Near the Kathmandu side portal, section with cut can be introduced to reduce the total length of the tunnel. The total length of the alignment itself does not change significantly (shortened by 200m). The location of the first hairpin bend is not affected as well.

Several other points were noted based on the result of the detailed topographic survey.

- The location of the first hairpin bend is in difficult terrain and a hairpin bend of radius 55m may be difficult, requiring large quantities of earthwork as well as retaining structures.

- The alignment passes through the foot of a dormant landslide area before the first hairpin bend so, a proper landslide countermeasure is required.

- The alignment passes the river with potential debris flow two times, before and after the first hairpin bend.

In order to overcome these drawbacks in the alignment, it is desirable to fix the first hairpin bend about 500m upstream of the alignment so that the alignment can avoid passing though the dormant landslide area as well as to cross the dangerous stream of debris flow. However, keeping the same maximum grade of 5%, it is impossible to, shift the location of hairpin to upstream and, so further lowering of the formation height of the tunnel will be required by a considerable amount.

11.3 Further Study Based on Seismic Refraction Survey

In the mean time, seismic refraction survey and analysis was also completed. The seismic refraction survey was conducted along a total of eight routes. The details of the analysis have been given in other chapters.

From the results of the analysis, the boundary of the fault was drawn and is shown in Figure 11.3. Unfortunately, the Kathmandu side portal of both the tunnels C2 and C4 alternatives are located along a fault line. The cost and safety to construct a tunnel in such condition will have great uncertainty. Besides, further lowering of the formation height of tunnel in alternative C4 is also not possible in such situation.

To avoid the fault lines, another alternative for tunnel location has been studied that passes along the middle of two fault lines. The route of the tunnel is shown in Figure 11.3 and is named as alternative C5. The road alignment for this tunnel alternative was also studied and fixed based on the detailed topographic survey.

11.4 Comparison of Different Alternatives

The alignment was also fixed based on the tunnel alternative C5 and is shown in Figure 11.3, with other two alignments, C2 and C4 for comparison. The profile of the new alternative C5 is given in Figure 11.4. Following features can be noted for this alternative alignment:

- The total length of the tunnel is 700m.
- The formation height of the tunnel can be lowered such that the first hairpin bend can be shifted upstream to more favorable terrain.
- The dormant landslide before the first hairpin bend is avoided.
- The crossing over the dangerous stream of debris flow twice before and after the first hairpin bend is avoided.
- The formation height of the road can be lowered considerably and hence the total length of alignment passing through very steep topography and difficult terrain is reduced considerably (in the section from Naubise side tunnel portal to the location of first hairpin bend).
- The stream crossings are relatively at downstream side of the river and hence the total length of bridges and cross drainage is reduced in this section.
- The total length of the road in this section alone is shortened by 1.2km due to lowering of the formation height of tunnel.

The alternative C5 has more technical merits than other alternatives. The road alignment avoids passing through any dormant landslides and also avoids crossing any dangerous stream of debris flow. The location of initial hairpin bend is also in relatively gentle terrain. Furthermore, since the formation height is lowered, the alignment passes through less steeper topographic conditions and the length of bridges and cross drainages is reduced. All these factors contribute to the following enhancement of the project features compared to that of the Optimum Route discussed in the previous chapter:

- The construction cost is reduced due to all these factors mentioned above except the length of the tunnel.
- The road disaster potential is minimized to a great extent, thus reducing the construction, operation, and maintenance costs.
- The economical rate of return can be assumed to improve due to shortening of total road length.

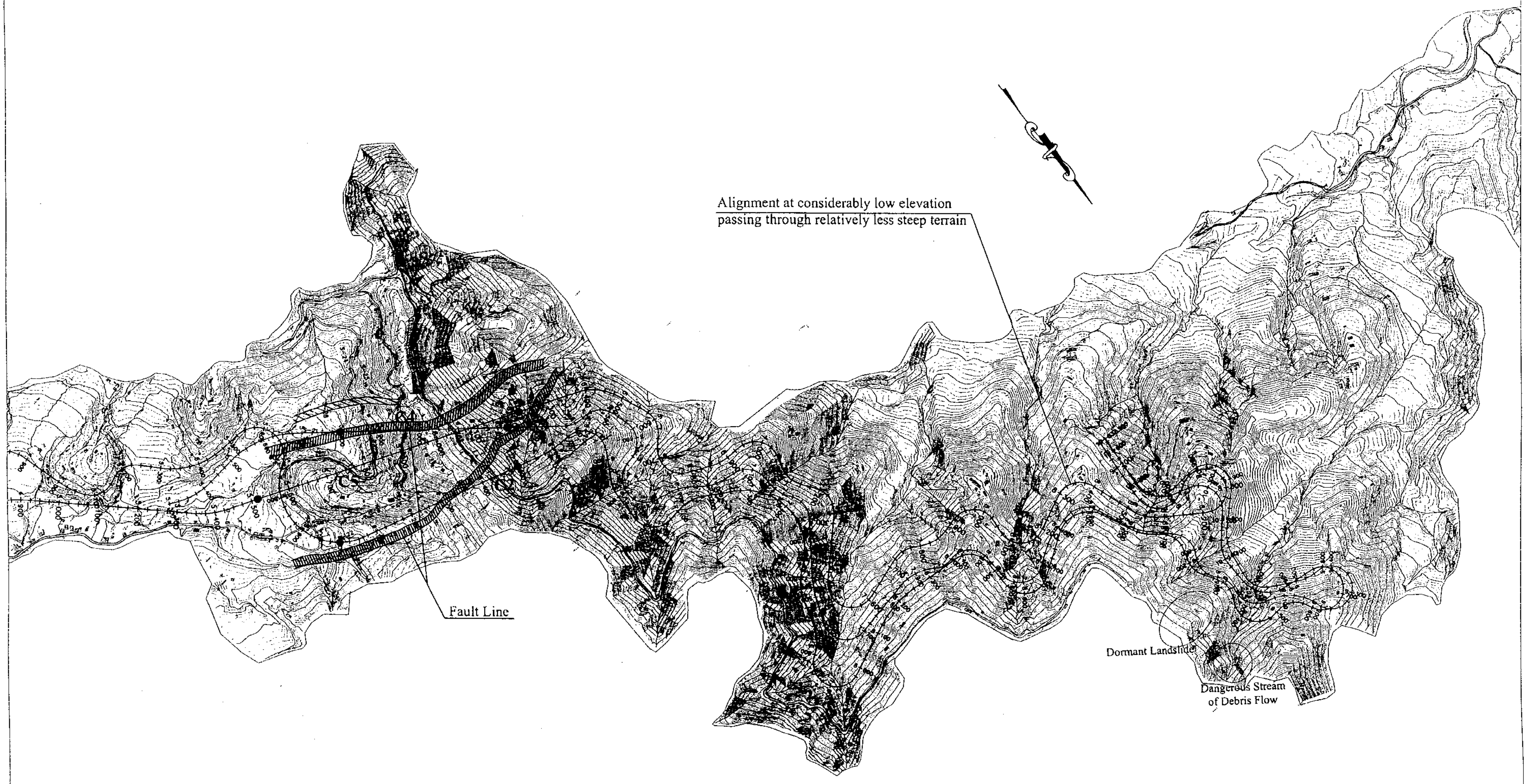

Figure 11.3 Final Tunnel Alignment C5
Scale 1:10,000

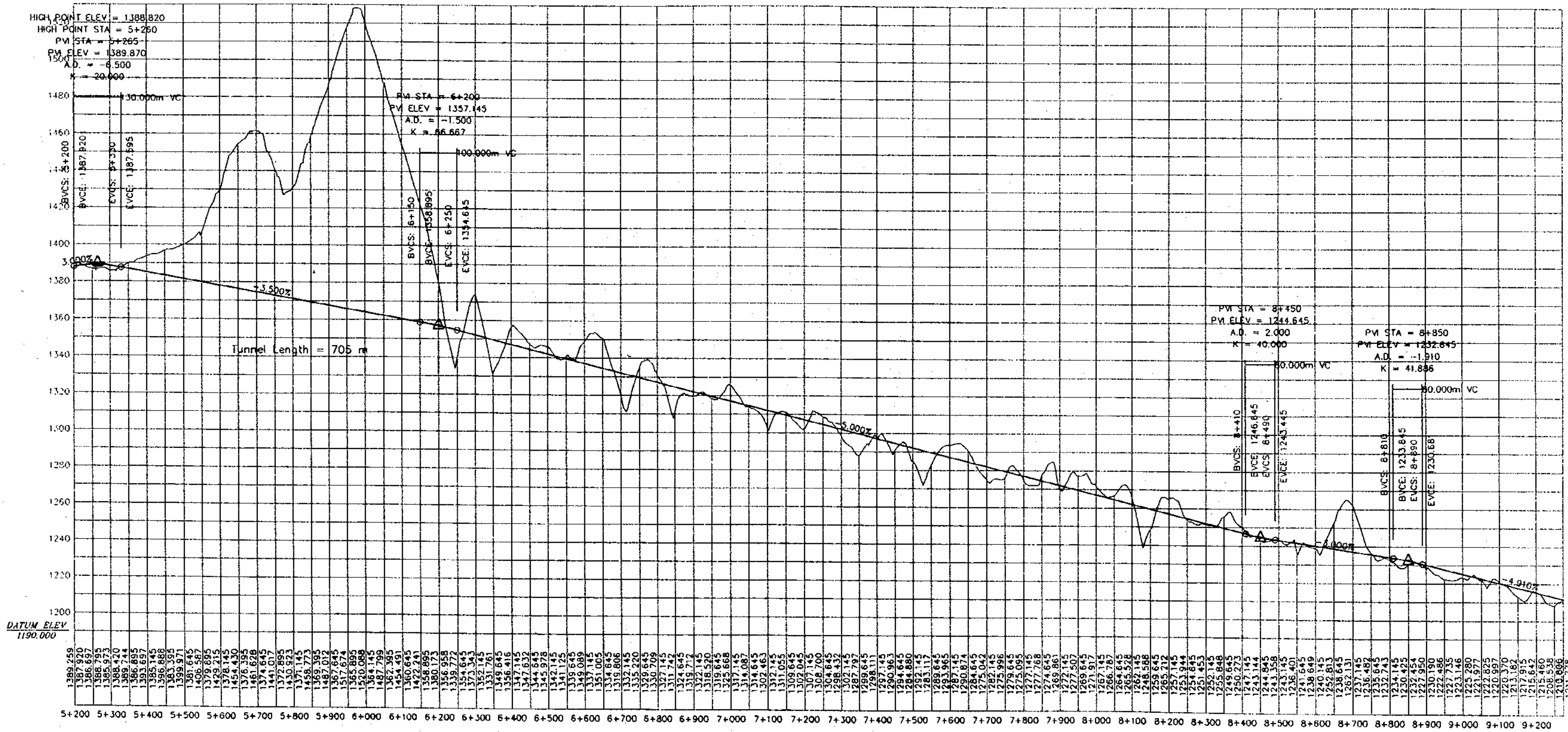

Figure 11.4 Profile of Final Tunnel Alignment C5
Scale 1:12,500

The only demerit is that the total length of tunnel itself is increased from 500m mentioned in the Optimum Route to a length of 700m that will eventually increase the total cost of the tunnel construction from the one estimated in the Optimum Route.

