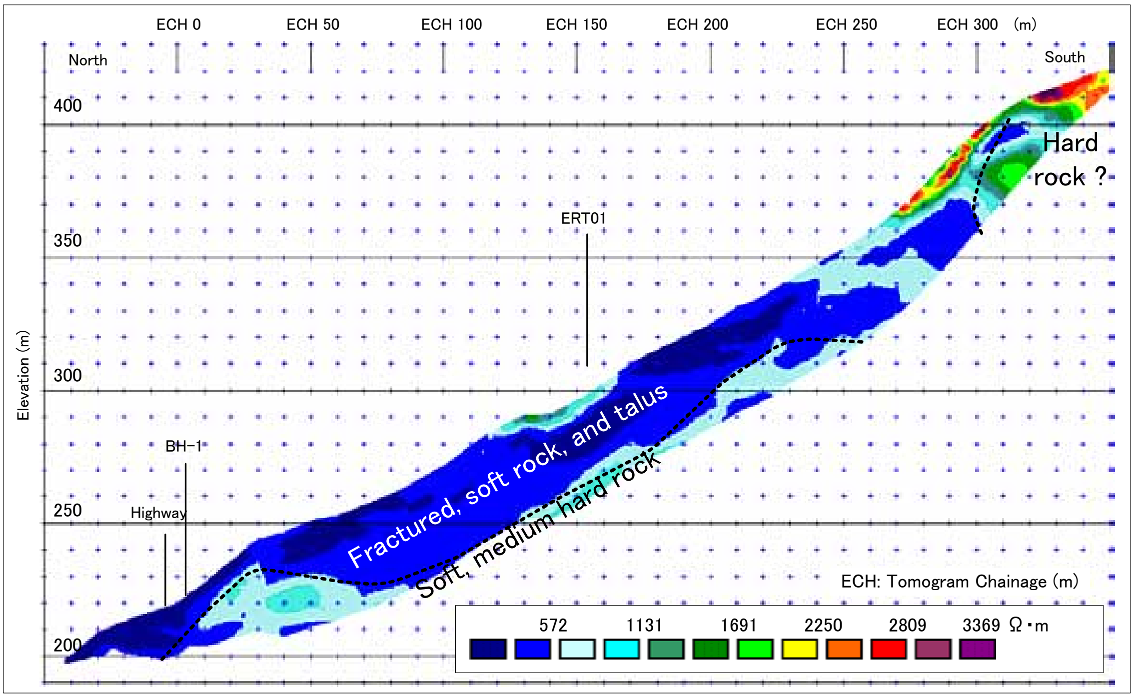


Figure 4.3.4 Colored geo-tomogram along ERT02 line in SL-1

4.3.2 Site SL-2

(1) Site Condition of SL-2

SL-2 site is a north facing convex shaped slope occupying a part of the hillside slope in between 23 km and 24 km of Narayangarh – Mugling Highway. The eastern boundary of the slope is defined by Kadam Khola. From the cursory view of the slope the western part seems to be more stable than the eastern part. The catchment of Kadam Khola is full of old and new landslide scars. The slope of SL-2 is drier in comparison to the slopes of SL-1.

The area of SL-2 is composed mainly of intercalated greenish phyllite and quartzite of Nourpul Formation. The phyllite sometime shows schistocity at places and kink bands are frequently observed. In general the bedrock is dipping toward north, northeast or northwest excepting at folds. The bedrocks at majority of exposures are intensely folded, fractured and sheared. Slickensides are common due to local shearing. A thrust crosses the area of SL-2 almost diagonally from northwest to southeast that separates more quartzitic rock of the southern block from more phyllitic rock of the northern block. There are hardly any bedrock exposures in the vicinity of thrust zone. Signs of instability were frequently noticed in the form of old and new landslide scars. Major part of the area of SL-2 is covered by colluvial soil mainly derived from slope wash and gravitational causes.

Symptoms of slope failure were noticed within the area of SL-2 site in the form of bulged and broken support walls (Figure 4.3.5). From the drawing of the profile it was revealed that the area around the road is composed of thick colluviums and the construction of road was carried out mainly over the landslide mass.

Figure 4.3.5 Comparative photographs of the masonry wall at SL-2. (right: photo on August 2, 2007; left: October 8, 2007)

(2) Drilling Survey

Drilling survey was not planned in SL-2.

(3) Geo-tomography (Longitudinal Profile Line, ERT03)

ERT03 lines were installed at almost right angle to the major geological structures (foliation and bedding plane) of the bad rocks.

The color tomogram of the ERT03 comprises of high value zones (1000 Ωm and above) and low value zones (1000 Ωm and below). Each value zone inclines northward. Therefore the color pattern seems to coincide with geological structures very well.

Comparatively higher value zones (green – purple on the color tomogram shown in Figure 4.3.6) are considered to be hard rocks, e.g., meta-sandstone and quartzite.

Lower value zones (dark blue - cyan) are considered to be soft – medium hard rocks (usually black phyllite or unconsolidated deposits).

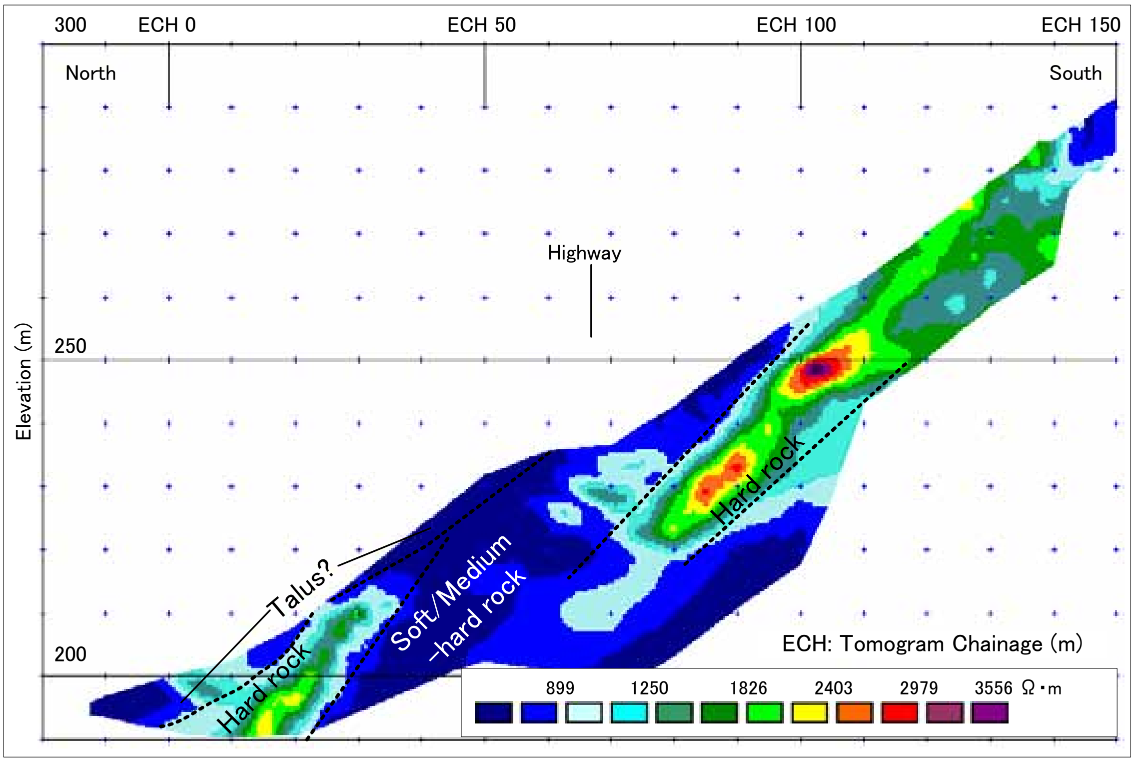


Figure 4.3.6 Colored geo-tomogram along ERT03 line in SL-2

4.3.3 Site SL-3

(1) Site Condition

SL-3 site is located in the hillside slope in between Simaltal Khola in the east and Sinduregaira Khola in the west approximately from 23.8 km to 24.2 km of Narayangarh-Mugling Highway. Both the boundary stream slopes are full of active and old landslide scars. Approximately first 50-60m of the slope above the road is steeper than the rest. The slope above 50-60m from the road level is comparatively gentle and terraced cultivated slope. There is abundant water outflow at the road level within the area of SL-3. Signatures of old shallow type of landslide scars were observed at some places just above the road.

Geologically the rocks of Nourpul Formation occupy the area. They are mainly represented by phyllite, quartzite and carbonates. In particular, the eastern part of the SL-3 site is composed of greenish phyllite and quartzite whereas the western part of the area constitute of dark grey to black phyllite with some quartzite. The middle part of the slope consists of phyllite, quartzite and minor amount of carbonate rocks. Bedrock normally outcrops in the steep slopes. In general, except at the fault zone and fold axis the rock dips toward north, northeast or northwest at steeper angle. Due to the existence of faults and thrusts within the area folding and shearing were frequently observed. The rocks were observed intensely crushed and powdered in the vicinity of the thrust zone. In the gentler slopes the entire area is covered by colluvial soil. Toward the western boundary of SL-3 site a fault crosses Sinduregaira Khola making an acute angle. More than that, a thrust that was encountered in the SL-2 site passes through the area of SL-3 also and runs almost in the east-west direction. The breakup slope above the road is almost defined by the Thrust alignment.

When a north- south engineering geological profile was drawn it was revealed that the area of drill hole location, which was heavily supported by anchor wall is an old landslide slope. At present the area supported by anchor wall seems to be stable. However, the area just west from the anchor wall that is also full of water is a stressed slope revealed by cracks, bulge and even breaking of a part of support wall in this area (Figure 4.3.7). On the other hand the hillside slope toward east of the anchor wall is composed of steeply dipping phyllite. Minor wedge failures were noticed in this area that may not cause serious damage to the road at present. However, timely treatment of these wedge failures may avoid any big failure in future.

Figure 4.3.7 (a) Comparative photographs of a part of SL-3 slope (Right: Photo on August 2, 2007; Left: Photo on September 6, 2007)

Figure 4.3.7 (b) Road side view of SL-3 slope

(2) Drilling Survey

A borehole named BH-3 was planned in SL-3 as shown in Figure 4.11, and drilled up to a depth of 33 m. Standard penetration tests were performed seven (7) times at depths of 2 m, 4 m, 6 m, 8 m, 10 m, 12 m and 14 m. Water tables during drilling the BH-3 hole were observed at around a depth of 25 m.

Table 4.3.2 below summarizes the result of drilling.

Table 4.3.2 Summary of BH-3

Depth	Description	Remarks
0.0 – 13.0 m	Consists of loose colluvial deposits of greenish grey to brown clay with pebbles, gravels, cobbles of phyllite and calcarious quartzite.	N values (blows/cm) 2.0 m: 50 / 14 4.0 m: 50 / 11 6.0 m: 50 / 9 8.0 m: 50 / 10 10.0 m: 50 / 25 12.0 m: 50 / 11 14.0 m: 50 / 6
13.0 – 33.0	Fresh, medium to strong hard, greenish to dark grey, fine grained, moderately to highly jointed, fragmented and fractured phyllite with quartz veins.	Nourpul Formation
Groundwater	GL -28.5 m (as of October 15, 2007), GL -28.4 m (as of January 25, 2008)	

After finishing the drilling at BH-3, a perforated PVC pipe with strain gauges has been installed for monitoring the movement of anticipated slides.

(3) Geo-tomography Survey

(a) Interpretation of Profile ERT04 (Longitudinal Profile)

ERT04 line was installed at almost right angles to the major geological structures like ERT 03 line.

The color tomogram can be roughly divided into two zones that are comparatively higher value zones indicating 2000 Ωm and above, and lower value zones indicating 2000 Ωm and above.

A low value zone is recognized between ECH 50 and ECH 220. This zone coincides with a loosened greenish gray/green phyllite and a landslide potential zone well.

High value zone between ECH 220 and ECH 400 seems to be medium-hard or fresh phyllites with quartzite/carbonate rocks.

The color tomogram seem to represent condition of the bedrocks and geological structures throughout the ERT04 line.

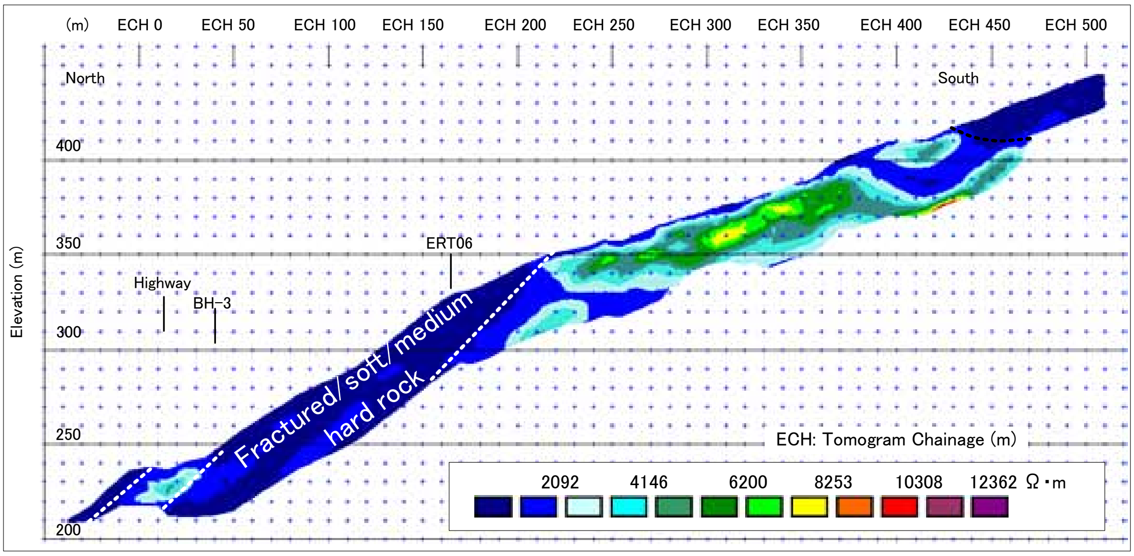
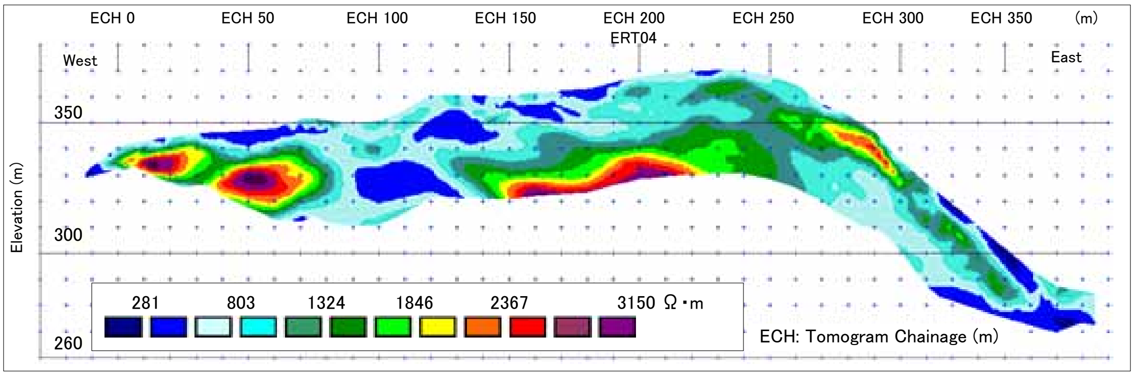


Figure 4.3.8 Colored geo-tomogram along ERT04 line in SL-3

(b) Interpretation of Profile ERT05 (Lateral Profile)

ERT05 line was installed, almost parallel to the major geological structures (foliation and bedding planes) of the bedrock like ERT 01. Therefore many factors (e.g. geology and topography) seem to have influenced to the geo-tomogram, and the tomogram of the ERT05 line shows a patchy pattern.



I: Overburden/Soft/fractured rock; II: Soft/fractured/Medium-hard rock; III: Medium-hard/Hard rock (anticipated)

Figure 4.3.9 Colored geo-tomogram along ERT05 line in SL-3

Comparatively high values of 2000 – 3000 Ωm are recognized at around ECH 0 – 80, a deeper part of ECH 150 – 220, and a shallower part of ECH 280 – 300.

Lower value zones indicating 2000 Ωm and below seem to surround the high value zones above.

4.3.4 Site SL-4

(1) Site Condition

The SL-4 site is located in between Bangesal Khola in the east and Simaltal Khola in the west at about 24.3 to 24.8 km along Narayangarh Mugling Highway. The nature of the slope around SL-4 site is a convex shaped indicating to have formed by the deep seated mass movement. At the centre of the road stretch the slope near the Trilusi River is slightly pushed to the north and forced to make smooth curve shaped. Similar to the slope of SL-3 the slope of SL-4 site is comparatively steep for the first 60-70m from the road and above that it is gentler. Bedrock exposures were not observed on the bank of Trisuli River below the entire road stretch of SL-4 site supporting the hypothesis of being a landslide body. The slopes of catchments area and the boundary streams or rather gullies on either side of the SL-4 site are full of active landslides indicating the nature of the slope material of SL-4 site. The slope above 60-70m above the road is mainly used for the dry cultivation purpose. In general it can be said that comparatively the slope is a dry slope except for the western boundary of the slope at roadside.

Similar to SL-3 site the site of SL-4 is also mainly composed of the rocks of Nourpul Formation, which is represented mainly by greenish phyllite and quartzite. Some grey to yellowish brown phyllite were also observed but the dominating rock type of greenish to grayish phyllite and quartzite are folded, faulted and intensely fractured. The proportion of quartzite component is far more less than that of phyllite in total. Generally the bedrock in this area is dipping toward north, northeast and northwest except near the fold. Folding is intense. The bedrock exposures were only exposed either on the deeply incised gully or on the hilltop. The gentle slope where dry cultivation was practiced is mainly composed of colluvial soil cover. A thrust that was mapped in SL-2 and SL-3 site was also observed in SL-4 site. The thrust runs almost east to west at a height of about 80-90m above the road level. The alignment of the thrust is almost marked by the breakup slope. The slope below the thrust is steeper than the slope above. Moreover, slope instability features due to the presence of intensely crushed rocks also mark the alignment of the thrust. The intensity of the crushing of rock can be observed in the base of a gully. The boundary streams of the SL-4 site are full of active landslide features and rocks crushed due to the thrusting in this area. Tension cracks were observed at a breakup slope or the thrust alignment indicating the sign of an inevitable large scale slope failure. A transverse normal fault crosses the eastern part of the SL-4 site which is marked by about 10cm thick fault gauge.

The slope was found almost dry except at western part where there are some roadside huts. The water outflow is in general from the bottom of the support wall of the road. It is expected that the water outflow is from the colluvial mass. Several features of distress of the slopes were noticed in the SL-4 site in the form of cracks on support walls as well as on the slopes. While going up from the drill hole site following the line of engineering geological profile, piles of loose rock blocks one on the top of other was observed, indicating a typical sign of slope failure. At the river level below the road, bulging of the gabion walls and cracks on the concrete protecting the gabion was noticed.

Figure 4.3.10 Right side view of SL-4 slope from Mugling side

(2) Drilling Survey

A borehole named BH-4 was planned in SL-4, and drilled up to a depth of 30.2 m. Standard penetration tests were performed twelve (12) times as shown in Table 4.5.3. Water table during drilling of the BH-4 hole was once measured at a depth of 26.5 m; however drilling after the depth of 26.5 m, any water tables could not be observed. Table 4.3.3 below summarizes the result of drilling.

Side wall collapse in the borehole frequently occurred below a depth of 24 m. The study team judged that it was technically difficult to drill more below a depth of 24 m without metal casing. There seems to consist of strongly weathered or sheared phyllites. However, it was considered that once metal casing was installed, it would be impossible to set a PVC pipe with staring gauges.

Based on field reconnaissance around BH-4, the borehole is located in a narrow zone where a thick layer comprising of talus and weak phyllites is distributed along a longitudinal section of the slope.

Table 4.3.3 Summary of BH-4

Depth	Description	Remarks
0.0 – 13.0 m	Consists of loose colluvial deposits of greenish grey to brown clay with pebbles, gravels, cobbles of phyllite and quartz.	N values (blows/cm) 2.0 m: 38 / 30 4.0 m: 50 / 27 6.0 m: 48 / 30 8.0 m: 42 / 30 10.0 m: 25 / 30 12.0 m: 50 / 30 14.0 m: 31 / 30 16.0 m: 50 / 7 18.0 m: 50 / 12 20.0 m: 50 / 10 22.0 m: 50 / 11 24.0 m: 50 / 30
13.0 – 30.2 m	Fresh to highly wearthered, soft, medium to strong hard, greenish, fine grained, moderately to highly jointed, highly fractured and fragmented phyllite with quartz veins.	Nourpul Formation
Groundwater	GL -26.5 m (as of October 15, 2007), GL -26.3 m (as of January 25, 2007)	

After finishing the drilling at BH-4, a perforated PVC pipe with strain gauges has been installed for monitoring the movement of anticipated slides.

(3) Geo-tomography Survey

(a) Interpretation of Profile ERT06 (Longitudinal Profile)

ERT06 line was installed at almost right angles to strikes of rock beds and foliation.

The color tomogram can be roughly divided into two zones that are higher value zones and lower value zones. The tomogram seems to represent of bed rocks.

Throughout ERT06 line, the tomogram represents 700 – 2000 Ωm and seem to be higher than the values of phyllites in other sites. The following reasons are considered: the bedrocks are loosened or weathered; the bedrocks are unsaturated with groundwater and ground water levels are comparatively lower; or the bedrocks are stiffer.

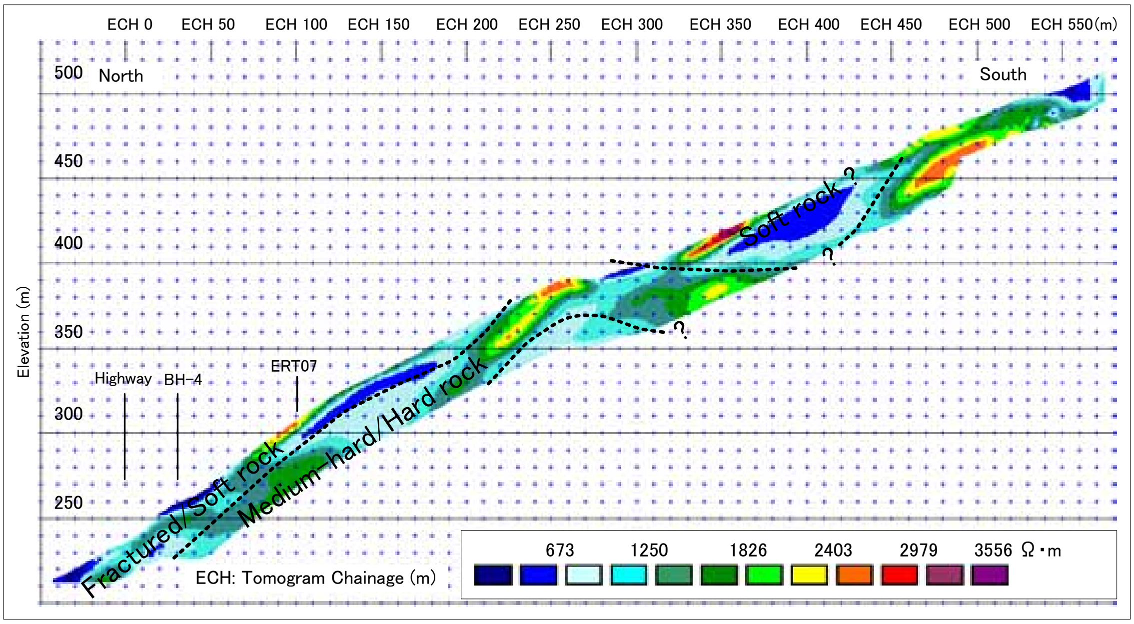


Figure 4.3.11 Colored geo-tomogram along ERT06 line in SL-4

(b) Interpretation of Profile ERT07 (Lateral Profile)

ERT07 line was installed, almost parallel to the major geological structures (foliation and bedding planes) of the bedrock like ERT 05. Therefore many factors (e.g. geology and topography) seem to have influenced to the geo-tomogram, and the tomogram of the ERT07 line shows a patchy pattern.

