

Nepal
Department of Roads (DOR)
Ministry of Physical Infrastructure and Transport
(MOPIT)

Data Collection Survey
on Road Disaster Prevention
in Nepal

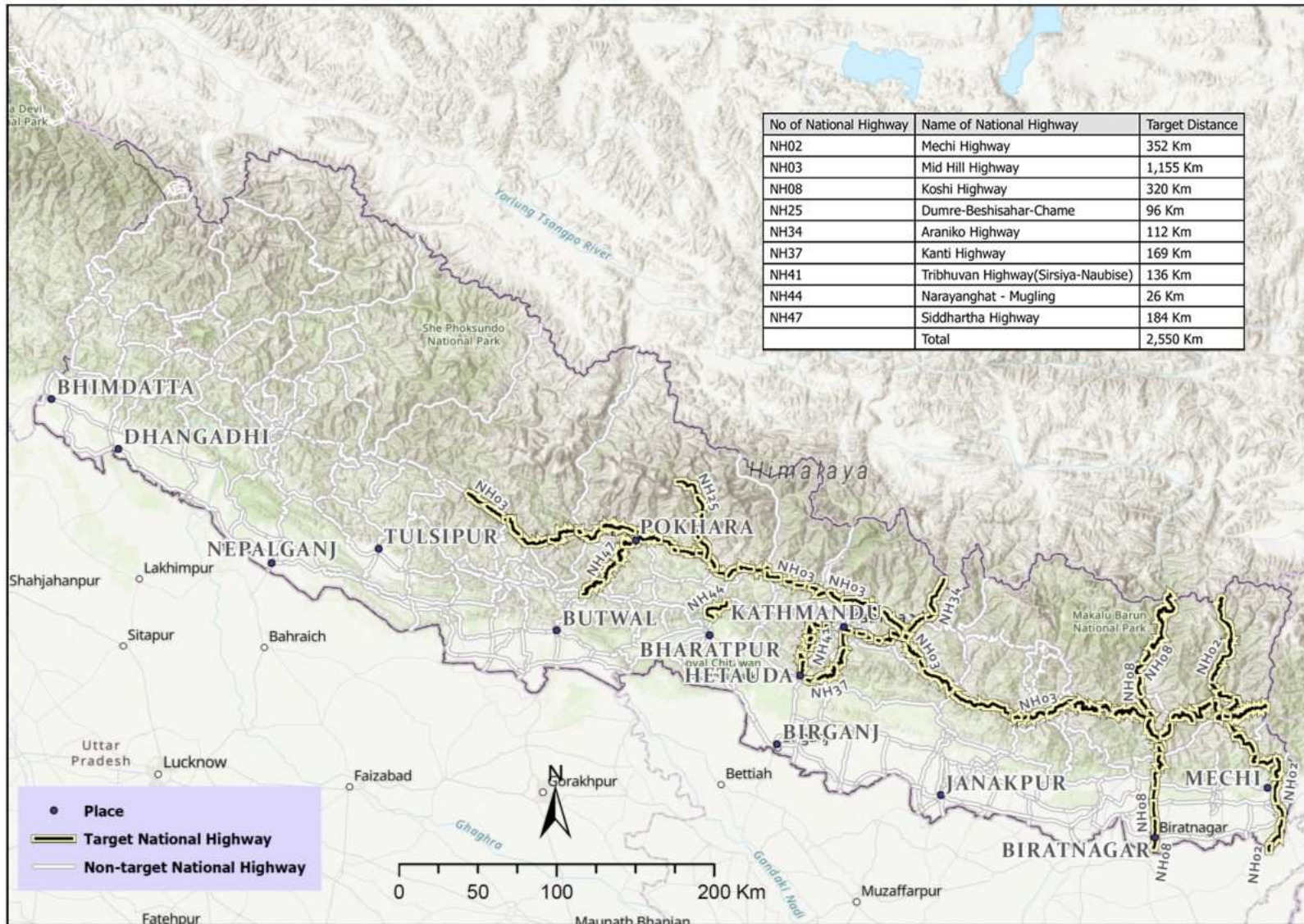
Final Report

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Survey Area

Abbreviations

AADT	Annual Average Daily Traffic
ADB	Asian Development Bank
ARMP	Annual Road Maintenance Plan
ADPC	Asian Disaster Preparedness Center
Ch	Chainage
C/P	C/P
DCID	Development Cooperation Implementation Division (Department of Roads)
DHM	Department of Hydrology and Meteorology (Ministry of Energy, Water Resources, and Irrigation)
DOFSC	Department of Forest and Soil Conservation (Ministry of Forest and Environment)
DOLI	Department of Local Infrastructure (Ministry of Industry, Commerce and Supplies)
DOR	Department of Roads (Ministry of Physical Infrastructure and Transport)
DMG	Department of Mines and Geology
DOR	Department of Roads (Ministry of Physical Infrastructure and Transport)
DPTC	Disaster Prevention Technical Center
DOTM	Department of Traffic Management (Ministry of Physical Infrastructure and Transport)
DRO	Division Road Office (Department of Roads, Ministry of Physical Infrastructure and Transport)
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction and Management
DUDBC	Department of Urban Development and Building Construction (Ministry of Urban Development)
DWRI	Department of Water Resources and Irrigation (Ministry of Energy, Water Resources and Irrigation)
EC	Common Era
EIA	Environmental Impact Assessment
EIS	Emergency Information System
EMP	Environmental Management Plan
EO	Earth Observation
EPA	Environmental Protection Act
EPR	Environmental Protection Rules
ESMF	Environmental and Social Management Framework
F/S	Feasibility Study
FRSMO	Federal Road Supervision and Monitoring Office (Road Board Nepal)
FIDIC	The International Federation of Consulting Engineers
GESU	Geo-Environmental Social Unit (Department of Road)
GLOF	Glacial Lake Outburst Flood
GFDRR	Global Facility for Disaster Reduction and Recovery
HCRS	Highway Condition Reporting System
HED	Heavy Equipment Division
HKH	Hindu Kush Himalaya
HMIS	Highway Management Information System
ICB	International Competitive Bidding
ICD	Inland Clearance Depot
IEE	Initial Environmental Examination
ICHARM	International Center for Water Hazard and Risk Management under the auspices of UNESCO
ICIMOD	International Centre for Integrated Mountain Development
IARMP	Integrated Annual Road Maintenance Plan
JICA	Japan International Cooperation Agency
LCB	Local Competitive Bidding
LiDAR	Light Detection and Ranging

MOICS	Ministry of Industry, Commerce and Supply
MOF	Ministry of Finance
MOFE	Ministry of Forests and Environment
MOHA	Ministries of Home Affairs
MOPIT	Ministry of Physical Infrastructure and Transport
MOUD	Ministry of Urban Development
MOEWRI	Ministry of Energy, Water Resources, and Irrigation
NCB	National Competitive Bidding
NCDRRM	National Council for Disaster Risk Reduction and Management
NLC	National Law Commission
NDRRMA	National Disaster Risk Reduction and Management Authority, Ministry of Home Affairs
NH	National Highway
NHN	National Highway Network
O/M	Operation and Maintenance
PQ	Pre-Qualification
PPMO	Public Procurement Monitoring Office
PVC	Polyvinyl Chloride
RBN	Roads Board Nepal
SDC	Swiss Agency for Development and Cooperation
SDE	Senior Divisional Engineer
SNH	Statistics of Strategic Road Network
SRN	Strategic Road Network
UNDRR	United Nations Office for Disaster Risk Reduction
RoW	Right of Way
WB	World Bank
WRRDC	Water Resources Research and Development Center

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Annex

Annex A. 216 Survey Sites.

A.1. List of 216 sites

A.2. Risk index ranking

Annex B. Longlist sites and the other assessment sites

B.1. Longlist sites and the other assessment sites

B.2 Traffic indicators

B.3. Photos

B.4. Road closing status

Chapter 1. Outline of the Survey

1.1. Outline and Background of the Survey

In Nepal, road transport accounts for about 90% of transportation. However, nearly 80% of the country's terrain is mountainous, leading to delayed road development due to challenging topographical and geological conditions. Roads in mountainous areas without appropriate slope engineering measures and drainage facilities are frequently blocked during the rainy season because of slides, collapses, rockfalls, shoulder collapses, mudslides, and other landslides. According to the Highway Condition Reporting System (HCRS) of the Department of Road (DOR) under the Ministry of Physical Infrastructure and Transport (MOPIT), road closures occurred at 221 sites on 27 of 80 national highways (NHs) in 2022 common era: CE (unless otherwise specified, the year will be shown in the common era, and the CE will be omitted.), with a total road closure time of 8,507 hours. The current situation is that road closures due to landslides are mainly handled only as an emergency response (post-response), such as soil removal, and this has caused an increase in road closures.