It is thus necessary to quantify and compare the increase in construction cost due to increase in length of tunnel and the decrease in construction cost due to shortening of total road length and other factors mentioned above. A rough estimate of the major work items is given in Table 11.1.

The estimate is based on the unit cost used during Interim Report and the cost of alternative C5 is simply derived from the ratio of road or tunnel length. In fact the construction cost of road per kilometer in Alternative C5 will be lesser due to favorable terrain conditions. The unit cost of the tunnel itself is less in case of 700m option since the geological conditions are relatively better along this tunnel route.

Table 11.1 Comparison of Construction Cost

Unit: NRs

Work Items	Alternatives		
	C2	C4	C5
Earthwork	149,100,000	144,400,000	120,300,000
Pavement	121,200,000	117,400,000	97,800,000
Slope Protection	159,900,000	154,800,000	129,000,000
Landslide Countermeasure	35,500,000	24,800,000	0
Cross Drainages	33,200,000	32,100,000	28,600,000
Bridge	157,900,000	142,200,000	68,100,000
Tunnel	559,100,000	503,200,000	656,000,000
Total	**1,215,900,000**	**1,118,900,000**	**1,099,800,000**

The above result shows that the total construction cost is almost same (marginally least in alternative C5) in all the alternatives and it is concluded that Alternative C5 with a tunnel length of 700m is better in terms of technical, financial, and economical viewpoints.

11.5 Longer Tunnel More Favorable?

The above result causes some curiosity whether further increase in tunnel length will give similar result providing more favourable project conditions or not. To answer this another alternative with much longer tunnel length in the same vicinity was also studied and the road alignment was also fixed for this alternative.

The horizontal alignment and the vertical profile are given in Figure 11.5 and the alternative is called C6.

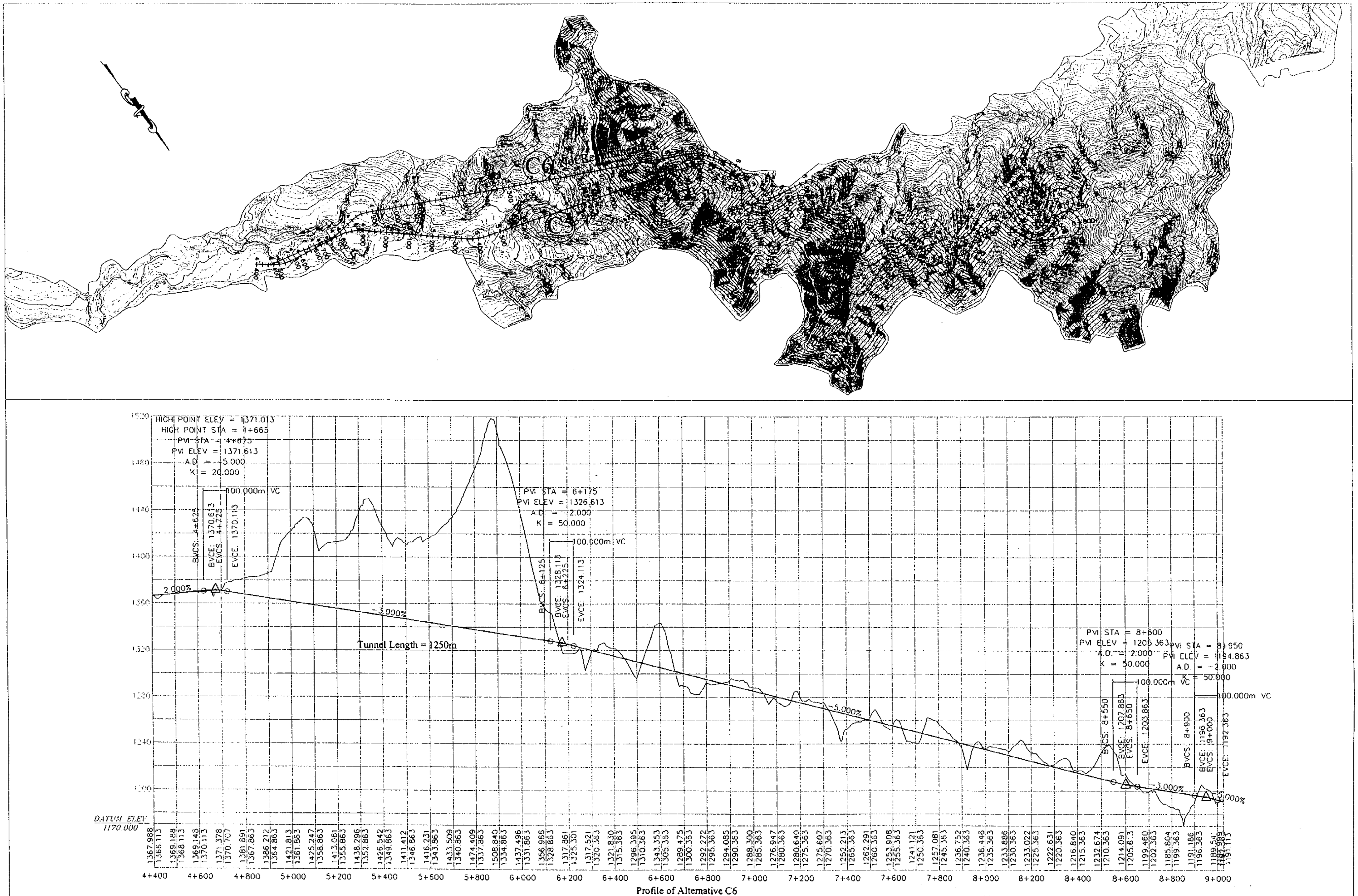

Figure 11.5 Another Long Tunnel C6 (Not Recommended)

Scale 1:15,000

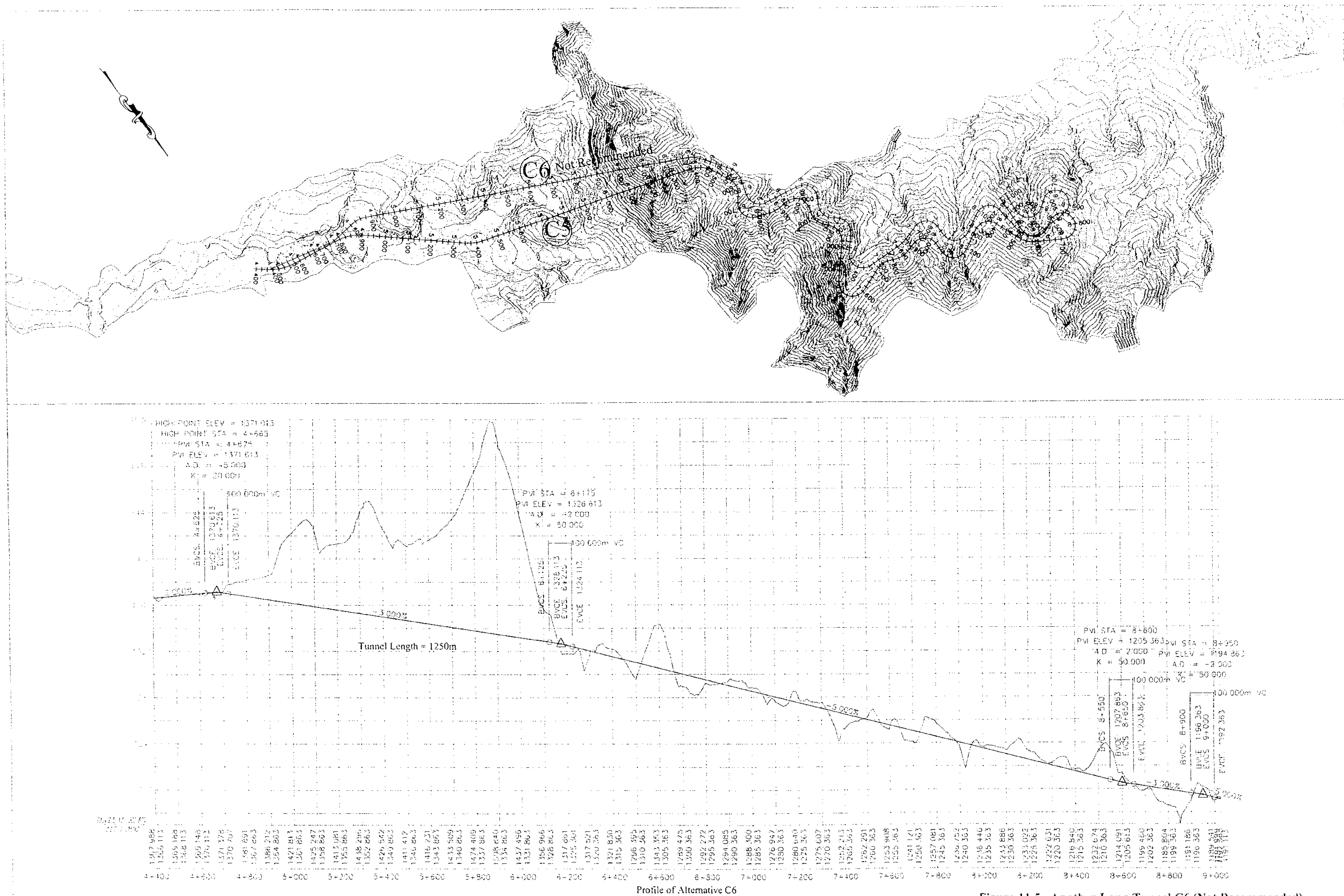

Figure 11.5 Another Long Tunnel C6 (Not Recommended)

Scale 1:15,000

The total length of the tunnel is about 1250m, if the formation height of tunnel is kept such that the height of cut at the tunnel portal (Kathmandu side) is almost same as that of alternative C5. However, the decrease in total road length in the alternative C6 is only about 300m compared to that of alternative C5. This is because the road alignment after the tunnel portal of Naubise side follows almost the same terrain as that of alternative C6. The location of first hairpin bend is at a similar location, but is at relatively difficult terrain due to excessive lowering of the formation height. Thus increasing the tunnel length to 1250m will require additional construction cost of approximately 600 million Nepalese Rupees. Besides, the longer tunnel length will require additional costs for installation of ventilation system and the maintenance cost will be increased drastically.

