CHAPTER 11 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

11.1 INTRODUCTION

To know general status of environmental and social conditions (ESC) around an infrastructure project, it is significant to realize appropriate benefits through the project. Target sites are mainly in hilly regions where elements of both environmental and social fields may be vulnerable. Therefore, it is required to investigate necessary information and to evaluate its possible impact in early stages of this Survey.

11.2 PURPOSE AND METHODOLOGY

The primary purpose of the ESC survey is to collect and confirm available and relevant information on the natural and social aspects of the project target areas including Section II (between Sindhuli Bazar and Khurkot). It is important to discuss the screening for the project based on the JICA's Guidelines for Environmental and Social Considerations (2010) (JICA Environmental Guidelines) before commencement of specific assistance for the project by Japanese ODA (Official Development Assistance). In addition to the general study on ESC, confirmation on existing information/data on ESC are collected prior to the estimated initial impact assessment in the future. Further study and confirmation on ESC based on JICA Environmental Guidelines shall be required when the project is discussed in a feasibility study level under JICA schemes. The information is collected through bibliographic (published material/document) surveys and interview surveys with targets, items, and methodologies as shown in Table 11.2-1.

Table 11.2-1 Purpose and Methodology of ESC

Purpose	Target	Items	Methodology
Collection and discussion of basic data, such as number of affected households, location of protected areas, etc., for improvement of the target roads	All sections, especially for the segment where road widening is difficult (Section II-Tunnel Area)	Areas required for land acquisition, number of affected households, protected areas, habitats of rare species, districts of indigenous people, possible dumping sites, etc.	- Walk-through survey of the project sites - Interview with local governmental representatives, organizations and other local resources - Existing reports (JICA's past surveys, DOR's F/S reports, etc.)
Collection and discussion of background data on ESC in Nepal such as legal framework, institutional framework, gap analysis between JICA Environmental Guidelines and domestic legal system, etc.	Section II and other sections	Land use, Natural environment, living areas of indigenous people, socio-economic situation, etc.	
Confirmation if the project will fall in "Sensitive Areas" defined in Appendix 3 of JICA Environmental Guidelines, or not.	Section II		

Source: JICA Survey Team

Field surveys were carried out in October and November. The first one was contracted out and was carried out by a local consultant under remote coordination with the Survey Team, as the scheduled visit of the Survey team member couldn`t realize following closure of the international airport due to surge in the cases

of Corona Virus. The second survey was conducted jointly by the team member and the local consultant. The dates, activities, surveyed locations, major activities conducted, items confirmed, and key resources are summarized in Table 11.2-2 and Table 11.2-3.

Table 11.2-2 Field Surveys

Date	Activity	Location	Major Activities / Items Confirmed
4-Oct	Meeting	DOR / BP Highway Project Office	・ ROW status, Current works carried out, Future Plans, Collection of passed reports and information
5-Oct	Meeting	Dhulikhel Municipality, Namobuddha Municipality	・ ROW situation and surrounding land-use status (not only along the existing road but also surrounding areas which covers alternative routes widely) ・ Distributions of indigenous people and socially venerable people such as refuges of quakes ・ Location of community forest (ask them location maps) ・ Consultation with Local Representatives
6-Oct	Field Observation	Section IV	
7-Oct	Field Observation	Section III	
8-Oct	Field Observation	Section II (Tunnel Section)	
9-Oct	Field Observation	Section I	
10-Oct	Meeting	Sindhuli Municipality	
8-10 Nov	Field Observation	All Sections	・ Natural and Social conditions along the existing road ・ Conditions around proposed tunnel portals of alternative plans (Section II) ・ Conditions around proposed alternative routes where the road widening is difficult (mainly in Section IV, III and I).

Source: JICA Survey Team

Table 11.2-3 Key Persons (Resource Persons) in the Field Surveys

No	Name of Person Consulted	Designation	Address
1.	Krishna Raj Dahal	Ward Chief Officer	Sunkoshi-5
2.	Owner of Aama Hotel	Local senior Resident	Sunkoshi-5
3.	Ram Chandra Acharya	Ward Chief Officer	Sunkoshi-3
4.	Owner of Karki Hotel	Local senior Resident	Namobuddha-7
5.	Damodar Adhikari	Local resident	Namobuddha-7
6.	Hari Krishna Shrestha	Local resident	Namobuddha-6
7.	Er. Ujjwal Aryal	Municipality Engineer	Namobuddha UM
8.	Dal Bahadur Lama	Mayor	Roshi RM
9.	Tara Prasad Gautam	Local resident	Roshi-7
10.	Ganesh Adhikari	Local resident	Roshi-7
11.	Ashok Kumar Shrestha	Mayor	Dhulikhel Municipalty
12.	Basanta Bbahadur Ranabhat	Ward Chief Officer	Dhulikhel-9
13.	Bishnu Dhital	Ward Chief Officer	Dhulikhel-11

Source:JICA Study Team

11.3 SITUATION OF ESC IN THE TARGET AREAS

11.3.1 Land Use

Land use along the existing Sindhuli Road is mainly categorized into the forest area, the river areas and the settlement areas with agricultural lands. Former two categories are the natural areas which is difficult

for development due to steep geography, natural disasters, and etc. Settlement areas are scattered along the road and form local markets with some population. Thus, land use along the road depends on natural conditions. However, better road conditions and increasing traffic volume may expand the development along the areas and may change agricultural land to other forms of land use.

Steep slopes without possible land use

Present land use as farming along the road

Road through Forest Areas

Settlement areas along the road

Source: JICA Survey Team

Figure 11.3-1 Samples of land use along the existing road

Some major settlement areas along the roadside are listed in the table below.

Table 11.3-1 Major Settlement Areas along the Road Alignment

No.	Chainage (Km)			Description of land type	Side of Road		Name of Settlement
	From	To	Length				
SECTION-I: BARDIBAS-SINDHULI BAZAAR							
1.	0+000	2+500	2.50	Settlement /Bazaar Area	Left	Right	Bardibas
2.	18+800	19+600	0.80	Settlement Area		Right	Bhiman
3.	27+900	28+200	0.30	Settlement Area	Left	Right	Karkare, Kamlamai
4.	35+400	40+200	4.80	Settlement /Bazaar Area	Left	Right	Sindhuli Madhi, Sindhuli Gadhi
SECTION-II: SINDHULI BAZAAR-KHURKOT							
1.	43+500	43+700	0.20	Settlement /Bazaar Area	Left	Right	Chiyabari
SECTION-III: KHURKOT-NEPALTHOK							
1.	74+700	76+700	2.00	Settlement /Bazaar Area	Left	Right	Khurkot
2.	93+600	94+000	0.40	Settlement /Bazaar Area	Left	Right	Mulkot
3.	107+700	108+300	0.60	Settlement /Bazaar Area			Dumja
SECTION-IV: NEPALTHOK-DHULIKHEL							
1.	119+900	120+300	0.40	Settlement /Bazaar Area	Left	Right	Mangal Tar
2.	138+200	139+400	1.20	Settlement /Bazaar Area	Left	Right	Bhakundebesi
3.	158+900	159+476	0.57	Settlement /Bazaar Area	Left	Right	Dhulikhel

Source: JICA Survey Team

11.3.2 Natural Environment

(1) Climate

Being in the monsoon climatic zone, Nepal receives excessive rainfall in the rainy season / the summer generally between May to September. The monsoon rain does not come in regular basis; therefore, the farmers have to depend on perennial rivers for their paddy field and other farming activities.

The climate of the project area varies depending on the elevation of various sections. However, the general climate of the area is cool and temperate. The average temperatures and rainfall of the project area (Kavrepalanchowk, Ramechhap and Sindhuli) is shown in Table 11.3-2.

Table 11.3-2 Average Temperature and Rainfall of Project Area

Districts	Temperature		Average Annual Rainfall
	Maximum	Minimum	
Kavrepalanchowk	28 ^{0}C	5 ^{0}C	1,570 mm
Ramechhap	20.8 ^{0}C	10.3 ^{0}C	1,299 mm
Sindhuli	24 ^{0}C	12.5 ^{0}C	2,360 mm

Source: District Profiles of Bhaktapur and Kavrepalanchowk Districts

Figure 11.3-2 and Table 11.3-3 show temperature and rainfall at Sindhuli Gadhi (Section II, altitude = approx. 1,400 m) and Sindhuli Bazar (boarder between Section II and Section III) along the target Sindhuli Road. These data indicate that the temperature and the rainfall are influenced by seasonal monsoon and the annual rainfall shows wide range from approx. 1,600 mm to 2,800 mm in the area.

Source: Preparatory Survey Report on the Project for Countermeasure Construction for the Landslides on Sindhuli Road (Section II), March 2012, JICA

Figure 11.3-2 Average Temperature in Sindhuli Gadhi

Table 11.3-3 Monthly Rainfall at Sindhuli Bazar

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2003						197.5	457.5	291.0	328.5	44.5	0.0	0.0	
2004	0.0	0.0	0.0	36.0	105.5	207.5	764.0	216.5	264.0	129.5	0.0	0.0	1,723.0
2005	0.0	0.0	0.0	0.0	56.0	86.5	362.5	746.0	239.5	142.0	0.0	0.0	1,632.5
2006	0.0	0.0	0.0	0.0	323.5	556.5	281.5	243.0	534.5	26.5	0.0	0.0	1,965.5
2007	0.0	0.0	0.0	59.5	190.5	546.0	796.0	465.0	540.0	217.5	0.0	0.0	2,814.5
2008	0.0	0.0	0.0	14.0	205.0	554.5	540.5	475.0	339.5	138.0	0.0	0.0	2,266.5
2009	0.0	0.0	0.0	15.0	120.0	87.0	352.5	295.5			0.0	0.0	
2010	0.0	0.0	0.0			15.5	439.5	478.0	377.0	74.5	0.0	0.0	
Average	0.0	0.0	0.0	20.8	166.8	281.4	499.3	401.3	374.7	110.4	0.0	0.0	2,080.4

Source: IEE for Countermeasure construction of Landslides in Sindhuli Road (Section II) of Sindhuli Road Project, 2012, DOR

(2) Forest

There are several types of forests along the target road sections such as government-managed forest, community-managed forest, lease-hold forest and private forest. the route survey conducted along the existing Sindhuli Road identified existence of several community forests (CF), which are managed and developed by community forest user groups (CFUGs) under the District Forest Office (DFO). It is reported that, around 18,133 CFUGs are managing 17 million ha of community forest in Nepal. This is almost 30.3% of the total forest area in the country. Out of 5,427,302 HHs in Nepal, 2,177,858 HHs are members (42.6%) of any community forests.

Based on the interview and reporting survey, forests along the existing road are also generally classified into government forest and community forest. Location of these community forests along the existing road are given in Table 11.3-4.

Table 11.3-4 Forest distribution and land use status along the Sindhuli Road

No.	Section (km)		Description of land type	Side		Name of Forest/Settlement
	From	To				
SECTION-I: BARDIBAS-SINDHULI BAZAAR						
1.	0+000	2+500	Settlement /Bazaar Area	Left	Right	Bardibas
2.	3+600	8+200	Forest	Left	Right	Patu CF
3.	8+250	12+480	Forest	Left		Kali Dhamal Bahunijhora CF
4.	13+300	14+500	Forest		Right	Bahunmara kalikhola CF
5.	14+500	15+800	Forest		Right	Chure Aapgachi CF
6.	15+800	17+500	Forest	Left		Bhiman Panesi CF
7.	15+800	17+500	Forest		Right	Janmukhi CF
8.	17+500	19+900	Forest	Left		Basantpur CF
9.	18+800	19+600	Settlement Area		Right	Bhiman
10.	19+900	21+900	Forest	Left		Hardiya CF
11.	21+900	24+600	Forest	Left		Mainawati CF
12.	24+600	27+200	Forest	Left		Kalyani CF
13.	27+300	27+700	Forest	Left		Sinduretar CF
14.	27+900	28+200	Settlement Area	Left	Right	Karkare,Kamlamai
15.	29+130	32+460	Forest		Right	Mainali Thakur CF
16.	32+480	35+100	Forest		Right	Jankalyan CF
17.	35+400	40+200	Settlement /Bazaar Area	Left	Right	Sindhuli Madhi, Sindhuli Gadhi
SECTION-II:SINDHULI BAZAAR-KHURKOT						
1.	41+200	43+300	Forest		Right	Chyangkot CF
2.	43+500	43+700	Settlement /Bazaar Area	Left	Right	Chiyabari
3.	43+300	48+800	Forest	Left		Chiyabari Dhurebas CF
SECTION-III:KHURKOT-NEPALTHOK						
1.	72+200	74+300	Forest		Right	Sayapatri CF
2.	74+700	76+700	Settlement /Bazaar Area	Left	Right	Khurkot
3	90+100	93+400	Forest	Left		Reethe Veer CF
4.	93+600	94+000	Settlement /Bazaar Area	Left	Right	Mulkot
5.	107+700	108+300	Settlement /Bazaar Area			Dumja
SECTION-IV: NEPALTHOK-DHULIKHEL						
1.	119+900	120+300	Settlement /Bazaar Area	Left	Right	Mangal Tar
2.	124+000	124+600	Forest	Left		Dharmik CF
3.	124+600	124+900	Forest	Left		Bandanda CF
4.	125+400	127+800	Forest	Left		Deepsaha CF
5.	132+300	135+500	Forest		Right	Charangephedi CF

SECTION-I: BARDIBAS-SINDHULI BAZAAR						
No.	Section (km)		Description of land type	Side		Name of Forest/Settlement
	From	To				
6.	138+200	139+400	Settlement /Bazaar Area	Left	Right	Bhakundebesi
7.	148+400	149+000	Forest	Left	Right	Kapilehwar CF
8.	150+600	151+600	Forest	Left	Right	National
9.	156+700	157+800	Forest	Left	Right	National
10	158+900	159+476	Settlement /Bazaar Area	Left	Right	Dhulikhel

Source: JICA Survey Team

(3) Ecosystem and Rare / Endangered Species

Based on document surveys and interview at fields, endangered species are not observed along the existing road, especially in Section I, Section III, and Section IV. Section II is mountainous with relatively rich forests, and there are some possibilities of habitation of rare/endangered species near the existing road. However, Section II is more likely to be bypassed with provision of a tunnel and it may not cause much change on the land surface.

Flora along the road is almost secondary vegetation and community forests are used as local socio-economical activities such as logging and livelihood fields as well as forest management. Fauna in such forests is fundamentally composed of limited and common species. Deep inside the forest area, far away from the existing road, there might be some special species that can be categorized as Vulnerable (VU) or in the upper category based on the IUCN (International Union for Conservation of Nature and Natural Resources). Therefore, further survey is needed in the subsequent study phases when the alignment and impact become more distinct now.

Simple survey shows possible species along the target road, especially in the forest nearby in Section I and Section II as shown in Table 11.3-5. And according to general confirmation and opinion from local residents and officials along the road, critical species in terms of IUCN category are not confirmed.

Table 11.3-5 Observed Species near the Project Areas

Flora (Major Tree Species)	Fauna
Sal (Mostly), Sajh, Kali Kath, Raj Briksha, Sindure, Karam (They are common species.)	Deer, Leopard, Wild Boar, Monkey species, etc. (Common species and they don't have habitat along the road. May have possibility of visiting and/or migrate near the roads)

Source: JICA Survey Team

In addition, the Preparatory Survey for the Project for the Sinhduli Road Earthquake Rehabilitation (2018, JICA) mentioned that Section II and Section III show the following characteristics;

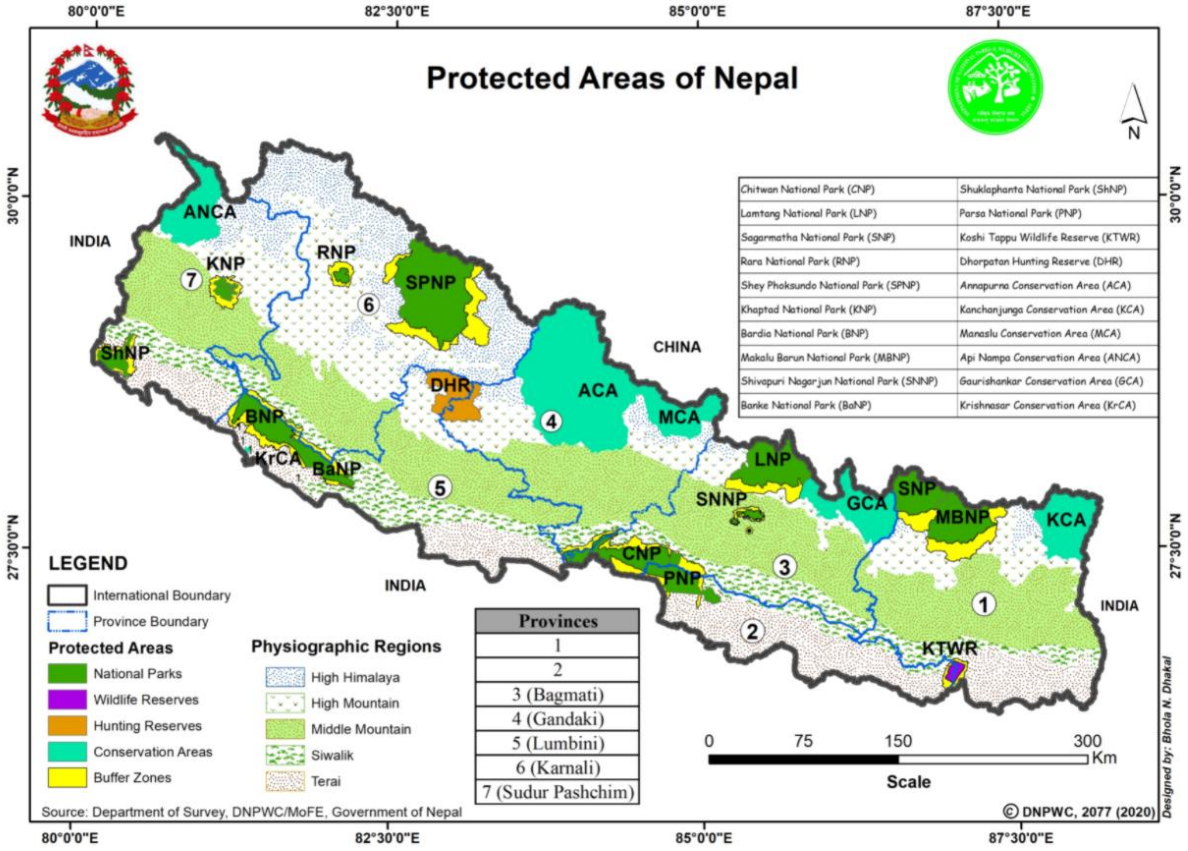
- No endemic plant species and wildlife were reported in the study area.
- Sal[1] is the only plant species which is legally protected as per Forest Act, 1992 and Forest Rules, 195 and can be directly affected by the project. Sal is protected because of its cultural/religious meanings, though its IUCN category is Low Risk/Least Concern.

[1] *Sal (Shorea robusta, IUCN Red List Category and Criteria: Lower Risk/Least Concern, Cultural Aspect: Sal is one of the three holy trees of Buddhism/Hinduism)*

- Sal is reported in the number of sample plots and is a dominant species in the Jaldevi community forests.
- Several mammals are confirmed in the areas along the target roads and planned alignment. But their habitats and/or ecological corridors are not exactly along the road and have certain distances, so the impact from the project might be very limited.

(4) Protected Areas

There are no protected areas in and around the target section of the project. Shivapuri Nagarjun National Park (SNNP) that is the nearest protected area is more than 15 km (from the north-end point of Dhulikhel). Moreover, SNNP and Sindhuli Road are in different regions and different watershed, so the possibility of migration between the protected area and the project sites are very low. Therefore, the project will not have impact on any protected areas. Consequently, special approvals are not required with regards to protected areas.



Source: Ministry of Forests and Environment

Figure 11.3-3 Protected Areas of Nepal

Table 11.3-6 Types of Protected Areas Defined by the Nepal National Parks and Wildlife Conservation Act (NPWCA), 1973 *

Type of Protected Areas	Description
National Park	An area set aside for the conservation, management, and utilization of flora, fauna, and scenery along with the natural environment.
Wildlife Reserve	An area set aside for the conservation and management of wildlife resources and their habitats.
Hunting Reserve	An area set aside for the management of wildlife by allowing hunters to hunt them.
Conservation Area	An area to be managed according to an integrated plan for the conservation of the natural environment and balanced utilization of natural resources.

* If a project is planned within above types of protected areas, the project owner has to discuss with Ministry or Forestry and Environment (MoFE) and relevant local autohides, and take actions for necessary approval process with EIA (Environmental Impact Assessment) approval procedures.
Source: Forest Action Nepal (1973)

11.3.3 Social Environment

(1) Land Acquisition and Resettlement

As a part of BP-Highway, Sindhuli Road is classified as highway which shall have a right-of-way (ROW) of 50 m (25 m from the centerline in both sides) based on the National Road Standard. Basically, any new construction within the ROW does not cause new land acquisition because the land originally belongs to state property.

However, along the Sindhuli Road, the 50 m width has not been practically accepted and only 30 m width is observed as the ROW and this width is clear and observed by the local landowners – the 30 m width ROW is equivalent to feeder roads standard. According to the local representatives, they are able to maintain 30 m width clearance and any construction within this width will not require any additional land, and no private houses are affected within this 30 m corridor. However, to maintain 50 m ROW and construct within 50 m width, the government side will need to acquire the additional land and private houses, as per legal procedure.

In addition, if the Project needs to improve the alignment by going beyond the present road center-line, for example, in sharp curve improvements, of constructing additional vehicle lay-bys, then additional land and private house may need to be acquired.

For the tunnel construction, the Project will need to construct new approach road sections, at both sides of the tunnel portal. In such cases, the construction of the new approach road will need to be done after land acquisition and possible resettlement may be required.

(2) Indigenous People and Ethnic Minority

Although there was observed several different ethnics along the project site, the situation is very common in Nepal. According to past instruction from MOFE and based on past project cases, the Project might not need to prepare ingenious people plan because the project-induced impacts may not affect these people severely in terms of traditional culture, living forms, and marginalization.

According to the map prepared by UK Aid project and as shown in Figure 11.3-4, project areas are originally maintained by Pahari and Tamang ethnic people. Therefore, these ethnic groups can be treated as indigenous, but there are other minority groups also living in the area.

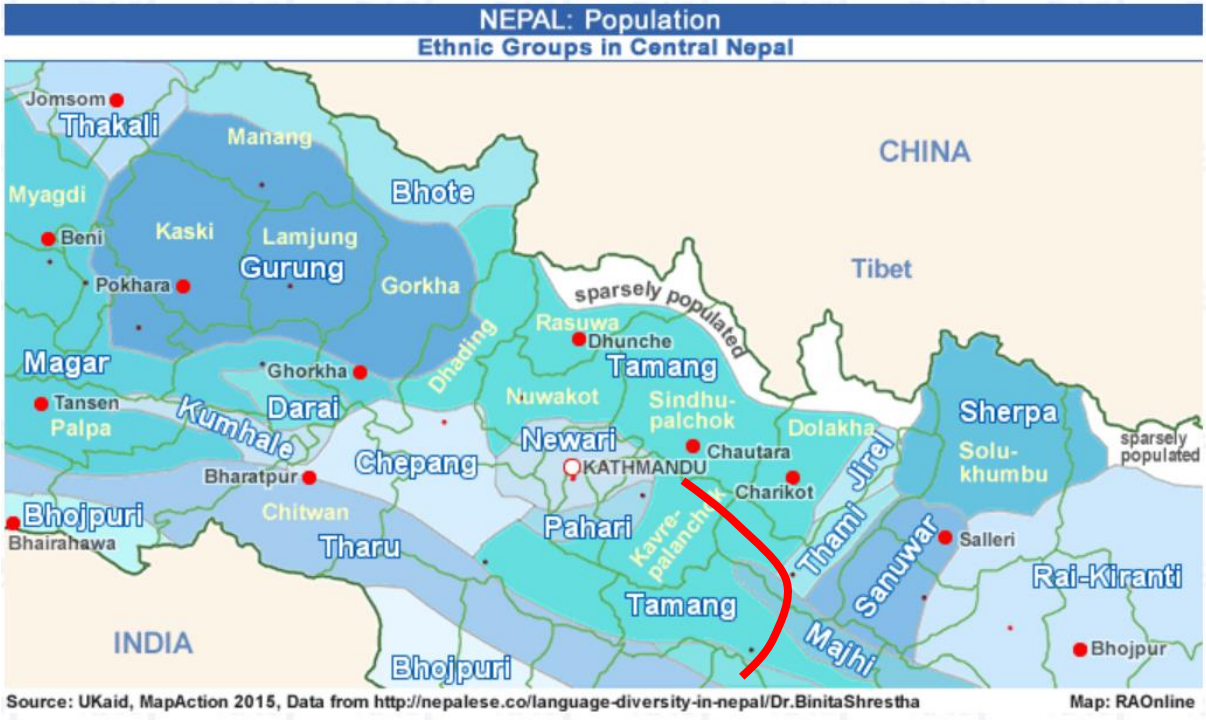


Figure 11.3-4 Distribution of Original Ethnic Groups

(3) Earthquake

There was an earthquake of Magnitude 7.8 with epicenter in Gorkha, on 25 April 2015. The project areas are not the epi-center of the past earthquake, but some vulnerable slopes were affected during the disaster time. According to interviews with the local people, there was no significant impact by the earthquake. Therefore, potential of impact from earthquake is very low in the target areas. Survey on immigrants were not covered in the interview. This needs to be confirmed in the succeeding study phases.

11.4 LEGAL FRAMEWORK ON ESC

11.4.1 Nepali Laws and Regulations

(1) Environment Protection Act (EPA), 2019 (2076)

The Parliament enacted the Environment Protection Act (EPA), 2076 B.S. (2019 A.D.) (The "Act") on July 19th, 2019. As a result, the earlier Environment Protection Act, 2053 B.S. (the "1997, Act") is now repealed. EPA is supplemented by Environmental Protection Regulation (EPR).

One of the main features of the Act in contrast to the 1997 Act, is that it mandates several compliances to Project Developers while developing a Proposal of a Project, to ensure that the implementation of the Project does not harm the environment. As per the present Act, a Project Developer needs to comply with the following compliances while developing a Project.

Screening standards for projects in EPR shows that road tunnels are classified into IEE projects while

water tunnels with length more than 1 km are classified as EIA required project. In addition, National Highway project are considered as EIA required project. Then it is difficult to determine what levels of environmental study is required for a certain project. Finally, Ministry of Environment and Forestry (MOEF) determines the level in practice.

Environmental Study Report – is to be prepared prior to initiation of the Proposal, depending on the Proposal, and includes the following:

- Summary of Environmental Study (environmental study report in short)
- Initial Environment Examination (examination of the possible impact on the environment and measures to mitigate it) or Environmental Impact Assessment (assessment of possible impact on the environment and solutions that can be opted)
- The Environment Protection Act, 2076 B.S. (2019 A.D.):
- Setting out the review and approval process of IEE (Initial Environmental Examination**)** and EIA Reports, that involve informing and consulting stakeholders.
- stipulate that no one creates pollution that would cause significant adverse impacts on the environment or harm to public life and health, or to generate pollution beyond the prescribed standards;
- specify the Ministry in charge of environment (currently the Ministry of Forests and Environment, MoFE) to conduct inspection of approved projects to ensure that pollution prevention, control or mitigation is carried out according to the approved IEE or EIA Report;
- provides for the protection of objects and places of national heritage and places with rare plants, wildlife and biological diversity; and
- states that any person/party affected by pollution or adverse environmental impact caused by anybody may apply to the prescribed authority for compensation to be recovered from the polluter/pollution generator

(2) Environment Protection Rules, 2020 (2077)

The government has made public the Environment Protection Rules (EPR) 2077 B.S. (2020 A.D.) on 15 June 2020. This EPR has also repealed EPR 2054 B.S. (1997 A.D.). The brief environmental study (BES) report is an addition in the EPR 2020. Environmental Protection Rules (EPR), 2077 B.S. (2020 A.D.) defines the implementing rule and regulations of the IEE/EIA process, elaborating the provisions in the EPA, 2076 B.S. (2019 A.D.). This EPR obliges the proponent to prepare Terms of Reference (ToR) as per the format prescribed in Schedule 6, 7 & 8 for BES, IEE & EIA respectively. The preparation, review and approval of IEE and EIA Reports are dealt with in Rules 3 to 9 and 12 to 13. Schedules 1, 2 & 3 list down the projects of activities that require BES, IEE and EIA, respectively and the proponent will proceed for preparing BES, IEE or EIA reports as mentioned in EPR

(3) Forest Act, 2019 (2076)

The new Forest Act has provisioned to provide forest area for national priority projects under section 10. Section 10 has mentioned that development projects have to submit EIA, detailed project report (DPR) or detailed engineering design to the ministry while proposing forest area for the project. Along with the

new Forest Act, a framework to provide forest area to national priority projects has mentioned that if any development project uses forest land, the project has to provide land equal to the area covered by the forest. If the project is not able to provide the land, then the act has also included a provision where the developer can compensate by paying the amount based on the valuation of the forest area.

(4) Public Road Act, 2031 (1974)

The Public Road Act, 1974 has been enacted to ensure the construction and operation of the road Projects smoothly. Section 3 of the Act empowers GON (Government of Nepal) to prohibit the construction of permanent structures (buildings) in the prescribed distance from the road, i.e., the Department of Roads (DOR) has the authority over everything within the boundaries of the road.

(5) Land Acquisition Act, 2034 (1977)

The Land Acquisition Act, 2034 empowers the Government to acquire land for development purposes, by paying compensation for the landowner. The Land Acquisition Guidelines, 1989 have been issued to facilitate the acquisition process under the Act. The Government will provide compensation to the concerned person and organization as decided by the Compensation Fixation Committee.

(6) National EIA Guidelines, 1993

The guideline states clear directions about the process of conducting EIA. This guideline makes EIA in Nepal legally mandatory and contains process for ensuring public involvement during the preparation of EIA report. It calls for information regarding identification of physical, biological, socio-economic and cultural impacts. Impacts ranking method also suggested in this guideline. It stresses the inclusion of mitigation measures to avoid, minimize and mitigate adverse impacts and maximize beneficial impacts resulting from the development Project and monitoring & environmental auditing in the EIA report. Its revision in 1997 calls for the ensuring local people's participation, collection of relevant information, identifying major issues of public concerns, evaluate them and establishing priorities for EIA study.

(7) Environmental and Social Management Framework, DOR, 2007

This Environmental and Social Management Framework report (ESMF) intends to provide technical and managerial inputs and guidance into the design of the strategic roads (both designated for rehabilitation and, to lesser extent, to new construction), through identification of key environmental and social issues related to the foreseen Projects, mitigate potential impacts and concerns and, devise opportunities to enhance the benefits. The framework integrates in a step-wise approach the most important environmental and social considerations into all stages of Project preparation, implementation, monitoring and operation and is applicable to all future Projects.

The ESMF is applicable to all proposed subproject activities and through all stages of the subproject cycle, i.e., from pre-planning, planning and design, implementation to post-implementation. The design flow of ESMF activities will be coordinated and integrated into the Project cycle.

11.4.2 JICA Guidelines for Environmental and Social Considerations

The JICA's guidelines for environmental and social considerations (2010) are aimed at encouraging project proponents to have a sound understanding of project impacts on the environment and also its social impact.

The guidelines also set a basis for the examination and review of environmental and social considerations so as to ensure that they are conducted in an appropriate manner. In addition, the roles, responsibilities, procedures and requirements for both JICA and the project proponents are outlined in the guidelines in order to meet these objectives. The policy also advocates transparency, accountability and predictability by JICA in its support for and examination of environmental and social considerations.

(1) Major Gaps on EIA between JICA's Guidelines and Nepal`s Legal Frameworks

Table below shows the results of policy gap analysis between JICA's Guidelines for Environmental and Social Considerations (2010) and domestic legal framework of Nepal. Principally, items mentioned by JICA's Guidelines are found in legal documents of Nepal, especially in ESMF. However, some detail conditions can be gaps and might be fulfilled with practical measures.

Table 11.4-1 Policy Gap between JIGA Guidelines and Nepalese Regulations (EIA)

No.	JICA Guidelines	Legislation of Nepal	Major Gap and Policy Adopted
Principle	• Environmental impact must be assessed and examined from the earliest possible planning stage. Alternatives or mitigation measures to avoided or minimize adverse impact must be examined and incorporate into the project plan.	• EPA and EPR stipulated necessisty of IEE/EIA to assess impact before the projects.	• Not so much gaps, however the principle of avoidance, minimization, and mitigation need to be applied based on the JICA Guidelines for Environmental and Social Considerations. • ESMF fufilled all requirements of JICA Guidelines in principle
Information Disclosure	• EIA reports (which may be referred to differently in different system) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them. • EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted.	• Rule 7 of EPR stipulates disclosure of information. The project proponent shall inform the VDCs/Municipalities, DDCs and other important stakeholders, individual or organizations concerned the implementation of the project and its impacts through a 15-day notice to be published in a national daily newspaper • and notified at VDC/Municipality, DDC, school, hospital/health post.	• No major gaps are identified. The official language of Nepal is Nepali language so that public notice, invitation and agenda, minutes of discussion and other documents are prepared in Nepali which are translated into English as common language of Nepal dependingon circumstances.As regards environmental assessment studies, IEE/EIA reports are basically prepared in English. • ESMF fufilled all requirements of JICA Guidelines in principle
Consultation	• For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local	• Community Participation for EIA process is specified in the National EIA	• There is basically no gap. • ESMF fufilled all requirements of JICA Guidelines in principle.

No.	JICA Guidelines	Legislation of Nepal	Major Gap and Policy Adopted
	residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined. The outcome of such consultations must be incorporate into contes of project plans. • In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared. • Consultations with relevant stakeholders, such as local residents, should take place necessarily throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared.	Guidelines 1993 which defined; Time for Community Participation, • Individuals, Groups and Agencies to be Involved. • Methods to Involve the Public	
Impacts to be Assessed	• The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. There also include social impacts. In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the projects are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project.	• Schedule 5 and Schedule 6 of EPR stipulates "Matter to be mentioned in IEE and EIA report respectively in which impacts to be assessed are specified. Those items almost covers items of impact based on JICA's Guidelines	• There is basically no gap. 30 items of impact which is usually used in JICA project should apply for the EIA study. As far as ESMF is applied, the conditions are fulfilled.
Monitoring	• Project proponents etc. should make efforts to make the results of the monitoring process available to local project stakeholders. • When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for	• Rule 13 of EPR stipulates "Monitoring and Evaluation".	• There is basically no gap. However, in order to fulfill both requirements of Nepal and the JICA Godliness perfectlly, EIA shall provaide appropriate monitoring format with monitoring plan including

No.	JICA Guidelines	Legislation of Nepal	Major Gap and Policy Adopted
	discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders' participation in relevant projects. Project proponents etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems.		methodology. • ESMF fufilled all requirements of JICA Guidelines in principle.
Ecosystem and Biota	Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests.	• Not available. However, any project in a prptected areas must be discussed with MoFE and pause necessary approval procedure and reviewing processes.	• Not so much gaps, however the principle of avoidance, minimization, and mitigation shall be applied based on the JICA Guidelines for Environmental and Social Considerations. • ESMF fufilled all requirements of JICA Guidelines in principle
Indigenous People	Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses.	• As Nepal is a multiethnic country, existence of ethnic minority / indigenous group is common. There is not officialized legal frameworks on impact by a project on indigenous people.	• Not so much gaps, however the principle of avoidance, minimization, and mitigation shall be applied based on the JICA Guidelines for Environmental and Social Considerations. If there are observed cases of indigenous people, separate plan or special treat shall be considered in EIA and RAP. • ESMF fufilled all requirements of JICA Guidelines in principle

Source: JICA Survey Team

(2) Major Gaps on RAP between JICA's Guidelines and Nepali Legal Frameworks

Policy gaps related to land acquisition and resettlement were analyzed by comparing with the JICA's Guidelines for Environmental and Social Considerations and the Nepali legal system as follows;

(a) Compliance to Nepali country system, such as Land Acquisition Act, Public Road Act, Road Standard, and etc.

(b) Application of Environmental and Social Management Framework (ESMF) with an equivalent standard of World Bank's Safeguard Policy (Operational Policy, OP)

(c) Following to JICA Guidelines for Environmental and Social Considerations as well as relevant World Bank's Safeguard Policy, Resettlement Sourcebook, and etc.

Table 11.4-2 Policy Gap between JICA Guidelines and Nepali Country System (RAP)

No.	(A) JICA Guidelines for Environmental and Social Considerations with World Bank Safeguard Policy	(B) Nepali Law & Regulations	Major Gaps between (A) and (B)
1.	Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.	The adverse impacts can be minimized or avoided or dealt with positive and constructive ways (1.1.1, ESMF)	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
2.	When population displacement is unavoidable, effective measures to minimize impact and to compensate for losses should be taken.	- The adverse impacts can be minimized or avoided or dealt with positive and constructive ways (1.1.1, ESMF) - Government of Nepal may, if it so deems necessary, acquire any land at any place for any public purpose, subject to compensation under this Act (Article 3, Land Acquisition Act)	No significant gaps are observed.
3.	People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.	Thus, the affected persons in the project will be entitled to various types of compensation and resettlement assistance that will help in the restoration of their livelihoods, at least, to the pre-project standards (7.3.1, ESMF)	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
4.	Compensation must be based on the full replacement cost as much as possible.	When GON requires assets, national law does not specify about the provision of mandatory replacement cost. Therefore, ESMF strongly recommended that: Practical provisions must be made for the compensation for all lost assets to be made at replacement cost without depreciation or reductions for salvage materials, and including any other costs such as transaction. Efforts must be made to assess the real replacement costs of land to the extent possible. A procedure should be established for determining compensation rates accurately plus rigorous efforts to assess the replacement costs and market rates for all assets, including labor costs for construction.	There might be a gap on determination of compensation rate between Nepali side and the JICA Environment Guidelines. In the past cases, deduction and/or using government fixed rate lower than market price are common. [Proposals for the gap-filling measure] The project owner (DOR) shall secure necessary budget for compensation based on a RAP and ask Compensation Determination Committee (CDC) to follow the methodology of replacement cost. Monitoring on such compensation process is also required.
5.	Compensation and other kinds of assistance must be provided prior to displacement.	ESMF referred OP 4.12: The measures (i.e., the RP) include provision of compensation and	No significant gaps are observed. This item is not clearly

No.	(A) JICA Guidelines for Environmental and Social Considerations with World Bank Safeguard Policy	(B) Nepali Law & Regulations	Major Gaps between (A) and (B)
		of other assistance required for relocation, prior to displacement, and preparation and provision of resettlement sites with adequate facilities, where required.	mentioned in domestic laws, however, ESMF covered it.
6.	For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public.	ESMF regulated RAP preparation.	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
7.	In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance.	- In Chapter 5, the section of 2.2.1: The Procedural Steps in Road IEEs and EIAs of ESMF, and other sections covers all conditions concerning public participation/consultation - Domestic EIA procedure supported by some conditions in ESMF requires public consultation meeting	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
8.	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people		
9.	Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans.		
10.	Appropriate and accessible grievance mechanisms must be established for the affected people and their communities.	5.1 and 7.5 of ESMF stipulated establishment of grievance redress mechanism (GRM)	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
11.	Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits.	N/A *Cut-off date is recommended to set as the date of Census survey (7.2.3, ESMF)	There is no direct regulation of recommendation regarding the item.
12.	Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no	In the proposed project, the absence of formal titles will not be a bar to resettlement assistance and rehabilitation. (7.3.1, ESMF)	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.

No.	(A) JICA Guidelines for Environmental and Social Considerations with World Bank Safeguard Policy	(B) Nepali Law & Regulations	Major Gaps between (A) and (B)
	recognizable legal right to the land they are occupying.		
13.	Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based.	N/A * EMSD just referred OP 4.12	Cash for land is the common way of compensation for both formal and informal land cases in Nepal, and PAPs also prefer to cash compensation generally.
14.	Provide support for the transition period (between displacement and livelihood restoration).	N/A	The item is not clearly mentioned even in ESMF. Some kinds of assistance have a function to support such transition period.
15.	Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc.	8.3 of ESMF or the part of Entitlement Matrix stipulated the considerations scheme for such vulnerable groups	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
16.	For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared.	7.10 of ESMF stipulated the abbreviated RAP under the condition of fewer than 200 people	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.
17.	Internal and external monitoring system must be established and implemented properly	8.8 of ESMF covers monitoring and evaluation	No significant gaps are observed. This item is not clearly mentioned in domestic laws, however, ESMF covered it.

Source: JICA Survey Team

11.5 INSTITUTIONAL FRAMEWORK

11.5.1 Ministry of Physical Infrastructure and Transport (MOPIT)

The MOPIT is the responsible agency for environmental monitoring and it should provide necessary guidance to the Proponent in accordance with the EPA (Environment Protection Act), 1997 and EPR, 1997. The ministry as a policy making body is also responsible for the overall guidance and policy formulation for the development of transport sector in Nepal. Hence, the Ministry will review and approve the final EIA report. It can also co-ordinate with other institutions for necessary arrangement for land acquisition and conflict resolutions, if any, for the smooth implementation of this Project. The Ministry can entrust and/or instruct the DOR for environmental monitoring works by providing necessary policy guidance, as the DOR is its technical arm.

11.5.2 Department of Roads (DOR)

The DOR is facilitating the integration of environmental aspects in the road construction, rehabilitation and maintenance projects by developing policies and guidelines. EIA reports submitted are reviewed by the Geo-

Environmental and Social Unit (GESU) of the DOR and forwarded to the MOPIT for approval. Furthermore, the DOR can also be involved in environmental monitoring works and instruct the project to comply with the environmental monitoring works and the environmental requirements during its constructions. DOR also instruct and manage implementation of RAP activities for related regional governments such as district offices in implementation stages.

11.5.3 Ministry of Forests and Environment (MOFE)

The ministry involved in environmental monitoring works is the MOFE. The ministry also has legal mandate to prepare the environmental auditing report after two years of project operation or commencement of the service from this proposal. MOFE also determines which level of documents on environment is required for a certain project such as EIA.

11.6 SPECIFIC ESC CONDITIONS FOR SECTIONS

11.6.1 Section I (Bardibas - Singhuli Bazar: 37 km)

Section I runs across relatively flat land from the southern end point of Bardibas. Land use of both sides of the road are secondary forest and riverbanks. There are several hilly areas with sharp consecutive curves will undergo improvement for enhancing the function of the road. The improvement may be within the existing ROW (Officially 25 m each or practically 15 m each from the existing road centerline), and there might not be critical environmental factors such as habitats or private properties. Thus, road improvement and simple widening activities are relatively easy in this section because of the flat geographical conditions and having sufficient land within the existing ROW. The northern end point of this section is Sindhuli Bazar where the roadsides have been developed as settlement and small business. However, this section will not require drastic change and is therefore deemed to be less impacted.

Secondary Forest

A river crossing the existing road

Source: JICA Survey Team

Figure 11.6-1 General Environmental Status of Section I

11.6.2 Section II (Sindhuli Bazar - Khurkot: 35.8 km)

Generally, Section II runs across mountainous area. Existing road is meandering through the section and the land use alongside is mostly forest. There are some villages at both end points of the section while no settlement areas are identified in between. As bypassing by provision of a tunnel is likely to be proposed for

this section, no large impact will be expected on the surface, such as tree felling and resettlement. But there might be light impact at the portals and approach roads, particularly acquisition of land.

Land to be possibly acquired was calculated for the 4 routes proposed for the bypass (refer Chapter 13) as tabulated in Figure 11.3-2. The table also provides the estimated number of affected structures. It should be noted that the land area provided is based on a desk study and the landowners are yet to be verified. The actual acquisition area might be less that those indicated as most of the area could possibly belong to the state.

Table 11.6-1 Approximate Areas of Land Acquisition and Numbers of Affected Structures

Routes	Required Area* (m^2) at Approach Roads			Number of Affected Structures		
	South Side	North Side	Total	South Side	North Side	Total
Route 1	63,867	19,166	83,033	7	8	15
Route 2	33,218	87,827	121,045	7	o	7
Route 3	26,735	19,183	45,918	8	8	16
Route 4	26,758	87,492	114,250	8	0	8

* Acquisition area may vary (decrease) as current figure could be inclusive of state-owned land

Source: JICA Survey Team

(1) North Portal Areas

There are mainly two options for the portals at north side near Khurkot. Portals of two alternative routes are located at the left bank of a mountain stream connecting to the Dudhkosi River, while another two alternative routes proposed run along the right bank of the stream.

Length of the approach road on the left bank is longer than the right bank because the location of the portals is in the upstream area. As the tunnel portal is located in dense forests, consideration for minimizing project induced impacts due to logging will be important. In addition, as the approach roads go through the river terraces, normally used for farming, impact on socio-economical aspects is also needed to be considered.

Designed portals in case of the right bank side of the stream is located at the foot of the mountains where residential structures are scattered. Since the portals are close to the existing road, length of the approach road is shorter than the route running on the left bank. Thus, the alternatives which has portals in the right bank side may show relatively less impact on both environmental and social considerations.

An image of the portal location at a mountainside

An image of the alignment of an approach road on the

(Alternatives in the left bank)

An image of the portal location and direction of the approach road to Khurkot
(Alternatives in the right bank)

river terraces (Alternatives in the left bank)

An image of the portal location and approach road from north side upward view
(Alternatives in the right bank)

Source: JICA Survey Team

Figure 11.6-2 Photos and Image of the North Portal Areas and the Approach Alignment

(2) South Portal Areas

There are mainly two options for the portals at south side near Chiyabari area. Two portals are located very close to each other and approach roads to the portals also maintain the same alignment. Therefore, there is no apparent difference among the 4 candidate routes in terms of environmental and social considerations.

One of the most outstanding impact of the south side of the Section II is the resettlement, Chiyabari that is located near the diverging point from the existing Sindhuli Road. There are several residential structures with small business and some religious trees and monuments. Any alternative route may affect small number of such structures, probably less than 10 cases, at this area.

From the Chiyabari to the south portals, there are only agricultural lands and a mountain stream and not so much trees are to be affected by the approach roads. Thus, vulnerable elements of natural and social environment in this south portal area might be very limited.

An image of the portal location and approach road from south side upward view
(Alternatives in the left bank)

An image of designed alignment of the approach road separated from the existing road to a residential area
(Alternatives in the right bank)

An image of the portal location at the middle of hillside
(Alternatives in the right bank)

A religious tree and monuments in the settlement area
near the starting point of the approach road
(Alternatives in the left bank)

Source: JICA Survey Team

Figure 11.6-3 Photos and Image of the South Portal Areas and the Approach Alignment

(3) Other Situations

Except for the area of portals, degree/kinds of impacts on some environmental items such as "protected area", "habitats of rare species", and "Indigenous people's living areas", and "expected soil disposal sites" are not so different among the candidate alternative routes at this preliminary discussion stage as shown in Table 11.6-2.

Table 11.6-2 Common environmental and social situations for all alternatives

Environmental Items	Description
Protected Areas	All alternative routes are not within any protected areas except some community forests / government forests. The nearest national park is far enough from the tunnel section. Impact on logging and livelihood in the community forests shall be considered.
Habitats of Rare Species	There is no outstanding difference of habitats conditions among the discussed alternative routes. Only the north portal in the left bank side has slightly higher risks on such habitats, for example road-kill, due to its location close to the dense forest areas. Further study on ecosystem is required in the following study.
Indigenous People's Living Areas	Resettlement impact on indigenous people around the section may occur, although the number of affected cases is limited. Further census survey with socio-economic survey is required in order to analyze the specific impact on their livelihood in the following study. However, the distribution and situation of ethnics and indigenous people in the section is not a special case but that is common situation in the region. On the other hand, if the situation fulfill conditions based on Word Bank's OP 4.10, necessary considerations as indigenous people are required.
Soil Disposal Sites	Possible location and methodology of soil disposal sites among the alternative alignments are same. One proposed idea is using debris of soil/muck/rock from the tunnel for land filling near the tunnel portals to construct a road-side station (service area). Examination for soil contamination is required before landfilling.

Source: JICA Survey Team

11.6.3 Section III (Khurkot - Nepalthok: 36.8 km)

Section III basically runs along the Sunkoshi River from Khurkot town to Nepalthok. There are several hilly areas, and the existing road has to detour such steep geography. Thus, there are several candidate sections for improvement of the road alignment by different kinds of construction as well as simple widening.

There is a local religious place within the exiting ROW where drivers and local people buy flowers or mirrors for putting on the slope of the road. Low land areas near the river are developed as small towns and traffic can stop for rest. Basically, the mountain side shows steep geography and possible road development areas are very limited because the other side is a riverbank. Therefore, dense forests or protected areas were not confirmed along the section.

A section along the Sunkoshi River

A religious spot along the road

Source: JICA Survey Team

Figure 11.6-4 General Environmental Status of Section III

11.6.4 Section IV (Nepalthok - Dhulikhel: 50 km)

Section IV gains its height from the border with Section III to the northern end point of Sinhduli road, Dhulikhel. The road leaves from the Sunkoshi River and runs through several towns. Thus, roadside along this section is relatively much developed. Some low land areas are also developed as a form of landfilling, quarry, and soil borrow pit. The side near to Dhulikhel shows steep mountainous geography and the existing road runs through hilly areas without dense forest. Because of good landscape of Himalaya from some areas in the section, there are small tea shops along the existing road. Including such social activities, impact due to land acquisition and resettlement shall occur when the project cause influences on land and private properties along the road due to road widening.

Hilly section with developed secondary flora

A land fill area facing to the exiting road

Source: JICA Survey Team

Figure 11.6-5 General Environmental Status of Section IV

11.7 EVALUATION

11.7.1 Evaluation for Sensitive Areas

According to the results of the survey, project criteria was discussed with check items based on the Appendix 3 of JICA's Environmental Guidelines. As a result, the project area at Section II with tunnel construction may not be classified as a sensitive area. The categorization based on JICA's Guidelines, however, are discussed with other factors such as sectors of the project, construction methodology, etc. hereunder. Table 11.7-1 shows the results of evaluation.

Table 11.7-1 Check List for JICA's Screening for "Sensitive Areas"

Check Items	Evaluation Results
A. National parks, nationally-designated protected areas (coastal areas, wetlands, areas for ethnic minorities or indigenous peoples and cultural heritage, etc. designated by national governments)	National parks and any other equivalent areas are not located along the project section. *The nearest national park, Parsa National Park, is almost 100 km far from the section.
B. Areas that are thought to require careful consideration by the country or locality	
(1) Natural Environment	
a) Primary forests or natural forests in tropical areas	N/A There are forest areas including Governmental Forest and Community Forest along the road. Those forests are almost secondary forests.
b) Habitats with important ecological value (coral reefs, mangrove wetlands, tidal flats, etc.)	N/A There are no such important habitats along the project alignment and nearby.
c) Habitats of rare species that require protection under domestic legislation, international treaties,	Need to be confirmed Further study is required to determine the status of rare species and impact on them.
d) Areas in danger of large-scale salt accumulation or soil erosion	Slopes along the target roads are geologically vulnerable and spotted soil erosion are observed around the weathering slopes and/or landslide areas.
e) Areas with a remarkable tendency towards	N/A

Check Items	Evaluation Results
desertification	
(2) Social Environment	
a) Areas with unique archeological, historical, or cultural value	N/A Each commune or village, however, may have religious places in their common lands.
b) Areas inhabited by ethnic minorities, indigenous peoples, or nomadic peoples with traditional ways of life, and other areas with special social value	N/A Although there was observed several different ethnics along the project site, the situation is very common in Nepal. According to past instruction from MOFE and based on past project cases, the Project might not need to prepare ingenious people plan because the project-induced impacts may not affect these people severely in terms of traditional culture, living forms, and marginalization.

Source: JICA Survey Team

11.7.2 Tentative Screening

A tentative screening for Section II was conducted based on collected data and information and compiled in a format (Appendix-5). Provision of tunnel at Section II may influence on pollution control, natural environment and social environment. Its degree of impact, however, has not been revealed clearly and further surveys are required to comprehend them.

Based on some important indicators, such as existence of protected areas, rare species' habitat, forest logging, and number of PAPs, the impact of the proposed project is limited/mild degree.

11.7.3 Draft Pre-Scoping

Based on the tentative screening and relevant information collected through the study, the draft pre-scoping (simple check of environmental items) of Section II (tunnel construction) was conducted on the basis of some assumptions as shown in Table 11.7-2. Conditions and further inspection are required to develop a complete final scoping matrix in the following study phases after discussing appropriate alternative studies.