In the 15th National Plan, the government of Nepal has set the goal of the road sector to achieve economic development through socio-economic and logistical development by expanding the national road network, which requires the construction of geohazards-resistant roads.

1.2. Purpose of the Survey

The purpose of this project is to identify areas with high-risk road landslides and to clarify the direction of future Yen loan project formulation by surveying the general situation of landslides, DOR's landslides management system, the status and issues of road slope control, and trends of international organizations and other donors' involvement in the construction of NHs in the central and southern parts of Nepal.

1.3. Target Areas and Highways for this Survey

The target area is the NHs within Koshi, Madhesh, Bagmati, and Gandaki provinces in the central and southern parts of Nepal. The main roads in this survey are the 80 NHs (NH01-80) managed by DOR.

After consultation with JICA and DOR, the target NHs shown in **Table 1-1** were finalized on June 21, 2023.

Table 1-1 Target NHs

Classification	Original Plan	Finalized plan
Same as the Original Plan	Mechi Highway (NH02, Length 352km)	
	Mid Hill Highway (NH03, Length 1,155km)	
	Koshi Highway (NH08, Length 320km)	
	Siddhartha Highway (NH47, Length 184km)	
	Araniko Highway (NH34, Length 112km)	
Added	-	Dumre-Beshisahar Chame (Except plains of Dumre side) (NH25, Length 96km)
	-	Kanti Highway (NH37, Length 169km)
	-	Narayanghat-Mugling (Except plains of Narayanghat side) (NH44, Length 26km)
Excluded	East-West Highway (NH01, Length 495km)	-
	Prithvi Highway (NH17, Length 173km)	-
Excluded Some Sections	Tribhuvan Highway (NH41, Length 155km)	Tribhuvan Highway (Except Kathmandu-Naubise) (NH41, Length 136km)
Total	A total of 2,946 km section of the above eight NHs	A total of 2,550 km section of the above nine NHs

Note: All NHs target only sections within Koshi, Madhesh, Bagmati, and Gandaki Province

Source: JICA Survey Team

[NHs Added to the Target of the Survey]

1) Dumre - Beshisahar - Chame (NH25)

Although traffic volume is low, this road was added to the target of the survey because the number of road closures and the duration of closures are significant. DOR has positioned the road as very important in terms of tourism revenue.

2) Kanti Highway (NH37)

Although traffic volume is low, this road was added to the target of the survey because it was found that the project office of DOR for “the North-South and Trade Highway Improvement Project Directorate,” which monitoring and mainly managing widening and rehabilitation projects. The strengthening of the north-south road network is actively working to reduce the risk of landslides. It is closer to Kathmandu than other highways. Therefore, it will likely be promoted as a pilot project in the future technical cooperation framework.

3) Narayanghat - Mugling (NH44)

This road was included in the survey because of its high traffic volume and significance from a logistics perspective.

[NHs Excluded from the Target of the Survey]

1) East-West Highway (NH01)

The Asian Development Bank (ADB) and World Bank (WB) have already been involved in reconstructing some parts of this highway. The survey does not include it because it runs through a plain area, and no slope collapses were identified.

2) Prithvi Highway (NH17)

ADB and WB are supporting the widening of the road, and slope control measures will be implemented; therefore, this NH is not included in the survey.

3) Tribhuvan Highway (NH41) (Kathmandu-Naubise)

WB is supporting the widening of the road, and slope control measures will be implemented; therefore, this NH is not included in the survey.

Chapter 2. Current Situation on Disasters in Nepal

2.1. General Information

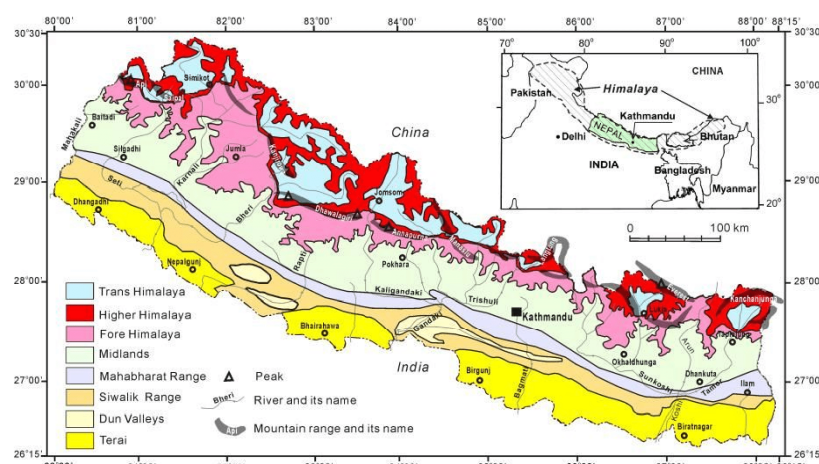
2.1.1. Topography

The area of Nepal is 147,181 square km, approximately half the size of Japan. The elevation in Nepal ranges from 60 m above sea level to the highest point of 8,848 m, Mount Everest. Nepal's topography consists of the west-northwest to east-southeast oriented landform sequence, as shown in **Table 2-1** and **Figure 2-1**. From the north, it can be broadly divided into the Higher Himalaya, Trans Himalaya/Fore Himalaya, Midlands, Mahabharat Range, Siwalik Range, Dun Valleys, and Terai Plain.

Table 2-1 Topographical Zones of Nepal

	Landscape (Ranjan Kumar Dahal, 2017) North – South	Topographic Feature
	Trans Himalaya	Valley area surrounded by Higher Himalayas.
	Higher Himalaya	Mountainous area with elevation of more than 6,000 m above sea level, where glacial erosion has formed long slopes with exposed rock surfaces.
	Fore Himalaya	Mountainous area that forms the front edge of the Himalayas, with long slopes.
	Midlands	Mountainous area between the Himalayan frontier and the Mahabharat Range where mountain basins such as the Kathmandu and Pokhara basins are interspersed. Gentle slopes formed by large-scale landslides and terraces of dammed lakes caused by landslides are distributed.
	Mahabharat Range	Mountain range has an elevation of 3,000 m above sea level. Steep, long Steep, long slopes have developed; in some parts, gentle slopes have been formed by large-scale landslides.
	Siwalik Range	Mountainous area with elevations ranging from 200m~1000m, with unstable steep slopes forming in some parts.
	Dun Valleys	Basin is located in the Siwalik Mountains belt at an elevation of about 200 m above sea level.
	Terai Plains	Plains range from 70 to 200m above sea level and occupy 13% of the country's land area.

Source: Edited by JICA Survey Team based on "Shuichi Hasegawa (Kagawa University) and Ranjan Kumar Dahal (Tribhuvan University) 2017 11th Asian Regional Conference of the International Association of Applied Geologists (ARC-11) Applied Geology of Nepal".



Source: Ranjan Kumar Dahal, 2017

Figure 2-1 Topographical Zones of Nepal

2.1.2. Geology

Nepal's geological formations and major fault systems are presented in **Tables 2-2, Figure 2-2, and Figure 2-3.**

The formation of Nepal's geological features is described as follows in the paper "Applied Geology of Nepal" by Dr. Shuichi Hasegawa (Kagawa University) and Dr. Ranjan Kumar Dahal (Tribhuvan University), presented at the 11th Asian Regional Conference of the International Association for Engineering Geology and the Environment (ARC-11) in 2017.

