Existing Failure

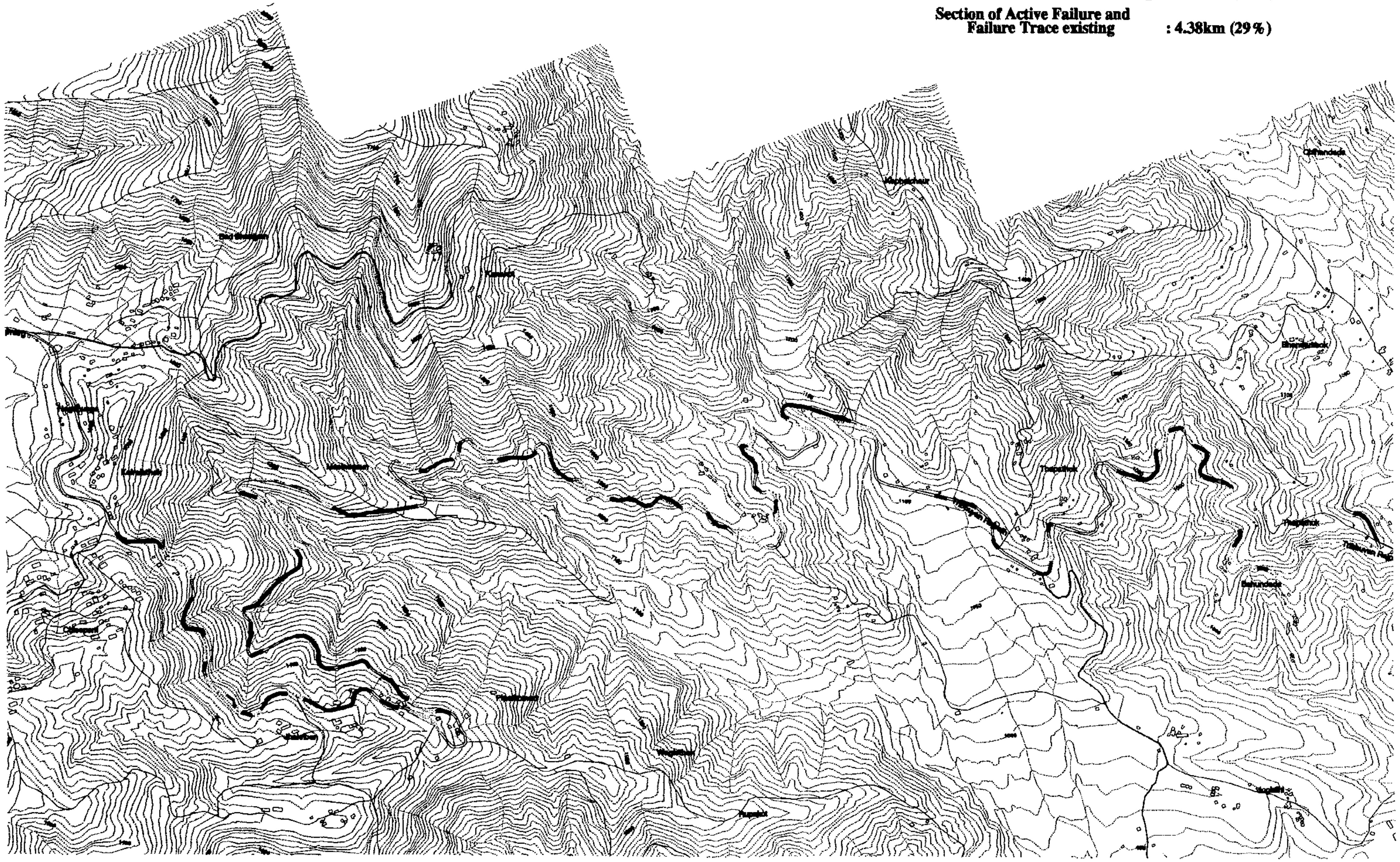
Section of Active Failure existing : 2.94km (19%)
Section of Failure Trace existing : 2.76km (18%)
Section of Active Failure and Failure Trace existing : 4.38km (29%)