The color tomogram widely comprises of values of 1500 Ωm and below. Higher values are observed at shallower parts between ECH 280 – 370.

This higher value zone seems to indicate very loosened rocks, slope failure zones or landslides.

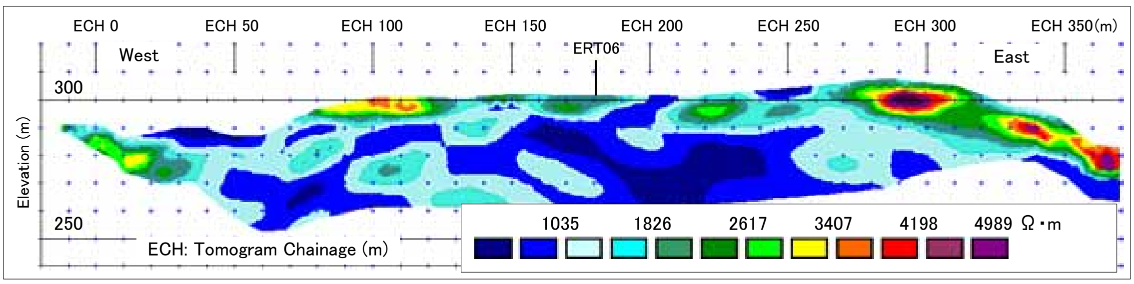


Figure 4.3.12 Colored geo-tomogram along ERT07 line in SL-4

V

ANALYSIS OF FREQUENCY SCORES FOR FRCD

V. ANALYSIS OF FREQUENCY SCORES FOR FRCD

The most suitable frequency scores (FSs) were analyzed by minimizing the residual sum of squares between actual value (FRCDabm) and the predicted value (FRCDpom).

Where:

FRCDabm= Actual frequency of RCD of a slope before structural measures are installed [no. of RCD per year]

FRCDabm is FRCD of the period between road construction and structural measures installation. If structural measures are not installed at the time of assessment survey then FRCDabm is FRCD of the period between road construction and date of assessment survey.

As records of road disasters do not exist, FRCDabm used in the analysis were the values based on the stakeholders' memories.

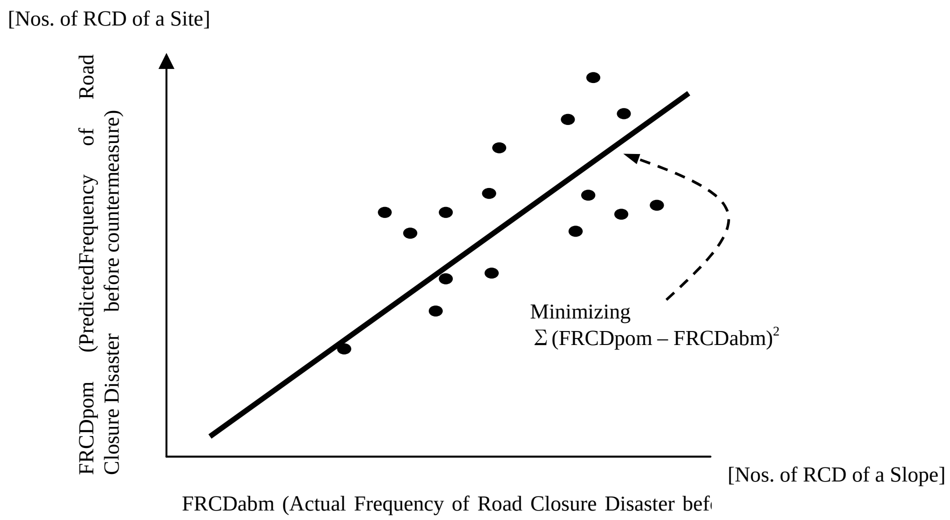


Figure 5-1 Illustration for Searching Most Suitable Frequency Scores and FRCDpom (Prediction Value) by Multivariate Statistical Analysis

Multivariate statistical analysis for searching the most suitable frequency scores was done using data of road slope risk assessment survey conducted in August 2007. The analyzed frequency scores are shown in Inventory sheets 2-1, 2-3, 2-4 (Figure 5.3.8, 5.3.9, and 5.3.10)

Correlation charts of analyzed FRCDpom and FRCDabm are shown in Figure 5-2.

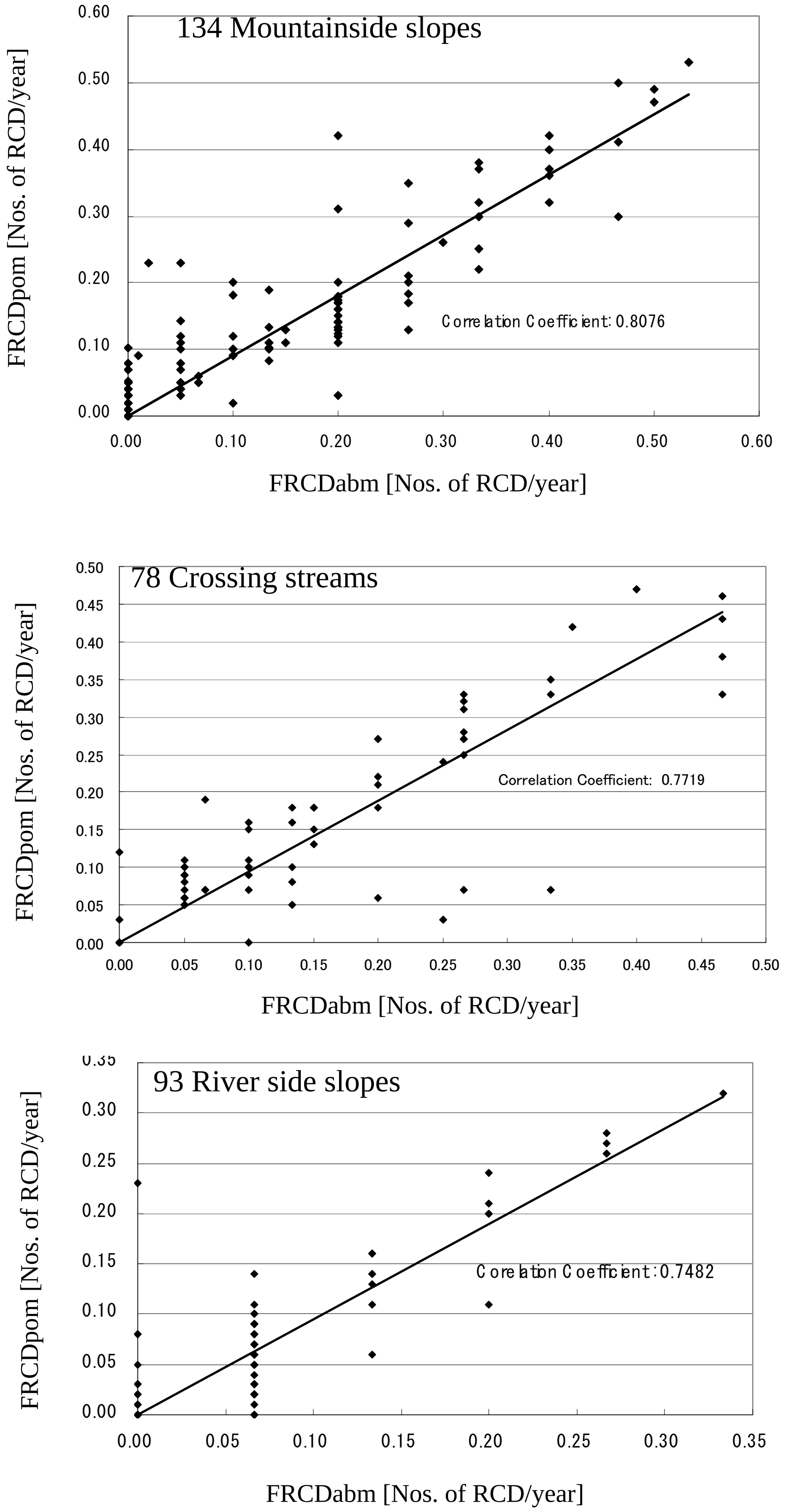


Figure 5-2 Correlation charts of analyzed FRCDpom and FRCDabm with Correlation Coefficient

VI

ROAD SLOPE ASSESSMENT SHEET OF 12 PRIORITY ROAD SEGMENT

11km+200 Kahale Khola

11km+500

12km+600 Dash Khola

21km+200

21km+560

21km+610 SL-1: landslide-1

23km+510 SL -2: landslide-2

23km+930

23km+960 SL -3: landslide-3

24km+235 SL -4: landslide-4

30km+690

34km+200

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region					Division Road Office	Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	11 km	280 m	until	11 km	318 m	Length : m	38		
Side of the site	Right side of the road									
Slope type	Crossing Stream					Potential Disaster Type (Main)	Debris flow			
						Potential Disaster Type (Sub)				
Risk Assessment Sheet 1, 2,3	Name of preparer					Assess ment date	Date	Month	Year	

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.000	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.267	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway			
Station from	11	km	280	m
Side of the site	Right side of the road			

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	0	1		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 km^2 > A ≥ 0.15 km^2		0.15 km^2 > A	FS2	(0.05)
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	0	1		0		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.05
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	0	0	1	0		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	1	0	0	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	0	1	0	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.09
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	0	1	0	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.01
Frequency score for FRCDp [RCD/year]	0.01					
	1					
						v
					FRCDpom = Σ (FS1:FS9)	0.31
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.80
					FRCDp: [RCD/year]	
					FRCDp = FRCDpom x CEM	0.25

Note

Yellow	1 should be input to selected category's cell.
Orange	1 should be input when corresponding to situation.
Light blue	Numerical value or term is automatically input.
Pink	Numerical value should be input (by engineering judgment).
Green	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	11 km	280 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches

3-2 Cross section sketches

Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.25
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	38
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	0
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	64,472
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	2.84
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,534
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	23,214,302
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	23,282,776
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	5,774,128

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	11 km	280 m	Side of survey	Right side of the road	
Name of planner					

1km+300m upstream from N-M highway

1km+750m upstream from N-M highway

4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	0+220m, Plain Cement Concrete Sabo Dam 73.0 m length, 5.0 m h	LS	1	7,300,000	7,300,000
2	0+310m, Plain Cement Concrete Sabo Dam 43.0 m length, 5.0 m h	LS	1	4,300,000	4,300,000
3	0+825m, Plain Cement Concrete Sabo Dam 45.0 m length, 7.0 m h	LS	1	6,300,000	6,300,000
4	1+300m, Plain Cement Concrete Sabo Dam 38.0 m length, 8.0 m h	LS	1	6,080,000	6,080,000
5	1+750m, Plain Cement Concrete Sabo Dam 29.6 m length, 7.0 m h	LS	1	4,144,000	4,144,000
6	0+125m right bank, Plain Cement Concrete Spur 20.9m	LS	1	418,000	418,000
7					0
	Total Cost				28,542,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.90
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	5,196,716
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.02

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %

Benefit/cost ratio	BCR_I		ratio	2.410
Economic net present value	$ENPV_I$		Rs	40,234,313
Economic internal rate of return	$EIRR_I$		percent	27%

Note
- (pink) Numerical value or terms should be input
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office	Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway								
Station	from	11 km	500 m	until	11 km	520 m	Length : m	20	
Side of the site	Right side of the road								
Slope type	Crossing Stream				Potential Disaster Type (Main)	Debris flow			
					Potential Disaster Type (Sub)				
Risk Assessment Sheet 1, 2,3	Name of preparer	Mikihiro MoRI(JICA Study Team) Shiba Khadka(DWIDP) Kailash Maghat(DOR)			Assess ment date	Date	Month	Year	
						17	Aug.	2007	

Photographs

General View

RCD on 16 AUG 2007

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.333	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.467	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway			
Station from	11	km	500	m
Side of the site	Right side of the road			

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	0	1		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 km^2 > A ≥ 0.15 km^2		0.15 km^2 > A	FS2	(0.05)
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	0	1		0		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	1	0	0	0		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	1	0	0	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	1	0	0	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.09
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	0	0	1	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.01
Frequency score for FRCDp [RCD/year]	0.01					
	1					
						v
					FRCDpom = Σ (FS1:FS9)	0.33
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.80
					FRCDp:	**[RCD/year]**
					FRCDp = FRCDpom x CEM	0.26

Note

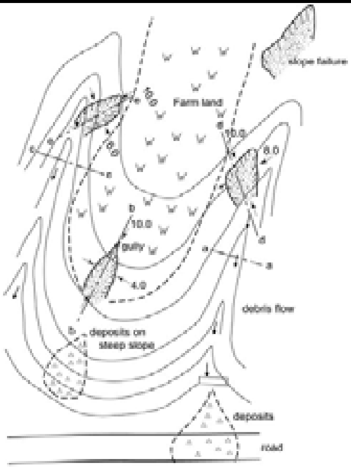
Yellow	1 should be input to selected category's cell.
Orange	1 should be input when corresponding to situation.
Light blue	Numerical value or term is automatically input.
Pink	Numerical value should be input (by engineering judgment).
Green	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

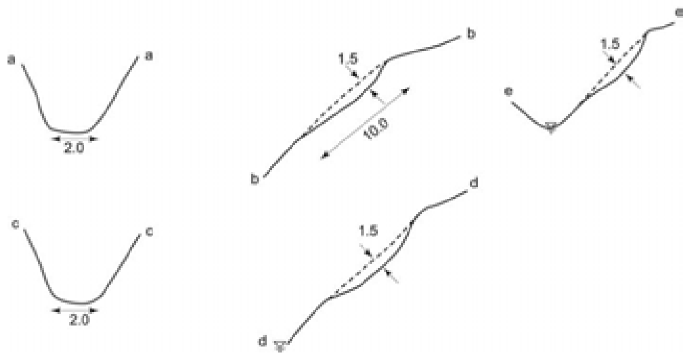
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	11 km	500 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.26
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	5
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	15
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	39,032
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.24
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	1,960
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	7,853,562
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	7,896,595
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	2,084,701

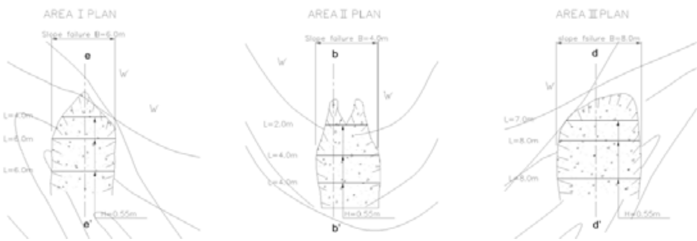
Note

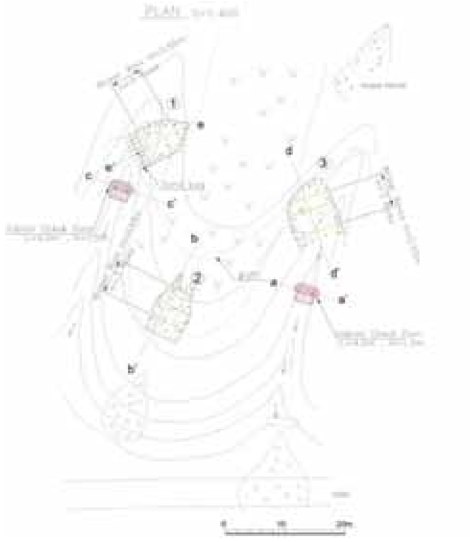
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

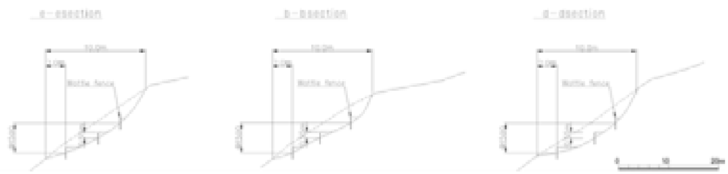
Road Name	Narayangharh-Mugling Highway				
Station from	11 km	500 m	Side of survey	Right side of the road	
Name of planner					

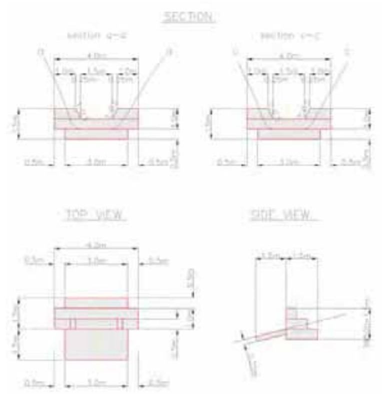
4-1 Plan layout of structural measures





4-2 Section layout of structural measures





4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Bio-engineering (Wicker)	LS	1	48,000	48,000
2	Gabion check dam work				0
3					0
4					0
5					0
6					0
7					0
Total Cost					48,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.55
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	1,146,586
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.12

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	315.837
Economic net present value	$ENPV_I$		Rs	15,112,163
Economic internal rate of return	$EIRR_I$		percent	2849%

Note
- Numerical value or terms should be input. (pink)
- Numerical value is automatically input. (light blue)

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region					Division Road Office	Bharatpure, Chitwan				
Road name	Narayangharh-Mugling Highway										
Station	from	12	km	600	m	until	12	km	631	m	Length : m 31
Side of the site	Right side of the road										
Slope type	Crossing Stream					Potential Disaster Type (Main)	Debris flow				
						Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer					Assess ment date	Date	Month	Year		

Photographs

General View

Das KhaLA

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.333	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.467	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink box) Numerical value or terms should be input.
- (green box) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway		
Station from	12	km	600 m
Side of the site	Right side of the road		

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	0	1		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 km^2 >A ≥ 0.15 km^2		0.15 km^2 > A	FS2	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	1	0		0		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.04
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	0	0	0	1		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	(0.03)
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	0	0	1	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	0	1	0	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.20
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	1	0	0	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.01
Frequency score for FRCDp [RCD/year]	0.01					
	1					
						v
					FRCDpom = Σ (FS1:FS9)	0.43
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.90
					FRCDp: [RCD/year]	
					FRCDp = FRCDpom x CEM	0.39

Note

- (Yellow) 1 should be input to selected category's cell.
- (Orange) 1 should be input when corresponding to situation.
- (Light blue) Numerical value or term is automatically input.
- (Pink) Numerical value should be input (by engineering judgment).
- (Green) Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	12 km	600 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches

3-2 Cross section sketches

Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.39
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	31
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	0
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	58,382
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	2.50
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,446
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	19,732,342
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	19,794,725
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	7,660,559

Note

(pink) Numerical value or terms should be input.

(cyan) Numerical value is automatically input.

Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway					
Station from	12	km	600	m	Side of survey	Right side of the road
Name of planner	MNWIDPP					

0+520m upstream, slit type plain cement concert sabo dam

0+000m to 0+300m Left bank, Gabion Spurs 10 m length

0+000m to 0+125m Canalization 125 m length

Sabo dams, 0+310m and 0+520m

4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	0+310m, Plain Cement Concrete Sabo Dam 80.0 m length, 7.0 m h	LS	1	11,200,000	11,200,000
2	0+520m, Plain Cement Concrete Sabo Dam 71.0 m length, 7.0 m h	LS	1	9,940,000	9,940,000
3	0+915m, Plain Cement Concrete Sabo Dam 50.0 m length, 7.0 m h	LS	1	7,000,000	7,000,000
4	1+125m, Plain Cement Concrete Sabo Dam 33.0 m length, 7.0 m h	LS	1	4,620,000	4,620,000
5	0+000m to 0+125m Canalization 125 m length	LS	1	2,500,000	2,500,000
6	0+000m to 0+300m Left bank, Gabion Spurs 10 m length	LS	1	100,000	100,000
7	Downstream of Bridge, Toe wall of Random Rubble Masonary 30 m length 2 m height	LS	1	300,000	300,000
	Total Cost				35,660,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.90
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	6,894,503
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.04

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	2.559
Economic net present value	$ENPV_I$		Rs	55,578,618
Economic internal rate of return	$EIRR_I$		percent	29%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	21 km	200 m	until	21 km	210 m		Length : m		10
Side of the site	Right side of the road									
Slope type	Crossing Stream				Potential Disaster Type (Main)			Debris flow		
					Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer					Assess ment date	Date	Month	Year	

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.350	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.350	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway			
Station from	21	km	200	m
Side of the site	Right side of the road			

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	1	0		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 km^2 >A ≥ 0.15 km^2		0.15 km^2 > A	FS2	(0.07)
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	0	0		1		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	1	0	0	0		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	1	0	0	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	1	0	0	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.20
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	1	0	0	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.01
Frequency score for FRCDp [RCD/year]	0.01					
	1					
						v
					FRCDpom = Σ (FS1:FS9)	0.42

Existing structural measure-type (Description)	CEM: Coefficient of effectiveness of structural measure	
	CEM	0.80
	FRCDp:	**[RCD/year]**
	FRCDp = FRCDpom x CEM	0.34

Note

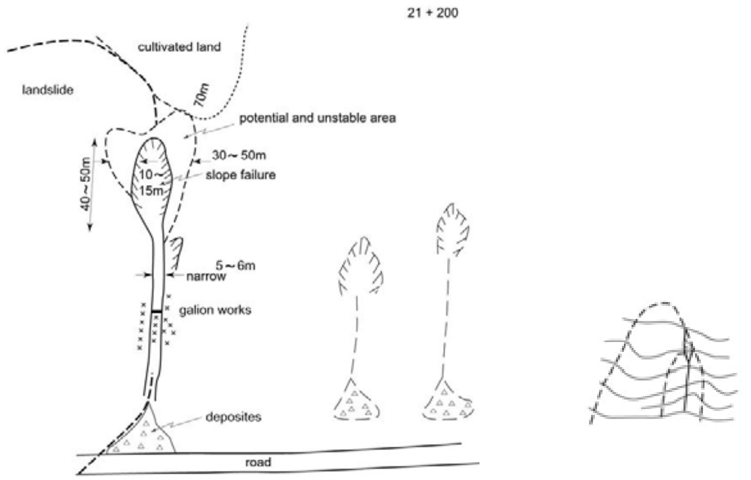
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

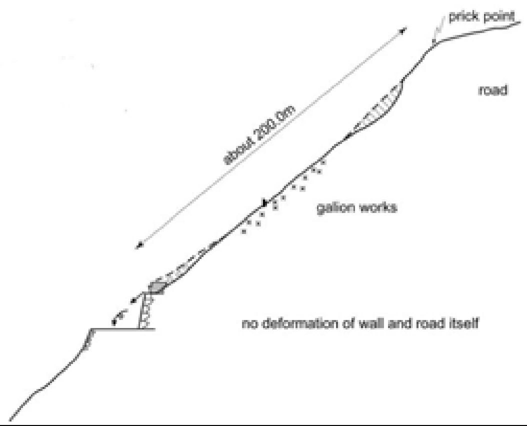
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	21 km	200 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.34
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	5
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	5
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	36,852
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.24
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	1,960
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	7,853,562
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	7,894,415
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	2,652,524