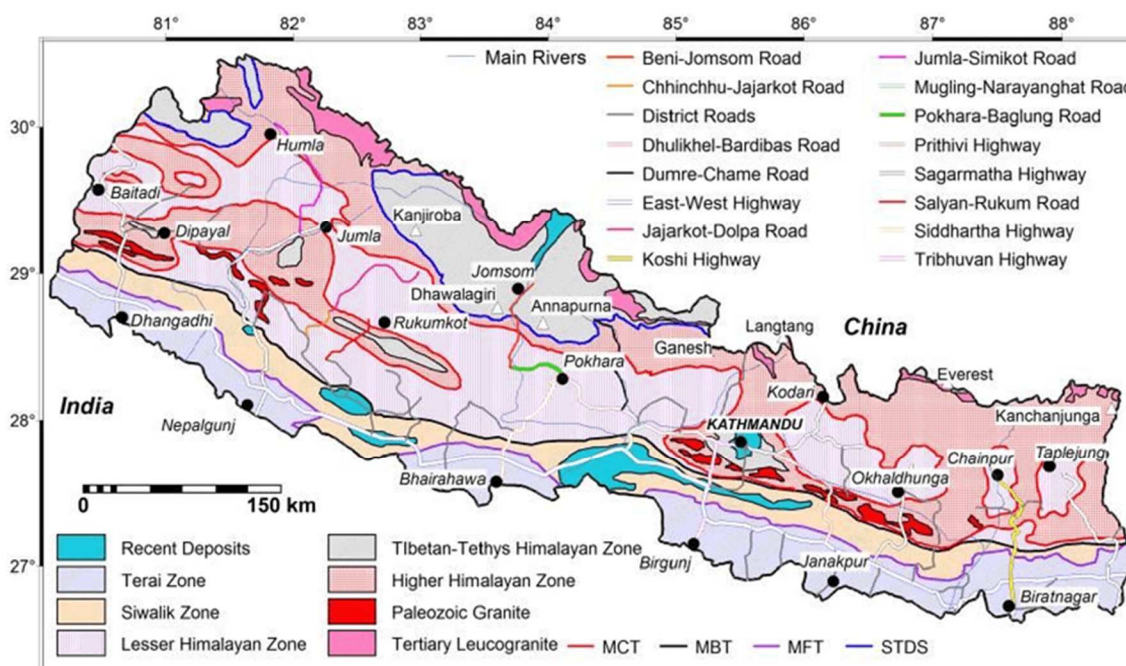
- ✓ The Indian subcontinent (present-day Indian Peninsula) was formed when the southern hemisphere continent of Gondwana broke up, moved northward, and collided with Eurasia about 55 million years ago. At that time, the Indian subcontinent was submerged under the Eurasian continent.
- ✓ About 30 million years ago, subduction moved to the present-day Main Central Thrust (MCT); 25 to 15 million years ago, the subducting Indian subcontinent surged as the Himalayan Mountain body concurrently with the penetration of the dominant white granite intrusive zone.
- ✓ As an activity of the South Tibetan Detachment System (STDS) 2200-1900 years ago, the strata deposited in the Tethys Sea between the Indian subcontinent and the Eurasian continent slipped to the north.
- ✓ After about 15 million years, subduction moved to the Main Boundary Thrust (MBT) and uplifted the Mahabharat Range.
- ✓ The currently subducting geotable earthquake fault has moved to the Himalayan Frontal Impulse Fault (Main Frontal Thrust: MFT), uplifting the Siwalik Hills.

The geology of Nepal is characterized by a wealth of discontinuities such as folds, faults, and fractures in the strata because of this zone activity.

Table 2-2 Geological Zone and Major Faults of Nepal

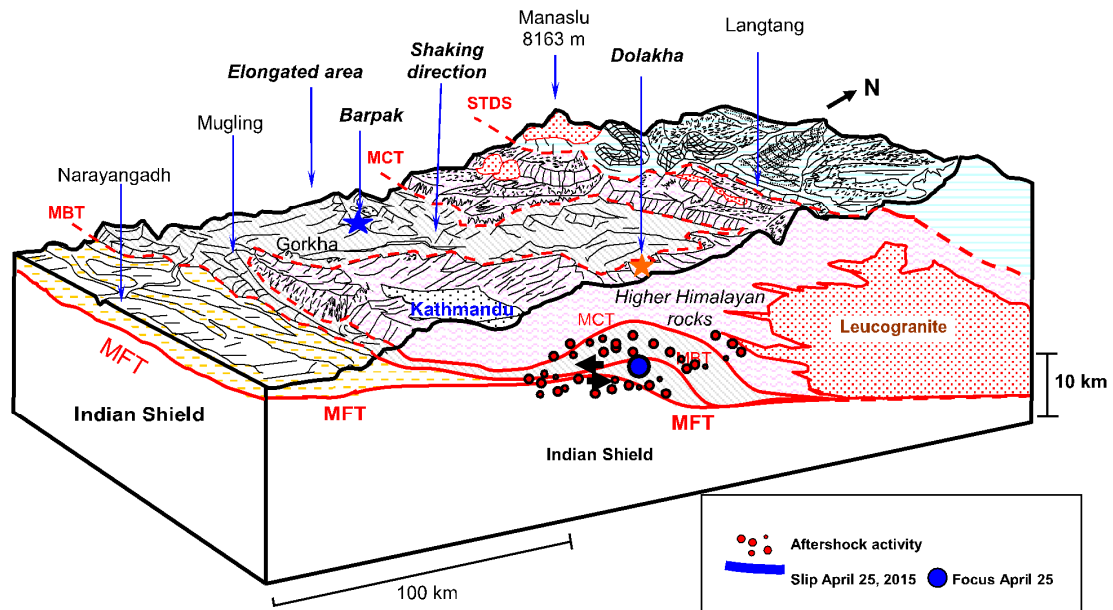
Geological Zone	Geological Structure and Features	Major Faults
Recent Deposit	Unconsolidated sediments deposited in the Kathmandu Basin and large rivers	-
Terai Zone	Thick unconsolidated Quaternary deposits	Himalayan Main Frontal Thrust (MFT): Forms the boundary between the Siwalik and Terai belts from an active fault zone and is linked to the terrible earthquake fault. As shown in Figure 2-3 , the seismic sources of the 2015 Gorkha earthquake were distributed along MFT. MFT is the most active fault at present.
Siwalik Zone	Neogene sedimentary rocks deposited on the Himalayan frontal margin	Main Boundary Thrust (MBT): MBT is the boundary between the Low Himalayan and Siwalik Belt, where significantly active faulting activity is continuously observed. The Low Himalayan belt forms cliffs on the northern side of the Siwalik Mountains.
Tertiary Leucogranite	Intrusive zone of superior white granite	
Tibetan-Tethys Himalayan Zone	Paleozoic to Tertiary marine shale, sandstone, limestone, and other sedimentary rocks	South Tibetan Detachment System (STDS): 2200-1900 years ago, the strata deposited in the Tethys Sea between the Indian subcontinent and Eurasia slipped northward along this fault line.
Lesser Himalayan Zone	Metamorphic, Paleozoic, and Mesozoic sedimentary rocks and Paleozoic granitoid	Main Central Thrust (MCT): It is said that the collision of the boundary plates between the Lesser Himalaya and the Higher Himalaya formed the Higher Himalaya through a low-angle thrust. MCT is an active fault that has been identified only in western Nepal, and some researchers believe that its activity has largely ceased
Paleozoic Granit	Part of the constituent rock body of the Lower Himalayan Belt	
Higher Himalayan Zone	Cretaceous sedimentary and metamorphic rocks deposited in the Tethys Sea	

Source: Edited by JICA Survey Team based on "Shuichi Hasegawa (Kagawa University) and Ranjan Kumar Dahal (Tribhuvan University) 2017 11th Asian Regional Conference of the International Association of Applied Geologists (ARC-11) Applied Geology in Nepal



Source: Ranjan Kumar Dahal, 2017

Figure 2-2 Geological Zones and Major Fault Systems in Nepal



Source: Ranjan Kumar Dahal, 2017

Figure 2-3 Geological Zones in Nepal, Models of Major Fault Systems, and Epicentral Distribution of the 2015 Gorkha Earthquake and its Aftershocks.