LEGEND

Contour(10m)
Contour(50m)
River

EXISTING FAILURE

Active Failure
Failre Trace
Both Active Failure and Failre Trace



1:15,000

0 100 200 300 400 500
m

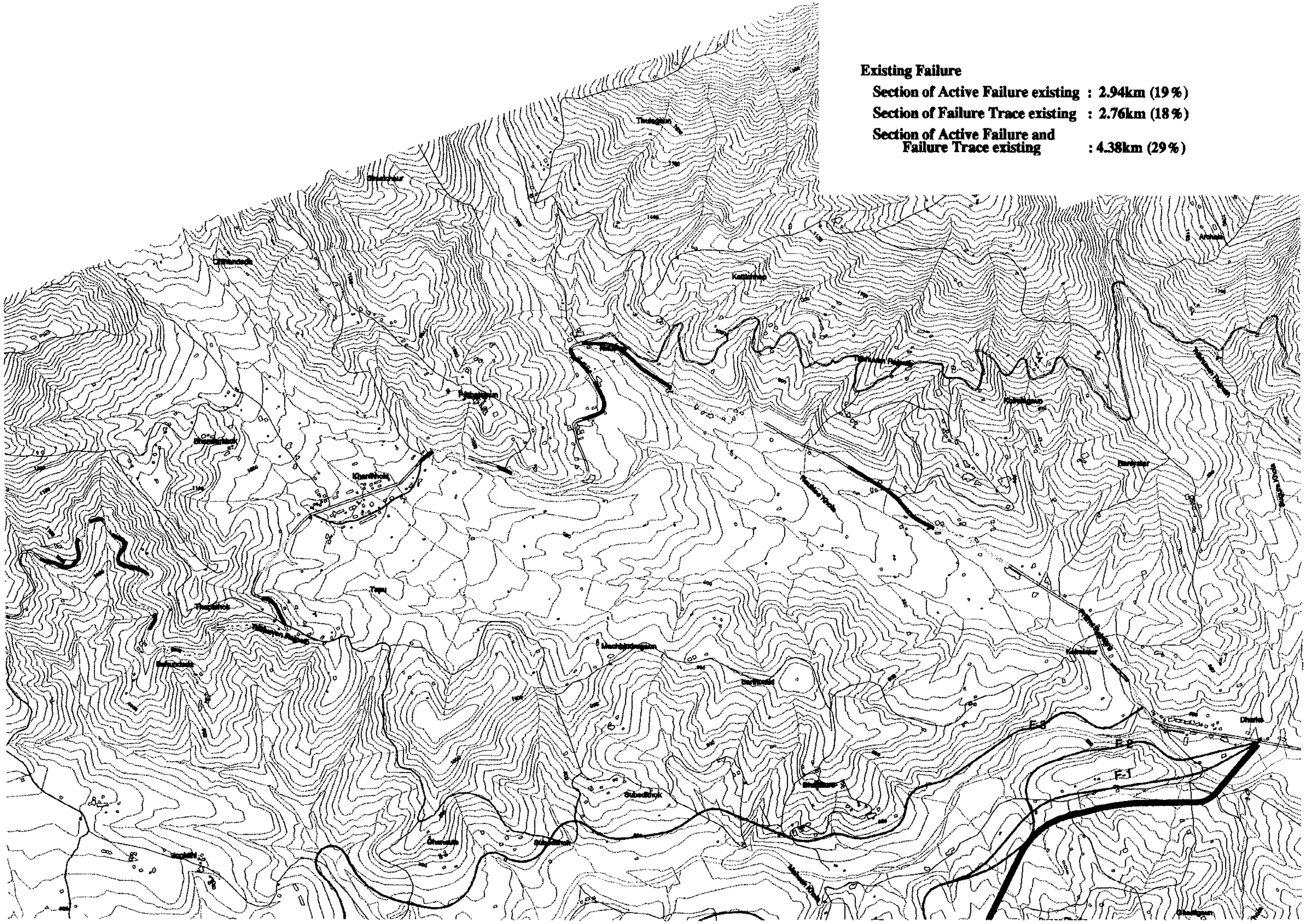
Figure 5.1 (1/2) ***Classification of section by slope soundness condition (existing Tribhuvan Highway)***

Existing Failure

Section of Active Failure existing : 2.94km (19%)

Section of Failure Trace existing : 2.76km (18%)

Section of Active Failure and Failure Trace existing : 4.38km (29%)



LEGEND

Contour(10m)

Contour(50m)

River

EXISTING FAILURE

Active Failure

Failre Trace

Both Active Failure and Failre Trace

1:15,000

0 100 200 300 400 500

m

Figure 5.1 (2/2) ***Classification of section by slope soundness condition (existing Tribhuvan Highway)***

Table 5.4 Road Length with Failure of Cutting Slope

	Road Length	Occupation among the road length from Dharke to the path
Slope with Active Failure	2.94km	19%
Slope with Failure trace	2.76km	18%
Slope with both failure	4.38km	29%
Total	10.08km	66%

It can be evaluated that these colored area, which show failures at present and/or in past period, have higher potential to cause slope failure again by rainfall or other cause. This evaluation result shows that 66% of whole stretch of the road has potentiality of failure. This ratio leads to the conclusion that the existing road has high potential of slope failures.

The reason of this high potentiality of slope failure in this section was examined in the investigation. The investigation found the fact that sufficient slope drainage is not provided in these slopes and it was concluded that this is the major reason to unstabilize these slope. The Study Team identified various type of erosion developed by run-off water from the hinterland on these slopes and failures finally caused by the erosion.

As the countermeasure against the above situation, it is considered that at least installation of suitable size of slope drain ditch with total length of 15km is necessary.

Furthermore, soil removal work of the top portion of these disaster potential slopes are required if they are to be made stable. The required volume of the soil removal work is estimated to be 22,000 m^3 or more. This soil removal work should be done at places above and adjacent to the existing road maintaining current traffic.

In addition, it will be quite difficult to construct temporary access roads to the places.

(2) Disaster potential of landform and geological feature

Not only slope disaster potential but also disaster potential of landform along the existing road must be considered. Dormant landslide and danger stream of debris flow have been plotted on the Hazard Map shown in Figure 5.2. From this Figure 5.2, three-danger stream of debris flow are crossing the existing road and failures are also located along the road.