From these studies, it has been concluded that the tunnel length of 700m, the location and the formation height as given in the drawings of alternative C5, produces the optimum road length resulting in optimum cost and benefits from the Project.

CHAPTER 12 PRELIMINARY DESIGN

12.1 General

The alternative route study, and the selection of optimum route thereafter, was based on a topographic map of 1:10,000 (prepared from existing 1:25,000) and the digital terrain model prepared from it. After the optimum route was established, detailed survey works were carried out for the entire length of the Project Road. Survey was done at least 50m on either side of the centerline. A wider band was surveyed at locations where there is possibility of change in alignment such as, location of hairpin bends and near stream and river crossings. The accuracy of the survey was at least 1:2,000 scale and the survey was carried out using total stations.

The traverse survey was conducted from the GPS control points and concrete monuments were established before starting the triangulation works. The spot heights were plotted in computers with 3-dimensional information and the digital terrain model was then created after inputting other topographic details.

The preliminary design was conducted based on the digital terrain model prepared from the survey and the topographic map obtained from this model.

12.2 Highway Design

12.2.1 Alignment study

The finalization of horizontal and vertical alignment is done in the following steps:

i) Initially, the optimum route alignment was adjusted based on the detailed topographical map.

ii) Detailed field survey was conducted to check the adjusted alignment, section by section. Control points, if any exist, were noted and necessary modifications were marked in the field.

iii) Further necessary adjustments in the horizontal and vertical alignments were made based on the field investigation.

iv) The alignment for the whole project length was defined and fine-tuning of horizontal and vertical alignments were made after checking all cross sectional data. The final alignment was thus fixed.

Initial adjustment of alignment and field investigation was done based on the progress of the topographic survey and not the whole alignment at one time. So, the discussion will be done section by section, which may be different than the defined sections of A through F in the alternative route study.

The following notations are used to name the alignments for discussion:

FINL - The final alignment in this report

OPTM - The optimum route defined in alternative route study (the optimum route does not mean the optimum alignment or final alignment)

Other abbreviations as Aa, Ab, or Ba, Bb are used for other alignments studied during modifications. **The stations used in this discussion are for Final Alignment unless otherwise stated specifically.**

Section from STA.0+000 to STA.0+900

Basically, three different routes (Aa, Ab, and Ac) as given in Figure 12.1, were studied in this section. The OPTM route crosses Manamati River twice due to the difference between detailed survey and the 1:25,000 scale topographic maps.

Alternative Aa, which is the southernmost alternative, starts close to the existing bridge over Manamati River at the Ring Road. This alignment follows the Manamati riverbank. This alignment was screened out mainly because the construction of intersection of the Project Road with Ring Road is difficult due to the presence of the existing bridge at the Ring Road. Besides, protection works against river flow will be required all along the route, which will increase construction cost.

The second alternative, Ab, starts about 200m north of alternative Aa and follows the same alignment as that of Aa after a length of about 400m from the beginning. In the beginning section of 400m, the alignment is in a flood prone area. So, the construction of the alignment in this section will affect the flooding condition in the area between the road and the Manamati River.

The high water level of the Manamati River in this section was surveyed based on local interviews. It was also checked from hydrological study. The area of flooding is given in Figure 12.1. To avoid the flood prone area, the alignment of OPTM was selected and was adjusted to produce the final FINL alignment up to STA.0+900.

Section from STA.0+900 to STA.1+800

Basically, three alternatives in this section were studied, one that follows nearly the OPTM alignment to cross the river around STA.1+300 but modified for new detailed survey data (Ba), the other passing from south of the existing road (Bb), and the third the FINL alignment. The alignments are given in Figure 12.1.

One of the control points in this section is the housing area from STA.1+400 to STA.1+600. The road in the two northern alternatives divides the community into two sides and the profile grade is lower than the existing ground, which may cause some social impacts to the community. Alternative Ba requires more houses to be demolished if considered within the ROW. Alternative Bb also affects more houses along the existing road. After consultation with DOR officials, the final alignment of FINL was selected, with the road profile grade lowered as much as possible. The length of the bridge is also least in this alternative.

Section from STA.1+800 to STA.3+800

The alignment in this section basically follows that of OPTM alignment with slight modifications for adjustment of circular curves. The slope failure area from STA.3+000 to STA.3+200 is one of the control points. The alignment is shifted outside towards the river so as not to pass through the foot of the failure and to create enough pockets against falling debris. River diversion work is necessary at this location, as shown in Figure 12.2.

The location of Ghatte Bridge is another control point in this section. The alignment would have been fixed to follow the existing road otherwise, from STA.3+400 to STA.3+600.

Section from STA.3+800 to Kathmandu Side Tunnel Portal

The alignment in the stretch was modified from the OPTM alignment based on the detailed survey. The alignment from STA.4+900 to STA.5+200 would have been shifted towards mountainside (alignment Bc) to avoid passing through the river, but very large cutting will be required to do this. So the alignment was shifted towards the riverside with river diversion works, as shown in Figure 12.3.

Other control point in this stretch is the stream crossing at STA.5+300. This stream crossing also controls the profile gradient inside the tunnel. The formation height of the tunnel at Naubise side is controlled by the location of the hairpin bends (and vice versa). The profile gradient in the tunnel was fixed to provide enough clearance at the stream crossing of STA.5+300. River diversion works are necessary at this location also. The detail is given in the drawings of plan and profile in other volumes of the report.

Section from Kathmandu Side Tunnel Portal to STA.14+000

The alignment in this stretch was modified from the OPTM alignment based on the location and formation height of the tunnel, as discussed in Chapter 11. The location of the first hairpin bend changed compared to the location in OPTM alignment, as given in Figure 12.4. The rest of the alignment is governed by the maximum profile grade of 5% and a maximum of 3% at the hairpin bend. The alignment is also controlled by the river along STA.14+000, where the profile cannot be raised much.

Section from STA.14+000 to STA.16+200

The alignment from STA.14+000 to the end was basically fixed for design speed of 60 km/h, except at difficult locations like stream crossings where the design speed is reduced to 50 km/h. The alignments are given in Figures 12.5 through 12.8.

The OPTM alignment in this stretch was modified based on the topographic map of the detailed survey. Alternative Ea was fixed mainly to reduce the total curvature and to apply radius of at least 90m, which is the absolute minimum for design speed of 50km/h. The alignment was checked in the field and the final alignment was selected.

The river flowing along with the alignment after STA.14+000 is one of the control points in this section. The final alignment was shifted to avoid this river. Other control points in this section are the crossing over Bhalu River and Chilauni River. The alignment near Badri Tar (STA.15+700) is shifted to avoid the houses and cross the river from behind such that there is a balance of cut and fill.

Section from STA.16+200 to STA.18+300

Alternative Ea in this section was also fixed initially to reduce the total curvature. This alternative alignment was checked in the field mainly at stream crossings. Crossing over Rupse river is one of the main control points in this section. Utilizing the existing road was considered as far as possible. The final alignment FINL was fixed to keep balance in earthworks and to minimize lengths of stream crossings.

Section from STA.18+300 to STA.20+700

The main control points in this section are the stream crossings over Dhobi Khola 1 and Dhobi Khola 2 at STA.19+300 and STA.19+800, respectively. Initially, alternative Ea was fixed shifting the OPTM alignment towards valley side. After checking the alignment in the field, it was concluded to shift the alignment towards the hillside to reduce the length of the bridges.

Section from STA.20+700 to the End STA.21+355

The OPTM alignment before the approach of bridge over Mahesh Khola follows the existing road. The profile grade at this section is considerably lower than the existing ground height, which is governed by the profile grade of the bridge over Mahesh Khola. This situation will require large cut on the left side hill. So the alignment was shifted to the right. A massive dormant landslide exists at the northern side and care was taken to avoid cutting at this section.

The end point of the Project Road was shifted a little east than in OPTM alignment because there exists a bridge on Prithvi Highway to the west that will be affected by the layout of the intersection, otherwise.