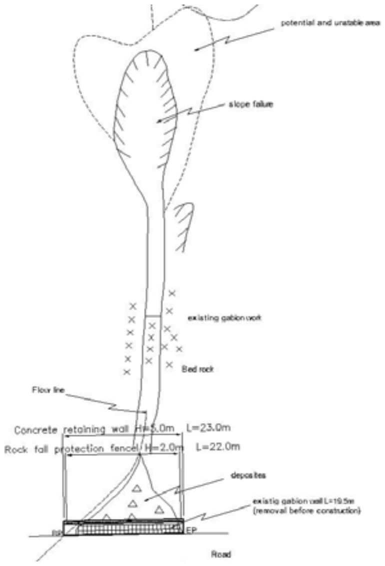
Note

- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

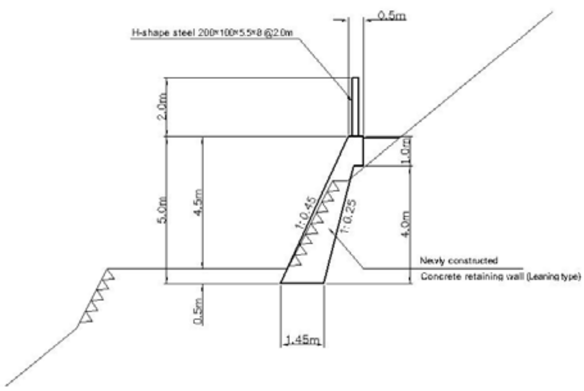
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	21 km	200 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Concrete retaining wall	LS	1	1,039,000	1,039,000
2	Rock fall protection fence				0
3	Demolishing of existing wall				0
4					0
5					0
6					0
7					0
	Total Cost				1,039,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.70
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	1,856,766
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.10

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	23.631
Economic net present value	$ENPV_I$		Rs	23,514,128
Economic internal rate of return	$EIRR_I$		percent	219%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	21 km	560 m	until	21 km	600 m	Length : m			40
Side of the site	Right side of the road									
Slope type	Crossing Stream				Potential Disaster Type (Main)		Debris flow			
					Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer				Assess ment date		Date	Month	Year	

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.000	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.267	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway		
Station from	21	km 560	m
Side of the site	Right side of the road		

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	0	1		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 $km^{2,}$ >A ≥ 0.15 km^2		0.15 km^2 > A	FS2	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	1	0		0		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.06
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	0	1	0	0		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	1	0	0	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	(0.01)
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	0	0	1	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.09
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	0	1	0	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.00
Frequency score for FRCDp [RCD/year]	0.01					
	0					
						v
					FRCDpom = Σ (FS1:FS9)	0.33
Existing structural measure-type (Description)					**CEM: Coefficient of effectiveness of structural measure**	
					CEM	0.40
					FRCDp: [RCD/year]	
					FRCDp = FRCDpom x CEM	0.13

Note

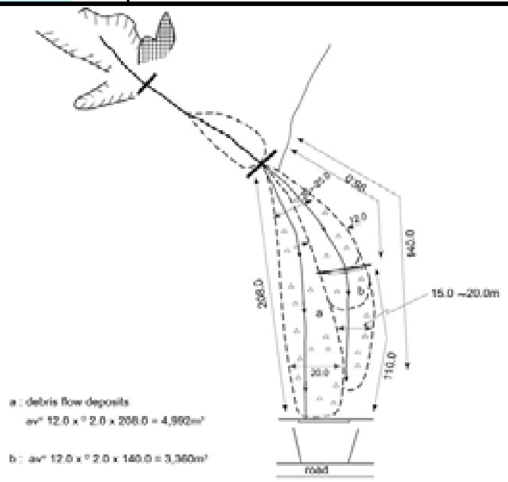
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

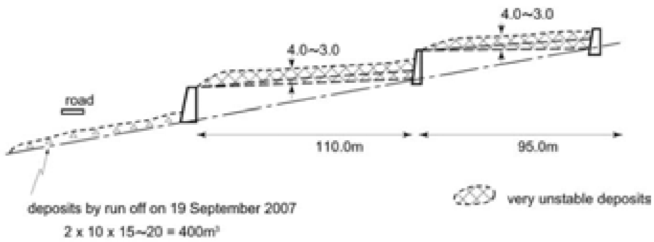
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	21 km	560 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.13
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	10
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	30
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	46,652
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.48
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,084
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	9,976,131
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	10,026,785
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	1,323,536

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	21 km	560 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures

4-2 Section layout of structural measures

4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Maintenance of sabo dam (debris removal) per year	m3	1035	280	289,800
2					0
3					0
4					0
5					0
6					0
7					0
Total Cost					289,800

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.30
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	397,061
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.09

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	2.166
Economic net present value	$ENPV_I$		Rs	2,826,203
Economic internal rate of return	$EIRR_I$		percent	77%

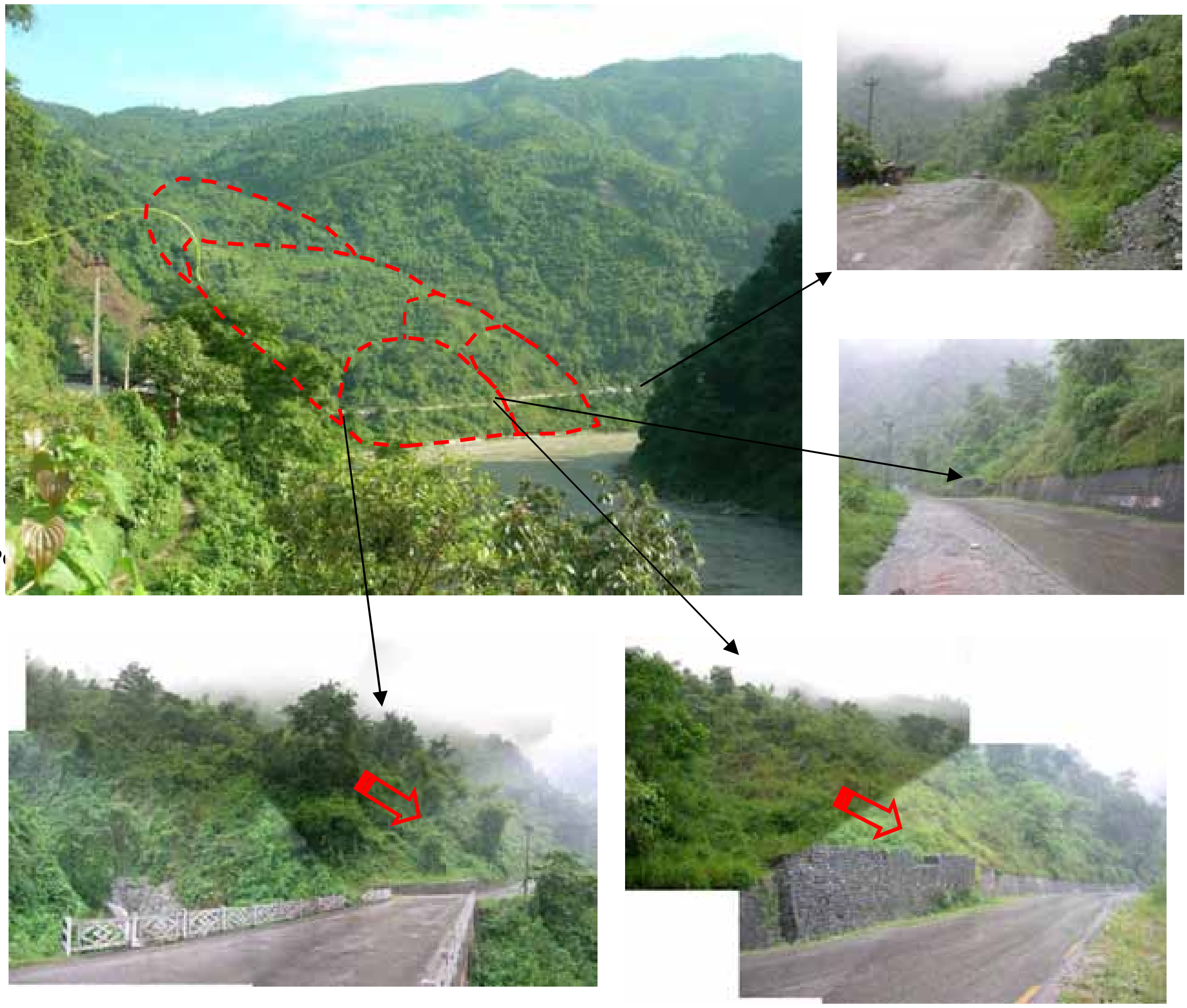
Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan				
Road name	Narayangharh-Mugling Highway										
Station	from	21	km	610	m	until	21	km	900	m	Length : m 290
Side of Road	Right side of the road										
Slope type	Mountainside Slope				Potential Disaster Type (Main)		Slope failure				
					Potential Disaster Type (Sub)						
Risk Assessment Sheet 1, 2,3	Name of preparer	Satoru NODA (JICA Study Team) Pathak (DWIDP) Dal Bahadur (DOR)			Assess ment date	Date	Month	Year			
						16	Aug.	2007			

Photographs

General View



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FRCDa: Actual frequency of RCD* of a site	0.000	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.400	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	21 km	610 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				Frequency score for FRCDp [RCD/year]	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.02
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	0	1	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	1	0	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	(0.05)
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	0	1	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	0	1	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.03
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	0	0	1	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	0	0	1	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	0	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	1	0	0	0		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.07
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	1	0	1	1		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.15
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	1	0	1			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	0	0	0		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	0	1	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.37
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.40
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.15

Note

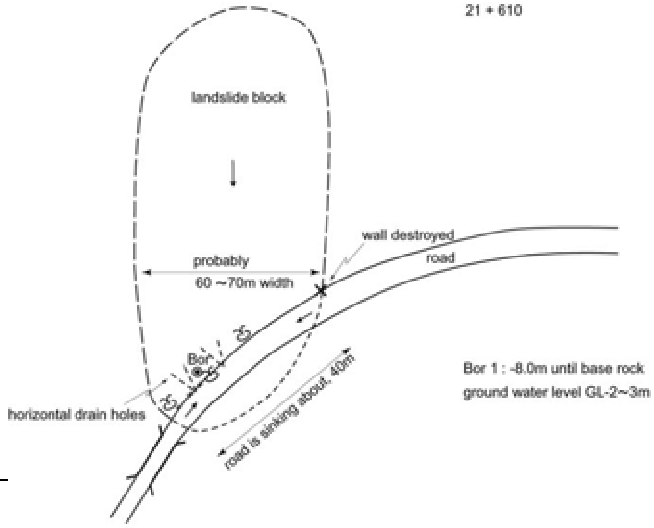
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

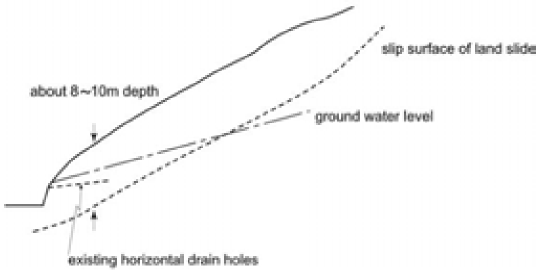
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	21 km	610 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.15
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	30
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	190
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	98,932
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	2.45
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,432
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	19,243,002
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	19,345,936
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	2,863,199

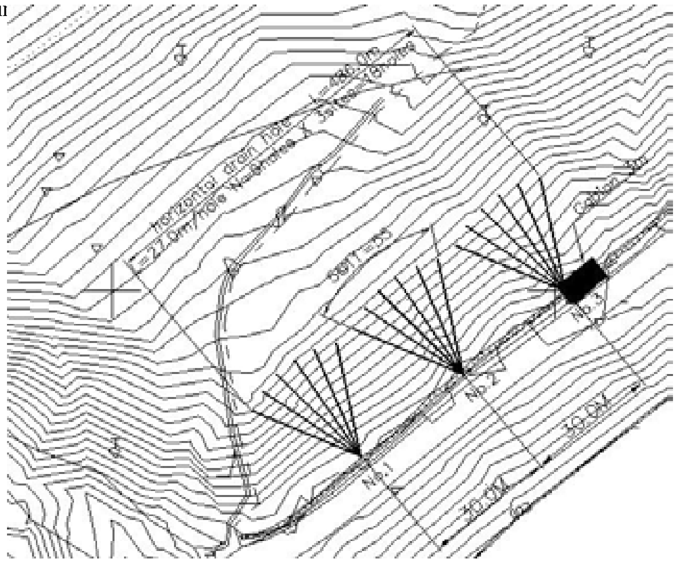
Note

- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

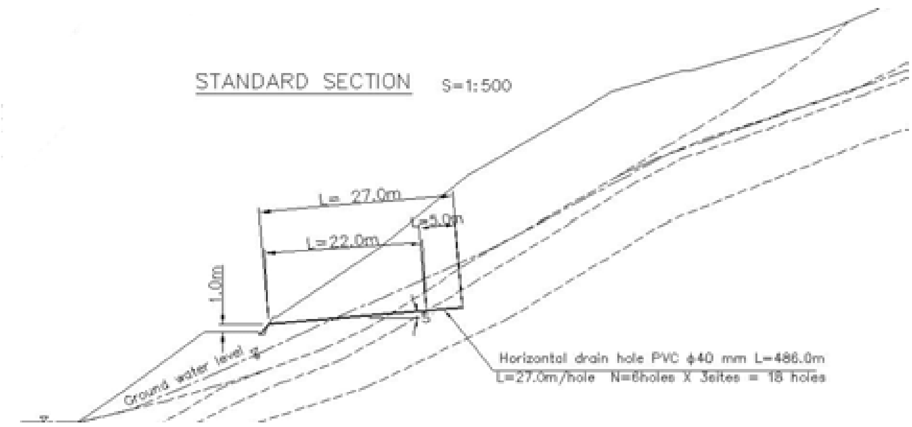
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway					
Station from	21	km	610	m	Side of survey	Right side of the road
Name of planner						

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Horizontal drain holes	LS	1	6,474,000	6,474,000
2					0
3					0
4					0
5					0
6					0
7					0
	Total Cost				6,474,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.75
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	2,147,399
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-317,814.89

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	4.385
Economic net present value	$ENPV_I$		Rs	21,916,799
Economic internal rate of return	$EIRR_I$		percent	45%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	23 km	510 m	until	23 km	710 m	Length : m	200		
Side of Road	Right side of the road									
Slope type	Mountainside Slope				Potential Disaster Type (Main)		Slope failure			
					Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer	Satoru NODA (JICA Study Team) Pathak (DWIDP)			Assess ment date	Date	Month	Year		
						20	Aug.	2007		

Photographs

General View






FRCDa: Actual frequency of RCD* of a site	0.000	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.333	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	23 km	510 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				Frequency score for FRCDp [RCD/year]	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.02
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	0	1	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.04
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	0	1	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	(0.05)
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	0	1	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	0	1	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	1	0	0	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	0	0	0	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	1	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.03
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	0	0	0	1		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.05
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	1	0	0	1		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.08
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	1	0	0			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	0	0	0		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	0	1	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.30
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.80
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.24

Note

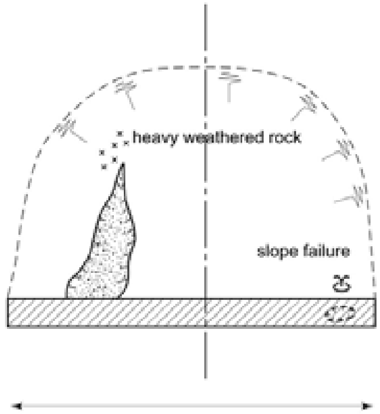
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

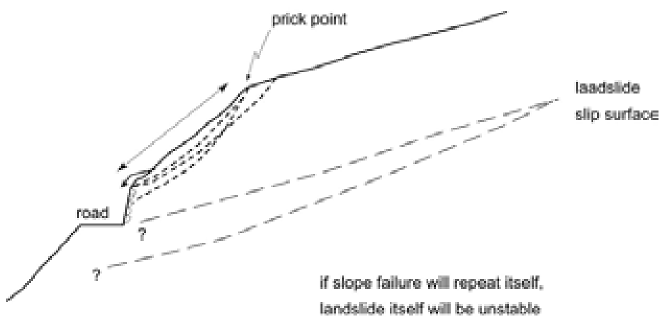
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	23 km	510 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.24
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	20
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	105
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width roac closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	71,702
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.97
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,280
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	14,474,969
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	14,550,672
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	3,492,161

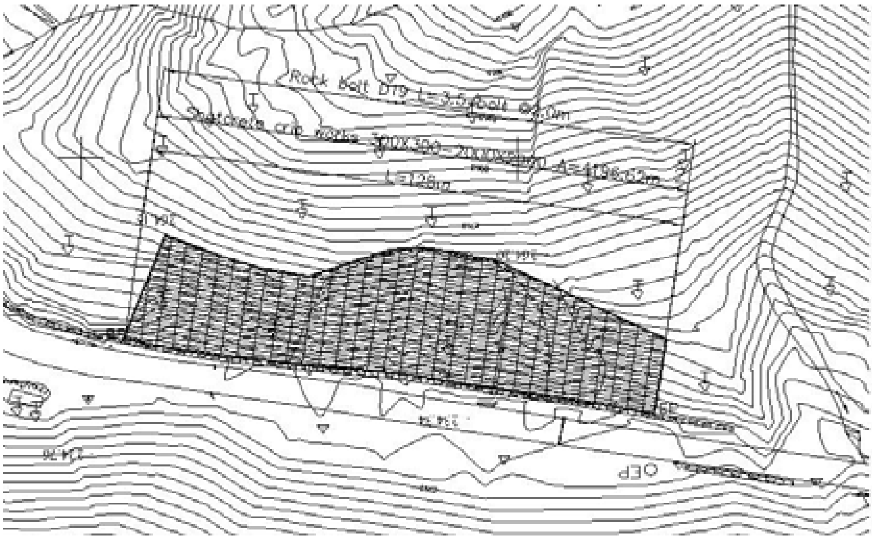
Note

(pink)	Numerical value or terms should be input.
(light blue)	Numerical value is automatically input.

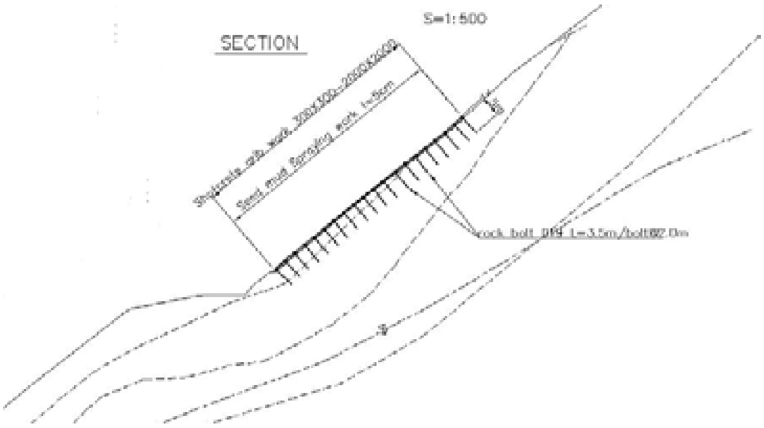
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	23 km	510 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Shotcrete crib work	LS	1	29,633,000	29,633,000
2	Rock bolt work				0
3	Seed-mud spraying work				0
4					0
5					0
6					0
7					0
	Total Cost				29,633,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.95
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	3,317,553
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-796,212.56

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	1.480
Economic net present value	$ENPV_I$		Rs	14,232,001
Economic internal rate of return	$EIRR_I$		percent	18%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region					Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway										
Station	from	23	km	930	m	until	23	km	960	m	Length : m 30
Side of the site	Right side of the road										
Slope type	Crossing Stream					Potential Disaster Type (Main)		Debris flow			
						Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer					Assess ment date		Date	Month	Year	

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.333	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.467	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

(pink) Numerical value or terms should be input.

(green) Terms should be input.

Road Slope Assessment Sheet 2-2: Potential Frequency of RCD (Crossing Stream)

Road name	Narayangharh-Mugling Highway		
Station from	23 km	930 m	
Side of the site	Right side of the road		

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				FS: Frequency score for FRCDp [RCD/year]	
Geometry						
Width of stream: W	3 m ≥ W	5 m ≥ W > 3 m	10 m ≥ W > 5 m	W > 10 m	FS1	0.00
Frequency score for FRCDp [RCD/year]	0.06	0.00	0.00	0.00		
	0	0	0	1		
Area of drainage basin : A	A ≥ 0.5 km^2	0.5 km^2 >A ≥ 0.15 km^2		0.15 km^2 > A	FS2	(0.07)
Frequency score for FRCDp [RCD/year]	0.00	-0.05		-0.07		
	0	0		1		
Gradient of stream at road crossing: G	G ≥ 20 °	20° > G ≥ 15 °	15° > G ≥ 10 °	10° > G	FS3	0.06
Frequency score for FRCDp [RCD/year]	0.07	0.06	0.05	0.04		
	0	1	0	0		
Steepest gradient of stream: G	G ≥ 40 °	40° > G ≥ 30 °	30° > G ≥ 15 °	15° > G	FS4	(0.03)
Frequency score for FRCDp [RCD/year]	0.00	-0.03	-0.03	-0.06		
	0	1	0	0		
Height from stream bottom to road: H	1 m ≥ H	2 m ≥ H > 1 m	5 m ≥ H > 2 m	H > 5 m	FS5	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	-0.01	-0.28		
	1	0	0	0		
Surface situation						
Dominant vegetation of drainage area	Bare	Grasses	Trees	Unknown	FS6	0.20
Frequency score for FRCDp [RCD/year]	0.20	0.09	0.09	0.07		
	1	0	0	0		
Dominant materials of stream sediment at road crossing	Cobbles, Boulders, Gravel	Sand	Silt, Clay	Bedrock	FS7	0.13
Frequency score for FRCDp [RCD/year]	0.13	0.01	0.01	0.00		
	1	0	0	0		
Disturbance						
Slope failure situation in drainage area	Newly-formed collapses are existing in main valley and branch valleys	Newly-formed collapses are existing only in main valley	Newly-formed collapses are existing only in branch valleys	Newly-formed collapses are not recognized	FS8	0.06
Frequency score for FRCDp [RCD/year]	0.06	0.04	0.02	-0.05		
	1	0	0	0		
Trace of debris on or beside the road	Trace of debris on or beside the road				FS9	0.01
Frequency score for FRCDp [RCD/year]	0.01					
	1					
						v
					FRCDpom = Σ (FS1:FS9)	0.38
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.60
						FRCDp: [RCD/year]
					FRCDp = FRCDpom x CEM	0.23

Note

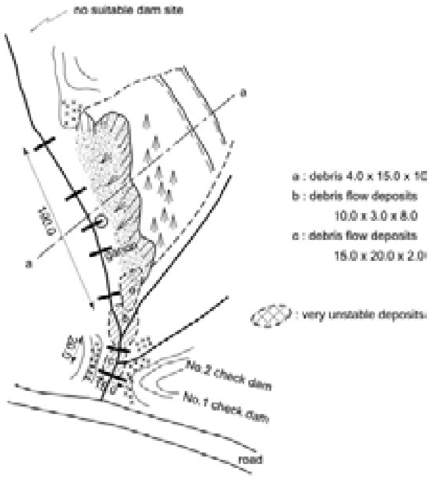
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