HAZARD MAP

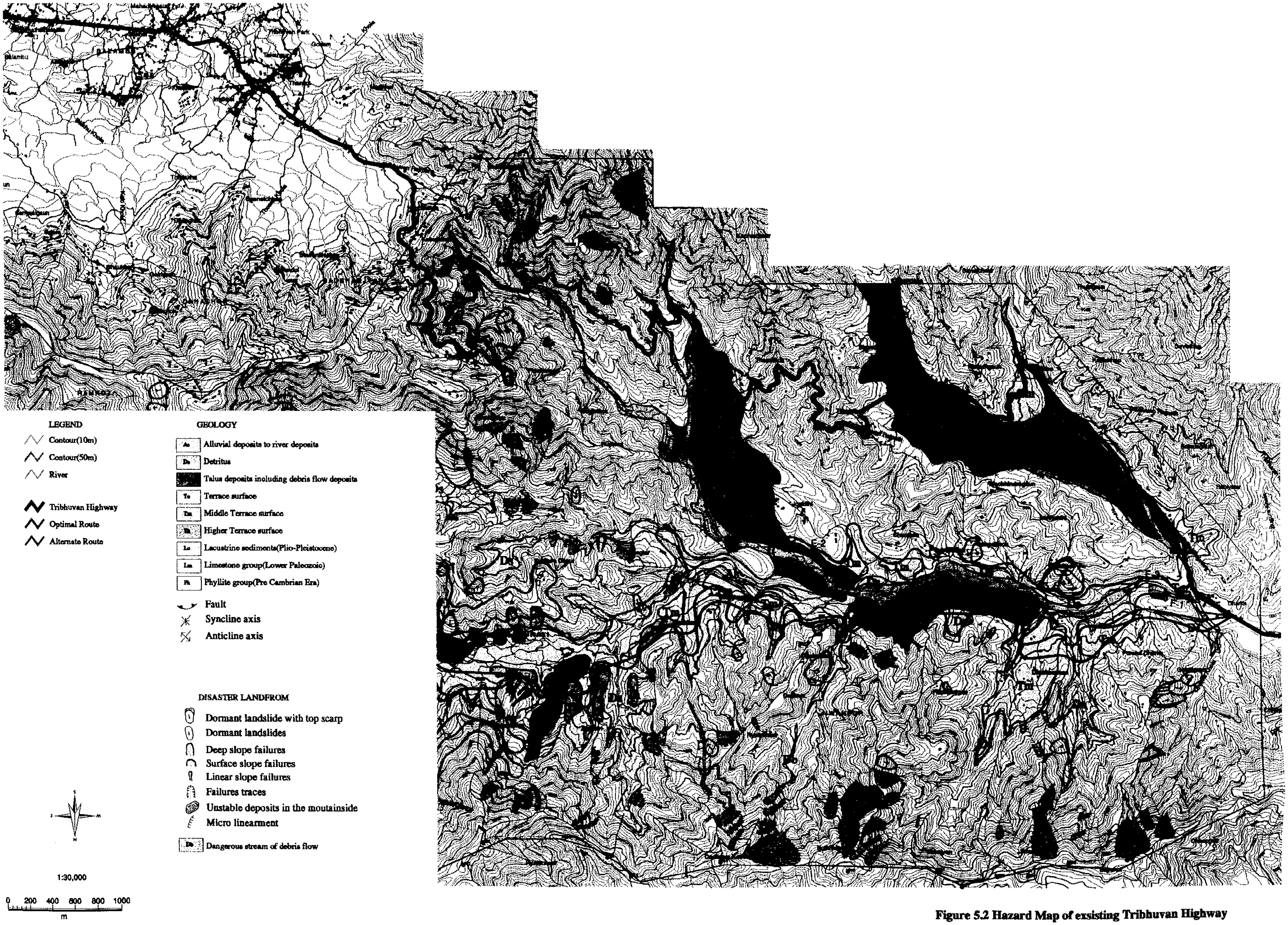


Figure 5.2 Hazard Map of exsisting Tribhuvan Highway

HAZARD MAP

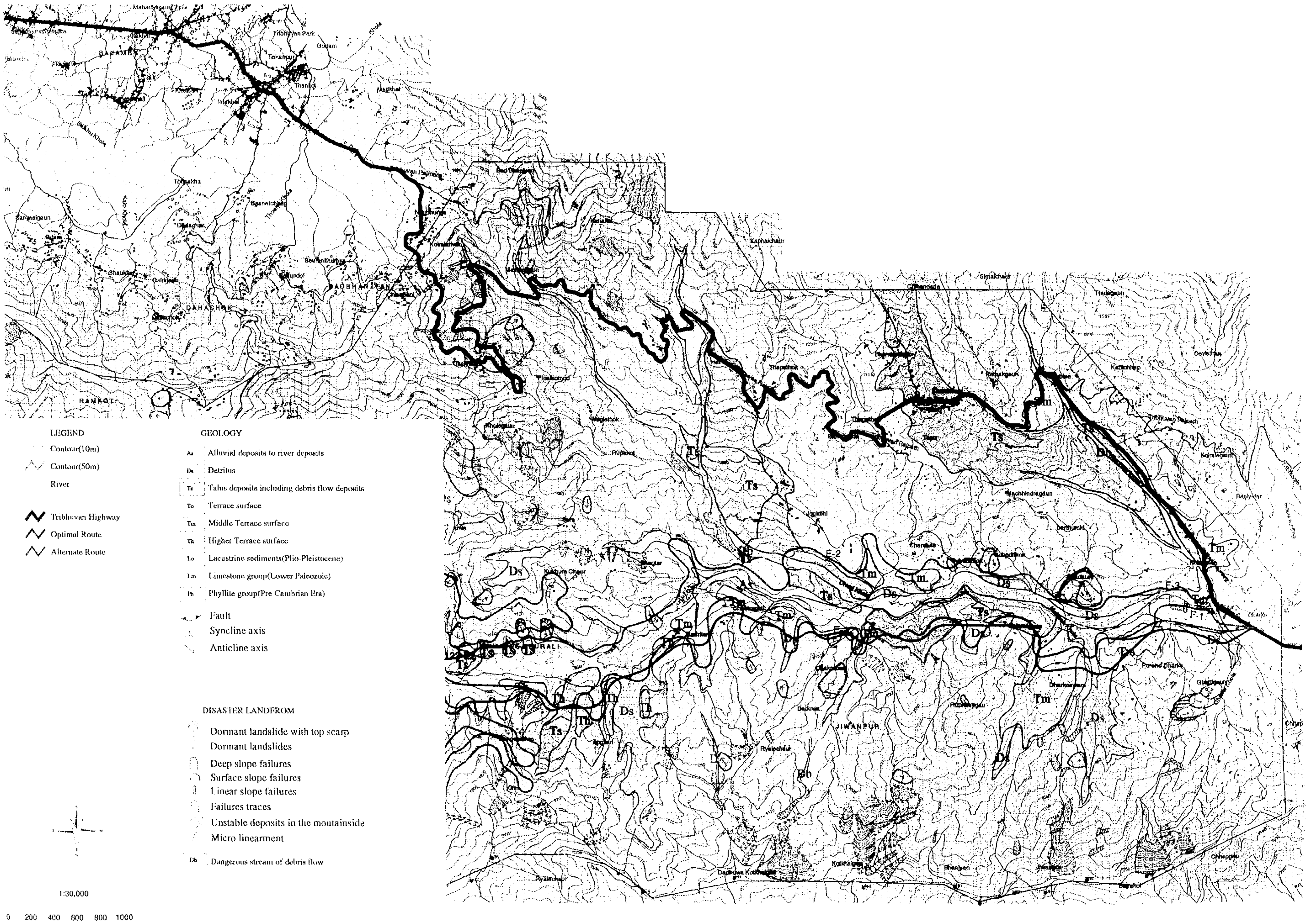


Figure 5.2 Hazard Map of exsisting Tribhuvan Highway

Failures and failures trace with large magnitude can be observed in the watershed of danger stream of debris flow. Also any countermeasure against these failures and debris flow has not been provided in the stream. For this reason, debris flow is very easy to occur by heavy rainfall. Regarding the bridges crossing these debris flow prone stream, it is highlighted that the bridges have insufficient vertical and horizontal clearance. This fact means that these bridges are exposed to the dangerous situation to be flushed out by the debris flow.