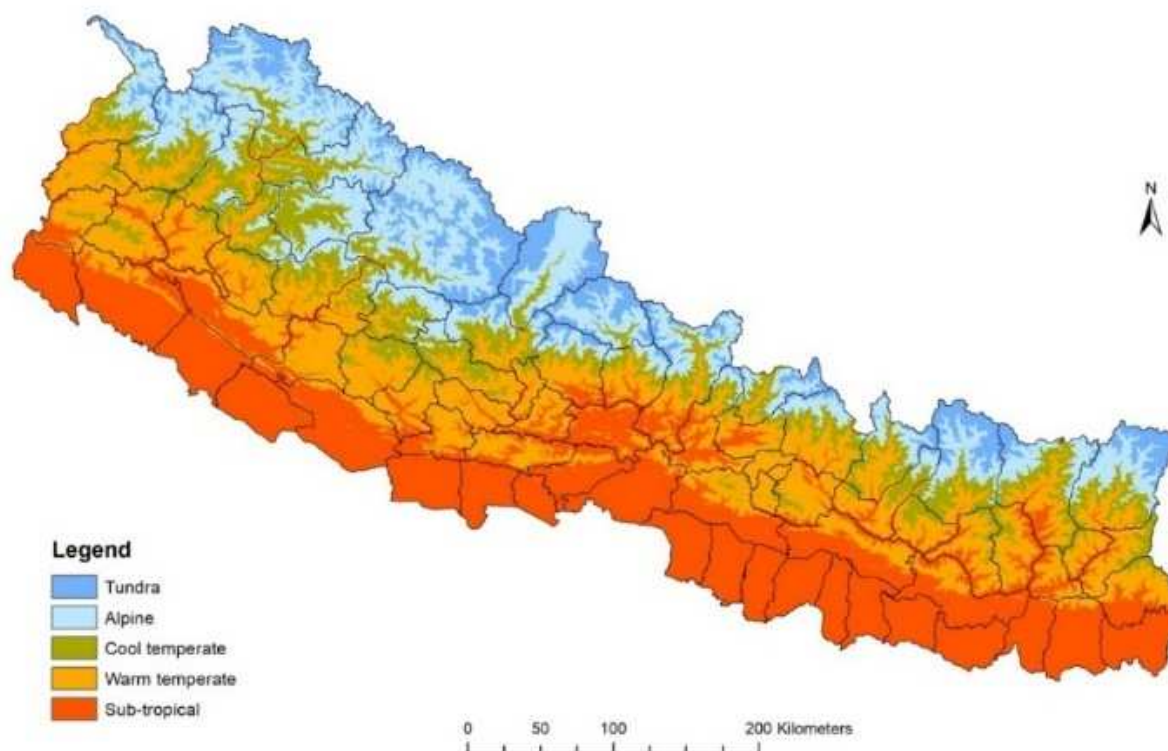
2.1.3. Climate

(1) Summary of Climate

Nepal is between $26^{\circ} 22' N$ and $30^{\circ} 27' N$ latitude. The north-south width of the country ranges from 130 km to 260 km. Elevation varies from 60 m in the southern plains to 8,848 m at the summit of Mount Everest in the northeast. As a result, Nepal's climate ranges from sub-tropical to year-round subzero tundra within less than 200 km. Approximately 80% of Nepal's rainfall occurs during the summer monsoon, from June to September, associated with the oceanic-to-continental monsoon. Winter rains are more common in the hilly western regions. The trend of high rainfall caused by the summer monsoon between June and September is more prominent in southeastern Nepal near the Bay of Bengal and less in northwestern Nepal.

(2) Climatic Zone

Nepal has a unique geography, with pronounced elevation variations, and thus has a diversity of climates within a short north-south section, influenced by elevation, terrain, and monsoons. Nepal's climatic zones are divided into five types: tundra, alpine, cool temperate, warm temperate, and sub-tropical, as shown in **Figure 2-4** and **Table 2-3**.



Source: JICA Survey Team based on Atlas of Climatic Zones of Nepal

Figure 2-4 Climatic Zone of Nepal

Table 2-3 Features of the Climatic Zone of Nepal

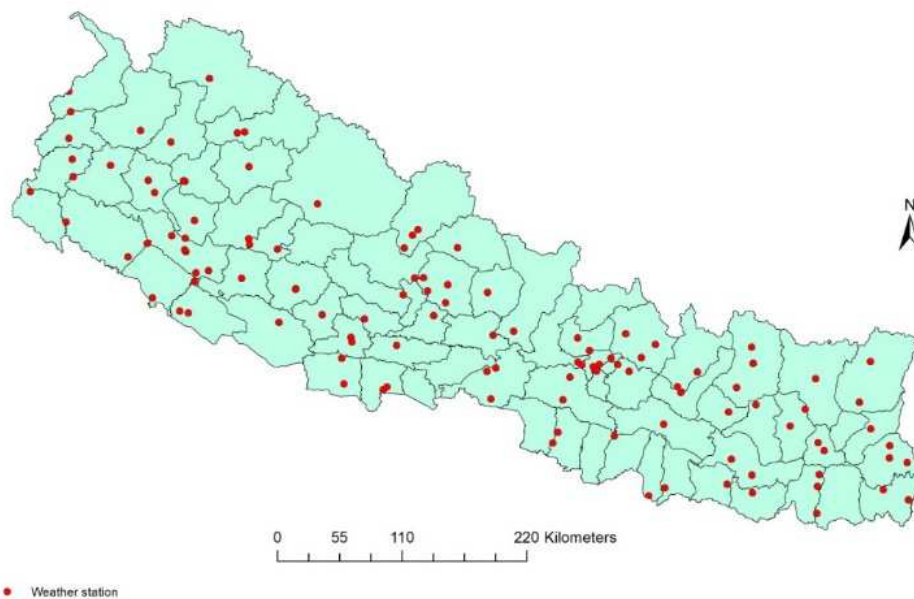
Climatic Zone Classification	Elevation	Temperature	Plant
Tundra	Over 5,000 m	Below 0 °C throughout the year	None
Alpine	3,300-5,000 m	Below 0 °C in winter, 5-15°C in summer	Alpine plants
Cool temperate	100-3,000 m	Below 0 °C in winter, 15-20°C in summer	Coniferous tree
Warm temperate	900-2,100 m	0-18 °C in winter, 17-30°C in summer	Deciduous broad-leaved trees
Sub-tropical	Under 900 m	6-25 °C in winter, 25-40°C in summer	Evergreen tree

Source: JICA Survey Team Based on Atlas of Climatic Zones of Nepal

(3) Weather Observatory

The competent authority for weather observation in Nepal is the Department of Hydrology and Meteorology (DHM) of the Ministry of Energy, Water Resources, and Irrigation (MOEWRI).

There are approximately 120 weather observatories in Nepal, and their measurements include rainfall, temperature, humidity, wind speed and direction, and solar radiation. They are located at elevations ranging from 72 m to 3,700 m above sea level. **Figure 2-5** shows the distribution of weather stations.

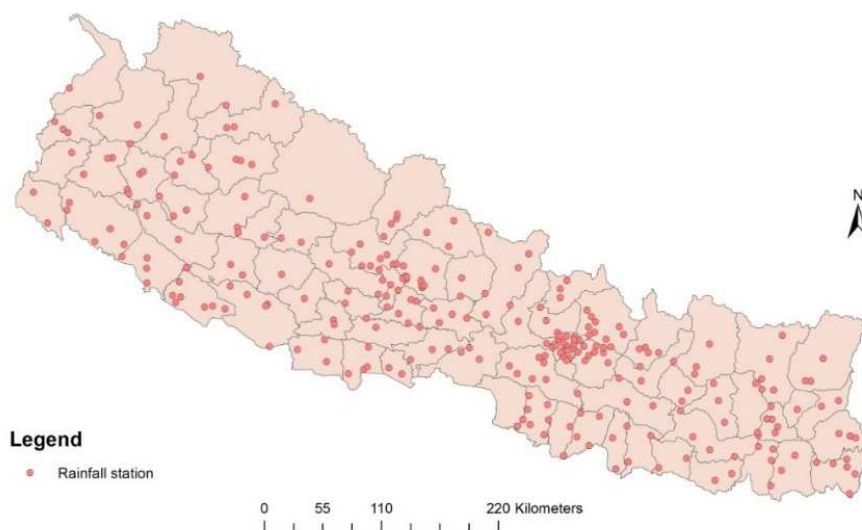


Source: JICA Survey Team Based on List by DHM

Figure 2-5 Weather Observatory in Nepal

(4) Rainfall

Approximately 280 rain gauge stations are shown in **Figure 2-6** (including 120 stations in **Figure 2-5**). These stations include both meteorological observation points and rainfall-only observation points. Most rainfall-only observation points adopt a manual method where the responsible personnel measure the daily accumulated rainfall in containers.