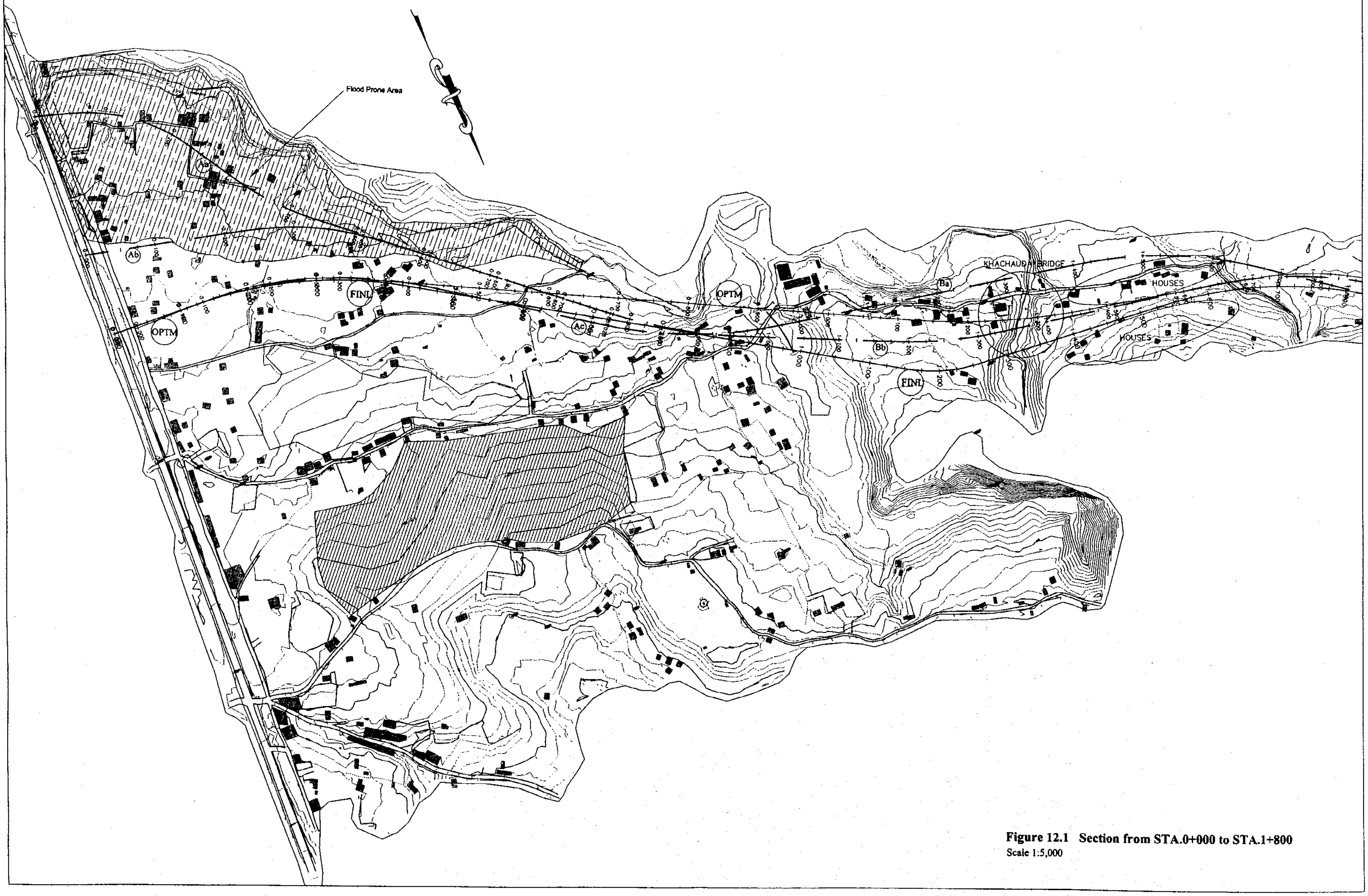

Figure 12.1 Section from STA.0+000 to STA.1+800
Scale 1:5,000

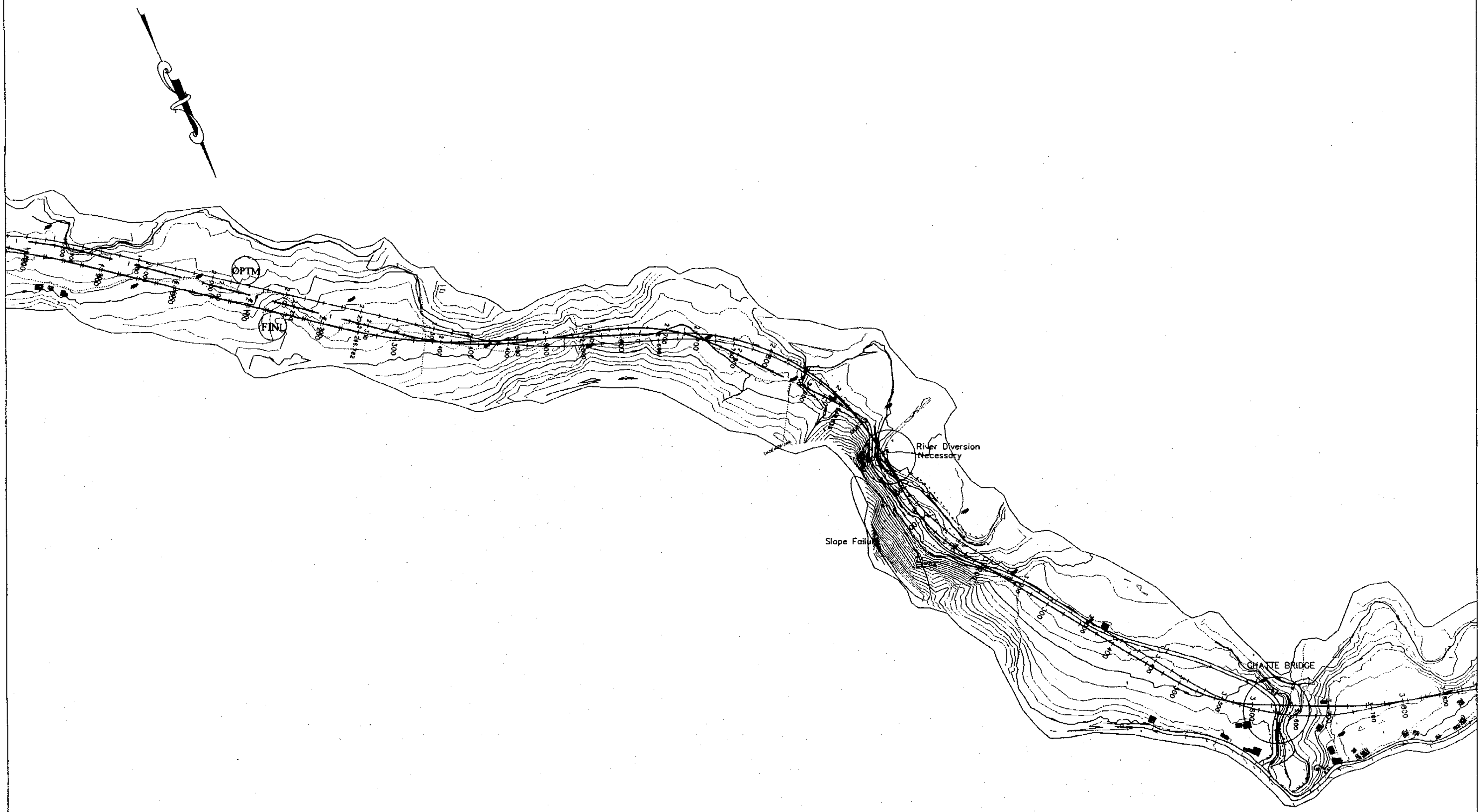

Figure 12.2 Section from STA.1+800 to STA.3+800
Scale 1:5,000

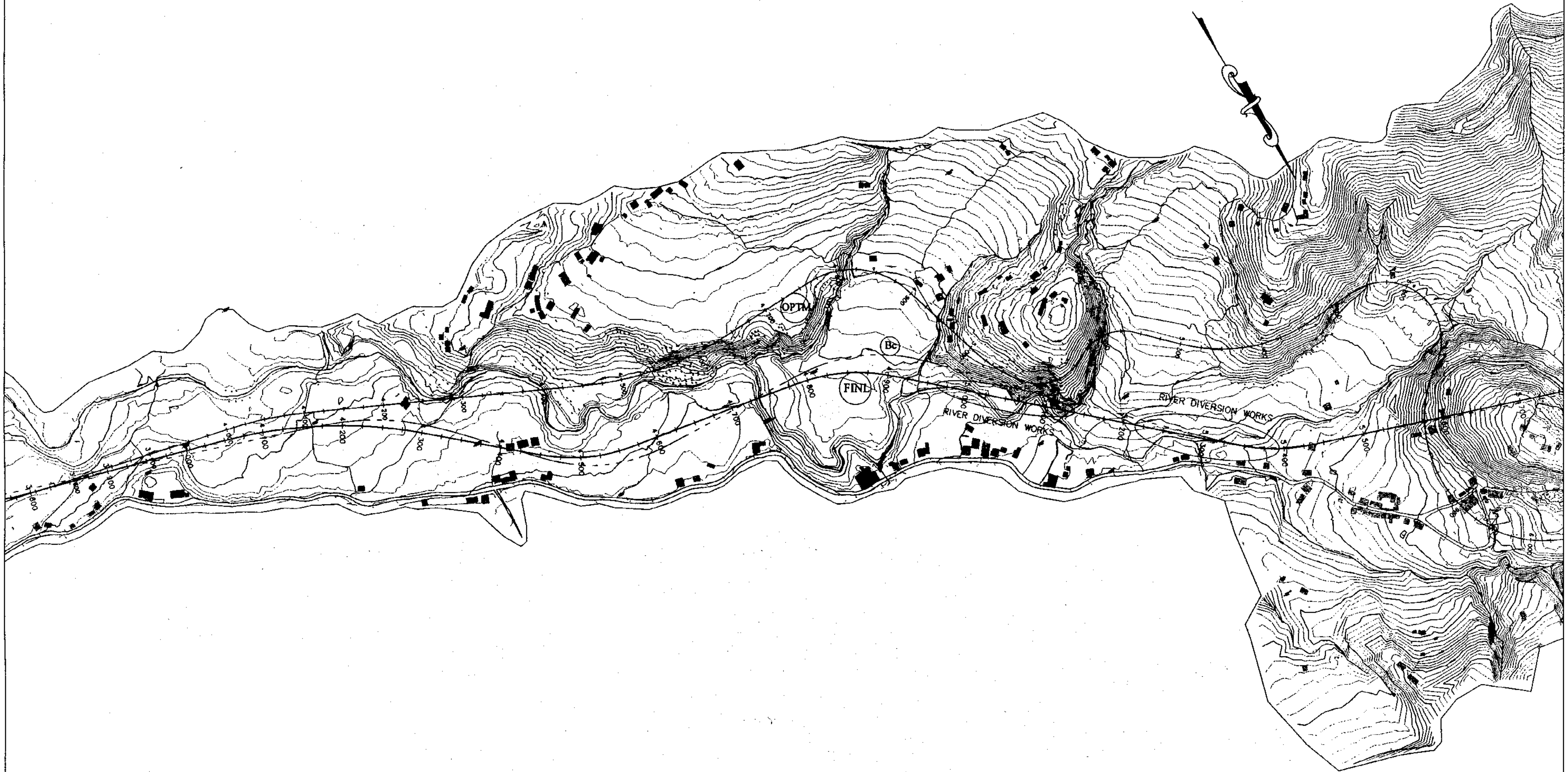

Figure 12.3 Section from STA.3+800 to Kathmandu Side Tunnel Portal