In case a big scale debris flow flushes out the bridge, the existing road should be closed at least for one month until the temporary bridge is constructed. After that, the road will be open partially for another one year until the new permanent bridge is constructed.

On the other hand a dormant huge landslide is also identified near hairpin curve through aerial photo observation. This landslide magnitude reaches 300m in width and about 500m in length. This landslide can be divided into three slide mass. Main mass covers from stream to near ridge including the existing road. Top scarp of main mass can not be observed clearly although a landform feature of upper portion is so disturbed. The slip surface of secondary mass is estimated to cross near the low side existing road. Last mass is located on the lower portion of main mass. This landslide mass can be estimated slightly active (gradually moving). Scouring of toe of the mass due to the stream flow is considered to accelerate instability of the landslide. The conceptual profile can be shown in Figure 5.3. Although it can not be judged when this huge landslide may actually collapse, it must be judged that the existing road will be fatally damaged, if it happens.

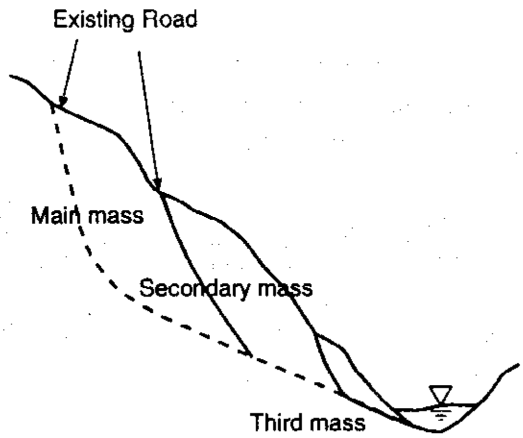


Figure 5.3 The conceptual profile of dormant landslide

Failures must be considered. Especially, failures distributes contently around the hairpin curve portion. These failures can be divided into active and trace failures. Also types of failures have various type, deep, surface and linear type. The features of these failures are weathered, poor geology, very steep gradient, and magnitude reached 100 - 200 m height and 100 - 200 m length. The common cause of these failures can be estimated to be concentrated surface water from the spring around the pass. Debris of failures among them sometimes reaches the existing road by a slight rainfall even now.

5.4 Evaluation of the Existing Tribhuvan Highway

Through a series of investigations and studies described in the previous sections, the Study Team comes to the following conclusions:

1) Evaluation on the geometric condition

The existing Tribhuvan Highway was constructed in 1950s and geometric condition of the road does not satisfy the requirements as the National Highway. This geometric substandard situation reduces traffic capacity in this section. Considering recent economical growth of Nepal and traffic saturation of the road, it is necessary to carry out improvement of both vertical and horizontal alignment.

However, it is judged that present alignments are so poor that alignment improvement up to the extent satisfying standard as the National Highway can not be done technically.

2) Evaluation on Disaster Prevention Aspect

In year 1993, a heavy rainfall occurred over a vast area of Nepal and Tribhuvan Highway was also seriously damaged. One bridge was flushed away by the rainfall.

According to the hydrological analysis using precipitation data of Dhuribesi gauging station, that located along the road, the return period of the 1993 heavy rain is estimated to be 12-years.

These facts indicate that the road has high potentiality in occurrence of big scale disasters in future at short intervals (5-15 years).

The number of potential disaster spots identified in this study are shown in Table 5.6 and summarized as follows.

- 66% of all cutting slopes in the section between Nagdhunga and Dharke have active failure or past failure trace. These slopes have high potentiality to cause slope failure triggered by heavy rainfall and/or earthquake
- Three debris flow streams are identified. The existing roads are crossing these debris flow streams by bridges. However since the bridges have no sufficient clearance for the debris flow passing, the bridges are exposed to the dangerous situation to be flushed out by the debris flow. As

countermeasures for the debris flow dangerous stream, realignment of the road and reconstruction of bridges are required

- Furthermore one huge dormant landslide is identified in hairpin curve area. The landslide has a magnitude of 300m in width and 500m in length, and the scouring of toe of the landslide mass by stream flow is considered to accelerate instability of the landslide. Since the existing road is passing at top of the landslide and middle of the landslide, it must be considered that the existing road will be fatally damaged, if actual collapse of the landslide happens.

Table 5.5 Number of Potential Disaster Spots

Classification of Type of Disaster	No.	Conceivable Measure Countermeasure
Slope Failure	110 (66% of all slopes)	- Installation of slope drainage (15km) - Removal of top of the slope
Debris Flow	3	- Realignment of the road - Reconstruction of 3 bridges
Land Slide	1	- Huge amount of counterweight embankment (7mil. m^3)

An estimate of the construction cost of the preventive countermeasures could not be done in this Study, however the cost must be huge, if full scale of such countermeasures are carried out judging from other similar projects.

Furthermore, considering such situation that the current traffic volume reaches the capacity of this section, it will be quite difficult to carry out the construction of the disaster prevention works while maintaining the traffic.

Judging from the above results, it is concluded that construction of countermeasures against slope failures, debris flows and landslide must need huge amount of investment beyond practical range.