Table 11.7-2 Draft Pre-Scoping

No	Item	Selection Status		Reasons for Selection
		PCS/ CS	OS	
1	Air Quality	✓	✓	**Construction Phase:** ・ Operation of construction equipment will generate dust and emission gas. ・ Traffic congestion in construction site will cause increase in exhaust gas from vehicles. ・ Dust will occur in borrow pit and quarry site. **Operation Phase:** ・ Air pollutant caused by increased traffic may generate much exhaust gas. ・ Improved traffic flow may reduce exhaust gas. ・ Exhaust gas may increase around the tunnel portals
2	Water Quality	✓	✓	**Construction Phase:** ・ Turbid water caused by construction works, especially tunnel constructions, is likely to affect existing surface and ground water resources. ・ In case of inadequate management in borrow pit and quarry site, turbid water from borrow pit and quarry site by rainfall may cause surface water contamination. **Operation Phase:** ・ Soil runoff due to heavy rain may occur in filling or steep slope sections and turbid water may cause surface water contamination.
3	Waste	✓		**Construction Phase:** ・ Construction waste caused by construction works and general waste from construction office will be generated. **Operation Phase:** ・ Impact on waste is unlikely to occur
4	Soil Contamination	✓		**Construction Phase:** ・ Muck from tunnel construction might be contaminated. **Operation Phase:** ・ Impact on soil contamination is unlikely to occur
5	Noise and Vibration	✓	✓	**Construction Phase:** ・ Construction works is likely to increase noise and vibration level. **Operation Phase:** ・ Noise and vibration level caused by vehicle driving will increase.
6	Ground Subsidence	✓	✓	**Construction Phase:** ・ Subsidence due to fill loading may occur. ・ Subsidence due to water drainage of tunnel drilling **Operation Phase:** ・ Leaking water from tunnel and drainage may cause subsidence
7	Offensive Odor	✓		**Construction Phase:** ・ Inappropriate treatment of construction material and waste might cause offensive odor **Operation Phase:** ・ Impact on offensive odor is unlikely to occur
8	Bottom Sediment	✓		**Construction Phase:** ・ Inappropriate treatment of slope protection and construction material might cause sedimentation along the section **Operation Phase:** ・ Impact on bottom sediment is unlikely to occur
9	Protected Area			**Construction Phase/Operation Phase:** There are no protected areas in and around the project site.
10	Ecosystem	✓	✓	**Construction Phase:**

No	Item	Selection Status		Reasons for Selection
		PCS/ CS	OS	
				・ Roadside tree/vegetation will be lost by widening works. In a mountainous section, tree cutting in a community forest may be required due to approach roads to the tunnel. ・ Turbid water caused by construction is likely to affect aquatic life. **Operation Phase:** ・ Roadkill might occur along the section.
11	Hydrology	✓		**Construction Phase:** ・ Water flow in the river or stream may be altered during construction works. ・ Tunneling works may influence the flow of groundwater and the groundwater level in the surrounding area, and amount of water from wells/springs may change. **Operation Phase:** ・ Water leaking from tunnel may cause impact on groundwater.
12	Topography and Geology	✓		**Construction Phase:** ・ Topography will be changed in the new road section and tunnel portals **Operation Phase:** ・ Impact on geographical features is unlikely to occur.
13	Land Acquisition and Resettlement	✓		**Pre-Construction Phase:** ・ Linear improvement and widening of existing road and construction of new alignment including the tunnel section will cause land acquisition and/or resettlement. **Construction Phase:** ・ Temporal lease of land and additional small-scale resettlement might be required. **Operation Phase:** ・ Additional resettlement and land acquisition will not be required
14	Poverty	✓		**Pre-Construction Phase/Construction Phase:** ・ Project might cause some degree of impact on poverty in the section such as resettlement, small business, and so on. **Operation Phase:** ・ Impact only on poor people is unlikely to occur
15	Ethnic Minority and Indigenous People	✓	✓	**Pre-Construction Phase/Construction Phase:** ・ If ethnic minority and/or indigenous people's family are affected as PAPs of involuntary resettlement, they may have severe impact on their life.
16	Local Economy such as Employment and Livelihood	✓		**Pre-Construction Phase:** ・ Land acquisition and resettlement may cause livelihood degradation of Project Affected Persons (PAPs). **Construction Phase:** ・ Construction will create job opportunities to local people. **Operation Phase:** ・ Reduction of travel time will contribute to local economies and promote tourism.
17	Land Use and Usage of Local Resources	✓		**Construction Phase:** ・ In case of new road construction, land use, mostly agricultural land and residential area, will be shifted to Right of Way. **Operation Phase:** ・ Land use along the target road section will change and achieve economic and social development. ・ Improved transportation will contribute to effective utilization of local resources.
18	Water Usage	✓	✓	**Construction Phase:**

No	Item	Selection Status		Reasons for Selection
		PCS/ CS	OS	
				・ Existing agricultural canals located in roadside will be affected by widening works. ・ Tunnel works might cause changes of water flow in surface and ground water ・ Water-use around the construction site/yard may affected by water from those areas **Operation Phase:** ・ Water from tunnel may cause impact on water usage around the area.
19	Existing Social Infrastructure and Services	✓		**Pre-Construction Phase:** ・ Relocation or protection of existing utilities, such as electric poll, water pipe and optical fiber cable will be required. **Construction Phase:** ・ Temporary traffic congestion in and around construction site will occur. **Operation Phase:** ・ Access to social services will be improved.
20	Social Institutions such as Socially Related Capital and Decision-making Organizations			**Construction Phase/Operation Phase:** ・ Because of improvement project of existing road and a new tunnel section, considerable impact on social institutions is unlikely to occur.
21	Misdistribution of Benefit and Damage			**Pre-Construction Phase/Construction Phase:** ・ Because of improvement project of existing road and a new tunnel section, considerable impact on social institutions is unlikely to occur. ・ Small business along the existing road which will be bypassed by the new tunnel alignment shall be affected due to decreasing of traffic / customers.
22	Local Conflicts of Interest			**Construction Phase/Operation Phase:** ・ Because of improvement project of existing road and a new tunnel section, considerable impact on social institutions is unlikely to occur.
23	Cultural Heritage	✓	✓	**Pre-Construction Phase/Construction Phase:** ・ There is not considerable cultural heritage along the section. However, if local pagoda or any other form of religious facilities is affected as resettlement property, they shall be compensated/mitigated properly. **Operation Phase:** ・ In case of religious facilities are affected, concerned persons or community may be affected.
24	Landscape	✓		**Construction Phase:** ・ Road site trees and forest area, which create particular scenery, will be lost by construction works. **Operation Phase:** ・ Considerable impact on landscape is unlikely to occur.
25	Gender	✓		**Construction Phase/Operation Phase:** ・ Women workers may be discriminated or sexually harassed by male workers and have different wage scale from male workers.
26	Children's Right	✓		**Operation Phase:** ・ Construction mobilization may cause child labor issue **Operation Phase:** ・ Considerable impact on children's right is unlikely to occur.

No	Item	Selection Status		Reasons for Selection
		PCS/ CS	OS	
27	Infectious Diseases such as HIV/AIDS	✓		**Construction Phase:** ・ Infection risks of HIV/AIDS may be increased among construction workers and local business offering food and entertainment. **Operation Phase:** ・ Considerable impact on infectious diseases is unlikely.
28	Labor Environment including Safety	✓		**Construction Phase:** ・ Dust and emission gas may affect workers health. ・ Sanitary conditions around construction site may get worse due to waste from workers and toilet. **Operation Phase:** ・ Considerable impact on working conditions unlikely
29	Accident	✓	✓	**Construction Phase:** ・ Labor accidents may occur in construction site, especially in tree cutting, slope protection and bridge construction works. ・ Traffic accident may occur at construction site **Operation Phase:** ・ Traffic safety including pedestrians will be improved by road widening and vehicle separation ・ Traffic accident due to more traffic volume and faster vehicle speed may increase ratio of traffic accident. ・ In the tunnel section, car trouble, car accident, vehicle fire, emergency cases may happen
30	Transboundary Impact and Climate Change	✓	✓	**Construction Phase:** ・ Operation of construction equipment will generate CO_2. **Operation Phase:** ・ CO_2 emission from vehicles will increase in future. ・ Improved traffic efficiency may reduce.

Source: JICA Survey Team

11.8 RECOMMENDATIONS FOR SUBSEQUENT SURVEYS

11.8.1 All sections (Including Section II)

Common and general recommendation for the future development of all sections of the Sinhduli Road is shown in Table 11.8-1.

Table 11.8-1 General Recommendation

Items	Recommendations
Pollution Control	• Measurement of air quality should consider the location of ventilation system of the tunnel. • Both surface and groundwater shall be measured to know baseline data as many as possible with considerations of rainy and dry seasons. • Possible assessment for soil contamination, especially assuming risks of muck from the tunnel sections. • Measurement survey for baseline data should consider rainy and dry season
Natural Environment	• Further survey on rare species shall be implemented with both documentation and field levels with the list of IUCN rating. • Inventory survey for necessary tree logging is required with practical mitigation plan based on relevant domestic legal framework such as Nepal Forest Guidelines (2006) and its updated documents

Items	Recommendations
Social Environment	• Apart from a Census survey for resettlement action plan (RAP), distribution of indigenous people shall be surveyed during the following study phases. • Integrated local traffic system between existing meandering mountainous road and new tunnel alignment shall be discussed from the view point of local economy and benefit for local communities including vulnerable people of traffic, utilization of exiting Sindhuli road, toll fee, and etc. • Road safety, especially for pedestrian should be considered for further improvement of the road. People are facing risks of traffic accident in the present conditions of road and traffic in all sections.

Source: JICA Survey Team

11.8.2 Section II

In addition to general recommendation to each environmental element as above, specific recommendation for Section II to be considered in the next study phase is discussed and shown in Table 11.8-2.

Table 11.8-2 The Other Recommendation for the Section II

Items	Contents
Associated Facilities and Cumulative Impact	It does not seem to be any qualified cases as associated facilities with the discussed tunnel section at the moment of this survey. Cumulative impact, however, should be surveyed and evaluated in the future survey period to avoid overlooking of such impact including stabilization of slopes along the planned alignment.
Secondary/Indirect Impact	Because the candidate sites of soil borrow pit, quarry, dumping site, camping site, etc. have not fixed yet at the time of this survey, secondary impact caused by such project-related facilities should be examined in detail during the following survey phases. Also, indirect impact including socio-economical changes on bypassed area shall be assessed with enough survey data in the following survey periods.
Special Considerations on Tunnel Portals	Impact and rights on land around the tunnel portals shall be further discussed with views of land ownership and protection zones of tunnel structures, such as land surface rights and restriction of development in the future.
Considerations for Rainy and Dry Season	Environmental items which may be affected by the rainy and dry season, such as hydrology, water-use, air pollution, shall be considered carefully before commencement of baseline surveys in the following survey periods to assess the impact correctly.
Impact on Socially Vulnerable People	Impact on vulnerable people, such as vendors along the existing road which is bypassed by the tunnel section, shall be assessed with care to avoid ignorance in mitigation and monitoring measures. Also, other form of vulnerability, such as refugee of the last earthquake, shall be confirmed and considered appropriately.

Source: JICA Survey Team

CHAPTER 12 REVIEW OF PRECEDING STUDIES/SURVEYS

12.1 INTRODUCTION

The Sindhuli Road (BP Highway) at Section II connecting the Khurkot to Sindhuli passes through steep mountainous area. This section has the following issues due to topographical restrictions in mountainous areas and has become a major traffic bottleneck section even after the completion of the Sindhuli Road.

a) Typical road width is 5.50 m, which is equivalent to 1.5 lanes. (it is difficult for opposing vehicles to pass each other except in the widening sections. In case of large vehicles, it is only possible under very low speed)

b) Consists of several zigzag sections with continuous sharp and hairpin curves and insufficient road width (large vehicles cannot pass smoothly)

c) The steepest vertical gradient at the section is about 10% (large vehicles cannot pass smoothly even if the climbing lane is provided)

d) A portion of the section passes between the Main Boundary Thrust (MBT), which is a major tectonic line of Nepal, and the Mahabharat Thrust (MT) (The geology at the section might be fragile, and slopes along the road has often been closed due to the collapses and landslides)

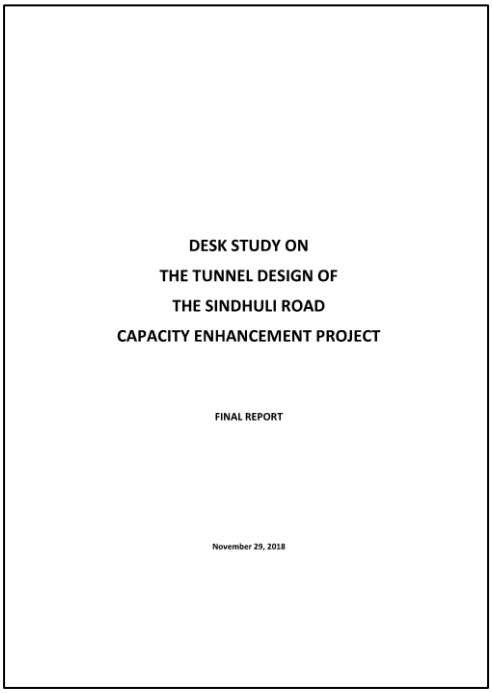
Section II of the Sindhuli Road passes through the Mahabharat Mountains and the Siwalik Hills, which extend continuously from east to west at the section and planning a bypass without having to cross the two high hills is near to impossible. As mentioned above, the terrain of this area is steep and fragile (see Figure 12.1-1). It is therefore not easy to widen the existing road although this is one of the cheapest and leading alternatives for the road function enhancement. Therefore, a bypass is a better option and since the area is mountainous, consideration for a mountainous tunnel would be more an effective method in the long run for the road function enhancement.

Prospect of tunneling at Section II has been studied in the past under two different surveys, i) Desk Study on the Tunnel Design of the Sindhuli Road Capacity Enhancement Project (2018: JICA Nepal Office) (hereinafter referred to as the JICA Desk Study Project) and, ii) Feasibility Study of Road Tunnels (Khurkot-Sindhuli Khanda Road Tunnel) (2019: Nepal Road Authority) (hereinafter referred to as the Nepal F/S Project) have been conducted (see Figure 12.1-2).

This chapter discusses about the technical review of the mountain tunnels studied in the two surveys along with the key issues on the tunneling at the section. In addition, the policy on the tunnel planning at the section in the Project based on the review results and the key issues is also described.

Source:JICA Survey Team

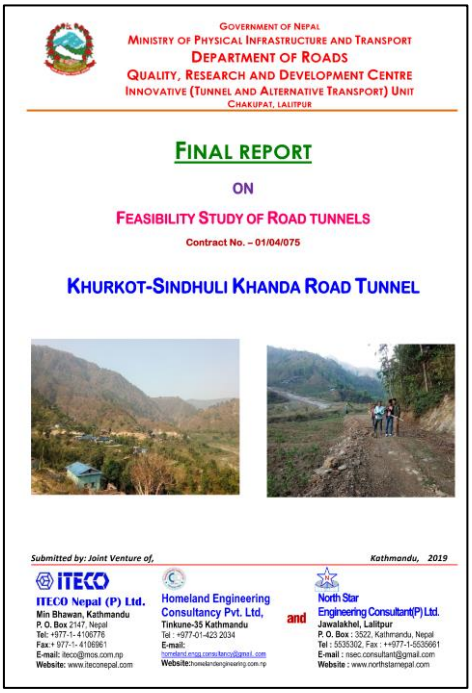
Figure 12.1-1 Section II (Sindhuli Road)


DESK STUDY ON
THE TUNNEL DESIGN OF
THE SINDHULI ROAD
CAPACITY ENHANCEMENT PROJECT

FINAL REPORT

November 29, 2018

(1) JICA Desk Study Project


GOVERNMENT OF NEPAL
MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT
DEPARTMENT OF ROADS
QUALITY, RESEARCH AND DEVELOPMENT CENTRE
INNOVATIVE (TUNNEL AND ALTERNATIVE TRANSPORT) UNIT
CHAKUPAT, LALITPUR

FINAL REPORT

ON

FEASIBILITY STUDY OF ROAD TUNNELS

Contract No. – 01/04/075

KHURKOT-SINDHULI KHANDA ROAD TUNNEL

Submitted by: Joint Venture of, Kathmandu, 2019

ITECO Nepal (P) Ltd. and Homeland Engineering Consultancy Pvt. Ltd, and North Star Engineering Consultant(P) Ltd.

(2) Nepal F/S Project

Source:JICA Survey Team

Figure 12.1-2 Reports to be Reviewed

12.2 PRECEDING STUDIES/SURVEYS

12.2.1 Desk Study on the Tunnel Design of The Sindhuli Road Capacity Enhancement Project

12.2.1.1 Outline

Outline of the study is as follows.

Completion Year: November 2018

Consultants: Local Consultant

Scope of Works:
a) To study alternative routes for the mountain tunnel and to provide a horizontal and vertical alignment of the recommended alignment
b) To identify location of an evacuation tunnel
c) To provide rough cost estimation of the project
d) To provide rough area for land acquisition and resettlement using satellite images

12.2.1.2 Study on Tunneling at Section II

(1) Alternative Route

A desk study on alternative routes with the mountain tunnel was conducted based on a topographic map of 1: 25,000 scale published by the Department of Survey in Nepal in the JICA Desk Study Project. The study was limited to desk study. Neither site reconnaissance along the tunnel routes nor geological surveys (borings and geophysical explorations) for the tunnel study were conducted.

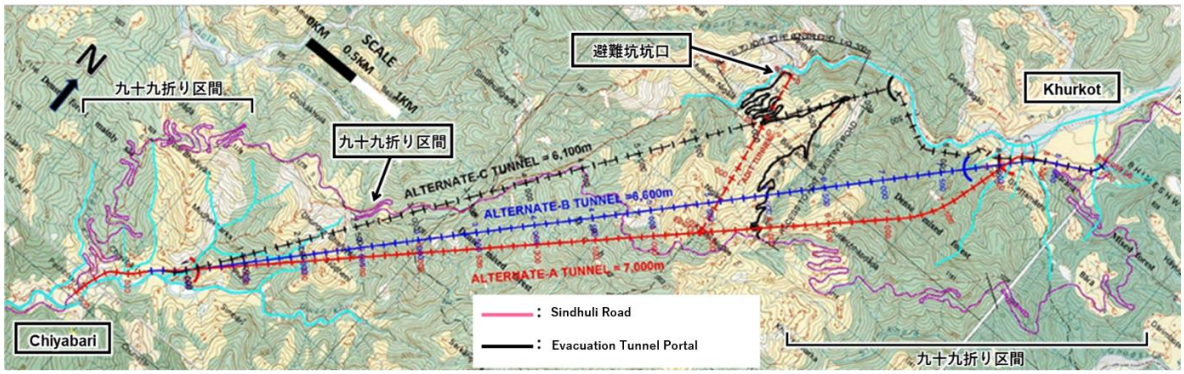
The tunnel routes proposed by the JICA Desk Study Project are as follows (see Figure 12.2-1).

Alternative-A: A southern portal is planned on the eastern ridge of the Zigzag section located in the Chiyabari district, and the northern portal is planned on the south side of the existing road (Sindhuli Road) in the Khurkot district. Tunnel length is 7,000 m. The horizontal alignment of the tunnel section straight with a curve of radius1,000m at the end.

Alternative-B: This alternative makes the tunnel length shorter than the alternative-A by making the horizontal alignment of the tunnel section straight. The southern portal of the alternative-B is in the same location as the one of the alternative-A, and the northern portal of the alternative-B is located on south side of the northern portal of the alternative-A. Tunnel length is 6,600 m. The horizontal alignment of the tunnel section is straight and has no curves.

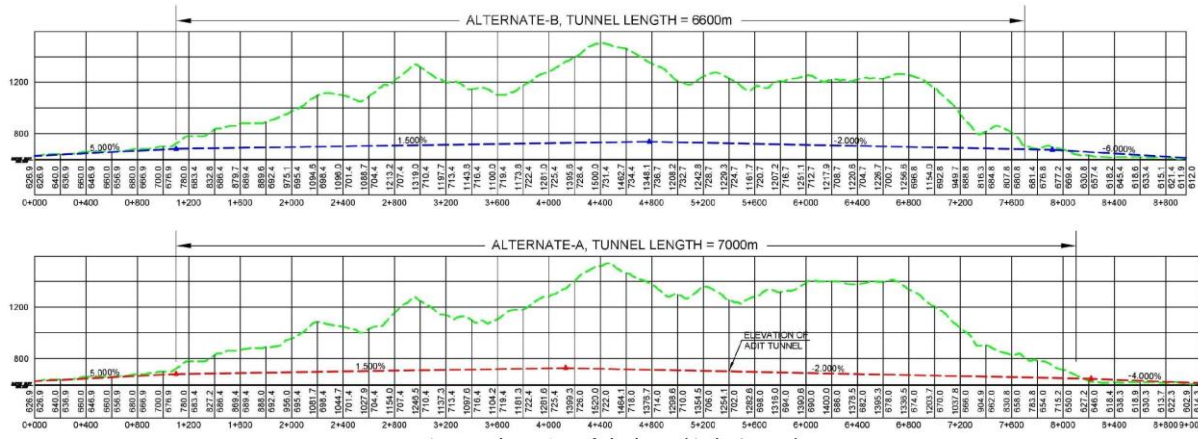
Alternative-C: This alternative is the shortest tunnel route. The southern portal of the alternative-C is in the same location as the one of the alternative-A and alternative-B, and the northern portal of the alternative-C is located on west side of the northern portal of the alternative-A and alternative-B. Tunnel length is 6,100 m. The horizontal alignment of the tunnel section is straight and has no curves.

For the alternative-A, an evacuation tunnel, which branches from the tunnel section near Sta. 5+900 to north side, and an access road connecting from existing roads (Sindhuli Road) to evacuation tunnel portal are planned (see Figure 12.2-1).



Source: Prepared with reference to "Final Report (Desk Study on the Tunnel Design of the Sindhuli Road Capacity Enhancement Project), P.7" by JICA Study Team

Figure 12.2-1 Alternative Routes with Mountain Tunnel（JICA Desk Study Project）



Note: Tunnel profile of the alternative-C is not described in the final report

Source: Final Report (Desk Study on the Tunnel Design of the Sindhuli Road Capacity Enhancement Project), P.7

Figure 12.2-2 Tunnel Profile (JICA Desk Study Project)

(2) Lane Operation

The following items regarding to the lane operation method of the tunnel are mentioned in the report.

- Since the tunnel length of the alternative-A is about 7,000 m, an evacuation tunnel is required. Therefore, the alternative-A is not recommended from the viewpoint of the construction cost if the tunnel is constructed as a single tube tunnel with 2 lanes.
- In case of a single tube tunnel with 2 opposing lanes and no rigid median strip to physically separate the two lanes, there is high risk of a head-on collision due to overtaking in the oncoming lane.
- A double tube tunnel with 1 lane (W=7.00 m: carriageway 3.50m, left shoulder 1.50m, right shoulder 0.50 m, both side inspection gallery 0.75 m) is recommended for lane operation method of the tunnel.

12.2.2 Feasibility Study on Road Tunnels (Khurkot-Sindhuli Khanda Road Tunnel)

12.2.2.1 Outline

Outline of the study is as follows.

Completion Year：	2019
Consultants：	ITECO Nepal (P) Ltd. JV with Homeland Engineering Consultancy Pvt. Ltd. and North Star Engineering Consultant Ltd.
Scope of Works:	Data collection and study on existing information of project site Site survey and reconnaissance Geological study and investigations Environmental Study Preliminary Design and Drawings Economic Analysis

12.2.2.2 Study on Tunneling at Section II

(1) Alternative Route

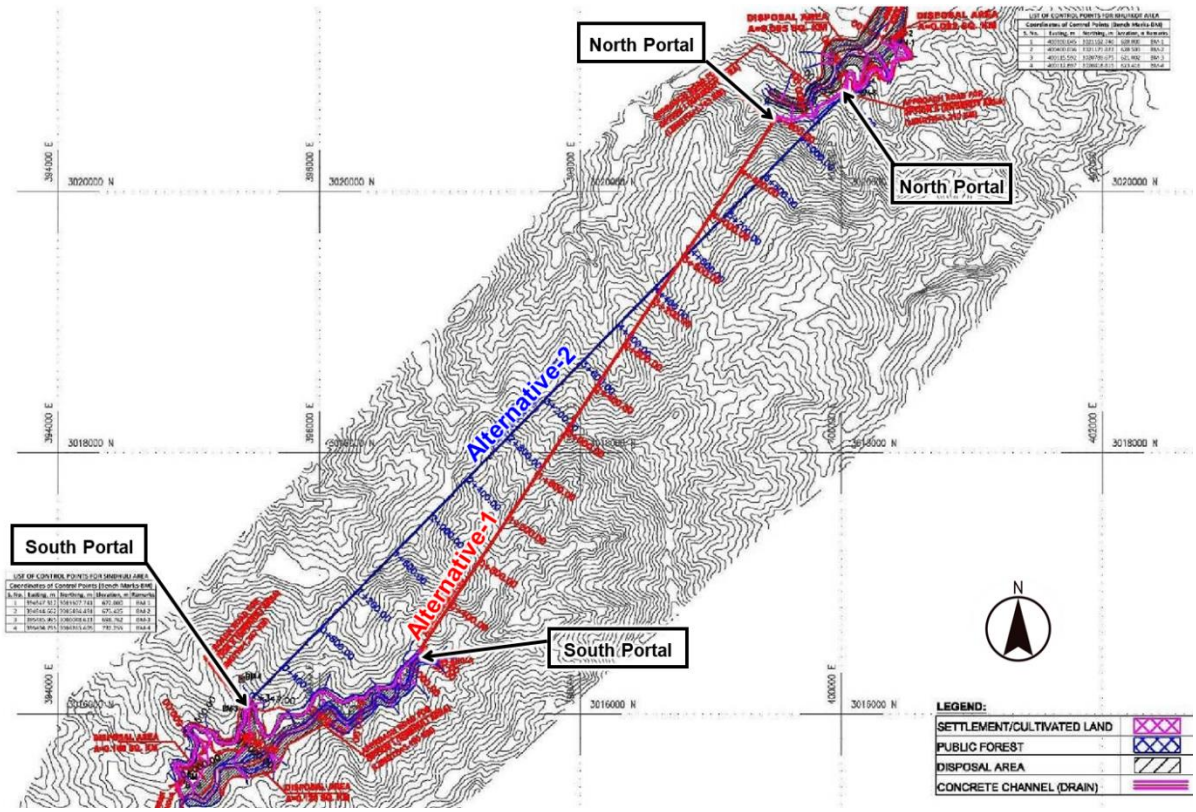
In the Nepal F/S Project, alternative routes with the mountain tunnel shown in Table 12.2-1 were proposed taking the geological and topographical conditions into account. Although it is stated in the report that the tunnel route study was carried out to avoid bad ground sections on the tunnel routes, the control points for the tunnel route study are not clarified.

The tunnel routes proposed by the Nepal F/S Project are as follows (see Figure 12.2-3 and Figure 12.2-4).

Table 12.2-1 Outline of Alternative Routes with Mountain Tunnel（Nepal F/S Project）

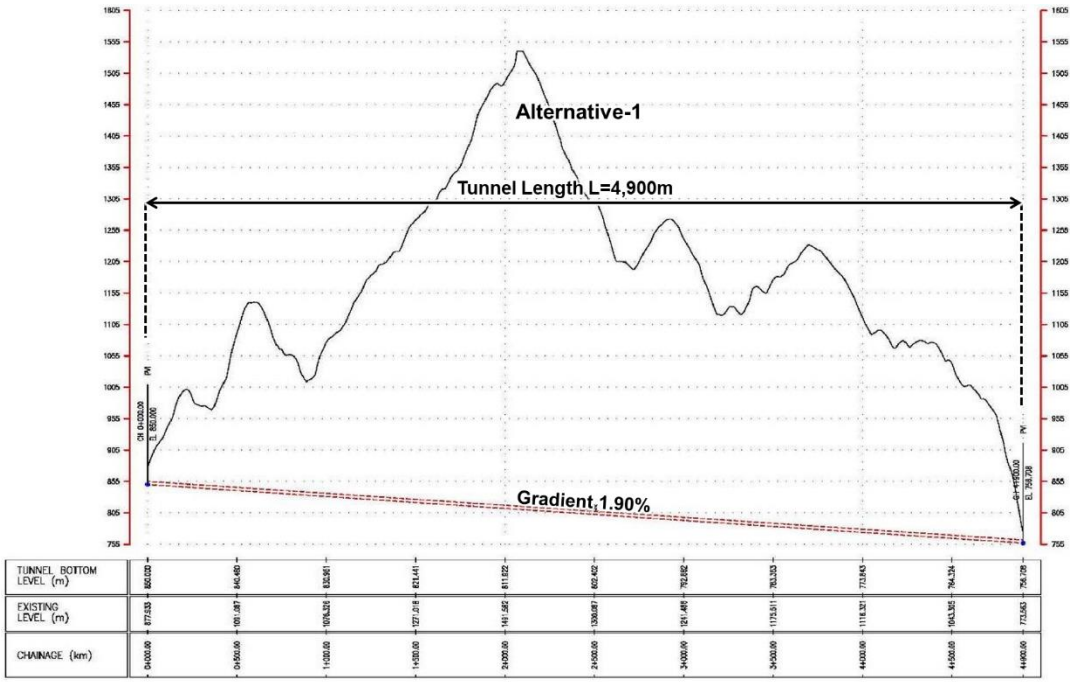
Alternative Routes	Tunnel Length	Tunnel Profile	Horizontal Alignment
Alternative-1	4,900 m	1,90%	Straight
Alternative-2	6,453 m	0.20%	Straight

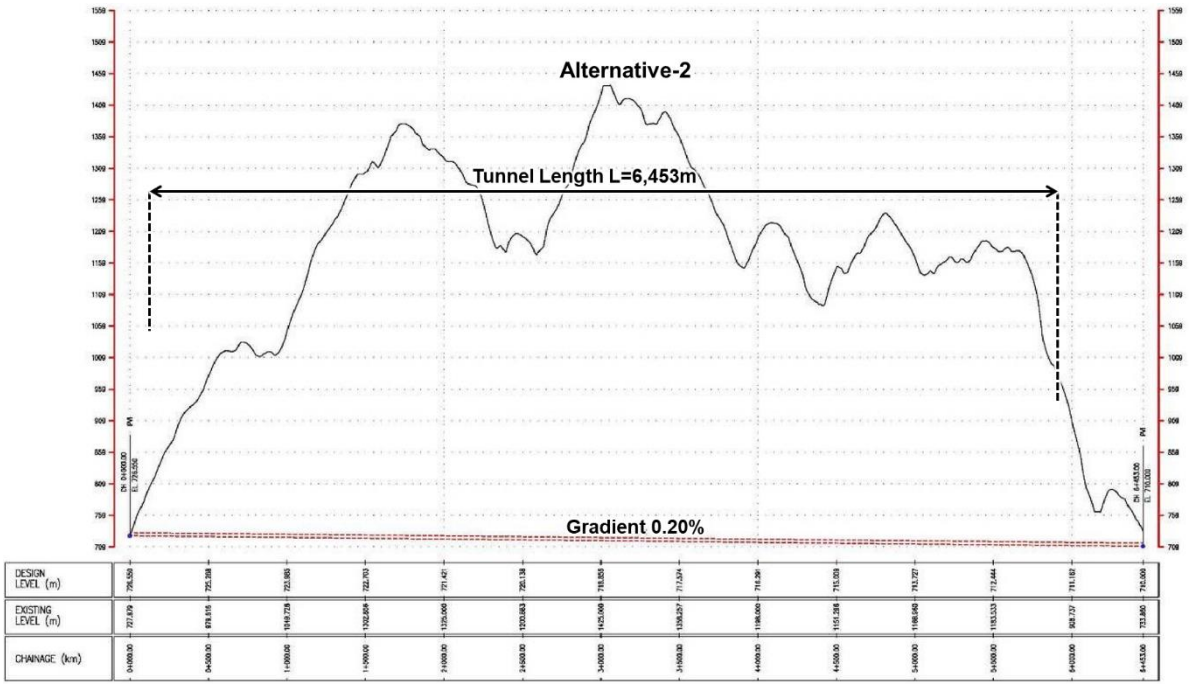
Source:JICA Survey Team



Resource: Prepared with reference to "Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel)), P.69" by JICA Survey Team

Figure 12.2-3 Alternative Routes with Mountain Tunnel（Nepal F/S Project）





Source: Prepared with reference to "Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel)), P.72~73" by JICA Survey Team

Figure 12.2-4 Tunnel Profile (Nepal F/S Project)

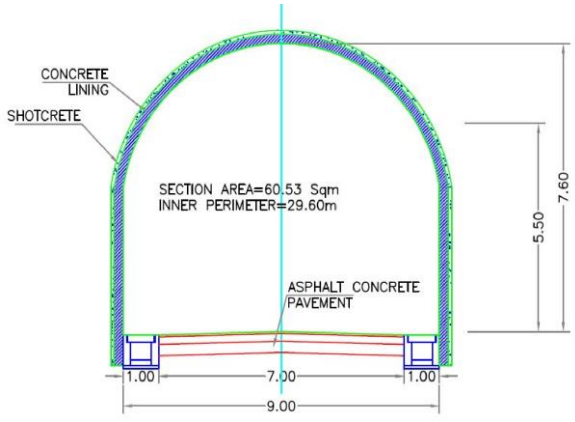
(2) Lane Operation and Cross Section

2 types of lane operation method of the tunnel below were studied in the Nepal F/S Project.

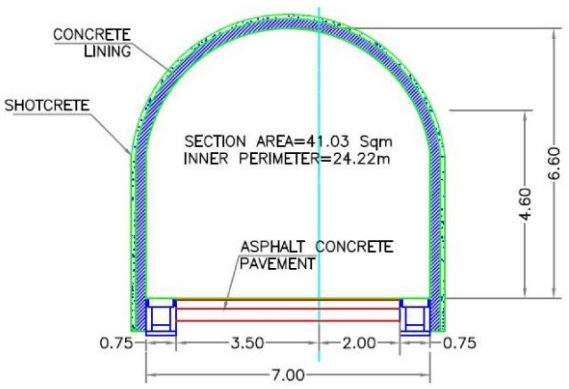
Type1: Single Tube Tunnel with 2 lanes + Evacuation Tunnel

Type2: Double Tube Tunnel with 1 lane

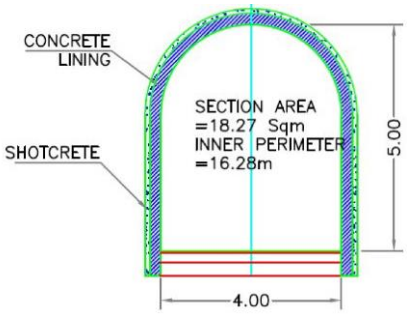
Figure 12.2-5 shows the tunnel cross section of each type.



Tunnel with 2 lanes



Tunnel with 1 lane



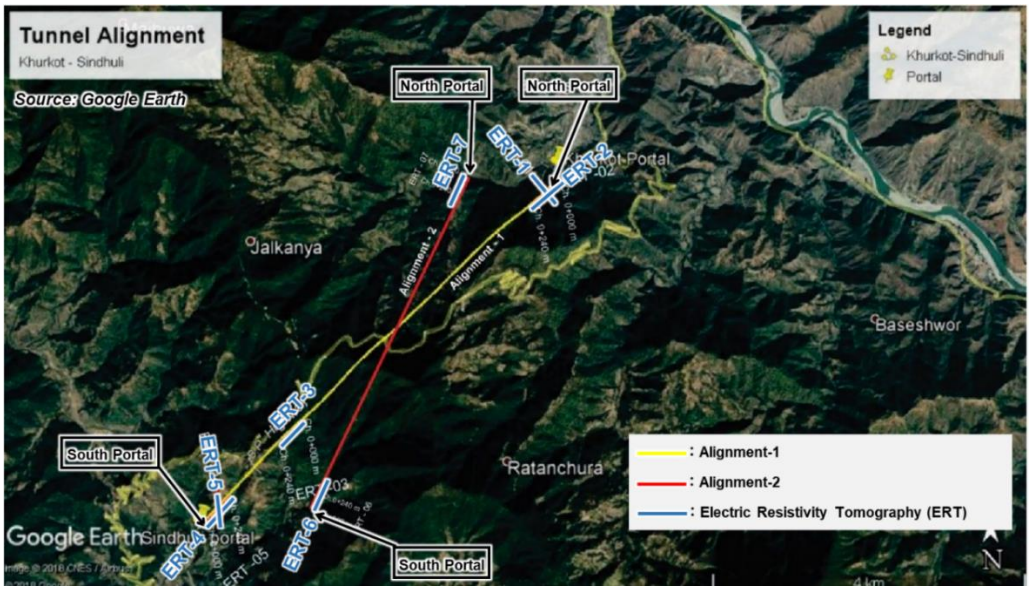
Evacuation Tunnel

Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel)), P.74~75

Figure 12.2-5 Tunnel Cross Section (Nepal F/S Project)

(3) Geotechnical Investigation (Electric Resistivity Tomography)

In this survey, the electric resistivity tomography (total 7 locations) was conducted to grasp the geological condition at the area of the proposed tunnel portals and the middle part of the tunnel. Outline of the electric resistivity tomography and its results are shown in Figure 12.2-6 to Figure 12.2-13 and Table 12.2-2.

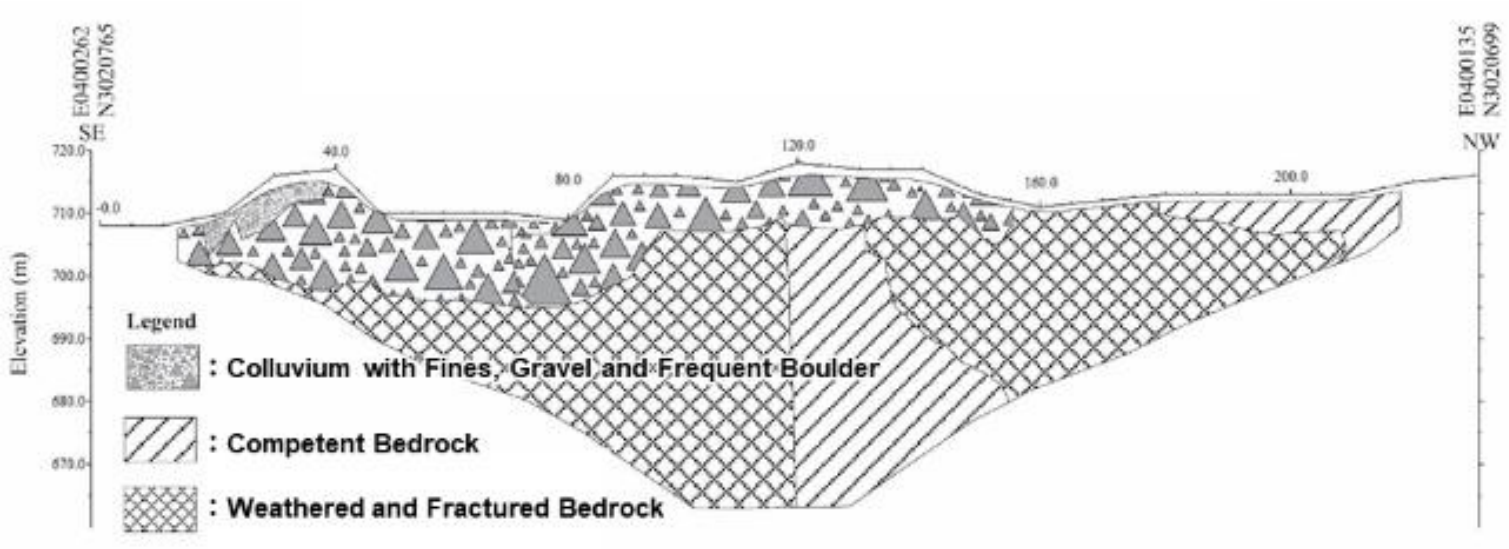


Source: Prepared with reference to "Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel)), P.44" by JICA Survey Team

Figure 12.2-6 Location Map of Electric Resistivity Tomography (ERT)

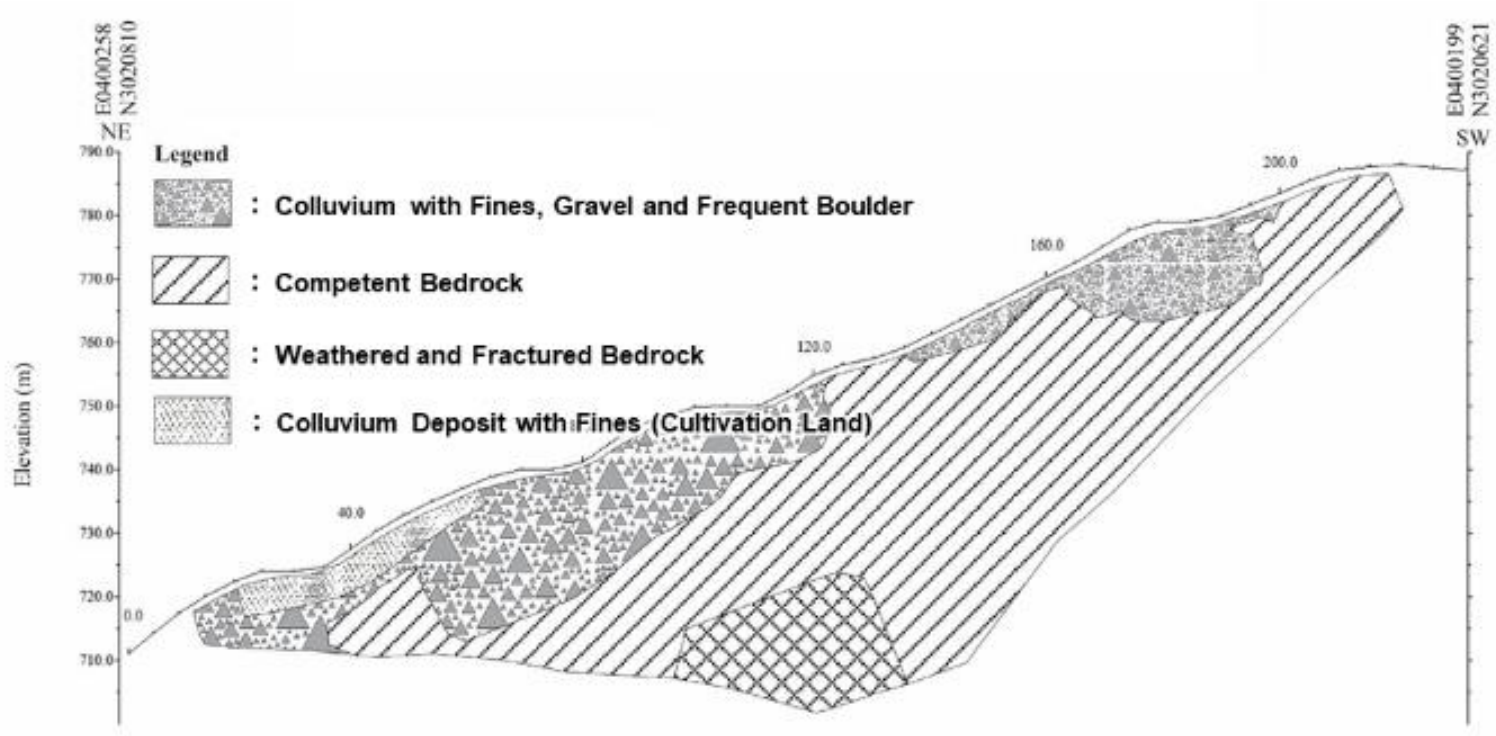
Table 12.2-2 Outline of ERT

Survey Location	Quantity	Electrode Installation	Survey Depth
ERT-1	L=240m	5m interval	52.4m
ERT-2	L=240m	5m interval	49.9m
ERT-3	L=240m	5m interval	49.9m
ERT-4	L=240m	5m interval	49.9m
ERT-5	L=240m	5m interval	49.9m
ERT-6	L=240m	5m interval	51.0m
ERT-7	L=240m	5m interval	52.0m



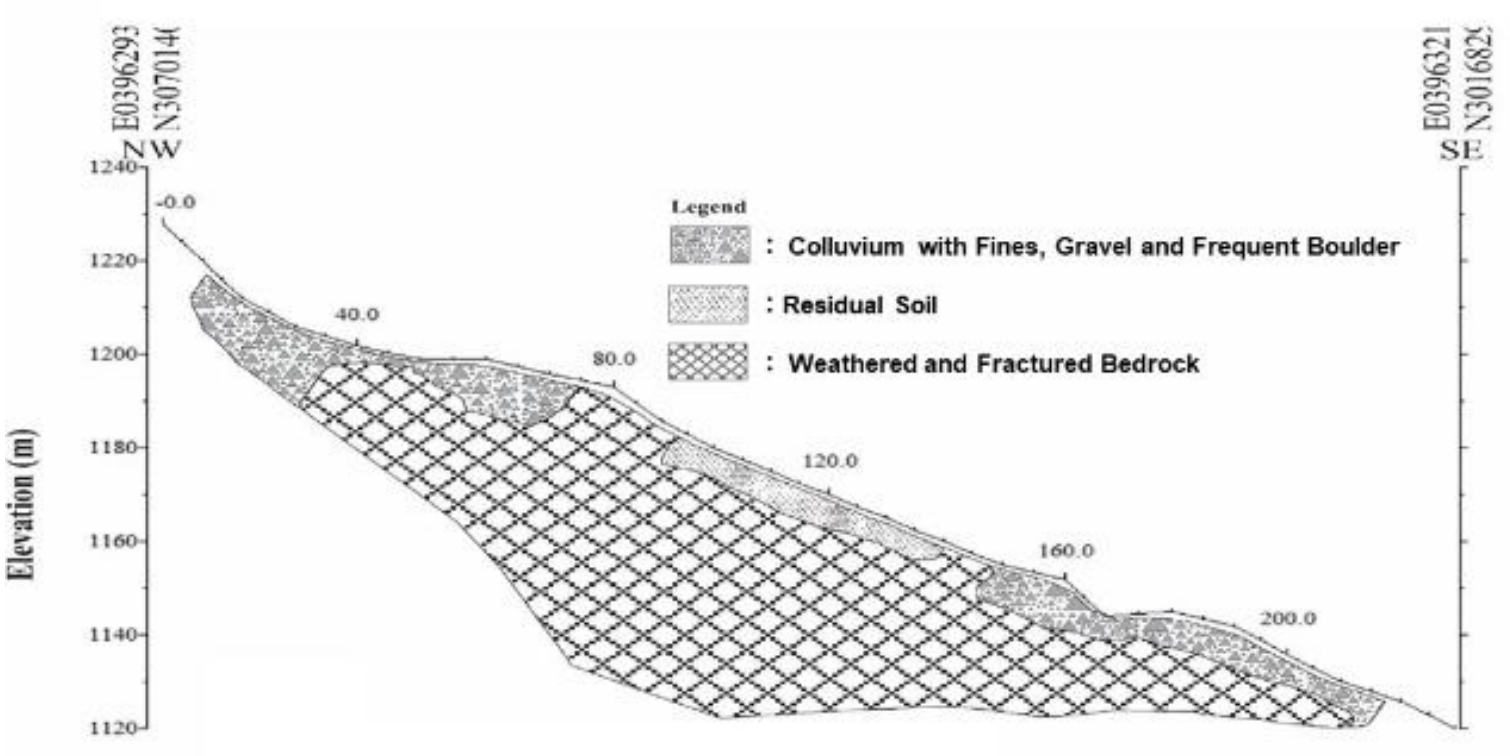
The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 8 m. The lower layer of topsoil is mainly weathered and fractured bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-7 Interpretative Geological Section along ERT (ERT-1)



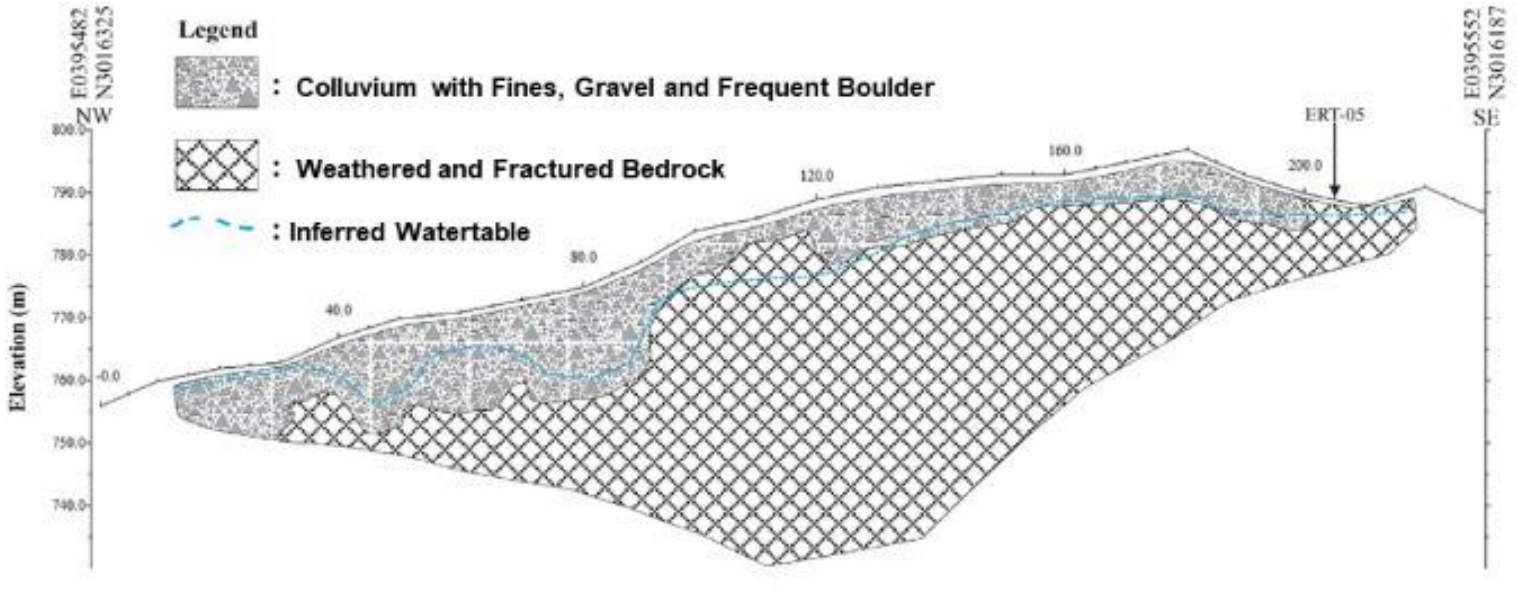
The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 8 m. The lower layer of topsoil is weathered and fractured bedrock and competent bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-8 Interpretative Geological Section along ERT (ERT-2)



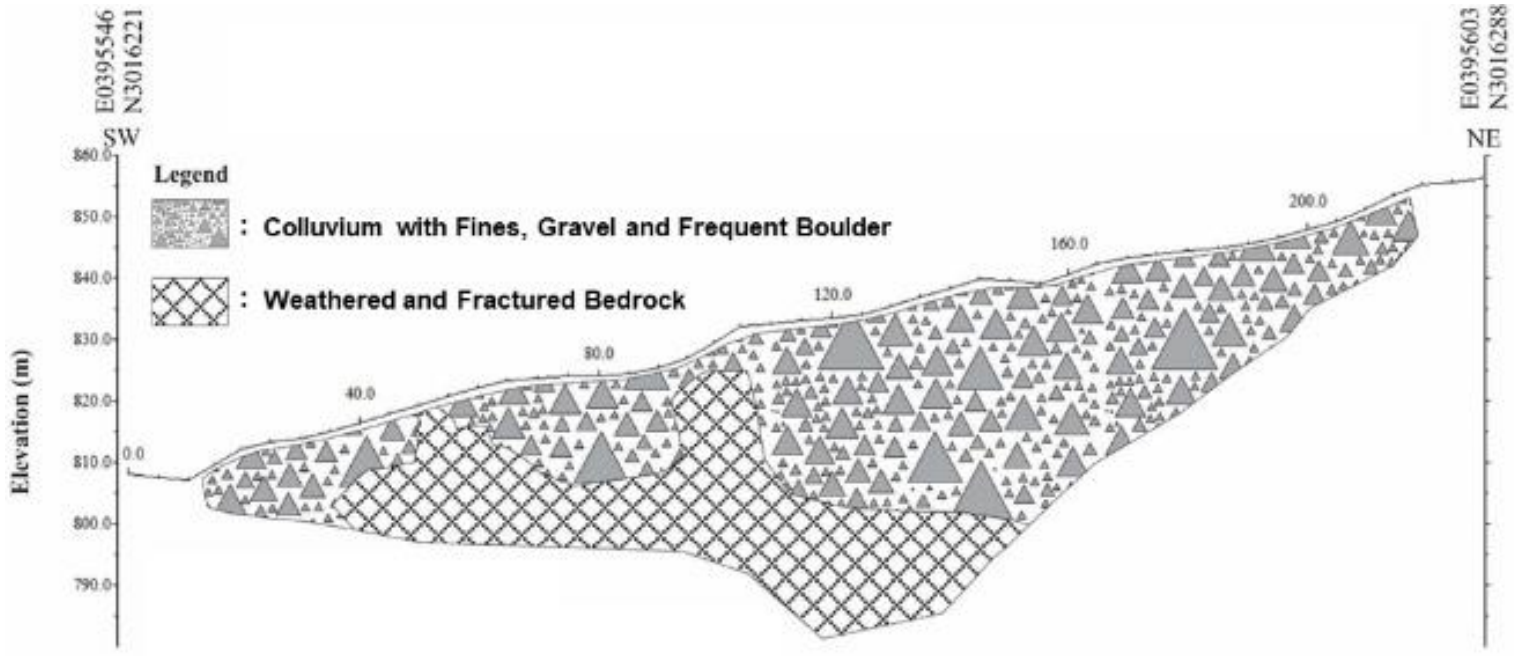
The average thickness of topsoil (colluvium with fines, gravel and frequent boulder and residual soil) is 5 m. The lower layer of topsoil is mainly weathered and fractured bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-9 Interpretative Geological Section along ERT (ERT-3)



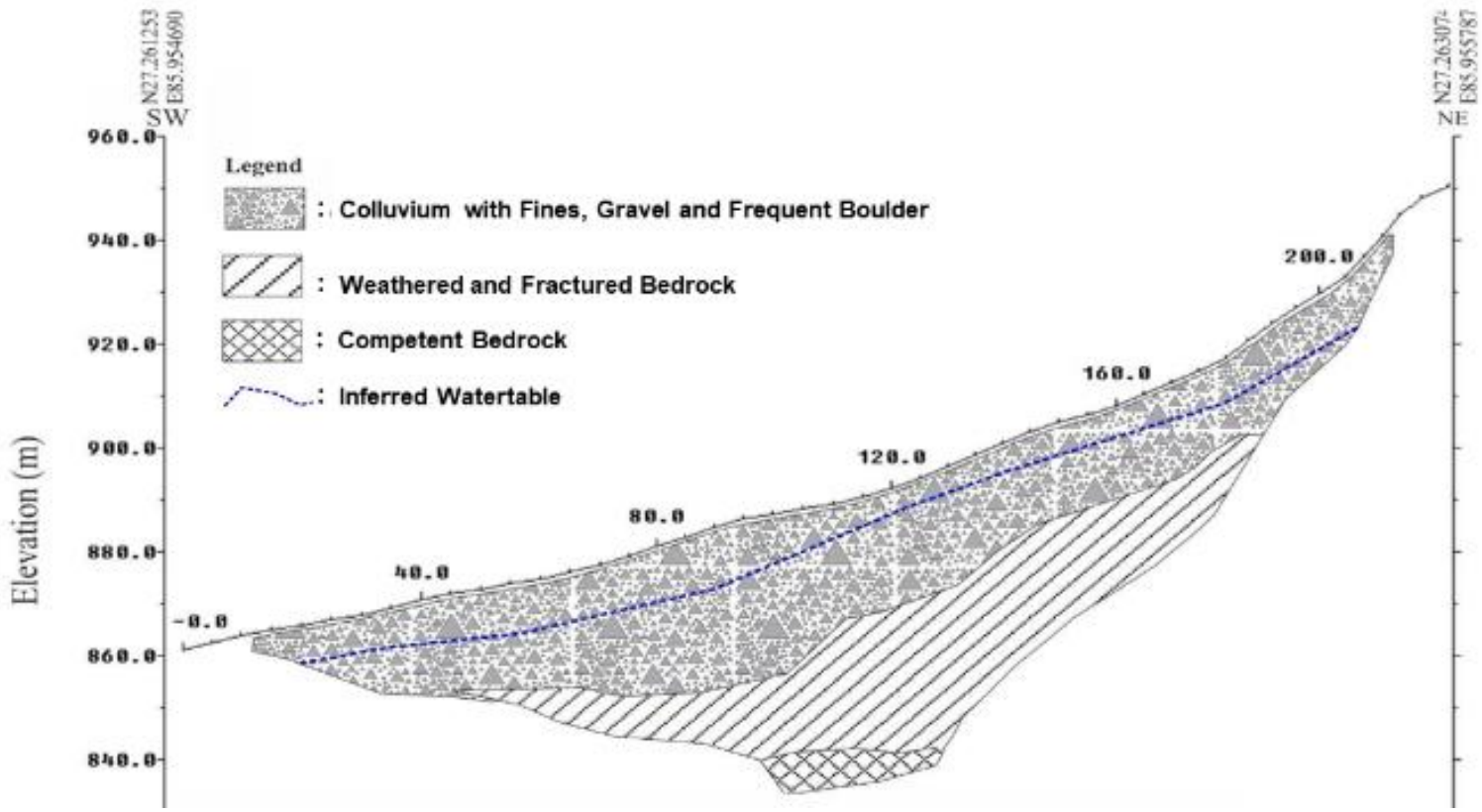
The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 11 m. The lower layer of topsoil is mainly weathered and fractured bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-10 Interpretative Geological Section along ERT (ERT-4)



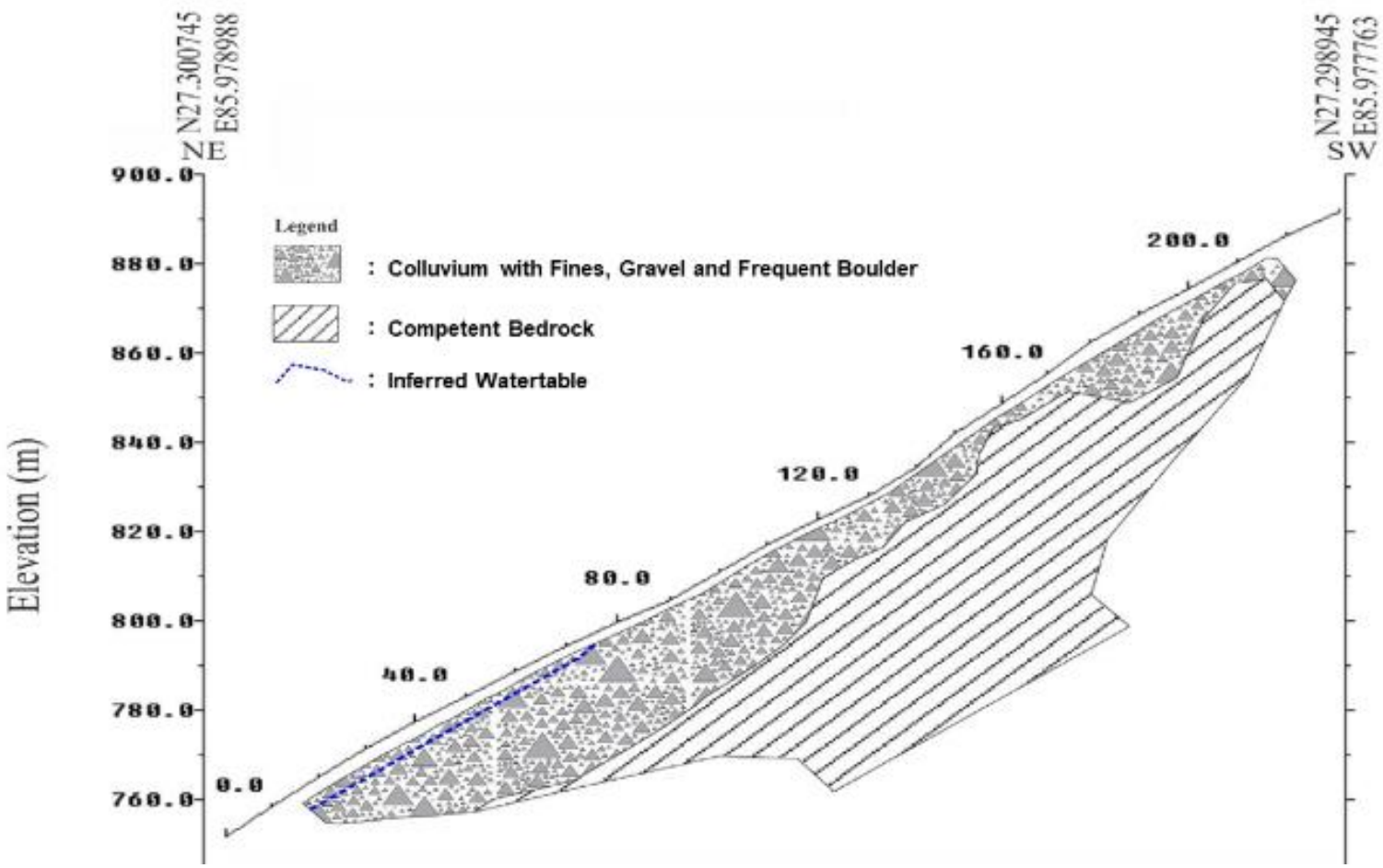
The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 18 m. The lower layer of topsoil is mainly weathered and fractured bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-11 Interpretative Geological Section along ERT (ERT-5)



The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 17 m. The lower layer of topsoil is mainly weathered and fractured bedrock.
Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-12 Interpretative Geological Section along ERT (ERT-6)



The average thickness of topsoil (colluvium with fines, gravel and frequent boulder) is 12 m. The lower layer of topsoil is mainly weathered and fractured bedrock. Expected groundwater line (inferred watertable) is very shallow.