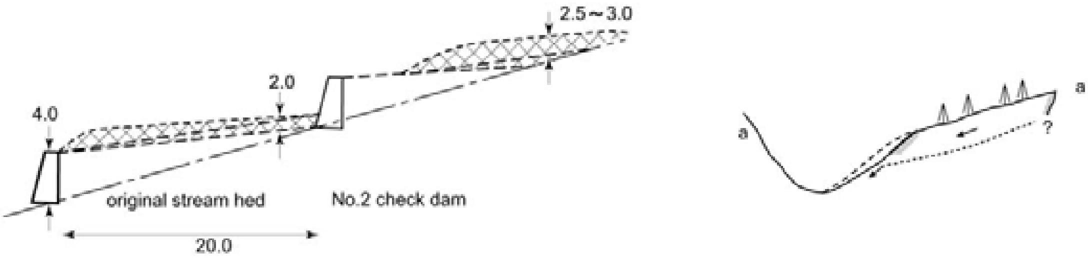
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	23 km	930 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.23
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	10
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	20
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	44,472
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.48
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	2,084
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	9,976,131
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	10,024,605
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	2,285,610

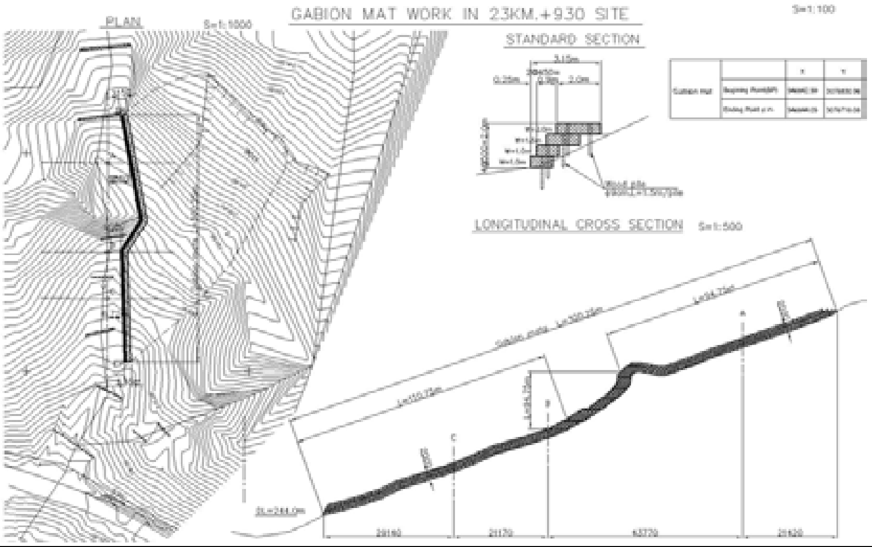
Note

- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

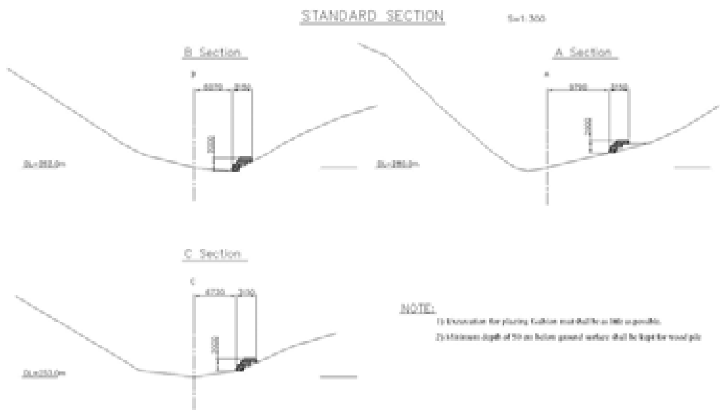
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	23	km	930	m	Side of survey: Right side of the road
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Gabion mat	LS	1	1,816,000	1,816,000
2	Removal of deposits				0
3					0
4					0
5					0
6					0
7					0
	Total Cost				1,816,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.70
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	1,599,927
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	0.07

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	11.651
Economic net present value	$ENPV_I$		Rs	19,342,930
Economic internal rate of return	$EIRR_I$		percent	111%

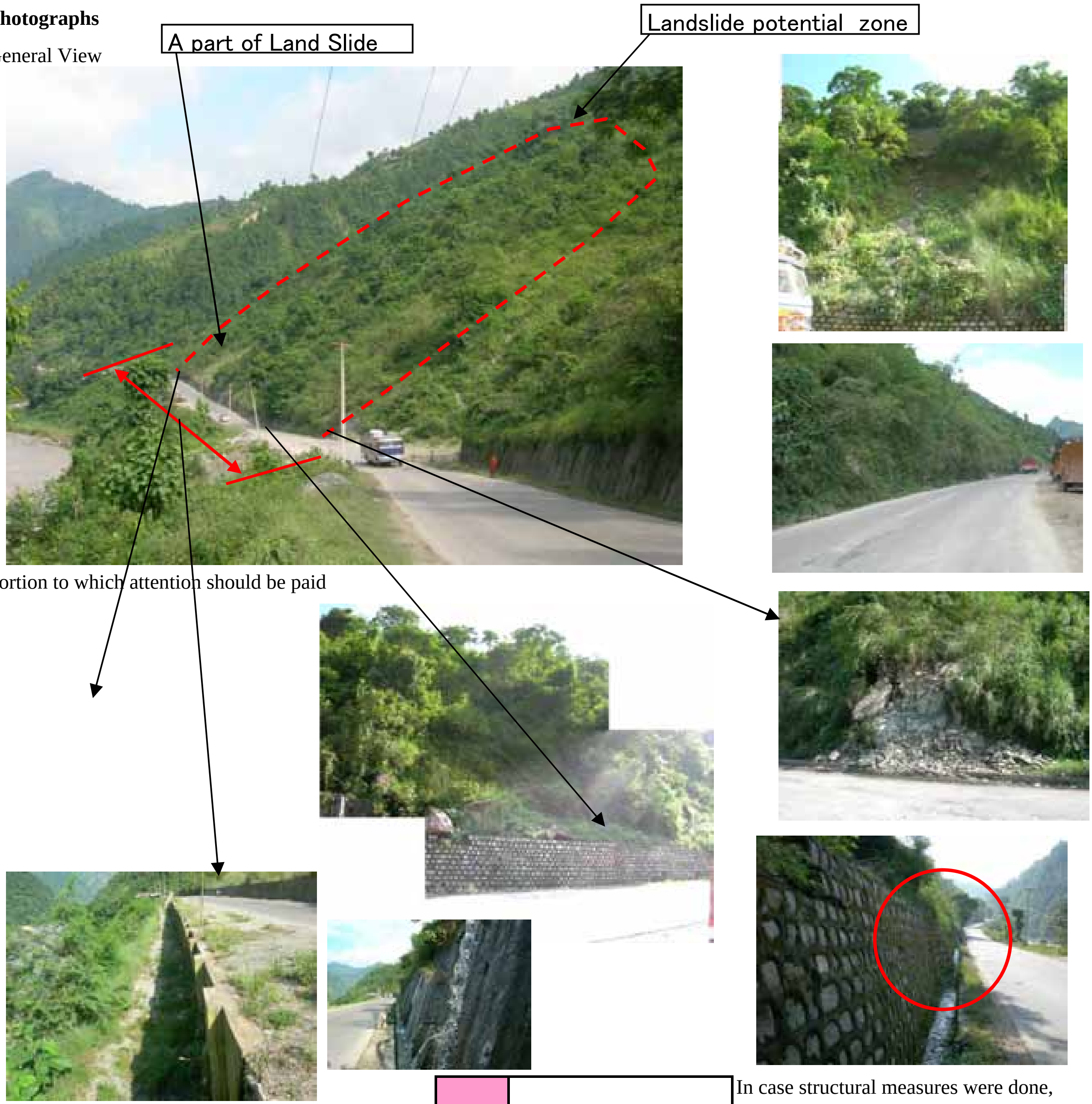
Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region			Division Road Office	Bharatpure, Chitwan				
Road name	Narayangharh-Mugling Highway								
Station	from	23 km	960 m	until	24 km	200 m	Length : m	240	
Side of Road	Right side of the road								
Slope type	Mountainside Slope			Potential Disaster Type (Main)	Slope failure				
				Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer	Satoru NODA (JICA Study Team) Pathak (DWIDP)		Assess ment date	Date	Month	Year		
					20	Aug.	2007		

Photographs

General View



FRCDa: Actual frequency of RCD* of a site	0.100	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.333	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	23 km	960 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	**Factor categories for FRCDp**				**Frequency score for FRCDp [RCD/year]**	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.02
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	0	1	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	1	0	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	(0.05)
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	0	1	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	0	1	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.03
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	0	0	1	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	0	0	1	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	0	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	1	0	0	0		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.07
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	1	0	1	1		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.08
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	1	0	0			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	0	0	0		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	0	1	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.30
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.80
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.24

Note

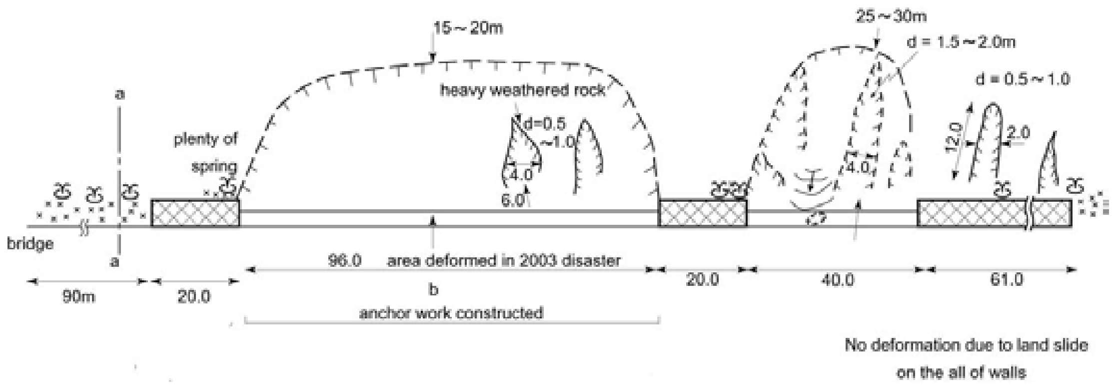
(yellow)	1 should be input to selected category's cell.
(orange)	1 should be input when corresponding to situation.
(light blue)	Numerical value or term is automatically input.
(pink)	Numerical value should be input (by engineering judgment).
(green)	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

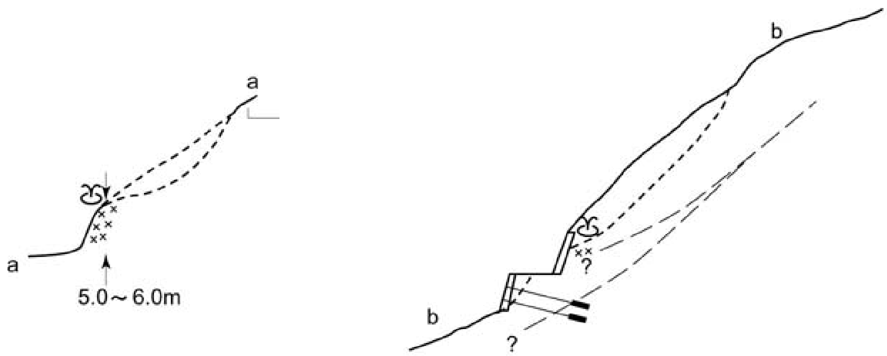
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway		
Station from	23 km	960 m	Side of the site: Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.24
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	100
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	220
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	166,372
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	5.84
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	3,030
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	57,115,500
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	57,285,874
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	13,748,610

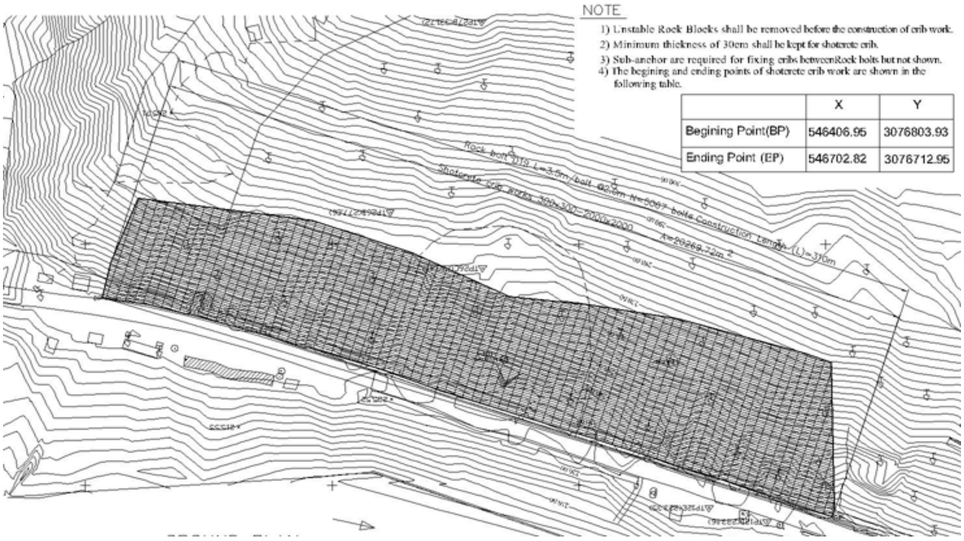
Note

- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

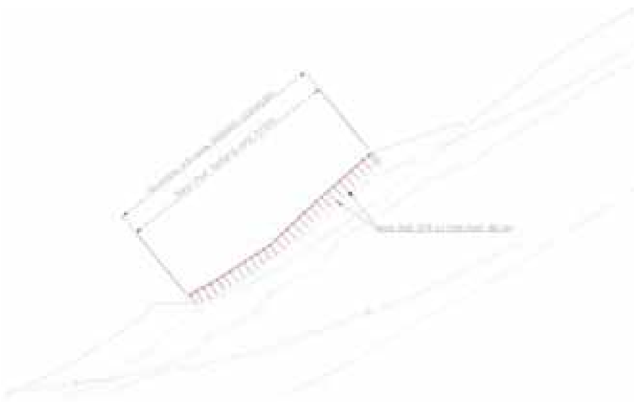
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	23 km	960 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Shotcrete crib work	LS	1	142,047,000	142,047,000
2	Rock bolt work				0
3	Seed-mud spraying work				0
4					0
5					0
6					0
7					0
	Total Cost				142,047,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.95
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	13,061,179
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-3,134,682.77

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	1.217
Economic net present value	$ENPV_I$		Rs	30,801,929
Economic internal rate of return	$EIRR_I$		percent	15%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	24 km	235 m	until	24 km	535 m	Length : m			300
Side of Road	Right side of the road									
Slope type	Mountainside Slope				Potential Disaster Type (Main)		Slope failure			
					Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer	Satoru NODA (JICA Study Team) I.P. Devkota (DWIDP)				Assess ment date	Date	Month	Year	
							21	Aug.	2007	

Photographs

General View

FRCDa: Actual frequency of RCD* of a site	0.000	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.333	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	24 km	235 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				Frequency score for FRCDp [RCD/year]	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	1	0	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.04
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	0	1	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	(0.05)
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	0	1	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.00
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	0	1	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.03
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	0	1	0	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	0	0	1	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	0	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	0	1	0	0		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.05
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	1	0	0	1		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.00
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	0	0	0			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	0	0	0		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	0	0	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.24
Existing structural measure-type (Description)					**CEM: Coefficient of effectiveness of structural measure**	
					CEM	0.80
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.19

Note

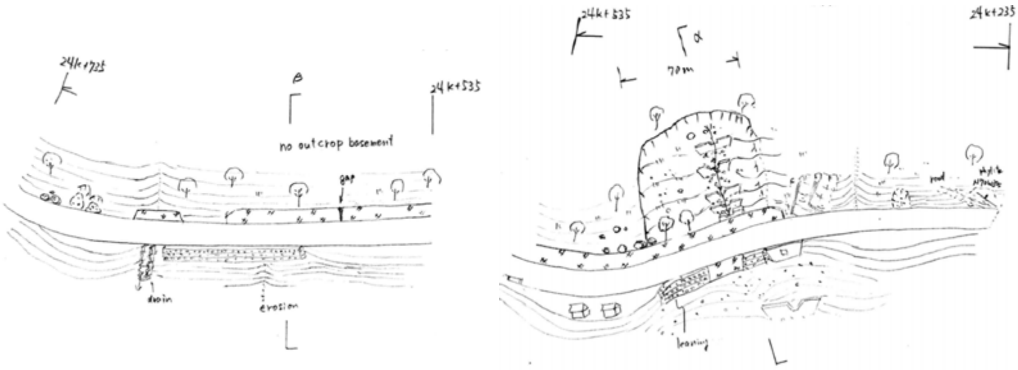
Yellow	1 should be input to selected category's cell.
Orange	1 should be input when corresponding to situation.
Light blue	Numerical value or term is automatically input.
Pink	Numerical value should be input (by engineering judgment).
Green	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	24 km	235 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches

Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.19
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	5
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	174
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	73,694
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.24
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	1,960
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	7,853,562
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	7,931,257
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	1,522,801

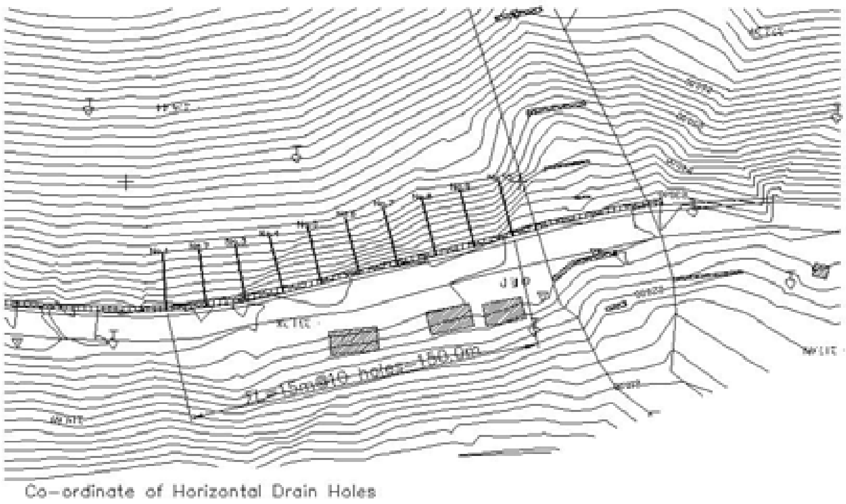
Note

- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

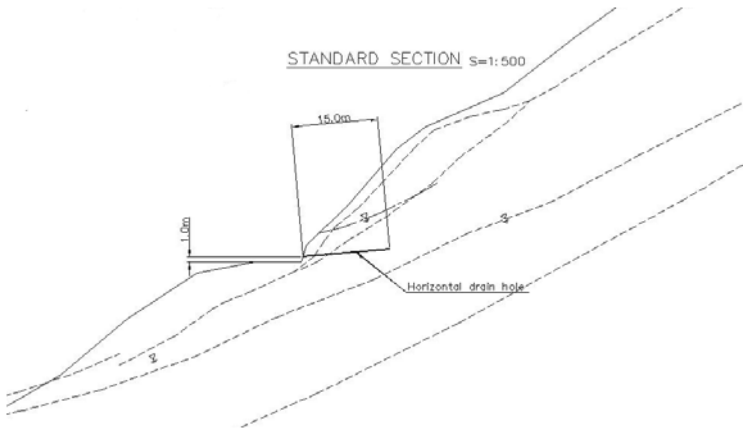
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	24	km	235	m Side of survey	Right side of the road
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Horizontal drain holes	LS	1	2,001,000	2,001,000
2					0
3					0
4					0
5					0
6					0
7					0
	Total Cost				2,001,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.75
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	1,142,101
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-219,283.21

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	7.532
Economic net present value	$ENPV_I$		Rs	13,071,155
Economic internal rate of return	$EIRR_I$		percent	74%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office			Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway										
Station	from	30	km	690	m	until	30	km	950 m	Length : m	260
Side of Road	Right side of the road										
Slope type	Mountainside Slope				Potential Disaster Type (Main)			Slope failure			
					Potential Disaster Type (Sub)						
Risk Assessment Sheet 1, 2,3	Name of preparer	Takeshi KUWANO (JICA Study Team) Yogendra Mishra (DWIDP)				Assess ment date	Date	Month	Year		
							16	Aug.	2007		

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.200	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.467	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	30 km	690 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				Frequency score for FRCDp [RCD/year]	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.02
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	0	1	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.04
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	0	1	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	(0.05)
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	0	1	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	1	0	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	1	0	0	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.02
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	1	0	0	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	0	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	0	1	0	0		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.04
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	0	0	1	1		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.01
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	1	0	0			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	0	0	0		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	0	0	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.30
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	0.80
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.24

Note

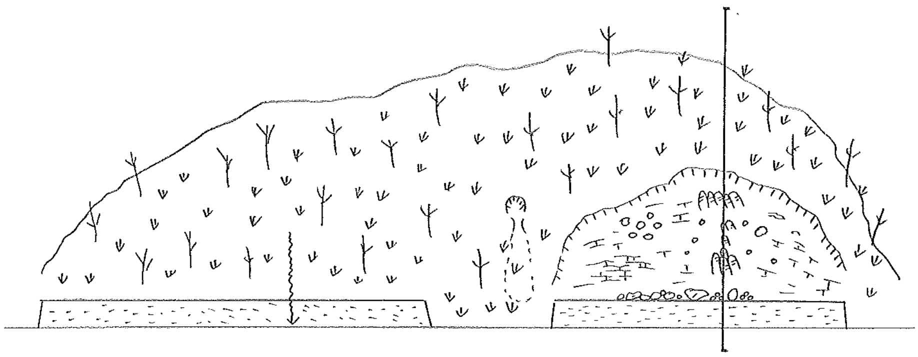
Yellow	1 should be input to selected category's cell.
Orange	1 should be input when corresponding to situation.
Light blue	Numerical value or term is automatically input.
Pink	Numerical value should be input (by engineering judgment).
Green	Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

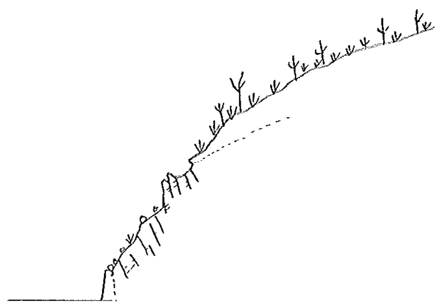
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway			
Station from	30 km	690 m	Side of the site	Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.24
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	5
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	75
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	52,112
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.24
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	1,960
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	7,853,562
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	7,909,675
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	1,898,322

Note

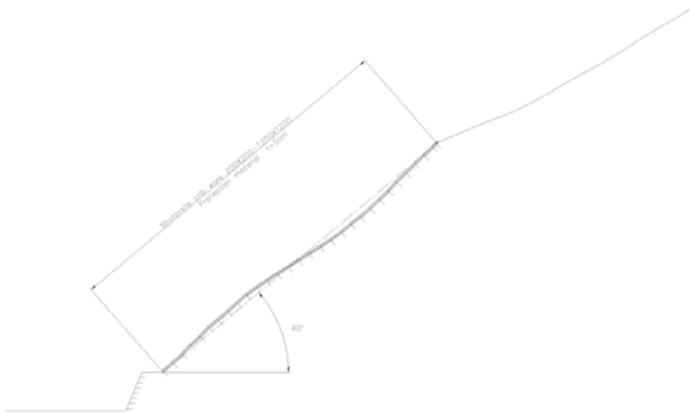
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	30 km	690 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures

4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Shotcrete crib work	LS	1	13,703,000	13,703,000
2	Seed-mud Spraying work				0
3					0
4					0
5					0
6					0
7					0
	Total Cost				13,703,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.85
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	1,613,574
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-387,257.47

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	1.556
Economic net present value	$ENPV_I$		Rs	7,616,333
Economic internal rate of return	$EIRR_I$		percent	18%

Note
- (pink) Numerical value or terms should be input.
- (cyan) Numerical value is automatically input.