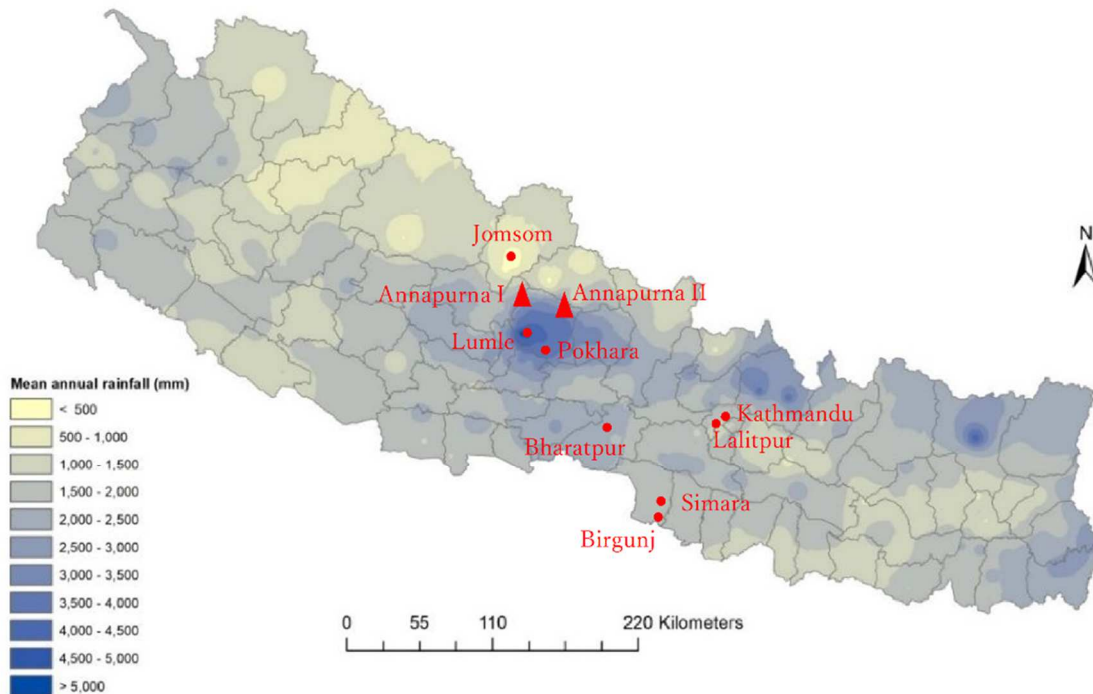


Source: JICA Survey Team Based on List by DHM

Figure 2-6 Rain Gauge Stations in Nepal

Two atmospheric flows influence rainfall in Nepal. In summer, heavy rains are generated by the moist monsoon winds from the Bay of Bengal. The summer monsoon is a phenomenon in which warm air at the ground surface becomes an updraft due to intense solar radiation during the summer. The ground surface becomes a low-pressure area, and moist winds flow in from the ocean side as surface winds. The rainfall by the summer monsoon tends to be more prominent by the elevation on the windward side of the mountain range extending from northwest-west to east-southwest in north-central Nepal, while much less in the leeward beyond the mountain range. The west wind mainly influences western Nepal during winter, causing snowfall in the Himalayas.

The average annual rainfall distribution map from 1980 to 2017 is shown in **Figure 2-7**. The Annapurna Mountains region has the highest and lowest annual rainfall stations. The highest annual rainfall is 5,441 mm at Lumle (on the upwind side of the monsoon) in Kaski District. The minimum annual rainfall is 280 mm at Jomsom (on the leeward side of the monsoon) in Mustang District.

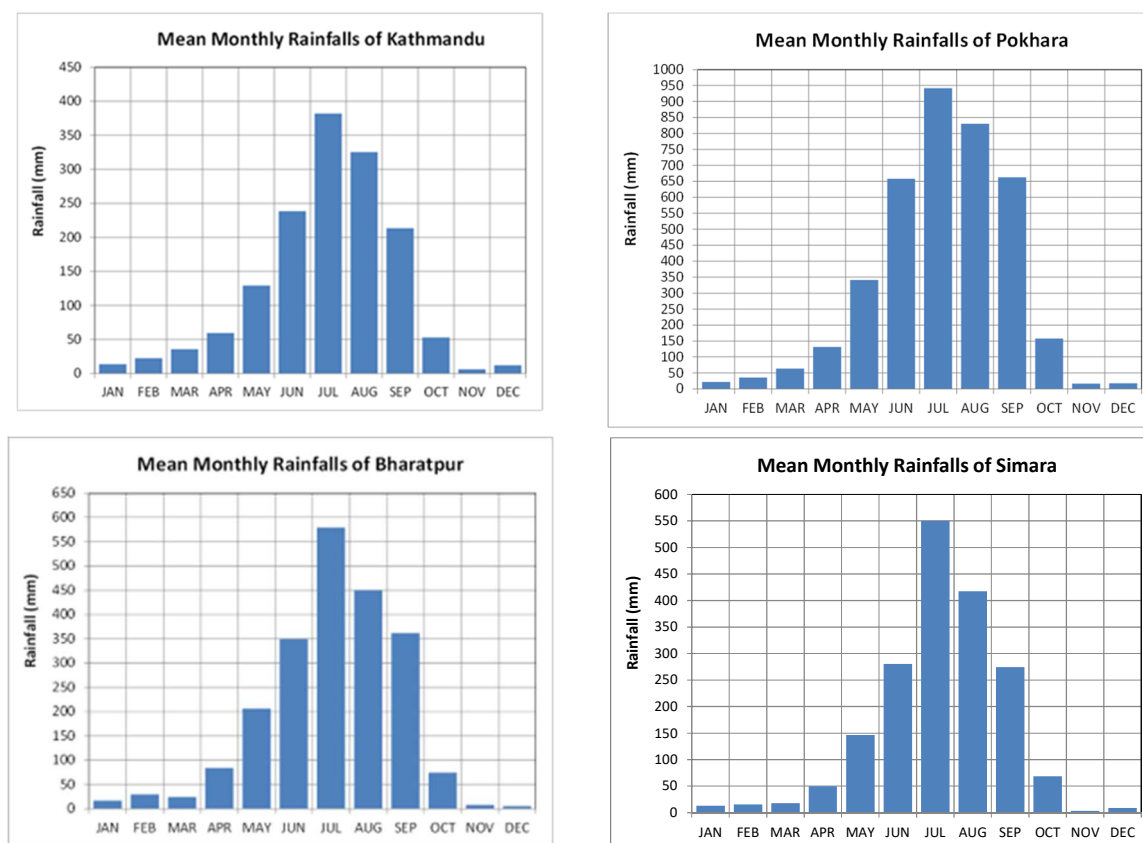


Source: JICA Survey Team Based on Water and Energy Commission Secretariat (WECS), Nepal

Figure 2-7 Distribution of Average Annual Rainfall in Nepal (1980-2017)

Rainfall characteristics were analyzed at four sites in Nepal: Kathmandu, the 1st most populous city in Nepal; Pokhara, the 2nd most populous; Bharatpur, the 3rd most populous (encompassing Narayanghat, a commercial district within the city); and Simara Airfield, 15 km north of Birgunj, the 5th most populated and largest distribution center in the country, on the border with India. Lalitpur, the fourth most populous city, is omitted because it is adjacent to Kathmandu (the ranking of the city population is based on Nepal 2021 census); Kathmandu and Pokhara are in the temperate zone, while Bharatpur and Simara are in the subtropical zone.

Figure 2-8 shows the distribution of average monthly rainfall; all four sites have a common characteristic: the summer monsoon winds from the Bay of Bengal cause a peak in rainfall in July. Monthly rainfall does not exceed 50 mm from November to March when the monsoon winds blow in the opposite direction.



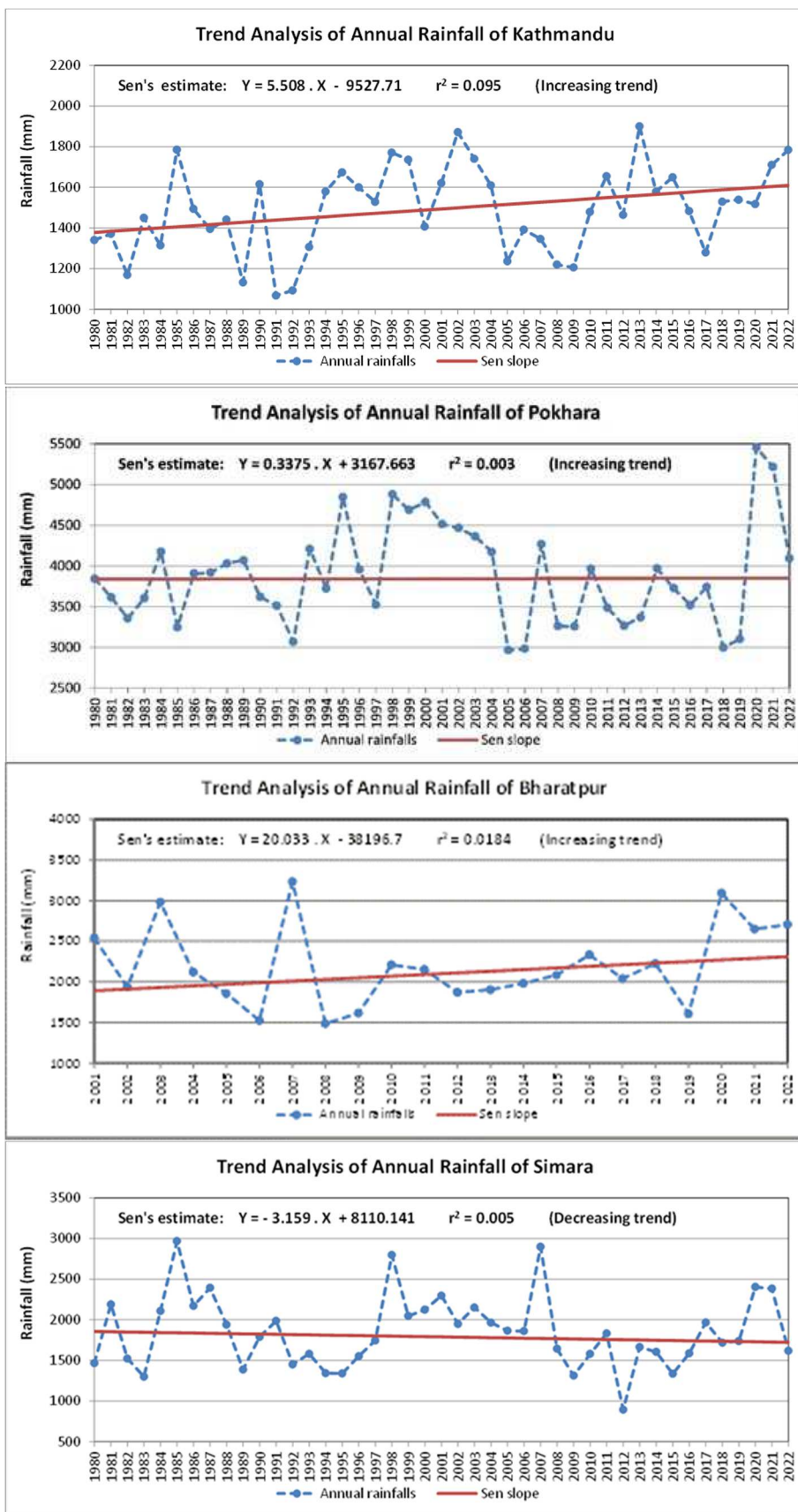
Source: JICA Survey Team Based on List by DHM