Source: Final Report (Feasibility Study of Road Tunnels (Khurkot - Sindhuli Khanda Road Tunnel))

Figure 12.2-13 Interpretative Geological Section along ERT (ERT-7)

12.3 REVIEW RESULTS

This section describes the review results of the tunnel studies undertook by the JICA Desk Study Project and the Nepal F/S Project. The review was conducted focusing on the following items that are important in tunnel routing.

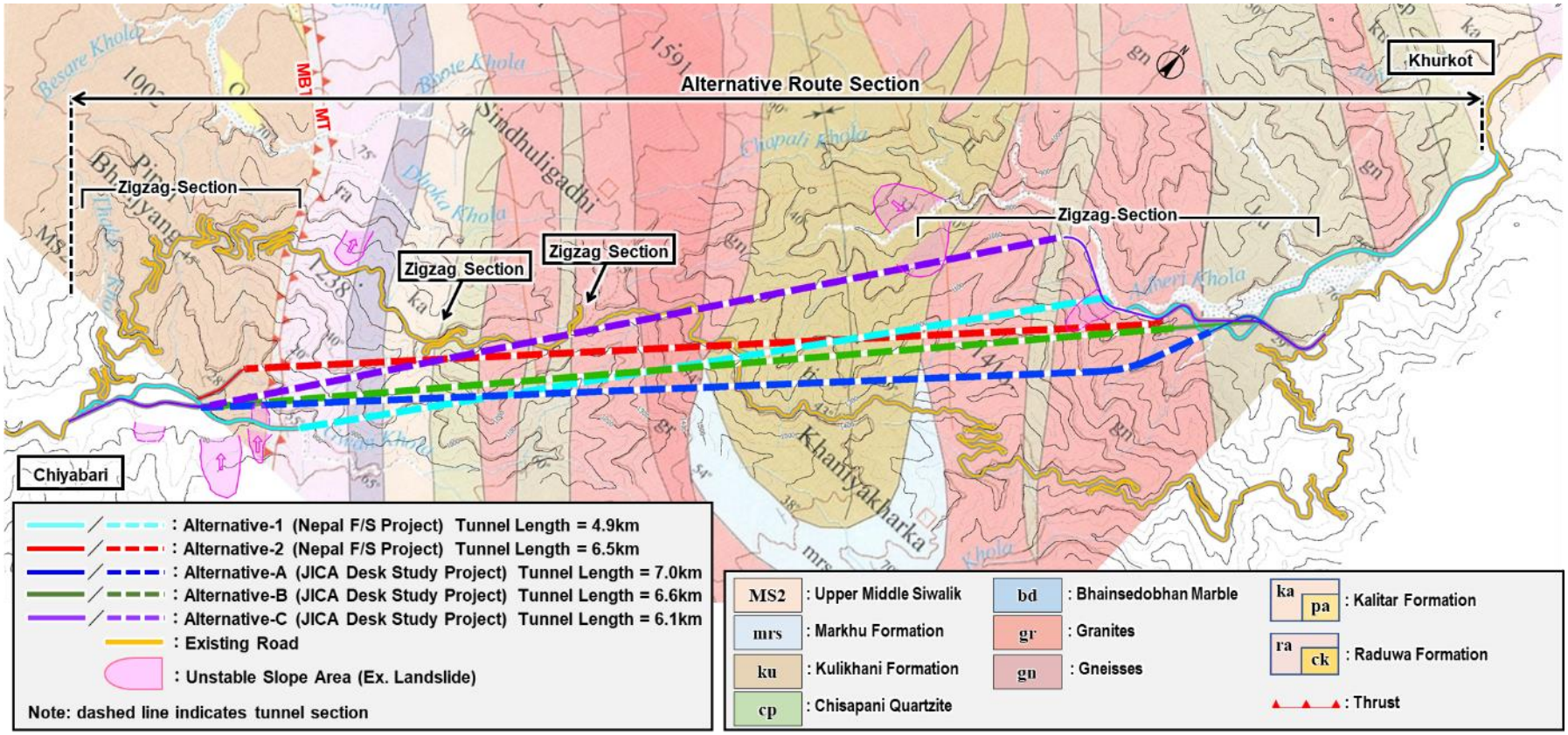
a) Tunnel Section (Alternative Route Section)
b) Tunnel Alignment
c) Lane Operation Method in Tunnel Section
d) Tunnel Structure

The review results are shown in Table 12.3-1.

Table 12.3-1 Review Results

Review Items	Study Results of Preceding Projects	Review Results
Tunnel Section	• Alternative routes with a tunnel have been planned at the section between Chiyabari province and Khurkot province to bypass all bottleneck sections of Section II. (JDSP/NFSP*1) (See Figure 12.3-1)	• The tunnel section between Chiyabari province and Khurkot province is generally appropriate.
Tunnel Alignment	• Total 5 tunnel routes, have been planned in the preceding projects, and tunnel length is approximately 5 km to 7 km. (JDSP/NFSP) • Horizontal alignment of the tunnels is straight or straight and gentle curve (JDSP/NFSP) • Vertical alignment (gradient) of the tunnels is 0.20% to 2.00% (JDSP/NFSP)	• A tunnel portal of the Alternative-1 studied by NFSP is planned at active/unstable slope area. (It is undesirable from the viewpoint of disaster prevention.) • Vertical alignment (0.20%) of the Alternative-2 studied by NFSP does not meet the requirement of the Nepal Road Standards 2070. (Minimum vertical alignment of tunnel section is 0.40% in the Standards) • Tunnel alignments of preceding projects have not been studied in consideration of the Main Boundary Thrust (MBT) and the Mahabharat Thrust (MT).
Lane Operation Method in Tunnel Section	• It was recommended that a double tube tunnel with 1 lane is safer than a single tube tunnel with 2 lanes in JDSP. • In NFSP, although 2 types of tunnel cost (a double tube tunnel with 1 lane and a single tube tunnel with 2 lanes) were estimated by each alternative, technical study for lane operation method was not conducted.	• Since comparative study of a double tube tunnel with 1 lane and a single tube tunnel with 2 lanes was not conducted, it is necessary to conduct the comparative study of both methods from various points of view such as road safety, cost, etc. • From the viewpoint of disaster prevention and road safety in tunnel, it is necessary to consider the necessity of a rigid median strip in the tunnel section, the conditions of vehicle traffic regulation in tunnel, the installation of an evacuation tunnel, etc.
Tunnel Structure	• Structural measures (auxiliary method) for MBT and MT were not considered. (JDSP/NFSP)	• It is necessary to consider auxiliary methods, which may apply to MBT and MT, based on the results of the site reconnaissance and geological survey.

*1: JDSP (JICA Desk Study Project), NFSP (Nepal F/S Project)
Source:JICA Survey Team



Source: JICA Survey Team

Figure 12.3-1 Alternative Route Section

CHAPTER 13 STUDY ON POSSIBILITY OF TUNNELING AT SECTION II

13.1 INTRODUCTION

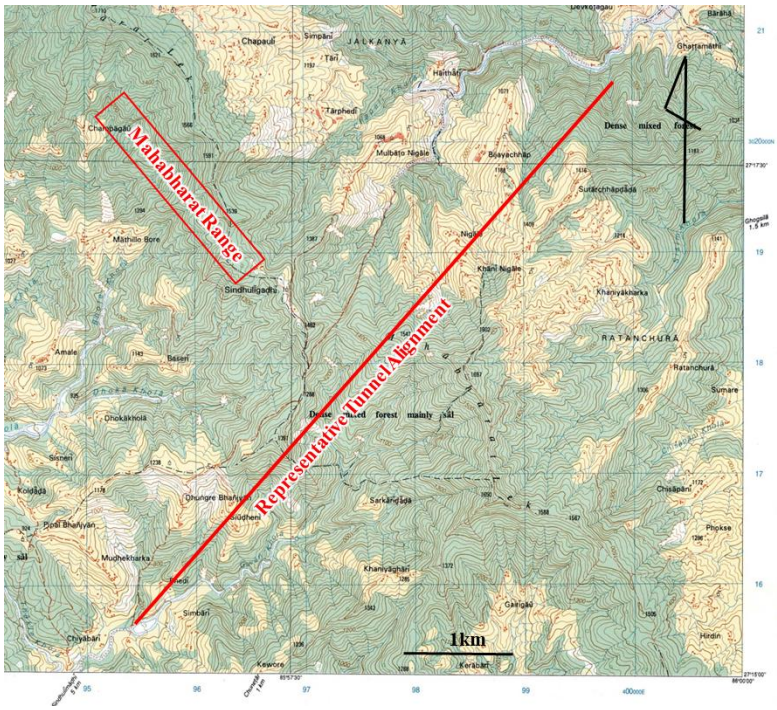
This chapter discusses about the outline study of tunneling at Section II. As already mentioned in the previous chapters, Section II is particularly the most extreme section among the sections of the Sindhuli Road and consideration of tunneling for the road function enhancement of the section is more rational. Under such condition, the study of justifiable routes is studied. Subsequently, the study also takes into consideration specifications as the cross section and tunnel classification.

The chapter also compiles the findings of the field reconnaissance conducted under the survey. Field reconnaissance was extensively conducted owing to the fact that the section passes along hilly regions and more importantly across two main thrusts the Main Boundary Thrust (MGT) and the Mahabharat Thrust (MT) and the findings are applied to the overall evaluation in determining the prospects of tunneling and construction of approach road.

13.2 TOPOGRAPHICAL AND GEOLOGICAL CONDITION AT SECTION II

13.2.1 Topographical Condition around the Planned Tunnel Site

The planned tunnel site is located in the Middle East of Nepal and the tunnel alignment traverses through the Mahabharat Range. The Mahabharat Range (Lesser Himalaya) is a major mountain range with NW-SE direction and with crest elevations of 1,500m to 2,700m, and runs in parallel with the Higher Himalaya (North) and Sub-Himalaya (South). The proposed tunnel alignment (NE-SW direction) through the feeder ridges separated from the main ridge with elevation of 900m to 1,700m (see Figure 13.2-1).



Source: 1/25,000 Topographic Map (No.2785 12D), Survey Department (1995)

Figure 13.2-1 Topographic Condition of the Proposed Tunnel Site

Mahabharat range has a steep terrain throughout, and the slope starting from the ridge has a very steep slope of more than 60 degrees. Medium to large scale of landslides are distributed mainly around the south tunnel portal and small to medium scale of slope failures are observed at the whole of the survey area.

The water system around the proposed tunnel site is divided into two by the Mahabharat Range extending in the NW-SE direction as mentioned above, and the rivers in this vicinity flow down in the direction orthogonal to the Mahabharat Range.

Gawan Khola and its tributaries, located around the south tunnel portal, flow down to the SW direction (Figure 13.2-2). Adheri Khola and its tributaries, located around the north tunnel portal, is a tributary to the Sunkoshi River, and flow down to the NE direction and joins Sunkoshi River at Khurkot (Figure 13.2-3).

Source: JICA Survey Team

Figure 13.2-2 View around the South Tunnel Portal

Source: JICA Survey Team

Figure 13.2-3 View around the North Tunnel Portal

13.2.2 Geological Condition around the Planned Tunnel Site

(1) Geological Condition

The main objective of provision of tunnel at Section II is to provide smoother route that will reduce the access time as well as to minimize risks of traffic accident and disasters thereby enhance the road function of the Sindhuli Road.

The planned tunnel alignment passes through the Mahabharat Range topographically and passes through the Higher Himalaya Zone as well as the Mahabharat Synclinorium geologically. Because of the long stress history of the mountain range, the survey area consists of several minor and major faults, folds, and their shear zones.

In the survey area, from south to north, sedimentary rocks of Siwalik Group belonging to the Sub Himalaya, sedimentary rocks and low-grade metasediments of Nawakot Complex belonging to the Lesser Himalaya, and relatively high-grade metasediments of Kathmandu Complex belonging to the Higher Himalaya are distributed. These groups and complexes are separated by low angle reverse faults of MBT and MT respectively. And MT is considered as the southward extension of the Main Central Thrust (MCT), (see Table 13.2-1, Figure 13.2-4, Figure 13.2-5)

Table 13.2-1 Stratigraphic Subdivisions of the Survey Area

Zone	Complex	Group	Formation	Symbol	Lithology	Thickness (m)	Geological Age
Higher Himalaya	Kathmandu	Phulchauki	Tistung Formation	ti	Metasandstone, Phyllite	1,000	Lower Paleozoic
		Slight Unconformity					
		Bhimphedi	Markhu Formation	mrs	Marble, Schist	-	Precambrian
			Gneiss	gn	Gneiss	600 - 900	Precambrian to Lower Paleozoic
			Sindhuli Granite	gr	Granite	650	
			Kulekhani Formation	ku	Quartzite, Schist	-	Precambrian
			Chisapani Quartzite	cp	Quartzite	200+	
			Kalitar Formation	ka	Schist, Quartzite	800	
			Bhainsedobhan Marble	bd	Marble	-	
			Raduwa Formation	ra	Garnet-Schist	450	
Mahabharat Thrust (MT) *southward extension of Main Central Thrust (MCT)							
Lessor Himalaya	Nawakot	Upper Nawakot	Benighat Slates	bg	Slate, phyllite	550	Paleozoic
Main Boundary Thrust (MBT)							
Sub Himalaya	-	Siwalik	Upper Middle Siwalik	MS2	Sandstone, Mudstone	1500	Middle Miocene

Exposed along the Tunnel Alignment

Source: JICA Survey Team

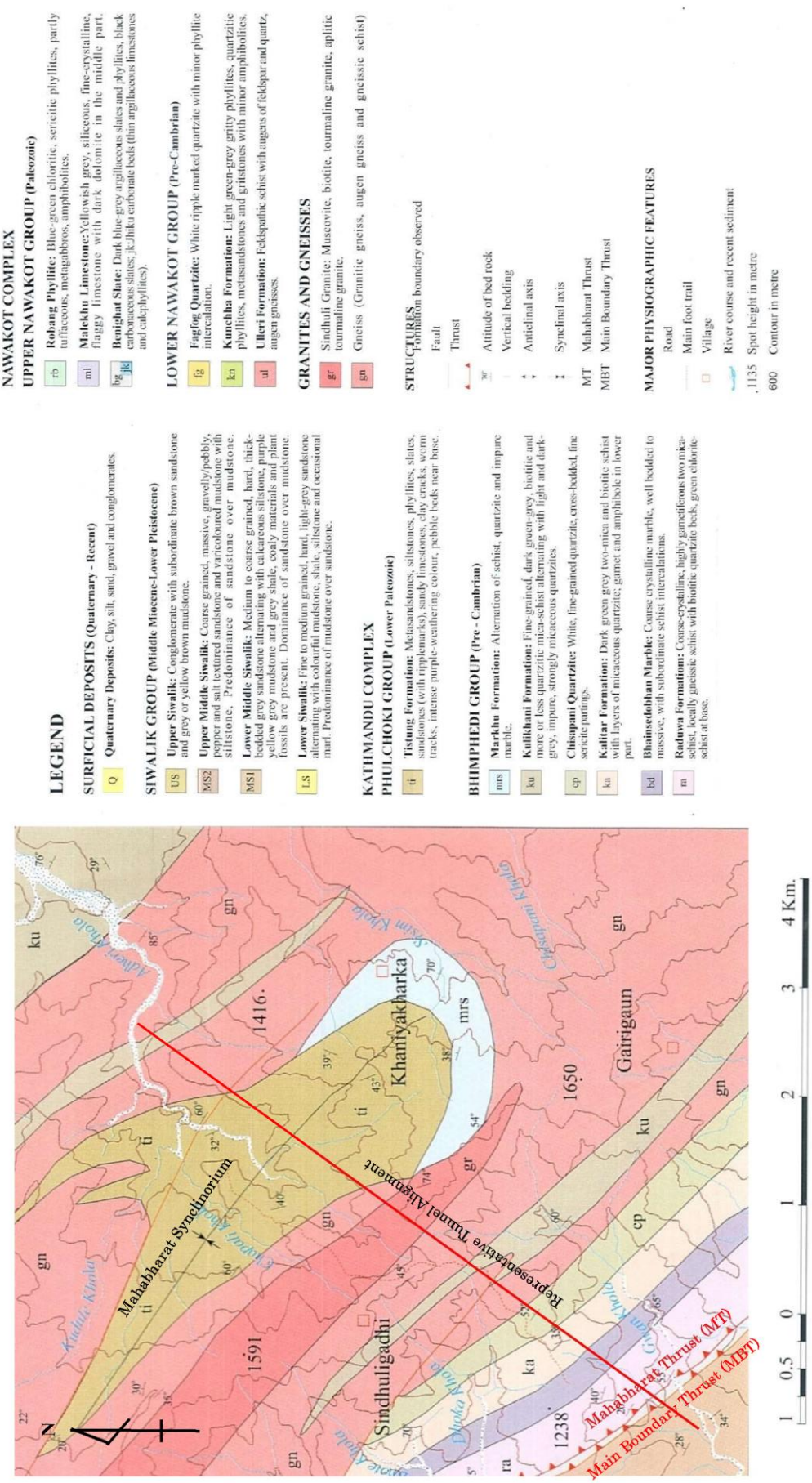
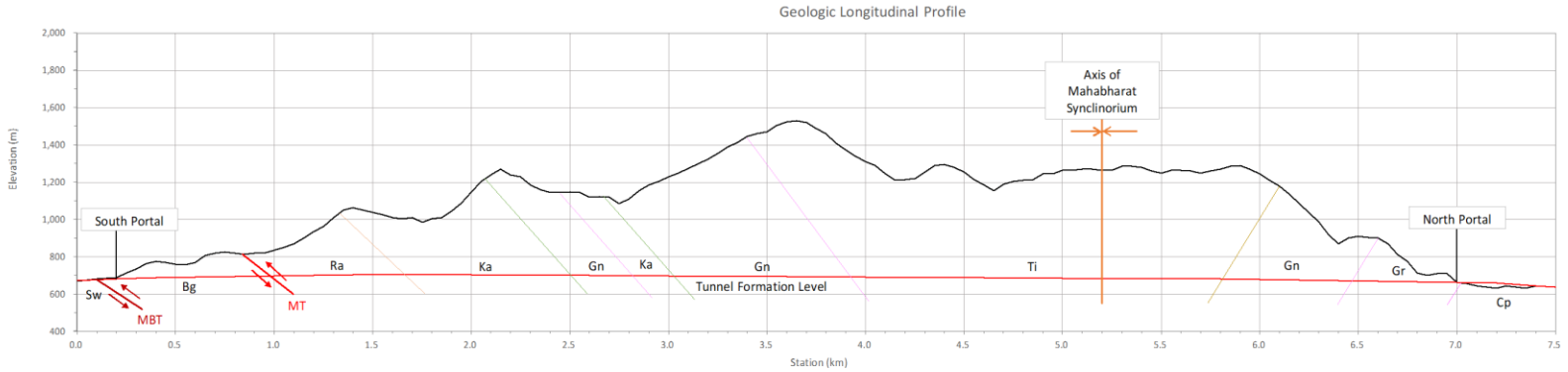


Figure 13.2-4 Geological Map of Survey Area

Source: Department of Mines and Geology 2008

Longitudinal Profile



Tunnel Alignment		South Portal	Tunnel										North Portal
Geomorphology	Siwalik Hill	Mahabharat Range											
Geology – Zone	Sub Himalaya	MBT (Main Boundary Thrust)	Lesser Himalaya	MT / MCT (Mahabharat Thrust / Main Central Thrust)	Higher Himalaya								
Geology – Complex	–		Nawakot Complex		Kathmandu Complex								
Geology – Age	Middle Miocene		Paleozoic		Precambrian				Precambrian to Lower Paleozoic	Lower Paleozoic	Precambrian to Lower Paleozoic		Precambrian
Geology – Group	Siwaliku Group		Upper Nawakot Group		Bhimphedi Group				Intrusive rock	Phulchauki Group	Intrusive rock		Bhimphedi Group
Geology – Unit	Middle Siwalik		Benighat Slates		Raduwa Formation	Kalitar Formation	Intrusive	Kalitar Formation	Intrusive rock	Tistung Formation	–	Sindhuli Granite	Chisapani Formation
Geology – Lithology	Sandstone, Mudstone		Slate / Phyllite, Quartzite, Limestone, Dolomite		Garnet Schist	Schist, Quartzite	Gneiss	Schist, Quartzite	Gneiss	Metasandstone, Phyllite	Gneiss	Granite	Quartzite, Schist
Geology – Symbol	Sw		Bg		Ra	Ka	Gn	Ka	Gn	Ti	Gn	Gr	Cp
Geology – Length (m)	–		800		580	920	320	230	880	1,900	700	670	–
Geology – Geological Structure / Dipping	Dip to NE		Dip to NE		Dip to NE					Axis	Dip to SW		
					Mahabharat Synclinorium								
Rock Condition of Tunnel Formation Level based on GSI (Geological Strength Index)	Class IV Poor rock	Class IV to V Very Poor to Poor			Class III Fair		Class II Good	Class III Fair	Class II Good	Class III Fair / Class III to IV Fair to Poor / Class III Fair	Class II Good	Class III to IV Fair to Poor	Class IV Poor
Note	Highly to moderately weathered soft rock.	Due to the influence of the MBT and MT, weak zone is observed with length of approximately 800m between MBT and MT. Highly to moderately fractured zone (carbonaceous phyllite, phyllite) and moderately to slightly fractured zone (quartzite, limestone, dolomite) are distributed in alternately, and forming the weak zone.			Almost fresh to slightly weathered rock with slightly to moderately jointed condition is expected at the tunnel formation level.	Almost fresh rock with moderately jointed condition is expected at the tunnel formation level.	Almost fresh rock condition is expected.	Almost fresh rock with moderately jointed condition is expected.	Although deep weathering is observed on the surface level, almost fresh rock condition is expected at the tunnel formation level.	Almost fresh rock with moderately jointed condition is expected at the tunnel formation level. Rock condition near the syncline axis is expected poor than that of other section.	Although deep weathering is observed on the surface level, almost fresh rock condition is expected at the tunnel formation level.	Almost fresh to slightly weathered rock with slightly jointed condition is expected at the tunnel formation level.	Moderately to slightly weathered and moderately jointed rock.

Source: Based on the actual geological condition; prepared by the JICA Survey Team

Figure 13.2-5 Geological Longitudinal Profile of Representative Tunnel Alignment

The outline of each formation is described below.

1) Siwalik Group

The Siwalik Group consists of sedimentary rocks of sandstone, siltstone, mudstone, and conglomerate. And it is lithostratigraphically subdivided into the Lower Siwalik, the Lower Middle Siwalik, Upper Middle Siwalik and the Upper Siwalik from the bottom to the top respectively. Only sandstone and mudstone of the Middle Siwalik are exposed in the southern part of the survey area. The Upper Middle Siwalik and the Benighat Slates of the Nawakot Complex is separated by MBT. The sandstones of the Middle Siwalik are salt, and pepper textured, poorly sorted, coarse-grained. The thickness of the sandstone bed is 5 to 7m and the sandstone is followed by thinly laminated mudstone. The general strike of the bed in the survey area is NW-SE and the bed dips towards NE.

2) Nawakot Complex

The Nawakot Complex consists sedimentary rocks and low-grade metasediments. And it is subdivided into the Lower Nawakot Group and the Upper Nawakot Group (Stocklin and Bhattarai 1977, and Stocklin 1980). In the survey area only the Benighat Slates of the Upper Nawakot Group is exposed. Benighat Slates of the Nawakot Complex and Raduwa Formation of Kathmandu Complex is separated by MT.

The Benighat Slates is exposed in the southern part of the survey area and it is bounded by the MBT in the south and the MT in the north. This formation consists of following 5 units in the survey area.

a) Slate Unit

Thin bands of gray to dark-gray slate alternating with very-thin to thin beds of limestone (slate>>limestone). Slate unit is highly weathered and highly fractured.

b) Phyllite and dolomite Unit

Thin-to-medium bedded white siliceous-dolomite alternating with greenish-gray and bluish-gray phyllite.

c) Carbonaceous Phyllite Unit

Strongly foliated, thick bands of carbonaceous phyllite. Dark-gray to black carbonaceous phyllite with elongated veins of quartz.

d) Quartzite and Phyllite Unit

Alternating bands of pelitic phyllite and thin bedded, fine to medium-grained, light gray quartzite (phyllite>>quartzite)

e) Limestone and Phyllite Unit

Medium-to-thick bedded, fine-grained, argillaceous, gray limestone overlain by bluish gray pelitic phyllite and medium-to-thick bedded white limestone. The general trend of the formation in the survey area is NW-SE and the bed dips towards NE.

3) Kathmandu Complex

The Kathmandu Complex consists relatively high-grade metasediments. It is subdivided into Bhimphedi Group consisting of high-grade metasediments of Precambrian age, and the Phulchauki Group consisting of un-metamorphic or weakly metamorphosed sediments of Precambrian to early middle Paleozoic age (Stocklin and Bhattarai 1977 and Stocklin 1980). These groups are possibly separated by a slight unconformity.

Around the planned tunnel site, from lower to upper, Raduwa Formation, Bhainsedobhan Marble, Kalitar Formation, Chisapani Quartzite, Kulikhani Formation, Markhu Formation of Bhimphedi Group, and Tistung Formation of Phulchauki Group are exposed.

a) Bhimphedi Group (Raduwa Formation)

This formation is separated from the rock units of the Nawakot Complex by the MT. The lithology of this formation is represented dominantly by dark green-gray mica schists of coarse crystalline aspect. Biotite is the predominating mineral, but sericite, muscovite, chlorite, and garnet are also commonly present. Red garnets sometimes reach up to 1 cm in diameter. And this formation also contains some subordinate bands of gray micaceous quartzite and its pale green or white, purer varieties. The upper contact of the Raduwa Formation with the Bhainsedobhan Marble is perfectly transitional, and marked by an approximately 20–30 m thick sequence of schist and marble. The general trend of the formation is NW-SE and the formation dips towards NE.

b) Bhainsedobhan Marble

The main component of the Bhainsedobhan Marble is coarse to very coarse crystalline (up to a few mm long calcite grains) form. The white marble also contains some pale yellow, pinkish or light brown dolomitic marble lenses and bands. The general trend of the formation is NW-SE and the formation dips towards NE.

c) Kalitar Formation

This formation is consists of predominantly psammitic schist with an occasional band of micaceous quartzite. The psammitic schist is medium to coarsely crystalline showing good schistosity. In this schist, biotite is the dominant mineral along with quartz, but muscovite, sericite and chlorite are also present in notable amount. The general trend of the formation is NW-SE and the formation dips towards NE.

d) Chisapani Quartzite

This formation consists of thin to thick bedded, slabby and white crystalline quartzite. This lithology is a good marker between the much darker quartzite and schist of the underlying Kalitar Formation and the overlying Kulekhani Formation. The general trend of the formation is NW-SE and the formation dips towards NE.

e) Kulekhani Formation

This formation consists of laminated, dark grey finely crystalline micaceous quartzite, and schist.

The thickness of the quartzite beds varies from 20 cm to 1m. Schist band thickness ranges from 30 cm to 1.5 m. The general trend of the formation is NW-SE and the formation dips towards NE.

f) Markhu Formation

In this formation, green grey to light grey, medium to massive bedded, fine to medium grained calcareous schist and micaceous calcareous quartzite are predominant. The light grey, thin beds of quartzite are also intercalated with calcareous schists. The general trend of the formation is NW-SE and the formation dips towards NE in the southern wing of the Mahabharat Synclinorium and dips towards SW in the northern wing of synclinorium.

g) Phulchauki Group (Tistung Formation)

This formation mainly consists of clastic sequences of metasandstone, metasiltstone, phyllite and slate. Some calcareous metasandstone beds are interbedded with phyllites. This formation is occupying the most part of synclinal cores together with gneiss and granite, and exposed near the axis of the Mahabharat Synclinorium. The general trend of the formation is NW-SE and the formation dips towards NE in the southern wing and dips towards SW in the northern wing of the Mahabharat Synclinorium.

4) Granite and Gneiss

At Sindhuli Ggdhi, the gneiss and granites occupying most part of synclinal cores together with Tistung Formation, and granites gradually change into granitic gneisses and then to augen and banded gneisses while moving towards the flanks.

a) Sindhuli Granite

The project site is characterized with the intrusion of granite in the Markhu Formation and Tistung Formation, which is observed at the north of Sindhuligadhi. The granite in this area represents grey to light grey, black and white, coarse grained, slightly weathered, massive granite with the presence of distinct feldspar phenocrysts. The granite contains tourmaline and muscovite. The tourmaline is measured with the variable size of millimeters to centimeters.

b) Gneiss

The Gneiss is exposed in north of Sindhuligadhi and occupying the most of synclinal cores together with Tistung Formation. In this area granitic gneiss and augen gneiss are dominant. The gneisses are grey to light grey, medium- to coarse-grained, medium to thickly foliated and slightly weathered with the presence of feldspar, quartz, biotite, muscovite, tourmaline and garnet. The phenocrysts of feldspar are distinct in augen gneiss.

5) Geological Structures

a) Mahabharat Synclinorium

The tunnel alignment passes through the Mahabharat Synclinorium as mentioned above. The dipping of beddings or foliations is towards NE at the southern wing and towards to SW at the northern wing. The axis of this synclinorium is located at the north part of the tunnel alignment.

b) Main Boundary Thrust (MBT)

The MBT passes along the south part of survey area. The thrust is defined by the sudden appearance of the older Benighat Slates of Upper Nawakot Group over the younger sandstones and mudstones of Upper Middle Siwalik Formation with concordant relation between.

c) Mahabharat Thrust (MT)

The MT passes along the south part of survey area. The thrust is defined by the sudden appearance of the older Raduwa Formation over the younger Benighat Slates with concordant relation between. The MT is considered that southward extension of Main Central Thrust (MCT), (Stocklin and Bhattarai 1977, Stocklin 1980, Acharya 2008).

(2) Important Geological Point

1) Fractured Zone between MBT and MT

Approximately 100 to 150 m zone around the MBT and approximately 50 m zone around the MT are subject to severe influence of the MCT and the MT and are recognized as fractured zone. During this period, the shearing is progressing and forming a sheared zone.

According to the results of ERT (Electrical Resistivity Tomography), which was carried out near the south tunnel portal, very low resistivity zone (week zone with high possibility of water retention) was observed around MBT and MT (see Figure 13.2-6).

On the other hand, in the zone between MBT and MT where the width is approximately 700m, highly to moderately fractured zone (slate, carbonaceous phyllite, phyllite) and moderately to slightly fractured zone (quartzite, limestone, dolomite) are distributed alternately, and forming the weak zone (see Figure 13.2-7).

Source: JICA Survey Team

Figure 13.2-6 Highly fractured carbonaceous phyllite

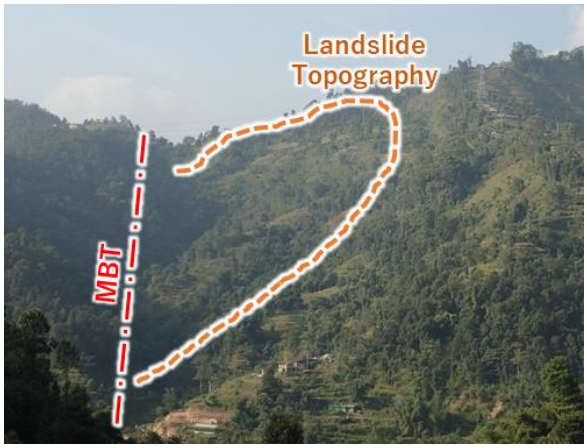
Source: JICA Survey Team

Figure 13.2-7 Moderately fractured phyllite

Furthermore, many large to medium scale landslides are observed in this weak zone (see Figure 13.2-8 and Figure 13.2-9).

Source: JICA Survey Team

Figure 13.2-8 Large scale of landslide topography observed on left bank of Gawan Khola



Source: JICA Survey Team

Figure 13.2-9 Medium scale of landslide topography observed on right bank of Gawan Khola

2) Landslides and Slope failures around the South Tunnel Portal

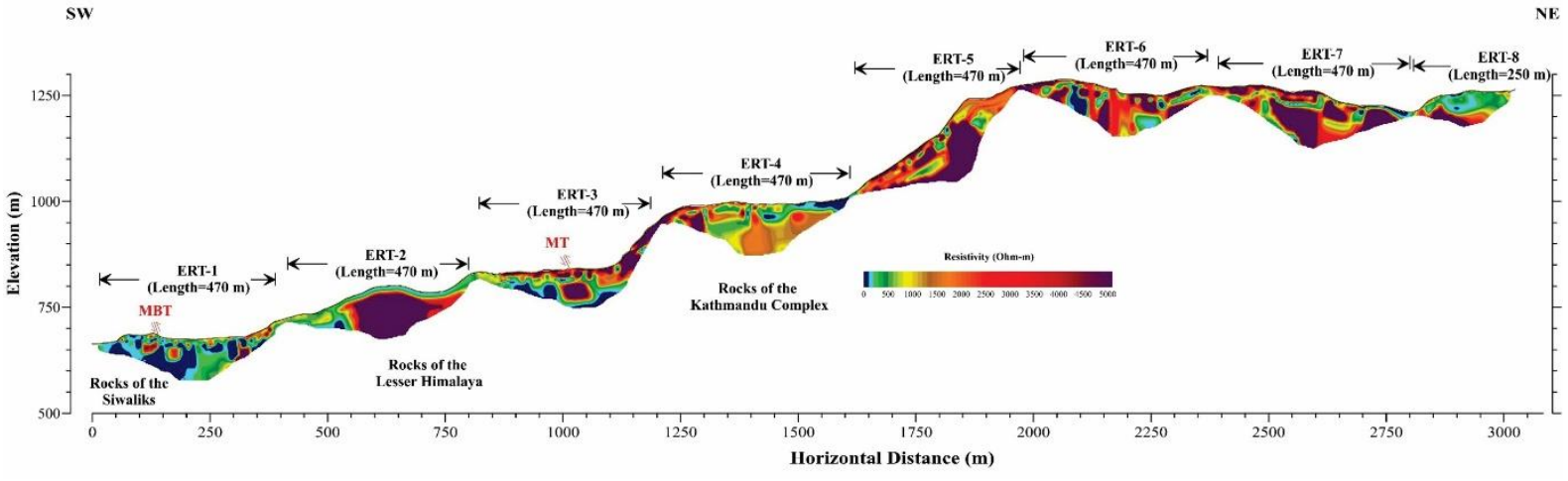
Landslide topography (topography with possible landslide) and slope failure were observed at the ridge where tunnel portal is proposed. Therefore, further geological investigation (drilling and ERT, etc.) and evaluation for these slope failures are recommended (see Figure 13.2-10).

Source: JICA Survey Team

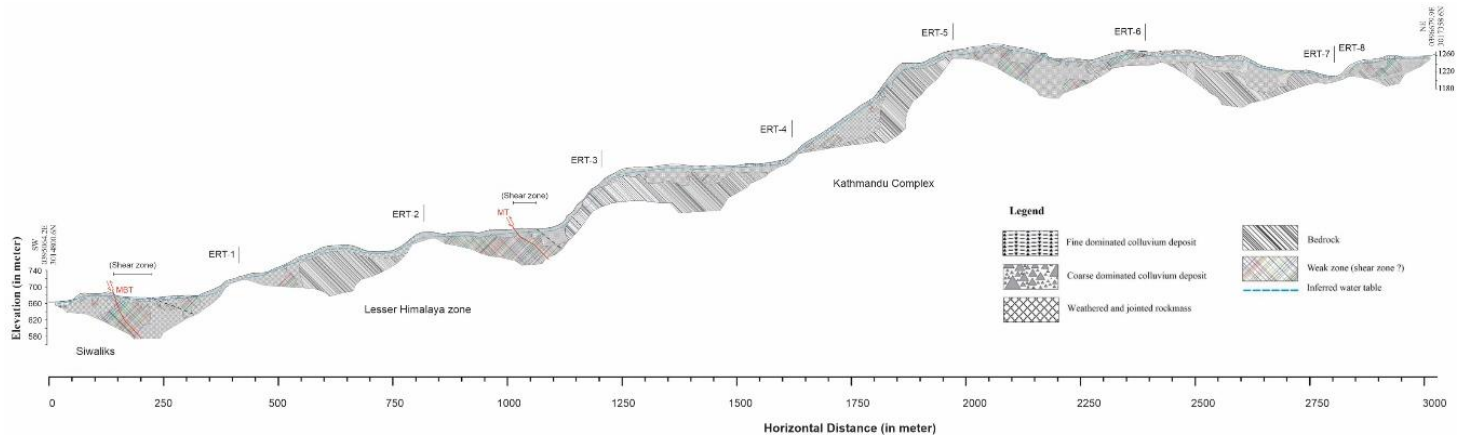
Figure 13.2-10 Landslide topography located near the proposed south tunnel portal

3) Rock Condition around the Axis of Mahabharat Synclinorium

It is confirmed that many small faults and rock deformation are observed around the syncline axis of Mahabharat synclinorium at the surface level and rock condition near the syncline axis is poor than that of away from the syncline axis. And it is considered that this poor rock condition is expected at the tunnel formation level (see Figure 13.2-11).



Electrical Resistivity Profile



Interpretative Geological Profile

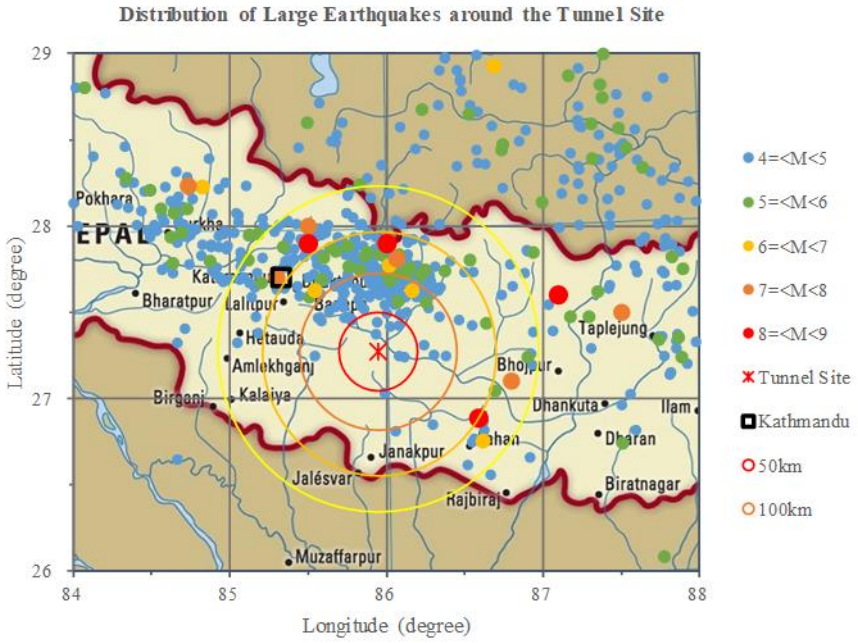
Source: JICA Survey Team

Figure 13.2-11 Result of ERT (Electric Resistivity Tomography)

13.2.3 Seismicity around Planned Tunnel Site

The entire territory of Nepal lies in high seismic hazard zone. The country's high seismicity is related to the movement of tectonic plates along the Himalayas that has caused several active faults. A total of 92 active faults have been mapped throughout the country by the Seismic Hazard Mapping and Risk Assessment for Nepal carried out as part of the Building Code Development Project – 1992-1994 (MHPP, 2994). According to "ISDR Global Assessment Report on Poverty and Disaster Risk 2009", maximum magnitude of earthquakes that these active faults are able to generate have also been identified as below, the faults in the Higher Himalaya tectonic area can generate maximum magnitude of 7 to 7.5, those along the MCT – 7.5 to 7.6, the mid-mountains – 6.5 to 6.9, and the MBT – 7 to 8 earthquakes. Along HFF, the faults have the capacity to generate 6.5 to 7.5 earthquakes.

No large earthquake which has magnitude of more than 5 was observed within the 50km range from the planned tunnel site (Figure 13.2-12). However, there is one large earthquake which has M6.3 (one of the aftershock of 2015 Gorkha Earthquake) in the 100km range. And two M6 class (2015), one M7 class (2015) and one M8 class earthquakes (1408) are observed within the 150km range. Furthermore, two M6 class (1916, 1988), three M7 class (1255, 1260, 1767) and two M8 class earthquakes (1833, 1934) are observed within the 200km range from the planned tunnel site.

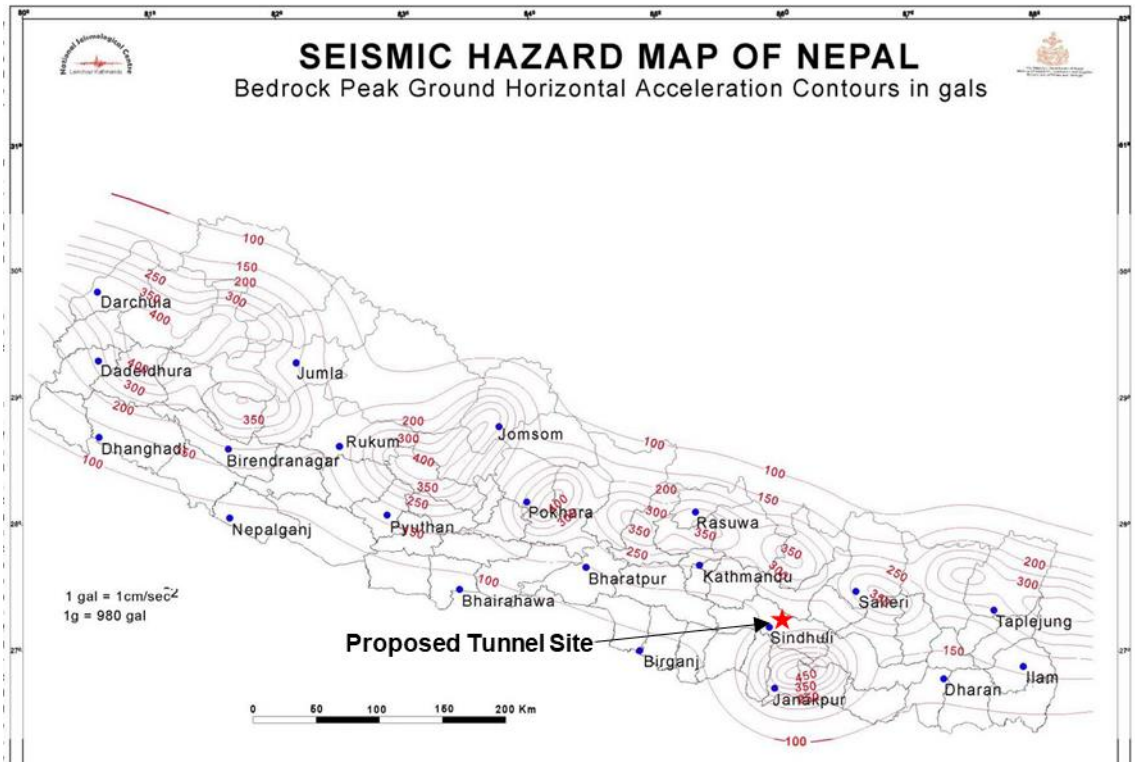


Source: JICA Survey Team

Figure 13.2-12 Distribution of Large Earthquakes around the Planned Tunnel Site

Due to 25th April 2015 Gorkha earthquake (M7.8) and its largest aftershock on May 12 (M7.3), the Sindhuli Road was damaged in a total of 25 places, including road surface subsidence, cracks, and slope failures in the Section II and III. Although, there was no detailed data regarding the largest peak ground acceleration around planned tunnel site, 241 gal on the EW component and 250 gal of the peak amplitude of the horizontal components were observed at the rock site KTP in Kirtipur, Kathmandu (Takai et al. 2016).

According to the Seismic Hazard Map of Nepal produced by the National Seismological Center (Figure 13.2-13), 150 gal of bedrock peak ground horizontal acceleration of an earthquake shall be supposed for design of the structures around the planned tunnel site.



Source: National Seismological Center, Nepal

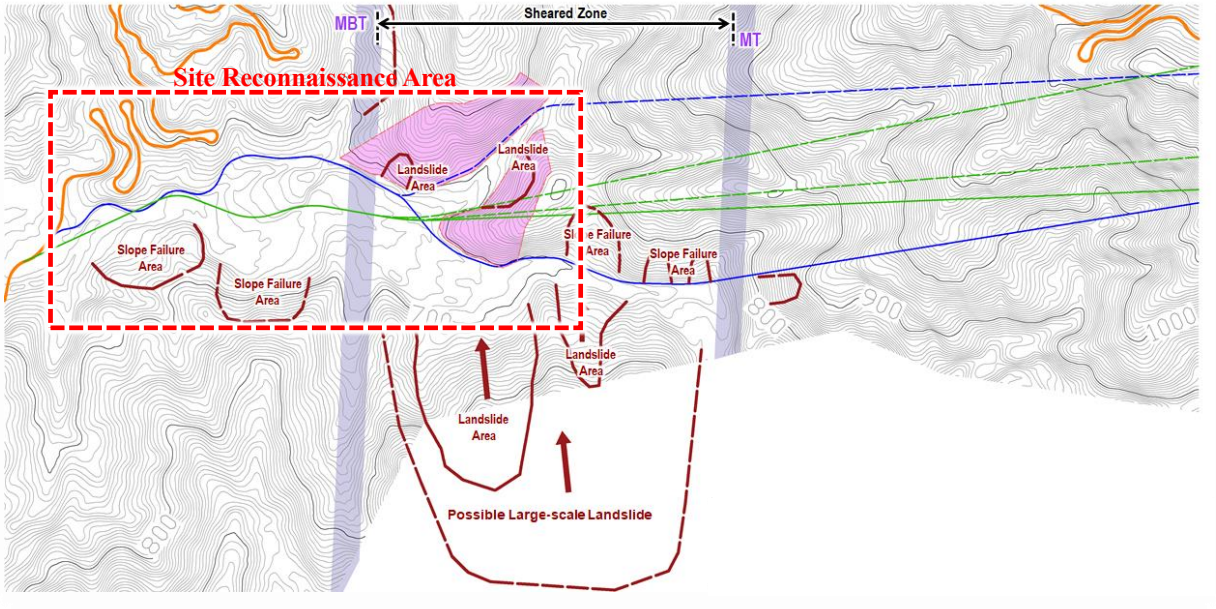
Figure 13.2-13 Seismic Hazard Map of Nepal

13.3 SITE RECONNAISSANCE AT APPROACH ROAD AND TUNNEL PORTAL

13.3.1 South Portal

(1) Reconnaissance Area

The South Portal area is from a part diverging from the existing road to the mountainous road where the south portal of tunnel is assumed. In this area, the newly proposed alignment (bypass) crosses the MBT and MT, the two famous thrusts in Nepal. From this divergence point over to the landslide near the peak of Section II is assumed as the area under influence of MBT, MT and sub thrust. For this reason, reconnaissance area is extensively planned and conducted at this area to obtain the information of MBT and fracture zone between the MBT and MT (Figure 13.3-1).

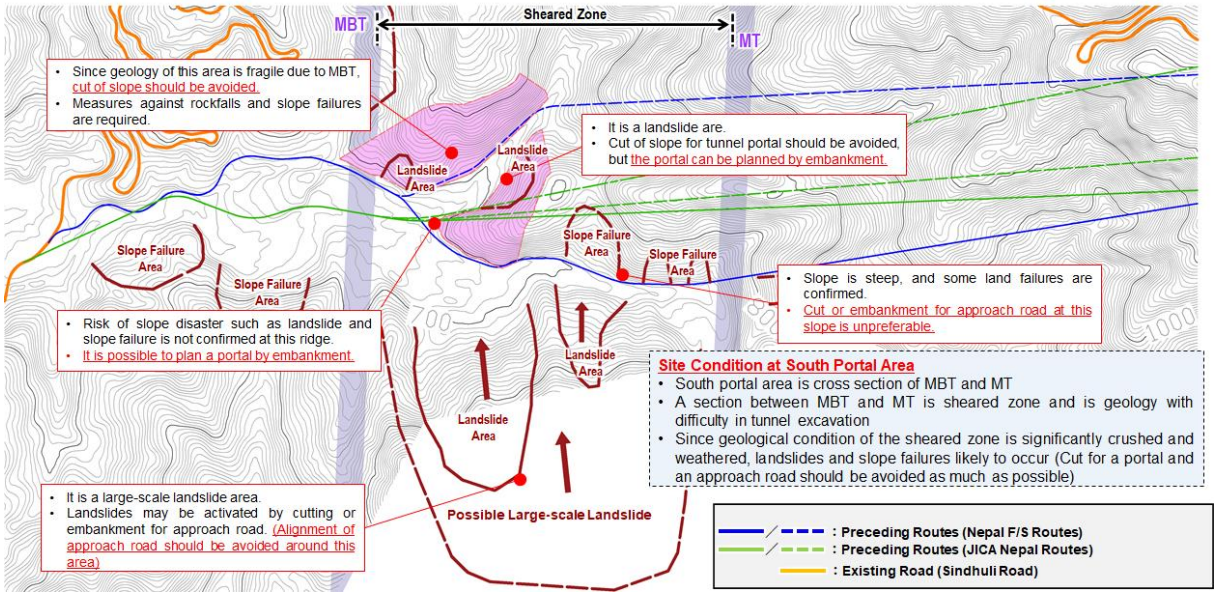


Source: JICA Survey Team

Figure 13.3-1 Site Reconnaissance Area of south tunnel portal

(2) Report of Site Reconnaissance

Report of Site Reconnaissance is shown in Figure 13.3-2.