Scale 1:5,000

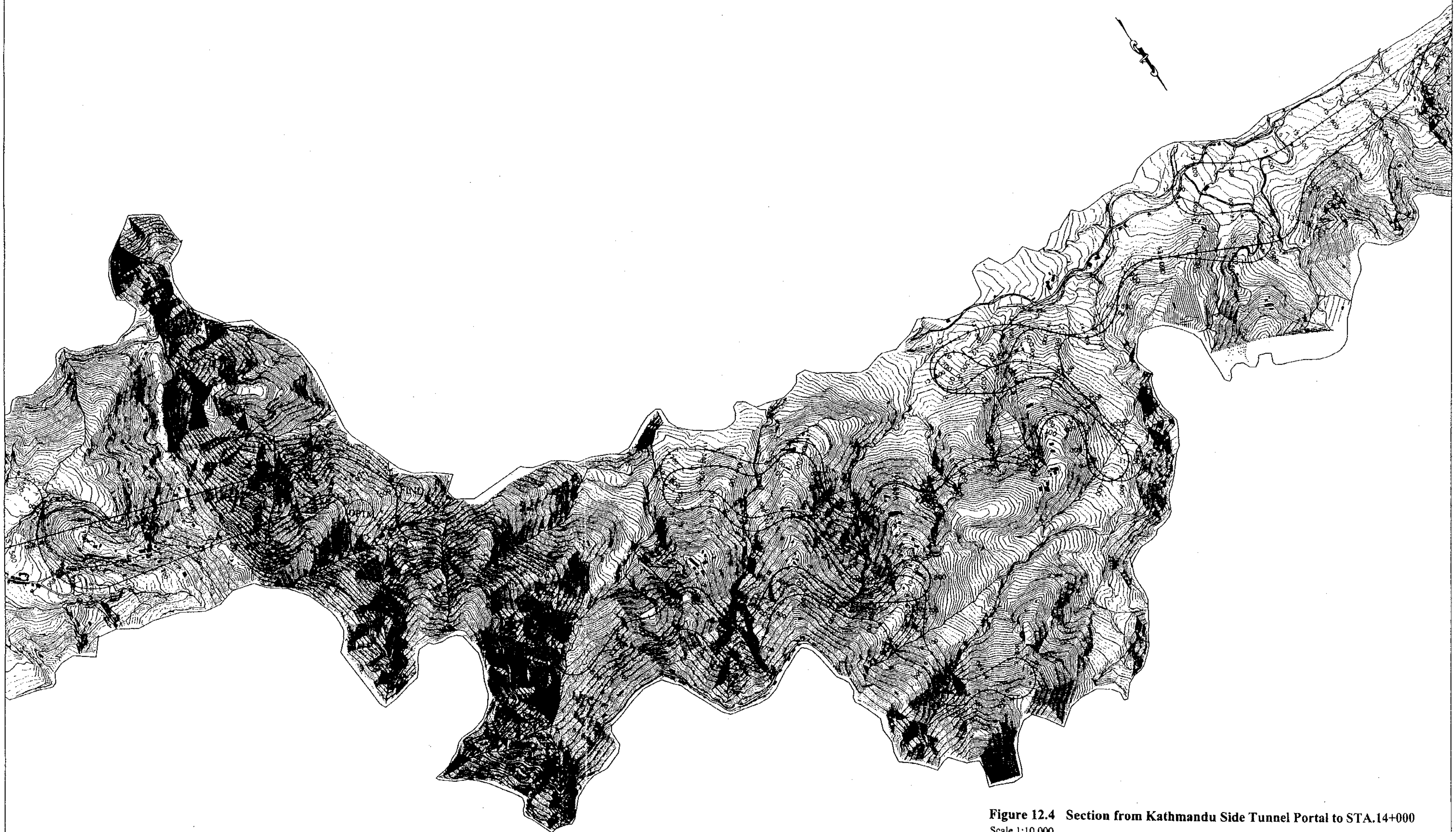

Figure 12.4 Section from Kathmandu Side Tunnel Portal to STA.14+000
Scale 1:10,000

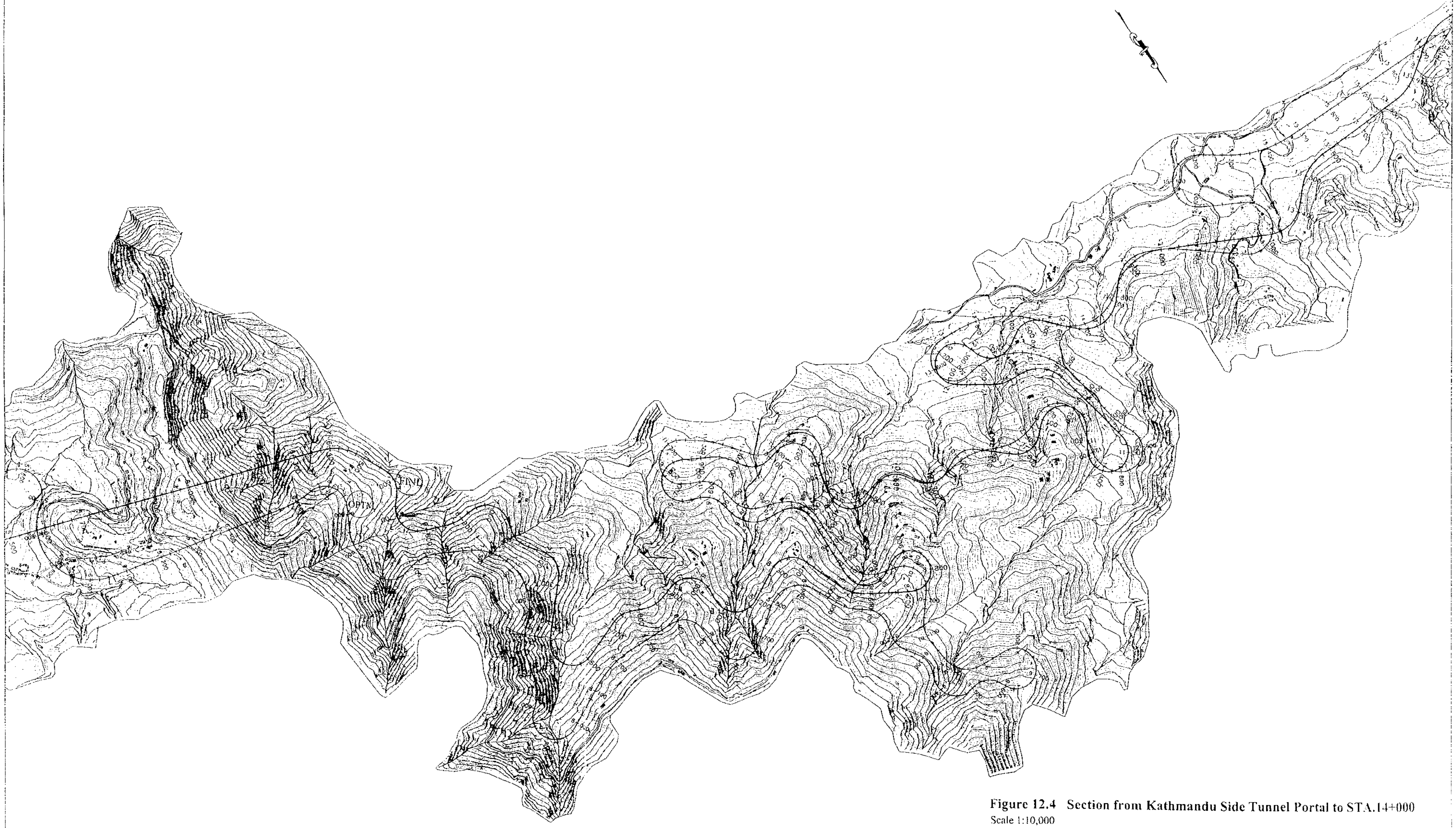

Figure 12.4 Section from Kathmandu Side Tunnel Portal to STA.14+000
Scale 1:10,000