Road Slope Assessment Sheet 1: General Information

Region	Central Development Region				Division Road Office		Bharatpure, Chitwan			
Road name	Narayangharh-Mugling Highway									
Station	from	34 km	200 m	until	34 km	640 m	Length : m			440
Side of Road	Right side of the road									
Slope type	Mountainside Slope				Potential Disaster Type (Main)		Slope failure			
					Potential Disaster Type (Sub)					
Risk Assessment Sheet 1, 2,3	Name of preparer	Takeshi KUWANO (JICA Study Team) Yogendra Mishra (DWIDP)				Assess ment date	Date	Month	Year	
							16	Aug.	2007	

Photographs

General View

Portion to which attention should be paid

FRCDa: Actual frequency of RCD* of a site	0.200	RCD/year	In case structural measures were done, FRCDa after structural measures period should be input.
FRCDabm: Actual frequency of RCD before measure of a site	0.533	RCD/year	for statistical use only

***RCD: Road closure disaster;** It includes not only the whole road closure but also partial road closures.

Note

- (pink) Numerical value or terms should be input.
- (green) Terms should be input.

Road Slope Assessment Sheet 2-1: Potential Frequency of RCD (Mountainside Slope)

Road Name	Narayangharh-Mugling Highway	
Station from	34 km	200 m
Side of Survey	Right side of the road	

Potential frequency of RCD (FRCDp)

Factor items for FRCDp	Factor categories for FRCDp				Frequency score for FRCDp [RCD/year]	
Geometry						
Road section length of survey slope: L	L ≥ 300 m	300 m > L ≥ 200 m	200 m > L ≥ 100 m	100 m > L	FS1	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.02	-0.02	-0.02		
	1	0	0	0		
Height of mountain side slope: H	H ≥ 90 m	90 m > H ≥ 60 m	60 m > H ≥ 30 m	30 m > H	FS2	0.04
Frequency score for FRCDp [RCD/year]	0.05	0.04	0.03	0.02		
	0	1	0	0		
Gradient of slope: G	G ≥ 60°	60° > G ≥ 40°	40° > G≥ 20°	20° > G	FS3	0.05
Frequency score for FRCDp [RCD/year]	0.05	-0.05	-0.05	-0.05		
	1	0	0	0		
Distance from road to toe of mountainside slope : D	1 m > D	3 m ≥ D > 1m	5 m ≥ D > 3 m	D > 5 m	FS4	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.00	-0.04	-0.04		
	1	0	0	0		
Slope shape	Valley type	Straight type	Ridge type	Combined type	FS5	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.03	0.00	-0.01		
	0	1	0	0		
Surface situation						
Dominant vegetation	Bare	Grasses	Trees	Surface protection by concrete/stone/block	FS6	0.07
Frequency score for FRCDp [RCD/year]	0.07	0.03	0.03	0.00		
	1	0	0	0		
Dominant materials of slope surface	Silt, Clay	Sand	Gravels	Cobbles, or Boulders	FS7	0.03
Frequency score for FRCDp [RCD/year]	0.02	0.02	0.02	0.00		
	0	0	0	0		
	Fractured rock	Weathered rock	Soft fresh rock	Hard fresh rock		
Frequency score for FRCDp [RCD/year]	0.03	0.03	0.02	0.04		
	1	0	0	0		
Collapsing/Sliding Structure	Dip slope structure (bedding plane) is present	Soil covering impervious bedrock	The rocks are hard at upper part and soft at foot part	The rocks are soft at upper part and hard at foot part	FS8	0.05
Frequency score for FRCDp [RCD/year]	0.05	0.05	-0.03	0.03		
	1	0	0	0		
Spring/ Surface water / Erosion/ Slide Configuration	Spring is Present	Surface Water is Present	Erosion is Present	Slide Configuration is lapping over the	FS9	0.05
Frequency score for FRCDp	0.03	0.02	0.02	0.02		
	1	1	0	0		
Disturbance						
Deformation/ Collapse	Collapse/ Fall	Continuous Cracks (more than 5 meter), Crevices **on Slope**	Fallen/ Inclined trees		FS10	0.09
Frequency score for FRCDp [RCD/year]	0.01	0.01	0.07			
	1	1	0			
	Open cracks below an over hang	Open cracks by toppling	Cross open cracks to cause wedge shape slide	Sliding direction open cracks		
Frequency score for FRCDp [RCD/year]	0.02	0.01	0.02	0.02		
	0	1	1	1		
	Vertical Crakes on Retaining Wall	Continuous Cracks (more than 5 m), Crevices **on Road**	Continuous Cracks retaining wall and Road	Depression/ Upheaval **on Road**		
Frequency score for FRCDp [RCD/year]	0.02	0.07	0.04	0.02		
	1	0	0	0		
FRCDpom: FRCDp without existing structural measure [RCD/year]						
					FRCDpom = Σ (FS1:FS10)	0.55
Existing structural measure-type (Description)				**CEM: Coefficient of effectiveness of structural measure**		
					CEM	1.00
FRCDp: [RCD/year]						
					FRCDp = FRCDpom x CEM	0.55

Note

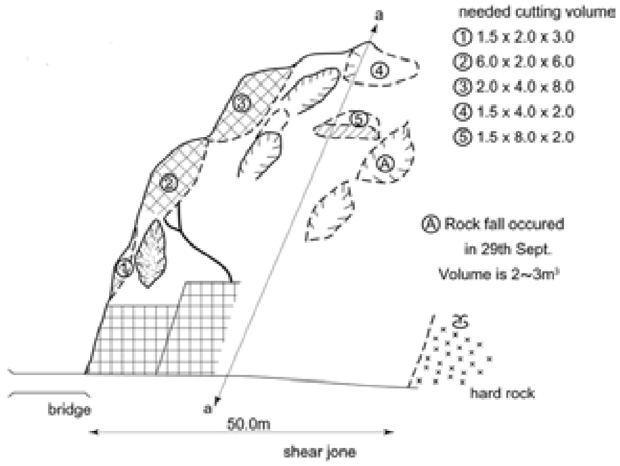
- (yellow) 1 should be input to selected category's cell.
- (orange) 1 should be input when corresponding to situation.
- (light blue) Numerical value or term is automatically input.
- (pink) Numerical value should be input (by engineering judgment).
- (green) Terms should be input.

Disturbance: deformation and collapses that do not close the road is not included in RCD and are called 'disturbance'.

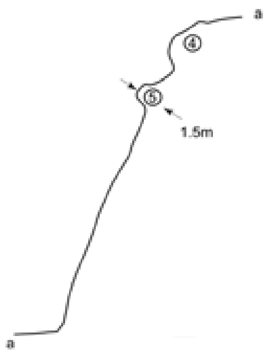
Road Slope Assessment Sheet 3: Potential Disaster Magnitude and Annual Loss

Road Name	Narayangharh-Mugling Highway		
Station from	34 km	200 m	Side of the site: Right side of the road

3-1 Front view/ Plane view sketches



3-2 Cross section sketches



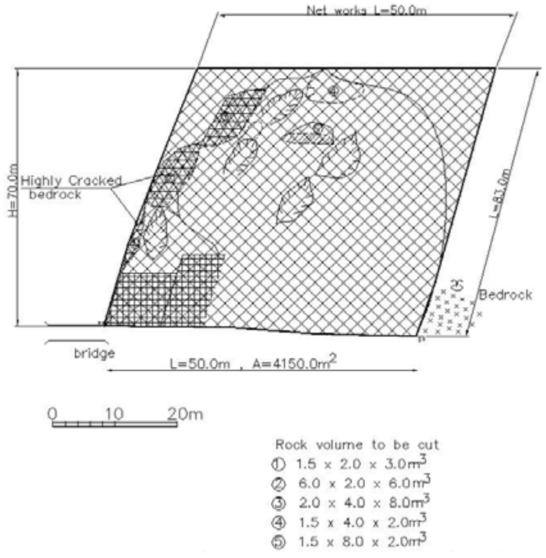
Item	Symbol	Equation	Unit	Quantity
3-3 Potential disaster frequency (evaluation as value of 2007)				
Potential frequency of road closure disaster	FRCDp		RCD/year	0.55
3-4 Potential Disaster Magnitude (evaluation as value of 2007)				
1-1) Potential length of road closure section of full width of a RCD	LRCpoF		m/RCD	5
1-2) Potential length of road closure section of partial width of a RCD	LRCpoP		m/RCD	45
Fixed cost for reopening per RCD	FCR		Rs/RCD	31,412
Unit reopening cost per one meter length of full width road closure	URCpMoF		Rs/m	870
Unit reopening cost per one meter length of partial width road closure	URCpMoP		Rs/m	218
2-1) Potential reopening cost of a RCD	RCp	RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP	Rs/RCD	45,572
2-2) Potential value of human lives loss of a RCD	HLLp		Rs/RCD	3,282
2-3) Potential value of vehicle loss of a RCD	VLp		Rs/RCD	719
Annual average daily traffic on the survey slope/stream	AADT		vehicles/day	3,225
Nos. of predicted closure days of the whole width road closure per RCD	NCDp	NCDp= 1+ LRCpoF/0.86/24	days/RCD	1.24
Average traffic suspension loss of vehicles	ASLoV	If NCDp < 0.1, ASLoV = 1,580 x NCDp; If 0.1 ≤ NCDp < 5.6, ASLoV = 693 x Ln(NCDp) + 1,810; If 5.6 ≤ NCDp, ASLoV = 3,030	Rs/vehicle	1,960
2-4) Potential loss of traffic suspension of a RCD	LTSp	LTSp=AADT x NCDp x ASLoV	Rs/RCD	7,853,562
Potential Loss of a RCD	Lp	Lp =RCp + HLLp + LTSp	Rs/RCD	7,903,135
3-5 Potential Annual Losses (evaluation as value of 2007)				
Potential Annual Loss of a site	ALp	ALp = FRCDp x Lp	Rs/year	4,346,724

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

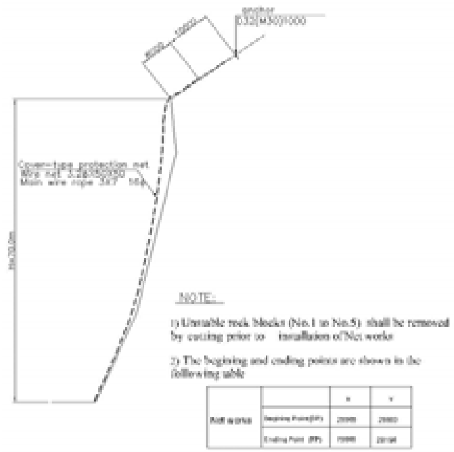
Road Slope Assessment Sheet 4-1: Structural Measure Feasibility (Alternative I)

Road Name	Narayangharh-Mugling Highway				
Station from	34 km	200 m	Side of survey	Right side of the road	
Name of planner					

4-1 Plan layout of structural measures



4-2 Section layout of structural measures



4- 3 Cost estimation (evaluation as value of 2009)

No.	Work	Unit	Quantity	Unit price (Rs)	Amount (Rs)
1	Rock fall protection net	LS	1	6,983,000	6,983,000
2					0
3					0
4					0
5					0
6					0
7					0
	Total Cost				6,983,000

4-4 Outcome (evaluation as value of 2009)

Items	symbol	equation	Unit	Quantity
2) Risk reduction ratio in RCD due to structural measure	RRR_I	ratio	ratio	0.85
3) Decrease in annual loss due to structural measure	DAL_I	$DAL_I = ALp*RRR_I$	Rs/year	3,694,716
Potential frequency of road closure disaster with structural measure	$FRCDpwm_I$	$FRCDpwm_I = FRCDp*(1- RRR_I)$	RCD/year	-2,032,093.14

4-5 Feasibility Indicators
(structural measure installation will be in 2009, benefit evaluation term is from 2010- 2029 or 20 years, discount rate is 12 %)

Benefit/cost ratio	BCR_I		ratio	6.993
Economic net present value	$ENPV_I$		Rs	41,850,967
Economic internal rate of return	$EIRR_I$		percent	69%

Note
- (pink) Numerical value or terms should be input.
- (light blue) Numerical value is automatically input.

VII

ECONOMIC VALUATION OF ROAD CLOSURE DISASTER

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VII. ECONOMIC VALUATION OF ROAD CLOSURE DISASTER

The most suitable frequency scores (FSs) were analyzed by minimizing the residual sum of

7.1 Introduction

7.1.1 Background

The road networks of Nepal are prone to frequent traffic blockades due to slope disasters induced by adverse natural conditions such as steep topography, fragile geology, and heavy rainfalls during monsoon seasons and earthquakes that occur frequently in the country.

Narayangharh – Mugling road section of Narayangharh - Gorkha Highway is the most important road section of Nepal connecting Kathmandu with India via East West Highway and Prithivi Highway. This road section is also highly prone to frequent traffic blockades due to Road Closure Disasters (RCD) during heavy rain fall. Every year these cause heavy economic losses to the country due to losses of human lives and delays in people's travel and transport of goods.

The structural measures at all slope of Narayangharh-Muguling highway might be constructed, we could not carry out the construction of structural measures at all disaster, according to several restriction condition such as social environment, economic situation, natural environment, previous facilities, administration and finance.

The risk assessment was carried out by using new method based upon the "Manual for supporting of the risk analysis and the risk management of road slope disaster (Draft version)" in Japan, HDM-4 and Original O-D survey. By this assessment, the priority level of countermeasure could be applied at economic prices of risk.

The road closures due to landslides and debris flows bear economic values such as cost of clearing the debris and opening the road, value of loss of human lives, value of damaged vehicles, values of delays that are imposed on motorists and motor carriers and additional costs in case of detour.

Economic prices/values are the prices/values which society pays and receives. It excludes subsidies since subsidies are government transfer payments. It also excludes tariffs, duties, taxes, excise and royalties as they are also government transfer payments.

7.1.2 Objectives

The main objective of this risk assessment is to estimate potential annual economic losses due to Road Closure Disaster triggered by landslides/rock falls etc. along Narayangharh - Mugling Highway.

7.1.3 Methodology

(1) Collection and Reviews of Data and Literatures

Literatures on the studies for economic valuation of road closures in different countries, especially in U.S, are reviewed extensively and are considered as the basis for this study.

Officials of Department of Roads and Department of Transport Management were also contacted and discussed to find out ways of estimating economic value of travel time. Statistical data of road lengths in Nepal and traffic on them were also collected from DoR.

Demographic and Economic data were collected from Central Bureau of Statistics, Kathmandu.

Vehicle dealers of Maruti, TATA, Hero Honda and Toyota, Tire dealers, vehicle workshops and Nepal Oil Corporation were contacted to obtain prices of vehicle, tires, cost of maintenance labor, fuel and lubricants. Similarly, Departments of Customs and Taxation were visited to obtain rates of duties, taxes, VATs etc on imports and sales of above items.

(2) Preparation of Questionnaires

Questionnaires for vehicle Origin and Destination Survey (I) and Passenger Interviews (II) were prepared and submitted to the project office for approval. The questionnaires were approved after minor changes. The approved questionnaires I and II are given in Annex 1.

(3) Arrangements for Field Survey

(i) Hiring of Survey Team

Four surveyors in Kathmandu and two in Mugling were hired for Origin and Destination (O-D) Survey and Passenger Interviews. The 4 surveyors were trained extensively in Kathmandu for carrying out Origin and Destination Survey and Passenger interviews. Other two were hired and trained in Mugling (during the survey it was realized that four surveyors were inadequate for interviewing large number of vehicles during O-D survey, as thought before. Hence two surveyors were hired and trained in Mugling.)

(ii) Letter to Bharatpur District Police

A letter issued by Department of Roads (DoR) to the District Police Office, Bharatpur asking the office to help during O-D surveys by providing policemen was obtained.

(4) Field Work

The 4 survey team members went to Bharatpur police office on 14th September 2007. In Bharatpur the surveyors handed over the letter to the in-charge and seek for help. The Bharatpur office then called police post in Mugling and asked them to help the surveyors in O-D survey. The surveyors then went to Mugling and met policemen. With the help of them the survey team selected a location 1Km south of Mugling along Mugling - Narayangharh road as a station for the O-D survey. The location was a small settlement having wide space for stopping vehicles for interviews.

(i) O-D Survey

The survey team with policemen started O-D Survey using questionnaire I at the selected location from 6 am in 15th September 2007. During the survey government, corporation, commercial, tourist and Indian plated all categories of vehicles namely: motorcycles, cars, jeeps, pickups, microbuses, minibuses, buses, mini-trucks, trucks, tankers, containers etc were coming from both directions were stopped and interviewed using the above Check list I. The survey was continued for three days to 17th September. Each day survey was carried out for 14 hours till 8 pm in the evening.

Altogether, 4036 vehicles were interviewed during the survey as detailed in Table 1.1.

Table 1.1 Details of Vehicles Interviewed during O-D Survey

Vehicle Category	Government	Corporation	Private	Commercial	Project	Tourist	Indian	Total
Motorcycle			307					**307**
Car		11	198				6	**215**
Jeep	25	6		27	37	9	13	**117**
Pickup	12	9	76	8				**105**
Bus				754		29		**783**
Minibus			1	212		4		**217**
Microbus			6	238		10		**254**
Truck	5	22	89	1476			44	**1636**
Minitruck		4	16	133				**153**
Tanker		20		143			23	**186**
Container			18	29			16	**63**
Total	**42**	**72**	**711**	**3020**	**37**	**52**	**102**	**4036**

Source: Consultants' O-D Surveys, 15 – 17th September 2007

(ii) Passenger Interviews

During the period 15 – 17th September samples of passengers of motorcycles, private cars, microbuses, minibuses and buses were also interviewed using questionnaire II. Altogether 200 passengers were interviewed.

(iii)Interviews with Local People

Local people mainly teachers, social workers, politicians and road supervisor of DoR Bharatpur residing in the settlements along the road section were met and discussed regarding past information on annual damages caused by landslides and debris in the road section especially that occurred in 2003. The information given were recorded and used for the report preparation. List of persons interviewed is given in Table 1.1 of Annex 2.

(iv)Meeting with Official of Bharatpur Road Division

Officials of Bharatpur Road Division, Department of Roads were contacted for past data on RCDs in Narayangharh – Mugling Road and costs of reopening them. They had not kept data by reopening time and cost for full width closure and partial closure separately. The data kept were only on total volume of debris by RCD and time taken to open the RCD. The data kept were only for the month of August 2007 not for other periods/years. However, the data were obtained for analysis. The data is given in Table 1.2 Annex 2.

(5) Analysis of Data

Using the Potential Annual Loss of a slope site (ALp), the study team applied the priority level of each slope. Following relationships are used to estimate the Potential Annual Loss of a slope site (ALp).

(i) ALp = FRCDp x Lp

Where:

FRCDp = Potential Frequency of RCD in a year
RCD = Road Closure Disaster
Lp = Potential Loss of a RCD [NRs./RCD]

The Lp is estimated using following relationships:

Lp = RCp + HLLp + VLp + LTSp

Where:

RCp = Potential Reopening Cost per RCD [NRs/RCD]
HLLp = Potential Value of Human Lives Lost per RCD [NRs/R/RCD]:
VLp = Potential Value of Vehicle Lost per RCD [NRs/RCD]:
LTSp = Potential Value of Loss Due to Traffic Suspension per RCD [NRs/RCD]:

(ii) RCp = FCR + LRCpoF x URCpMoF + LRCpoP x URCpMoP

Where:

FCR= Fixed Reopening Cost per RCD [NRs/RCD]
LRCpoF= Potential length of road closure section of full width [m]
URCpMoF= Unit reopening cost per one meter length of full width road closure [NRs/m]
LRCpoP= Potential length of road closure section of partial width [m]
URCpMoP= Unit reopening cost per one meter length of partial width road closure [NRs/m]

(iii) HLLp=ANHD x UHL

Where:

ANHD= Average Number of Human Death per RCD [nos. of persons/RCD]
UHL= Unit Value of Human Life Lost [NRs/ one person]

(iv) VLp=ANVL x UVL

Where:

ANVL= Average Number of Vehicles Lost per RCD [vehicles/RCD]

UVL= Unit Value of Vehicle Lost [NRs/vehicle]

(v) LTSp = AADT x NCDp x ASLpV

Where:

AADT= Annual Average Daily Traffic of Passenger Vehicles [Vehicles/ day]

NCDp= Nos. of predicted Closure Days of the whole width of the road on the survey site per RCD [Days]

ASLpV= Average Suspension Loss per Vehicle [NRs/vehicle]

7.2 Findings of Surveys

7.2.1 Reopening

There were 308 RCDs in 10 years in Narayangharh – Mugling road (1997 to 2006) as shown by the data of road slope/stream inventory survey. Hence, 31 RCDs, in average, are occurred every year mostly during the months of rainy season (July to October). Similarly, the data also reveal that average length of a RCD is 15 hours and time taken to reopen a RCD (use of loader) is 5.10 hours. These are confirmed by the data of RCDs in the road kept by Bharatpur DoR divisional office for the month of August 2007.

The DoR Division office has kept a loader in its site office at Mugling for clearing the RCDs in Narayangharh – Mugling road. Similarly, every year a loader operator is assigned for 4 months (from July to October) to operate the loader for opening RCDs.

7.2.2 Past Disaster

Due to heavy rain in 30th July of 2003, many landslides and debris flows were triggered and heavy damage occurred along the Narayangharh – Mugling road section and in Ruwa Khola near Marsyangdi power house at 4Km west of Mugling. Due to the landslides triggered by the same rain many people lost their lives at Manakamna village. It took seven days to open the road section closure due to the landslides and debris. The landslides and debris flow took lives of 24 people including 4 persons in Jalbire, 1 person at 5Km, 2 persons in Simaltar, 5 persons in Jugedi and 6 persons in Chandibhanjyang due to damage of a house and washed out by the debris flow. Similarly, 4 people (3 children and one woman) lost their lives in Bangesal during the rainy season in 2006. It is also in record that two persons (husband and wife) had lost their lives when a house was washed out by Chuni River during the heavy rain falls in 1999. Hence, 24 persons were died by the landslides and debris flows (RCD) during last 10 years.

In the 2003 disaster, a truck was buried in the debris at 21Km in Narayangharh – Mugling road. Fortunately, driver could escape and there was no casualty. Hence, 1 vehicle was lost/damaged by the slides and debris (RCD) during last 10 years.

7.2.3 Annual Average Daily Traffic and O-D Survey

In March 2007, Government of Nepal Ministry of Physical Planning and Works Department of Roads, Road Maintenance and Development Project Sector Wide Road Programme: Feasibility

Study Report on Narayangharh - Mugling Road has provided Annual Average Daily Traffic (AADT) of vehicles in the road for the year 2006. The traffic is projected using the annual growth rate of 6.05% as suggested by the study to obtain following AADT of vehicles (Table 2.1) for 2007:

Table 2.1 AADT in Narayangharh - Mugling Highway

Vehicle Types	AADT (Vehicles/Day)			Composition (%)
	Mugling to Narayangharh	Narayangharh to Mugling	2-Way	
Multi-axle Trucks	31	25	56	1.74
Trucks	591	535	1126	34.91
Minitrucks	55	51	106	3.29
Large Bus	329	335	664	20.58
Mini Bus	87	93	180	5.62
Microbus	116	105	221	6.84
Car/Van/Jeep	181	187	368	11.41
Utility	58	48	106	3.29
Three-wheeler	1	0	1	0.03
Motorcycle	194	183	378	11.70
Tractor	7	6	13	0.39
Other Motorised Vehicles	2	0	2	0.07
Rickshaw	2	2	4	0.13
Total	1654	1571	3225	100.00

The O-D survey revealed that:

i) 19.6% vehicle drivers said they would wait up to 2 hours before taking detour.
   15.5% vehicle drivers said they would wait up to 4 hours before taking detour.
ii) 14.4% vehicle drivers said they would wait up to 4 hours before deciding to cancel the trip.
iii) 7.9% vehicle drivers said they would wait up to 5 hours before deciding to cancel the trip.
iv) 42.6% vehicle drivers said they would wait up to 30 hours until the road is open.