CHAPTER 6 ENGINEERING SURVEY AND ANALYSIS

6.1 General

In order to obtain necessary engineering data and information of the Study area, the following field surveys were carried out by the local consultants registered in the Kingdom of Nepal.

1) Topographic survey
2) Hydrological survey
3) Geological survey

6.2 Topographic Survey

For the sake of the alternative route study and the preliminary engineering design, the following topographic surveys were carried out;

1) Control points survey using Global Positioning System (GPS)
2) Ground survey using Total Station

6.2.1 Control points survey

In advance of the ground survey, six control points were established in the Project area by using Global Positioning System (GPS). Levelling survey was also conducted, starting from the existing National Bench Mark to find the exact level of the control points.

The results of the Control Point Survey are given in Table 6.1

Table 6.1 Results on GPS Co-ordinates in Nepal Datum (UTM Grid)

Station Name	Location	Northing	Easting	Elevation
NK – 01	Sitapaila	3066165.81	626311.10	1331.968
NK – 02	Danda Pauwa	3067456.86	624114.34	1372.817
NK – 03	Bhimdhunga	3068428.84	621703.18	1518.597
NK – 04	Bhut Danda	3069730.77	618288.77	1058.731
NK – 05	Biruwa Danda	3068598.69	616115.37	946.634
NK – 06	Purano Dharke	3068882.24	612649.84	842.213

Note: Elevation of station NK-04 was computed by GPS data processing using geoid model – Nepal 97

6.2.2 Ground survey using Total Station

Ground survey was carried out along the Project Road covering the area necessary for the alignment study. Total Stations was used for the survey to obtain the survey data in digital form.

Heights and co-ordinates of survey spots for the topographic mapping was measured by radiation method based on the traverse points established from the co-ordinates of the GPS stations. All natural features, land-use such as vegetation, paddy field, river, streams etc. were recorded with proper descriptions during data entry in the data recorder. All existing artificial structures on the ground such as road, footpath, bridges, drainage, well, houses, fence, and other visible features were also recorded with proper descriptions.

The recorded data from the total stations were downloaded onto the computers and the topographic maps with contours were prepared using CAD system. These digital maps contain the 3-dimensional properties and can be used to produce the 3-dimensional digital terrain modelling of the surveyed area.

6.3 Hydrological Surveys

6.3.1 General

The hydrological survey works were conducted for the estimation of flood discharge volume and flood water level, which were used for the determination of the Project Road profile and preliminary design of river crossing structure, such as pipe culverts, box culverts and bridges. The survey includes the following components:

- Rainfall analysis
- Run-off analysis
- Flood water level analysis

6.3.2 Rainfall Analysis

The rainfall analysis was conducted for the sake of estimation of rainfall intensity in the catchment by various return periods. There are two gauging stations - Dhunibesi station and Thankot station – in the vicinity of the Project area, and the daily rainfall data of these station was used as the base data.

Table 6.2 Summary of Rainfall Stations

Station	Station No	Latitude (N)	Longitude (E)	Elevation (m)	Established	Available Records	Mean Annual rainfall (mm)
Thankot	1015	27°41'	85°12'	1,630	Sep 1966	1971-90, 95, 96	2,123
Dhunibesi	1038	27°43'	85°11'	1,085	Apr 1971	1971-96	1,541

Using maximum daily rainfall of each year of the stations, frequency analysis was carried out for the estimation of the probable maximum daily rainfall. For the frequency analysis, Gumbel method was applied. The result of the analysis is presented in the Table 6.3.

Table 6.3 Probable Maximum Daily Rainfall (in mm/day)

Stations \ Return Period (Yr)	2	5	10	25	50	100
Dhunibesi	97	137	164	196	221	290
Thankot	97	128	148	173	192	210

The rainfall intensity curves by specific return period were established by Monobe's equation, which is generally applied in mountainous catchment, based on the probable maximum daily rainfall. The formula is presented by eq. (6.1) below.

$$R_t = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \qquad \text{...eq. (6.1)}$$

where, R_t : Rainfall intensity in t hours (mm/hr)
R_{24} : Daily rainfall (mm)
t : Time lag (hr)

The Rainfall Intensity duration tables for Dhunibesi and Thankot are presented in Table 6.4 and the corresponding figures are shown in Figures 6.1 and 6.2, respectively.

Table 6.4 Rainfall Intensity (mm/hr)

Dhunibesi							Thankot						
	24 hours Rainfall at return periods (Yr)							24 hours Rainfall at Return Periods (yr)					
Yr	2	5	10	25	50	100	Yr	2	5	10	25	50	100
mm	97.38	137.2	163.6	196.9	221.7	246.2	mm	97.74	128.1	148.1	173.5	192.3	211.0
Time (hr)	R_2	R_5	R_{10}	R_{25}	R_{50}	R_{100}	Time (hr)	R_2	R_5	R_{10}	R_{25}	R_{50}	R_{100}
1	33.758	47.573	56.720	68.277	76.850	85.361	1	33.885	44.395	51.354	60.146	66.669	73.144
2	21.266	29.969	35.731	43.012	48.413	53.774	2	21.346	27.967	32.351	37.890	41.999	46.078
4	13.397	18.879	22.509	27.096	30.498	33.875	4	13.447	17.618	20.380	23.869	26.458	29.027
8	8.440	11.893	14.180	17.069	19.213	21.340	8	8.471	11.099	12.838	15.037	16.667	18.286
12	6.441	9.076	10.821	13.026	14.662	16.286	12	6.465	8.470	9.798	11.475	12.720	13.955
16	5.317	7.492	8.933	10.753	12.103	13.443	16	5.336	6.992	8.088	9.472	10.500	11.519
20	4.582	6.457	7.698	9.267	10.430	11.585	20	4.599	6.025	6.970	8.163	9.048	9.927
24	4.057	5.718	6.817	8.206	9.236	10.259	24	4.073	5.336	6.172	7.229	8.013	8.791