Source: JICA Survey Team

Figure 13.3-2 Outline of Site Reconnaissance of south tunnel portal

The outline of site reconnaissance shows that the area between the part diverting over from the existing road and MT lies in a heavily fractured zone. Fractured and heavily weathered rock are mainly in this area and their stage varies at each area. The main contents of rock in this area are sedimentary rock and metasediments and there are many active landslide and slope failure as these rock beds unstable

and easily moved.

Some of the landslides and slope failures are traces from the past occurrences, but many, especially along the river, are active and young. This means new landslides and slope failures are caused by erosion at the bottom of a slope continuously (Figure 13.3-3). The former reports show the MBT crosses the planed south portal and these are confirmed during the reconnaissance under this survey which concluded the line of MBT (Figure 13.3-4).

Source: JICA Survey Team

Figure 13.3-3 New failure near the south portal

Source: JICA Survey Team

Figure 13.3-4 MBT line crossing the south portal

When large and active thrust like the MBT exists, highway and tunnel engineering need to consider the bands with sub thrust, cracked and fractured zone. As these bands appear as landslides and failures on the surface ground and unfirm cut face stability in the tunnels it is possible to construct a road and tunnel safely by applying countermeasures for the slope and auxiliary methods for the tunnels. On the tunnelling at these conditions like MBT and its fracture zone, there are many alternative plans that may be applied. If geological condition is suitable and landslide plane is shallow, it will be possible to design the tunnel under the landslide plane and fracture zone.

(3) Evaluation of the candidate route

This section shows the evaluation of the candidate route on the reconnaissance report. But this evaluation is based on the findings from limited surveys and investigations conducted under this survey. It is therefore important that the report be reassessed reflecting more and accurate results from further geological survey and environment survey in the subsequent surveys/studies. The blue lines on the Figure 13.3-2 are the routes proposed under the desk study of the Nepal F/S Project. The upper blue line (West side) touches the ridge of the hill in front of the MBT and after crossing the MBT it curves through the ridge with several traces of landslides and failures and takes a steep climb up the valley towards the portal. This plan is advantageous because it shortens the tunnel length as the portal is at a higher position. But the demerit here is that the route has to pass the ridge that is weak and severely fractured compounded with cutting of the existing ground that is under the influence of the MBT. This plan should therefore be avoided because this will require large-scale countermeasures for stabilization

of the slopes. Furthermore, a portion of the alignment after passing the weak slope up to the portal is curved and the slope is steep. But if the portal is extended toward the crossing point of the MBT allowing the tunnel to pass through the weak ridge as well as reduced the countermeasures for the slope stability, a good alignment to the portal and through the tunnel can be attained. Therefore, the upper blue line (West side) is recommended as a good candidate route.

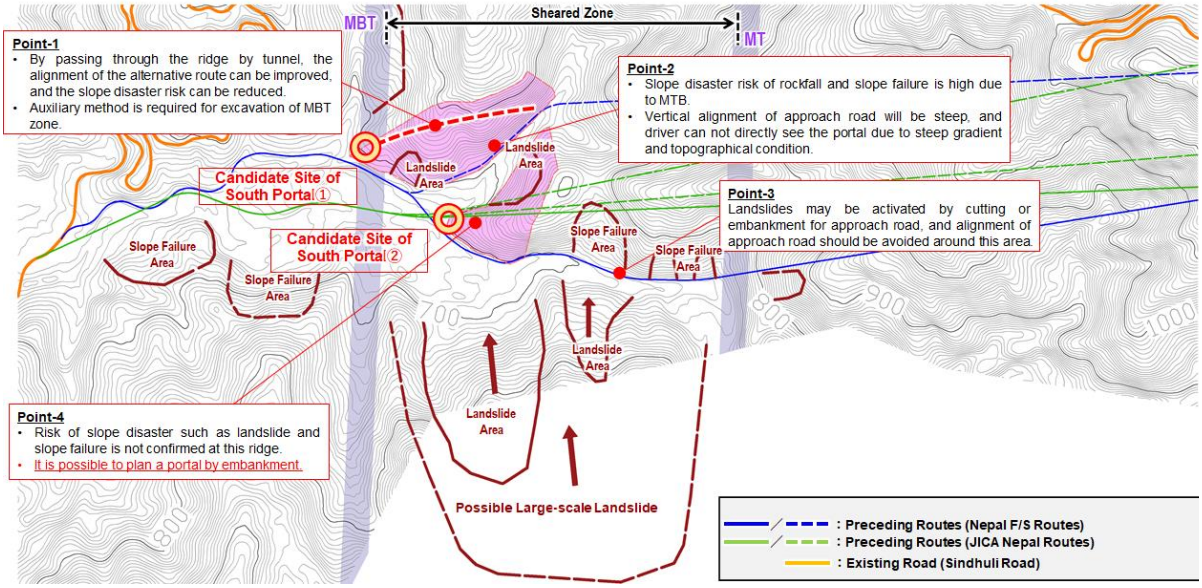
On the other hand, the bottom blue line (East side), which is the recommended route in the Nepal F/S Project, is evaluated as improper or needs further considerations. Although this route contributes to shortening the tunnel length, it passes through several landslide and slope failure areas and will be susceptible to disasters.

The green lines in the drawings indicate routes proposed by the JICA Desk Study Project. All the routes converge at one point indicating that the portal and the approach road are common to all routes. The portal is set at a comparatively stable topography/slope and avoids passing the weak ridge area that needs cutting or banking as in the Nepal`s F/S Project. It is therefore noteworthy that despite an output of a simple desk study, the route and the portal locations have been selected at the most suitable (stable) location within the routes proposed by the Nepal`s F/S Project.

There is an apparent trace of slope failure observed were setting a portal by cutting the slope is deemed very difficult. The only safety site for setting the portal is the small ridge of hill which is out of the trace of the slope failure. However, considering the length of the main tunnel, an evacuation tunnel is indispensable. The total width of the main tunnel and the excavation tunnel combined will likely be about 50m. For a tunnel this wide, it will be very difficult to locate the portal at this small ridge, as it will require extensive cutting slope stabilizing countermeasures. But, if the portal is protruded out from the slope (slightly increase the tunnel length) and the slope is provided with counter-fill, this would be a superior option (Figure 13.3-5). Figure 13.3-6 illustrates the upper findings. Additional investigation of boring/drilling is conducted at the preconcerted point for the portal to observe the comparison between the surface reconnaissance of fractured rock condition and the core extracted from the boring.

Source: JICA Survey Team

Figure 13.3-5 Candidate Portal 2 and Slope Failure



Source: JICA Survey Team

Figure 13.3-6 Summary of South Portal

(4) Evaluation of the Fractured Zone

One of the main purposes of surface reconnaissance is observation of the conditions of MBT and fractured zone. The reconnaissance conducted under this Survey in October, identified the surface between the MBT and the MT covered with heavily fractured rock. This fractured zone, which is composed mainly of acute angled phyllite and schist has crashed and folded by due to repeated high ground stress and high weathering. Fractured rock become the small strips and alteration tips. Some outcrops seem the base rock, but they are not massive. Figure 13.3-7 shows the condition of fractured zone in this area.

Source: JICA Survey Team *Source: JICA Survey Team*

Figure 13.3-7 Condition of Fractured zone

The potential influences from the fractured zone to the tunnel is the instability of the cut face, collapse of crown and high pressure for support. The fragile geology will require application of auxiliary methods for securing safety of the tunnel for an approximate length of 1km. In such case, application

of division cut face method or multiplex support system could be required. This severity is not even found in the Nagdhunga Tunnel. However, it is too early to conclude at this stage that the construction of a tunnel here may not be technically feasible. More surveys/ advanced investigations need to be carried out for making a definitive conclusion

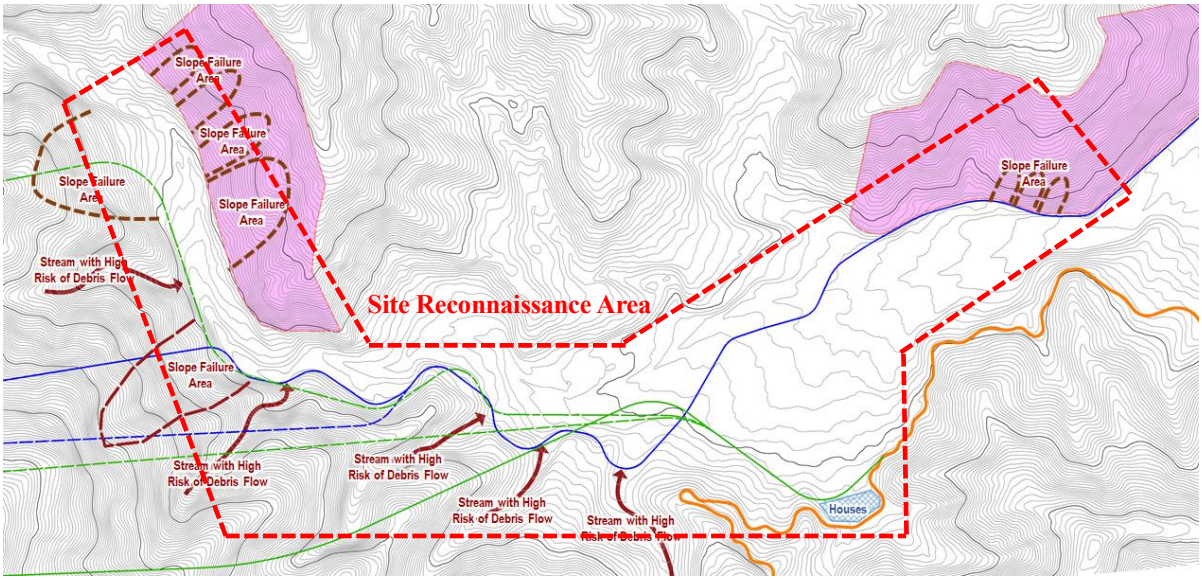
13.3.2 North Portal

(1) Reconnaissance Area

The geology of the tunnel area is composed of rock- granite and gneiss. Field surface reconnaissance of the tunnel route and Electric Resistivity Tomography (ERT) at the beginning side of the tunnel (Sindhuli Bazaar side) were conducted with the aim to understand the basic rock condition of the area. Findings of the surveys/investigation can generally conclude macroscopically that the rock condition of the tunnel alignment is good and strong for tunnelling. But possibility of heavily weathered granite along the joints and cracks cannot be dismissed. Possibility of its existence needs to be investigated with utmost care as existence of weak rocks can possibly result into excessive water flow during tunnel excavation. Surveys for identifying low velocity zone and weathering severity of rocks are suggested to be conducted in the subsequent study.

The North Portal area covers the section from the assumed north portal to the section diverging point at the existing road. The rock condition of this area is sophisticated and difficult to understanding, but the hardness of rock is stable. This implies that excavation of the tunnel is not problematic. The problems found on this survey to set the portal are rock fall and movement of rock mass as there are many traces of rock failures. The rock fall and rock mass movement should be avoided to secure safety of/at the portal. There are many mountain streams that often cause massive debris flow. The reconnaissance was conducted mainly focusing on the possible risks from the debris flow. Also, here two routes can be considered for approach road - the right bank route and the left bank route. The severity of disaster at these banks might vary vastly. Therefore, the Survey was conducted on both sides of the river and checked the possible severity of disaster.

The reconnaissance area is shown in Figure 13.3-8.

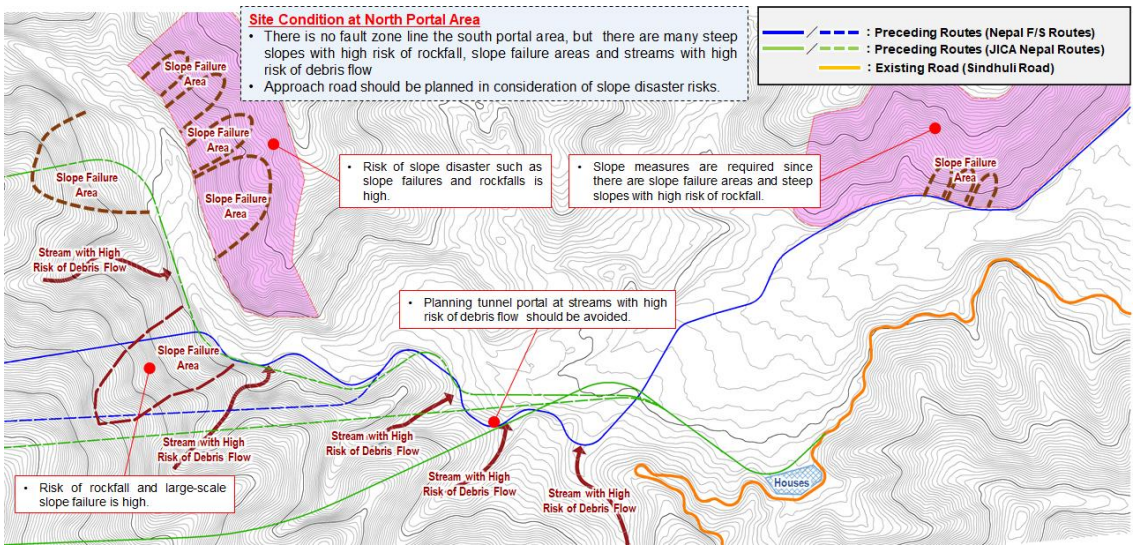


Source: JICA Survey Team

Figure 13.3-8 Site Reconnaissance Area of north tunnel portal

(2) Report of Site Reconnaissance

Findings from the fielde reconnaissance is illustrated in Figure 13.3-9.



Source: JICA Survey Team

Figure 13.3-9 Outline of Site Reconnaissance of north tunnel portal

The field reconnaissance findings show the topography of the area is steep with alternate distribution of high angle phyllite and schist with some granite block. It is easy to slip and fall and there are many large to small trace of past landslides and slope failures with some of them locating at the assumed portal sites. The height of some of the slope failures is over 100m and it is not easy to stabilize the slopes with simple prevention methods. Mountain streams in this area have the risk of debris flow as the upstream area is a granite zone (Figure 13.3-10). There are many huge rocks as big as houses scattered upstream. The debris volume and size need to be heeded during the design of a structure to

span the river.

Source: JICA Survey Team

Source: JICA Survey Team

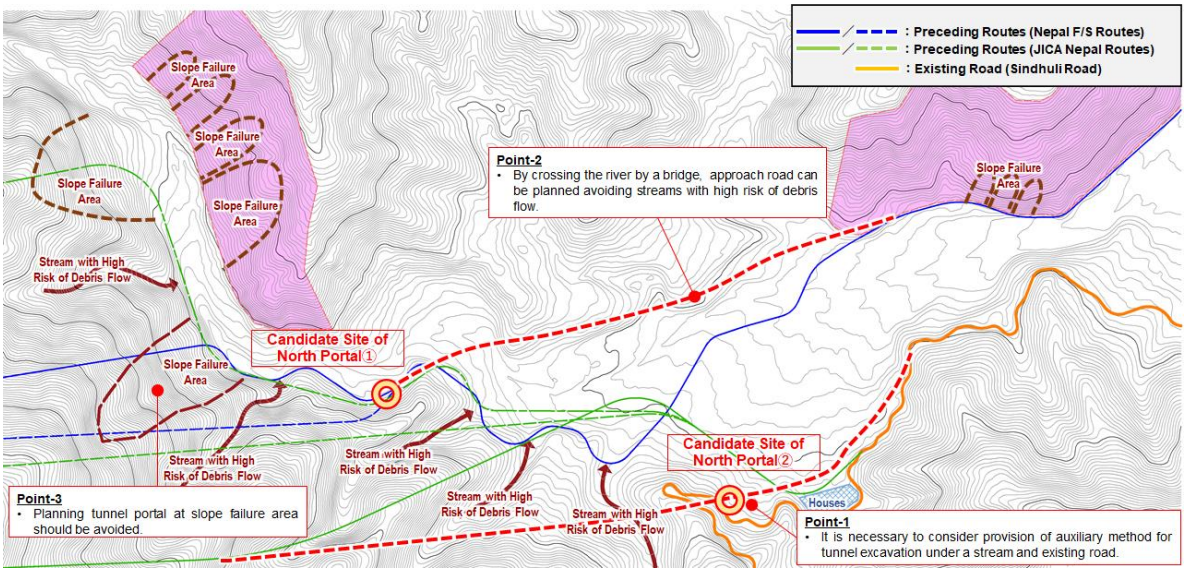
Figure 13.3-10 Condition of mountain torrents around the north portal

(3) Evaluation of the candidate route

This section shows the evaluation for the candidate route on the reconnaissance report. But this evaluation is based on the findings from limited surveys and investigations conducted under this survey. It is therefore important that the report be reassessed reflecting more and accurate results from further geological survey and environment survey in the subsequent surveys/studies. The blue lines are the routes proposed under the desk study of the Nepal F/S Project. The upper blue line (West side) is located on the slope failure area and height of the slope failure is very high. This plan should therefore be avoided because this will require large-scale countermeasures for stabilization of the slopes. The lower blue line (East side) is located on the granite slope which has slipped by granite joint continuously and because of this slipping there is a fresh rock surface of granite. On this rock condition it is possible to set the portal but with application of suitable collapse prevention methods

The green lines in the drawings indicate routes proposed by the JICA Desk Study Project. The portal in the route indicated by bottom line (East side) is located away from the mountain streams as it will be difficult to secure sufficient overburden above the tunnel at the mountain stream. But the consequence is that the route will cross the mountain stream near the portal. Also, the horizontal alignment of the approach road to the portal is not smooth. Judging from these, it would be irrational to set the portal on this point.

The situation can be remedied, provided that securing sufficient overburden artificially by application of debris flow countermeasures at the mountain stream is possible. In that case, the stream can be passable by a tunnel and the portal can be located below the existing road (as indicated by the red broken line connecting the original line). For reference, this would be a derivative plan of the original route proposed under the JICA Desk Study Project. The alignment of the route is smooth and is recommendable. The summary of the above findings is provided in Figure 13.3-11.



Source: JICA Survey Team

Figure 13.3-11 Summary of the Findings at the North Portal

13.4 ALTERNATIVE ROUTE WITH TUNNEL

13.4.1 Policy on Tunnel Planning

This section describes the policy on the tunnel planning at Section II based on the review results of preceding projects (JICA Desk Study Project and Nepal F/S Project) and the key issues of tunnel planning identified through field reconnaissance and investigations conducted under this survey.

(1) Section of Alternative Route with Tunnel

In the preceding study, the JICA Desk Study Project and Nepal F/S Project, alternative route studies with a long mountain tunnel between Chiyabari district and Khurkot district were conducted as a road function enhancement measure at Section II.

As mentioned in the beginning of this chapter, bypassing the most critical section (bottlenecks for smooth and safe traffic mobility) between Chiyabari district and Khurkot district that consists of numerous zigzag sections with sharp curves and steep gradient and many slopes disaster-prone areas is an effective method for enhancement of the road function. If the bottleneck sections are individually improved by provision of shorter tunnels (short bypasses), this will require tunnels at many locations. And also, the alignment of the route will not improve since spot wise improvement will, to some extent, retain some poor alignment sections of the existing road. Therefore, the improvement of the existing road by providing short tunnels is irrational. In other words, improving the entire bottleneck sections with a long mountain tunnel is effective, advantageous and thus rational in terms of enhancement effect of disaster-resiliency and road function. This might have been the general concept of the preceding studies in that the alternative routes with short tunnels have not been studied and compared.

From the above, it is considered that the basic concept on road improvement with a long mountain tunnel and the tunnel route section studied in the preceding studies are generally appropriate. Therefore, the study of road function enhancement for this section to be pursued under this Survey will also apply

the basic concept of provision of a long mountain tunnel between the Chiyabari district and the Khurkot district.

(2) Alignment of Alternative Route with Tunnel

From the topographical condition of the area and the proposed routes in the two preceding studies, it is apparent that the tunnel to be planned here will be about 5km to 7km long.

Article 46 of the Road Act in Japan prohibits the passage of vehicles carrying dangerous substances such as petroleum in road tunnels with a length of 5 km or more from the viewpoint of fire disaster prevention. However, there are no such laws or regulations in Nepal since the road tunnels have not been developed so far. Therefore, it is important to share information on the background and ideas of the Road Act in Japan with DOR and confirm the intention of DOR with regards to the tunnel length from the viewpoint of fire disaster prevention and reflect it in the planning of the tunnel.

In the JICA Desk Study Project, although the evacuation tunnel was planned only in Alternative-A, which adapts the longest tunnel (7 km), the grounds for the necessity of the evacuation tunnel are unclear. In Japan, the evacuation tunnel or escape passage is fundamentally installed in high standard highway tunnels and major national highway tunnels exceeding 3 km in length. Meanwhile, an evacuation tunnel is planned for the Nagdhunga Tunnel, which is the first road tunnel in Nepal (less than 3 km in length) and currently under construction. Based on such cases, it is necessary to install an evacuation tunnel or escape passage even in the tunnel planning in this Project since the tunnel length is likely to be 5 to 7 km.

Section II of Sindhuli Road orthogonally crosses the Main Boundary Thrust (MBT) and the Mahabharat Thrust (MT). MBT and MT have never been broken through by road tunnel excavation in Nepal, and there are few documents regarding the risk during excavation and the geological characteristics of them. In this Project, the site reconnaissance and geological survey will be conducted in order to roughly grasp the geological characteristics and locations of MBT, MT and parallel faults. In addition, the results of the site reconnaissance and geological survey will be utilized to evaluate the technical validity of alternative routes with the mountain tunnel and to consider the structural outline of the tunnel.

(3) Lane Operation Method of Mountain Tunnel Section

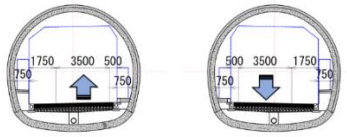
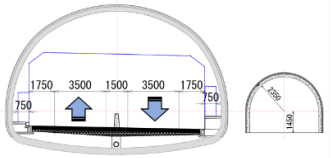
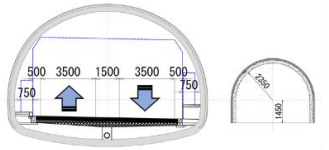
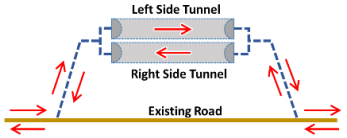
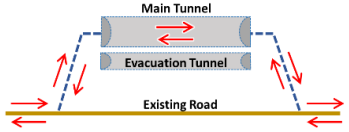
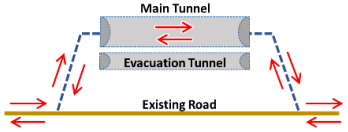
In terms of safety, JICA Desk Study Project puts double tube tunnel with 1 lane over a singly tune tunnel with 2 lanes. However, most of the serious accidents in long road tunnels in Japan and overseas are rear-end accidents. Therefore, it cannot be generally said that a double tube tunnel with 1 lane is superior to a single tube tunnel with 2 lanes in terms of traffic safety. In the case of a double tube tunnel with 1 lane, it is difficult to conduct firefighting and rescue activities utilizing the opposite lane, unless the tunnel accommodates extra space for passage of such emergency vehicles. On the other hand, looking from construction and cost efficiencies, as shown in Table 13.4-1, a single tube tunnel with 2 lanes is assumed to be superior to a double tube tunnel with 1 lane. Therefore, the validity of the lane operation method by a single tube tunnel with 2 lanes is high.

In addition, if 4 lane operation is required after the construction of a double tube tunnel with 1 lane, it will be necessary to widen both tunnels or provide separate ones, which in either case will have high-cost implication and long construction period. Also, the traffic flow is greatly affected by road closure or traffic regulation of both tunnels. But in the case of a single tube tunnel with 2 lanes and an evacuation tunnel, it is possible to widen to 4 lanes by widening the evacuation tunnel. Therefore, road closure or traffic regulation of a single tube tunnel with 2 lanes is not required during the widening works. This also applies to conducting tunnel inspection. In case of double tube tunnel with 1 lane, road closure is required for the periodic inspection for the tunnel structures and facilities. On the other hand, in case of single tube tunnel with 2 lanes, the periodic inspection for the tunnel structures and facilities can be conducted by traffic restrictions of one side lane. For example, in Japan, a single tube tunnel with 2 lanes has been basically adopted in consideration of the impact of 4 lane widening for tunnel in the future on the existing road traffic.

In recent years, there have been increasing number of cases in Japan, where a rigid median strip is installed in road tunnels on high standard highways that does not assume 4 lanes operation in future. In this case, since installation of the median strip needs an additional space, a larger tunnel cross section is required. On the other hand, since head-on accidents can be physically avoided by the rigid median strip, the speed limit is often set higher than when a rigid median strip is not installed. Based on such cases, applicability of a single tube tunnel with 2 lanes with the rigid median strip should be considered in the Survey.

A long tunnel with a length of 5 to 7 km is assumed at the section, and it is also necessary to consider emergency facilities, information and communication equipment and disaster prevention system for the tunnel. In the Nepal F/S Project, a single tube tunnel with 2 lanes, an evacuation tunnel and cross passages connecting between the main tunnel and evacuation tunnel are planned. As mentioned above, according to Japan standards, an evacuation tunnel adjacent to the main tunnel are basically installed in tunnels exceeding 3 km in length. Therefore, the necessity of an evacuation tunnel should be considered in the Survey.

Table 13.4-1 Comparison of Lane Operation Method

Operation Method	Option 1 : 2-tube Tunnel		Option 2 : Two-way Tunnel with Rigid Median Strip		Option 3 : Two-way Tunnel without Rigid Median Strip	
Schematic Diagram	 Double Tube Tunnel		 Main Tunnel (2 Lanes) Evacuation Tunnel		 Main Tunnel (2 Lanes) Evacuation Tunnel	
	Road width: 3.5 m, Shoulder width: 1.75 m (L.S), 0.5m (R.S) Inspection gallery: 0.75 m×2		Road width: 3.5 m×2, Shoulder width 1.75 m×2 Median: 1.5 m, Inspection gallery: 0.75 m×2		Road width: 3.5 m×2, Shoulder width 0.5 m×2 Median: 1.5 m, Inspection gallery: 0.75 m×2	
Lane Operation Method						
Trafficability	・The tunnel cross section is small, and the driver tends to feel oppressive while driving ・The light of oncoming vehicles does not affect the driver's sight.	△	・The tunnel cross section is the biggest, and the drivers are less likely to feel oppressive while driving ・The rigid median strip can be expected to block the lights of oncoming small vehicles	○	・The tunnel cross section is bigger than Option-1, and the drivers are less likely to feel oppressive while driving ・The light of oncoming vehicles affects the driver's sight.	△
Safety	・Disadvantageous in dealing with serious accidents due to narrow effective width compared to other cases ・No risk of head-on accident	△	・Opposing lane can be utilized in an effective manner for rescue operation (evacuation) and firefighting during disasters ・No risk of head-on collisions as rigid median strip is installed	○	・Opposing lane can be utilized in an effective manner for rescue operation (evacuation) and firefighting during disasters ・Accidents leading to head-on collisions can happen even if plastic poles are provided along the center	△
Construction Efficiency	・Construction equipment procurement may face difficulty as the size of the tunnel is smaller than other cases ・Construction machines required is twice than that is required for Option 2 and 3.	△	・Construction efficiency is high as main excavation is only for a single cross section ・Excavation of the evacuation tunnel can be utilized for pilot tunnel to investigate the ground condition of MBT and MT	○	・Construction efficiency is high as main excavation is only for a single cross section ・Excavation of the evacuation tunnel can be utilized for pilot tunnel to investigate the ground condition of MBT and MT	○
Cost Ratio	1.0 (Cross-section Area: 65.1m^2 x 2 tunnels)	○	1.2 (Cross-section Area: 118.8m^2 (Main Tunnel)/ 18.7m^2 (Evacuation Tunnel)	△	1.0 (Cross-section Area: 98.3m^2 (Main Tunnel)/ 18.7m^2 (Evacuation Tunnel)	○
Surrounding Environment	More vehicles required and as such impact on existing road high if construction is simultaneous	△	Less impact on existing road due to a smaller number of construction vehicles	○	Less impact on existing road due to a smaller number of construction vehicles	○
Assessment	**Risk of traffic severance is low but safety, construction efficiency, environmental impact is inferior to other cases. Double tube tunnels are rarely applied for long tunnels. There aren't many in Japan too**	△	**Most superior to other options. High improvement effect can be expected from the viewpoint of road function enhancement. Evacuation tunnels allow to perceive the geology (auxiliary methods) and impact of groundwater that could be applied to the main tunnel**	◎	**Improvement from viewpoint of logistics strengthening is high and is superior in terms of safety and cost. Evacuation tunnels allow to perceive the geology (auxiliary methods) and impact of groundwater that could be applied to the main tunnel**	○

≪Legend≫ ◎ : Superior ○ : Good △ : Poor

Source:JICA Survey Team

(4) Lane Operation Method of Mountain Tunnel Section

The necessity of auxiliary methods for poor ground sections at MBT and MT was not considered in the JICA Desk Study Project and the Nepal F / S Project.

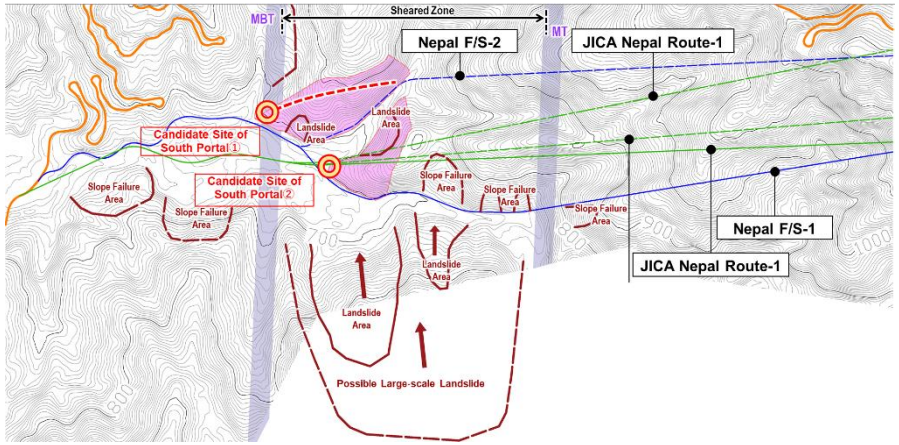
In the Survey, the location and geological characteristics of MBT and MT will be roughly evaluated by the site reconnaissance and geological survey, and the necessity of auxiliary methods will also be considered based on the results of the site reconnaissance and geological survey.

13.4.2 Evaluation of Alternative Routes Studied in Preceding Projects

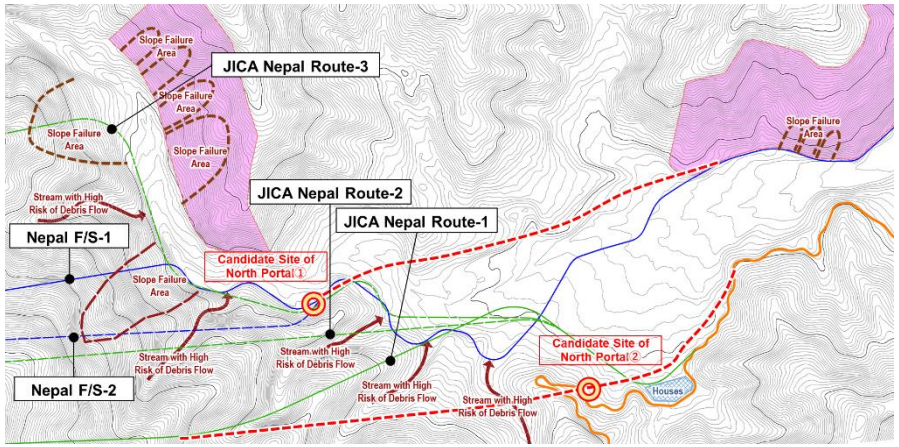
Based on the result of the site reconnaissance around tunnel portals, the validity of alternative routes studied in the preceding projects are evaluated in terms of disaster risks.

Since the alternative routes were studied mainly through desk study, both portal locations and approach roads are not planned in consideration of disaster risks. As shown in Table 13.4-2, all alternative routes consisting of a tunnel and approach roads are deemed to have high disaster risks, and it is necessary to plan new alternative route in consideration of disaster risk.

Table 13.4-2 Comparison of Alternative Routes Studied in Preceding Projects



Plan (South Portal Area)



Plan (North Portal Area)

Routes	Approach Road (South)		South Portal		North Portal		Approach Road (North)	
JICA Nepal Route-1	· Disaster risks such as landslide and slope failure are low	○	· Disaster risks such as landslide and slope failure are low	○	· Portal is located at a stream with high risk of debris flow (Portal location is not preferable)	×	· Disaster risks such as landslide and slope failure are low	○
JICA Nepal Route-2	· Disaster risks such as landslide and slope failure are low	○	· Disaster risks such as landslide and slope failure are low	○	· Portal is located at a stream with high risk of debris flow (Portal location is not preferable)	×	· There is a stream with high risk of debris flow along the route	△
JICA Nepal Route-3	· Disaster risks such as landslide and slope failure are low	○	· Disaster risks such as landslide and slope failure are low	○	· Portal is located at an area of slope failure (Portal location is not preferable)	×	· There are several streams and slope failure areas along route	×
Nepal F/S-1	· There are several landslide and slope failure areas along route	×	· Portal is located at an area of slope failure (Portal location is not preferable)	×	· Portal is located at an area of slope failure (Portal location is not preferable)	×	· There are several streams and slope failure areas along route	×
Nepal F/S-2	· There is an area of slope failure along the route	△	· Portal cannot be seen directly from the approach road due to topographical condition	△	· Disaster risks such as landslide and slope failure are low	○	· There are several streams and slope failure areas along route	×

○: Good △: Fair ×: Bad

Source: JICA Survey Team

13.4.3 Selection of Candidate Routes

Based on the policies on tunnel planning and the result of site reconnaissance conducted under this Survey, 4 candidate routes shown in Table 13.4-3 are planned in the Study.

Plan of candidate routes, plan and profile of each candidate route and plan of portal area are shown in Figure 13.4-1 to Figure 13.4-6.

Table 13.4-3 Outline of Candidate Routes

Routes	Components	Length (m)	Horizontal Alignment	Vertical Alignment
Candidate Route-1	Tunnel	7,685	R=5,000m to tangent	i=1.3 to 1.6%
	Approach Road	1,591	R=100m to tangent	i=2.0 to 6.0%
Candidate Route-2	Tunnel	6,906	R=1,000m to tangent	i=0.9 to 1.6%
	Approach Road	3,921	R=55m to tangent	i=0.6 to 6.0%
Candidate Route-3	Tunnel	7,941	R=4,000m to tangent	i=1.0 to 1.6%
	Approach Road	1,346	R=55m to tangent	i=2.0 to 6.0%
Candidate Route-4	Tunnel	7,159	R=1,000m to tangent	i=1.0 to 1.5%
	Approach Road	3,760	R=55m to tangent	i=1.9 to 6.0%

Source:JICA Survey Team

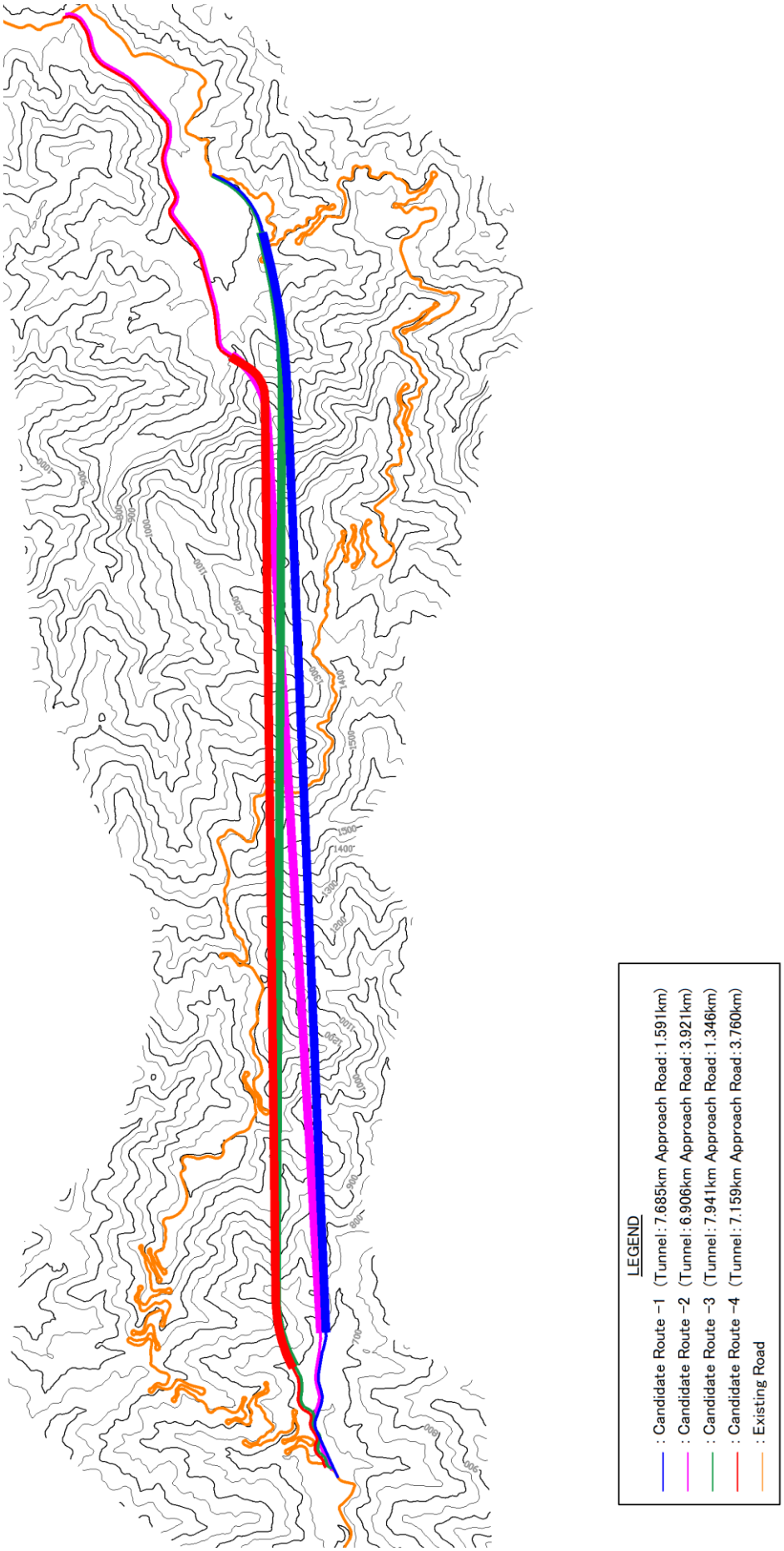
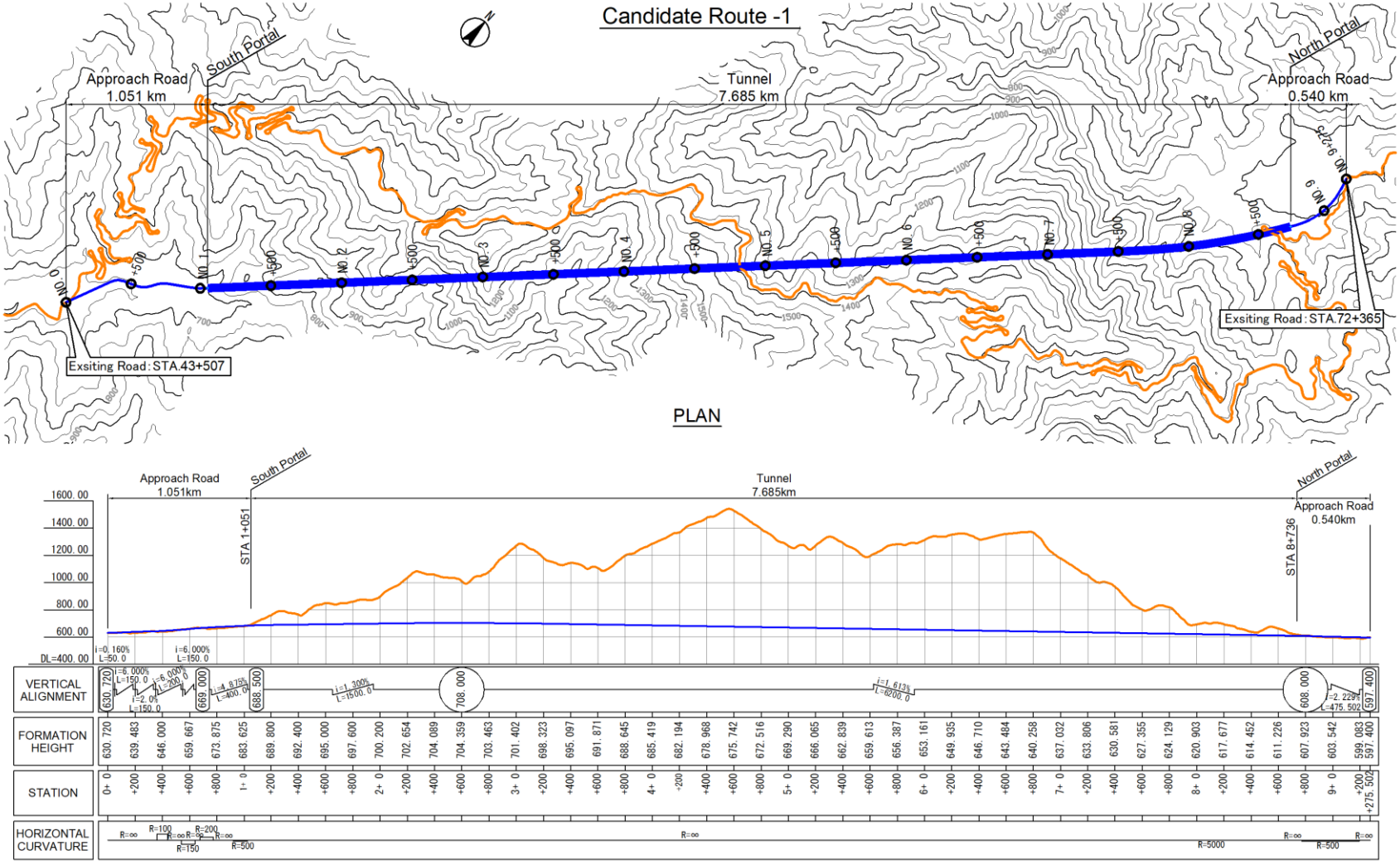


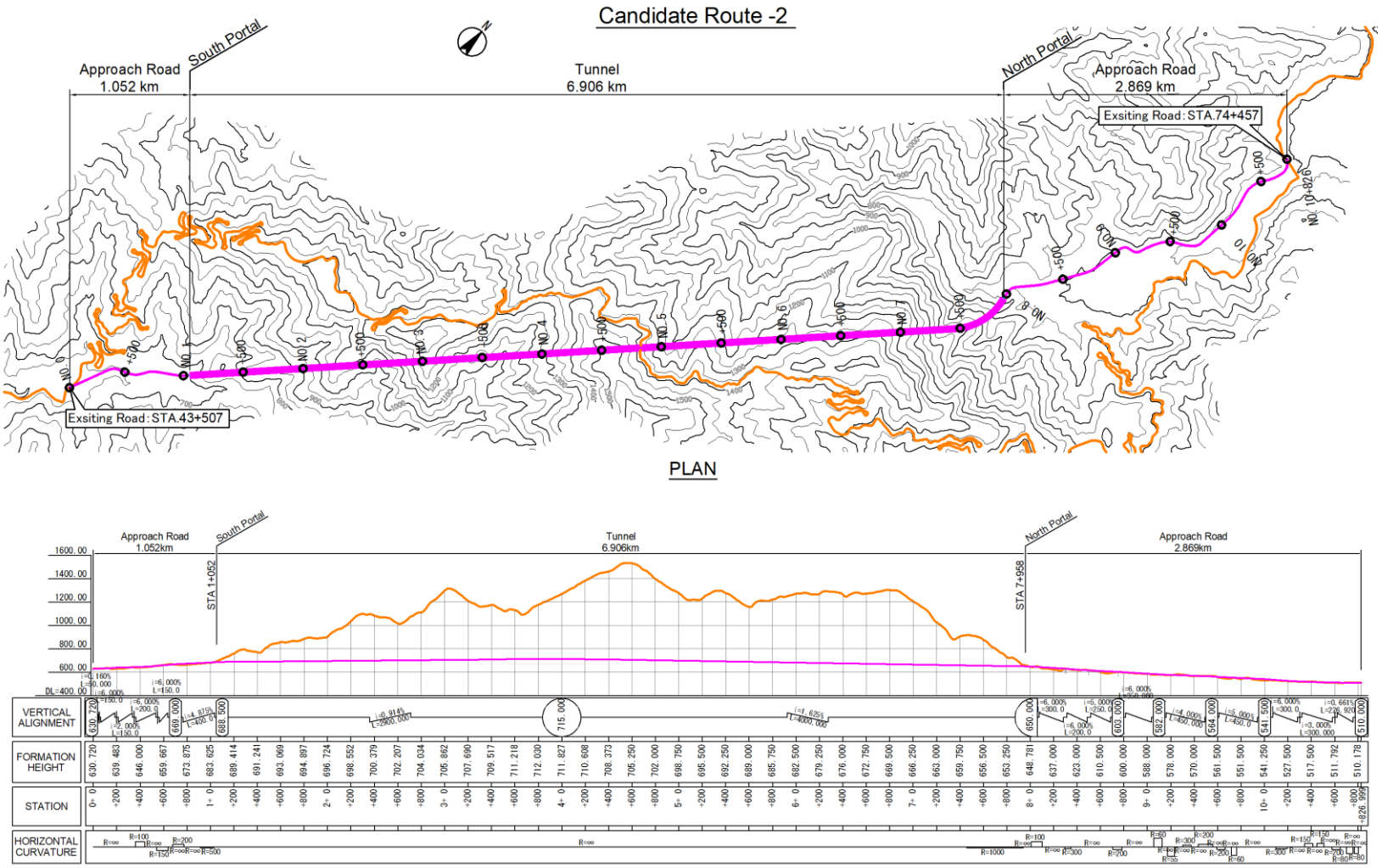
Figure 13.4-1 Plan of Candidate Routes

Source: JICA Survey Team



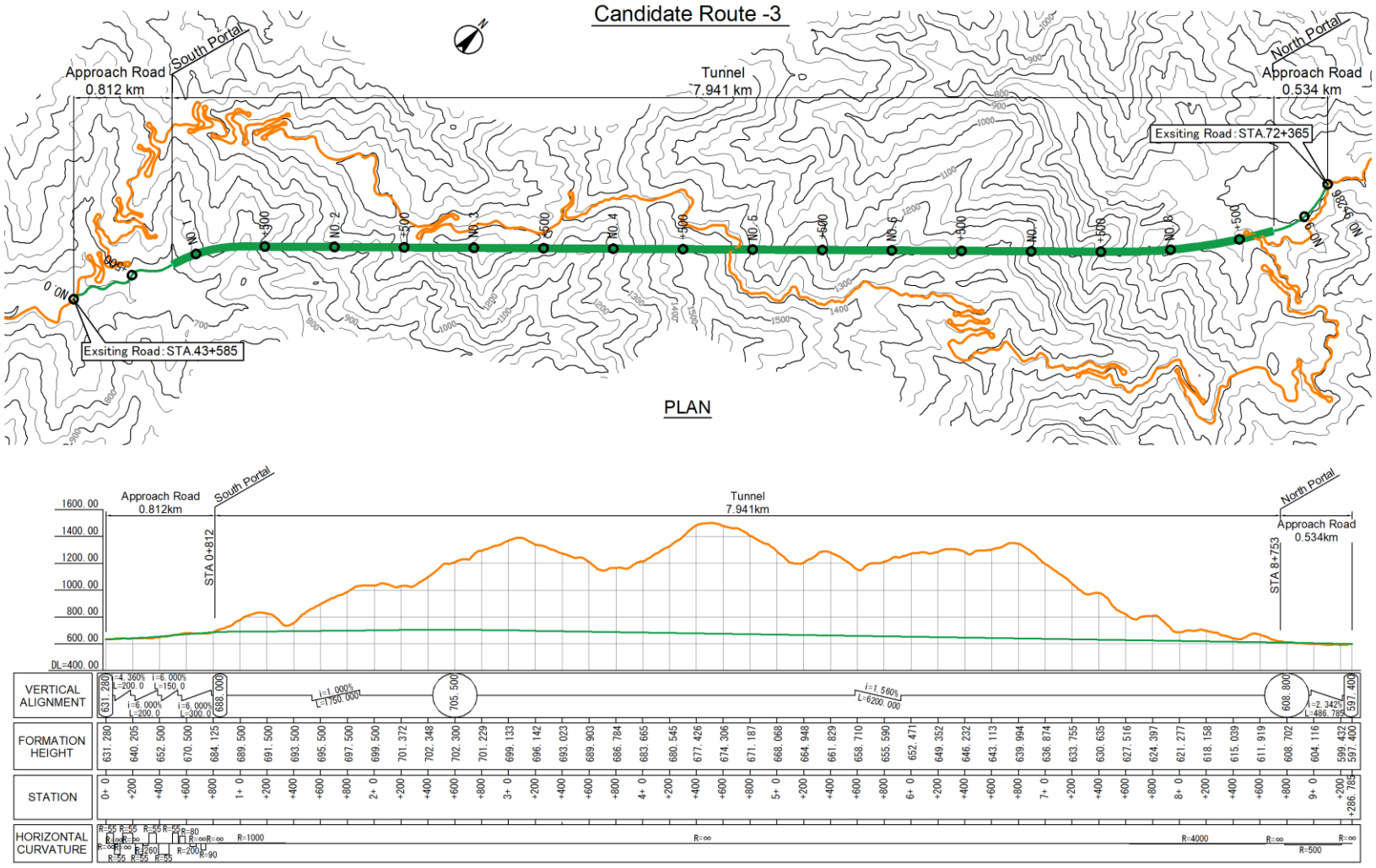
Source: JICA Survey Team

Figure 13.4-2 Plan and Profile of Candidate Route-1



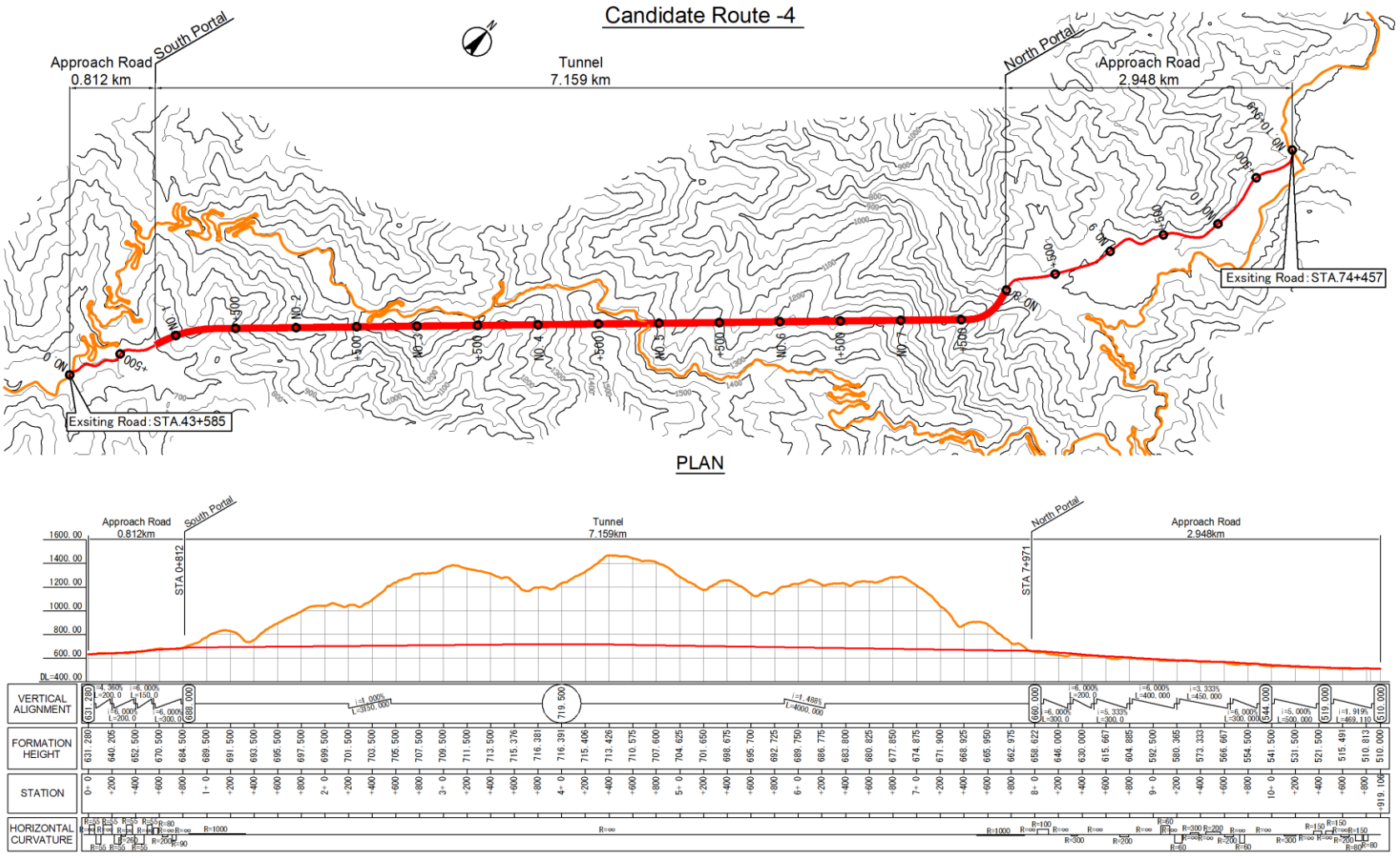
Source: JICA Survey Team

Figure 13.4-3 Plan and Profile of Candidate Route-2



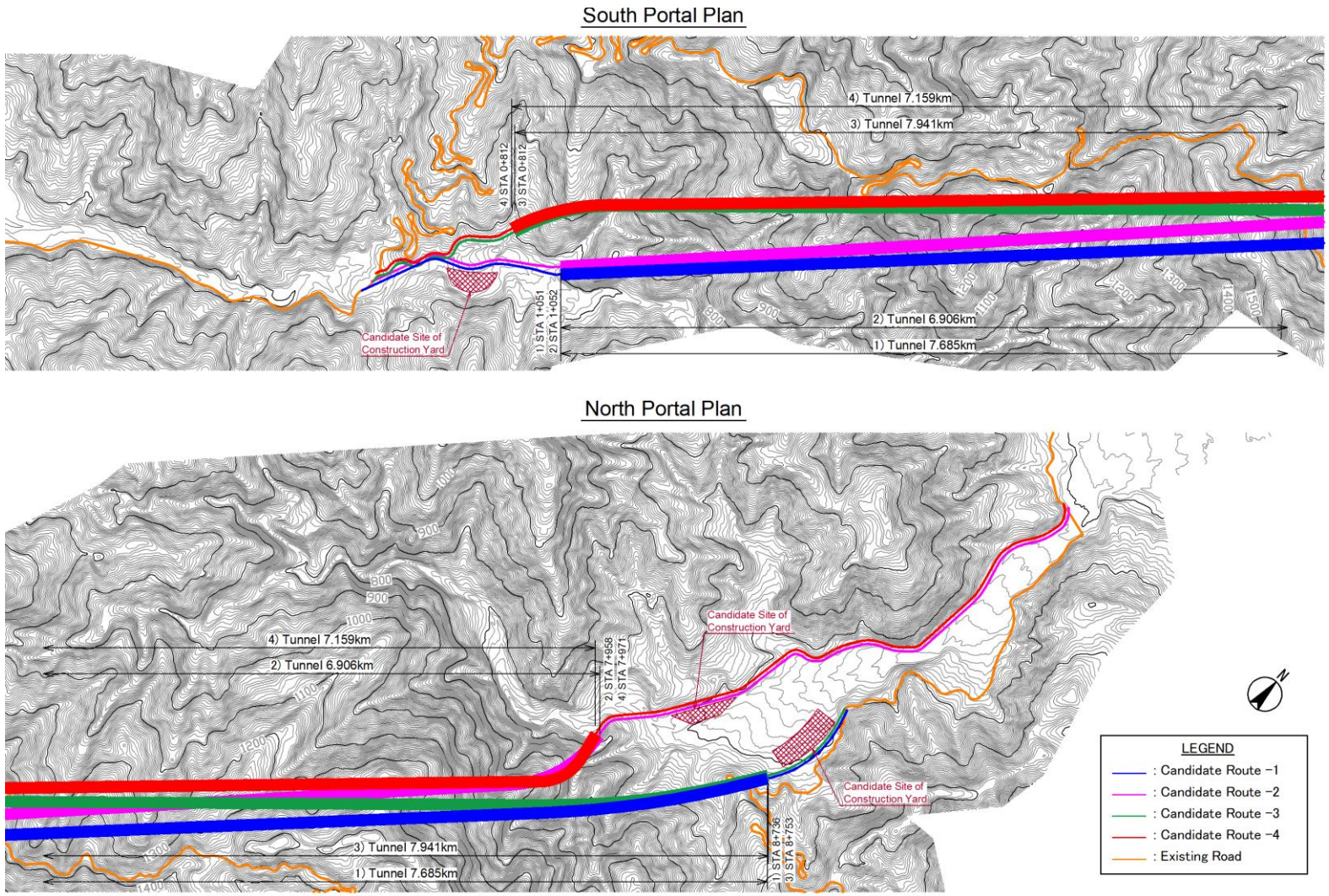
Source: JICA Survey Team

Figure 13.4-4 Plan and Profile of Candidate Route-3



Source: JICA Survey Team

Figure 13.4-5 Plan and Profile of Candidate Route-4



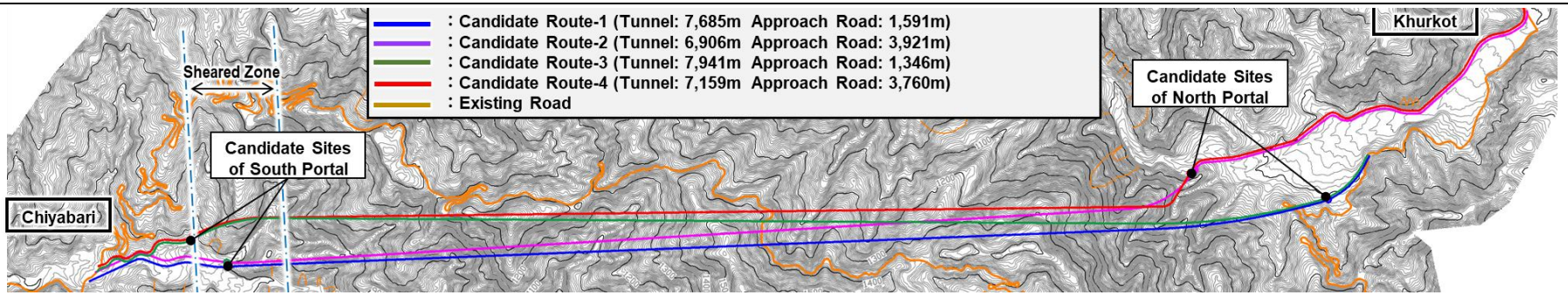
Source: JICA Survey Team

Figure 13.4-6 Plan of Portal Area (South and North)

13.5 COMPARISON OF CANDIDATE ROUTE

As shown in Table 13.5-1, comparative study on candidate routes is conducted from various aspects such as safety, construction efficiency, maintenance easiness, environment and social consideration and cost. Comparative study results recommend Candidate Route-1 and Candidate Route-2.