Figure 12.5 Section from STA.14+000 to STA.16+200
Scale 1:5,000

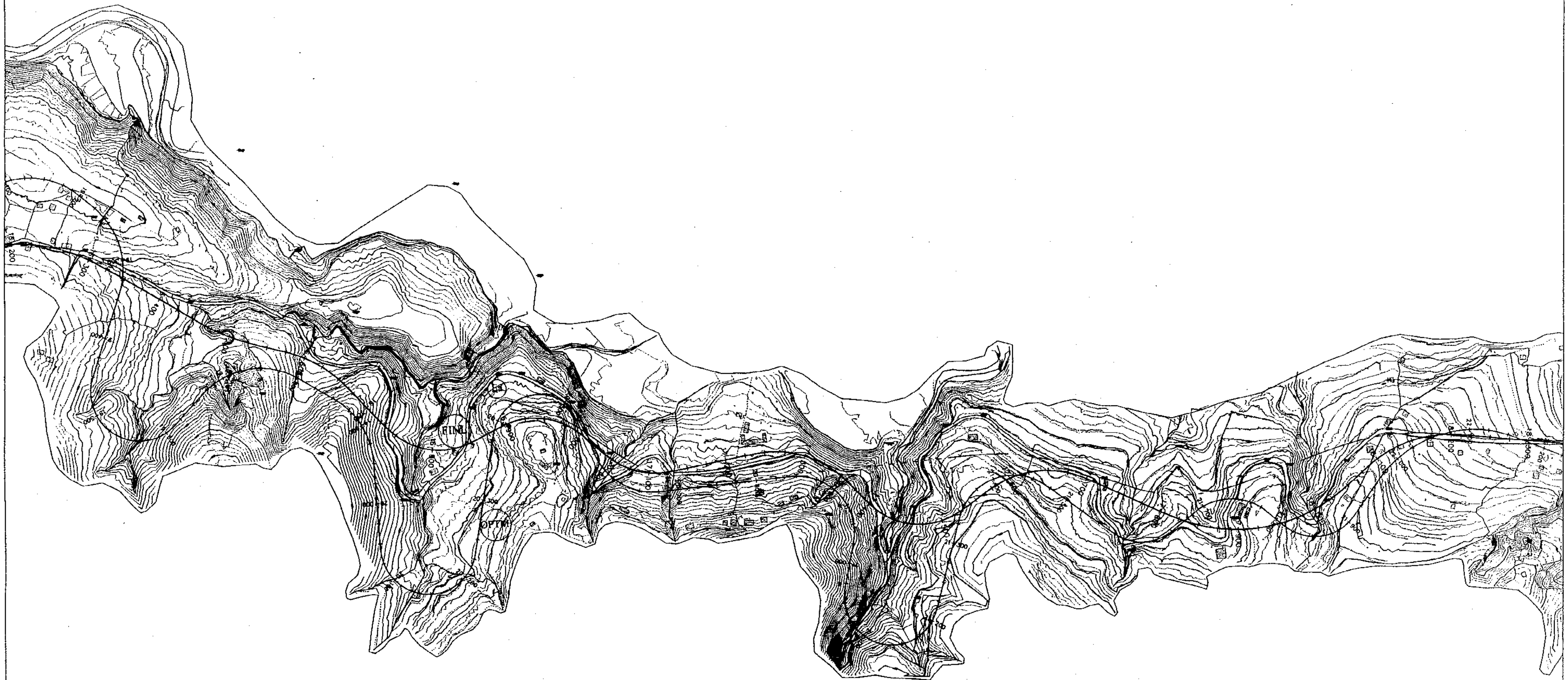

Figure 12.6 Section from STA.16+200 to STA.18+300
Scale 1:5,000

Figure 12.7 Section from STA.18+300 to STA.20+700
Scale 1:5,000

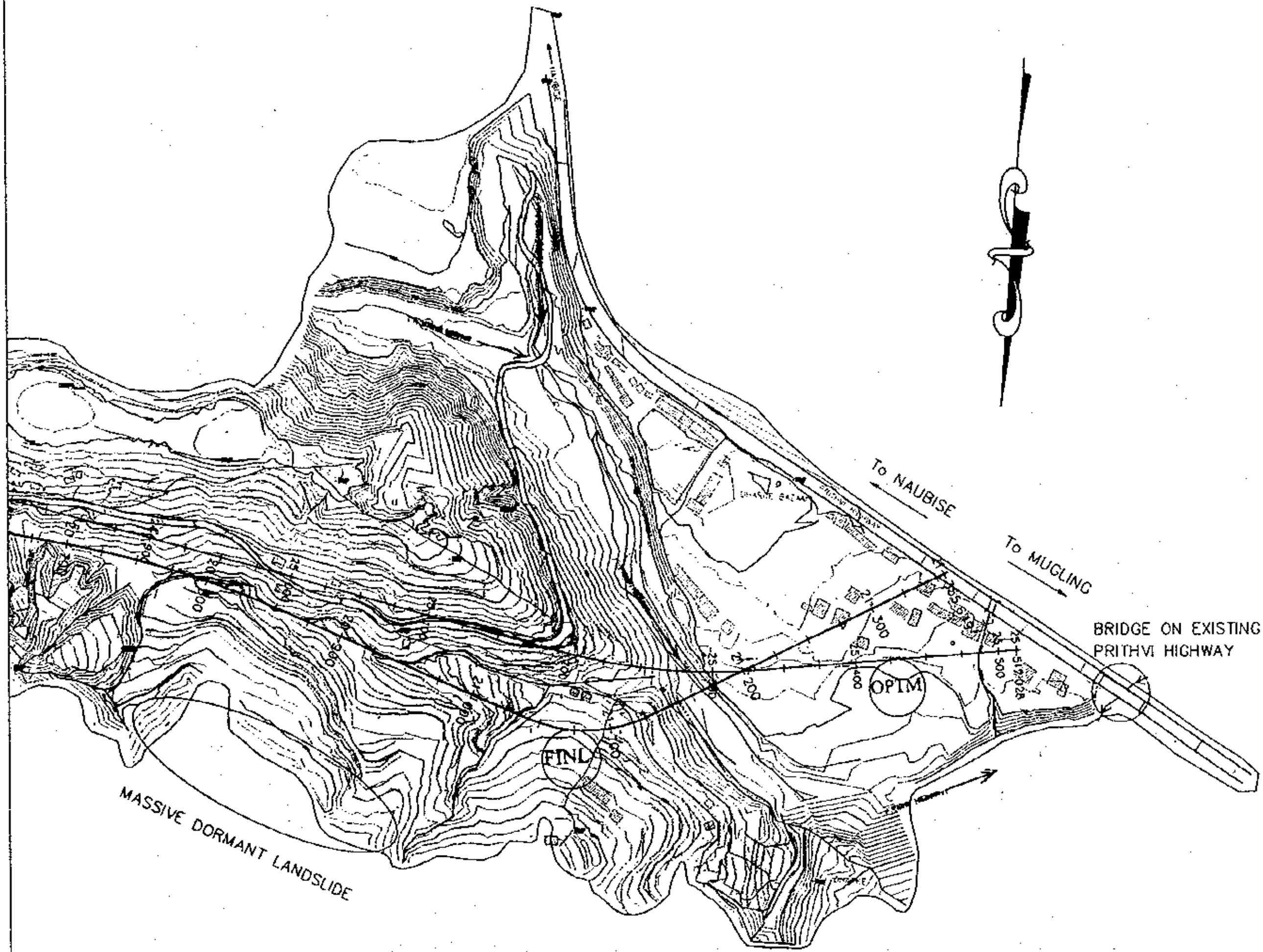

Figure 12.8 Section from STA.20+700 to End STA.21+355
Scale 1:5,000

12.2.2 Intersections

Two major intersections have been designed, one at the beginning point where the Project Road intersects with the Ring Road and the other at the end point where the Project Road intersects with the existing Prithvi Highway.

The intersection angle at Ring Road is almost at a right angle. Installation of a traffic signal is proposed at this intersection, which can be classified as an urban intersection. Turning lanes have been provided and sidewalks are also proposed in the vicinity of the intersection.

Installation of a traffic signal at present is not required at the intersection of Dharke because the turning volumes are low. The intersection is designed considering the Project Road as the major road. The length from the end of Dharke Bridge to the end point is designed with four lanes. This is to facilitate parking of the heavy vehicles on the street around the intersection, before entering the Project Road.

12.2.3 Slope protection

Slope gradient design in road cross section is an important factor since it affects the occurrence of road disaster as well as environmental aspects. As such, proper road protection works is expected to reduce the life cycle cost of road in the long-term.

The Study Team investigated the existing cutting slopes along the Trivuban Highway which has similar geological and landform conditions as that of the Project Road. The slope gradients, failure and erosion were investigated during the survey works. It was found that as much as 78% of the slopes between Dharke and Nagdhunga have been eroded and failure can be observed. It was also observed that about 60% of the erosion and the cause of failure is due to poor or no drainage system in the slope itself. This indicates that a good drainage system in the slope is as important as the gradient of slope itself in the design of slope.

1) Cutting slope gradient

The standard gradient for the cutting slope in the Project is given in Table 12.1. This standard was considered based on the results of slope stability survey along Trivuban Highway, mentioned above, and on the standard design given by JRA (Japan Road Association). High cutting slopes should be designed with berms of one-meter width at every 7m interval of cut height. Any structure like stone masonry wall is recommended on the lowest step of the cut slope. This is in consideration to the long-term slope slipping stress.

Table 12.1 Standard Slope Gradient for Cutting Slope

Geology	H<5.0m	H<7.0m	H>7.0m H<14.0m	H>14.0m H<21.0m	H>21m
Detritus	1:0.8	1:1.0	>1:1.2	-	-
Terrace sediment	1:0.8	1:1.0	>1:1.2	-	-
Red Soil	-	1:0.8	>1:1.0	-	-
Weathered Phyllite	-	1:0.8	1:1.0	-	
Sound Phyllite	-	1:0.5	1:0.8	1:1.0	-

2) Embankment slope gradient

Stability of embankment slope generally depends on the filling material and the slope gradient. In this Project, the embankment material is mainly derived from the excavated material from hillside. The standard gradient for the embankment slope is given in Table 12.2. A berm of 1.0m width should be provided every 5m height interval. Additionally, a berm of 2.0 to 3.0m width should be provided in case of embankment height greater than 15m for stability as well as for maintenance purposes. For high embankments, protection of toe of embankment by either concrete wall or gabion or other structures is recommended depending on landforms.

Table 12.2 Standard Slope Gradient for Embankment Slope

Height	H<15.0m	H>15.0m
Gradient	1:1.5	1:1.8

3) Other facilities for the slope design

As mentioned earlier, the existing road of Trivuban Highway, in the section from Nagdhunga to Dharke lacks proper drainage system on and around the cutting slopes. This condition promotes concentration of surface run-off water on the slopes. The concentration of water induces slope erosion, eventually causing slope failures. In order to counteract this mechanism of slope failure, proper drainage system on and around slopes should be provided along with vegetation on slopes, as slope protection measure.