The Weighted Average of waiting time becomes 15 Hours per RCD (wait before deciding alternatives or opening of closure).

Similarly,

i) 10.8% of vehicle drivers said that they would take detour to Mugling - Pokhara - Bartung - Butwal - Narayangharh or Narayangharh - Butwal - Bartung - Pokhara - Mugling if the road is closed more than 2 hours.

ii) 24.3% of vehicle drivers said that they would take detour to Mugling - Naubise - Hetauda - Narayangharh or Narayangharh - Hetauda - Naubise - Mugling if the road is closed more than 2 hours.

In the same survey 17% vehicles showed their interest to pay up to NRs. 150.00 to use similar alternative toll road. Similarly, 5% showed their interest to pay up to NRs. 300.00.

The passenger interviews revealed that 8% were traveling for official work, 23.5 were for trade and business, 5% were traveling for study related works, 2% were for medical treatment, 55.0% were traveling for visiting relatives and entertainment and remaining 7.5% were for other purposes.

7.3 Estimation of Potential Loss of a Site Due to RCDs

7.3.1 Reopening Cost

The potential reopening cost of a RCD is estimated using unit cost per disaster magnitude (length of road closure site). The unit cost is formulated using past disaster data. From the past disaster data between Feb 1st and May 31st in 2007 (shown as Table 1.2 at Annex 2), the actual numbers of RCD is 23 times and the average volume of debris of RCDs is 189.04 m^3/RCD. On the other hand, as the average time taken to clear debris by loader per RCD is 2.0 hours/RCD, the average reopening time per RCD is 5.0 hours/RCD (The operation time between disaster site and site office is 3 hours).

The reopening cost of a RCD comprises fixed cost and variable costs (the cost incurred during opening of each RCD). The fixed cost comprises operator’s salary and allowances, depreciation of loader and overhead for operation of the site office. Similarly, variable cost comprises cost of fuel and oil consumptions and cost of laborers. The unit fixed reopening cost is calculated at NRs.722,476 at 23 RCDs, and estimated at NRs.31,412 per RCD. And the unit variable cost is estimated at NRs.5026.91 per RCD. Table 3.1 shows details of estimated unit fixed and variable reopening costs per RCD.

Table 3.1 Reopening Cost per RCD

Headings	Amount per RCD (NRs.)
1. Unit Fixed Reopening Cost	
a. Operator's salary @NRs.10000 per month for 4 months	1,739
b. Allowances @NRs.140 per day for 120 days	730
c. Depreciation of Loader @10% of NRs.6,000,000.00 per Annum	26,087
Subtotal	28,556
d. Overhead @10% of Subtotal	2,856
Total Fixed Cost	31,412
2. Unit Variable Reopening Cost	
a. Average cost of fuel consumption @ consumption of 20 liters of diesel per hour of loader operation and NRs.44.46 per liter of diesel	4,446
b. Average cost of oil consumption @ consumption of 0.086 liter of oil per hour of loader operation and NRs.156.57 per liter of oil	67

c. Average cost of 4 labors @NRs.20.59 per hour per laborer	412
Total Variable Cost	4,925
Unit Reopening Cost per Debris Volume (m^3)	26

Source: Consultants' Survey and Estimates, 2007

The unit variable cost is changed by the debris volume. Thus, it is assumed to have the two types of typical road closure disaster. The typical road closure disaster of full width, i.e. there is the debris that the vehicles are stopped on the two-way traffic lane, is shown as Figure 3.1. The typical road closure disaster of partial width, i.e. there is the debris that the vehicles are stopped at least one-way traffic lane, is shown as Figure 3.2.

On the typical debris that the vehicles are stopped on the two-way traffic lane, the typical height of debris is about 9.56m and the typical volume of debris is 33.47m^3/m. And, on the typical debris that the vehicles are stopped at least one-way traffic lane, the typical height of debris is about 4.78m and the typical volume of debris is 8.37m^3/m.

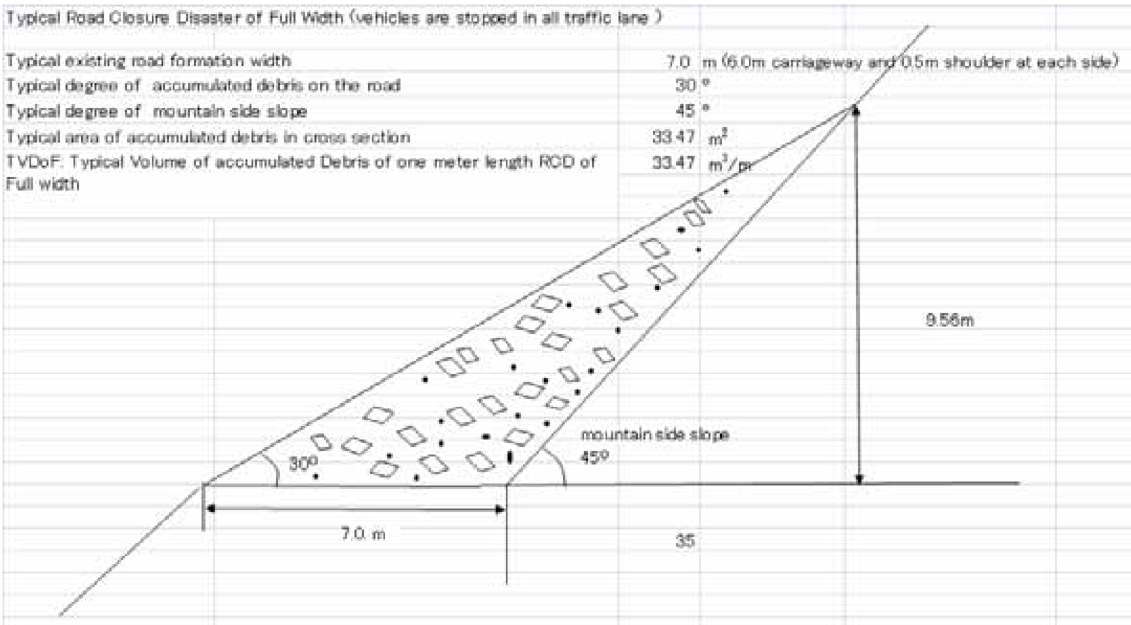

Figure 3.1 Typical Road Closure Disaster of Full Width (7.0m)

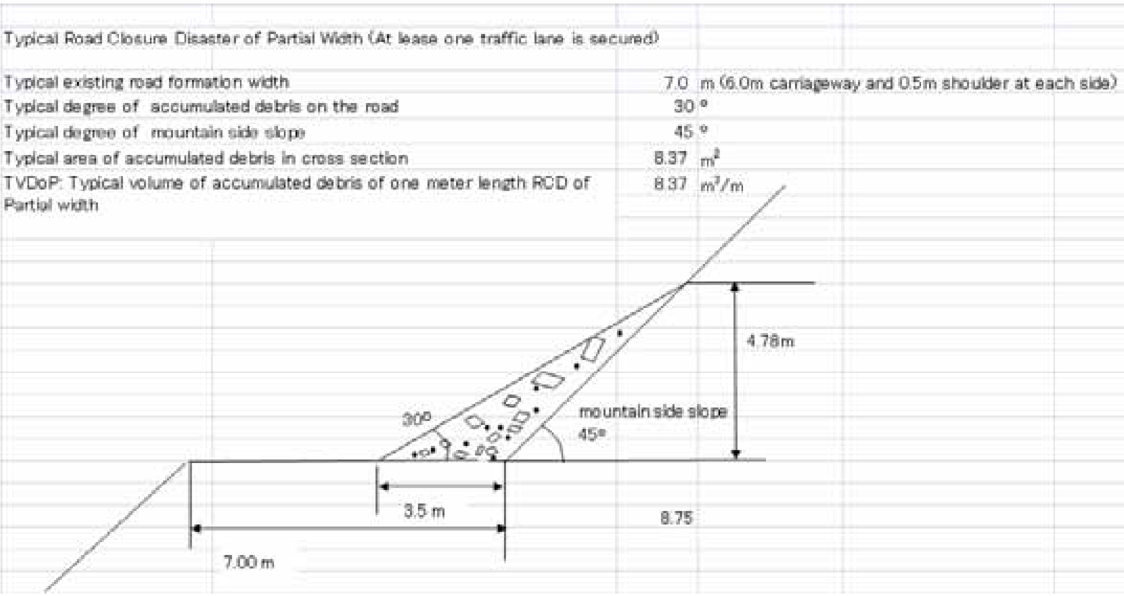

Figure 3.2 Typical Road Closure Disaster of Partial Width (3.5m)

The average variable cost of a RCD is 4,925 NRs/hour, by calculating the fuel cost, the engine oil cost and the labors cost. As the average volume of debris per RCD is 189.04m^3/RCD, by using this cost and volume, the unit reopening economic cost per debris volume is about 26 NRs/m^3. Therefore, by using the typical volume of debris per meter, the unit reopening cost per meter at the case of two-way traffic stopping (URCpMoF) is estimated at 870NRs/m and another of one-way traffic stopping (URCpMoP) is estimated at 218NRs/m.

7.3.2 Value of Human Lives Lost

In 1996 Transport Research Laboratory (TRL), UK had undertaken a study to estimate road accident costs in Nepal. The study had estimated average economic value of loss of a human life (UHL). Same methodology and parameters are used to estimate average economic value of loss of a human life at 2007 prices.

The two main components in determining loss of a human life consist of:

1) The number of years/days of work lost due to death, and
2) The average annual income of a dead person

The number of working years lost is estimated at 29 years as the average age of a fatality in an road accident was found to be 29 years and the retirement age of a person is estimated at 58 years as government employees retire at this age.

Since, the lost output is calculated only for the missing working years, average per capita income is considered to be inappropriate as it represents all ages. Hence, the national output per head of working population or an average wage is used to estimate the lost out put. With over eighty percent of the economically active population involved in agricultural, the wage rate for agriculture labor dominates but many of them are away from roads and any accident risk, therefore, the semi-skilled labor rate is used as an average wage rate. This rate is NRs.230 per day in 2007.

The prevailing annual average wage rate of a semi-skilled labor is NRs.83,950. Hence, when the wages for 29 years are discounted @12% discount rate, the net present value for total lost output for a death becomes NRs. 673,832.

On the other hand, the unit value of human life lost is easily estimated by GDP, population and average life expectancy. This is the ordinary method followed in Japan which is as presented below.

UHL = (GDP/POP) x (ALE/2)

Where, GDP: Gross Domestic Product [NRs/year],
POP: Population of Nepal [persons],
ALE: Average Life Expectancy at birth in Nepal [years]

By using the statistical data of 2006, the GDP, POP and ALE of 2007, are estimated at 598,511 million NRs, 28.2 million persons and 63.6 years, respectively. Thus, the UHL estimated by the above relation is NRs. 674,288.

If the parameters such as the average annual wage can not be determined, the Japanese ordinary method will be used. But, as the several parameters are determined, the TRL’s method will be more effective one. The UHL of Japanese ordinary method is nearly equal to the UHL of TRL’s one. Thus, the UHL is estimated at about 674,000 NRs/person as an intermediate value.

Numbers of RCD is evaluated by the road slope assessment survey in 2007 under this study, based on interviews of DOR staffs and inhabitants along the road.

There were no human lives lost in 10 years. However, in 2003 a truck was buried in the debris at 21Km fortunately, driver could escape and there was no casualty. But, this driver should die if he was not rescued in time. Thus, it is thought that the human death by the disaster “on”

Narayangharh-Mugling highway is one person.

On the other hand, the average traffic volume for past 10 years is 0.714 times than it in 2006, as the traffic increase of 80% in 10 years is assumed (increase of about 6% in 1 year). Thus, the traffic level at 2007 is about 1.5 times, according to the following equation.

Traffic volume ratio at 2007 = (1+0.06)/0.714 = 1.4863

According to the assumption that the probability of human death by road disaster is in proportion to the traffic volume, the probability of the persons died by road disaster is estimated at approx 1.5 times. If average numbers of human death is considered as the casualty “on” Narayangharh-Mugling highway, the numbers of human death is estimated at approx 1.5 persons. Thus, the average numbers of human death per RCD (ANHD) is 1.5/308 person/RCD.

As above results, the potential value of human lives lost per RCD is estimated at NRs. 3,282.

7.3.3 Value of Vehicles Lost

The study of TRL, UK, 1996 mentioned above had also estimated average value of loss of vehicles. Same methodology and parameters are used to estimate average vehicle damage cost at 2007 prices.

The net vehicle damage cost incurred in road accidents is estimated by using following relationship:

Net Vehicle Damage Cost = Average Vehicle Repair Cost

- (Custom Duties and VAT on Spare Parts and any Salvage estimate)
+ Insurance excess (Insured Vehicles Only – 10% Vehicles)
+ Survey Fees (Insured Vehicles Only – 10% Vehicles)
+ Lost Business (Commercial Vehicles Only)

The net vehicle damage cost components reported in “Draft Report of Accident Costing in Nepal, 1996” of TRL are shown as Table 3.2. The repair cost is estimated according to the data surveyed on nine insurance companies. The lost business cost is based on NRs15 for 100km/day for a tow weeks. Thus its value is NRs. 21,000.

Table 3.2 Net Vehicle Damage Cost in "Draft Report of Accident Costing in Nepal, 1996"

Vehicle type	Repair Cost (NRs)	Duty & VAT on Spare-Parts (NRs)	Estimated Salvage (NRs)	Insurance excess* (NRs)	Survey Fee* (NRs)	Lost Business (NRs)	Net Vehicle Damage Cost (NRs)
Bus	97,956	22,314	1,000	100	0.3	21,000	95,742.3
Truck	90,597	20,660	6,900	200	0.3	21,000	84,237.3
Car	31,674	7,215	700	100	0.1	0	23,859.1
Motor-cycle	12,029	2,740	1,200	100	0.1	0	8,189.1

*) Both insurance excess and survey fee have been listed at one-tenth their average cost as it is assumed that only 10% of vehicles involved in accidents are insured and incurred these costs.

For commercial vehicle it needs to consider the loss in business during repair time. The road users' operation cost is estimated by RED calculation of HDM-4, and then Table 3.3 summaries the road users' operation cost components. The lost business cost is estimated based on operation cost for the days suppose to be operated for a two weeks period.

Table 3.3 Road Users' Operation Cost at 2007 (NRs.)

Vehicle type	Day Operation (km/day)	Operation Cost (NRs/km)
Bus	242.0	18.29
Truck	234.5	22.12
Car	120.0	9.23
Motor-cycle	NA	NA
Other Vehicles	52.4	17.17

The vehicle damage cost components such as repair cost and estimated salvage should be increase proportionally by inflation rate. The average inflation rate in 11 years of 1996 to 2007 is about 6.1%. By using inflation rate and cost of 1996, the study team estimated average vehicle repair cost, salvage estimates, insurance excess and survey fees. Only repair cost of other vehicle is surveyed at several auto repair workshops.

Spare parts were found to represent two-thirds of repair costs as reported in "Draft Report of Accident Costing in Nepal, 1996". And the spare parts are multiplied by 25% import duty and 13% sales tax to estimate at the economic cost of vehicle repairs. While import duties range from

25% for Indian parts to over 100% for Japanese imported parts, Indian parts were assumed to dominate the repair market and their respective duty rates are used.

Based on the data, net vehicle damage cost in road accidents is estimated at NRs.147,669. Table 3.4 summaries the net vehicle damage cost components. The cost is considered to be value of vehicle lost per RCD.

Table 3.4 Net Vehicle Damage Cost at 2007 (NRs.)

Vehicle type	Repair Cost (NRs)	Duty & VAT on Spare-Parts (NRs)	Estimated Salvage (NRs)	Insurance excess* (NRs)	Survey Fee* (NRs)	Lost Business (NRs)	Net Vehicle Damage Cost (NRs)
Bus	188,415	51,814	1,923	192	0.6	61,952	196,822.6
Truck	174,260	47,922	13,272	385	0.6	72,617	186,068.6
Car	60,924	16,754	1,346	192	0.2	0	43,016.2
Motor-cycle	23,137	6,363	2,308	192	0.2	0	14,658.2
Other Vehicles	44,907	12,349	4,480	192	0.2	12,597	40,867.2
Weighted Average							147,669.3

*) Both insurance excess and survey fee have been listed at one-tenth their average cost as it is assumed that only 10% of vehicles involved in accidents are insured and incurred these costs.

7.3.4 Value of Losses of Traffic Suspension

(1) Value of Travel Time of Vehicles

In March 2007, Government of Nepal Ministry of Physical Planning and Works, Department of Roads, Study of North - South Fast Track Linking Kathmandu to Terai, 2007, had estimated following value of time of passenger vehicles. Value of time of goods vehicles (truck, mini-trucks etc) are not considered in economic cost estimates.

i) Value of Time of Motorcycle = NRs. 6.75/Hour/Vehicle (1.8 passengers)
ii) Value of Time of Car = NRs.150/Hour/Vehicle (4 passengers)
iii) Value of Time of Bus = NRs.180/Hour/Vehicle (40 passengers)
iv) Value of Time of Mini Bus = NRs.90/Hour/Vehicle (20 passengers)
v) Value of Time of Microbus = NRs.58.5/Hour/Vehicle (13 passengers)
vi) Value of Time of Three Wheeler = NRs.54/Hour/Vehicle (12 passengers)
vii) Value of Time of Rickshaw = NRs.9/Hour/vehicle (2 passengers)

Based on the report of the study of N-S Fast Track, our study team has estimated the unit value of travel time (UVTT). Table 3.5 summaries the unit value of travel time components. Our study team assumed that the value of time of goods vehicles is equal to car’s value. Thus, the weighted average of UVTT is estimated at about 130 NRs/hours/vehicle.

Table 3.5 Unit Value of Travel Time in Narayangharh - Mugling Highway

Vehicle Types	AADT (Vehicles/Day)			UVTT (NRs/hours/ vehicle)	Remarks
	Mug to Nara	Nara to Mug	2-Way		
Multi-axle Trucks	31	25	56	150.00	Equal to Car value
Trucks	591	535	1126	150.00	Equal to Car value
Minitrucks	55	51	106	150.00	Equal to Car value
Large Bus	329	335	664	180.00	
Mini Bus	87	93	180	90.00	
Microbus	116	105	221	58.50	
Car/Van/Jeep	181	187	368	150.00	
Utility	58	48	106	150.00	Equal to Car value
Three-wheeler	1	0	1	54.00	
Motorcycle	194	183	378	6.75	
Tractor	7	6	13	150.00	Equal to Car value
Other Motorised	2	0	2	150.00	Equal to Car value
Rickshaw	2	2	4	9.00	
Total	1654	1571	3225		
Weighted average				129.56	

(2) Value of Loss due to Detour Taken by Vehicles

From the results of O-D survey, there are two detour routes. They are the detour Mugling - Pokhara - Bartung - Butwal - Narayangharh or the other way, and the detour Mugling - Naubise - Hetauda - Narayangharh or the other way. The length of the detour through Butwal and so on is 363.3Km and that of detour through Hetauda and so on is 278.1Km. Similarly, the length of the original route Mugling - Narayangharh is 36.0Km.

Hence, if a vehicle takes detour to Mugling - Pokhara - Bartung - Butwal - Narayangharh or the other way, it has to travel additional distance of 325.3Km to reach the destination. Similarly, if a vehicle takes detour to Mugling - Naubise - Hetauda – Narayangharh or the other way, it has to travel additional distance of 240.1Km to reach the destination.

Vehicle Operation Costs (VOC) of vehicles in the above three roads are estimated by using the Roads Economic Decision Model (RED) calibrated to Nepali conditions. The model is developed based on relationships and assumptions contained in the World Bank’s Highway Design Manual (HDM-4). The RED model is more suitable for estimating VOCs for Nepali roads and evaluation of the roads.

In order to predict VOC, the model requires following three sets of data:

- Unit prices of each VOC component of vehicles
- Characteristics of vehicles
- Characteristics of the project road

(i) Unit Prices

In predicting VOC, the model predicts the amount of resources consumed such as fuels, oils, tires, crew costs etc, and then multiplies these consumptions by the unit prices of each resource. It is therefore necessary to provide unit prices of VOC components as the basic input data.

Unit economic prices of each VOC component of vehicles required by the model are estimated from the data obtained from Dept of Customs, dealers of vehicles and tires, motor workshops and Nepal Oil Corporation.

The calculated economic prices of VOC components are given in Table 3.6, 3.7 and 3.8.

Table 3.6 Economic Prices of Vehicles (NRs)

Vehicle Type	Economic
Multi Axle-truck	1,808,000
Medium Truck	1,390,000
Light Truck	1,180,000
Large Bus	1,650,000
Mini-bus	1,440,000
Micro-bus	989,800
Car/Van/Jeep (Average)	565,700
3 Wheeler	130,000
Motor cycle	75,400
Rickshaw	9,000

Source: Consultants' Survey, Kathmandu, August 2007

Table 3.7(a) Economic Prices of Fuel and Oil

Item	Economic Price (NRs./Litre)
Diesel	44.46
Petrol	47.62
Lubricants	156.35

Source: Consultants' Survey, Kathmandu, August 2007

Table 3.7(b) Economic Prices of Tires

Vehicle Type	Economic Price (NRs)
Multi Axle-truck	14,620
Medium Truck	11,740
Mini-truck	5,970
Large Bus	11,820
Mini-bus	6,390
Microbus	4,390
Car/Van¥Jeep (Average)	2,210
3 Wheeler	1,460
Motor cycle	770
Rickshaw	300

Source: Consultants' Survey, Kathmandu, August 2007

Table 3.8 Average Economic Crew Costs

Vehicle Type	Driver		Helper Wage (NRs/hr)	Average/ Vehicle (NRs/hr)	Adjusted (NRs/hr)
	No. per Vehicle	Wage (NRs/hr)			
Heavy/Med Truck	1	50	20	70	52.5
Mini-truck	1	40	20	60	45.0
Large Bus	1	50	25	75	56.3
Mini-bus	1	60	20	80	60.0
Microbus	1	60	10	70	52.5
Car/Van/Jeep	0.5	50		25	18.8
3 Wheeler	1	40		40	30.0
Bullock Cart	1	35		35	26.3
Rickshaw	1	40		40	30.0

Source: Field Survey and Consultants' Estimates, August 2007

On the basis of field survey, Rs.32 per labor per hour is estimated as the average wage rate of maintenance labor.