Figure 2-8 Average Monthly Rainfall Distribution for the Three Largest Cities in Nepal and the Largest Indian Border Logistics Hub (1980 - 2022)

Figure 2-9 shows the interannual variation of annual rainfall and Sen's slope, which indicates a trend of temperature and rainfall. An upward trend is observed in Kathmandu and Bharatpur, whereas the situation in Pokhara shows little change, and Simara has a weak downward trend.

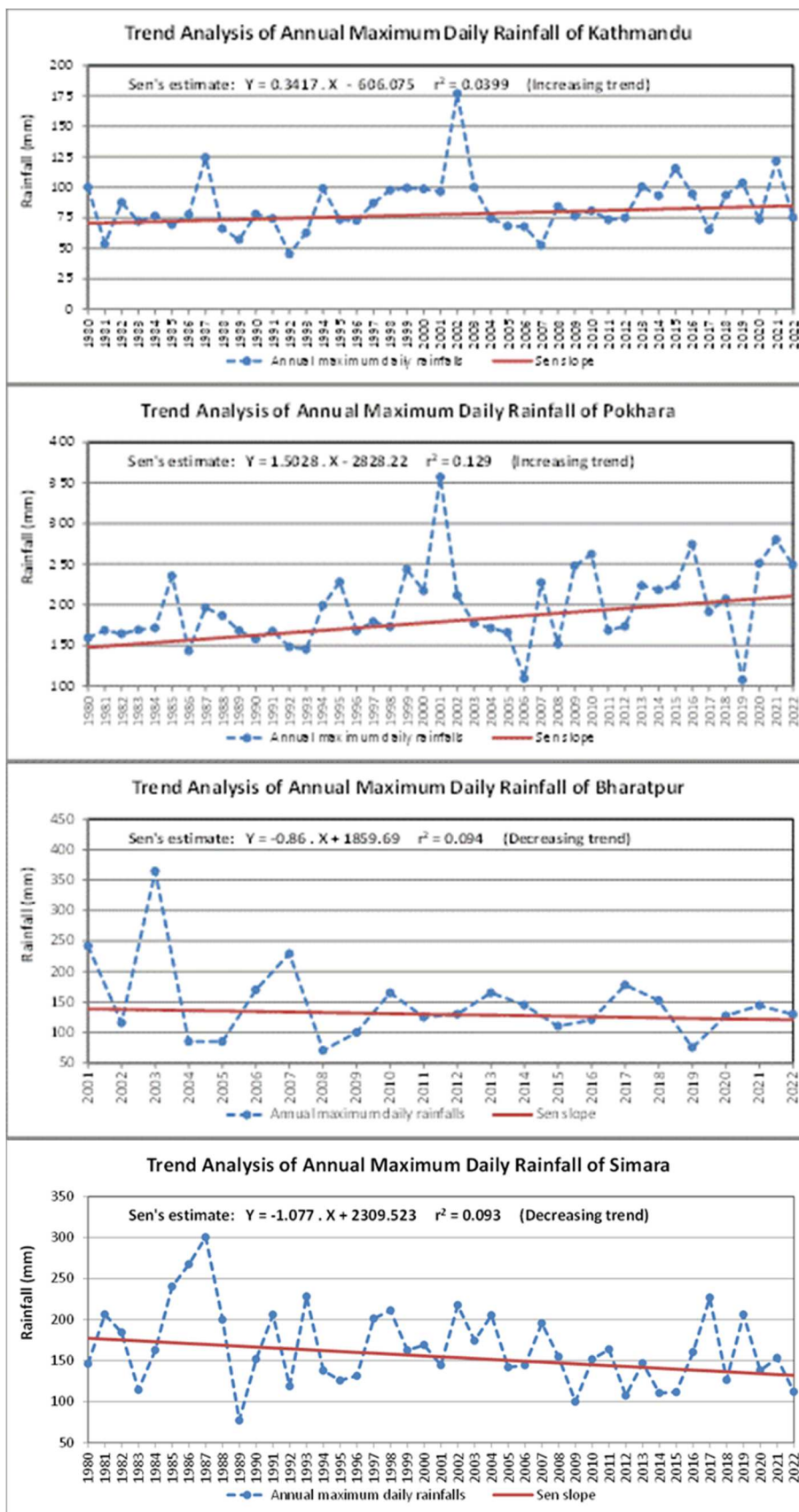
Figure 2-10 shows the interannual variation of maximum daily rainfall and its Sen's slope¹. Kathmandu and Pokhara in the temperate zone show an increasing trend over time, whereas Bharatpur and Simara in the sub-tropical zone show a decreasing trend. An increase in short-term heavy rains is also known in sub-tropical regions, and it is thought that periods of dry conditions and short-term heavy rains are increasing together.

¹ Sen's Slope is a method for estimating the slope of a time series, and the slope is calculated as the median of the slopes between all pairs of observed values.



Source: JICA Survey Team Analyses Based on DHM Data

Figure 2-9 Trend of Annual Rainfall in the Three Largest Cities in Nepal and the Largest Indian Border Logistics Hub (1980-2022)



Source: JICA Survey Team Based on List by DHM

Figure 2-10 Trend of Annual Maximum Daily Rainfall for the Three Largest Cities in Nepal and the Largest Indian Border Logistics Hubs (1980-2022, 2001-2022 for Bharatpur only)

2.1.4. Population

Population and population density by province are shown in **Table 2-4**, based on 2021 census data from the Central Bureau of Statistics. Population and population density by cities with populations of 200,000 or more are shown. The location map of provinces and cities is shown in **Figure 2-11**.

Table 2-4 Population and Population Density in each Province, Nepal

Province Name	Area (km ²)	Population				Density (people per km ²)
		1991	2001	2011	2021	2021
Koshi Province	25,905	3,520,335	4,201,795	4,534,943	4,972,021	192
Madhesh Province	9,661	3,605,277	4,604,713	5,404,145	6,126,288	634
Bagmati Province	20,300	3,505,092	4,569,597	5,529,452	6,084,042	300
Gandaki Province	21,856	1,757,005	2,044,145	2,092,153	2,479,745	113
Lumbini Province	19,707	3,299,093	4,180,225	4,757,692	5,124,225	260
Karnali Province	30,213	937,781	1,359,618	1,623,602	1,694,889	56
Sudurpashchim Province	19,539	1,679,301	2,191,330	2,552,517	2,711,270	139
Total	147,181	18,303,884	23,151,423	26,494,504	29,192,480	198

Source: Edited by the JICA Survey Team Based on the 1991, 2001, 2011, 2021 Census of the Central Bureau of Statistics