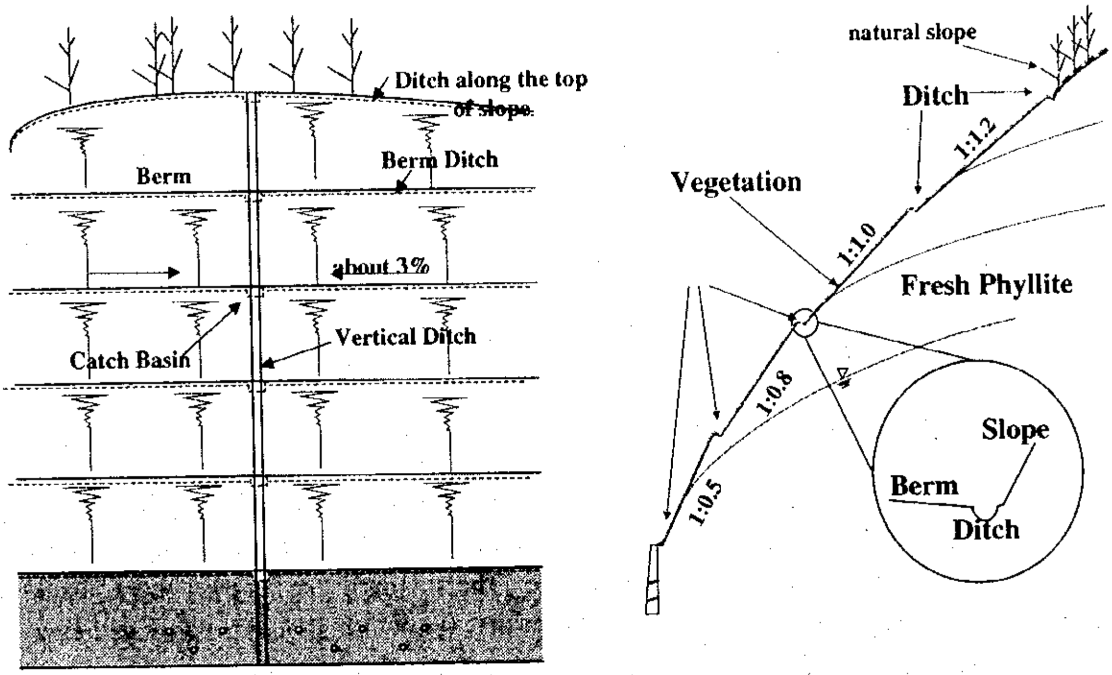

Figure 12.9 Drainage System on Cutting Slope

12.2.4 Drainage structures

One of the determining factors in selecting the size of the side ditch was the available width for its installation. In the mountainous and steep area, it is not desirable to change the width of the ditch from section to section which will cause additional earthworks and retaining structures. The width of the ditch in this Study was hence fixed at 1.0m. However, other widths may also be studied during the detailed design stage if required.

The design of the side ditch is commenced through the following steps:

1) Catchment area was calculated between two successive major cross drainage (culverts or bridges), the water from which will run-off on the road surface. The discharge volume is calculated from the following expression:

$$Q = f.I.Ac / 360$$

Where,

Q = Discharge, m^3/sec
f = Runoff Coefficient
I = Average rainfall intensity (5 years return period)
= 108.5mm/hr
Ac = Catchment area, km^2

2) The capacity of the side ditch is calculated from the Manning's equation as follows:

$$Q_d = \frac{A \times R^{2/3} \times S^{1/2}}{n}$$

Where,

Qd	=	Capacity of the ditch
A	=	Flow area of ditch (based on 1m width)
R	=	Hydraulic depth
S	=	Gradient of ditch (same as road profile gradient)
n	=	Manning's Coefficient for the ditch material

3) The capacity of the ditch was checked against the discharge from the catchment area. Additional cross drainages were introduced where the capacity of the ditch was exceeded.

In addition to this, cross drainages were also designed at places where the road alignment crosses existing canals for irrigation purposes. The length of canals to be relocated was also calculated based on field survey as well as from the detailed topographic survey. Where the alignment passes through paddy fields on both sides, for example in Sitapaila and Ramkot area, additional cross drainages will be required not to affect the irrigation system in the paddy field. The exact number required should be investigated during detailed design stage.

The treatment of outlet water from the cross drainages in the area of paddy field should also be investigated during detailed design stage, such that the outlet water does not affect the agricultural land.

12.2.5 Pavement design

The values of equivalent single axle load (ESAL) for different vehicle types were obtained from the report of "Axle Loading on the Strategic Road Network and Heavy Vehicle Management" published by DOR in January 1999.

The national average value of ESAL factor for all trucks was 4.55 as given in the report and has been directly applied for the Project also. The report does not give ESAL factor for other vehicle types and these were thus calculated from the data on the weighted average of rear axle loads, given in the same report. The national average values were used for this case also. The ESAL factor for each axle was calculated as the 4.55th power to the ratio of surveyed axle load (in tonnes) divided by 8.2, that is the value of standard axle load in tonnes. The ESAL factor of the vehicle is the total of ESAL factors of each axle of the vehicle. The data on passenger cars were not available and a value of 0.001 was assumed. Passenger cars virtually have no effect in the design of pavement structures.

Following values of ESAL factor have been used for the Project Road:

Table 12.3 ESAL Factors for Different Vehicle Types

Vehicle Type	PCar	MiniBus	Bus	Mini Truck	All Trucks
ESAL Factor	0.001	0.01	0.30	0.15	4.55

Traffic volume for different types of vehicles was obtained from the traffic analysis, mentioned in chapter 7. The forecast traffic volume for the Project Road with and without the Kathmandu-Terai direct link was considered, since there is a possibility of Kathmandu-Terai direct link project to be implemented in near future. The details have been given in chapter 7.

The design life of pavement is taken as 15 years and the estimated traffic volume for different vehicle types for each year were multiplied by corresponding ESAL factors and were summed up to give the total design ESAL value for the Project.

The design ESAL value was estimated to be 25 million and 27 million with and without the implementation of Kathmandu-Terai direct link, respectively.

Following material properties were considered for various pavement layers:

- Design CBR of the subgrade is taken as ≥7%. This is the average CBR value of the subgrade material within a depth of 1m. Selected subgrade material should be used to achieve this design CBR value.

- Design CBR value of the subbase course material is taken as ≥30%. The excavated material from the hard rock cutting may also be mixed in proper portion to achieve this CBR value. However, the gradation of material with different sieve sizes should meet to the requirements of subbase course material.

- Design CBR value of the base course material is taken as ≥80%. The material with proper gradation from the crusher plant should be used to achieve the design CBR value.

For the conditions as given in the pavement design standards, the thickness of various pavement layers were calculated based on the AASHTO method of flexible pavement design. The calculated thickness of different pavement layers is given in Table 12.4. The design thickness of the pavement layers are taken as 30cm, 30cm, 5cm, and 5cm for subbase, base, asphalt concrete binder and asphalt concrete surface courses, respectively, with a total thickness of 70cm.

Table 12.4 Calculated Thickness of Pavement Layers

Total ESAL	Design Thickness (cm)				
(millions)	Subbase	Base	AC Binder	AC Surface	Total
25	30	29	5	5	69
27	30	30	5	5	70

12.2.6 Other incidentals

The guardrails, pavement markings, traffic signs and other road furniture will be considered during detailed design stage.

Along the Ring Road, trucks are commonly seen parked at the roadsides. The loading and unloading of trucks are also being done at the roadsides due to the lack of a truck terminal. This situation seriously reduces road capacity and safety. The Study Team recommends utilizing the area at the beginning of the Project Road near Manamati River as the location of a truck terminal.

From the study of high water level, the Study Team concluded that this area is prone to flooding due to narrow opening of the Manamati Bridge on the Ring Road and poorly managed river thereafter. After the construction of the Project Road, the land price at this location is expected to rise. It is recommended that this area should be acquired before the construction of the Project Road and necessary steps should be taken in advance for the construction of the truck terminal. The approximate area for the construction of the truck terminal is given in Figure 12.10. The embankment material for the construction of the truck terminal may be obtained from the surplus amount of soil in the Project Road.

12.3 Bridge & Culvert Design

1) General

Along the optimum route, 10 bridges and 53 culverts are planned as the river crossing structures. The type of structure and size is decided from the hydrological, geographical, and geological condition. The location, flood discharge, and type of each structure are summarized in Table 12.5.

Among ten bridges, three bridges exist in the Kathmandu Valley area (from Ring road to Bindhunga), one is located in mountainous area and the remaining six are in Mahesh Khola plain area.

Kathmandu Valley is relatively flat and the road alignment is formed in a straight line or with a gentle curve. The geometry of the Project Road at all bridge sites in the valley has straight configuration. On the other hand, mountainous area and Mahesh Khola plain area have steep slope and undulation. In these areas most bridges are planned to be curved bridges for shortening the bridge length and keeping favourable road alignment. Five of the ten bridges are curved bridges.

Thulo Khola Bridge is located at the most steep mountainous area in this Project. The valley that the bridge crosses over has high potential of debris flow. For the design of the bridge, it is most important to keep enough vertical clearance and river width against debris flow.

Dharke Bridge crosses Mahesh Khola where the river has high potential of debris flow and experienced serious damage in 1993. The debris flow reached near the proposed bridge site. However, the river slope around the proposed site is so gentle that the energy of debris flow is already reduced at the proposed location. Therefore, for the design of bridge, no debris flow but mudflow should be considered.

2) Vertical Clearance

Most bridges except Dharke Bridge have catchment area less than 3 km^2 and flood discharges are less than $80m^3/s$. Thulo Khola should be designed against debris flow and Dharke Bridge against mudflow.

Except Thulo Khola Bridge and Dharke Bridge, the vertical clearance is decided from H.W.L (High Water Level) plus freeboard. If the peak velocity is more than 3m/sec, the energy level is also considered.