Table 13.5-1 Comparison of Candidate Routes



Routes		Candidate Route-1		Candidate Route-2		Candidate Route-3		Candidate Route-4	
Alignment	Tunnel	R=5,000m~Straight (i=1.3~1.6%)		R=1,000m~Straight (i=0.9~1.6%)		R=4,000m~Straight (i=1.0~1.6%)		R=1,000m~Straight (i=1.0~1.5%)	
	Approach Road	R=100m~Straight (i=2.0~6.0%)		R=55m~Straight (i=0.6~6.0%)		R=100m~Straigh (i=2.0~6.0%)		R=55m~Straight (i=1.9~6.0%)	
Safety	South Approach Road	・ Disaster risk of tunnel portals and approach road is low	○	・ Disaster risk of tunnel portals and approach road is low	○	・ Since a part of road passes through an area of slope failure, slope protection is needed at the section	△	・ Since a part of road passes through an area of slope failure, slope protection is needed at the section	△
	North Approach Road	・ Disaster risk of tunnel portals and approach road is low	○	・ Since a part of road passes through an area of slope failure, slope protection is needed at the section	△	・ Disaster risk of tunnel portals and approach road is low	○	・ Since a part of road passes through an area of slope failure, slope protection is needed at the section	△
Construction Efficiency		・ Length of sheared zone to be excavated is shorter than route-1 and route-4 (○) ・ Construction period are longer than route-2 and route-4 (△)	○	・ Length of sheared zone to be excavated is shorter than route-3 and route-4 (○) ・ Construction period is shorter than route-1 and route-3 (○)	◎	・ Tunnel passes through MBT, and length of sheared zone to be excavated is longer than route-1 and route-2 (△) ・ Construction period are longer than route-2 and route-4 (△)	△	・ Tunnel passes through MBT, and length of sheared zone to be excavated is longer than route-1 and route-2 (△) ・ Construction period is shorter than route-1 and route-3 (○)	○
Maintenance Easiness		・ Maintenance scale of tunnel facilities is same as other routes (-) ・ Maintenance scale of approach road slope is smallest (○)	○	・ Maintenance scale of tunnel facilities is same as other routes (-) ・ Slope maintenance of approach road is required (△)	△	・ Maintenance scale of tunnel facilities is same as other routes (-) ・ Slope maintenance of approach road is required (△)	△	・ Maintenance scale of tunnel facilities is same as other routes (-) ・ Slope maintenance of approach road is required (△)	△
Environment and Social Consideration		・ Number of Affected Structures: Approx. 15 cases ・ Necessary Land Area: Approx. 4.5 ha ・ Required forest logging and changes of land surface is relatively smaller	○	・ Number of Affected Structures: Approx. 7 cases ・ Necessary Land Area: Approx. 11.4 ha ・ Required forest logging and changes of land surface is relatively bigger.	△	・ Number of Affected Structures: Approx. 16 cases ・ Necessary land area: Approx. 3.6 ha ・ Required forest logging and changes of land surface is relatively smaller	○	・ Number of Affected Structures: Approx. 8 cases ・ Necessary land area: Approx. 11.1 ha ・ Required forest logging and changes of land surface is relatively bigger.	△
Cost (Billion NPR)		37.1	○	37.7	△	37.8	△	37.5	△
Assessment		Disaster risk is lowest. And also, construction efficiency and maintenance easiness are advantageous	○	Construction efficiency is highest in terms of tunnel route and length. And also, cost is advantageous.	○	Tunnel is longest, and there are disaster risks along the route. (more disadvantageous than other routes)	△	Construction efficiency is advantageous, but maintenance scale of slope protection is largest	△

◎: Excellent ○: Good △: Fair

Source:JICA Survey Team

13.6 STUDY ON TUNNEL STRUCTURE

13.6.1 Outline

Japan is one of the most advanced and experienced countries in the world in the field of tunneling. The geology and geotechnical condition of Nepal is very similar to that of Japan. Therefore, the study on tunnel structure under of the Survey is based upon the experiences in Japan and the Japanese Standards listed in Table 13.6-1. These standards are applied to all the highway tunnels and national road tunnels in Japan, and most of them have been constructed by New Austrian Tunneling Method (NATM), which is a univera¥sally applied standard construction method of mountain tunnels. This method is applicable also in to proposed tunnel at Chiyabari-Khurkot as geologically and topographically this section lies in a steep mountainous and hilly area. However, as the tunnel section is assumed to encounter sheared zone between MBT and MT at south portal area, provision of auxiliary method will be necessary to secure stability of tunnel ground arch and the face during excavation.

Table 13.6-1 List of Applied Japanese Standards for Study on Tunnel Structure

Standard	Issue	Year
Standard Specifications for Tunneling-2016: Mountain Tunnel	Japan Society of Civil Engineers	2016
Road Tunnel Technical Standards for Tunnel Structure	Japan Road Association	2003
Road Tunnel Technical Standards for Tunnel Ventilation	Japan Road Association	2008
Commentary on Road Structure Ordinance	Japan Road Association	2021
Road Tunnel Technical Standards for Emergency Facilities	Japan Road Association	2019
Design Guideline (Part3)	Nippon Expressway Research Institute Company (NEXCO)	2016

Source:JICA Survey Team

13.6.2 Basic Conditions

Basic conditions applied to the study on tunnel structure are shown in Table 13.6-2.

Table 13.6-2 Basic Condition on Study on Tunnel Structure

Conditions		Parameters	Remarks
Design Speed		30km/h	Tunnel Section
Number of Lanes		2	Single-tube tunnel with 2 lanes
Cross-section	Carriageway	3.50m	Nepal Road Standard 2070
	Shoulder	1.75m	Commentary on Road Structure Ordinance
	Inspection Gallery	0.75m	Road Tunnel Technical Standards for Tunnel Structure
	Median Strip	1.50m	Nepal Road Standard 2070
Superelevation (%)		2.0%	Nepal Road Standard 2070
Maximum Vertical Gradient (%)		3.0%	Road Tunnel Technical Standards for Tunnel Structure and condition of Nagdhunga Tunnel
Vertical Clearance		5.0m	Nepal Road Standard 2070

Source:JICA Survey Team

13.6.3 Rock Classification Method and Standard Support Patterns of the Tunnel

Based on the site reconnaissance and the results of the geological survey conducted under the Survey, the ground level of tunnel section is classified with reference to the index shown in Table 13.6-3. Also, the support patterns for the tunneling shown in Table 13.6-4 and Table 13.6-5 are standardized based on that ground levels. From the results in Table 13.4-1, the tunnel cross section is planned as 2 lanes with a rigid median strip. Therefore, the width of inner section (approximately 13.5m) corresponds to large section tunnel, and the support patterns shown in Table 13.6-5 should be applied.

Tunnel support types in this Study are mainly classified into 4 types to reflect the geotechnical condition of the tunnel so far encountered. They are CI, CII, DI and DIII.

Type CI is applied to the ground where rock mass is partly weathered or altered, and discontinuous planes are generally and relatively stable. Type CII is applied to the ground where rock mass is partly weathered or altered and fractured. Type DI is applied to the ground where rock mass is sheared or weathered. Type DIII is applied to sections near to tunnel poral where formation of ground arch is difficult.

Rock classification and support pattern for the tunnels of the candidate routes are shown in Table 13.6-6.

Table 13.6-3 Rock Mass Classification System

Rock class	Condition of rock mass	RQD	Stability of face	Convergence
B	Rock is fresh and hard. Discontinuous planes are stable and the possibility of loosening due to tunnel excavation is very small.	60 to 90	The strength is significantly higher than the expected load and only occasional local spalling of rock fragment may occur.	Convergence of tunnels is negligible.
CI	Rock is partly weathered or altered. Discontinuous planes are generally relatively stable	20 to 70	The strength is higher than the expected load and the loosening is expected to be local.	Convergence of tunnels is usually within the elastic range.
C II	Rock is partly weathered or altered and fractured.	20 to 70	Strength is not significantly higher than the expected load, but is sufficient to limit the elastic deformation. Rock chunks along slippery discontinuous planes tend to spall.	Convergence stops to increase before the tunnel face has advanced a distance of 2 D, where D is the tunnel diameter. Convergence of tunnels does not exceed 50 mm.
D I	Rock is significantly weathered and softened or sheared.	< 20	Partial plastic displacement and elastic deformation could occur. Or even if the strength is high enough to limit the elastic deformation, significant loosening of ground along slippery discontinuous planes could occur.	Where the strength is small and the invert concrete is not placed at an early stage, the convergence could reach 30 to 60 mm and does not stop to increase even if the tunnel face has advanced more than 2 D
D II	Rock is completely weathered and partly softened to soil, or heavily sheared.	< 20	The strength is low compared to the expected load and large plastic deformation as well as elastic displacement could occur. In addition to the low strength, significant loosening of ground along slippery discontinuous planes and large displacement could occur.	Convergence of tunnels could reach as far as to 60 to 200 mm and does not stop to increase even if the tunnel face has advanced more than 2 D, if the invert concrete is not placed at an early stage

Rock class	Condition of rock mass	RQD	Stability of face	Convergence
DIII	It is tunnel portal section where the overburden is around 1.0 D to 2.0D.	—	It is difficult to form the ground arch due to a thin overburden.	—
E	Ground such as faults, fractured zones and large talus deposit.	—	Squeezing occurs and generates occasional collapse in face area.	Large deformation could reach to 400mm.

Notes: RQD (Rock Quality Designation): Indicator of degree of rock crack. The total length of rod-like cores of more than 10 cm included in the boring core length 1.0 m is indicated by percentage.

Source: JICA Survey Team (refer to Design Guideline -Part3-)

Table 13.6-4 Standard Support Patterns for Two-Lane Tunnels (Width of Inner Section 8.5-12.5m)

Ground class	Support pattern	Cut per advance (m)	Rock bolts				Shotcrete	Steel rib			Lining thickness (cm)		Allowable deformation (cm)	Excavation method
			Length (m)	Spacing		Construction range	Thickness (cm)	Upper half size	Lower half size	Installation Interval(m)	Arch & wall	Invert		
				Peripheral (m)	Longitudinal (m)									
B	B	2.0	3.0	1.5	2.0	Upper half 120°	5	-	-	-	30	0	0	Full face with micro bench or top heading cut
C I	C I	1.5	3.0	1.5	1.5	Upper half	10	-	-	-	30	(40)	0	
C II	C II-a	1.2	3.0	1.5	1.2	Upper and lower halves	10	-	-	-	30	(40)	0	
	C II-b							H125	-	1.2				
D I	D I-a	1.0	3.0	1.2	1.0	Upper and lower halves	15	H125	H125	1.0	30	45	0	
	D I-b	1.0	4.0							1.0				
D II	D II	1.0 or less	4.0	1.2	1.0 or less	Upper and lower halves	20	H150	H150	1.0 or less	30	50	10	

Notes: The support patterns are divided into a and b as shown below.
a: Standard support pattern generally used for all rock types
b: Support pattern used in the initial design only when the tunnel excavation is expected to result in a larger displacement in clay stone, black schist, mudstone, shale, tuff, or other rock types.
Note that the values in ( ) for the invert are applied to tertiary mudstone, tuff, serpentinite, and other ground rocks, weathered crystalline schist, and sulfuric soil.

Source: Road Tunnel Technical Standards for Tunnel Structure

Table 13.6-5 Standard Support Patterns for Two-Lane Tunnels (Large Section Tunnel: Width of Inner Section 12.5-14.0m)

Ground class	Support pattern	Cut per advance (m)	Rock bolts				Shotcrete	Steel rib			Lining thickness (cm)		Allowable deformation (cm)	Excavation method
			Length (m)	Spacing		Construction range	Thickness (cm)	Upper half size	Lower half size	Installation Interval (m)	Arch & wall	Invert		
				Peripheral (m)	Longitudinal (m)									
B	B	2.0	4.0	1.5	2.0	上半	10	-	-	-	40	0	0	Full face with micro bench, top heading cut, center diaphragm method, center drift advancing method
C I	C I	1.5	4.0	1.2	1.5	Upper and lower halves	15	-	-	-	40	(45)	0	
C II	C II	1.2	4.0	1.2	1.2	Upper and lower halves	15	H150	-	1.2	40	(45)	0	
D I	D I	1.0	6.0	1.0	1.0	Upper and lower halves	20	H150	H150	1.0	40	50	0	
D II	D II	1.0 or less	6.0	1.0	1.0 or less	Upper and lower halves	25	H200	H200	1.0 or less	40	50	10	

出典： Road Tunnel Technical Standards for Tunnel Structure

Table 13.6-6 List of Support Patterns Length of Candidate Routes

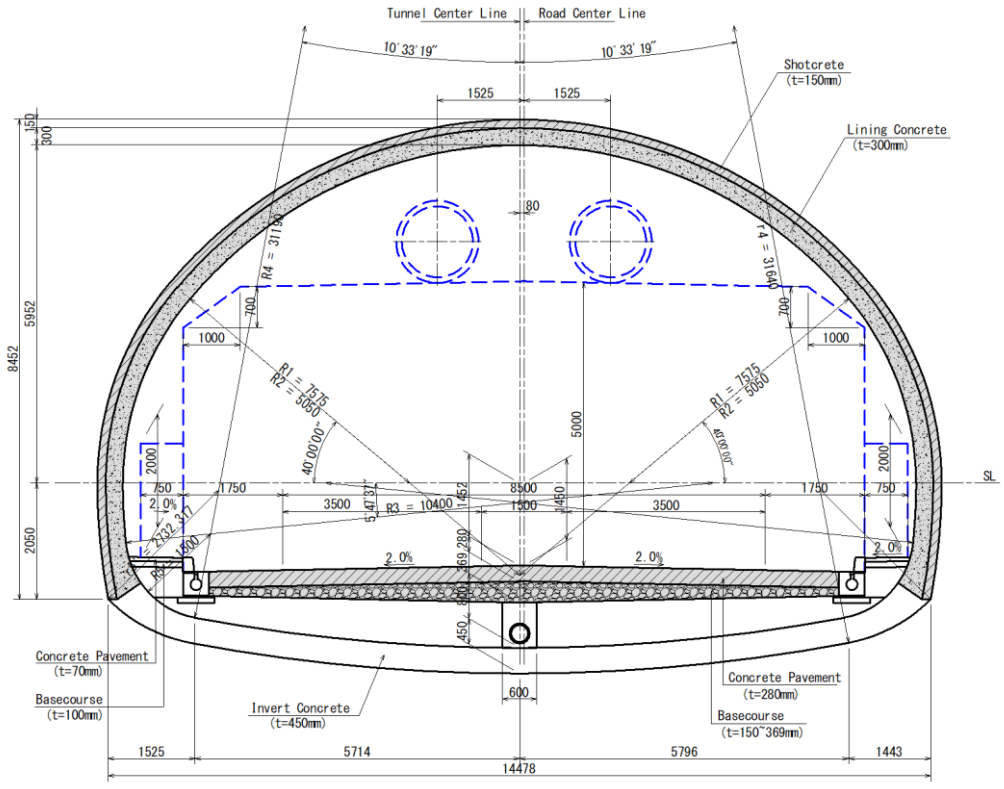
Routes	Length of Support Patterns (m)				
	CI	CII	DI	DIII	DIIIp*
Candidate Route-1	4,360 (56.7%)	2,250 (29.3%)	100 (1.3%)	95 (1.2%)	880 (11.5%)
Candidate Route-2	3,865 (56.0%)	1,470 (21.3%)	100 (1.4%)	56 (0.8%)	1,410 (20.5%)
Candidate Route-3	4,560 (57.4%)	2,230 (28.1%)	100 (1.3%)	101 (1.3%)	950 (12.0%)
Candidate Route-4	3,995 (55.8%)	1,570 (21.9%)	100 (1.4%)	39 (0.1%)	1,455 (20.8%)

* DIIIp: DIII + Auxiliary Method (AGF method)

Source:JICA Survey Team

13.6.4 Tunnel Cross-Section

Based on the basic conditions shown in Table 13.6-2, typical tunnel cross-section is set. Typical tunnel cross-section is shown in Figure 13.6-1.



Source:JICA Survey Team

Figure 13.6-1 Typical Tunnel Cross-Section (DI)

13.6.5 Tunneling Method

13.6.5.1 Tunnel Driving Method

There are two tunnel excavation methods; drill & blasting (D&B) and mechanical excavation. D&B method is generally applied in hard rock mass, and mechanical excavation is generally applied in middle hard rock mass and soft rock mass.

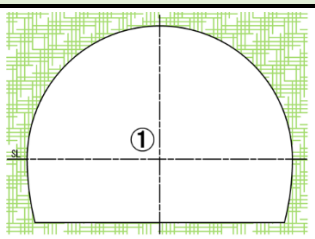
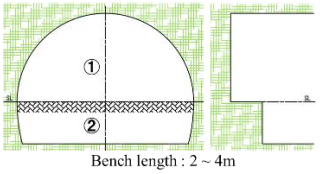
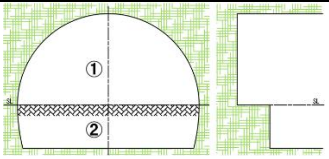
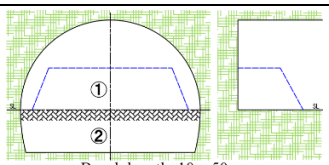
Geology of the tunnels in the Study is assumed to consist mainly of middle hard rock or hard rock of gneiss, schist, phyllite and granite and is generally classified as hard rock mass (qu>50 MPa). For this type of rock mass, the Japanese standards for tunnel structure recommends D&B method. Therefore, D&B method is recommended in the Study.

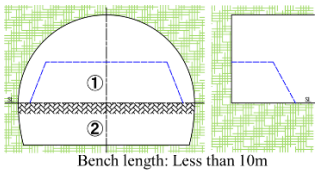
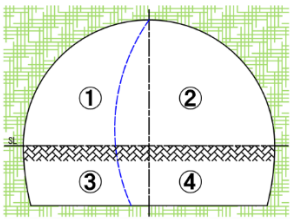
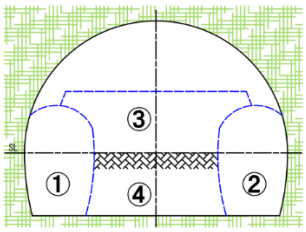
13.6.5.2 Excavation Method

Tunnel excavation method is classified as shown in Table 13.6-7. Since the tunnel routes passe through MBT and MT around south portal area, ground condition of the section about 1 km from south portal deems to be sheared zone where is located between MBT and MT. Therefore, auxiliary method for face stabilization is required at the section, and the bench cut method is recommended in excavation method in consideration of construction process of auxiliary method.

On the other hand, since the tunnel section other than sheared zone between MT and MBT is composed of relatively stable and hard bedrock (gneiss, schist, phyllite, granite), the full face method or the full face method with auxiliary bench is recommended.

Table 13.6-7 Classification and Characteristics of Standard Excavation Method

Excavation Method		Division of Section of Heading	Applicable Ground Condition	Advantages	Disadvantages
Full Face Method			Common excavation method for small section tunnel Very stable ground for large section tunnel (A=30m^2) Unfit for good grounds interspersed with poor ground that may require the change of the excavation method	Labor saving by mechanized construction Construction Management including safety control is easy because of the single-face excavation.	Full tunnel length cannot necessarily be excavated by full face alone. Changing of excavation method will be adopted as required. Fragment rocks from the top of the tunnel may fall down with increased energy & additional safety measure are required.
Full Face Method with Auxiliary Bench Cut		 Bench length : 2 ~ 4m	Comparatively stable ground, but difficult using the Full Face Method. Full-face excavation is made difficult during construction. Presence of some poor ground in fairly good ground.	Labor saving due to mechanized construction Construction management including safety control is easy because of the single-face excavation.	Difficult to switch to other excavation method when the face does not stand up.
Bench Cut Method	Long Bench Cut	 Bench length: more than 50m	Ground is fairly stable, but Full-face excavation is difficult.	Alternate excavation of top heading and lower bench reduces equipment and manpower needs.	Alternate excavation system elongates the construction period.
	Short Bench Cut	 Bench length: 10 ~ 50m	Applicable to various ground such as softly ground, swelling ground, and medium to hard rock ground. (The most fundamental and popular method.)	Adaptable to change in the ground condition.	Parallel excavation makes difficult the balancing of cycle time for top heading and bench.

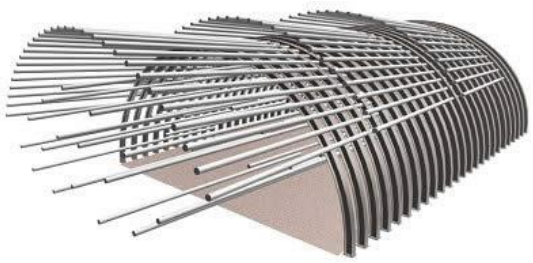
Excavation Method		Division of Section of Heading	Applicable Ground Condition	Advantages	Disadvantages
	Mini Bench Cut	 Bench length: Less than 10m	Deformation control of the excavated inner section is more urgently required than in the case of the Short Bench Cut. Squeezing ground that require an early closure of the excavated section	Easy to make early closure of the invert.	Parallel excavation makes difficult the balancing of cycle time for top heading and bench.
Center Diaphragm Method		 One method is to provide a diaphragm only to the top heading, while the other is to provide both a top heading and a bench.	Ground of shallow overburden where ground surface settlement is required to be kept at a minimum. Comparatively poor ground condition for a large section tunnel.	Face stability is secured by dividing into small sections. Ground Surface settlement can be significantly reduced. Divided sections of heading are larger than those used in the Side Drift Method, and larger machines can be used.	Displacement or settlement during the removal of the diaphragm shall be checked. Time for diaphragm removal is added to the construction period. The adoption of a special auxiliary method in the tunnel is difficult.
Side Drift Method			Bearing capacity of the ground is not sufficient for adopting the Bench Cut Method. Ground of shallow overburden where ground surface settlement is required to be kept at a minimum.	Ground surface settlement can be reduced. Temporary diaphragms can be more easily removed than those of center diaphragm method.	Small machines have to be used for drift excavation.

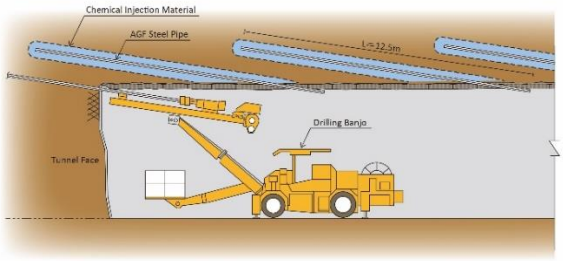
Source:JICA Survey Team (refer to Standard Specifications for Tunneling-2016: Mountain Tunnel)

13.6.6 Auxiliary Method

Some of the auxiliary methods are designed in the support patterns such as fore-poling and fore-piling likely umbrella (see Figure 13.6-2) in accordance with geological conditions and tunnel surrounding environmental such as very poor ground, fault zones and neighboring (adjacent) construction with important structures.

The tunnel passes through sheared zone between MBT and MT where is located at a section about 1km from south portal. Therefore, since the face, especially tunnel crown, likely to be unstable at the section, auxiliary method for face stabilization is required. All Ground Fastening (AGF) Method, one of auxiliary method for face stabilization and long span fore-pilling method, is applied for unstable ground such as unconsolidated soils, fault zones, etc. that cannot expect the arching effect. Therefore, AGF method is recommended in auxiliary method at the section.





Source:
Technical Document of AGF Method -6th revised edition- (Right)
JICA Project Team (Left)

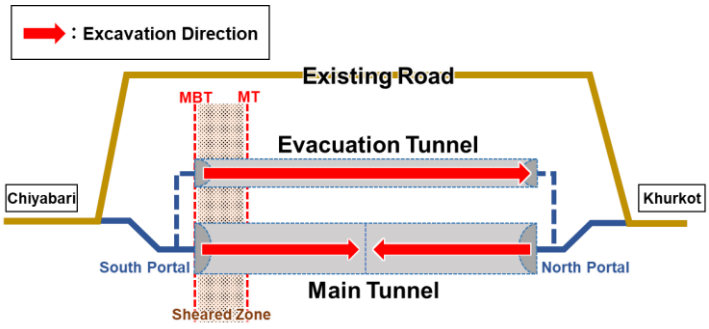
Figure 13.6-2 Long Span Fore-Piling (AGF Method)

13.6.7 Construction Planning and Temporary Facilities and Equipment for Construction

(1) Construction Plan

Construction plan of the tunnel such as excavation direction, excavation method and process are recommended as follows;

- Since length of the tunnel is over 7km, north and south portals are recommended in the portal where excavation starts in terms of shortening construction period (see Figure 13.6-3),
- Evacuation tunnel is excavated from south portal (excavation of the evacuation tunnel can be utilized for pilot tunnel to investigate the ground condition of MBT, MT and sheared zone between both faults),
- NATM and D&B method are recommended in both tunnel driving method and excavation method based on expected rock condition at tunnel section (TMB expecting high speed excavation is potentially applied for a section where is relatively stable and hard rock other than sheared zone between MBT and MT (see Figure 13.6-4)).



Source:JICA Survey Team

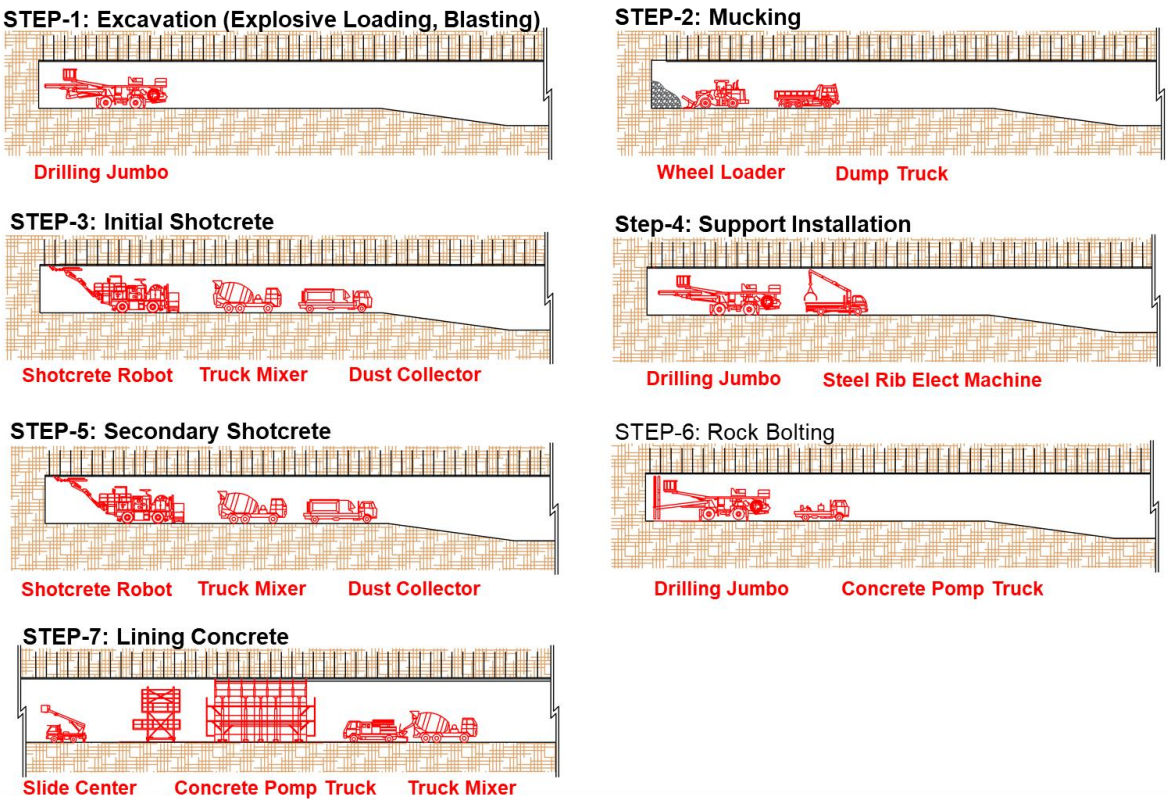
Figure 13.6-3 Construction Plan (Excavation Direction)

Source: https://ugitec.co.jp/products/tbm/

Figure 13.6-4 TBM (Open Type)

The sequence of tunnel excavation (D&B method) is shown in Figure 13.6-5.

Also, the guideline for preventive countermeasures against accidents from rock fall in the face of mountain tunnel construction (18 Jan. 2018, Ministry of Hearth, Labor and Welfare, Japan), should be followed/referred during the tunnel construction.



Source:JICA Survey Team

Figure 13.6-5 Sequence of D&B Method

(2) Temporary Facilities and Equipment for Tunnel Construction

Major temporary facilities and equipment for tunnel construction are as follows.

- Substation
- Repair Station
- Material Warehouse
- Rest House
- Intake Pomp/Water Pomp
- Water Tunk
- Explosive Handling Shop
- Blasting Supplies Shop
- Generator
- Turbid Water Treatment Facility
- Ventilation Facilities, Duct, Dust Collector
- Material Yard
- Batching Plant for Shotcrete
- Batching Plant for Lining Concrete
- Site Office

Detailed layout of the temporary facilities/equipment and detailed tunnel construction plan will be considered in consideration of the result of the tunnel excavation plan, road construction plan and influence on the noise caused by the construction.

As shown in Figure 13.6-3, since excavation of main tunnel from both portals is recommended in terms of construction efficiency, construction yard should be planned near both portals. Candidate sites of construction yard are shown in Figure 13.4-6.

13.6.8 Facilities necessary for Tunnel

Table 13.6-8 lists the facilities to be installed in road tunnels (inside and outside) for securing safe and smooth traffic flow.

Table 13.6-8 Facilities to be Installed Tunnel

Facilities		Equipment
Tunnel Ventilation	Tunnel Inside	Jet Fan*/ CO meter/ VI meter/ AV meter
	Tunnel Outside	Local Control Panel
Tunnel Lighting	Tunnel Inside	Interior Lighting/ Entrance Lighting/ Emergency Lighting
	Tunnel Outside	Road Lighting/ Local control panel, etc.
Emergency Facilities	Tunnel Inside	Emergency Telephone/ Push Button Alarm/ Fire Detector/ Fire Extinguisher/ Fire Hydrant/ Guide Board, Hydrant/ Water Sprinkler System/ CCTV Camera, etc.
	Tunnel Outside	Local Control Panel/ Water Supply Pump/ Water Tank/ Pump Panel/ Emergency Information Board, etc.
Other Facilities	Tunnel Inside	-
	Tunnel Outside	Electrical Room/ Management Office/ Power supply system/ Back-up Generator, etc.

*To install inside Outbound Tunnel.

Source:JICA Survey Team

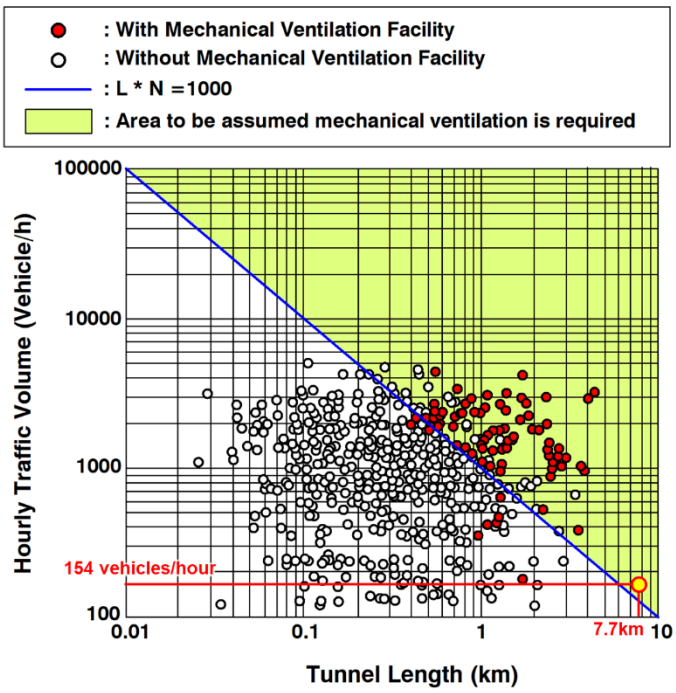
(1) Ventilation Facilities

Ventilation in the tunnel forcibly discharges harmful substances discharged by the vehicle outside the tunnel and secures safety and comfortability for driving inside the tunnel by keeping the concentration of harmful substances in the tunnel below the control standards. And also, it is important to provide better environment for the superintendents that undertake the tunnel maintenance work.

The necessity of tunnel ventilation and the detailed specification of ventilation equipment are considered based on various elements such as tunnel cross-section, tunnel length, traffic volume in the tunnel and natural environment around the tunnel. In case ventilation volume inside the tunnel by natural wind is not enough to meet safe and comfortable condition inside the tunnel, mechanical ventilation system must be necessary. Study for the necessity of mechanical ventilation system is described in below.

The tunnel ventilation facilities should be planned in consideration of tunnel cross-section, the difference in elevation at tunnel portals, traffic conditions and weather conditions. The tunnel ventilation facility planning affects the safety and construction cost, and it is necessary to further investigate and study tunnel ventilation facilities in the future. In this Study, the necessity of tunnel ventilation facilities for the tunnels are estimated based on actual cases of Japan road tunnels in the past. The figure which is shown in Figure 13.6-6 is used as one of indicator to determine the necessity

of ventilation facilities easily. From Figure 13.6-6, mechanical ventilation deems to be required in the tunnels.



※ *3,680 vehicles/day (2031) ÷24 hours =154 vehicles/hour*

Source: Prepared with reference to "Road Tunnel Technical Standards for Tunnel Ventilation" by JICA Study Team

Figure 13.6-6 Actual Cases of Japan Tunnels with/without Mechanical Ventilation

(2) Tunnel Lighting

Lighting inside the tunnel is very important to secure traffic safety. Tunnel lighting is composed of Primary Lighting, Entrance Lighting and Emergency Lighting (in case of power cut). Detailed layout and the specification are considered based on the following factors. In recent years, LED lighting which meets the following factors is used as tunnel lighting in many countries including Japan. Therefore, LED lighting is applied for design.

- High efficiency with long life
- Accommodating against high temperature, durability and humidity
- Appropriate luminescent color
- High luminous flux to meet the required high lighting level
- Easy maintenance
- Low running cost

1) Interior Lighting

Basic lighting is installed at regular intervals over the entire length of the tunnel to provide the necessary brightness for the drivers so that they can see the obstacles ahead under constant speed.

2) Entrance Lighting

Entrance lighting is installed to adjust the difference between outdoor brightness and brightness in the tunnel. Therefore, it is necessary to set the luminance so that the influence of luminance can be mitigated when change when the driver enters the tunnel.

3) Emergency Lighting during Power Failure

In case of a sudden loss of power, emergency lighting is required to prevent visual obscuration for the drivers already running in the tunnel. Power shall be supplied from the UPS immediately as uninterruptible power source.

4) Lighting outside the Tunnel Entrance

The street lamp at the exit of tunnel shall be installed adequately to guide the drivers coming up from the tunnel, especially in nighttime. No street lamp at the exit road may cause the constriction of the visual field of drivers and may lead to the accidents.

(3) Tunnel Emergency Equipment/Facilities

1) Tunnel Classification and Emergency Equipment/Facilities

Tunnel emergency equipment and facilities are to support the information transmission to road users and road administrator, evacuation, self-extinguishment and fire fighter activities when accidents or disasters occur inside the tunnel.

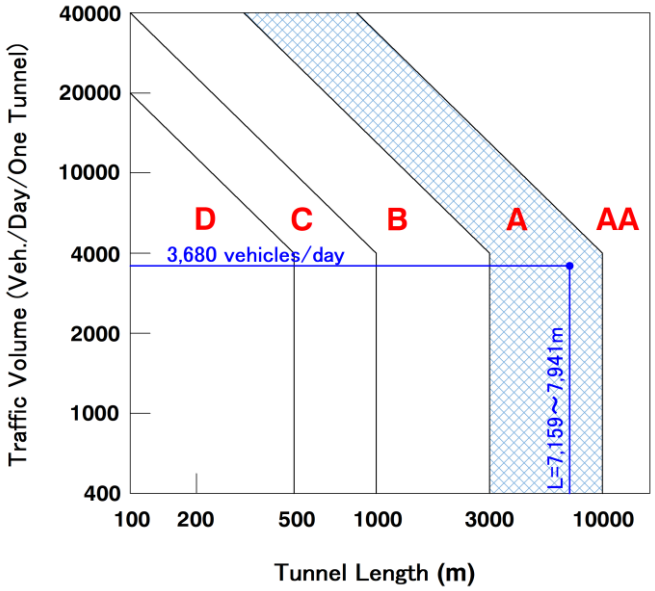
In Japanese Standards, Road Tunnel Technical Standards for Tunnel Ventilation and Design Guideline (Part3), are determined by tunnel classification shown in Table 13.6-9. Also, tunnel classification is classified to Class-AA, Class-A, Class-B, Class-C and Class-D according to traffic volume inside tunnel and tunnel length as shown in Figure 13.6-7. According to this table, the higher the tunnel classification, it is necessary to install various emergency equipment. Since the tunnels in the Study is 7,159m to 7,941m in length, tunnel class is Class-A.

Table 13.6-9 Installation Standard of Emergency Facilities

Facilities \ Classification of Tunnel		AA	A	B	C	D	Remarks
Information and Alarm Facility	Emergency Telephone	○	○	○	○		200m interval
	Push Button Alarm	○	○	○	○		50m interval
	Fire Detector	○	△				To be provided in Class A tunnel with ventilation system or water sprinkler system. (50m interval)
	Emergency Information Board	○	○	○	○		Information board at tunnel entrance
Fire Fighting Facility	Fire Extinguisher	○	○	○			50m interval
	Fire Hydrant	○	○				200m interval
Evacuation Guide Facility	Guide Board	○	○	○			200m interval
	Smoke Removal System or Evacuation Route	○	△				Ventilation system shall be used for smoke removal. Evacuation tunnel shall be provided for Class A tunnel. 3,000 m or more in length, bidirectional traffic and longitudinal ventilation system.
Other Emergency Facility	Hydrant	○	△				To be provided in Class A tunnel with fire hydrant.
	Radio Communication Support System	○	△				To be provided in Class A tunnel 3,000 m or more in length. Required and recommended for tunnel operation and maintenance.
	Radio Re-broadcast System or Loud Speaker System	○	△				To be provided in Class A tunnel 3,000 m or more in length. Class A tunnel with evacuation passage.
	Water Sprinkler System	○	△				To be provided in Class A tunnel 3,000 m or more in length. (more than 50m interval)
	Monitor System	○	△				To be provided in Class A tunnel with water sprinkler system. (150m to 200 interval)

Note： ○: Mandatory (standard) △: Recommended

Source: Prepared with reference to "Road Tunnel Technical Standards for Emergency Facilities" and "Design Guideline (Part3)" by JICA Study Team



※3,680 vehicles/day (2031)

Source: Road Tunnel Technical Standards for Emergency Facilities

Figure 13.6-7 Tunnel Classification

2) Emergency Telephone

Provision of Emergency Telephones as shown in Figure 13.6-8 are planned at both entrances to notify the tunnel accidents or disasters to the tunnel administrator and at intervals of 200 m in the tunnel.

Emergency Telephone on wall

Emergency Telephone at Entrance

Emergency Telephone Box

Source:
https://radiate.jp/20130421/higashi-fushimi/
https://blogs.yahoo.co.jp/biwako_1164/59547680.html
https://travel.watch.impress.co.jp/img/trw/docs/1049/821/html/12.jpg.html

Figure 13.6-8 Emergency Telephone

3) Push Button Alarm

Provision of Push button alarm system as shown in Figure 13.6-9 are planned to be set at 1.2 to 1.5 m above road surface and at intervals of 50 m to notify the tunnel accidents or disasters to the tunnel administrator. This alarm system will connect with the emergency telephone and firefighting system.

Push Button Alarm with Fire Extinguisher & Fire Hydrant

Push Button Alarm

Source:
https://car.watch.impress.co.jp/img/car/docs/685/703/html/049.jpg.html
https://www.iwasaki.co.jp/projects/examples/detail.php?EID=t34&cat=3

Figure 13.6-9 Push Button Alarm

4) Fire Detector

Fire Detector shown in Figure 13.6-10 reacts to the smoke generated by the fire in the tunnel and detects the fire accident in the tunnel. It is planned at intervals of 50 m inside the tunnel. In many cases, it functions as a switch for activating the emergency information board, firefighting facilities and the ventilation facility with the reaction of the fire detector.

Source:
http://nexcokiyomi.hida-ch.com/index_7.html
http://www.pref.akita.jp/chuodo/new/newimg/h19.05.31new.html

Figure 13.6-10 Fire Detector

5) Emergency Information Board

Emergency alarm system as shown in Figure 13.6-11 sends accidents and disaster information to road users by visual signals (alarm display) or audible alarms.

It is necessary to have adequate communication function to inform the road users of the disaster and accident situation in the tunnel, and it is installed in an appropriate place not to interfere with fire extinguishing activity and evacuation activities by road users.

Emergency Information Board

Control Panel

Source:
http://kitanihon-t.com/results/
http://www.iwate-shinkodenki.com/case/case25.html

Figure 13.6-11 Emergency Information Board

6) Fire Extinguishers

Fire extinguishers are shown in Figure 13.6-12. They are utilized for self-firefighting by the road users and are planned at intervals of 50 m.

Source:
http://www.pref.yamanashi.jp/kanjo/kanri/manriki.html
https://car.watch.impress.co.jp/docs/news/688076.html

Figure 13.6-12 Fire Extinguishers

7) Fire Hydrants

Fire hydrants are as shown in Figure 13.6-13. They are utilized for self-firefighting by the road users and are planned at every 200 m interval. At the same time, the hydrant for supporting firefighting activities may be installed. In that case, the fire hydrant and the hydrant will be installed at same place.

Source:
http://asahisetsubi.co.jp/construction/463/
http://photozou.jp/photo/show/629359/116028160

Figure 13.6-13 Fire Hydrants

8) Guide Board

Guide boards shown in Figure 13.6-14 are illuminated signs to inform the location of Tunnel portal to road users. Guide board are to be set at intervals of 200 m.

Source:
https://www.iwasaki.co.jp/projects/examples/detail.php?EID=rhi07&cat=1
http://www.pref.yamanashi.jp/kanjo/kanri/manriki.html

Figure 13.6-14 Guide Board

9) Smoke Removal System and Evacuation Route

The tunnel ventilation system is planned for the purpose of both smoke removal and tunnel ventilation. Jet fan will act to extract smoke in the event of fire in the tunnel.

Evacuation route facilities are evacuation tunnel, evacuation connection tunnel and evacuation port and are planned to evacuate users in the tunnel to a safe space. Smoke removal system and evacuation route are shown in Figure 13.6-15.

Since an evacuation tunnel and cross passages are planned, it is the basis of evacuation to escape to tunnel portal or the evacuation tunnel in case of fire. A door is installed at the cross passages connecting the evacuation tunnel and the main tunnel to prevent smoke from entering the evacuation tunnel.

Smoke Removal System (Jet Fan)

Evacuation Route (Evacuation ConnectionTunnel)

Source:
http://www.hanshin-exp.co.jp/company/skill/library/tech/post.html
https://radiate.jp/20081213/kitakan_opening_tochigi-ibaragi/

Figure 13.6-15 Smoke Removal System and Evacuation Route

10) Hydrant at Tunnel Portal

Hydrant at tunnel portal as shown in Figure 13.6-16 are planned at both tunnel portals to support the

firefighting activity by firefighter.

Source:
http://daikitihanayama.web.fc2.com/2004Touring/yasya/Re/y3.html
http://www.pref.yamanashi.jp/kanjo/kanri/manriki.html

Figure 13.6-16 Hydrant at Tunnel Portal

11) Wireless Radio System

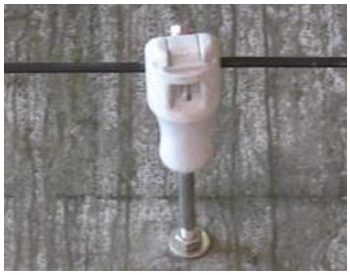
Coaxial cable as shown in Figure 13.6-17 are planned under the tunnel lighting system or the tunnel center wall to allow tunnel staff, firefighter and police to use radios.

Source: https://car.watch.impress.co.jp/img/car/docs/685/703/html/048.jpg.html

Figure 13.6-17 Wireless Radio System

12) Radio Re-Broadcasting System and Loud Speaker System

Radio re-broadcasting system secure radio broadcast in tunnel by using lead antenna at tunnel entrance. When an emergency in the tunnel occurs in environment where radio waves around the tunnel reach, the system shall be used to transmit emergency information radio signals to car users in the tunnel. In addition, the loud speaker system transmits the information on accident situation and evacuation to tunnel users away from the vehicle by radio broadcasting with speakers installed in the tunnel. Radio re-broadcasting system and loud speaker system are shown in Figure 13.6-18.



Guide Wire for AM Radio

AM Aerial Wire

Loud Speaker System

Source: https://travel.watch.impress.co.jp/img/trw/docs/1048/548/html/53.jpg.html

Figure 13.6-18 Radio Re-Broadcasting System and Loud Speaker System

13) Monitor System

The monitor system (CCTV Camera) like the one shown in Figure 13.6-19 is designed based on the tunnel plan and profile, focal length of cameras, and the size of objectives. The cameras will be installed at tunnel wall and they are planned to be installed at 150-200 m intervals of tunnel. Also, they are planned to be install at the emergency parking bay.

Source: http://www.densetsu-ndd.co.jp/construction/construction-329/

Figure 13.6-19 Monitor System

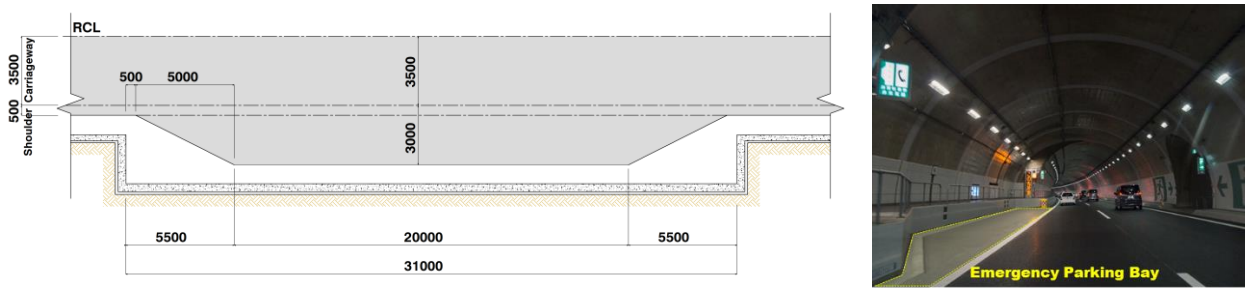
(4) Other Facilities

1) Emergency Parking Bay

Emergency parking bay is a facility that secures a safe and smooth traffic flow inside the tunnel by providing a parking space for mechanically malfunctioned vehicles.

Based on the Design Guideline Part 4 issued by Nippon Expressway Research Institute Company (NEXCO), emergency parking bay is installed in the tunnel at intervals of about 750 m. Proposed space of the emergency parking bay is shown in Figure 13.6-20.

As for the location and installation number of the emergency parking bay, it is necessary to sufficiently discuss and consider the necessity of installation of that and decide the details in the detailed design stage.



Source:JICA Survey Team (Layout of Emergency Parking Bay)
https://radiate.jp/20140628/sagami_open/ (Photo)

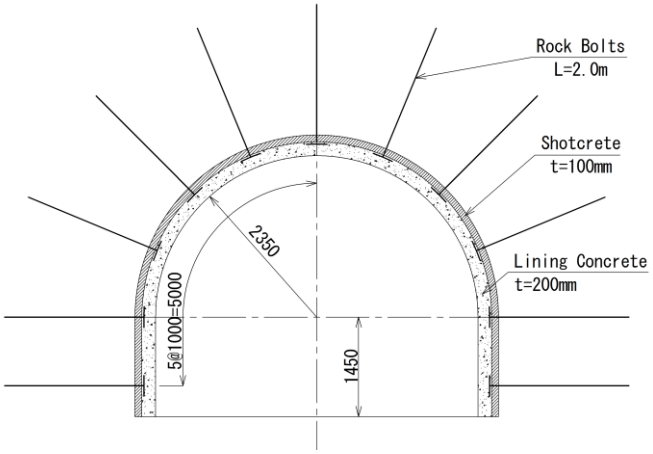
Figure 13.6-20 Emergency Parking Bay

2) Evacuation Tunnel and Cross Passage

Evacuation tunnel and cross passage shown in Figure 13.6-21 are planned to evacuate tunnel users in

the event of a fire or other accident in the tunnel. Most of the evacuation tunnels in Japan are planned in parallel with the main tunnel, and the cross passages is planned as evacuation routes connecting the main tunnel and the evacuation tunnel. According to the Road Tunnel Technical Standard for Tunnel Structure, cross passages are planned at intervals of about 700-800 m in many cases in Japan.