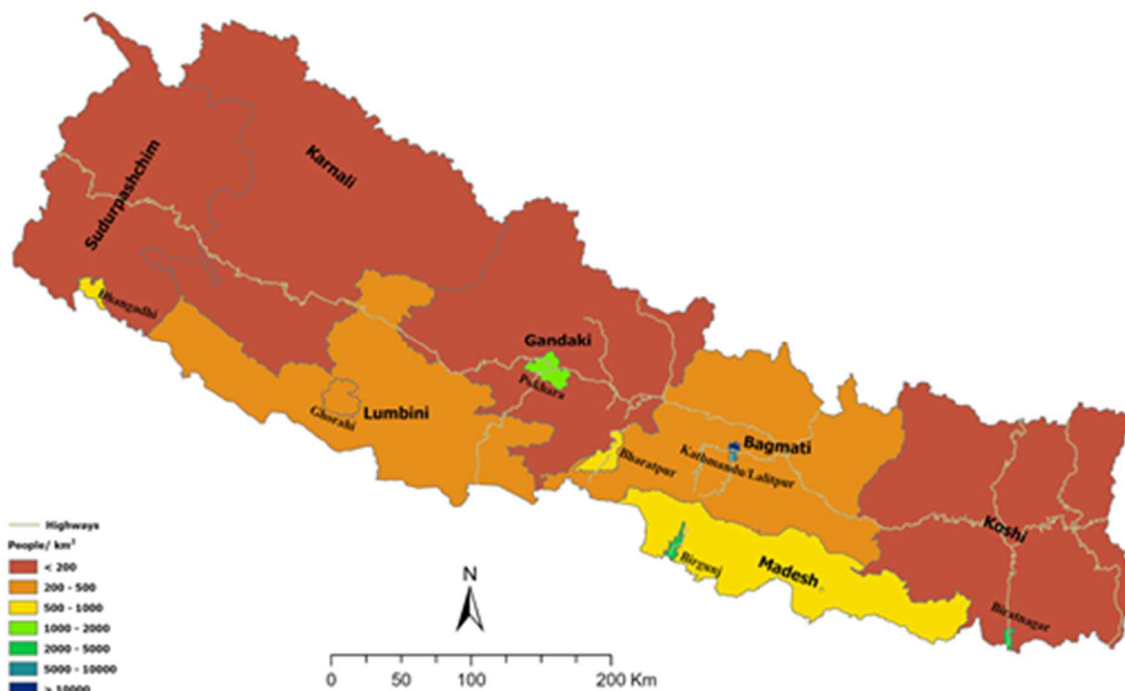
Table 2-5 Population and Population Density of Major Cities, Nepal

Name of City (Municipalities ²)	NH	Province	District	Area	Population (2021)	Population Density (2021)
				(km ²)	(people)	(people/km ²)
Kathmandu Metropolitan City	NH41 NH37	Bagmati Province	Kathmandu	49.45	862,400	17,439
Pokhara Metropolitan City	NH03 NH47	Gandaki Province	Kaski	464.24	513,504	1,106
Bharatpur Metropolitan City *2	NH44	Bagmati Province	Chitwan	432.95	369,268	852
Lalitpur Metropolitan City	NH41 NH37	Bagmati Province	Lalitpur	36.12	294,098	8,142
Birgunj Metropolitan City	NH41	Madhesh Province	Parsa	132.07	272382,	2,062
Biratnagar Metropolitan City	NH08	Koshi Province	Morang	77.00	243,927	3,167
Dhangadhi Sub-Metropolitan City	—	Sudurpashchim Province	Kailali	261.75	198,792	759
Ghorahi Sub-Metropolitan City	—	Lumbini Province	Dang	522.21	200,530	384

*2 Narayanghat is the commercial district of Bharatpur Metropolitan City

Source: Edited by the JICA Survey Team based on the 2021 census of the Central Bureau of Statistics

² The municipalities are categorized into three categories: Metropolitan municipality (500,000+ population), Sub-metropolitan municipality (200,000+ population) and Municipality (10,000+ population). There are 6 Metropolitan Municipalities, 11 Sub-metropolitan Municipalities, and 276 Municipalities. The demographic category is not strictly applied. After Table 2-5, the description of Metropolitan Municipalities and sub-Metropolitan Municipalities will be omitted.



Source: Edited by the JICA Survey Team based on the 2021 census of the Central Bureau of Statistics

Figure 2-11 Location Map of Provinces and Major Cities in Nepal

The population density is the highest in Madhesh province, which is in the southwestern region on the Indian border and Terai plains. It is the smallest of the seven provinces, with 6.5% of the nation's area, while its population accounts for 21% of the nation's population. The largest city is Birgunj, the gateway city to the Indian border, with a population of 268,000, the fifth largest in the country.

The second most densely populated province is Bagmati, which includes Kathmandu, the largest city located in the Kathmandu Valley, and the adjacent Lalitpur, the fourth most populous, and Bharatpur, the third most populated in the southwest of the Bagmati province.

Bharatpur is known by the name of its commercial district, Narayanghat. The main logistics from Birgunj in Madhesh province and Sunauli in Lumbini province along the Indian border passes through NH 44: Narayanghat - Mugling Highway, which connects the capital Kathmandu, the second largest city Pokhara, and other major cities. Chitwan District, where Bharatpur is located, is a food supply area and the main domestic supplier of chicken meat, which is also exported. Multinational companies in the beverage industry are also based there.

In recent years, the population has increased in all provinces, as shown in **Table 2-4**. Between 2011 and 2021, the population of Madhesh, Bagmati, and Gandaki provinces has increased by a factor of 1.13 (6.1 million / 5.4 million), 1.10 (6.1 million / 5.5 million), and 1.19 (2.5 million / 2.1 million), respectively. According to the future population estimates shown in **Table 2-6**, the population in the districts with the major cities is expected to increase continuously after 2021.

Table 2-6 Population in 2021 and Expected Future Population by the Districts, Nepal

Census Nepal 2021					Census Nepal 2011	Estimated future population based on Census Nepal 2011				
City Name	City	District	District (2021)	City Population/District Population (%)	District (2011)	District (2016)	District (2021)	District (2026)	District (2031)	
	Population		Population		Estimated Population	Estimated Population	Estimated Population	Estimated Population	Estimated Population	
Kathmandu	862,400	Kathmandu	2,041,587	42.2	1,744,240	2,011,978	2,300,890	2,522,103	2,729,056	
Pokhara	513,504	Kaski	600,051	85.6	492,098	543,767	597,988	643,183	683,513	
Bharatpur	369,268	Chitwan	719,859	51.3	579,984	644,219	711,629	766,462	815,116	
Lalitpur	294,098	Lalitpur	551,667	53.3	468,132	525,211	585,982	635,151	680,157	
Birgunj	272,382	Parsa	654,471	41.6	601,017	663,559	729,291	784,922	834,768	
Biratnagar	243,927	Morang	1,148,156	21.2	965,370	1,036,841	1,108,654	1,175,177	1,230,237	
Dhangadhi	198,792	Kailali	904,666	22.0	775,709	870,771	971,320	1,050,982	1,122,577	
Ghorahi	200,530	Dang	674,993	29.7	552,583	605,796	660,742	706,858	746,519	

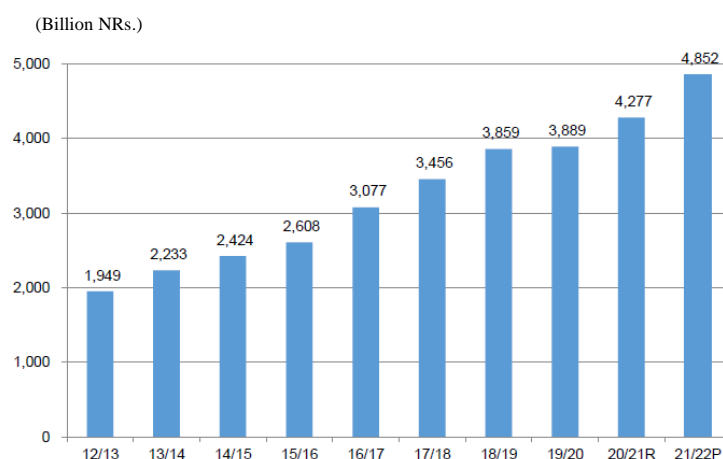
Note: District population projection (2021) is estimated based on Census Nepal 2011; therefore, the estimated values do not match the actual values from Census Nepal 2021

Source: Edited by JICA Survey Team based on 2011/2021 Census and Statistical Yearbook 2021 of the Central Bureau of Statistics

2.1.5. Economy and Industry

(1) Nepal's GDP

The trend of Nepal's nominal GDP from Nepali FY³ 2012/13 to FY 2021/22 is shown in **Figure 2-12**. Nepal's nominal GDP has been increasing approximately 2.5 times from NRs. 1.949 trillion in FY 2012/13 to NRs. 4.852 trillion in FY 2021/22. In addition, the trend of Nepal's nominal GDP per capita (**Figure 2-13**) shows an increase of about 1.7 times from USD814 in FY 2012/13 to USD1,372 in FY 2021/22.