The vertical clearance for Thulo Khola Bridge is kept from the debris flow level, since the site of the bridge is in a debris flow prone area.

The site of Dharke Bridge is anticipated to be a passing area of the mudflow. For the calculation of the H.W.L. the flood discharge is used with the 20% surcharge considering the mudflow.

Vertical clearances should be kept at least to the figures shown in Table 12.6.

Table 12.5 List of Location of Bridges and Culverts

Struc. No.	Station	River Name	Catch. Area (sq km)	Flood Discharge (cu m)	Type of Structure
C-1	0 + 380		0.10	2.9	Pipe Culvert
C-2	1 + 10		0.33	9.6	Box Culvert
Br-1	1 + 292	Kachaudha Khola	1.68	32.6	Bridge
C-3	1 + 650		0.10	2.9	Pipe Culvert
C-4	2 + 850		0.09	2.6	Pipe Culvert
Br-2	3 + 648	Ghatte Khola	3.00	69.2	Bridge
Br-3	4 + 728	Tribeni Khola	2.55	73.5	Bridge
C-5	4 + 910		0.12	3.5	Box Culvert
C-6	5 + 130		0.23	6.7	Box Culvert
C-7	5 + 305	Tribeni Khola	0.34	9.8	Box Culvert
C-8	6 + 240		0.04	1.2	Pipe Culvert
C-9	6 + 340		0.02	0.6	Pipe Culvert
C-10	6 + 710		0.16	4.6	Box Culvert
C-11	6 + 850		0.04	1.2	Pipe Culvert
C-12	7 + 100		0.02	0.6	Pipe Culvert
Br-4	7 + 497	Thulo Khola	0.74	21.4	Bridge
C-13	7 + 825		0.03	0.9	Pipe Culvert
C-14	8 + 120		0.18	5.2	Box Culvert
C-15	8 + 550	Bokshi Khola	0.02	0.6	Pipe Culvert
C-16	9 + 70	Bokshi Khola	0.03	0.9	Pipe Culvert
C-17	9 + 490		0.25	7.2	Box Culvert
C-18	10 + 55		0.28	8.1	Box Culvert
C-19	10 + 335		0.02	0.6	Pipe Culvert
C-20	10 + 440	Bokshi Khola	0.08	2.3	Pipe Culvert
C-21	10 + 690		0.02	0.6	Pipe Culvert
C-22	10 + 750		0.01	0.3	Pipe Culvert
C-23	10 + 920		0.01	0.3	Pipe Culvert
C-24	11 + 20		0.01	0.3	Pipe Culvert
C-25	11 + 380		0.05	1.4	Pipe Culvert
C-26	11 + 560		0.06	1.7	Pipe Culvert
C-27	11 + 960	Badhan Khola	0.06	1.7	Pipe Culvert
C-28	12 + 380	Badhan Khola	0.08	2.3	Pipe Culvert
C-29	12 + 565		0.02	0.6	Pipe Culvert
Br-5	12 + 703	Ari Khola	2.69	77.5	Bridge
C-30	13 + 160	Archale Khola	0.32	9.3	Box Culvert
C-31	13 + 330	Chanpe Khola	1.19	34.4	Box Culvert
C-32	13 + 750		0.07	2.0	Pipe Culvert
C-33	14 + 345		0.64	18.5	Box Culvert
C-34	15 + 565		0.16	4.6	Box Culvert
C-35	16 + 810	Jungale Khola	0.28	8.1	Box Culvert
Br-6	16 + 129	Bhalu Khola	1.38	39.9	Bridge
C-36	16 + 270		0.07	2.0	Pipe Culvert
C-37	15 + 740	Chaulani Khola	0.02	0.6	Pipe Culvert
C-38	15 + 825		0.74	21.4	Box Culvert
C-39	16 + 470		0.15	4.3	Box Culvert
C-40	16 + 490		0.15	4.3	Box Culvert
C-41	16 + 505		0.15	4.3	Box Culvert
C-42	16 + 605		0.02	0.6	Pipe Culvert
C-43	16 + 780	Kumai Khola	0.36	10.4	Box Culvert
C-44	17 + 555		0.05	1.4	Pipe Culvert
C-45	17 + 130		0.03	0.9	Pipe Culvert
C-46	17 +320		0.01	0.3	Pipe Culvert
C-47	17 +350		0.01	0.3	Pipe Culvert
Br-7	17 +423	Rupse Khola	2.24	64.6	Bridge
C-48	17 +765	Angeri Kolsi	0.03	0.9	Pipe Culvert
C-49	17 +875		0.01	0.3	Pipe Culvert
C-50	18 +990	Kartike Kolsi	0.29	8.4	Box Culvert
C-51	18 +425		0.04	1.2	Pipe Culvert
C-52	18 +570		0.22	6.4	Box Culvert
C-53	19 +290		0.03	0.9	Pipe Culvert
Br-8	19 +310	Dhobi Khola 1	2.31	66.6	Bridge
C-54	19 +505		0.12	3.5	Box Culvert
Br-9	19 +820	Dhobi Khola 2	1.25	36.1	Bridge
C-55	20 +290		0.09	2.6	Pipe Culvert
C-56	20 +480		0.16	4.6	Box Culvert
C-57	21 +35		0.06	1.7	Pipe Culvert
Br-10	21 +136	Mahesh Khola	72.97	687.9	Bridge

Source: JICA Study Team

Table 12.6 Vertical Clearance

No.	River Name	Flood Discharge (cu m)	River Slope	Riverbed (EL. m)	H. W. L (EL. m)	Energy L (EL.m)	Freeboad (m)	EL. of Bottom Edge of Girder to be kept (m)
Br-1	Kachaudha Khola	32.6	0.02	1299	1300.7	1300.8	0.6	1301.4
Br-2	Ghatte Khola	69.2	0.01	1340.7	1344.8	1344.9	0.6	1345.5
Br-3	Tribeni Khola	73.5	0.01	1366	1369.3	1369.5	0.6	1370.1
Br-4	Thulo Khola	21.4	0.13	1275.5	1276.2	1276.6	0.6	1277.2
Br-5	Ari Khola	77.5	0.03	1047.8	1050.7	1051	0.6	1051.6
Br-6	Bhalu Khola	39.9	0.05	937	940	940.4	0.6	941.0
Br-7	Rupse Khola	64.6	0.07	860	862.3	862.9	0.6	863.5
Br-8	Dhobi Khola 1	66.6	0.05	829	832.2	832.7	0.6	833.3
Br-9	Dhobi Khola 2	36.1	0.1	829.3	831	831.6	0.6	832.2
Br-10	Mahesh Khola	687.9	0.01	776	783	785.2	0.8	786.0

Source: JICA Study Team

The elevation of each H.W.L except Dharke Bridge is calculated by Uniform flow Calculation and that of Dharke Bridge is by Non-uniform flow calculation.

3) Minimum Span Length

The minimum span length of each bridge is shown in Table 12.7.

Table 12.7 Minimum Span Length of each Bridge

Bridge Name	Minimum Span Length (m)
Thulo, Ari, Bhalu	12.5
Kachauda, Ghatte, Tribeni, Rupse, Dhobi 1, Dhobi 2	15.0
Dharke	23.5

Source: JICA Study Team

4) Selection of Bridge Type

The type of each bridge was determined according to the design criteria stipulated in Clause 8.4.4.

- Type of Foundation

Spread foundation is applied to all bridges, except Thule Khola Bridge, from geological and economical points of view. Cast-in-place well-type pile foundation is used for Thulo Khola Bridge, since the bridge is located on very steep slope and minimisation of excavation work is required.

- Type of Substructure

Inverse T type abutment and oval wall type pier is applied to all bridges due to economical reason.

- Type of Superstructure

Superstructure type of each span is proposed as follows,

Span Length (Ls)	Type of Superstructure
Ls < 18.5	RC Hollow Slab
18.5 < Ls	Steel Girder (I type or Box type)

RC Hollow Slab type is favourably employed for the maximisation of use of local material. Prestress concrete bridge is also considered to be applicable to a part of bridges which are propose to be steel bridge. However, because of inefficiency to fabricate special PC equipment for only a few bridges, constraint as the curved bridge and limitation of construction yards, the PC type bridge is not recommended in this Project.

Proposed type of all bridges, length and span arrangement is summarized in Table 12.8.

Table 12.8 Summary of Bridge Types and Length

No.	Station	River Name	Bridge Length (m)	Span Arrangement (m)	Type
Br-1	1 + 292 - 1 + 329	Kachaudha Khola	37.0	2@18.5	RC Hollow Slab
Br-2	3 + 648 - 3 + 682	Ghatte Khola	34.0	2@17	RC Hollow Slab
Br-3	4 + 728 - 4 + 756	Tribeni Khola	28.0	2@14	RC Hollow Slab
Br-4	7 + 497 - 7 + 558	Thulo Khola	61.0	18.0+25.0+18.0	RC Hollow Slab+Steel I Girder
Br-5	12 + 703 - 12 + 731	Ari Khola	28.0	2@14.0	RC Hollow Slab
Br-6	16 + 129 - 15 + 156	Bhalu Khola	27.0	27.0	Steel I Girder
Br-7	17 + 423 - 17 + 468	Rupse Khola	45.0	30.0+15.0	RC Hollow Slab+Steel I Girder
Br-8	19 + 310 - 19 + 339	Dhobi Khola 1	29.0	29.0	Steel I Girder
Br-9	19 + 820 - 19 + 855	Dhobi Khola 2	35.0	35.0	RC Hollow Slab+Steel I Girder
Br-10	21 + 136 - 21 + 186	Mahesh Khola	50.0	50.0	Steel Box Girder

Source: JICA Study Team

5) Culvert Design

For the culvert design, the following matters should be kept.

- The size of pipe culvert should be more than ø1.2m to make maintenance works easy.
- Pipe or box culverts should be designed with using concrete head wall, wing wall and scour protection.
- The allowable velocity range passing in culverts should be between 0.8 m/sec to and 3.0 m/sec to prevent sedimentation and to avoid scouring.
- Ten-year return period should be applied to culvert design.