As for the location and number of the cross passages, it is necessary to sufficiently discuss and consider the necessity of installation of that and decide the details in the detailed design stage.



Source: Design Guideline (Part3)

Figure 13.6-21 Cross-section of Evacuation Tunnel and Cross Passage

3) Evacuation Tunnel and Cross Passage

Description of the tunnel management office and the electric room are shown in Table 13.6-10.

Table 13.6-10 Description of Tunnel Management Office and Electric Room

Facility	Description	
Tunnel Management Office	Function	・ Administration building for maintenance staff and toll-collection related staff to carry out the tunnel operation and monitoring ・ Parking area of tunnel maintenance vehicles and emergency vehicles
	Facilities	・ Administration Office Space ・ Stock Room for Equipment ・ Traffic Control Center (including rest space for patrol team, machine room for control system etc.) ・ Other (Reception, Meeting Room, Toilet etc.) ・ Parking space 10 lots
Electric Room	Function	・ Primary receiving facility for the tunnel ・ Installation room for control device of tunnel emergency facilities
	Facilities	・ Communication Machine Room ・ Electric Room for Control Device ・ Generation Room ・ Pump Room

13.6.9 Power Supply Condition

(1) DEMAND of ELECTRICITY

Tunnel projects require electricity for ventilation and lighting under both construction and operation.

1) Under Construction

In Japan, the electricity supply for construction sites is usually 3.3kV or 6.6kV and step-down at construction yard to avoid loss under transition to 100~440V by transformers to supply electricity to each construction equipment. Normally, three-phase altering current is used.

As it is assumed to excavate the tunnel from both portals, power receiving facility is needed on both portals. In the details study, power receiving capacity is determined as a total of necessary power of each equipment operating simultaneously. However, 800kVA for each portal is assumed referring to the experience of similar tunnel projects in Japan without calculation of each equipment.

2) Under Operation

In detailed study, it is recommended to study which way of one portal receiving or both portal receiving is economical. In case that transmission length become longer, voltage drop occurs and results in the necessity of larger diameter of electric cable, which affect to space of cables in the tunnel cross section.

At this moment, 1,000kVA one-side receiving is assumed taking into consideration of the length of 7.6 km based on that a 5km tunnel with similar cross section area in Japan is receiving 600kVA in one portal side.

(2) Power Procurement

As per the estimated power demand, information related to power procurement is surveyed. There are three types of electric power supplier

NEA (Nepal Electricity Authority)
IPP (Independent Power Producer) *
VUCL (Vidhyut Utpadan Company Limited) *

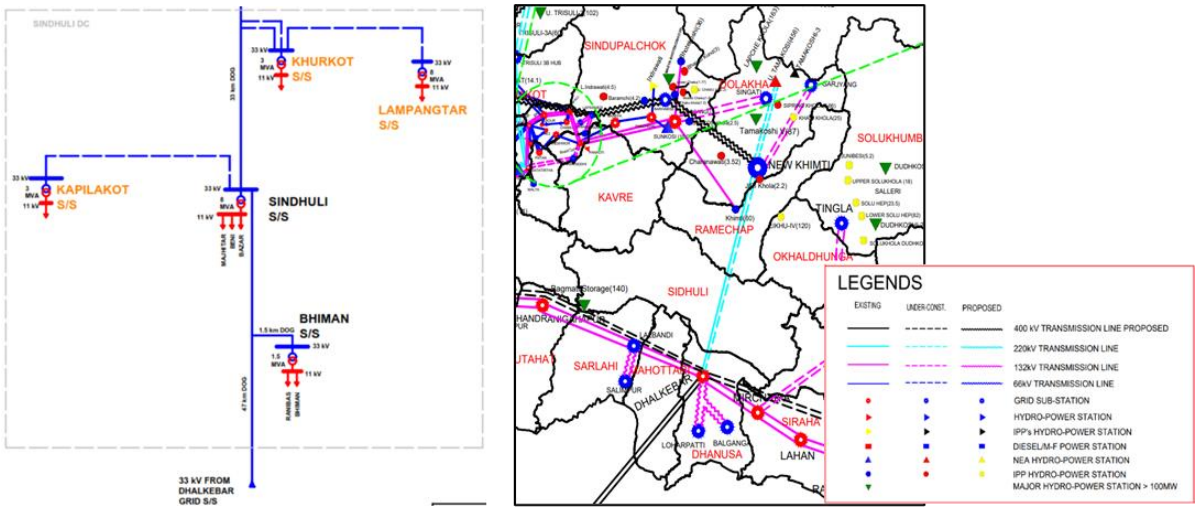
** After the electricity act of 1992, the market has become unbundled at the generation point, allowing private producers to participate in the market.*

Transmission line consists of primary side (middle voltage) of 11kV and secondary side (low voltage) of 400/230V. Most of these transmission lines are built on overhead distribution facilities excluding leader form substation. 11kV lines are pulled out from distribution substations (132/11kV, 66/11kV, 33/11kV) and stretched around in cities with twig-like systems. Cable normally used for 11kV distribution lines is three-phase wiring Aluminum Conductors Steel Reinforced with cross section of 100, 50, and 30mm^2.

As shown in Figure 13.6-22, there are three 33/11kV substation along Sindhuli road at Khurkot, Sindhuli and Bhima. From these substation, 11kV transmission lines are distributed. In the interview with a engineer of NEA Sindhuli Distribution Center (SDC), the following information was obtained;

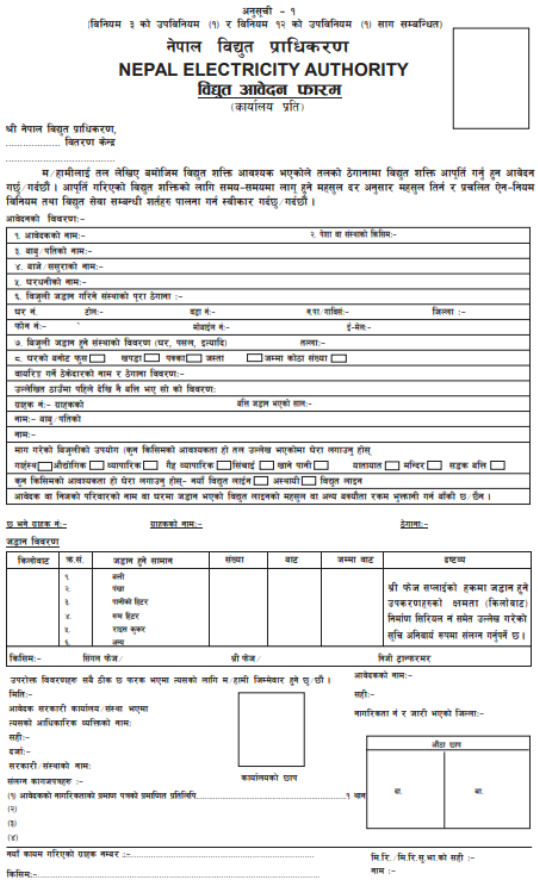
- Sindhuli substation possess a 6/8 MVA transformer which enable to transmit electricity to four routes

- If the tunnel project requires more than 6MVApower, it is needed to submit the request of suppling power. Then, SDC will start to examine it.
- In case that SDC cannot handle the request, SDC will ask Grid department / Province Division Office to manage this request from tunnel project organization> The project organization should wait for the study by System Planning Department of NEA.
- On receiving side, it needs to set up a 33/11/0.4kVsubstation so as to be able to receive 33kVA electricity.
- Figure 13.6-23 is a request sheet in Nepal language to be submitted to SDC



Source : JICA Survey Team

Figure 13.6-22 Electric Power Facilities around Planned Tunnel



अनुसूची – १
(विनियम ३ को उपविनियम (१) र विनियम १२ को उपविनियम (१) सग सम्बन्धित)

नेपाल विद्युत प्राधिकरण
NEPAL ELECTRICITY AUTHORITY
विद्युत आवेदन फारम
(कार्यालय प्रति)

श्री नेपाल विद्युत प्राधिकरण,
..... वितरण केन्द्र

म /हामीलाई तल लेखिए बमोजिम विद्युत शक्ति आवश्यक भएकोले तलको ठेगानामा विद्युत शक्ति आपूर्ति गर्नु हुन आवेदन गर्छु/गर्दछौं । आपूर्ति गरिएको विद्युत शक्तिको लागि समय-समयमा लागु हुने महसुल दर अनुसार महसुल तिर्ने र प्रचलित ऐन-नियम विनियम तथा विद्युत सेवा सम्बन्धी शर्तहरु पालना गर्न स्वीकार गर्दछु/गर्दछौं ।

आवेदकको विवरण:–

१. आवेदकको नाम:–	२. पेशा वा संस्थाको किसिम:–
३. बाबु/पतिको नाम:–	
४. बाजे/ससुराको नाम:–	
५. घरधनीको नाम:–	
६. बिजुली जडान गरिने संस्थाको पुरा ठेगाना :–	
घर नं. टोल:–	बाटो नं:– नगर पालिका:– जिल्ला :–
फोन नं:–	मोबाइल नं:– ई-मेल:–
७. बिजुली जडान हुने संस्थाको विवरण (घर, पसल, इत्यादि)	ताल्ला:–
८. घरको बनौट फुस ☐ खप्पड ☐ पक्का ☐ जस्ता ☐ जम्मा कोठा संख्या ☐	
वायरिङ गर्ने ठेकेदारको नाम र ठेगाना विवरण:–	
उल्लेखित ठाउँमा पहिले देखि नै बत्ति भए सो को विवरण:	
ग्राहक नं:– ग्राहकको	बत्ति जडान भएको साल:–
नाम:– बाबु/पतिको	
नाम:–	
भाग गरेको बिजुलीको उपयोग (कुन किसिमको आवश्यकता हो तल उल्लेख भएकोमा घेरा लगाउनु होस्)	
गार्हस्थ्य ☐ औद्योगिक ☐ व्यापारिक ☐ सिंचाई ☐ खाने पानी ☐ यातायात ☐ मन्दिर ☐ सडक बत्ति ☐	
कुन किसिमको आवश्यकता हो घेरा लगाउनु होस्– नयाँ विद्युत लाइन ☐ अस्थायी ☐ विद्युत लाइन	
आवेदक वा निजको परिवारको नाम वा घरमा जडान भएको विद्युत लाइनको महसुल वा अन्य बक्यौता रकम भुक्तानी गर्न बाँकी छ/छैन ।	

पु भने ग्राहक नं:– ग्राहकको नाम:– ठेगाना:–

जडान विवरण

किलोवाट	क्र.सं.	जडान हुने सामान	संख्या	वाट	जम्मा वाट	दृष्टव्य
	१ २ ३ ४ ५ ६	बत्ती पंखा पानीको हिटर रुम हिटर राउल कुकर अन्य				श्री फौज सप्ताईको हकमा जडान हुने उपकरणहरुको क्षमता (किलोवाट) निर्माण सिरियल नं समेत उल्लेख गरेको सुचि अनिवार्य रुपमा संलग्न गर्नुपर्ने छ।

किसिम:– सिंगल फेज / थ्री फेज / निजी ट्रान्सफरमर

उपरोक्त विवरणहरु सबै ठीक छ फरक भएमा त्यसको लागि म हामी जिम्मेवार हुने छु/छौं ।
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दर्जा:–
सरकारी/संस्थाको नाम:
संलग्न कागजपत्रहरु :–
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कार्यालयको छाप

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नाम :–

Source : JICA Survey Team

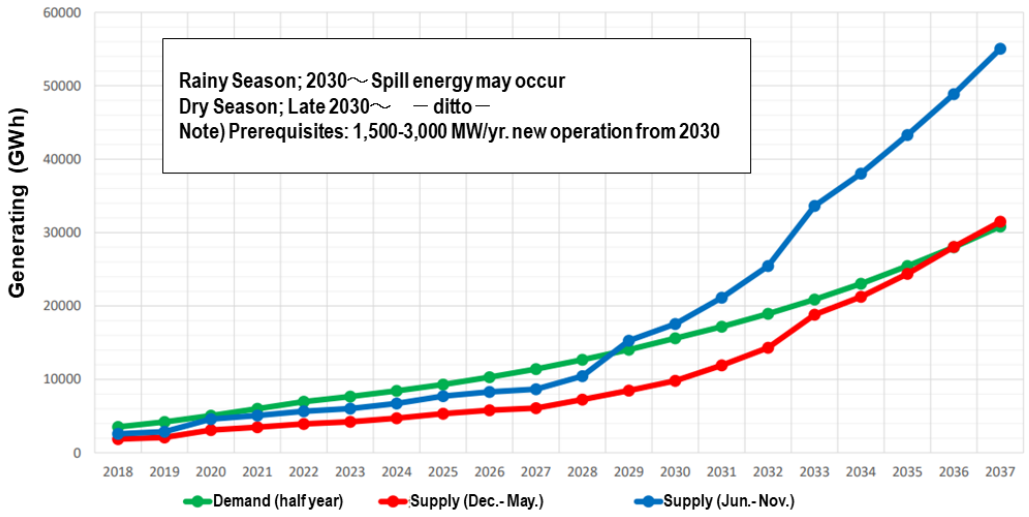
Figure 13.6-23 Request Sheet of Power Supply

(3) Future Plan of Electricity Power Facilities

According to Figure 13.6-24 in JICA's survey report1 which shows supply and demand of power from 2019, import of power from India is foreseen to be necessary in 2021 and the improvement of balance of supply and demand in domestic market cannot be expected until 2030.

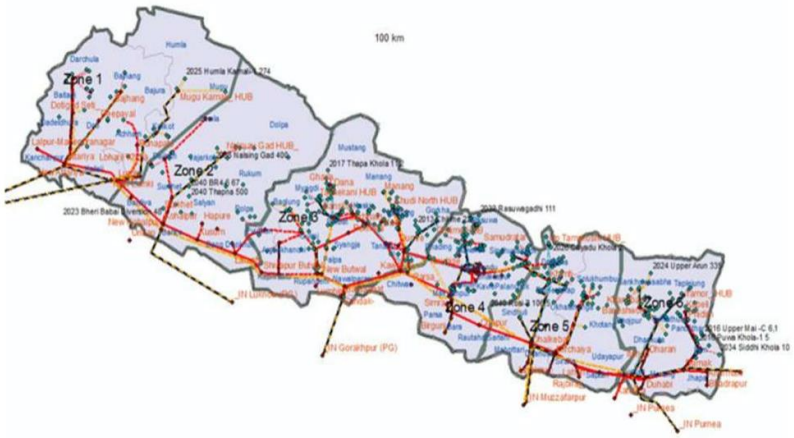
On the other hand, Figure 13.6-25 presents the transmission grid development plan of nationwide by 2035 and zone 4 including Sindhuli road by 2040.

[1] *Final Survey Report of Collecting and Confirming Information regarding Inter-city Power Distribution Development Plan in Nepal, 2019 (JICA)*

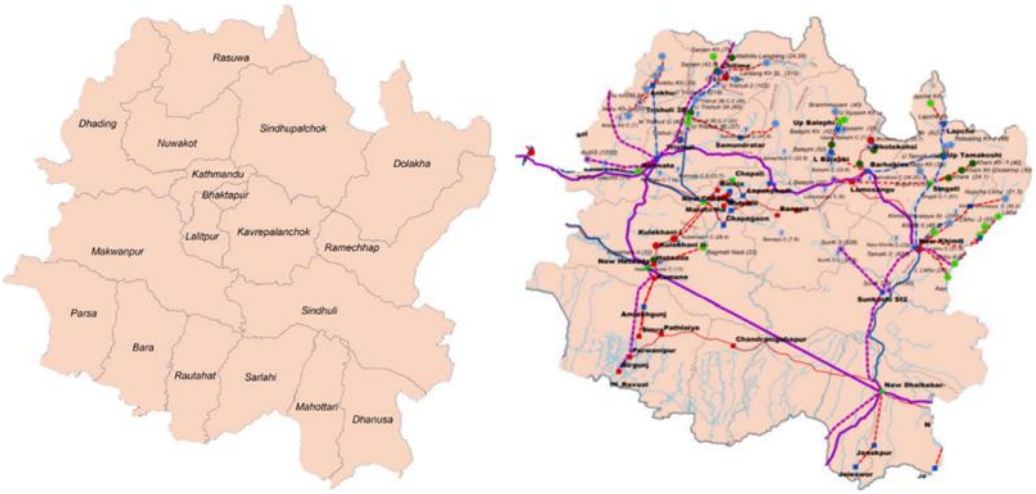


Source：Final Survey Report of Collecting and Confirming Information regarding Inter-city Power Distribution Development Plan in Nepal, 2019 (JICA)

Figure 13.6-24 Foreseen of Supply and Demand Balance of Power in Nepal



(a) Nationwide（2035）



(b) Zone-4 (2040)

Source：Transmission System Development Plan of Nepal (Government of Nepal Ministry of energy, water resources & irrigation, July 2018)

Figure 13.6-25 Transmission Line Plan

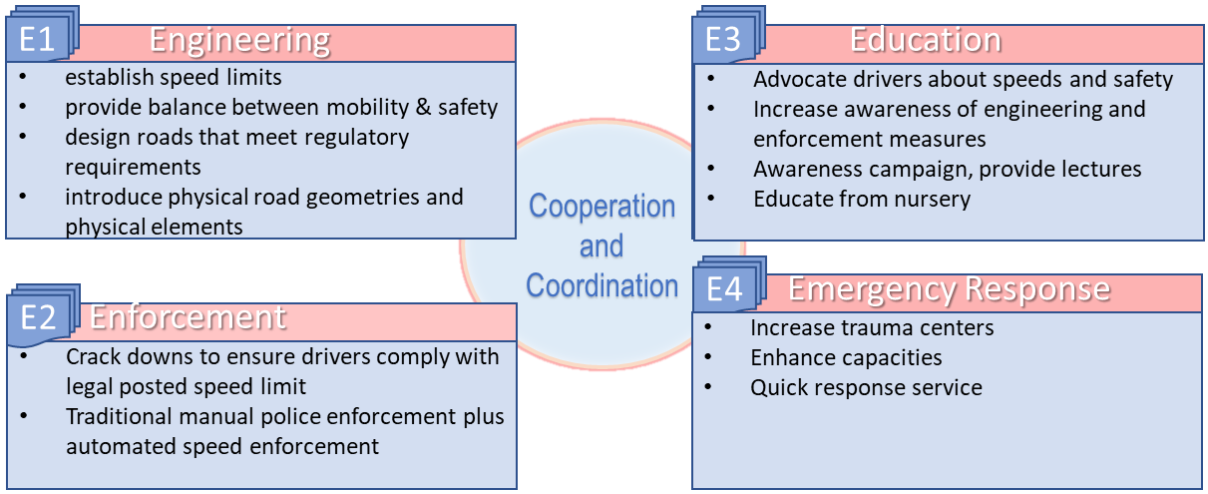
CHAPTER 14 ROAD SAFETY

14.1 INTRODUCTION

Road safety crisis is a growing global epidemic. According to WHO (World Health Organization), every year about 1.35 million people die globally from road-traffic accidents (RTAs) or more than 3,000 on a daily basis, and 20 - 50 million are injured every year. More than half of all road traffic deaths are among vulnerable road users. Pedestrians, cyclists, and riders of motorized 2- and 3-wheelers and their passengers are collectively known as "vulnerable road users" and account for half of all road traffic deaths around the world. Road traffic crashes are also a major cause of death among all age groups and the leading cause of death for children and young adults aged 5–29 years. Countries around the world are adapting policies and strategies with specific action plans to reduce fatalities and serious injuries. But implementation is yet to gain sufficient momentum, particularly in low-income countries as the proportion of such mishaps is higher in these countries; and Nepal is not an exception. Road safety is a shared responsibility. Engineering, Education, and Enforcement (3Es) are considered as three key elements of road safety. Recently, Emergency Response has been added to the elements as the response plays a vital role in the aftermath of accidents.

14.2 KEY ELEMENTS of ROAD SAFETY

Road safety is a shared responsibility. Many countries/governments advocate 4Es [1] (Engineering, Enforcement, Education, and Emergency Response) as the key elements for corresponding to Road Safety.



Source: JICA Survey Team

Figure 14.2-1 Key Elements (4Es) of Road Safety

- **Engineering** is used to establish speed limits that are appropriate to the primary purpose of the road; provide a balance between mobility and safety for all roadway users; design roads that produce desired speeds while meeting regulatory requirements; and introduce physical road geometries and physical elements to create a road that induces drivers to travel at the desired speed.

[1] *Some speed management programs are considering other Es in their speed management plans. Jurisdictions sometimes consider evaluation, environment, and equity when appropriate in a local community.*

- **Enforcement** encompasses the actions taken by authorities to ensure that drivers are complying with the legal posted speed limit. While traditional manual police enforcement at spot locations is the more commonly used strategy, automated speed enforcement is becoming more acceptable as a proven method to reduce illegal speeding while allocating law enforcement resources to more critical matters.
- **Education** entails providing information to drivers about speeds and safety and increasing awareness of engineering and enforcement measures to reduce speeding.
- **Emergency services** involve quick response of all necessary emergency personnel to a scene to minimize the severity of a crash.

14.3 ROAD SAFETY AGENCY

Lead agency for road safety in Nepal is the MOPIT (Ministry of Physical Infrastructure and Transport). MOPIT Minister chairs the National Road Safety Council (NRSC), which once or at the initial stage of establishment used to be headed by the Secretary of the then Ministry of Labor and transport management. However, this council was dormant since its establishment and never quite functioned. Since, the NRSC is the option that most of the countries globally pursued to coordinate road-safety interventions, conferring responsibilities to MOPIT was unanimously consented and endorsed on 31 January 2012. The functions of the agency include coordination, legislation and monitoring and evaluation of road safety strategies.

14.4 ROAD SAFETY ACTION PLAN AND STRATEGIES

14.4.1 Road Safety Action Plan

The country`s Road Safety Action Plan 2013-2020 (RSAP 2013-2020) was formulated in 2013 by Ministry of Physical Planning, Works and Transport Management (MPPWTM) in compliance to the mandate from the UN Global Action. It obligates all stakeholders to follow this plan to improve and manage road-safety in an integrated manner. It also sets out the activities that concerned agencies need to implement to achieve the desired goals of reducing road traffic injuries and resultant economic losses in Nepal. This is the first of its kind established in the country. RSAP for the next decade (2020-2030) is under formulation process and is reported to be issued soon. The new RSAP will revise and update the current plan incorporating the outcomes and lessons learned in the 2013-2020 period.

The RSAP incorporates interventions under the following five pillars to road-safety.

- Pillar-1: Road safety management (consisting of 19 action plan targets)
- Pillar-2: Safer roads and mobility (consisting of 26 action plan targets)
- Pillar-3: Safer vehicles (consisting of 22 action plan targets)
- Pillar-4: Safer road users (consisting of 16 action plan targets)
- Pillar-5: Post-crash response (consisting of 11 action plan targets)

Only about half the plan targets were reported to be established/performed. This however is yet to be authenticated.

14.4.2 Road Safety Strategies

Detailed formulation of the road safety strategies is one of the major activities proposed in the plan. However, the plan tentatively proposes the followings.

VISION
Safe road-infrastructures and services backed with effective post-crash response and conducive environment resulting in little or no casualties from the RTAs

Mission
(i) To mitigate the loss of life, properties and economic loss from RTAs. (ii) To complement the broader mission of the National Strategy on the Prevention and Control of Violence, Injuries and Disabilities[2] (iii) To meet the targets of the UN Decade of Action (iv) To provide a common framework for stakeholder agencies to implement the various interventions required to mitigate RTAs outcomes

14.5 ROAD SAFETY AUDIT

14.5.1 Audit Manual

Road Safety Audit (RSA) manual was prepared in 1997 by Traffic Engineering and safety Unit (TESU) [3]of the DOR (Department of Roads). The manual is prepared with an aim to raise road safety awareness amongst highway engineers and others concerned. The manual defines RSA as a systematic method of checking the safety aspects of road schemes in order to detect potential safety hazards before or even after the road is open to traffic. The DOR`s policy mandates for a periodic road safety audit of new major road construction and upgrading to ensure safer roads and mobility. RSA is carried out by a specialist or a team of specialist who are independent of the design process. The manual applies for RSA for four stages[4];

i) Stage 1 Audit: Feasibility Study stage
ii) Stage 2 Audit: Preliminary Design stage
iii) Stage 3 Audit: Detailed Design stage (main audit)
iv) Stage 4 Audit: Pre-opening stage

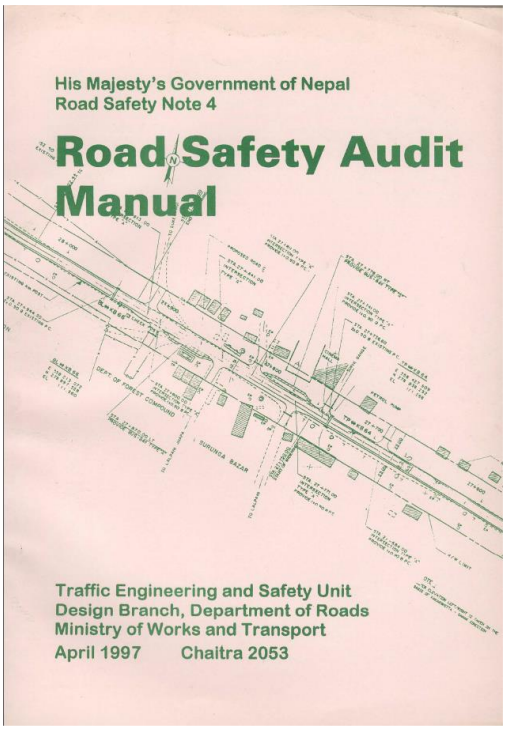


Figure 14.5-1 Road Safety Audit Manual

However, according to DOR, the agency also has an experience of conducting post-construction audit (audit of existing road). The audit was conducted for the section of Kalanki-Koteswor of the Ring Road in a bid to control the increasing number of RTAs on the section. Following the audit the department has

[2] *National Strategies for Prevention and Control of Violence, Injuries and Disabilities in Nepal; GON*
[3] *TESU has been restructured and renamed as Road Safety and Traffic Unit (RSTU) – as of November 2021.*
[4] *The manual in Nepal mandates auditing at 4 stages, but Federal Highway Agency of USA recommends auditing in 5 stages – the last one is the audit for post-construction stage (or even for existing road)*

decided to construct six over-head bridges at one kilometer interval apartment from the eight existing bridges and three overhead existing bridges along the section.

14.5.2 Audit Flow

Source: JICA Survey Team

Figure 14.5-2 Steps in Road Safety Audit

14.6 ROAD SAFETY BUDGET

MOPIT`s fund for road safety is allocated in the national budget and possesses a road safety strategy which is partially funded. Shows the budget allocated to MOPIT for Road Safety for the last three fiscal years. It is apparent from the figures that budget allocated is in an increasing trend, which is evident that road safety issue is attracting more attention.

Table 14.6-1 Budget Allocated for Road Safety for Past Three Fiscal Years

Fiscal Year	2019/20*	2020/21	2021/22
Budget (Million NPR)	97.9	220.7	500.0

Note: * actual expense, budget for FYs 2020/20 and 2021/22 are estimates

Source: Red Book 2078/79

14.7 ROAD SAFETY STATUS IN NEPAL

14.7.1 Road Safety Status

Nepal has one of the highest rates of road deaths in South Asia. According to the WHO, Total number of deaths in Nepal for 2016 is estimated at 4,622. Fatalities per 100,000 population is 15.9. The fatality rate is fairly in par with its neighboring countries. However, fatalities compared in terms of number of vehicles registered in the country, Nepal ranks top with 40.0 persons per 10,000 vehicles. This is two times higher than that of Bhutan (16.7), 3 times of India (13.0) and 5 times of Sri Lanka (7.1). The fatalities and serious injuries are causing Nepal approximately 1,194 million US Dollar.

General facts compiled in reference to past research and monitoring about road safety in Nepal can be summarized as followings;

- About half the RTAs is recorded in Kathmandu Valley alone, where number of vehicles registered account to almost half of the countries fleet ply.
- The severity of RTA injuries in the Valley is under-reported.
- Pedestrians are the most vulnerable groups
- Accident prone areas are intersections in urban areas and black spots on highways (bridge approaches, roadside built-up areas, intersections, sharp curves and high vertical grade sections) in rural areas.

- While motorbike accidents are significant in urban areas trucks and bus accidents dominate the rural areas
- One third of the accidents are reported to occur after sunset, when traffic is low
- Absence of safety facilities, improper and sub-standard design, unsafe road and roadsides, excessive vehicles that do not comply to the UN Vehicle Safety Regulations, imperfect rules and regulations, road users` non-compliance to safety standards, poor emergency response service, low-quality construction, lack of timely maintenance, lack of awareness (education), extreme climate and terrain, driver negligence are the major causes responsible for the accidents.

From above, it is not an exaggeration to say that road safety strategies and practices in Nepal are at a rudimentary stage. Despite of the establishment of the RSA plan and issuance of the RSA manual, targets set for RTAs in Nepal are far from accomplishment. Nepal also advocates 4Es, yet the effort is yet to show promising results. All four key elements of road safety need to be improved for reducing fatalities and serious injuries in the country.

14.7.2 Safety Initiatives Adapted

Following steps have been taken by the government Formation of Road Safety Council, 2017.

- Mandating road safety audit in new road constructions and upgrading (Piloted in donor funded projects)
- Comprehensive driving license test
- Conduction of Road Safety Awareness campaigns among all stakeholders
- Revision of Nepal Road Design Standard
- Implementation of RSAP (RSAP 2013-2020)
- Crack down on road safety (limited on strategic roads)
- Promulgation of laws related to road safety (speed limit/drink-driving, drug-driving, use of helmet, seat belt[5] etc.)
- Establishment of Trauma Center (in Kathmandu)
- Vehicle fitness testing center (in Kathmandu)

14.8 ROAD SAFETY ISSUES

14.8.1 General Safety Issues in Nepal`s Highways

Nepal is a mountainous country. Most of its roads are constructed in the hills which encompasses various safety issues that is indigenous to such roads. Nepal`s Road Safety Action Plan lists safety issues in Nepal`s highways as follows.

- Poor visibility at blind corners (no lighting, occurrence of haze and fogs)
- Poor shoulders with insufficient width (uneven and partly collapsed)
- Unforgiving side-drains
- None or inadequate (non-robust) safety barriers
- Improper layout of turnouts in single lane roads

[5] *As of November, 2021Seat belt law applies to drivers but not to front and rear seat occupants. The enforcement rate is ranked 5th in a total of 10. Helmet law applies to driver only. Pillion rider even children are not required to wear. Enforcement of helmet law is high (8 out of 10). Drink-driving law enforcement is also high (8 out of 10).*

- Sharp consecutive curves compounded with steep vertical grades
- Lack of climbing lanes in steep hill areas
- Potholes and sudden undulations due to lack of timely and adequate maintenance
- Sub-standard and torn-out vehicles (especially buses and trucks) that are far away for complying to UN`s safety vehicle regulations
- Over-crowdedness (number of passengers exceeding allowable number)
- Non-compliance to rules such as speed limits, wearing of helmets and seatbelts
- Lack of safety awareness (drunken driving)
- Lack of proper enforcement of law, rules and regulations

14.8.2 Road Safety Issues of the Sindhuli Road

Several trips were conducted to understand the road safety status of the Sindhuli Road. Site observation with assistance from the visual image captured by the Drive Recorder were applied for the road safety survey and Prompt List recommended by the Federal Highway Association Road Safety Audit for Existing Road Audit Stage was referred for the purpose. Hereunder the safety status is briefly discussed with the purpose to identify potential locations and items of safety issues and to provide simple recommendations. Similar survey is recommended to be conducted during the succeeding stages. The recommendations provided may be referred to for such surveys in the coming stages. However, it should be noted that then the prompt list to be used should be selected in correspondence with the stage the survey is to be conducted. For example, for the next survey stage, the PL for Planning Stage Audit should be referred.

(1) Road Alignment and Cross Section

1) Visibility, sight distance

Visibility and sight distance are often unsecured at sharp curves, particularly at hair-pin curves like in Section II from Sta.44+0 to Sta.71+200, Section III from Sta. 80+300 to Sta.80+800, Sta. 85+800, Sta.89+0 to Sta. 89+700 and between Sta.92+200 and Sta.93+500. But since the design speed is low, this is not much of an issue as at the sharp curves on the ridges. This kind of curves exist more along Section III and IV. At section IV there are curve mirrors (convex mirror) installed at most critical curves. Some of the mirrors have been probably broken or stolen.

Recommendation: Installation of curve mirrors and warning sings

2) Design speed and Speed Limit

Design speeds set differs for each section, which are not high as regarded from the current role and function of the road/sections. However, traffics, to be precise the daily/frequent users such as buses and microbuses, tend to speed-off at higher velocity than the speed limit imposed on the sections. This is made possible by three facts; i) the road was initially designed as a gravel road but later it was asphalted, ii) the road is a 1.5 lane road that makes it easy to accelerate, especially at tangential sections, iii) familiarity

Recommendation: increasing speed limit signs, pavement markings, rumble strips etc.

3) Passing

Requires substantial reduction of speed. Frequent passing on tangential sections to overtake slow vehicles. Turn outs are provided for passing of opposing vehicles but are not in full function as it is not easily noticeable.

Recommendation: Increasing no takeover warning signs, installation of noticeable signs for use of turnouts, widening of turnouts.

4) Cross section elements

Lane width is wider for a 1-lane road and narrow for 2-lane operation. Shoulder widths at both sides are also insufficient. Cross-fall is elevated towards the side ditch (adverse superelevation at curves)

Recommendation: Widening to 2-lane road (conforming to Road Design Standard) securing of 1.5m or wider shoulder

5) Drainage

No issues identified particularly with the drainage facilities except for the fact that the road is superelevated towards the drains.

Recommendation: provision at other side of the curve to eliminate adverse superelevation

(2) Auxiliary Lanes

1) Tapers

Tapers are observed at turnouts and at ends of widening at curves only. There are no climbing lanes or other form of additional lanes including at intersections.

Recommendation: extension of tapers for easy exit and entry at turnouts. This however applies if the road will remain in the current state (1.5 lane wide). This will not be necessary if the road is widened to 2-lanes, unless bus-bays, climbing lanes or other additional lanes are provided.

2) Lane width and shoulder widths

Auxiliary lanes are provided for several hundred meters at both the beginning point (Bardibas) and end point (Dhulikhel). Taper and lane width are adequate, but shoulder width is narrow. Turnouts are provided using the shoulders. Therefore, there is no shoulder at turnouts

Recommendation: Securing sufficient shoulder widths (conforming to standards)

3) Signs, Signages and Markings

Signs indicating turnouts and reduction of lanes at some locations are misplaced or unnoticeable due to wearing (paint fading away, shape disturbed, direction absurd etc.). Signages were not confirmed. Markings (center line and edge line) are provided. Zebra crossings and other markings were not confirmed as well

Recommendation: Maintenance, repair, replace and new installment

4) Turning Traffics

Very rare, but sometime traffics turn around at tangent sections, turnouts and/or at sections with open space adjacent to the shoulder.

Recommendation: Provision of U-turn spaces at adequate intervals (3-5kms)

(3) Intersections and connecting roads

1) Locations and Configurations

Currently, exiting intersections are more a connecting point of two or more roads rather than like those seen in urban areas. But development in and around intersections is progressing rapidly. Soon, the connecting points will require to be converted into or planned as an intersection with appropriate configuration. Current major connecting points are at Sta.0+0 (with E-W Highway at Bardibas), Sta. 18+500 (with Madan Bhandary Road), Sta.37+0 & Sta.38+0 (Sindhuli Bazar), Sta.74+280 (M-H Highway), Sta.76+100 (Khurkot Bazar), Sta. 150+0 (Dhulikhel). Intersections at Sindhuli Bazar and Khurkot Bazar consist of oblique legs.

Recommendation: New connecting points should be planned as an intersection from the beginning. Also, for existing connecting points, relocation should be considered such that crossing roads intersect at an angle of 90 degrees to the possible extent.

2) Visibility and sight distance

Currently, visibility and sight distance at the connecting roads are secured. But rapid development in and around the intersections are anticipated to soon hinder visibility and sight distance. Especially intersections mentioned above are of concern.

Recommendation: Secure sufficient right-of-way for future improvements of the intersections

3) Signage and markings

Signage and markings are sufficient for the current configuration of the connecting points but are wearing.

Recommendations: Similar to those mentioned for auxiliary lanes.

4) Lightings and traffic signals

Lightings are provided in certain intersections but are not light enough. No intersection is equipped or controlled by traffic signals (till date no chronic traffic congestion is evident)

Recommendations: Increasing lightings. Traffic signals may be desirable at Bardibas, intersection with MB Highway and Dhulikhel.

(4) Signs and Lightings

1) General sign issues

Signs are provided along the entire stretch. Issues are as afore mentioned. Lightings are provided in a selected area.

Recommendation: for signs refer to those for intersections and connecting roads.

2) Sign legibility and supports

There are some signs that are not legible. Supports of existing signs are functional.

Recommendations: periodic maintenance (cleaning and replacing) of signs and supports

3) Lightings

Only confirmed at built-up areas.

Recommendations: Consideration for provision of lightings at black-spots (sharp curves, hair-pin curves) and built-up areas desirable.

(5) Markings and Delineations

1) Centerline, edge lines, other markings

Markings are observed to have been placed recently. Being a 1.5 lane road, there is no centerline. But edge lines are put almost throughout the entire stretch.

2) Guideposts and reflectors

Guideposts and reflectors to help guide and set specific boundaries are not found to be provided. However, guard posts and guard blocks are provided at the valley side of the road. This functions both as protection against falling down and as a guide for drivers. Section III has reflectors on these guard posts.

Recommendation: Consideration for provision of reflectors

3) Curve warnings and delineators

Curve warnings are mostly provided by use of signs and curve mirrors. Curve mirrors provided are seen vandalized.

Recommendations: replacement of vandalized curve mirrors.

(6) Barrier and Clear Zones

1) Barriers

Concrete blocks that function both as guidepost and barrier are provided at the valley side for guidance and to stop out of control vehicles from falling. Provision of metal guard rails are limited. Concrete blocks are provided throughout the stretch except at flat sections of section I. Barriers/guideposts at Sections II and III are robust and installed at small intervals and are effective. But most sections in Section IV only have guideposts, which are weak and installed in a wider interval.

Recommendations: consideration for replacement of guideposts at Section IV to barriers or guard blocks

2) Footpath railings

Pedestrian is provided at built-up areas in Bardibas and Dhulikhel. Several hundred meters at Dhulikhel is provided with railings.

Recommendation: provision of railings at 4-lane section in Bardibas, consideration for extension including Dhulikhel and installation at built-up area in combination with provision of footpath.

(7) Bridge and Culverts

1) Design features

Bridges also have 1.5-lane width only and is not equipped with a footpath.

Recommendation: Prioritizing and providing accordingly (longer bridge at or near built-up areas in floodways of Section I and causeways at Khurkot, Dihi Phant Sta.81+100, and Sta 102+0)

(8) Floodways and Causeways

Floodways are frequently blocked by debris accumulated on top of it causing difficulty crossing it. Sometimes the extent is so severe the traffics is severed until the deposit is removed.

Recommendations: maintenance to clear passage downstream of the floodway.

1) Ponding and flooding

Traffics are sometimes stuck in the floodway due to ponding and accumulation of debris.

Recommendations: consideration for provision of signals or manual gate to stop entry of vehicles until safe passing is secured.

(9) Pavement

1) Pavement defects

No significant defects were observed.

2) Skid resistance

Sharp horizontal curves, steep grades, combination of grades and curves, and the approach to intersections are susceptible to reduction of skid resistance.

Recommendations: identifying critical sections, measuring of skid resistance and repaving with thin overlays or repaving using micro-surfacing

3) Ponding/Icing/Snow accumulation

Icing can occasionally occur during winter season at elevated sections of Section II and Section IV (especially along the north face of the hills that are not exposed to the sunlight).

Recommendations: provision of warning signs (temporarily during cold season)

(10) Other Safety Issues

1) Headlight glare

In the absence of lightings, drivers use high beams. This causes overall reduction of visibility and causing failures in detecting objects, pedestrians.

Recommendations: education to raise awareness of drivers

2) Animal emergence

Rare but emergence of animals is confirmed, especially at nighttime mostly along the forest area in Section II.

Recommendations: identifying frequent spotting areas and putting warning signs.

3) Rest areas

There are villages or built-up areas where the road users can rest. Namely, Sindhuli Bazaar, Khurkot, Mulkot, Nepalthok, Bhakundebesi etc. However, these areas are mostly areas where meal and/or tea are available. Rest area that includes gas station, service station, shops selling local products, and information dissemination area (rest area like Michi no Eki in Japan) is not available.

Recommendations: consideration for provision of a rest area at least that includes restaurants and a gas station.

4) Emergency Response

The earlier the victims of RTAs be carried and treated at a specialized medical facility (trauma center), the better is their chances of survival. Currently, there is only one authorized trauma center in Nepal, which is in Kathmandu. Most of the victims of RTAs along Sindhuli Road are treated at Kathmandu University Hospital in Dhulikhel. The hospital currently does not have a trauma center but is under preparation for its establishment.

Recommendations: Desirable to establish a hospital, if not a general medical facility at a couple of locations.

14.9 ACKNOWLEDGEMENT AND RECOMMENDATION

The road safety survey results presented are not for the purpose of immediate actions to be taken. These are intended for incorporation in the planning stage if/when the road is subject to improvement or upgradation.

Also, the survey above has been conducted with reference to the prompt list of the FHWA, USA. Nepal`s RSA manual also provides checklist that gives the safety features that need to be considered. However, the lists only provide a very generalized summary of needs. As it is important that site circumstances and other constraints be taken into consideration for a comprehensive RSA, it is suggested that prompt list of FHWA or those applied by other international agencies be referred and applied accordingly in the subsequent studies.

As DOR mandates performing Road Safety from as early as the Feasibility Study stage, it is recommended that road safety aspects be checked, safety issues identified, and adequate measures incorporated in the corresponding surveys/plans.

CHAPTER 15 STUDY ON REST AREAS

15.1 INTRODUCTION

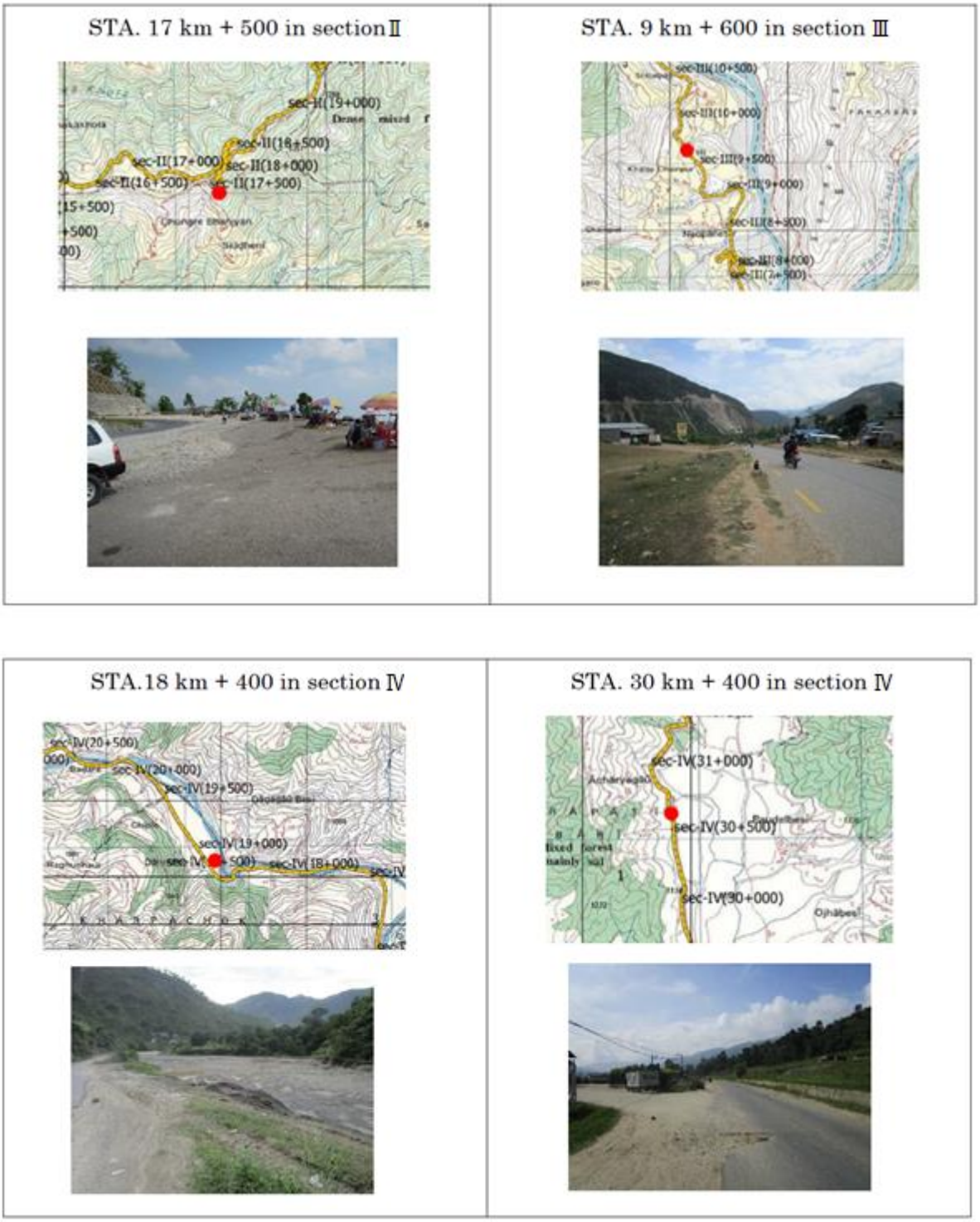
Pre-Feasibility Study (F/S) on rest areas on the Sindhuli Road was carried out in September 2019 under the Project for Operation and Maintenance of the Sindhuli Road undertaken by JICA. This F/S report mainly includes;

- Current situation and potential sites for rest areas
- Development plan
- Recommendations

In Pre-F/S report, altogether 10 areas as shown in Figure 15.1-1 and Figure 15.1-2 are proposed as candidate sites for roadside rest areas. These include the rest areas currently used by drivers.

This chapter provides updates of these candidates, based on findings from the site survey carried out under this Survey.

Figure 15.1-1 Potential Rest Areas as of 2019 (Currently Used as Rest Area)



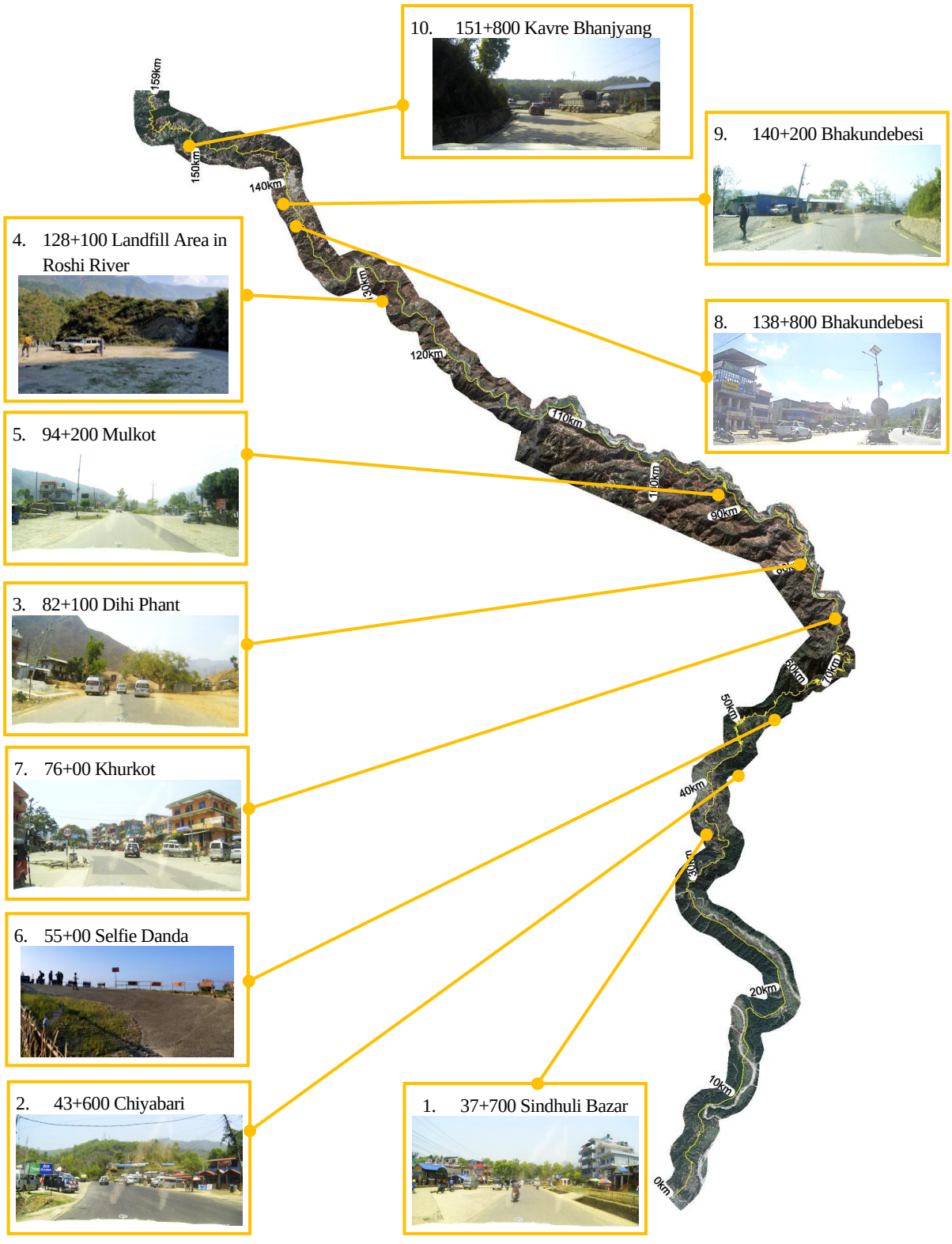
Source: Technical Report (Draft) Pre F/S of Rest Area in Sindhuli Road

Figure 15.1-2 Potential Rest Areas as of 2019 (Newly Suggested)

15.2 CURRENT SITUATION AND CANDIDATE SITES

15.2.1 Location Map

Location of rest areas that were surveyed in the F/S in 2019 are shown in Figure 15.2-1.



Source: JICA Survey Team

Figure 15.2-1 Location Map of Rest Areas

15.2.2 Current Situation

Current situation of potential areas and observation and findings from the observation of the sites under this Survey including is summarized in Table 15.2-1.

Table 15.2-1 Current Situation of Potential Areas

S.N	Location	Photo	Observation / Findings
1.	37+700 Sindhuli Bazar		• Approximate travel time is 50 mins from Bardibas and 4 hours 20 mins from KTM. • There are many buildings and facilities to rest.
2.	43+600 Chiyabari		• Approximate travel time is 1 hour from Bardibas and 4 hours from KTM • There are many buildings and facilities to rest.
3.	55+00 Selfie Danda		• Approximate travel time is 1.5 hour from Bardibas and 3.5 hours from KTM • There are many street vendors alongside the road. • Here is popular spot for selfie shots because of beautiful scenery.
4.	76+00 Khurkot		• Approximate travel time is 2 hours from Bardibas and 3 plus hours from KTM • There are many buildings and facilities to rest.
5.	82+100 Dihi Phant		• Approximate travel time is 2 hours from Bardibas and 3 hours from KTM Although there are no facilities to rest, enough space for rest area along the road is confirmed.

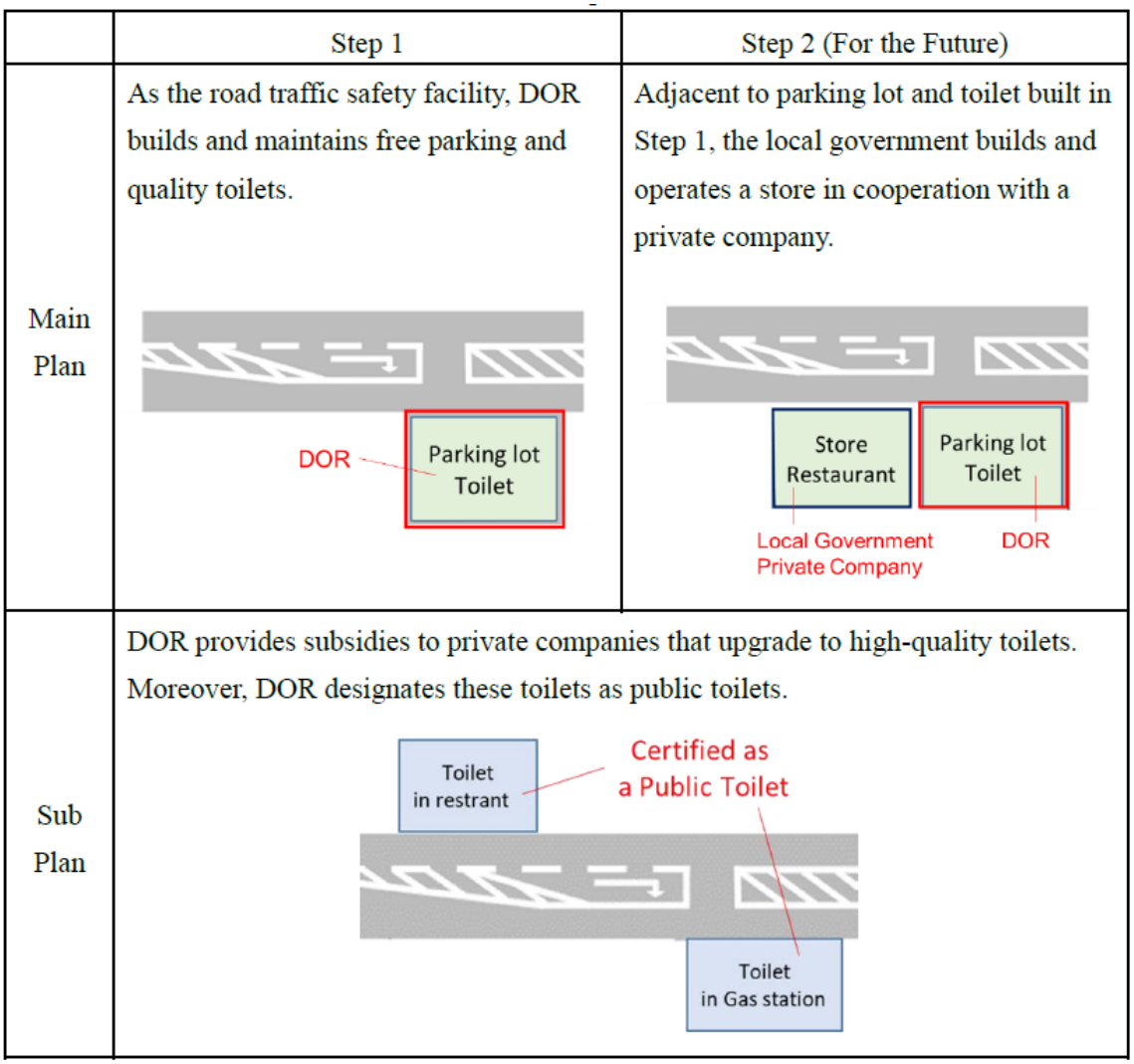
S.N	Location	Photo	Observation / Findings
6.	94+200 Mulkot		• Approximate travel time is 2.5 hour from Bardibas and 2.5 hours from KTM • There are some restaurants and hotels. • Enough space for rest area along the road is confirmed.
7.	128+100 Landfill Area in Roshi River		• Approximate travel time is 3 hours from Bardibas and 2 hours from KTM • This area is developed by landfill in the Roshi River bank • Enough space for rest area along the road is confirmed.
8.	138+800 Bhakundebesi		• Approximate travel time is 3.5 hour from Bardibas and 1.5 hours from KTM • There are many buildings and facilities to rest.
9.	140+200 Bhakundebesi		• Approximate travel time is 3.5 hour from Bardibas and 1.5 hours from KTM • Enough space for rest area along the road is confirmed.
10.	151+800 Kavre Bhanjyang		• Approximate travel time is 4 hour from Bardibas and 1 hours from KTM • Limited space for rest area along the road is confirmed.