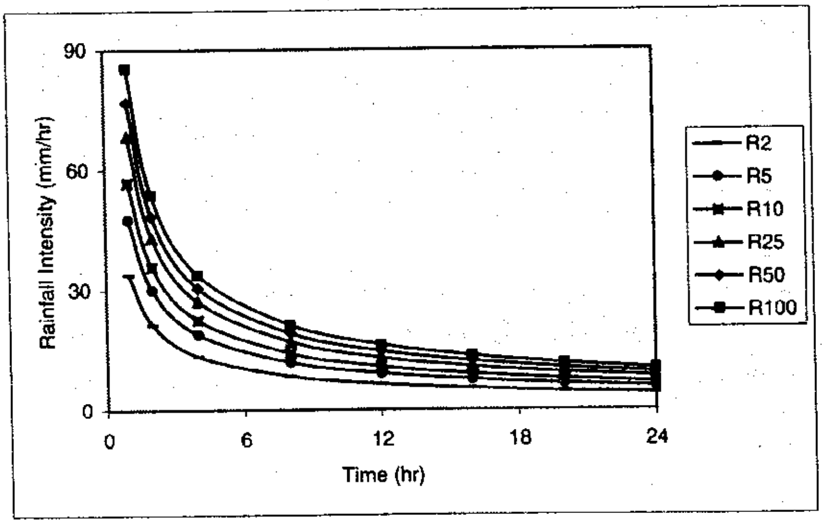


Figure 6.1 Rainfall Intensity curve of Dhunibesi Station

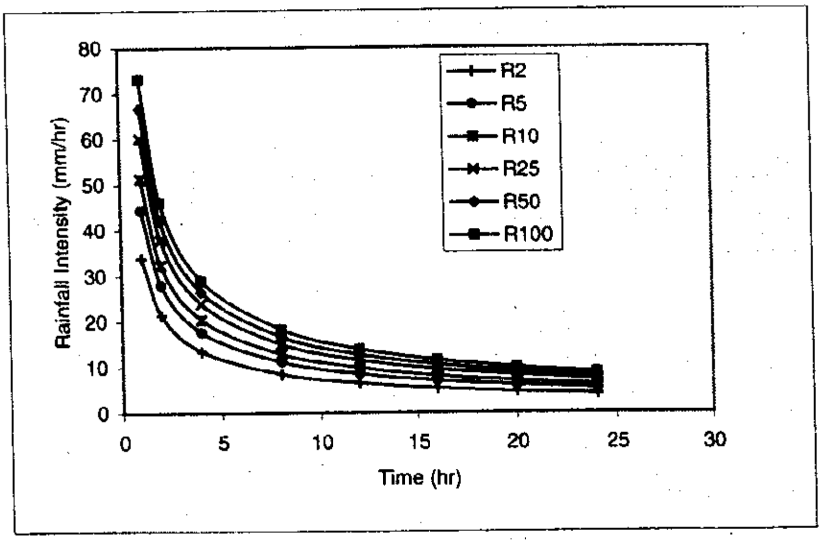


Figure 6.2 Rainfall Intensity curve of Thankot Station

6.3.3 Run-off Analysis

A rational formula was used for calculation of the flood discharge volume from the catchment. The form of the formula is as follows:

$$Q_P = \frac{f\ r\ A}{3.6} \qquad \ldots\text{eq.}(6.2)$$

where, Q_P = Maximum flood discharge in m^3/s

f = Dimensionless run-off coefficient (0.55 ~ 0.65)

r = Intensity of catchment average rainfall within the time of flood concentration in mm/h

A = Catchment area in km^2

The intensity of rainfall during time to flood is calculated from eq. (4.1). For the Manamati River watershed subbasins, Thankot precipitation data is used as the representing station data and for the Mahesh River watershed subbasins, Dhunibes precipitation data is used.

6.3.4 Flood Water Level Analysis

Flood water levels at all major river crossing sites were calculated by Manning's equation based on the flood discharge volume estimated in Clause 6.3.3.

For the Dharket Bridge site, flood water level calculation was conducted by un-uniform flow calculation, since the site has huge catchment area and complex river alignment. The results of the analysis are summarized in Appendix.

6.4 Geological Survey

6.4.1 Geological Boring Investigation

The geological surveys in this stage, were conducted to confirm the geological conditions around the conceivable tunnel sites, potential landslide area and expected bridge sites.

The scope of works is summarized as follows.

i) Field geological reconnaissance base on the base map 1:10,000 scale.
ii) Drilling works including Standard Penetration Test (SPT) for 27 boreholes. Among the 27 holes, 5 holes, which are at possible tunnel alignments are named with a prefix "T", 16 holes are named with prefix "LS", representing landslide, and other 6 holes are named "B" representing bridges.
iii) P-S Wave Velocity logging for the analysis of physical to rock-mechanical properties of the ground.
iv) Laboratory Testing for the confirmation of physical/rock-mechanical/soil-mechanical properties.

The summary of the completed quantity of above works is presented in Table 6.5, and the location of Boreholes is as shown in Figure 6.3. Geological map of the area in the vicinity of Bhindhunga Pass is prepared based on the surface geological survey and presented in Figure 6.4.

Table 6.5 Work Quantities of Geological Survey

(1) Geological Boring, Laboratory Test and P.S Wave Logging

(1.1) FOR TUNNEL

Tunnel Route	Drill Hole No.	Depth (m)	Top EL. of Hole (EL)	BTM El. of Hole (EL)	Standard Penetration Test (time)	Laboratory Test (nos.)					PS
						Ph	U	Chemical test			holes
								pH	Sound	Sum	
C-2	T-21	30	1450	1420	21	5	4	2	2	4	1
	T-22	50	1470	1420	24	5	4	2	2	4	1
C-1	T-11	15	1410	1395	15	5	4	4	0	4	1
	T-12	100	1470	1370	17	13	10	1	8	9	1
	T-13	52	1387	1335	0	9	9	0	8	8	1
Subtotal	5 holes	247			77	37	31	9	20	29	5