(ii) Characteristics of Vehicle

Table 3.9 and 3.10 summarize the vehicle characteristics assumed for the estimation of VOC

Table 3.9 Vehicle Characteristics

Vehicle Type	Fuel Type	No. of Wheels	Operating Weight (tones)	ESA	No. of Passengers	% of Private Trips
Multi Axle-truck	Diesel	10	30.00	21.00	-	0
Heavy Truck	Diesel	6	17.50	7.50	-	0
Mini-truck	Diesel	6	7.00	0.10	-	0
Large Bus	Diesel	6	10.00	0.80	45.0	0
Mini-us	Diesel	6	5.00	0.04	28.0	0
Microbus	Diesel	4	2.00	0.01	10.0	0
Car/Van/Jeep	Petrol	4	0.80	0.00	2.5	50
3 Wheeler	Petrol	3	0.40	0.00	5.0	0
Motor cycle	Petrol	2	0.20	0.00	1.5	100
Rickshaw	-	3	0.30	-	1.5	-

Source: Manufacturers, Operators and Consultant's Estimates, August 2007

Table 3.10 Vehicle Utilization Data

Vehicle Type	Annual km	Annual working hours	Average life (years)
Multi Axle-truck	60,000	2,500	10
Medium Truck	40,000	1,800	10
Mini-truck	30,000	1,300	10
Large Bus	80,000	2,800	12
Mini-bus	50,000	2,400	10
Microbus	50,000	2,400	10
Car/Van/Jeep	20,000	550	14
3 Wheeler	15,000	1,200	10
Motor cycle	10,000	400	10
Rickshaw	7,200	1,000	6

Source: Manufacturers, Operators and Consultant's Estimates, August 2007

(iii)Characteristics of Project Road

Table 3.11 summarizes the road characteristics assumed for the estimation of VOCs in the 'with project' situation.

Table 3.11 Representative Characteristics of the Three Roads

Characteristics	Value		
	M-N	MHN	MBN
Width (m)	7	7	7
Rise and Fall (m/Km)	5	45	45
Curvature (Degree/Km)	50	250	250
Roughness (IRI)	8	12	8

Source: Consultants' Assumptions

M-N : Mugling - Naryangharh original route, **MHN** : Detour route of Mugling - Naubise - Hetauda - Narayangharh, **MBN**: Detour route of Mugling - Pokhara - Bartung - Butwal - Narayangharh

The calculated VOCs using the RED Model are presented in Table 3.12

Table 3.12 Vehicle Operation Costs in Three Roads

Vehicle Types	VOC (NRs./Km)		
	M-N	MHN	MBN
Multi-axle Trucks	49.06	61.80	57.37
Trucks	32.89	45.04	41.56
Minitrucks	21.85	25.98	23.24
Large Bus	29.85	37.36	33.90
Mini Bus	24.51	26.63	25.76
Microbus	16.48	17.08	14.98
Car/Van/Jeep	13.42	13.71	11.90
Three-wheeler	5.04	5.11	4.52
Motorcycle	2.96	3.02	2.63
Rickshaw	3.44	3.44	2.60
Other Motorised Vehicles	14.00	16.00	18.00
Weighted Average	24.19	30.59	28.45

Source: Consultants' Estimates, 2007

M-N : Mugling - Naryangharh original route, **MHN** : Detour route of Mugling - Naubise - Hetauda - Narayangharh, **MBN**: Detour route of Mugling - Pokhara - Bartung - Butwal - Narayangharh

Similarly, weighted average values of the calculated VOC in each road section are shown as Table 3.13.

Table 3.13 Unit Vehicle Operation Costs in Each Road Section

Road section name	Road section length (km)	Unit vehicle operation cost (NRs/Km)
Mugling - Narayangharh	36.0	24.19
Mugling - Naubise	94.8	22.37
Naubise - Hetauda	106.5	28.49
Hetauda - Narayangharh	76.8	21.07
Mugling-Pokhara	90.5	22.37
Pokhara-Butawal	159.1	28.49
Butawal-Narayangharh	113.7	22.03

The vehicle speeds calculated using the RED Model are presented in Table 3.14.

Table 3.14 Vehicle Speeds in Three Roads

Vehicle Types	Speed (Km/Hour)		
	M-N	MHN	MBN
Multi-axle Trucks	22.80	20.00	22.10
Trucks	22.30	20.90	24.00
Minitrucks	23.70	22.10	24.90
Large Bus	25.70	23.70	26.60
Mini Bus	25.30	24.20	27.40
Microbus	29.00	28.10	31.30
Car/Van/Jeep	27.20	26.60	30.50
Three-wheeler	21.40	21.00	22.90
Motorcycle	27.00	26.50	30.50
Rickshaw	10.10	10.10	12.90
Other Motorised Vehicles	20.00	20.00	20.00
Weighted Average	24.69	23.43	26.55

Source: Consultants’ Estimates, 2007

M-N : Mugling - Naryangharh original route, **MHN** : Detour route of Mugling - Naubise - Hetauda - Narayangharh, **MBN**: Detour route of Mugling - Pokhara - Bartung - Butwal - Narayangharh

Similarly, weighted average values of the calculated Vehicle Speed in each road section are shown as Table 3.15.

Table 3.15 Average Vehicle Speeds in Each Road Section

Road section name	Road section length (km)	Average vehicle speed (Km/hour)
Mugling - Narayangharh	36.0	24.69
Mugling - Naubise	94.8	20.48
Naubise - Hetauda	106.5	19.65
Hetauda - Narayangharh	76.8	20.95
Mugling-Pokhara	90.5	20.48
Pokhara-Butawal	159.1	19.65
Butawal-Narayangharh	113.7	20.60

Vehicle operation cost of a vehicle equals to the road section length multiplied to the unit vehicle operation cost in each road section. As the unit value of traffic time of a vehicle is 130 NRs/hour/vehicle, the value of traffic time of a vehicle is calculated by the road section length and the average vehicle speed. The total unit cost of traffic is calculated by the vehicle operation cost of a vehicle and the value of traffic time of a vehicle. The unit detour loss of a vehicle is difference of the total unit cost of traffic between the original route and the divert route. Table 3.16 summaries the total unit cost of traffic.

Hence, the unit detour loss of a vehicle when divert to Naubise or Hetauda is estimated at about 2,400 NRs/vehicle, and the unit detour loss of a vehicle when divert to Pokhara or Butwal is estimated at about 5,100 NRs/vehicle.

Table 3.16(a) Total Unit Cost of Traffic Diverted to Naubise or Hetauda

Item	Vehicle operation cost of a vehicle (NRs/vehicle)	Value of traffic time of a vehicle (NRs/vehicle)	Total unit cost of traffic (NRs/vehicle)
Divert to Mugling -Naubise-Hetauda	5,155	1,306	6,461
Original route Mugling - Narayangharh- Hetauda	2,489	1,181	3,670
Unit detour loss of a vehicle when divert to Mugling -Naubise-Hetauda	2,666	125	2,791
Divert to Narayangharh- Hetauda-Naubise	4,652	1,181	5,834

Original route Narayangharh-Mugling-Naubise	2,992	791	3,783
Unit detour loss of a vehicle when divert to Narayangharh-Hetauda-Naubise	1,611	379	2,051
Unit detour loss of a vehicle when divert to Naubise or Hetauda	2,163	258	**2,421**

Table 3.16(b) Total Unit Cost of Traffic Divert to Pokhara or Butawal

Item	Vehicle operation cost of a vehicle (NRs/vehicle)	Value of traffic time of a vehicle (NRs/vehicle)	Total unit cost of traffic (NRs/vehicle)
Divert to Mugling -Pokhara-Butawal	6,557	2,873	9,430
Original route Mugling –Narayangharh -Butawal	3,376	907	4,283
Unit detour loss of a vehicle when divert to Mugling -Pokhara-Butawal	3,182	1,965	5,147
Divert to Narayangharh-Butawal-Pokhara	7,038	1,770	8,808
Original route Narayangharh-Mugling-Pokhara	2,895	764	3,659
Unit detour loss of a vehicle when divert to Narayangharh-Butawal-Pokhara	4,142	1,006	5,148
Unit detour loss of a vehicle when divert to Pokhara or Butawal	3,662	1,486	**5,148**

According to the O-D survey, the study team estimated that vehicles deroured to Pokhara or Butawal are 10.8% of non-waiting vehicles, and that vehicles detoured to Naubise or Hetauda are 24.3% of non-waiting vehicles.

(3) Value Loss due to Cancellation of the Trip

The study team interviewed the passengers or their willingness to pay instead of canceling the trip if there are similar alternative toll road and also interviewed on the time waited to open the road closure.

Table 3.17 summarizes the frequency of non-waiting vehicles components. The relationship between the non-waiting percentage (NWP) and the waiting hour (WH) is shown in Figure 3.3. As a result, it has been obtained the correlation equation is NWP=0.2152x Ln(WH) + 0.0955.

Table 3.17 Frequency of Non-Waiting Vehicle to Reopening

Waiting hours: WH (hrs)	Accumulation count	Non-waiting percentage: NWP
2	768	19.1%
4	1,696	42.3%
5	1,935	48.2%
72	4,013	100.0%

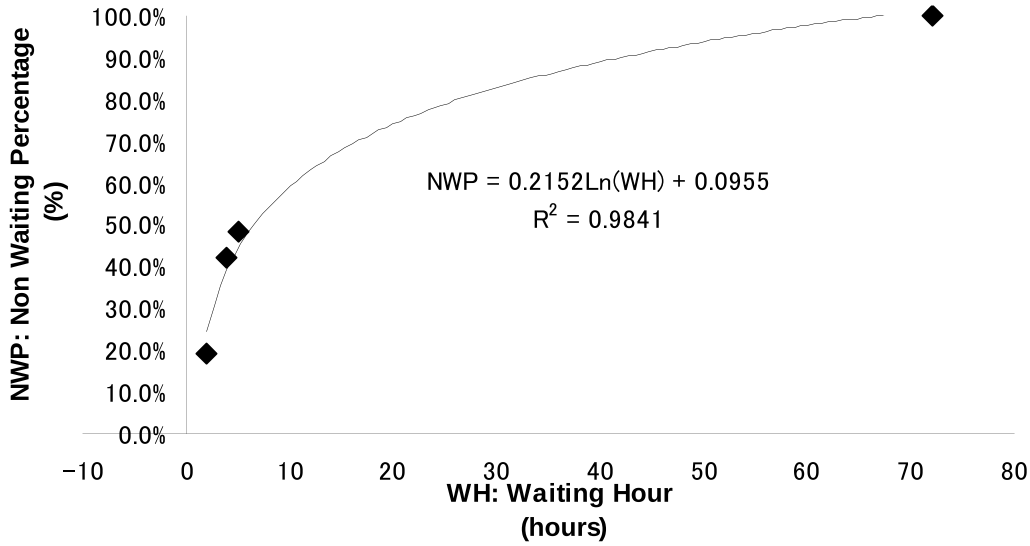

Figure 3.3 Relationship between Non Waiting Percentage and Waiting Hour

In the O-D survey, 17% vehicles showed their interest to pay up to NRs. 150.00 to use similar alternative toll road. Similarly, 5% showed their interest to pay up to NRs. 300.00 for the same.

Vehicle which driver detours instead of waiting is 35.1%. The vehicle cancelled trip is estimated by above willingness to pay. That is, if road is closed, vehicle which cancels trip and dose not detour is 64.9%. Among the cancellation vehicles, 42.9% drivers of non-waiting vehicle evaluated that the cancellation loss is NRs 75/vehicle, 17.0% drivers in non-waiting vehicle evaluated that the cancellation loss is NRs 150/vehicle and 5.0% drivers in non-waiting vehicle evaluated that the cancellation loss is NRs 300/vehicle.

Hence, if 64.9% vehicles cancel trips, average cancellation loss of a vehicle is NRs 73/vehicle (= 42.9% x NRs 75/vehicle + 17.0% x NRs 150/vehicle + 5.0% x NRs 300/vehicle).

Annex 1

Questionnaire I

Department of Roads

Origin and Destination Survey

Date:……..../

Road: **/2007**

Station: **Start Time:**

Traffic Type: Passenger, Motorcycle, Car, Car, Jeep, Pickup, Microbus, Minibus, Bus, Minitruck, Truck, Tanker, Container

Plate Type: Private, Commercial, Corporation, Government, Tourist, Project

S.No.	Origin	Destination	If There Were Similar Alternative Toll Road, Ready to Pay NRs……. Instead of Waiting	Wait to Open the Road Closure for ………….Hrs Before Deciding to Abandon the Waiting	Take Detour Via (Tansen/Hetauda)	Cancel Trip by Road and Take Flight to Simra/Bharatpur/Bhairahawa
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Annex 2

Questionnaire II

Department of Roads

Passenger Interview Survey

Road: **Date:……../ /2007**

S.No.	Origin	Destination	Transport Vehicle	Government Work	Trade/ Business	Study	Medical	Others	Visiting Relatives	Entertainment
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

Annex 3

Table 1.1 List of Interviewed People

S.No.	Name	Designation
1	Mr. Pardhun Kumar Khadka	Secretary, Kabilas Village Development Committee
2	Mr. Bhowa Bahadur Gurung	Teacher, Kabilas High School, Jugedi, Kabilas VDC
3	Ms. Saraswoti Adhikari	Facilitator, Jugedi, Kabilas VDC
4	Mr. Tak Bahadur Gurung	Former Chairman, Das Dhunga, Kabilas VDC
5	Mr. Purna bahadur Chhetri	Supervisor for 18-36 km Narayangharh – Mugling Road , Divisional Office, DoR, Bharatpur
6	Mr. Humakant Bhurtel	Engineer, Divisional Office, DoR, Bharatpur
7	Mr. Yogeshwar Dhakal	Divisional Office, DoR, Bharatpur
8	Mr. Dhamke Lal Gurung	Business Man, Jugedi, Kabilas VDC
9	Mr. Prakash Malla	Inspector, District Police Office, Chitwan
10	Mr. Gambir Shrestha	Senior Divisional Engineer, DoR, Kathm,andu
11	Mr. Sharma	Distribution Section, Nepal Oil Corporation, Kathmandu
12	Mr. Aryal	Salesman, Arun International, Kathmandu
13	Mr. Chaudhari	Salesman, Sipradi Motors Company, Kathmandu
13	Mr. Hira Kaji Maharjan	Salesman, Tire House, Kathmandu
14	Mr. Hikmat Singh	Senior Officer, Department of Customs, Kathmandu
15	Mr. Krishna Dangol	Owner, Motor garage, Kathmandu

Annex 4

Table 1.2 Land Slide Clearing Data of Narayangharh – Mugling Road

S.No.	Date	Chainage	Quantity (Cu. M)	Time Taken to Clear (Hour)
1	4/2/2007	17+575	227.50	1.5
2	4/2/2007	24+400	159.25	1.5
3	16/4/2007	24+400	157.50	1.5
4	18/4/2007	24+400	157.50	1.5
5	18/4/2007	27+400	137.50	1.5
6	31/4/2007	22+400	382.50	4.0
7	32/4/2007	22+400	270.00	3.5
		Total	1491.75	

1	1/5/2007	22+200	273.00	3.0
2	2/5/2007	24+400	183.75	2.0
3	2/5/2007	28+300	371.25	5.0
4	10/5/2007	24+400	151.93	1.5
5	19/5/2007	20+400	168.00	2.0
6	20/5/2007	24+400	121.87	1.0
7	20/5/2007	20+400	192.00	2.0
8	22/5/2007	19+900	35.00	0.5
9	22/5/2007	20+400	68.75	1.0
10	22/5/2007	24+300	153.00	1.5
11	22/5/2007	27+450	112.50	1.5
12	23/5/2007	24+400	67.50	1.0
13	23/5/2007	28+300	37.50	0.5
14	315/2007	24+300	80.52	1.0
15	31/5/2007	27+580	540.00	6.0
16	31/5/2007	28+300	299.70	3.0
		Total	2856.27	
		Average	189.04	2.0

VIII

ECONOMIC VALUATION OF RUWA KHOLA

Table of Contents

VIII. Economic Loss Evaluation of Ruwa Khola Disaster

8.1 Introduction

8.1.1 Background

The road networks of Nepal are prone to frequent traffic blockades due to slope disasters induced by adverse natural conditions such as steep topography, fragile geology, and heavy rainfalls during monsoon seasons and earthquakes that occur frequently in the country.

Mugling – Pokhara road of Prithivi Highway is one of the most important road sections of Nepal connecting Kathmandu with Pokhara, Parbat, Baglung, Myagdi, Mustang, Syanja, Palpa and and rest of the country through Mahendra Highway at Butwal.

High flood in the Rowa river after heavy rainfall in the 30th July of 2003 had triggered many slides and debris flows which washed away bridge over the river and many civil structures of Marsyangdi Hydropower Plant constructed along the river were damaged.

The flood also washed away a civilian bus, a car and a van and buried in the debris. Fortunately there was no casualty.

Flood water was also entered the underground floor of the hydropower plant causing great damages to the turbine and other equipments which interrupted electricity supply for many days.

These effects of the flood had great economic consequences such as cost incurred in clearing the debris and opening of a diversion road for temporary traffic movements and construction of new bridge; values of loss of vehicles, damage of civil structures, loss of electricity generation and travel delays that are imposed on motorists and motor carriers; and additional costs in case of detour.

Economic prices/values are the prices/values which society pays and receives. It excludes subsidies since subsidies are government transfer payments. It also excludes tariffs, duties, taxes, excise and royalties as they are also government transfer payments.

8.1.2 Objectives

The main objective of the Consultant's service is to estimate potential annual economic losses due to Damages triggered by the flood in Rava river.

8.1.3 Methodology

(1) Collection and Reviews of Data and Literatures

Literatures on the studies for economic valuation of road closures in different countries, especially in U.S, are reviewed extensively and are considered as the basis for this study.

Officials of Department of Roads and Department of Transport Management were also contacted and discussed to find out ways of estimating economic value of travel time. Statistical data of road lengths in Nepal and traffic on them were also collected from DoR.

Demographic and Economic data were collected from Central Bureau of Statistics, Kathmandu.

Vehicle dealers of Maruti, TATA, Hero Honda and Toyota, Tire dealers, vehicle workshops and Nepal Oil Corporation were contacted to obtain prices of vehicle, tires, fuel and lubricants. Cost of maintenance labor was collected from maintenance workshops. Similarly, Departments of Customs and Taxation were visited to obtain rates of duties, taxes, VATs etc on imports and sales of above items.

(2) Preparation of Questionnaires

Questionnaires for vehicle Origin and Destination Survey (I) and Passenger Interviews (II) were prepared and submitted to the project office for approval. The questionnaires were approved after minor changes. The approved questionnaires I and II are given in Annex 1&2, respectively.

(3) Arrangements for Field Survey

(i) Hiring of Survey Team

Six surveyors were hired in Kathmandu for Origin and Destination (O-D) Survey and Passenger Interviews. The surveyors were trained extensively for carrying out Origin and Destination Survey and Passenger interviews.

(ii) Letter to Lamjung District Police

A letter issued by Department of Roads (DoR) to the Lamjung District Police Office at Byas Municipality, asking the office to help during O-D surveys by providing policemen was obtained in Kathmandu.

(4) Field Work

The survey team members went to Byas Municipality on 3rd February 2008. In Byas the surveyors handed over the letter to the in-charge of Lamjung District Police Office and seek for help. The office then called police post in Khaireni and asked them to help the surveyors in O-D survey. The surveyors then went to Khaireni and met policemen. With the help of them the survey team selected a location 1Km East of Marsyangdi Hydropoower Plant along Mugling - Pokhara road as a station for the O-D survey. The location called Benitar was a small settlement having wide space for stopping vehicles for interviews.

(i) O-D Survey

The survey team with policemen started O-D Survey using questionnaire I in Benitar from 6 am in 4th February 2008. During the survey government, corporation, commercial, tourist and project vehicles namely: motorcycles, cars, jeeps, pickups, microbuses, minibuses, buses, mini-trucks, trucks, tankers, containers etc coming from both directions were stopped and interviewed using the above questionnaire I. The survey was continued for three days to 6th February. Each day survey was carried out for 14 hours till 8 pm in the evening.

Altogether, 3151 vehicles were interviewed during the survey as detailed in Table 8.1.1.

Table 8.1.1 Details of Vehicles Interviewed during O-D Survey

Vehicle Category	Private	Commercial	Project	Government	Corporation	Tourist	Total
Motorcycle	632	0	0	0	0	0	**632**
Car	283	8	4	2	9	14	**320**
Jeep	59	0	8	13	3	7	**90**
Pickup	160	1	0	1	0	0	**162**
Bus	0	544	0	0	4	160	**708**
Minibus	0	303	0	0	0	0	**303**
Microbus	10	482	1	0	0	19	**512**
Truck	52	238	0	0	0	0	**290**
Minitruck	42	65	0	0	0	0	**107**
Tanker	1	23	0	0	3	0	**27**
Total	**1239**	**1664**	**13**	**16**	**19**	**200**	**3151**

Source: Consultants' O-D Surveys, 4 – 6th February 2008

(ii) Passenger Interviews

During the same period 4 – 6th February altogether 270 passengers of motorcycles, private cars, microbuses, minibuses and buses were interviewed using questionnaire II at Annex 2.

(iii)Interviews with Local People

Local people mainly teachers, social workers, politicians, traders and hotel/lodge operators residing in the Khaireni and Mugling Bazar were met and discussed regarding damages caused by flood in Rava river in 2003. The information given were recorded and used for the report preparation. List of persons interviewed is given in Table of Annex 3.

(iv)Meeting with Officials

Officials of Environmental Division of Nepal Electricity Authority, Kathmandu and Marsyangdi Hydropower Plant in the power house itself were contacted to find out damages caused by the Rava river flood in 2003 and costs associated with the reopening and reinstate them. The recorded data on details of the damages and the associated costs were collected from them. The data is given in questionnaire II at Annex 2.