Source: JICA Survey Team

15.3 DEVELOPMENT PLAN

15.3.1 Development Plan

In the Pre-F/S report, development plan is composed of main plan and sub plan by taking 2 stepwise measures as illustrated in Figure 15.3-1.



Source: Technical Report (Draft) Pre F/S of Rest Area in Sindhuli Road

Figure 15.3-1 Development Plan

This plan was formulated based on the existing road condition (1.5 lane). However, looking ahead to the future 2-lane improvement of Sindhuli Road that will accommodate all types of vehicles, following studies and actions in addition to the plans above is deemed necessary.

- Study on scale of facilities and parking lots
- Study on required facilities, and operation & maintenance methods
- Availability of land to be acquired

15.3.2 Necessary Procedures

Necessary procedures are summarized in the Pre-F/S report as shown in Table 15.3-1.

Table 15.3-1 Necessary Procedures

	Step 1	Step 2 (For the Future)
Main Plan	1 Addition of DOR's regulations and securing budget 2 Design 3 Construction 4 Operation and Maintenance	1 Organizing the method of cooperation between local governments and private companies 2 Arrangement of store installation rules and Management contract 3 Design and Construction 4 Select operator and start operation
Sub Plan	1 Addition of DOR's regulations and securing subsidy budget 2 System operation	

Source: Technical Report (Draft) Pre F/S of Rest Area in Sindhuli Road

15.4 RECOMMENDATION

15.4.1 Installation of "Michi-No Eki "

In the Pre-F/S report, it is recommended to install "Michi-No-Eki" along Sindhuli Road. "Michi-no-Eki" is a multi-purpose facility that serves not only for tourists but also for social and economic activities in the local community. Refer to https://www.japan.travel/en/guide/michi-no-eki/.

After improvement of the Sindhuli Road, traffic volume will increase. This implies to more use of rest area by the road users. In addition, there are touristic spots and recreational facilities alongside the Sindhuli Road. Therefore, for both resting and information dissemination purposes, development of rest areas such as "Michi-No-Eki" is rational. To make the facility more functional the rest area will require additional facilities.

The major facilities that are recommended are as listed below.

- Counter where latest/immediate information on traffic condition and closures are provided
- Maintenance Office of the Road
- Administrative Information Desks
- Police Box
- Meeting Rooms for Community
- Tenancy Spaces for Shops or Cafe Restaurants
- Toilets
- Fuel and Service Station

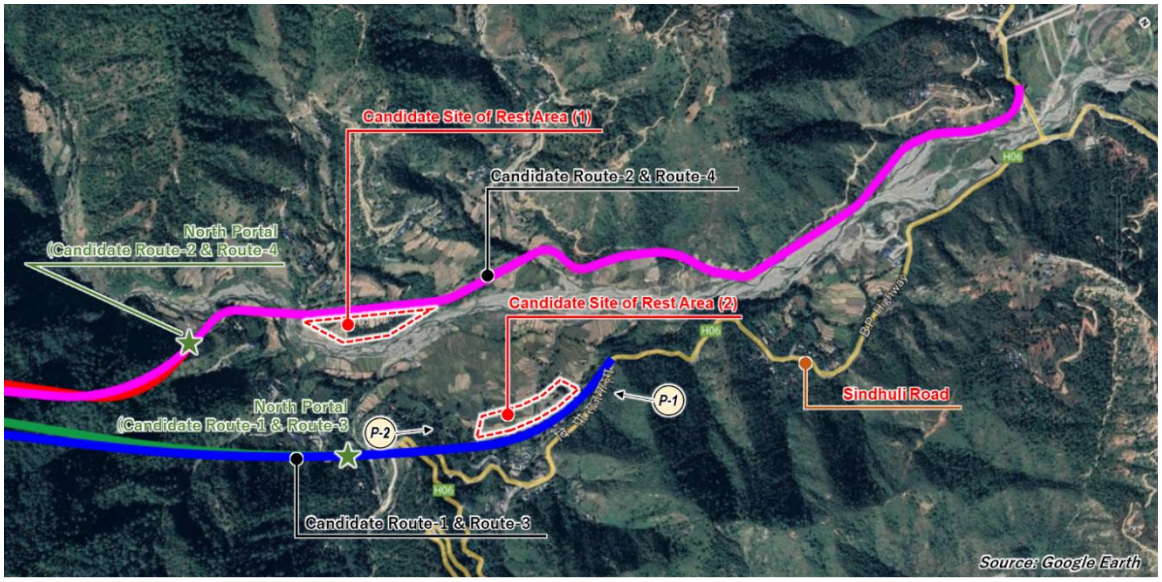
It is expected that rest areas that are equipped with the above-mentioned facilities and provide various information will have higher demand than facilities with simple food serving purpose only. This type of multi-functional facility will further contribute in raising the local economy.

15.4.2 Effective Land Utilization near Tunnel Portals

Alternative routes with a mountain tunnel are planned at Chiyabari-Khurkot section (Section II) as the improvement measure for enhancement of road function. Since approach roads connecting to north portal of Khurkot side are planned to pass through relatively flat farmland, it is possible to secure space to build a

tunnel management office, toll gate for tunnel passage (subject to decision from the road authority), and even Michi-No Eki (rest area). Figure 15.4-1 and Figure 15.4-2 show the candidate sites of the Michi-No Eki near north portal.

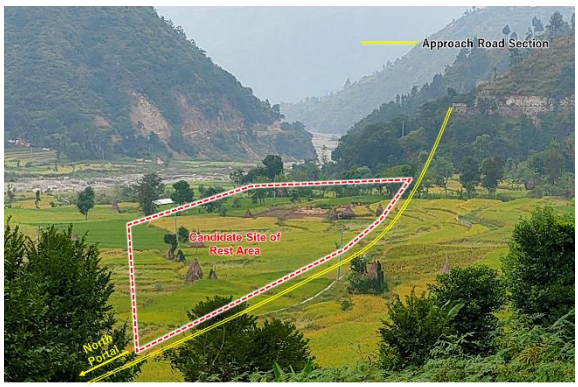
A space of 17,000 m^2 or more can be secured at this candidate site, and facilities such as police box, community meeting room, local product store, restaurant, toilet, parking lots and gas station can be built. In addition, since contrasting view of the nature and the artificial structure (tunnel portal, road) can be enjoyed from the rest area, expectation for development as a recreational area is also high. Meanwhile, Sindhuli Gadhi, one of the most historical places (forts) that is famous for the wars between the then Gorkha Army of Nepal and the British troops is only about several kilometers. Therefore, the space can also accommodate a facility for dissemination of the information.



Source: JICA Survey Team

Figure 15.4-1 Location Map of Candidate Sites of Rest Areas near Tunnel Portal

Candidate Site of Rest Area (P-1)
Source: JICA Survey Team



Candidate Site of Rest Area (P-2)
Source: JICA Survey Team

Figure 15.4-2 Photos of Candidate Sites of Rest Areas near Tunnel Portal

CHAPTER 16 CONSTRUCTION PLANNING AND COST ESTIMATE

16.1 INTRODUCTION

Information and data related to the procurement of labor, construction materials, construction equipment, etc. in order to implement the road function enhancement measures were collected and analyzed. The estimated construction cost is based on the measures mentioned in Chapters 10 and 13 and tunneling of Section II. The results are summarized hereunder.

The data and information described in this chapter are based on the analysis of available public materials, and findings from field surveys, and interviews with related parties. A more specific procurement and construction planning that is based on updated data obtained through detailed investigations and surveys are suggested.

16.2 CONSTRUCTION PLAN

16.2.1 Procurement Plan

Procurement conditions for necessary laborers, construction materials and construction equipment for this project are studied.

16.2.1.1 General Conditions

(1) Labor

As to the laborers engaging in this project, workers who do not need special skills such as ordinary workers, security guards are readily procurable from around the site, while engineers and skilled workers need to be procured from other urban cities such as Kathmandu. In addition, it is not difficult to procure the workers form India as they can enter Nepal without a VISA. However, experienced foremen for the specific construction such as tunneling, countermeasure against landslide, reinforcement earth method and metal-road method for bridge works, which requires advanced technique and safety considerations are not available in the country. These foremen need to be procured from a third country or Japan.

As a reference on this matter, the unit costs of various kinds of laborer allied in Kavrepalanchowk district is presented in Table 16.2-1, which are published by DOR (Department of Roads).

(2) Construction Materials

Table 16.2-2 summarizes the information related to various kinds of construction materials, which were obtained by interviewing with engineers in Nepal.

Natural material like stone, sand, aggregate etc., which will be extensively utilized in large amount in the project, are easily available from the riverbeds of Sunkoshi River (75km～108km) and Roshi Khola (108km～132km) as well as from the nearby local quarries. Other materials such as cement, rebar, etc, should be procured from Kathmandu or Janakapur (90km from Sindhuli) and India if not sufficiently available in Nepal market. However,the construction materials used in special work with little experience are not distributed in Nepal, and thus needs to be procured from a third country including Japan.

(3) Construction Equipment

Rental business of construction machines has been spreading in Nepal.

Basically, construction equipment for tunnel construction should be planned to procure from 3rd countries, including from Japan for maintaining certain level of quality and maintenance services. On the other hand, the procurement of general construction machines for the construction at open areas is easily available locally on a rental basis. However, large size machines and special machines may need careful judgement for reliable suppliers.

Table 16.2-3 summarizes the information related to various kinds of construction equipment obtained by interviewing with the engineers in Nepal.

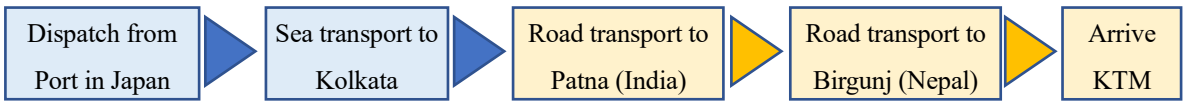
As a reference, results of interview to engineer who is currently involved in the Nagdhunga tunnel construction project are as follows;

- Nepalese sub-contractors own most of construction equipment for open area
- Most of heavy construction machines for tunneling works are imported from Japan
- Diesel fuel is imported by Nepal Oil Corporation from India.
- Explosive produced by Nepalese army are available but imported from India considering quality assurance.
- Some parts of tunnel facilities may be able to import from subsidiary of European countries, which industry locates in India.

Table 16.2-6 and Table 16.2-7 summarize the construction equipment (limited capacity). Procurement rate of these equipment is published by DOR. This equipment is easily procurable in Nepal.

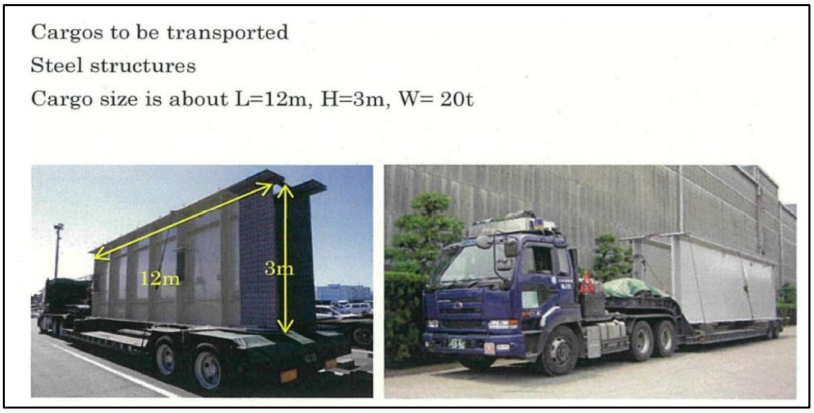
(4) Procurement from Other countries

Procurement route from Japan is as shown below. This is based on information gathered from reports of previous Sindhuli Road Construction Plan and experiences of completed construction works.



This route pass through the highway roads in India, heavy and large size equipment can be transported. However, the existing Sindhuli road is on narrow and difficult alignments. Detailed study of transportation of each necessary equipment is inevitable.

The materials and construction equipment mobilized from India, other third countries and Japan are transported by 40FT size trailer as shown in Figure 16.2-1. This is confirmed by interview with Japanese logistics provider in India.



Source: JICA Survey Team

Figure 16.2-1 Semi-Trailer for Inland Transportation (reference)

Table 16.2-1 Labor Unit Price (Kavrepalanchok district)

All items increased in about 5% from 077/78 to 078/79.

	Description	077/078 rate (NRP/Md.)	078/79 rate (NRP/Md.)
1	Unskilled Labor	725.00	760.00
2	Unskilled Labor working in highlands	725.00	760.00
3	Porters (40 kg per / 4 fund)	725.00	760.00
4	Unskilled labor and porter's hero	725.00	760.00
5	Skilled workers:(carpenter, mason, painter, plumber, electrician)	990.00	1040.00
6	Semi-skilled workers:(carpenter, mason, painter, plumber, electrician, mechanics, light vehicle driver)	825.00	865.00
7	Heavy equipment operator	880.00	925.00
8	Survey helper, line man, camp helper, tape man, chain man, cleaner	715.00	750.00
9	Guard, peon, Watchman	715.00	750.00
10	Road supervisor	770.00	810.00
11	lane man (Length worker)	605.00	635.00
12	Supervisor, Facilitators, Catalysts etc. (on wages)		
	Night watchman	715.00	750.00
	Surveyor (like overseer) technician	1105.00	1160.00
	Survey helper	715.00	750.00
	Chain man, tape man, staff man, drill helper, truck helper, sayas	855.00	900.00
	Sweeper, Mehtar	570.00	600.00
	Ordinary machine operator, wire binder	870.00	915.00
	Welder assistant	745.00	780.00
	Architect/ engineer	1325.00	1350.00
	Sub- engineer, draft man, nasu (technical)	1105.00	1125.00
	Assist. Sub-engineer, draft-man, buyer (technical)	880.00	955.00
	Pitch sprayer	615.00	645.00
	Pitch Boiler	615.00	645.00
13	Nursery Hero	585.00	700.00

Source: JICA Survey Team

Table 16.2-2 Material Procurement (1/2)

Material Name	Procurement			Remarks
	Nepal	India	Japan or 3rd country	
Civil Works				
Cement	○	○		Imported and domestic products are both distributed
Bitumen Materials	○			Imported products (generally distributed)
Stone	○			Imported products (generally distributed)
Grable, Sand, Aggregate	○			Available from quarries
Earth fill material	○			Imported products (generally distributed)
Reinforcement bar	○	○		Imported and domestic products are both distributed
Guiderail (steel)	○			Imported products (generally distributed)
Concrete barrier	○			Imported products (generally distributed)
Gabion with wire	○			Imported products (generally distributed)
Wire mesh for gabion	○			Imported products (generally distributed)
Restressed concrete strand (steel wire)		○	◎	◎: recommendation from quality viewpoint
Bearing for bridge		○	○	
Concrete pipe for drainage	○			Imported products (generally distributed)
PVC pipe	○			Imported products (generally distributed)
Nonwoven fabric	○	○		Imported products (generally distributed)
Diesel（Fuel）	○	○		Imported products (generally distributed)
Wooden panels for concrete form	○	○	○	Imported and domestic products are both distributed
Wooden scaffold material	○			Imported products (generally distributed)
Steel scaffold material			○	Quality assurance
Rock bolt materials	○		◎	◎: recommendation from quality viewpoint
High-strength network	○		◎	◎: recommendation from quality viewpoint
Precast-concrete products (Curb stone, Drainage, etc.)	○			Imported and domestic products are both distributed
Concrete admixtures	○			Imported products (generally distributed)
H shaped steel beam			○	Quality assurance

Source: JICA Survey Team

Table 16.2-3 Material Procurement (2/2)

Material Name	Procurement			Remarks
	Nepal	India	Japan or 3rd country	
Tunnel Civil Works				
Steel support		○	◎	◎: recommendation from quality viewpoint
Rock bolt		○	◎	◎: recommendation from quality viewpoint
AGF material for fore piling method			○	AGF (all ground fastening) for supplemental supporting.
Retardant fluid for backing injection material		○	◎	◎: recommendation from quality viewpoint
Water tight sheet			○	
Wire mesh for sprayed concrete	○	○	◎	◎: recommendation from quality viewpoint
Tunnel Facility				
Facilities for emergency				
- Information System			○	
- Alarming system			○	
- Fire safety (fighting) equipment			○	
- evacuation guidance system			○	
- Others			○	
Ventilation （Jet fun etc.）			○	
Lighting （LED light)			○	
Electric supply			○	
Monitoring and control			○	
Telecommunication			○	

Source: JICA Survey Team

Table 16.2-4 Equipment Procurement (1/2)

Equipment Name	Specification (Example)	Procurement		
		Nepal	India	Japan or 3rd country
Civil Works				
Bulldozer	4～21ton	○		
Ripper mounted bulldozer	21ton	○	○	
Hydraulic Excavator (Backhoe)	0.3～1.0m^3	○		
Wheel loader	2.1m^3	○		
Dump truck	4～10ton	○		
Track flat body /Trailer	10～20ton	○		
Truck crane	～30ton (25t capacity)	○		
Vibrohammer	30～90kW	○		
Breaker	0.25～1.2m3	○		
Motor grader	3.1m	○		
Road roller	10～12ton	○		
Tire roller	3～20ton	○		
Vibration roller	3～4ton	○		
Concrete (Batching) plant	45m^3/hr	○	○	○
Water tanker	8ton	○		
Oil tanker	8ton	○		
Rough Terrain Crane	<35 ton	○	○	
Rough Terrain Crane	35ton<			○
Sheet pile driver				○
Borehole pile rig (with all accessories)		○		
Electric generator	100-600kVA	○	○	◎

◎ large size equipment is recommended to procure from quality viewpoint

Source: JICA Survey Team

Table 16.2-5 Equipment Procurement (2/2)

Equipment Name	Specification (Example)	Procurement		
		Nepal	India	Japan or 3rd country
Tunnel Civil Works				
Load header	65kW-4P, 200/110kW-4/8P	○		◎
Drill Jumbo	2 or 3 boom			○
Giant breaker	Hydraulic, 3t	○		◎
Concrete spray robot	25m3/hr			○
Steel support installation equipment (Elector)				○
Excavator (backhoe)	0.6m3	○		◎
Wheel loader, side dump	2.3m3			○
Wheel loader	1～5m3	○		◎
Tractor excavator	1～4m3	○		◎
Slide center for concreting final lining				○
Stage for water tight sheet work				○
Ventilation blower	500, 1000, 3,000m3/min			○
Ventilation duct	dia. 1,500mm			○
Water treatment plant	50～200ton/hr			○
Dust collector				○
Concrete pump	90m^3/hr		○	○
Concrete mixer track	3～10ton		○	○
Concrete finisher for pavement				○
Concrete spreader for pavement				○
Concrete traveler for pavement				○
Belt conveyor for muck				○
◎: recommendation from quality viewpoint				

Source: JICA Survey Team

Table 16.2-6 Rate of Plant and Machinery (1/2)

Equipment Name	Capacity/Category
Asphalt Plant	up to 10 Ton
Asphalt Paver	112kw/16.5Ton
Asphalt, Mobile Mini Hot-mix Plant	6.5 ton
Air Compressor	150 to 275cfm
Air Compressor (Portable)	110HP/412 CFM
Chipping Spreader	90kw/8.5ton
Crane Mobile	5+ to 40 ton
Cutter Concrete	
Dozer Wheel	181 to 230 HP
Dozer Track	80 to 230 HP
Bitumen Distributor	4 to 6 KL
Bitumen Distributor(Truck Mounted)	202kw/8000Ltr
Mini Dumper	1 to 4 Cu. M.
Hydraulic Self Propelled Surface Top Hammer Drill	3 ton
Excavator Track	up to 150 HP
Excavator Track	14 ton
Excavator + Breaker	111 to 150HP
Hydraulic Excavator with Breaker (racked)	14 ton
Hydraulic Excavator with Breaker (racked)	148 HP
Mini Excavator	< 1.1 ton
Excavator, Wheeled	163hp/20.8Ton
Excavator, Long Reach	139hp/24.2Ton
Forklift Truck	< 2.5 ton
Generator	up to 50KVA
Motor Grader	90HP 135 HP 145 HP
Chip Spreader	

JICA Survey Team Original Source: DOR Equipment Hire Rate

Table 16.2-7 Rate of Plant and Machinery (2/2)

Equipment Name	Capacity/Category
Loader Wheel	1.2 ～2.5 Cu.M
Multi-purpose loading machine (Load all)	55Kw
Backhoe Loader	<90 HP
Skid Steer Loader with breaker	55 HP
Skid Steer Loader with fork lifter	55 HP
Water Pump (Engine)	up to 6"
Water Pump (Elect.)	5, 7.5 HP
Pile Driver*	10 ton
Road Marking Machine	50 liters
Roller 3 Wheel	up to 12 Ton
Roller Pneumatic	up to 20 Ton
Roller Vib. Pedestrian (Double Drum)	up to 0.6 ton
Roller Vib. Pedestrian	0.5 ton
Double Drum Vibratory Roller, Pedestrian (Walk Behind)	up to 1 ton
Roller Vib. Sheep foot	up to 10 ton
Roller Asphalt	up to 7 ton
Roller Vib. Self-Prop (Soil Compactor)	10 ton
Roller Vib. Self-Prop.	3～11ton
Roller, Combination Vibratory	1.4 ton 1.6 ton
Spray Emulsion	up to 1KL
Roller, Combination Vibratory	up to 7 ton
Track flat bed	up to 150 HP
Truck Tipper	up to 150 HP
Truck Tipper	From 150+ HP
Trailer Tractor	10 + to 25 ton
Transport Truck(15ton)	15 ton
Trailer Tractor Semi Low-Bed	40 ton
Water Tanker	up to 8 KL
Tractor	up to 85 HP
Compactor H/Towed	Compactor H/Towed
Welding Generator	3 kVA

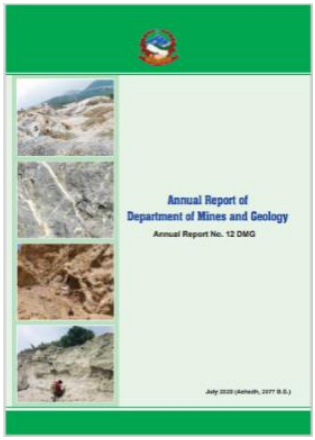
Source:JICA Survey Team Original Source: DOR Equipment Hire Rate

16.2.1.2 Main Construction Materials

(1) Stone, Sand and Aggregates

It is reasonable to assume the procurement of these materials from general market in Nepal. There are

two types of origin, from quarries at hill and mountain areas using crushing process of large size rocks and gravels and from riverbeds.



Annual Report of Department of Mines and Geology[1] explains future possibility of limitation of mining at riverbeds of large rivers flowing in Terai and riverbeds of rivers and hills in Churia region to conserve the natural environment as well as to a measure against curbing illegal procurement. As a countermeasure for this situation, they surveyed potential quarry sites in Mahabharata range where good quality material is expected. Tinkanya-6/7 and Ranichuri-9 which locate near Sindhuli road are introduced in Sindhuli District as one of 14 districts surveyed.

Table 16.2-8 Synopsis of the Areas for the Mining of Construction Materials in Sindhuli District

S. No.		1	2	3	4
District		Sindhuli	Sindhuli	Sindhuli	Sindhuli
VDC and Ward No.		Ranichuri 9 and Tinkanya 6 &7	Ranichuri 9 and Tinkanya 6 &7	Ranichuri 9 and Tinkanya 6 &7	Ranichuri 9 and Tinkanya 6 &7
Lease No.		M1	M2	M3	M4
Coordinates	Easting X1	405750	405500	405250	405000
	Easting X2	406000	405750	405500	405250
	Northing Y1	3011000	3011000	3011000	3011000
	Northing Y2	3012000	3012000	3012000	3012000
Lease Area in Km2		0.25	0.25	0.25	0.25
Mine Area in Hectares		25	25	25	25
Quarry Area in Hectares		4.91	4.82	4.96	4.86
Rock Type		Metasandstone	Metasandstone	Metasandstone	Metasandstone
Mining Method		Open Cast	Open Cast	Open Cast	
Geological Reserve in m3		3213290	1911040	1256800	2007520
Mineable Reserve in m3		2892528	1719936	1131120	1806768
Daily Production in m3		250	250	250	250
Mine Life in Yrs		42.80	25.50	16.80	26.80

Source: JICA Survey Team

The different quarry site of Nepal has been identified by Department of Mines and Geology and Road Construction and Maintenance Materials Study (RCMMS), Department of Road.

On the other hand, some quarries under operation were found at river sides or mountain sides along Sindhuli road during site visiting in September 2021. (Figure 16.2-2)

Since it is not confirmed whether the operation is under authorized permission and the quality of outputs satisfy the requirement as construction materials, it will be needed to investigate on these concerns.

According to a document regarding original Sindhuli road Section 3 construction project, they procured materials form 8 quarries at river sides. Mining is allowed in January and February in each year and the allowable amount of mining is determined by District Development Committees (DDCs) who provide

[1] **Annual Report of Department of Mines and Geology No.12 DMG July 2020 (Ashadh, 2077 B.S.) (Table 16.2-8)*

licenses to the highest bidders to operate quarries on the riverbeds in annual basis.

The reference paper of Er. Buddhi Raj Joshi and Dr. Madhav Prasad Koirala[2] explains a) summary of Quarries, b) quality of output materials investigated as an example, c) environmental issue of quarry development and operation. Regarding b), the different properties of stone aggregate of Kotre Quarry are tested for the sustainability regarding quality of the aggregate such as the physical, mechanical and chemical properties (Crushing value, Impact Value, LAA) as pavement materials and found that almost of the demand of stone aggregate was fulfilled. However, regarding c), they advocate that the engineering part of these quarry location, methods of extraction, environmental impact and many other aspects should be regularized.

Even though the procurement depends on the market condition at the necessary time, it will be important to develop the procurement plan taking into consideration of necessary amount, quality and effect of environmental protection regulations.

2 *Sustainable Stone Extraction for Using as Construction Material and Suitability Properties: Case Study of Kotre Quarry Of Nepal, Er. Buddhi Raj Joshi and Dr. Madhav Prasad Koirala, Pokhara University. 2018*

Table 16.2-9 Quarry Sites of Nepal

Location of Limestone deposit/ District	**Deposit (MT.)**	**Present Status & Remarks**
Sindhali Limestone, Udayapur	72	Mines and factory in operation
Bhanise & Okhare, Limestone Makwanpur	20	Mines and factory in operation
Chobhar Limestone, Kathmandu	14.5	Factory is closed
Jogimara Limestone, Dhading	3.6	Mine in operation by Hetaunda Cement Ind.
Beldanda Limestone, Dhading	1.72	Mines and factory in operation.
Kakaru Khola, Sindhuli	1	Mines and factory in operation.
Narpani Limestone, Arghakhanchi	17	Production started
Nigale Limestone, Dhankuta	6.3	Cement Plant under construction
Badichaur Limestone, Makwanpur	NA	Cement Plant under construction
Dang Limestone	NA	Cement Plant under construction
Rolpa Limestone, Rolpa	NA	Cement Plant under construction
Chaukune Limestone, Surkhet	31	Process to establish a cement industry
Kajeri Limestone, Salyan	29	Process to establish a cement plant.
Sarada limestone, Dang	525	Proposed for a large cement factory
Hapure Limestone, Dang	26.5	Process to establish a cement plant
Gandhari Limestone, Dang	17.6	Process to establish a cement plant
Halesi Limestone, Khotang	8.0	Mining not possible
Lakharpata Limestone, Surkhet	30.0	Evaluation warranted
Supa Khola Limestone, Arghakhanchi	8.20	High overburden ratio
Diyarigad, Chauraha, and Bhimeshor	>250.00	Promoted for detail exploration and mining
Limestone, Baitadi		for a cement Ind.
Chuladhunga – Ghyampathumka Limestone, Udayapur	40.00	Planned to promote a cement industry
Galtar Limestone, Udayapur	21.54	Planned to establish a cement factory
Bhattedanda Limestone Lalitpur	5.68	Detail evaluation warranted
Lele Limestone, Lalitpur	3.98	Recently established a cement factory
Nandu Limestone, Kavre	4.67	Detail evaluation warranted
Pandrang Limestone, Makwanpur	2.56	Planned for cement industry
Badichaur Limestone, Makwanpur	2.80	In process to establish cement factory
Darshan Danda Limestone, Gorkha	NA	Planned for cement industry
Kanchan Limestone Quarry, Palpa	1.60	Quarry is in operation since long time
Shakti Khor, Chitwan	3.20	Industry established
Others	>150.00	Possible deposits
Total deposit	**>1,297.59**	**Proved + Probable + Possible**

Source: Department of Mines and Geology (DMG, FY 2066/67) and "Road Construction and Maintenance Materials Study (RCMMS)"

	
9/22 13:58 (Section 2)	9/24 13:43 (Section 3, 94km)
	
9/24 14:24 (Section 3, 98km)	9/25 10:48 (Section 4, 120km)
	
9/25 11:46(Section 4, 128km)	9/25 11:54 (Same operation with left site)
	
9/25 13:22(Section 4, 130km)	9/25 13:47(Section 4, 132km)

Source: JICA Survey Team

Figure 16.2-2 Example of Quarries along Sindhuli Road Section III to IV

(2) Cement

According to the report of Nepal Rastra Bank Economic Research Department[3], the cement and clinker production has followed an upward trend in Nepal and 55 cement industries are in operation with an annual capacity of 15 million metric tons in 2020. Figure 16.2-3 depicts the pattern of change in the import of cement and clinker between 2014/15 and 2018/19. There has been a sharp decline in the import of cement and clinker. The gap between the domestic demand and supply of cement has gradually narrowed down.

Considering this situation, most of necessary cement is procurable inside Nepal. However, the report pointed out that there is necessity to import from India due to the following reasons, so it will be inevitable to confirm the market condition in the next study predicting the construction schedule;

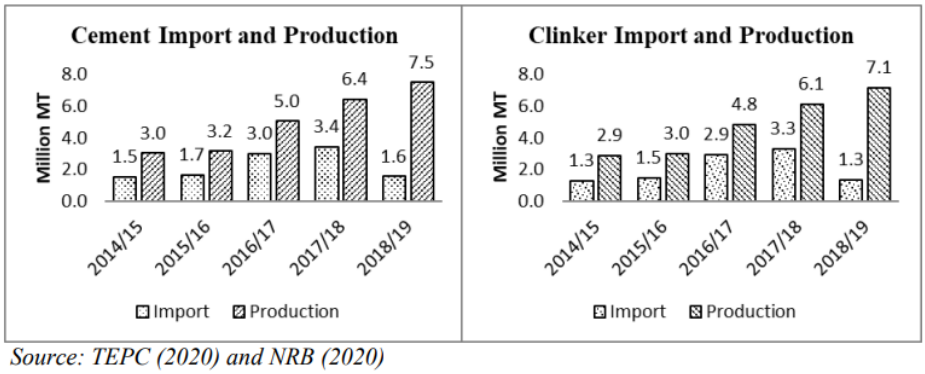
1) Domestic cement industries have a limited ability to supply cement in bulk quantities as needed by large scale projects if simultaneously undergoing. When cement supply consists of smaller batches, considerable time gets wasted in the testing process which slows down the construction activities.
2) There are concerns about quality assurance of cement produced in Nepal industries.

In case importing from India, 50 kg bags are a basic unit (neither bulk lorry nor 1 ton bag). Transportation route is as follows;

India (Railway or Track) ⇒Custom. Temporary Storage⇒Domestic Transportation in Nepal (200km with track) ⇒ Storage at the construction site (normally 2 weeks)

The contractor needs daily procurement management, storage control and quality control.

*) Foreign Direct Investment in Cement Industry in Nepal -A Study on Socio-economic Impact- Nepal Rastra Bank Economic Research Department Economic Development Division, May 2021



Source: TEPC (2020) and NRB (2020)

Figure 16.2-3 Import and production of cement and clinker in Nepal

Annual report of Department of Mines and Geology also describe the cement production industry.

1) Two decades ago there were two government owned cement companies（Hetauda Cement Industries Ltd、Udayapur Cement Factory）covered domestic demand since the demand was small. After that

[3] *Foreign Direct Investment in Cement Industry in Nepal -A Study on Socio-economic Impact- Nepal Rastra Bank Economic Research Department Economic Development Division, May 2021*

period, the domestic cement demand has increased with progress of infrastructure development and Nepal was forced to have relied on the import from India. Then, Nepal government promoted the private investment to cement industry in Nepal.

2) As a result. Currently 90% of domestic demand is covered by six domestic cement companies（Sivam, Sona-pur, Maruti, Ghorahi, Rolpa, Bishal, Nigale etc cement industries Pvt. Ltd.） and the shortage is covered by import from India.

3) To prepare for the future demand increase of cement, the potential limestone quarries were surveyed. As a result, Kakurthakur Limestone Deposit （52.78 million ton reserve, Maruti Cement Pvt. Ltd.） in Sindhuli district is introduced.

(3) Recycle of construction materials

In the road improvement project, it is necessary to dismantle existing structures such as retaining walls, drainages and course ways along the road of 130km length excluding 30km tunnel.

Table 16.2-10 summarize the qualities of existing structure of Sindhuli road.

Table 16.2-10 Quantities of structure of original Sindhuli road development project

Section	I	II	III	IV	Total
Length(km)	37.0	36.0	37.0	50.0	160.0
Earth work(1000m3)	146	1,000	686	1,026	2,858
Concrete(1000m3)	9	106	87	66	268
Gabion (1000m3)	36	122	120	28	306
Plum concrete retaining wall (1000m2)	0	157	113	132	402
Drainage (1000Lm)	8	48	56	74	186
Simple pavement (1000m^2)	14	170	180	289	653
Bridge（Nos）	9	1	0	5	15
Couse way（Nos）	5	3	12	19	39

Bridge：5 Steel bridges sand 10 Concrete bridges, total length is 1,030m

Course way：14 box types and 25 overflow types total length is 2,390m

Source：2017/11/1 Japan Road Conference (Presentation by Nippon Koei. Ltd.)

(a) Rainwater Drainage facility

(b) Retaining wall

Source: JICA Survey Team

Figure 16.2-4 Example of existing structures to be dismantled

It is not desirable from both environmental and economical viewpoints that the dismantled materials are all disposed. In Japan, most of dismantled construction materials is recycled.

In general, dismantled concrete blocks are crushed into small pieces or particles and used as recycle material after being separated from cement. The method of separating stiffened cement adhering to aggregates are rubbing with heating method, screw triturating method and eccentric rotary method. Small size plant is also available.

Table 16.2-11 Recycle of Construction Materials (Japan)

Original	Material Name	Usage
Dismantled Construction Material	Concrete blocks	Recycle aggregates, Sub base/base course materials
	Asphalt concrete blocks	Subbase/base course materials, Recycle asphalt

Source: JICA Survey Team

According to the interview to local engineer in Nepal, stones used for retaining walls is recycled by cleaning all mortal or concrete patching particles from the stones.

(4) Reuse of Tunnel muck

In case that that the area adjacent to tunnel is available as disposed area of muck by tunnel excavation, it is lucky from the viewpoint of reducing transportation expense of muck.

On the other hand, it is more desirable to reuse muck as much as possible in other sections within the project. In this project, reuse of muck for embankment of approach road to tunnel should be considered to be realized.

As the first important condition, it is inevitable to grasp the possibility of slaking and its degree and to confirm inclusion of heavy metals which may induce the long-term settlement (deformation) of embankment.

Rock muck from tunnel excavation is usually larger size material, the normal compaction control method for soil embankment cannot be applied. One method is to divide the excavated rocks into smaller pieces less than one compaction layer thickness (e.g. 100mm) which are acceptable to apply a normal embankment construction works, but this additional process results in decrease of construction efficiency and effect of cost down due to increase of crushing cost.

From these considerations, it is usual to apply construction method regulation method, in which machine and times of compaction are determine by test construction, so as to enable rock utilization with soil with minimum process of treatment of rock muck. These conditions should be considered in the construction plan in the design stage.

As a trial calculation, the followings are calculated;

- Expected amount of muck: (110m2+20m2)×7,700m=100million m3 (Embankment volume will increase by 1.15～1.40 times due to volume change rate to roughly 120 million m3)

- If used for approach road of 1,600m length, the cross section area is 750m2, which is similar to embankment of the height of 15m.

16.2.2 Spoil Disposal Area

(1) Information by Interview

The following information is obtained by interview to an engineer related to Nagudunga tunnel project.

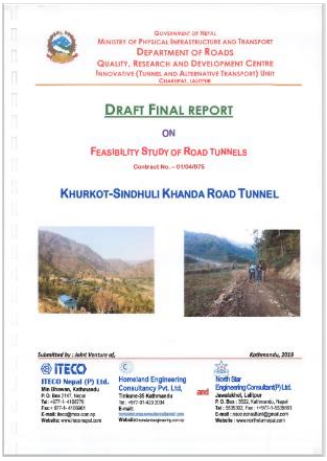
1) Agreement of landowner for private land or permission of government organization for public land is required
2) No special limitation to dispose on farm land and river area exists on the presupposition that the disposed materials do not contain hazardous material.
3) Tunnel muck of about 20 million m3 is planned to be disposed at the valley just across the western portal to minimize the transportation distance of the muck and to avoid traffic generation on the already congested highway.

The following information is obtained by interview to a Sindhuli Bardibas road project officer, Mr. Rabindra Das;

1) Generally, Government of Nepal recommend disposal areal in the government land (like river banks or barren land) and if government land are not available or not enough then private land near riverbank shall also be utilized if environmental authorities allows/permits (like dumping and laying top cultivable soil).
2) Need to obtain a permission of environmental government organization
3) In some cases, covering of the surface of disposed area is required so as to enable to use far land.

(2) Existing Study of Sindhuli Tunnel

The report of Sindhuli tunnel Feasibility study by Nepal consultant in 2018 plans following spoil disposal area.



The area of planned approach roads on both north and south portal presents configuration of medium size rivers (Gwan Khola on south portal, Abdheri Khola on north portal) which connect mountain stream to large rivers (north Sunkoshi River). Therefore, the river improvement enabling the water flow safely is planned as well as disposal area along both sides of the riverbank.

It is predicted that the government of Nepal has accepted this idea of disposal area development and it might be possible to adopt this idea in this report.

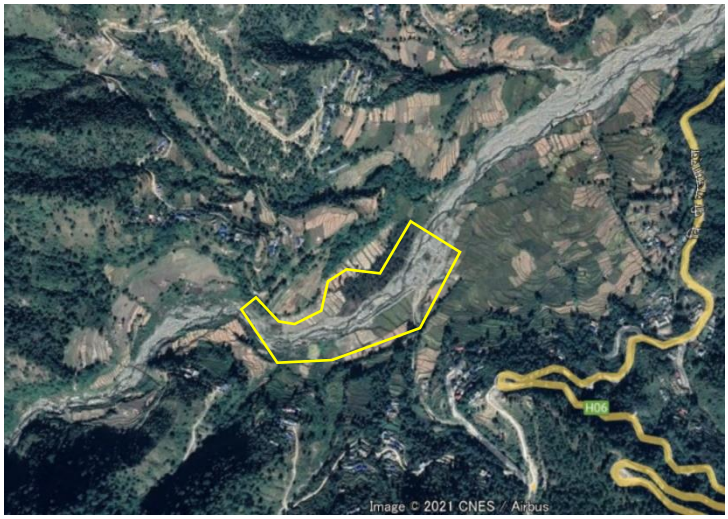
As mentioned in the previous clause, tunnel muck should be used as embankment material for approach roads as much as possible and remaining soils can be used to increase the elevation of land along the approach roads. The clearing surface clearing soils prior to embankment work should be stored temporary and recycled as surface soil for farmlands so that the farmers can continue the farming at the area.

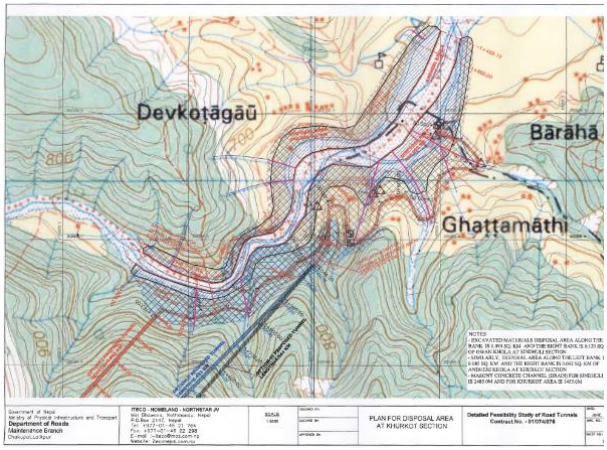
Planning of soil disposal areas proposed in the report is shown in Table 16.2-12. Their location and photos are shown in Figure 16.2-5 and Figure 16.2-6.

Table 16.2-12 Disposal area plan in the FS report

	North Portal（Khurkot）	South Portal（Sindhuli Bazar）
Area (km2)	0.177	0.268
Disposal Capacity (m3)	575,000	875,000
Length of rivers to be improved (m)	1,455	2,485

Source: JICA Survey Team



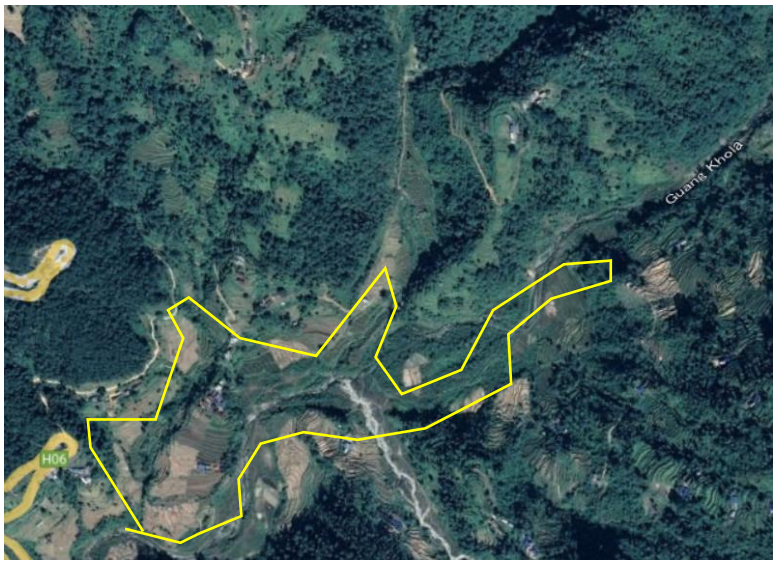


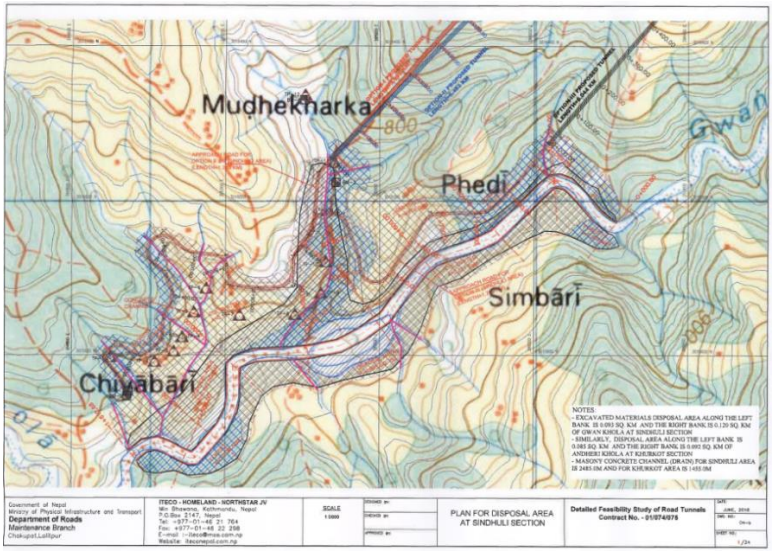
View to opposite direction form portal

View to Portal direction

Source: JICA Survey Team

Figure 16.2-5 Planed Mock Disposal Area in Feasibility Study of Sindhuli Road Tunnel in Section2 (North portal)





View to opposite direction form portal

View to Portal direction

Source: JICA Survey Team

Figure 16.2-6 Planed Mock Disposal Area in Feasibility Study of Sindhuli Road Tunnel in Section2 (North portal)

16.2.3 Camp Yard and Temporary Stock Yard

From Section I to south portal of planned tunnel in Section II, there are villages with large farmland scattered along the Ratu River, Kamala River and Gwang River excluding 29km to 36km. From the north portal in Section II to Section III, longer stretch run mountainside along Sunkoshi River and no usable land can be found in these stretches. However, land use of riverbank (village and farmland, e.g. Figure 16.2-7) or land on gentle slope locate every 5 km at maximum distance.

Therefore, it will not be difficult to find the lands for construction camp and temporary storage yards,

In front of both portals, there are enough areas to be utilized as temporary construction yard (10,000m2 for each) considering the topography and current land use conditions.

The negotiation with landowners is necessary for these temporary uses of private lands.

Source: JICA Survey Team

Figure 16.2-7 Image of Camp Yard at Section III, 94km+000 （view from zigzag road at 93km+700）

16.2.4 Traffic Regulation and Safety Management during Construction

One of difficulties on road improvement construction is appropriate management of the existing traffic. Thorough study on traffic regulation under construction works is needed. The traffic volume on the road includes both common vehicles and construction vehicles including large size vehicles in some construction works. The route of transportation to Section II and Section III up to the south portal is from Bardibas and the route to up to north portal in Section II and Section III-IV is from Dhulikel.

The following situation should be considered.

(1) One-sided traffic regulation

1) In case of large size vehicle traffic

Considering the efficiency of equipment and material transportation, it is desirable to use larger size vehicles as much as possible. Preliminary study on traffic regulation to grasp the overall predicted conditions where and what kind of regulation will be necessary along the Sindhuli road for larger size vehicles needs to be studied as well. In addition, since there are some locations where the current alignment does not allow the large size vehicles passing though without any specific consideration, it

will be necessary to study the necessity of road improvement or some temporary widening of road in the earlier stage of the project.

2) In case that the centerline of alignment is kept as it is, the widening of the road should be executed in both sides of the road. This work requires one-side traffic regulation during both cut slope mountain side and installation of new retaining wall for valley side widening which are executed in different construction schedule. Especially for cutting of mountain side slope, it is necessary to set temporary walls between work area and one-side traffic lane to prevent from overflow of cut-downed rocks and soils. Further, the width of work area should be determined considering the necessity of loading and carrying out them.

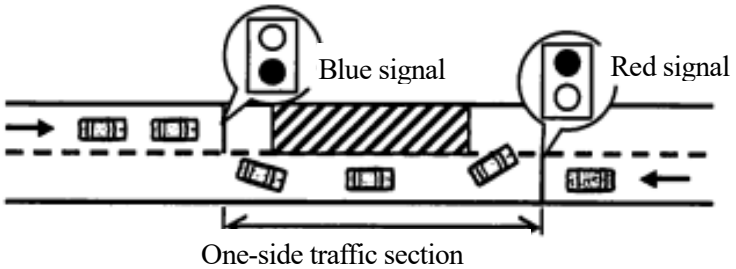
3) Even flat area, the one-side traffic regulation is necessary during pavement work.

4) Flagmen or temporary signal equipment should be designated to control the movement of vehicles and secure smooth and safe traffic.

Since traffic regulation on two-way direction road assume one-side traffic close and another lane is allowed to use for one direction, change of traffic direction system is needed. In this case, clearance time (duration of both direction signals are red) should be considered for one-side altering traffic capacity. This is necessary time for the last vehicle which entered one-side traffic lane just before the control signal turn from blue to red.

The allowable traffic capacity on this occasion is calculated as follows;

CT＝L×(3,600/1,000)/V
CT: Clearance time（sec）
L: Length of construction area（m）、V：Vehicle speed(km/h)
Qk=Qko×g
Qk: Traffic capacity in case of one-side traffic（Nos/min）
Qko：Traffic capacity of one lane within multiple lanes（Nos/min）
g：Rate of possible running time in one cycle G/C
G：Possible running time of one direction in one cycle（=C/2-CT）
C: Duration of one cycle（sec）



Source: JICA Survey Team

Figure 16.2-8 Image of One-side Altering Traffic Section

Figure 16.2-8 presents an example of calculation assuming V=20km/hr. and Qko=20 vehicles / min as a reference. For example, one direction traffic capacity is 4.0 vehicles/ min in case that the one-side traffic

section is 300m and cycle time of 180 sec.

Table 16.2-13 Calculation Example of One-side Altering Traffic（－:failure）

	V=	20	km/hr		Qko=	20	台/min						
	C(sec)												
L(m)	60	90	120	150	180	210	240	270	300	330	360	390	420
100	4.0	6.0	7.0	7.6	8.0	8.3	8.5	8.7	8.8	8.9	9.0	9.1	9.1
200	-2.0	2.0	4.0	5.2	6.0	6.6	7.0	7.3	7.6	7.8	8.0	8.2	8.3
300	-8.0	-2.0	1.0	2.8	4.0	4.9	5.5	6.0	6.4	6.7	7.0	7.2	7.4
400	-14.0	-6.0	-2.0	0.4	2.0	3.1	4.0	4.7	5.2	5.6	6.0	6.3	6.6
500	-20.0	-10.0	-5.0	-2.0	0.0	1.4	2.5	3.3	4.0	4.5	5.0	5.4	5.7
600	-26.0	-14.0	-8.0	-4.4	-2.0	-0.3	1.0	2.0	2.8	3.5	4.0	4.5	4.9
700	-32.0	-18.0	-11.0	-6.8	-4.0	-2.0	-0.5	0.7	1.6	2.4	3.0	3.5	4.0
800	-38.0	-22.0	-14.0	-9.2	-6.0	-3.7	-2.0	-0.7	0.4	1.3	2.0	2.6	3.1
900	-44.0	-26.0	-17.0	-11.6	-8.0	-5.4	-3.5	-2.0	-0.8	0.2	1.0	1.7	2.3
1000	-50.0	-30.0	-20.0	-14.0	-10.0	-7.1	-5.0	-3.3	-2.0	-0.9	0.0	0.8	1.4

Source: JICA Survey Team

(2) Fully Traffic Closing

It is assumed that fully traffic closing is forced to implement in some cases depending on contents of road improvement construction and safety consideration. An example of the later one is the point with large rock blocks on the slope which must be removed for cutting work.

In case that the duration of the work is long, it is necessary to set a detour avoiding the location including temporary bridge to cross the rivers in some locations. There may be possibility to avoid long detour by setting temporary piers or just simply widening valley side.

These rough planning should be carried out considering overall project schedule and order of improvement locations.

Some reference information helpful to consider detour at the opposite bank of the river along the road are presented in Figure 16.2-9.

1) 76km+200 Existing River Crossing Bridge which vehicle can pass through (Sunkoshi River)

2) 96km+200 Existing River Crossing Bridge which vehicle can pass through (Sunkoshi River)

3) 108km+100 Existing River Crossing Bridge which vehicle can pass through (Sunkoshi River)

4) 118km+600 Temporary road crossing river (Roshi Khola 108km+800～132km+200)

5) 120 km +600 Temporary road crossing river (Roshi Khola 108km+800～132 km +200)

Figure 16.2-9 Possibility of Crossing Rivers for Tenporary Traffic

16.2.5 Others

(1) Locations difficult to widening

Figure 16.2-10 shows photographs at Section IV 109 km +700, where a suspension pedestrian bridge exists in direction perpendicular to the Sindhuli road. Since both main tower and anchorage locate very close to the road, it is necessary to dismantle the structure or to find another route.

At this moment, the importance of this bridge is unknown, but the temporary out of service is inevitable to improve the road. It may be necessary to consider that both pedestrians and vehicle traffic are to pass a temporary road crossing Roshi Khola in dry season with small amount of river water flow.

Source: JICA Survey Team

Figure 16.2-10 Location difficult to widen the road at Section 3 PK109+700

16.3 ESTIMATE OF TENTATIVE CONSTRUCTION COST

16.3.1 Outline of Each Section and General Effect to Construction cost

・**Section I** begins at Bardibas on the E-W Highway and go north direction on Siwalik hills, then reach to Sindhuli Bazar. The total length is 37km. The elevation of the starting point is about 225m above sea level. It increases gradually as the road goes further to the north and elevation of end point is about 500m. Due to gentle vertical alignment on the flat terrain with relatively small difference of elevations between starting and end points, no conspicuous large-scale earthwork consisting of high cuts/embankments will be required.

→ Minimum construction cost is expected.

・**Section II** runs from Sindhuli Bazar to Khurkot, which faces Sunkoshi River, passing though Mahabharat Range. The total length is 36km. The elevation of both starting point and end point is both 500m and the highest point of Mahabharat Range is about 1350m above sea level. The first 7km of the road runs on the Siwalik hills (elevation 500m～900m) and the remaining north stretch runs along mountainous terrain with very steep slope, where many locations constructed with large scale cut and embankment.

→29km within 36km is to be substituted by the new tunnel, the construction cost is largest among 4 sections. Remaining 7km also runs at steep slope, which require larger cost.