(1.2) FOR LANDSLIDE

Landslide Spot	Drill Hole No.	Depth (m)	Top EL. of Hole (EL)	BTM El. of Hole (EL)	Standard Penetration Test (time)	Laboratory Test (nos.)					PS
						Ph	U	Chemical test			holes
								pH	Sound	Sum	
LS-1	LS-11	35	1489.96	1454.96	13	2	2	3	2	5	1
	LS-12	25	1451.37	1426.37	24	2	2	1	2	3	1
LS-2	LS-21	40	1523.78	1483.78	20	2	2	1	2	3	1
	LS-22	30	1500.00	1470.00	12	1	2	1	2	3	1
	LS-23	25	1480.00	1455.00	20	1	2	1	1	2	1
	LS-24	23	1464.37	1441.38	16	0	1	1	1	2	1
LS-3	LS-31	30	1371.42	1341.42	8	1	1	0	2	2	1
	LS-32	30	1346.58	1316.58	13	2	4	3	2	5	1
	LS-33	30	1320.00	1290.00	25	2	2	1	1	2	1
	LS-34	25	1281.84	1256.84	22	1	1	1	1	2	1
LS-4	LS-41	30	1343.24	1313.24	7	3	3	1	4	5	1
	LS-42	25	1308.68	1283.68	11	1	1	2	1	3	1
	LS-43	20	1282.26	1262.20	15	1	1	1	2	3	1
LS-6	LS-61	35	1356.72	1321.74	17	1	1	1	1	2	1
	LS-62	35	1320.00	1285.00	21	1	1	0	1	1	1
	LS-63	25	1280.00	1255.00	25	1	1	0	1	1	1
Subtotal	16 holes	463			269	22	27	18	26	44	16
Total		710			346	59	58	27	46	73	21

(1.3) FOR BRIDGE

Water-shed	Drill Hole No.	Depth (m)	Top EL. of Hole (EL)	BTM El. of Hole (EL)	Standard Penetration Test (time)	Laboratory Test (nos.)					PS
						Ph	U	Chemical test			holes
								pH	Sound	Sum	
Mananati	B-1	20	1312.6	1292.6	20	4	4	4	4	8	N.A.
	B-2	20	1371.6	1353.0	20	4	4	4	4	8	N.A.
Mahesh	B-3	25	849.0	824.0	25	4	4	4	4	8	N.A.
	B-4	20	881.0	86.0	20	4	4	4	4	8	N.A.
Mahesh (Dharke)	B-5	20	792.0	772.0	20	4	4	4	4	8	N.A.
	B-6	20	787.0	767.0	20	4	4	4	4	8	N.A.

Ph : Physical test   U : Unconfined compression test   Sum : Subtotal

pH : Value measurement   Sund : Soundness test   P.S : P-S wave velocity logging

Figure 6.3 Location Map of Boreholes

Scale: 1:40,000

* LEGEND ; See Figure 10.5 .

Figure 6.4 Geological Map of Bhimdhunga Pass Area

0 500m Scale 1:10,000

Figure 6.4 Geological Map of Bhimdhunga Pass Area

6.4.2 Seismic Refraction Survey

After the optimum route, the short-tunnel option had been selected, the seismic refraction survey using blasting was carried out to obtain more geological information in the vicinity of the tunnel site. Evaluation of base rock property for planning and design of tunnel excavation is usually done by seismic velocity. Therefore, seismic refraction survey is one of most reliable geological survey method especially for tunnel.

The survey provide an estimation of special physical nature of rock rather than specific type of rock. The differential output of velocities show various factors such nature of rock as soft or hard, degree of weathering and degree of fracture.

In this study, the survey was conducted along eight (8) survey lines in total.

The alignment of the survey lines are shown in Figure 6.5. The figure shows eight spreads viz. S-21, to S-28. The description of each of the spreads is given in Table 6.6

Table 6.6 Description of Seismic Profiles

S. No.	Seismic Line No.	Length (m)
1	S-21	650
2	S-22	690
3	S-23	345
4	S-24	500
5	S-25	500
6	S-26	500
7	S-27	215
8	S-28	220
	Total Length	3,620

After data processing and analysis, rock strata by different seismic velocities (Seismic Profile) were obtained. The rock strata were classified into five (5) velocity layers as shown in Table 6.7.

Table 6.7 Velocity Layers and Rock Formation

Velocity layer	Velocity (Km/sec)	Thickness (m)	Rock Properties
First Layer	0.3 – 0.5	0 – 7	Top soil, laterite
Second Layer	0.7 – 0.9 0.8 – 1.0	3 – 15	Compacted soil and Debris
Third Layer	1.2 – 1.4 1.4 – 1.6 1.5 – 1.7	10 – 23	Compacted soil and Highly weathered phyllitic rock
Fourth Layer	1.9 – 2.1 2.2 – 2.4	12 – 25	Moderately weathered phyllitic rock
Bottom Layer	3.0 – 3.2 3.4 – 3.6 4.0 – 4.2		Slightly weathered phyllitic rock

Low velocity zones, which are the zones that have much lower velocity than the adjoining ones, are identified at 11 points. These low velocity zones show geological weak zone which may represent shear zone, local fault or a highly weathered and/or fractured rocks.

Type of base rock in this area is phyllitic rock in Pre-Cambrian age highly weathered layer reaches to 33mm depth and slightly weathered layer reaches to 60 m depth.

Bottom layer has velocity of 3.0km/s ~ 4.2km/s and it can be classified into soft to medium hard phyllitic rock.

Location of the fracture zones identified by the survey is presented in Figure 6.5.

The seismic velocity profile of individual survey lines are presented in Appendix.