(5) Analysis of Data

[Method Used to Estimate Potential Annual Loss of a Site (ALp)]

Following relationships are used to estimate the Potential Annual Loss of a Site (ALp)

(i) Alp = FCSLDMp x Lp

Where:

FCSLDMp = Potential Frequency of CSLDM in a year

CSLDM = Civil Structure Loss and Damage to Marsyangdi Power Plant

Lp = Potential Loss of a CSLDM [NRs./CSLDM]

The Lp is estimated using following relationships:

Lp = DROCp + CSLDMp + VLp + VELp + LTSp+ LDp + VCLp

Where:

DROCp = Potential Diversion Road Opening Cost per CSLDM [NRs/CSLDM]

CSLDMp = Potential Value of Loss of Civil Structures and Damage to Marsyangdi Power Plant per CSLDM [NRs/CSLDM]

VLp = Potential Value of Vehicle Lost per CSLDM [NRs/CSLDM]

VELp = Value of Electricity Lost due to Closure of Plant [NRs./CSLDM]

LTSp = Potential Value of Loss Due to Traffic Suspension per CSLDM [NRs/CSLDM]

LDp = Potential Value of Loss Due to Traffic Detour per CSLDM [NRs/ CSLDM]

VCLp = Poential Value of Loss due to Cancellation of the Trip [NRs/ CSLDM]

(ii) DROCp = UFDROC + PLOT x UVOC

Where:

UFDROC= Fixed Reopening Cost per CSLDM [NRs/RCD]

PLOT = Potential Length of Opening Time per CSLDM (Hrs.) (Use of Loader)

UVOC = Unit Variable Opening Cost per CSLDM (NRs/hour)

(iii) CSLDMp=ANHL

Where:

ANHL: Average Cost of Lost Civil Structures and Damage to Marsyangdi Power Plant per CSLDM [NRs/CSLDM]

(iv) VLp=ANVL x UVL

Where:

ANVL: Average Number of Vehicles Lost per CSLDM [vehicles/RCD]

UVL: Unit Value of Vehicle Lost [NRs/vehicle]

(v) VELp = ALEx UVL

Where:

ALE: Average Loss of Electricity due to Closure of Plant

UVL: Unit Value of Electricity

(vi) LTSp = AADTP (Passenger Vehicles) x ULTS x WTP

Where:

AADTP: Annual Average Daily Traffic of Passenger Vehicles [Vehicles/ day]

ULTS: Unit Value of Loss Due to Traffic Suspension of a vehicle [NRs/Hour/Vehicle]

WTP: Potential Waiting Time per CSLDM [Hours]

(vii) LDp = AADT*X [(RLMNBPM*UVOCMNBPM + TTMNBPM x UVT)+ AADT*Y [(RLMPBNM*UVOCMPBNM + TTMPBNM x UVT)]

Where:

RL = Road Length (Km)

TTMNBPM = Travel time in Marsyangdi - Narayanghat – Butwal - Bartung – Pokhara – Marsyangdi Road [Hours/Vehicle]

TTMPBNM = Travel time in Marsyangdi - Pokhara - Bartung - Butwal - Narayanghat – Marsyangdi Road [Hours/Vehicle]

UVOCMNBPM = Unit Vehicle Operation Cost in Marsyangdi - Narayanghat – Butwal – Bartung – Pokhara – Marsyangdi Road [NRs/Km/Vehicle]

UVOCMPBNM = Unit Vehicle Operation Cost in Marsyangdi - Pokhara - Bartung - Butwal - Narayanghat – Marsyangdi Road [NRs/Km/Vehicle]

UVT = Unit Value of Time [NRs/Hour/Vehicle]

X = % vehicles which wanted to detour via Marsyangdi - Narayanghat - Butwal – Bartung – Pokhara – Marsyangdi road

Y = % vehicles which wanted to detour via Marsyangdi – Pokhara – Bartung – Butwal – Narayanghat – Marsyangdi road

(viii)VCLp = AADT*Z [(RLAO*UVOCRAO + TTRAO x UVT + AWTBCT x UVT)]

Where:

RL = Road Length (Km)

UVOCRAO = Unit Vehicle Operation Cost in Road to All Origins [NRs/Km/Vehicle]

TTRAO = Travel time in Road to All Origins [Hours/Vehicle]

AWTBCT = Average Waiting time before cancellation of trip [Hours]

UVT = Unit Value of Time [NRs/Hour/Vehicle]

Z = % vehicles which wanted to cancel the trip

Multiplication by 2 is considered for return trip to same origins

8.2 Findings of Surveys

There has been one CSLDM in 10 years in Marsyangdi Power Plant (1997 to 2006) as shown by the data of road slope/stream inventory survey. Hence, 0.1 CSLDM is, in average, has occurred every year mostly during the months of rainy season (July to October). Data reveal that time taken to reopen a CSLDM (use of loader) for people (not vehicles) through diversion is 10 hours and average length of road closure to vehicle traffic per CSLDM is 17 days. Hence, average length of road closure per CSLDM per year is 1.7 days. As three vehicles (a civilian bus, a car and a van) were lost/damaged by the floods in the river during the last 10 years the average number of vehicle lost per year is estimated at 0.3 vehicles.

During the O_D survey almost all vehicles were covered. Since, night traffic was negligible the recorded traffic of 14 hours itself was used to estimate Average Daily Traffic (ADT). The observed traffic is adjusted by a Standard Seasonal Correction Factor (SCF) of 1.02 to obtain following Average Annual Daily Traffic (AADT):

Table 8.2.1 AADT in Mugling - Pokhara Road

Vehicle Category	AADT	Composition (%)
Motorcycle	215	20.06
Car	109	10.16
Jeep	31	2.86
Pickup	55	5.14
Bus	241	22.48
Minibus	103	9.62
Microbus	174	16.25
Truck	99	9.21
Minitruck	36	3.40
Tanker	9	0.86
Total	1071	100.00

Source: Field O-D Survey 4-6th February 2008

The O-D survey revealed that:

i) 18.9% vehicle drivers said they would wait up to 2 hours for opening of diversion road before taking detour.

ii) 15.1% vehicle drivers said they would wait up to 3 hours for opening of diversion road before taking detour.

iii) 24% vehicle drivers said they would wait up to 2 hours for opening of diversion road before deciding to cancel the trip.

iv) 5% vehicle drivers said they would wait up to 3 hours for opening of diversion road before deciding to cancel the trip.

v) 37% vehicle drivers said they would wait up to 6 hrs until the diversion road is open before taking detour.

The Weighted Average of waiting time becomes 3.68 per hour per CSLDM (wait before deciding alternatives or opening of diversion road).

Similarly,

i) 33.6% of vehicle drivers said that they would take detour to Marsyangdi - Pokhara - Bartung - Butwal – Narayanghat- Marsyasngdi.

ii) 37.4% of vehicle drivers said that they would take detour to Marsyangdi - Narayanghat - Butwal - Bartung - Pokhara – Marsyangdi.

In the same survey 5% vehicles showed their interest to pay up to NRs. 150.00 to use similar alternative toll road. Similarly, 1.8% showed their interest to pay up to NRs. 300.00. Others were not ready to pay for using alternative road.

The passenger interviews revealed that 8.1% were traveling for official work, 27.0% were for trade and business, 11.5% were traveling for study related works, 7% were for medical treatment, 42.2% were traveling for visiting relatives and entertainment and remaining 4.1% were for other purposes.

8.3 Potential Losses of a Site Due to CSLDM

8.3.1 Value of Losses of Civil Structures and Damages to Marsyangdi Power Plant

The flood in 2003 had washed away and damaged many civil structures and equipment of Marsyangdi Power Plant. Their details and estimated economic values are presented in Table 8.3.1. The economic values are estimated by applying a Standard Conversion Factor (SCF) of 0.92 to financial values. The factor is a standard factor used by many studies of DoR road projects. The unit value of losses of civil structures and damages is estimated at NRs.58.349 million and annual average value of loss is estimated at NRs.5.84 million.

Table 8.3.1 Value of Loss of Civil Structures and Damages to Marsyangdi Power Plant

Item	Value (NRs.in Mill)
1. Economic Value of Losses of Civil Structures in Rowa Rver	
i. 4m*230m Black Topped Road	3.174
ii. 15m*5m Concrete Bypass Bridge	12.420
iii. 3m*4m*60m Concrete Box Culverts	8.280
iv. Lateral Canal connected with Cooling System and Shaft Shields	13.800
v. 4 nos. of Check Gabion Structures	4.000
Sub-total	**41.674**
2. Economic Value of Loss of Bridge over Rowa Rver	
i. Only Structure of 7.6m*33m Concrete Bridge	0.92
Sub-total	**0.92**
2. Economic Value of Damage Inside Marsyangdi Hydropower Project	
i. Equipment	3.680
ii. Tools	0.023
iii. Plant and Machineries	8.280

iv. Pipe Line	1.012
v. Building and Civil Structures	0.828
vi. Distribution Trasformer	0.276
vi. Others	1.656
Sub-total	**15.755**
Total	**58.349**

Source: Consultants' Survey and Estimates

8.3.2 Value of Vehicles Lost

The study of Costing Road Accidents in Nepal by DoR/TRL, UK, 1996 had estimated average value of loss of vehicles in road accidents. Same methodology and parameters are used to estimate average cost of lost/damaged vehicles at 2007 prices.

The net vehicle lost/damaged cost incurred in road accidents is estimated by using following relationship:

Net Vehicle Damage Cost = Average Vehicle Repair Cost

- (Custom Duties and VAT on Spare Parts and any Salvage estimate)

+ Insurance excess (Insured Vehicles Only – 10% Vehicles)

+ Survey Fees (Insured Vehicles Only – 10% Vehicles)

+ Lost Business (Commercial Vehicles Only)

Estimates of average vehicle repair cost, data on spare parts, salvage estimates, insurance excess, survey fees and lost business of commercial vehicles were obtained by extensive surveys in and outside kathmandu. Based on the data net vehicle damage cost in road accidents were estimated. The cost is adjusted by 2007 prices The adjusted cost is NRs.134,815.00. Table 8.3.2 summarizes the components of vehicle damage cost. The cost is considered to be value of vehicle lost per CSLDM**.** The unit value of vehicle lost by CSLDM is estimated at NRs.134,815.00 and annual average value of the loss is estimated at NRs.40444.50.

Table 8.3.2 Net Vehicle Damage Cost (NRs.)

Vehicle-type	Repair Cost	Duty & VAT on Spare-Parts	Estimated Salvage	Survey Fee	Lost Business	Net Vehicle Damage Cost
Bus	NRs.164,254	NRs.45,170	NRs.16,425	NRs.2,700	NRs.66,377	NRs.171,736.00
Truck	NRs.159,688	NRs.43,914	NRs.15,969	NRs.2,700	NRs.77,804	NRs.180,308.45
Car	NRs.52,814	NRs.14,524	NRs.5,281	NRs.2,000	NRs.0	NRs.35,008.93
Motor-cycle	NRs.9,582	NRs.2,635	NRs.958	NRs.100	NRs.0	NRs.6,088.97
Other Vehicles	NRs.44,907	NRs.12,858	NRs.4,491	NRs.1,700	NRs.0	NRs.29,258
Weighted Average	NRs.127,215	NRs.34,987	NRs.12,721	NRs.2,287	NRs.53,022	NRs.134,815

8.3.3 Value of Lost Electricity Generation

As mentioned above the flood water entered into the underground floor of the hydropower plant had caused great damages to the turbine and other equipments which interrupted electricity supply for many days. The interruption of electricity supply caused loss of 13.5 million units of electricity. The value of electricity distribution per KWh is NRs.6.5 per unit. Hence, the value of loss due to interruption of electricity per CSLDM is estimated at NRs. 87.70 million and annual average loss is NRs. 8.77 million.

8.3.4 Reopening Cost

The DoR Division office has kept a loader in its site office at Mugling for clearing the RCDs or CSLDM in Mugling – Pokhara road. Similarly, every year a loader operator is assigned for 4 months (from July to October) to operate the loader for opening CSLDM.

The potential cost of opening a diversion per CSLDM is estimated using unit cost per disaster magnitude (length of road closure). The unit cost is formulated using past data.

The reopening cost of a CSLDM comprises fixed cost and variable costs (the cost incurred during opening of each CSLDM). The fixed cost comprises operator's salary and allowances, depreciation of loader and overhead for operation of the site office. Similarly, variable cost comprises cost of fuel and oil consumptions and cost of labourers. The unit reopening cost is estimated at NRs.292330.25 per CSLDM comprising NRs.282480 fixed cost and NRs.9850.25 variable cost. Table 8.3.3 shows details of estimated unit fixed and variable reopening costs per CSLDM. Hence, the unit value of reopening cost per CSLDM is estimated at NRs. 292,330.25.00 and annual average cost is NRs. 29,233.03.

Table 8.3.3 Reopening Cost per CSLDM

Headings	Amount per CSLDM (NRs.)
1. Unit Fixed Reopening Cost	
a. Operator's salary @NRs.10000 per month for 4 months	40000.00
b. Allowances @NRs.140 per day for 120 days	16800.00
c. Depreciation of Loader @10% of NRs.6,000,000.00 per Annum	200000.00
Subtotal	256800.00
d. Overhead @10% of Subtotal	25680.00
Total Fixed Cost	**282480.00**
2. Unit Variable Reopening Cost	
a. Average economic cost of fuel consumption @ consumption of 20 litres of diesel per hour of loader operation and NRs.44.46 per litre of diesel for 10 hours	8892.00
a. Average economic cost of oil consumption @ consumption of 0.086 litre of oil per hour of loader operation and NRs.156.57 per litre of oil for 10 hours	134.65
e. Average economic cost of 4 labours @NRs.20.59 per hour per labourer for 10 hours	823.60
Total Variable Cost	9850.25
Total Reopening Cost per CSLDM	**292,330.25**

Source: Consultants’ Survey and Estimates, February 2008

8.3.5 Value of Losses of Traffic Suspension

In March 2007, Government of Nepal Ministry of Physical Planning and Works, Department of Roads, Study of North - South Fast Track Linking Kathmandu to Terai, 2007, had estimated following value of time of passenger vehicles. Value of time of goods vehicles (truck, mini-trucks etc) are not considered in economic cost estimates.

Value of Time of Motorcycle = NRs. 6.75/Hour/Vehicle (1.8 passengers)

Value of Time of Car = NRs.150/Hour/Vehicle (4 passengers)

Value of Time of Bus = NRs.180/Hour/Vehicle (40 passengers)

Value of Time of Mini Bus = NRs.90/Hour/Vehicle (20 passengers)

Value of Time of Microbus = NRs.58.5/Hour/Vehicle (13 passengers)

Weighted Average = NRs. 100.76/Hour/Vehicle

The Potential Waiting Time per vehicle per CSLDM as mentioned above is 3.68 hours. Hence, value of loss due to Traffic Suspension per CSLDM is estimated at NRs. 3,437,400.0 and annual average value is NRs. 343,740.00.

8.3.6 Value of Loss due to Detour Taken by Vehicles

Length of the detour Marsyangdfi - Pokhara - Bartung - Butwal – Narayanghat - Marsyangdi or the other way is 330Km.

Hence, if Pokhara is considered to be origin or destinations of all vehicles a vehicle has to travel additional distance of 245Km to reach the destination.

Vehicle Operation Costs (VOC) of vehicles in the above three roads are estimated by using the Roads Economic Decision Model (RED) model calibrated to Nepali conditions. The model is developed based on relationships and assumptions contained in the World Bank's Highway Design Manual (HDM-4). The RED model is more suitable for estimating VOCs for Nepali roads and evaluation of the roads.

In order to predict VOC, the model requires following three sets of data:

Unit prices of each VOC component of vehicles

Characteristics of vehicles

Characteristics of the project road

(i) Unit Prices

In predicting VOC, the model predicts the amount of resources consumed such as fuels, oils, tires, crew costs etc, and then multiplies these consumptions by the unit prices of each resource. It is therefore necessary to provide unit prices of VOC components as the basic input data.

Unit economic prices of each VOC component of vehicles required by the model are estimated from the data obtained from Dept of Customs, dealers of vehicles and tires, motor workshops and Nepal Oil Corporation.

The calculated economic prices of VOC components are given in Table 8.3.4, 8.3.5 and 8.3.6.

Table 8.3.4 Economic Prices of Vehicles (Rs)

Vehicle Type	Economic
Multi Axle-truck	1,808,000
Medium Truck	1,390,000
Light Truck	1,180,000
Large Bus	1,650,000
Mini-bus	1,440,000
Micro-bus	989,800
Car¥Van¥Jeep (Average)	565,700
3 Wheeler	130,000
Motor cycle	75,400
Rickshaw	9,000

Source: Consultants' Survey, Kathmandu

Table 8.3.5 Economic Prices of Fuel and Oil

Item	Economic Price (Rs./Litre)
Diesel	44.46
Petrol	47.62
Lubricants	156.35

Source: Consultants' Survey, Kathmandu

Table 8.3.6 Economic Prices of Tires

Vehicle Type	Economic Price (Rs)
Multi Axle-truck	14,620
Medium Truck	11,740
Mini-truck	5,970
Large Bus	11,820
Mini-bus	6,390
Microbus	4,390
Car/Van¥Jeep (Average)	2,210
3 Wheeler	1,460
Motor cycle	770
Rickshaw	300

Source: Consultants' Survey, Kathmandu

Table 8.3.7 Average Economic Crew Costs

Vehicle Type	Driver		Helper Wage (Rs/hr)	Average/ Vehicle (Rs/hr)	Adjusted (Rs/hr)
	No. per Vehicle	Wage (Rs/hr)			
Heavy/Med Truck	1	50	20	70	52.5
Mini-truck	1	40	20	60	45.0
Large Bus	1	50	25	75	56.3
Mini-bus	1	60	20	80	60.0
Microbus	1	60	10	70	52.5
Car/Van/Jeep	0.5	50		25	18.8
3 Wheeler	1	40		40	30.0
Bullock Cart	1	35		35	26.3
Rickshaw	1	40		40	30.0

Source: Field Survey and Consultants' Estimates

On the basis of field survey, Rs.32 per labor per hour is estimated as the average wage rate of maintenance labor.

(ii) Characteristics of Vehicle

Table 8.3.8 and 8.3.9 summarize the vehicle characteristics assumed for the estimation of VOC

Table 8.3.8 Vehicle Characteristics

Vehicle Type	Fuel Type	No. of Wheels	Operating Weight (tonnes)	ESA	No. of Passengers	% of Private Trips
Multi Axle-truck	Diesel	10	30.00	21.00	-	0
Heavy Truck	Diesel	6	17.50	7.50	-	0
Mini-truck	Diesel	6	7.00	0.10	-	0
Large Bus	Diesel	6	10.00	0.80	45.0	0
Mini-us	Diesel	6	5.00	0.04	28.0	0
Microbus	Diesel	4	2.00	0.01	10.0	0
Car/Van/Jeep	Petrol	4	0.80	0.00	2.5	50
3 Wheeler	Petrol	3	0.40	0.00	5.0	0
Motor cycle	Petrol	2	0.20	0.00	1.5	100
Rickshaw	-	3	0.30	-	1.5	-

Source: Manufacturers, Operators and Consultant's Estimates

Table 8.3.9 Vehicle Utilisation Data

Vehicle Type	Annual km	Annual working hours	Average life (years)
Multi Axle-tTruck	60,000	2,500	10
Medium Truck	40,000	1,800	10
Mini-truck	30,000	1,300	10
Large Bus	80,000	2,800	12
Mini-bus	50,000	2,400	10
Microbus	50,000	2,400	10
Car/Van/Jeep	20,000	550	14
3 Wheeler	15,000	1,200	10
Motor cycle	10,000	400	10
Rickshaw	7,200	1,000	6

Source: Manufacturers, Operators and Consultant's Estimates

(iii) Characteristics of Project Road

Table 8.3.10 summarizes the road characteristics assumed for the estimation of VOCs in the 'with project' situation.

Table 8.3.10 Representative Characteristics of the Two Roads

Characteristics	Value
Width (m)	7
Rise and Fall (m/Km)	45
Curvature (Degree/Km)	250
Roughness (IRI)	8

Source: Consultants' Assumptions

The calculated VOCs using the RED Model are presented in Table 8.3.11

Table 8.3.11 Vehicle Operation Costs in The Three Roads (NRs./Km)

Vehicle Types	VOC (NRs./Km)
Trucks	41.56
Minitrucks	23.24
Bus	33.90
Mini Bus	25.76
Microbus	14.98
Car/Van/Jeep	11.90
Motorcycle	2.63
Weighted Average	20.25

Source: Consultants' Estimates

Hence, Unit Vehicle Operation Cost is NRs.20.25/Km/Vehicle.

Hence, a vehicle if it takes detour has to spend extra VOC, in average, of NRs.9923.6 per round trip.

The vehicle speeds calculated using the RED Model are presented in Table 8.3.12.

Table 8.3.12 Vehicle Speeds in Three Roads (Km/Hour)

Vehicle Types	Speed (Km/Hour)
	MBN
Trucks	24.00
Minitrucks	24.90
Bus	26.60
Mini Bus	27.40
Microbus	31.30
Car/Van/Jeep	30.50
Motorcycle	30.50
Weighted Average	28.61

Source: Consultants' Estimates

Hence, Unit Vehicle speed is 28.61/Km/hour.

Difference of travel time of a vehicle if it takes detour, in average, is estimated at 8.7 hours/vehicle.

Hence, a vehicle if it takes detour looses, in average, NRs.1,725.62 per round trip due to longer travel time.

Hence, total value of loss due to detour taken by vehicles per CSLDM is estimated at NRs. 8,861,012.00 and annual average loss is NRs. 886,101.20.

8.3.7 Value of Loss due to Cancellation of the Trip

The average distance from Marsyangdi to all origins of vehicles is assumed to be 100 km. Hence, total loss in VOC due to cancellation of trips is estimated at NRs. 3700850.00.

It is found that the average waiting time in Marsyangdi is estimated at2.17 hours/vehicle.

Similarly, it was also found that the average speed of vehicles in the road to all origins is 28.61 Km per hour and average travel time to Marsyangdi from all origins of vehicles is estimated at 3.5 hours/vehicle.

Hence, total value of lost time in waiting and travel due to cancellation of trips per CSLDM is estimated at NRs. 1043689.00.

Finally, the total estimated value of loss due to cancellation of trips per CSLDM is estimated at NRs. 4,744,538.84 and average annual value is NRs.474,453.88.

8.3.8 Total Value of Annual Average Loss of a Site Due to CSLDM

The total value of annual Average loss of a site due to CSLDM is estimated as follows:

Parameters	NRs.
Reopening Cost	29,233.03
Value of Loss of Civil Structure and damage to Power Plant	5,834,900.00
Value of Vehicles Lost	40,444.00
Value of Loss of Electricity	8,770,000.00
Value of Loss due to Traffic Suspension	343,740.00
Value of Loss due to Detour Taken by Vehicles	886,101.20
Value of Loss due to Cancellation of Trips	474,453.88
Total	16,378,872.11

Hence, annual average loss due to CSLDM is estimated at NRs. 16,378,872.11.

Questionnaire I **Annex 1**

Department of Roads

Origin and Destination Survey

Date:……../

Road: **/2008**

Station: **Start Time:**

Traffic Type: Passenger, Motorcycle, Car, Car, Jeep, Pickup, Microbus, Minibus, Bus, Minitruck, Truck, Tanker, Container

Plate Type: Private, Commercial, Corporation, Government, Tourist, Project

S.No.	Origin	Destination	If There Were Similar Alternative Toll Road, Ready to Pay NRs……. Instead of Waiting	Wait to Open the Road Closure for …………Hrs Before Deciding to Abandon the Waiting	Take Detour Via (Tansen/Narayanghat)	Cancel Trip by Road and Take Flight to Bhairahawa/kathmandu	Purpose
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Annex 2

Questionnaire II

Department of Roads

Passenger Interview Survey

Road: **Date:……../ /2008**

S.No.	Origin	Destination	Transport Vehicle	Government Work	Trade/ Business	Study	Medical	Others	Visiting Relatives	Entertainment
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

Annex 3

Table. List of Interviewed People

S.No.	Name	Designation
1	Mr. Shiva Chandra Jha	Director, Environmental and Social Studies Department
2	Mr. Bindu Praksh Joshi	Incharge, Site Office, Marsyangdi Hydropower Plant
3	Mrs. Parbati Sharma	Owner of Hotel/Lodge in Khaireni bazar
4	Mr. Parth Mani Sharma	Trader in Khaireni bazar
5	Mr. Shrestha	Loader Operator - Field Office, DoR, Mugling
6	Mr. Jitendra Gurung	Business Man, Jugedi, Kabilas VDC
7	Mr. Sharma	Divisional Engineer, Lekhnath Municipality,
8	Mr. Shriprashad Agrahari	Senior Bridge Engineer, Kthmandu
9	Mr. Sanat Upadhyaya	Senior Road Engineer, Kthmandu
10	Mr. Bhupendra Shakya	Senior Envioronmental Engineer
11	Mr. Gambir Shrestha	Senior Divisional Engineer, DoR, Kathm,andu
12	Mr. Sharma	Distribution Section, Nepal Oil Corporation, Kathmandu
13	Mr. Aryal	Salesman, Arun International, Kathmandu
13	Mr. Chaudhari	Salesman, Sipradi Motors Company, Kathmandu
14	Mr. Hira Kaji Maharjan	Salesman, Tire House, Kathmandu
15	Mr. Hikmat Singh	Senior Officer, Department of Customs, Kathmandu
16	Mr. Krishna Dangol	Owner, Motor garage, Kathmandu