・**Section III** begins at Khurkot, where the elevation is about 500m. This section is approximately 36.8 km long and ends at Nepalthok. The elevation of starting and end points is about 500m and 550m

respectively, and the highest point is at the elevation of 650m at PK89+800. The elevation change is smaller than other sections, the road runs the quite steep hillsides on the right bank of Sunkoshi River. Several villages exists along the road, where many slope failures and landslides have been occurring in the past.

→The improvement of the road on steep hillsides along the river require the difficulty structure for widening road resulting in large construction cost.

・**Section IV** connects Nepalthok and Dhulikel with total length of about 50km. The section passes first 22km along Roshi River and then after passing through a flat area in Bhakundebesi (PK137+100～PK145+700) the road begins to ascend relatively steep hill gradually to about 1500m at Dhulikhel. Large-scale cuts/fill are not prominent in this section except some specific locations.

→Longest section and partially runs steep slope, so the cost is not low

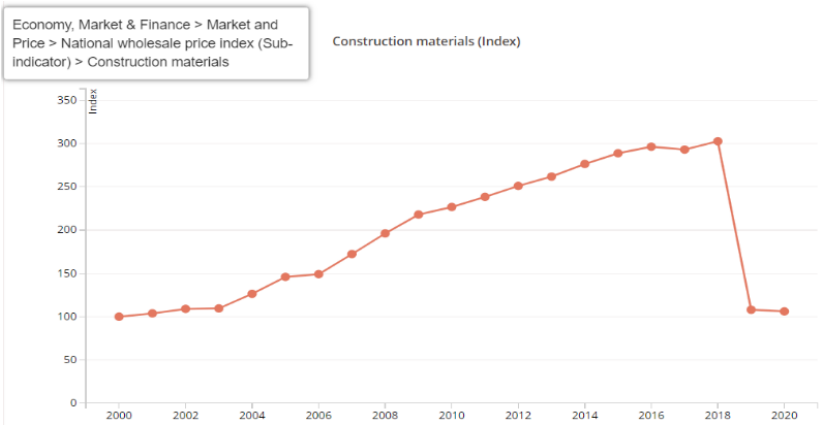
16.3.2 Related Items to Cost Estimate

(1) Transition of Labor and Material Cost of Construction Field

Due to the economic growth and promotion of infrastructure development in the last two decades, the labor and material cost for construction has been increasing as shown in Figure 16.3-1. After the earthquake in 2015, higher escalation was found due to demand for recovery construction of damaged structures. Then, the values in 2019 and 2020 have dropped suddenly. This may be effect by COVID-19.

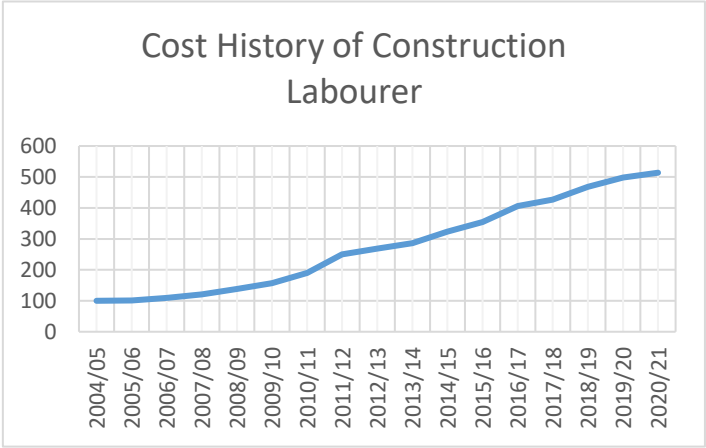
On the other hand, Figure 16.3-2 which summarizes the data of labor cost obtained from other documents.

In cost estimation, DOR unit cost data of FY2020/21 (2077/78) is basically used. When the macro unit cost data of similar structure of road project in Nepal is adopted, escalation rates, 1.2 times for the data of FY2016/17 and 1.05 times for the data of FY2019/20, are considered.



Source : https://nepalindata.com/data/

Figure 16.3-1 Transition of Labor and Material Cost of Construction Field



Source ：National Salary and Wage Rate Index

Figure 16.3-2 Transition of Labor Cost of Construction Field

16.3.3 Rough Construction Cost Estimate

(1) Assumptions on Cost Estimate

1) Road (Earth work, Breast and Retaining wall, Side ditch, slope protection, etc.)：based on the cost estimate data of similar projects in Nepal and DOR's DDC rate (District Development Committee rate[4]) of FY2077/78 (2020/21) for the representative cross sections in Chapter 10.
2) Bridge：based on the unit cost derived from cost estimate data of similar DOR projects in Nepal
3) Tunnel：based on the unit rate of a similar size tunnel in Japan and the each length of various support patters depending on predicted ground condition of tunnel section, which is presented on geological profile.
4) Corse way：based on assumed concrete volume and DDC rate
5) Pavement：based on assumed concrete volume and DDC rate assuming
(surface course t=50mm, binder course t=50mm, base course t=100mm and sub-base course t=150mm, Width: 10m assumed for all sections)
6) Road furniture and ancillary facilities：based on the unit cost derived from cost estimate data of similar DOR projects in Nepal

(2) Representative Cross Sections for Cost Estimate

Five cross sections for open section（Type-2, Type-3A、Type-3B、Type-4, Type-5） and Tunnel section（Type-6） are supposed. The yellow line represents the existing cross section on open area cross sections. In the cost estimate, dismantling work is considered prior to complete the final widened cross section depicted by rigid lines.

(3) Locations where the alignment improved

The cost of the locations in Table 16.3-1 presents locations of study for alignment improvement and alternative routes, which are studied in Chapter 10. The construction cost for alignment improvement is

[4] *NORMS for RATE ANALYSIS:*
Standard Specifications for Road and Bridge Works (approved on BS 2058.3.15.), Ministry of Physical Infrastructure and Transport Department of Roads

reflected in the cost estimate in the next clause. For remaining sections, widening of the existing road is applied for cost estimate.

Table 16.3-1 Locations of improvement of alignment

No.	Section	STA. No.	Alternative Route
1	I	2km+600 - 2km+900	ALT-1E
2		5km+200 - 5km+600	ALT-2B
3	II	41km+800 - 43km+500	ALT-3A
4	III	80km+200 - 80km+800	ALT-4B
5		85km+750 - 86km+050	ALT-5B
6		87km+650 - 94km+650	ALT-6D
7		96km+900 - 97km+250	ALT-7B
8		101km+900 - 105km+000	ALT-8A
9		106km+800 - 107km+800	ALT-9B
10		109km+400 - 110km+200	ALT-10A
11	IV	112km+000 - 113km+300	ALT-11A
12		113km+350 - 114km+900	ALT-12A
13		115km+300 - 117km+450	ALT-13A
14		123km+650 - 124km+800	ALT-14A
15		127km+600 - 128km+500	ALT-15A

Source: JICA Survey Team

(4) Results of Cost Estimation

Table 16.3-2 summarize the result of cost estimate. For each section;

- Section I: 3,900 million NRP
- Section II: 39,500 million NRP
- Section III: 21,300 million NRP
- Section IV:11,400 million NRP
- Total: 76,100 million NRP

Construction cost for tunnel Section II consists of the followings;

・Tunnel including both main tunnel and evacuation tunnel (length 7,691m): 36,000 million NRP

・Approach road for both north and south portal (length 1,600m): 900 million NRP

Total: 36,900 million NRP

Others excluding tunnel relating stretch, total construction cost is expected 43,500 million NRP and 0.332 million NRP/m. For each section;

- Section I: 0.106 million NRP
- Section II: 0.382 million NRP
- Section III: 0.578 million NRP

- Section IV: 0.228 million NRP

These figures reflect the topographic conditions as described in clause of 16.2.1 and unit cost (NRP/m) of Section III is the highest among 4 sections.

If alternative route for No.6 in Table 16.3-1, which may reduce the total cost, is adopted, 4,300 million NRP reduction is expected, but the future detailed study is necessary on this matter.

Table 16.3-2 Result of Cost Estimation

Section	I	II			III	IV	Overall		
	Road Improvement	Road Improvement	Tunnel	Tunnel Approach	Road Improvement	Road Improvement	Excluding tunnel	Tunnel	TOTAL
Length (km)	36.8	6.9	7.7	1.6	34.7	49.6	128.0	9.3	139.6
Cost (million NRP)	3,923	2,634	36,002	870	21,256	11,395	39,208	36,872	76,080
Cost/Length (million NRP/km)	107	382	4,676	544	613	228	306	-	-
Exclusive of Design cost (F/S, DD), consulting services cost, O&M cost, contingency, land acquisition & compensation cost, taxes, inflation etc.									

Source: JICA Survey Team

CHAPTER 17 APPLICABILITY OF ADVANCED TECHNOLOGY

17.1 INTRODUCTION

This Chapter presents the prospects on the applicability of advanced technologies in the survey and construction of long road tunnels and slope management (slope-stability) on the Sindhuli Road. Information obtained from the on-going Naghdhunga Tunnel Construction Project with regards to the cut-of edge technologies applied in the project and hearings conducted with Society of Consulting Architectural & Engineering Firms (SCAEF) of Nepal on the slope management combined with the findings from the studies conducted under this Survey is reflected. Applicability of such technologies to the tunnel and the slopes of the Sindhuli road is evaluated from the following points.

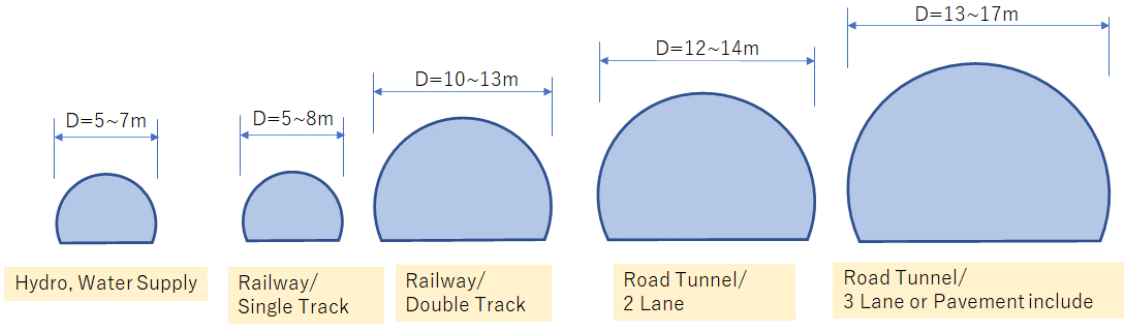
i. Necessity for the introduction of advanced technologies with respect to the technical attainment level of Nepal
ii. Necessity of technological transfer
iii. Sustainable Development of the transferred technologies
iv. Contribution for SDGs
v. Consistency to government policy (i-construction, Society5.0)

17.2 NECESSITY OF ADVANCED TECHNOLOGY

17.2.1 Perception for the capacity of Tunnelling and Slope Management in Nepal

There is no road tunnel with 2lanes or more or having a width (diameter) of over 10m excepting the cut and covered tunnel (Kalanki underpass) before the Nagdhunga Tunnel Project started. But Nepal has abundant experience on hydro-power tunnels. These tunnels are for conveyance of water and are about 3 to 5m in diameter. The exact statistics of the tunnels constructed till date is unknown as the data is not even available with the Nepal Tunnel Association (NTA). However, there are reports of tunnel 10km long that was constructed using the TBM. Apparently, there neither are existing railway tunnels nor plans for construction of railway, subway tunnels.

Figure 17.2-1 show the diameter of tunnels for various purposes. It is apparent that road tunnels and hydro tunnels differ significantly. Therefore, where the cut rock face of the tunnel is easy to stabilize in hydro-tunnels, it becomes difficult in the road tunnels. This fundamental understanding on tunnel technology is yet to be perceived by the tunnel and road engineers of Nepal. There are no engineers either in the DOR (Department of Roads) or in consulting firms, or even contractors with experience of a large tunnels like road tunnels.



Source: JICA Survey Team

Figure 17.2-1 Comparison of Excavation Scale of Tunnel for Various Purpose

Management of slopes along highway is almost not practiced unless in the consequence of a failure. It seems customary to construct a road and cut the hills in a slope that is considered to be stable (almost vertical) without application of stabilizing measures. As a consequence, the slopes are vulnerable, and the surface is frequently and easily washed away during torrential downpour that often results into temporary disruption of traffics. Seldom and only in large scale failure areas application of wire nets and rock bolts are observed. However, due to lack of timely and adequate maintenance and improper drainage, most of them are prematurely unfunctional (damaged). Also, even slopes with apparent failure risk are seen to be left unattended, which emphasizes that slope management that envisages possible disruptions is not yet in normal practice. Despite, road slope management in the Sindhuli Road has been properly put into practice. This is because of the continued assistance by Japan even after completion and handing over of the road to the government of Nepal.

Source: JICA Survey Team

Figure 17.2-2 Collapse of Roadside Slope and Temporary Traffic at the Mid-Hill Highway

Source: JICA Survey Team

Source: JICA Survey Team

Figure 17.2-3 Outflowed Restraining (wire net and rock bolts) and Pilling Huge Rock Mass

17.2.2 Necessity of Advanced Technology for Long Road Tunnel

The construction of the Nagdhunga Tunnel is encountering difficulties due to heterogeneous and unstable geological condition that are more sophisticated than the condition predicted during the detailed design, which were based on results of vast geological investigation. In Nepal, the fundamental characteristics of rock for tunnelling is metamorphic rock and this feature is similar along the roadside of the Sindhuli road, especially at the tunneling area in Section II. The advanced geological survey and test and excavating technic will be required to obtain correct information with regards to the geological conditions where heterogeneous metamorphic rock sites are anticipated.

The necessity of advanced technology for the new Sindhuli road and the tunnel during the survey/study stage, design stage, excavation and construction stage and post-construction operation stage is discussed separately hereunder.

(1) Survey and Design Stage

The geological condition of Sindhuli road tunnel is mainly metamorphic rock. The proposed bypass must traverse a very fragile fractured zone that is distributed over around 1km between the MBT and the MT. In order to ensure safe and smooth construction, the importance of precise geological information that matches with the actual condition of the ground is very high. Application of advanced survey and investigation technologies (boring, exploration) is thus necessary. Beyond the fractured zone, the distribution is qualitatively assumed from the results of ERT (Electric Resistivity Tomography) as rock mainly consisting of granite and gneiss, which are both hard rocks. However, from the laboratory test conducted on the samples extracted, these rocks are found porous and as such it is anticipated to have joints. Since the overburden is very thick, it is physically not possible to obtain accurate information and ascertain the condition by boring/exploration. This is the reason why advance geophysical exploration technology is necessary to be applied.

(2) Excavation and Construction Stage

The biggest and serious issue anticipated to be encountered during excavation of the tunnel is the fractured zone distributed between the MBT (Main Boundary Thrust), MT (Mahabharat Thrust) and its neighboring area at the south portal. One of the common auxiliary methods applied to reinforce such poor geology is the AGF method (long pipe umbrella method re long pipe fore-piling method). AGF method is extensively used in Japan for similar purpose. This is also adopted in the Nagdhunga tunnel. Where the rocks are even more fractured and have risks of large deformation during excavation due to high ground pressure, in Japan normally multiple support system is adopted. This is very much likely during excavation of the tunnel proposed at Section II. Therefore, adoption of the above technology is suggested.

On the other hand, at the portal on the north side (Khurkot side) where the tunnel alignment underpasses the existing Sindhuli Road, the overburden is very shallow. Here, close observation and strict subsidence control is suggested.

By and large, rock distribution along the tunnel is hard. But since the alignment runs deep inside (far from the surface) with thick overburden and with the limited surveys/investigation under this survey, the actual condition of the rock is unknown. Therefore, it is important to check the condition ahead during excavation safety during cut face work. The proposed tunnel in Section II is relatively long. Methods like forward drilling/exploration (prospect drilling) and probing device are suggested to be included in the work cycle. Recently, various on-site visualization methods are broadly applied in such cases in the developed countries including Japan.

(3) In Service Stage

As the tunnel length is relatively long, facilities like lighting, ventilation, emergency facilities will be extensively required. As the two ends of the tunnel are far apart, in an unlikely even of disasters access between the two portals becomes difficult. Therefore, it is important to correspond during the time of an emergency in accordance with the pre-prepared program/manual. In addition to this, a system that ensures the electrical rooms (facility control) provided at the two portals interlink and function efficiently is developed for the safety of the users

17.2.3 Necessity of Advanced Technology for the Slope Management on Mountainous Road

As described in Section 17.2.1 slope management of mountainous roads is rarely implemented in Nepal. Sustainable slope management of Section III, Section IV and the stretch between Section III and the north portal of the Sindhuli Road is indispensable in order to maintain the road as a reliable disaster-resilient logistics road. For this, a comprehensive slope management based on the theory of asset management that contributes to effective slope maintenance that takes the results of the periodic and routine inspection into consideration including control and adaptation concepts is necessary.

17.3 APPLICABLE ADVANCE TECHNOLOGY FOR LONG TUNNELS

17.3.1 Technology of Survey and Design Stage

(1) Advanced High Quality Boring Method

Advanced high quality boring method, also commonly known as high quality sample extraction method, is a method that enables almost 100% extraction of high-quality core even at fault disturbance zones, fractured zones, landslide mass and cracked rocks.

This method requires special boring tools and high excavation management skills. The area where borings are required has similar geological properties mention above. However, this type of method (technology) is still not available in Nepal. This method is preferable but to apply this in Nepal, materials and equipment such as tools and technical guidance on excavation management is indispensable.

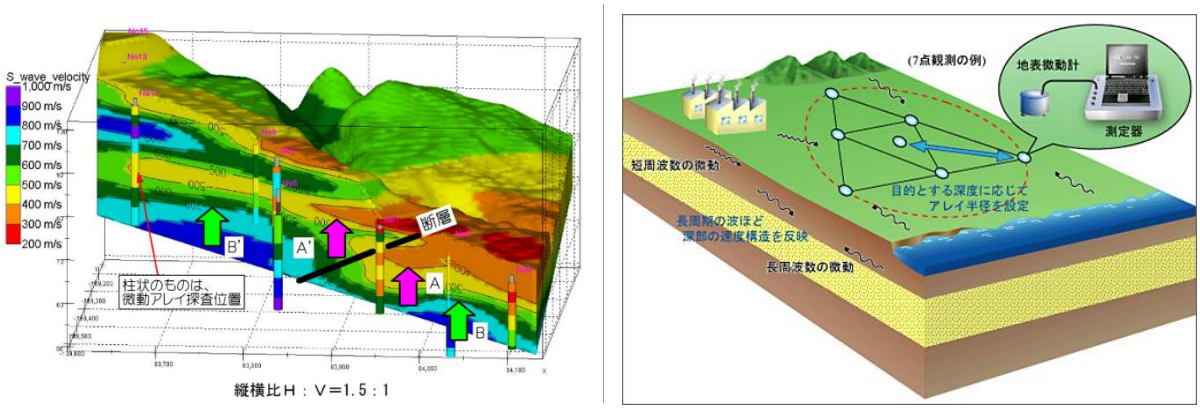
This technology is indispensable for the survey of fractured zone in Sindhuli south portal and application is therefore preferable but in such case the equipment, tools and technical transfer are required. The technical transfer is expected to enhance understanding and knowledge of engineers in Nepal.

Source: JICA Survey Team

Figure 17.3-1 Comparison Core of Conventional Method (upper) and Advanced High Quality Boring Method (lower)

(2) Microtremor Array Observation Survey

Micrometer Array Observation Survey is one of the geophysical survey methods for shallow to deep ground. This method catches many usual surface microtremor with plural high-sensitivity sensors and provides the S-wave distribution on analysis. This survey applies the analysis of macro-condition in deep rock ground and able to provide the information of deep rock condition where seismic prospecting wave and resistivity electrical investigation could not reach likely Sindhuli road tunnel.



Source: JICA Survey Team

Figure 17.3-2 Outline of Submarine Array Microtremor Observation Survey

17.3.2 Excavation and Construction Stage

(1) Multiple Support System

Multiple support system is a widely used construction method in Japan. It is used in the construction of tunnels with extremely poor ground with major deformation of cutting face and diameter (internal displacement).

This method applies the primary support which permits large deformation. It then applies the secondary support and stabilizes the cut face after the ground stress has reduced. This method is applied where umbrella methods likely AGF Method cannot correspond against the deformation. This is deemed effective at the fractured zone at the south portal area of Sindhuli tunnel.

Source: JICA Survey Team

Figure 17.3-3 Outline of Multiple Support System

(2) Technology for deformation control at the crossing with shallow overburden

In Japan, tunnels are often constructed as renovations of existing roads, so they often intersect with existing roads and structures with thin soil cover. Therefore, a monitoring system technology that is linked with the cut face work has been established that constantly monitors the displacement of the

crossing object and the subsidence control by the long steel pipe fore-piling method and the pipe-roofing method.

From the proposed alignment of the bypass, there will be a situation where the north portal intersects with the existing Sindhuli Road. The valley side of the road is supported by poor rigidity gabion retaining wall, so subsidence and deformation control are required.

If the existing road is damaged due to excessive road surface subsidence or structural deformation, it may take a long time to restore and resume traffic, so the application of this technology is recommended.

Source: JICA Survey Team

Figure 17.3-4 Example of Technology for deformation control at the crossing road with shallow overburden

(3) Technology for Effective Tunnelling in Safety with ICT and AI Solution

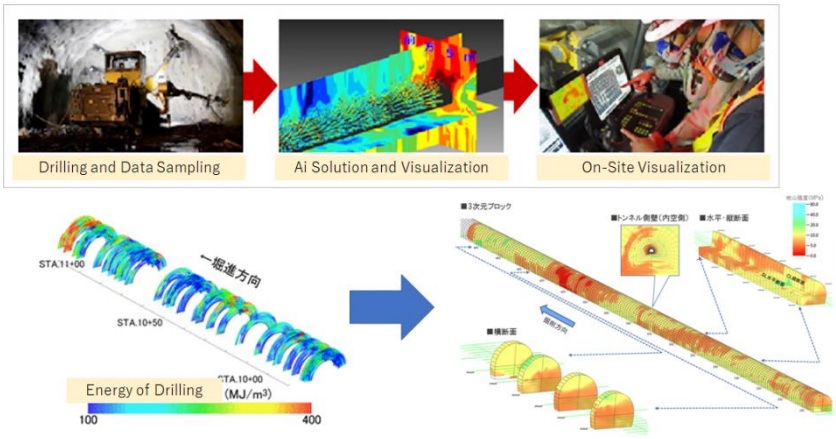
There are many technological development points to called Society 5.0 and i-construction in Japan. The trend of development is safety level up in cutting works with reducing the foreman and increasing the working speed on standardization technology with ICT (Information and Communication Technology) and AI solution. And Visualizing technology of deformation is developing point of Japan. ICT and AI solution which is recommendable should be shown in below.

In recent years, most of the technological developments in the construction field in Japan are oriented toward Society 5.0 and i-construction, and the development direction is to improve the safety of cut face work and standardize and automate special cut face work using ICT and AI technology. The mainstream is to reduce the number of facets and improve work speed by using technology. In addition, technological development such as displacement visualization is a field in which Japan is prominently advanced. The ICT and AI utilization technologies that are considered to be applicable to the Sindhuli Road tunnels are shown below.

1) Probing Method in Front of Tunnel Facing

It is a technology to know the properties of the ground behind the cut face, which could cover about several meters to 10 meters, by attaching a sensor to a rock drill of a drill jumbo and measuring the drilling energy. In most cases, there are more than 100 blasting holes at a time. Since the measured

data is immediately analyzed by AI and returned to the face work, sudden spring water and geological defects can be grasped in advance, which leads to improvement of safety of face work and improvement of work efficiency such as adjustment of drilling pattern.

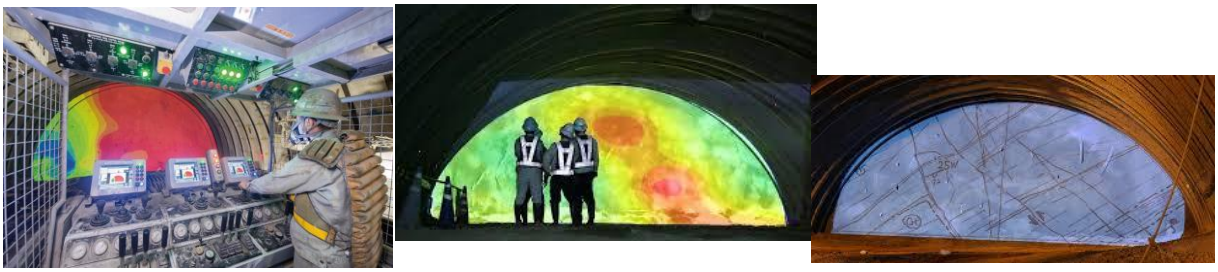


Source: JICA Survey Team

Figure 17.3-5 Probing Method in Front of Tunnel Facing and Excavation Support System with Visualization of AI Solution

2) On-Site Visualization of Geological Information with Projection Mapping

Observing and understanding rock types, crack and joints, and bedrock strength at the face of a mountain tunnel is an advanced technique that requires a high skill. In more cases, the face is covered with shot-concrete immediately after blasting and shaving, so it is not possible to see the previous face in the next work stage. This is an on-site visualization technology that utilizes the results of AI analysis of the face forward exploration and face observation records described in a) and projects them onto the actual face.



Source: JICA Survey Team

Figure 17.3-6 On-Site Visualization of the geological information on the cutting face

17.3.3 Operation Stage

(1) Facility Control

In a long and high-grade highway tunnel like the proposed 7km tunnel in the Sindhuli Road, many facilities, especially emergency facilities, will be installed and operated in conjunction with each other. Such conjunction of facilities is called control. Such controls are planned and operated at a high level worldwide including Japan. In the case of the tunnel here also, cooperation with fire departments and police, and daily management are considered to be management of both portals, and it is desirable to

introduce facility control based on an international or the Japanese method.

(2) Jet Fan with Inverter Control for Ventilation System

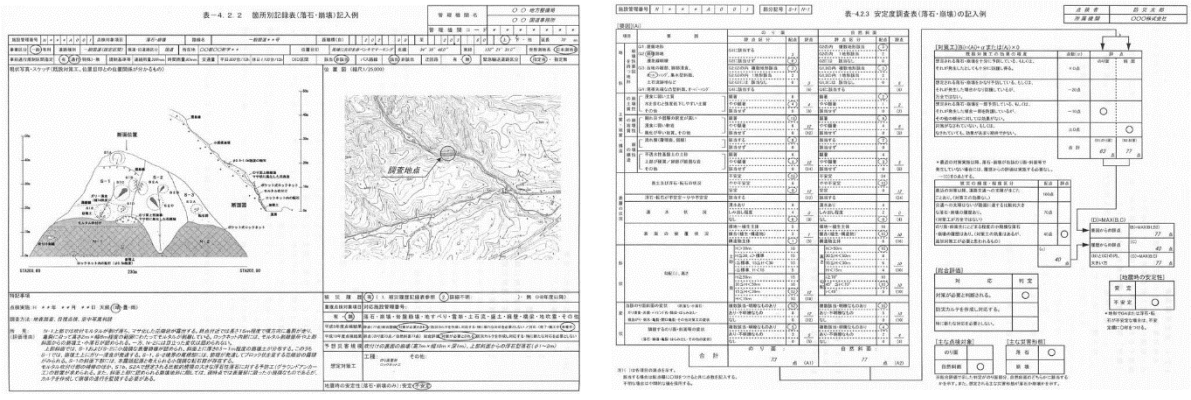
One recommended item for individual equipment is the jet fan with inverter control. It is a facility applied to control the movement of smoke in an emergency when a fire breaks out due to an accident inside a tunnel. Normally, it is used to eliminate exhaust gas from vehicles like a general jet fan, but in emergency operation, the jet fan operating speed is adjusted according to the smoke concentration to be excluded, enabling effective operation. This type of jet fan can be expected to reduce operating costs and maintenance costs during normal operation and is one of the things that should be introduced along with facility control in the Sindhuli Road tunnel where many jet fans will be installed.

17.4 APPLICABLE ADVANCE TECHNOLOGY FOR SLOPE MANAGEMENT

17.4.1 Slope Management

In Japan, with the recognition that roadside slopes are also one of the road facilities, regular inspections and inspection results are recorded and aggregated. This contributes to preparing long-term repair plans that covers appropriate budget allocation and preparation of long list and short list of repair works which helps implementation in line with the outcomes.

In Nepal, the most important point is to foster awareness that roadside slopes are also one of the road facilities, and to build a system for proper management based on the awareness of risk management and asset management. In that respect, it is desirable to introduce a management system that creates carte based on regular inspections and manages slopes based on the data.



Source: JICA Survey Team

Figure 17.4-1 Example of slope management record in Japan

17.4.2 High Energy Absorption Net

It is not realistic to make the entire roadside slopes of the Sindhuli Road risk-free after its improvement in view of the current budget constraint.

General slope countermeasures that can be applicable are shotcrete, concrete framework, rock bolt, ground anchor, rockfall prevention ntes, rock shelters etc. The cost of these general countermeasures may be high depending on the installation conditions.

Under budget constraint, high energy absorption fence (which is extensively used in developed countries including Japan) can prevent and reduce the damage caused by falling rocks. This is a net that is installed on the roadside or on the slope. It provided with high elasticity and impact resistance on the columns, nets, etc. in advance, which functions and captures rockfall and prevent it from falling on the road surface.

Source: JICA Survey Team

Source: JICA Survey Team

Figure 17.4-2 Example of High Energy Catch Net in Japan

CHAPTER 18 IMPROVEMENT EFFECT

18.1 INTRODUCTION

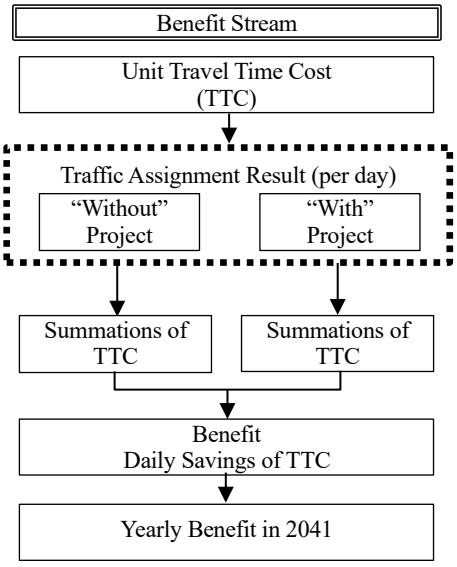
In this Survey, traffic demand forecast was simply conducted to grapes traffic demand and trend on the Sindhuli Road based on population data and GDP growth rate. In order to quantitively study and evaluate improvement effects that are deemed to be brought about by the capacity enhancement of the Sindhili Road, traffic demand forecast based on wide area road network model is required, which is not included in this survey due to lack of readily available data and other budgetary and timeframe constraints. Traffic analysis including wide area road network is suggested for implementation in the succeeding project.

Therefore, this chapter provides improvement effects only in terms of travel time saving effect of Sindhuli Road capacity enhancement using the results of future demand forecasts in 2041 explained in Chapter 8 and study results in Chapter 10 and 13.

18.2 TRAVEL TIME SAVING EFFECT OF THE PROJECT

18.2.1 Methodology

Improvement of the project road can play a very important role in strengthening the accessibility and economic growth. A preliminary economic evaluation of travel time saving and travel cost saving were carried for “With Project” and “Without Project” cases.



Source: JICA Survey Team

Figure 18.2-1 Workflow of TTC Saving Benefit

The travel time cost (TTC) is the cost lost by a vehicle when it travels. The TTC is normally calculated based on the average labor productivity and income of the country. As the DOR (Department of Roads) don’t configure official TTC for road projects in Nepal, the Survey Team adopted the TTC estimated in the SD Road Project Survey. Basically, reduction in travel time is the main component in the derivation of the TTC saving. The annual savings was calculated as the difference in travel time between the base road network and with Sindhuli Road project. The unit TTC of vehicles is shown in Table 18.2-1. And the

average number of passengers and average Loading Weight of Heavy Truck are shown in Table 18.2-2, Table 18.2-3 and Table 18.2-4 respectively.

Table 18.2-1 Unit Travel Time Cost, W/O Motorcycle

Classification	NPR/veh.-min
Car & Taxi	8.6
Utility Pick up	13.3
Micro Bus	19.8
Mini Bus	45.4
Large Bus	48.2
Light Truck	4.9
Heavy Truck	6.3
Multi-axel Truck	6.9
Others	9.1

Source: SD Road Project Report (JICA)

Table 18.2-2 Average Number of Passengers by Type of Vehicle

Classification	Average number of passengers per year
Car & Taxi	2.9
Utility Pick up	3.1
Micro Bus	12.4
Mini Bus	28.3
Large Bus	30.0
Light Truck	2.3
Heavy Truck	2.0
Multi-axel Truck	2.2
Others	2.1

Source: SD Road Project Report (JICA)

Table 18.2-3 Average Loading Weight of Heavy Truck on Weekday

		Number of Veh.	Total Weigth (t)	Loading wight (t/veh)
10	Fuel (Gas)	16	164	10.4
20	Agricultural product	31	346	11.1
30	Livestock products	28	323	11.5
40	Construction material	860	8,305	9.7
50	Machinery, Equipment	1	27	18.0
60	Food Product	39	345	8.8
90	Ohers	51	416	8.2
	Total / Avarage	1,027	9,926	9.7

Source: SD Road Project Report (JICA)

Table 18.2-4 Average Loading Weight of Heavy Truck on Holiday

		of Veh.	Weigth (t)	wight (t/veh)
10	Fuel (Gas)	1	21	16.0
20	Agricultural product	7	109	14.9
30	Livestock products	31	300	9.8
40	Construction material	907	9,439	10.4
50	Machinery, Equipment	9	110	12.0
60	Food Product	31	307	9.8
90	Ohers	17	199	11.6
	Total / Avarage	1,004	10,484	10.4

Source: SD Road Project Report (JICA)

18.2.2 Estimation of Economic Benefit (TTC Saving)

The daily TTC savings in 2041 is estimated based on the unit TTC by vehicle type and the total vehicle-hour. The analysis of the TTC saving benefit is performed for the two cases shown in Table 18.2-5.

Table 18.2-5 Estimation Case

Case	Description
Case 1	All section has 2-lane carriageway
Case 2	Case 1 with tunneling at Section II

Source: JICA Survey Team

Travel time, and travel time saving for each case are shown in Table 18.2-6 and Table 18.2-7. The required time is calculated using the design speed of each Section.

Table 18.2-6 Travel Time Using Existing Road in 2041 (Case 1)

Section		Distance (Km)		Design Speed (Km/h)		Travel Time (minutes)	
		With	Without	With	Without	With	Without
Section I	Bardibas Area	2.5	2.5	60	50	2.5	3.0
	Others	34.5	34.5	40	30	51.8	69.0
Section II		35.8	35.8	30	20	71.6	107.4
Section III		36.8	36.8	30	20	73.6	110.4
Section IV		50.0	50.0	30	20	100.0	150.0
Total		159.6	159.6	-	-	299.5	439.8

Source: JICA Survey Team

Table 18.2-7 Travel Time Using Existing Road and Tunnel in 2041 (Case2)

Section		Distance (Km)			Design Speed (Km/h)			Travel Time (minutes)	
		With		Without	With		Without	With	Without
Section I	Bardibas Area	2.5		2.5	60		50	2.5	3.0
	Others	34.5		34.5	40		30	51.8	69.0
Section II		Tunnel	7.7	35.8	Tunnel	30	20	32.4	107.4
		Approach	1.6		Approach	30			
		Others	6.9		Others	30			
Section III		36.8		36.8	30		20	73.6	110.4
Section IV		50.0		50.0	30		20	100.0	150.0
Total		140.0		159.6	-		-	260.3	439.8

Source: JICA Survey Team

The calculation of the travel time saving is shortened time for using the Sindhuli Road before/after the maintenance and the shortened time for switching from westbound route to Sindhuli road. In addition, the travel speed between vehicle types is the same. The daily TTC saving by year is estimated based on the unit TTC by vehicle type and the total vehicle-hour. The results of the TTC saving in each case are shown in Table 18.2-8 and Table 18.2-9. As a result of the analysis, TTC saving is expected to be 2,585 million NPR / year in Case 1, and 3,080 Million NPR / year in Case 2.

Table 18.2-8 TTC Saving Using Existing Road in 2041 (Case 1) (Million NPR / year)

			2. Car & Taxi	3. Utility Pick up	4. Micro Bus	5. Mini Bus	6. Large Bus	7. Light Truck	8. Heavy Truck	9. Multi-axel Truck	10. Others	Total
Sindhuli Road	Section I	Bardibas Area	1.8	2.7	0.5	1.4	0.3	0.2	1.2	0.4	2.0	10.4
		Others	28.3	46.8	23.0	40.8	0.0	11.2	37.7	0.0	6.7	194.6
	Section II		58.7	97.2	47.7	84.7	0.0	23.3	78.3	0.1	14.0	403.9
	Section III		76.2	191.3	57.3	166.4	0.0	23.0	79.0	1.6	40.1	634.9
	Section IV		125.7	275.6	62.7	249.0	0.0	30.1	121.6	0.0	0.6	865.3
Conversion from Westward Route			46.7	169.8	155.4	56.0	26.4	2.7	19.8	0.0	0.0	476.8
Total			337.4	783.3	346.6	598.3	26.7	90.5	337.6	2.2	63.5	**2,585.9**

Source: JICA Survey Team

Table 18.2-9 TTC Saving Using Existing Road and Tunnel in 2041 (Case 2) (Million NPR / year)

			2. Car & Taxi	3. Utility Pick up	4. Micro Bus	5. Mini Bus	6. Large Bus	7. Light Truck	8. Heavy Truck	9. Multi-axel Truck	10. Others	Total
Sindhuli Road	Section I	Bardibas Area	1.8	2.7	0.5	1.4	0.3	0.2	1.2	0.4	2.0	10.4
		Others	28.3	46.8	23.0	40.8	0.0	11.2	37.7	0.0	6.7	194.6
	Section II		122.9	203.4	99.8	177.4	0.0	48.8	164.0	0.1	29.3	845.8
	Section III		76.2	191.3	57.3	166.4	0.0	23.0	79.0	1.6	40.1	634.9
	Section IV		125.7	275.6	62.7	249.0	0.0	30.1	121.6	0.0	0.6	865.3
Conversion from Westward Route			51.9	188.4	172.4	62.1	29.3	3.0	22.0	0.0	0.0	529.1
Total			406.7	908.2	415.8	697.1	29.5	116.3	425.5	2.2	78.8	**3,080.1**

Source: JICA Survey Team

18.3 SUMMARY OF ESTIMATION RESULTS

Table 18.3-1 Summary of Estimation Results

Case	Without Project	With Project	
		Case 1 (All section has 2-lane carriageway.)	Case 2 (Case 1 with tunneling at Section II)
Travel Time	439.8 minutes (7.3 hour)	299.5 minutes (5.0 hour)	260.3 minutes (4.3 hour)
Time Saving	—	140.3 minutes (2.3 hour)	179.5 minutes (3.0 hour)
Cost Saving	—	2,585 million NPR / year	3,080 million NPR / year

Source: JICA Survey Team

CHAPTER 19 CONCLUSION AND SUGGESTION

19.1 INTRODUCTION

This chapter discusses on pre-conditions for undertaking surveys and implementation of the project in addition to suggestions and recommendations that need to be considered as a way forward in the succeeding study stages.

19.2 PRE-CONDITIONS FOR IMPLEMENTATION OF THE PROJECT

Sindhuli Road is a 160km long national highway and is the shortest route connecting Kathmandu with the East Terai regions and the northeast regions of the country. This Survey was carried out to understand the current condition of the existing road and its operation, conduct traffic survey for future projection and study the needs and possibility of capacity enhancement. The Survey finds and proposes measures for the capacity enhancement, but there are some pre-conditions for undertaking the succeeding surveys/studies. They are as discussed hereunder.

19.2.1 Capacity Enhancement of the Entire Stretch

One of the pre-conditions for undertaking the subsequent is the capacity enhancement that covers the entire 160km stretch of the Sindhuli Road.

The project aims to enhance the mobility and accessibility functions between Kathmandu and the eastern regions including Terai. To realize this, simply widening the existing road to dual lane and improving specific section only is not sufficient. A complete and comprehensive approach that include improvement of the alignment, enhancing disaster-resilience and safety of the entire stretch is indispensable.

Besides, making a commitment by Nepal side to enhance the entire stretch of Sindhuli Road is one of the important pre-condition to proceed the subsequent study for tunneling at Section II.

19.2.2 Timely Undertaking

In addition, the project is deemed to be of a huge size in terms of its cost and technology required. It`s completion will also take substantial period - unless the scope is divided and undertaken simultaneously, completion within the target period would be impossible, if not extremely challenging. The capacity enhancement measures consist of various methods, from that which is technically and financially possible for the GON to implement on its own to that which will require advanced technology for which international assistance will be recommendable. Regardless of how the divisions of the demarcation will be, it is important that the undertakings maintain harmony and consistency, such that the capacity of the Sindhuli Road is realized in the prescribed target period.

19.2.3 Initiatives of Nepal Side for Project Implementation

The 5-year Strategic Plan of MOPIT sets out, among other objectives, widening of all roads under the jurisdiction of the MOPIT / DOR to 2-lanes or more road. Narayanghat – Mugling Road, which is the only section with narrower width was dualized in 2020. MH Highway and M-B Highway that connect to the Sindhuli Road are being and will be constructed with 2 or more lanes. In February 2020, consultancy

service for detailed design for improvement of Section III and Section IV was announced by the DOR for under its own fund, but for reasons unclear was withdrawn in July of the same year. Budget for maintenance of the Sindhuli Road is however allocated as indicated in the Red Book 2021/22.

It is thus apparent that the GON is very much aware of the importance and need of the Sindhuli Road. However, as described in this report, there are budgetary and technical issues in the improving of the Sindhuli Road. Nepal side is required to take necessary steps, such as specifically identifying and including the project in the development plans, preparing implementation plans, allocating necessary budget etc. to resolve these issues and realize the Sindhuli Road 2.0. This report is expected to serve as a material for assisting Nepal side for consideration toward the realization of the Sindhuli Road 2.0.

19.3 RECOMMENDATIONS AND SUGGESTIONS

19.3.1 Reconsideration for Division of Sections

The findings of the study conducted under this Survey is compiled in sections that was demarcated during the construction (4 sections, total length 160km). Conditions of capacity enhancement scopes may be better interpreted in a different sectioning that is based on the topography, regional characteristics, traffic volume, methods to be applied etc. In addition, the standard cross-section to be applied is suggested to take the following points into consideration.

- Consideration for road users other than traffic vehicles
- Geometric conditions to be applied (Nepal`s Road Design Standard, Asian Highway Design Standard, Consistency with M-H Highway and M-B Highway)
- Topography and geology of the target area and its surroundings
- Construction controls/constraints (detour during construction, traffic closures etc.)
- Drainage, land use, ROW, etc

The study under this Survey was based on 1.0m resolution 3D satellite images with high-precision digital elevation model (AW3D). However, there are limitations in accuracy such as the influence of tree height and the inability to reproduce the current road. In addition, since the geology is at the reconnaissance level, more detailed geological investigation such as borings/exploration and other physical tests should be conducted, especially in places where landslides are a concern. Furthermore, the hydraulic and hydrological data are also referred from preceding studies. The abnormal (extreme) weather that triggered several landslides through the country including the target area needs to be taken into consideration.

Apart from those given above, following items are particularly important and needs to be considered in the succeeding survey / study.

- Level / standard of maintenance and cost are in trade-off relation. It is therefore necessary to scrutinize the contents of the study scopes. In particular, since the design speed has immense influence on these two factors, the design speed should be appropriately set following close and repeated discussion with the DOR.

- This Survey adopts the design conditions/ criteria based on the Road Design Standard of Nepal. The conditions.
- Surveys and investigations conducted under this study at areas of landslide and slope failure sections was limited to visual inspection and desk study. Appropriate assessment and reflection in the design while referring to the field reconnaissance and international survey / investigation methods commonly are deemed important in the succeeding study.
- The estimated construction cost provided in Chapter 16 is tentative. It also does not include disaster risk during construction. It is thus suggested that these risks are taken into consideration with proper assessment and in close discussion with the DOR to set the necessary cost in the provisional sum.
- Pavement design applied under this study is based on the number of heavy vehicles provided by the traffic demand forecast. Condition of the roadbed or potential attraction to/from the on-going K-M Fast Track are not considered. It is suggested that surveys/investigations required for the pavement design including assumed traffic diversions to/from the K-M Fast Track, its toll fee etc. are taken into consideration in the future traffic volume prediction and ultimately to the pavement design. In addition, to ensure durability of the pavement, management of overloaded vehicles is also important.
- Construction period estimated under this Survey may change depending on the construction plans, such as utilizing the exiting road by imposing one way traffic or providing a detour etc., to be adopted. Therefore, the Sindhuli Road 2.0 plan roadmap proposed in this survey needs to be revised based on the results of the construction plan study conducted in the subsequent survey.

19.3.2 Tunneling at Section II

(1) Fractured Zones of Main Boundary Thrust and Mahabharat Thrust

As discussed in Chapter 13, it is understood that a band width of about 100 – 150m around MBT and about 50m at MT at the south portal area are highly shattered fault zones. Under limited time due to effect from the global pandemic, sufficient investigations were not able to be conducted. In future surveys, it is therefore desirable that more detailed geological investigations (boring, elastic wave exploration, etc.), be conducted to understand more accurately the location (section) and properties of the fault zones for justifying the candidate routes and reflect it in the excavation method.

(2) Lane Operation Method of the Tunnel Section

Several lane operation methods of the tunnel section were compared, and their characteristics summarized. There is a high possibility that the tunnel to be planned at Section II is expected to be a lengthy tunnel. Therefore, in such case it is important to consider the optimal lane operation method in consideration of the disaster risk, safety inside the tunnel including emergency facilities to be installed, and disaster prevention system.

Therefore, it is suggested that the lane operation method of the tunnel section is discussed closely with the DOR and decide the lane operation method considering not only the cost required for tunnel construction but also the disaster risk and safety of the tunnel.

(3) Excavation Method

The tunnel route crosses highly fractured zone at the MBT (Main Boundary Thrust) and the MT (Mahabharat Thrust) at the south portal area. Since there is concern about destabilization of the face in this section, it is important to consider the optimum excavation method and support structure based on the results of future geological surveys.

In addition, at the stage of this survey, a AGF method is proposed as a measure to stabilize the face of the section, but it is necessary to optimize the auxiliary method in the subsequent surveys/studies based on the characteristics of the ground.

(4) Construction Planning of Tunnel

The tunneling at Section II is more than 7 km long. Excavation from both portals is recommended, which is also the basis of cost estimation conducted under this Survey. This Survey proposes candidate construction yard sites around the south and north portals. Necessary investigation and surveys are suggested for formulating a concrete temporary equipment layout plan at these candidate sites. In addition, as the rock classification assumed at most of the tunnel section is CI to CII there is a high possibility for adoption of a blasting method using dynamites. Therefore, thorough confirmation of the necessary procedures and processes for handling explosives is suggested to be considered and reflected in the construction plan.

(5) Power Supply for Tunnel

Electricity of 1,600kVA is required during tunnel construction and 1,000kVA during operation. High tension lines were identified at the target area. Power supply is thus considered possible, but plan for provision of distribution line will be required. Nevertheless, for following reasons, power supply by means of a power generator is suggested.

- For corresponding to sudden power outage and other possible emergency situations,
- Negotiations and procedures maybe sophisticated and lengthy and construction to lay distribution lines for power may take time

To operate traffics inside the tunnel smoothly and safely, it is utterly important that the facilities inside the tunnel is timely and adequately maintained. Proper education for transfer of technology, knowledge, know-hows on maintenance and operation of the tunnel is therefore highly suggested.

19.3.3 Traffic Demand Forecast

Traffic demand forecasts conducted under this Survey takes into account only the socio-economic framework of Nepal and traffic volume conducted by the research team. There are many developments such as completion and opening of the K-M Fast Track, eastern section of M-H Highway and M-B Highway, north-south corridors etc. On one hand, the completion of the K-M Fast Track will attract traffics from the Sindhuli Road temporarily resulting to reduction of the volume currently plying there. However, on the other hand, the significance of the Sindhuli Road is expected to rise with respect to the development of other highways including growth of the country.

The traffic demand forecast in this survey takes into account the impact of the opening of K-M Fast Track but does not take into account the impact of tolls (willingness to pay) due to unavailability of reliable data.

Therefore, analysis that is based on detailed road network (vital road network of the entire or at least of the eastern region of the country) that takes into consideration the impact of the tolls and the updated highway network is inevitable for accurate forecast of the traffic demand including the traffic distribution.

19.3.4 Environmental and Social Considerations

(1) All Section (Including Section II)

Common and general recommendation for the future development of all sections of the Sinhduli Road is shown in Table 19.3-1.

Table 19.3-1 General Recommendation

Items	Recommendations
Pollution Control	• Measurement of air quality should consider the location of ventilation system of the tunnel. • Both surface and groundwater shall be measured to know baseline data as many as possible with considerations of rainy and dry seasons. • Possible assessment for soil contamination, especially assuming risks of muck from the tunnel sections. • Measurement survey for baseline data should consider rainy and dry season
Natural Environment	• Further survey on rare species shall be implemented with both documentation and field levels with the list of IUCN (International Union for Conservation of Nature and Natural Resources) rating. • Inventory survey for necessary tree logging is required with practical mitigation plan based on relevant domestic legal framework such as Nepal Forest Guidelines (2006) and its updated documents
Social Environment	• Apart from a Census survey for resettlement action plan (RAP), distribution of indigenous people shall be surveyed during the following study phases. • Integrated local traffic system between existing meandering mountainous road and new tunnel alignment shall be discussed from the view point of local economy and benefit for local communities including vulnerable people of traffic, utilization of exiting Sindhuli road, toll fee, and etc. • Road safety, especially for pedestrian should be considered for further improvement of the road. People are facing risks of traffic accident in the present conditions of road and traffic in all sections.

Source: JICA Survey Team

(2) Section II

In addition to general recommendation to each environmental element as above, specific recommendation for Section II to be considered in the next study phase is discussed and shown in Table 19.3-2.

Table 19.3-2 The Other Recommendation for the Section II

Items	Contents
Associated Facilities and Cumulative Impact	It does not seem to be any qualified cases as associated facilities with the discussed tunnel section at the moment of this survey. Cumulative impact, however, should be surveyed and evaluated in the future survey period to avoid overlooking of such impact including stabilization of slopes along the planned alignment.
Secondary/Indirect Impact	Because the candidate sites of soil borrow pit, quarry, dumping site, camping site, etc. have not fixed yet at the time of this survey, secondary impact caused by such project-related facilities should be examined in detail during the following survey phases. Also, indirect impact including socio-economical changes on bypassed area shall be assessed with enough survey data in the following survey periods.
Special Considerations on Tunnel Portals	Impact and rights on land around the tunnel portals shall be further discussed with views of land ownership and protection zones of tunnel structures, such as land surface rights and restriction of development in the future.
Considerations for Rainy and Dry Season	Environmental items which may be affected by the rainy and dry season, such as hydrology, water-use, air pollution, shall be considered carefully before commencement of baseline surveys in the following survey periods to assess the impact correctly.
Impact on Socially Vulnerable People	Impact on vulnerable people, such as vendors along the existing road which is bypassed by the tunnel section, shall be assessed with care to avoid ignorance in mitigation and monitoring measures. Also, other form of vulnerability, such as refugee of the last earthquake, shall be confirmed and considered appropriately.

Source: JICA Survey Team

19.3.5 Construction Planning and Cost Estimate

In the subsequent study of the projects, the followings items are suggested to be given considerations.

- Study market condition of materials and equipment considering predicted construction schedule.
- Reuse and/or disposal of tunnel muck and dismantled construction material based on the information in this report after determining the final tunnel route and necessary approach roads.
- Understanding the details of valley side retaining walls by obtaining calculation sheets including the ground conditions. In some locations, inspection for the existing structure may be required. This work is inevitable for the study and design of widening the existing road.
- Studying the possibility to avoid dismantling of the existing structure as much as possible.
- Efficient method for transportation of large-scale construction materials and equipment, especially possible size of semi-trailer at the hair-pin curves.
- Conduct investigations at the mountain side slope to study necessary slope protection measures.
- Study other conceivable methods of enhancement measure and its construction cost. Especially, this survey applies mountain bridge as improvement measures at certain hairpin curves. Considering possibilities for alternatives that are cost-efficient are suggested(provision of turn outs etc.).
- Conduct surveys to examine the status of application of recycled material (recycle method, quality assurance etc.).
- Scrutinization of construction cost estimate based on the more specific design.
- Study of traffic management methods based on existing traffic and construction vehicles and machines.

19.4 RECOMMENDATIONS

In addition to suggestions mentioned above, the followings are recommendations from the JICA Survey Team for realizing and ensuring smooth implementation of the project.

Tentative Construction Cost

- The result of this study estimates the total construction cost for capacity enhancement of the Sindhuli Road that includes dualization of the entire section and tunneling at Section II is approximately 76.1 billion NPR. The construction cost for tunneling at Section II solely is about 36.9 billion NPR. It is therefore important that the scale of the project is well understood and accepted by the GON, including the MOF prior to moving forward for the implementation of the tunneling at Section II.

Specific and Indicative Plans

- In particular, although MOPIT/DOR have positive opinions and are supportive with the capacity enhancement of the Sindhuli Road, more specific plans indicating the time frame are required. Therefore, it is necessary that Nepal side clarify the feasibility of dualization, which is a prerequisite for the capacity enhancement.

Technical Aspects

- The critical section is Section II where construction of the bypass that consists of about 8km long tunnel is expected to take the longest period – about 8 years. It is therefore recommended that the improvement of other sections be commenced in line with the study of the tunneling.
- Provision of tunnels in some mountainous sections in Section III can have significant outcome and might be advantageous in the long run. Study for examining the possibility of such provision is recommended
- The entire stretch of the Sindhuli Road was planned, designed and constructed under the grant aid assistance from Japan. Local material and technology were extensively used, but many sections consist of sophisticated technology that is unique to Japan. Widening at these sections needs understanding the details of these technologies.
- There are sections that can be undertaken by the GON on its own, both technically and financially. These sections are recommended to be undertaken by the GON. This will help minimize the investment and enhance awareness of ownership.
- To ensure high benefit-cost ratio (BCR), adopting a sub-optimal solution that addresses capacity enhancement of sections projected to have high BCR while widening other sections to the extent sufficient for passing over of opposing vehicles or addition of turnouts progressively.