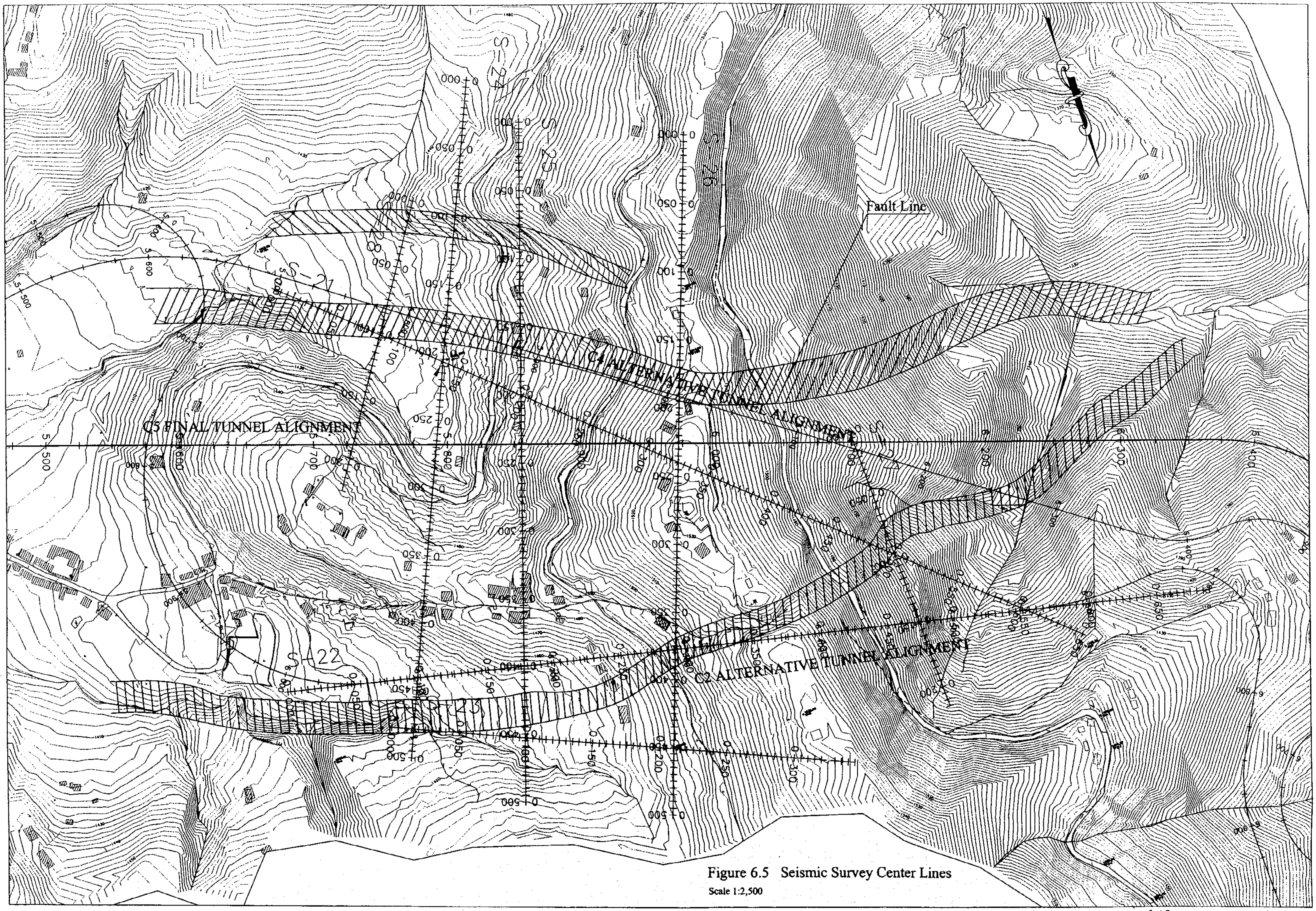


Figure 6.5 Seismic Survey Center Lines

Scale 1:2,500

6.5 Material Survey

Material survey was conducted for the sake of confirmation of suitability of in-situ excavation material for embankment, subgrade and subbase course material. Location of sampling sites is shown in the Figure 6.6. In the figure name of sampling location headed by 'M' means sampling site of the possible embankment material and headed by 'C' means sampling site of possible subbase course material.

Crushed stones of following existing crushing plants were also examined for their suitability for base course and concrete aggregate.

i) Thankot Crushing Plant (Q-1)
ii) Ramkot quarry site (Q-2)
iii) Godawari Marble (Q-3)

Test items and number of sampling is summarized in Table 6.8.

Table 6.8 Quantity of Material Survey

Category	Items		Location	Remarks
For embankment	Sampling			
	Physical Test	Gradation Analysis Density Specific Gravity Liquid/Plastic Limit Moisture Content	M-1 ~ M-25	
	Compaction Test		M-2,6,9,12,16,22,24	7 soil classification @4 times
	CBR Test		M-2,6,9,12,16,22,24	7 soil classification @3 times
For subbase course	Sampling			
	Physical Test	Gradation Analysis Density Specific Gravity Liquid/Plastic Limit Moisture Content	C-1, 2	incl. Phyllite & Laterite
	Compaction Test		C-1, 2	2 soil classification @4 times
	CBR Test		C-1, 2	2 soil classification @3 times
For concrete	Sampling			
	Physical Test	Gradation Analysis Density Specific Gravity Liquid/Plastic Limit Moisture Content	Q-1 ~ 3	
For basecourse	Compaction Test		Q-1 ~ 3	3 soil classification @4 times
	CBR Test		Q-1 ~ 3	3 soil classification @3 times

According to the laboratory test results, following assessments are obtained.

i) Some weather rock has superiority for the subbase course material, however fluctuation in CBR-value is quite big. Therefore it will be doubtful to use these material for sub-base course

ii) Although these weathered rock materials are not suitable for subbase course, almost of them have CBR value more than 7. Therefore, it is concluded that these weathered rock material (mainly Phyllite and Laterite) can be used for subgrade material.

iii) Common soils can be used for the material of road embankment deeper than 1.0 m from the subgrade level.

iv) Crushed stone from existing plants has suitable properties for concrete aggregate and base course material.

M-1 to M-25 Physical Tests
M-2, M-6, M-9, M-12, M-16, M-19, M-22, M-24 CBR and Compaction Tests also
C-1, C-2 Aggregate Tests

Figure 6.6 Location of Material Survey Points
Scale: 1:40,000