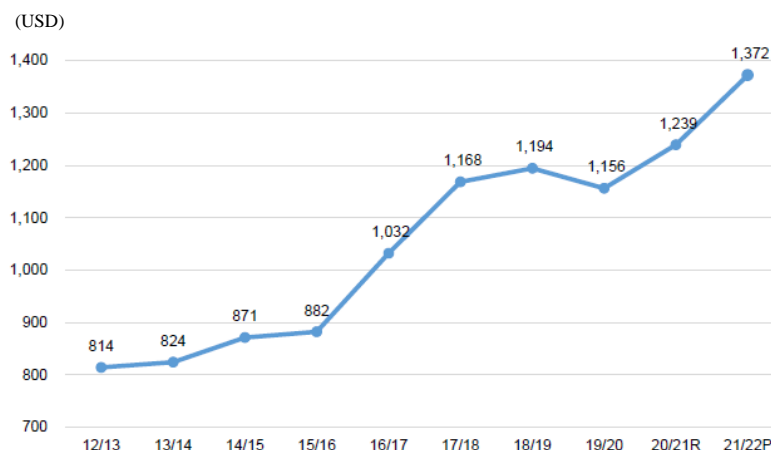
(Note) R is the adjusted value, P is the estimated value

(Source) MoF (2022), Economic Survey 2021/22

Source: Embassy of Japan in Nepal, "Illustration: Nepal Economy 2023".

Figure 2-12 Nominal GDP Change Over the Years

³ Nepali FY is generally from July 16th to July 15th of the following year.



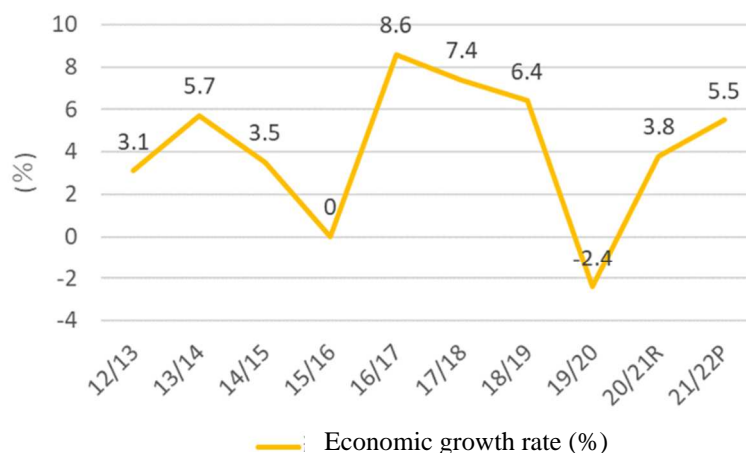
(Note) R is the adjusted value, P is the estimated value.

(Source) MoF (2022), Economic Survey2021/22

Source: Embassy of Japan in Nepal, "Illustration: Nepal Economy 2023".

Figure 2-13 Nominal GDP per Capital

Figure 2-14 shows the trend of Nepal's economic growth rate, with a growth rate of 5.5% in FY2021/22, following a growth rate of 3.8% in FY2020/21. In FY 2015/16, the growth rate is considered to have been 0% due to the earthquake that occurred on April 25, 2015. In FY 2019/20, the growth rate is considered to have been -2.4% due to COVID-19.



(Note) R is the adjusted value, P is the estimated value

(Source) MoF (2022), Economic Survey2021/22

Source: Edited by the survey team based on "Illustration: Nepal Economy 2023," Embassy of Japan in Nepal

Figure 2-14 Trend of Economic Growth Rate

(2) Industry

According to the Ministry of Finance (MOF), the tertiary sector was the main industry in Nepal in FY2020/21, accounting for 61.41% of the total Gross Value Added (GVA) (Table 2-7). In the tertiary industry, wholesale and retail trade and repair of motor vehicles and motorcycles accounted for the largest share, followed by the real estate industry. The primary and secondary sectors accounted for 25.49% and 13.10%, respectively. Comparing FY2020/21 to FY 2012/13, GVA in the tertiary industry has increased 2.37 times. For the primary and secondary sectors, GVA increased 1.64 and 1.86 times, respectively, and is expected to continue to grow.

Table 2-7 GVA by Industry Sector

NRs in 10 million

Industrial Classification	2012/13	Ratio of 2012/13 (%)	2020/21	Ratio of 2020/21 (%)	Annual increase rate (%)
Agriculture, forestry, and fishing	55,794	31.39	91,192	24.90	6.3
Mining and quarrying	1,057	0.59	2,153	0.59	9.3
Primary sector	56,851	31.98	93,345	25.49	6.4
Manufacturing	11,209	6.31	19,956	5.45	7.5
Electricity, gas, steam, and air conditioning supply	2,009	1.13	4,178	1.14	9.6
Water supply; sewerage, waste management and regenerating activities	1,103	0.62	2,062	0.56	8.1
Construction	11,519	6.48	21,791	5.95	8.3
Secondary sector	25,840	14.54	47,987	13.10	8.0
Wholesale and retail trade; repair of motor vehicles and motorcycles	27,427	15.43	58,439	15.96	9.9
Transportation and storage	10,592	5.96	19,637	5.36	8.0
Accommodation and food service activities	3,478	1.96	5,878	1.60	6.8
Information and communication	4,033	2.27	8,117	2.22	9.1
Financial and insurance activities	8,116	4.57	25,672	7.01	15.5
Real estate activities	17,448	9.82	33,299	9.09	8.4
Professional, scientific, and technical activities	1,626	0.91	3,710	1.01	10.9
Administrative and support service activities	840	0.47	2,912	0.80	16.8
Public administration and defense; mandatory social security	8,263	4.65	28,766	7.85	16.9
Education	10,220	5.75	29,666	8.10	14.2
Human health and social work activities	2,128	1.20	6,528	1.78	15.0
Arts, entertainment, and recreation; Other service activities; and Activities of households as employers; undifferentiated goods and services producing activities of households for own use	868	0.49	2,293	0.63	12.9
Tertiary sector	95,039	53.48	224,917	61.41	11.4
Total GVA	177,730	100.00	366,249	100.00	9.5

Source: MOF, Economic Survey 2021/22

(3) Manufacturing

Table 2-8 shows the output value of the manufacturing sector. The primary manufacturing sector is food products (24.75%), followed by other non-metallic mineral products (10.42%) and electricity, gas, steam, and air conditioning supply (8.82%).

Table 2-8 Value of Output by Manufacturing (FY2019/20)

NRs in 10 thousand

Division	Value of Output	Percentage of Output (%)
Other mining and quarrying	24,738,036	2.06
Food products	297,293,059	24.75
Beverages	56,679,453	4.72
Tobacco products	6,403,101	0.53
Textiles	27,365,570	2.28
Wearing apparel	22,075,494	1.84
Leather and related products	8,805,734	0.73
Wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	34,838,316	2.90
Paper and paper products	10,993,473	0.92
Reproduction of recorded media	8,900,206	0.74
Coke and refined petroleum products	2,511,370	0.21
Chemicals and chemical products	55,284,859	4.60
Basic pharmaceutical products and pharmaceutical preparations	15,077,169	1.26
Rubber and plastic products	42,739,643	3.56
Other non-metallic mineral products	125,186,095	10.42
Basic metals	101,315,981	8.43
Fabricated metal products, except machinery and equipment	86,784,650	7.23
Computer, electronic, and optical products	2,901,073	0.24
Electrical equipment	17,037,608	1.42
Machinery and equipment n. e. c.	1,671,106	0.14
Motor vehicles, trailers and semitrailers	317,662	0.03
Furniture	24,376,984	2.03
Other manufacturing	78,466,050	6.53
Repair and installation of machinery and equipment	2,348,630	0.20
Electricity, gas, steam, and air conditioning supply	105,919,236	8.82
Water collection, treatment, and supply	19,564,585	1.63
Sewerage	80,412	0.01
Waste collection, treatment, and disposal activities; materials recovery	21,342,209	1.78
Remediation activities and other waste management services	110,070	0.01
Total	1,201,170,729	100.00

Source: Central Bureau of Statistics, National Industrial Survey National Report 2019/2020

(4) Tourism Industry

The annual number of tourist arrivals in 2022 is about 610,000, as shown in

Table 2-9. In 2018, the number of visitors entering Nepal exceeded 1 million, but in 2019-2020, the number of tourists declined significantly due to COVID-19. The number of tourists in 2022 has been recovering to about 610,000.

Table 2-10 also shows the number of tourists by the purpose of their visit in 2022. Including tourists who came for mountain climbing, about 74% of the tourists came for sightseeing.

Table 2-9 Number of Tourists and Average Length of Stay

Year	Total		By Air		By Land		The average length of stay
	Number	Annual growth rate (%)	Number	Percent (%)	Number	Percent (%)	
2013	797,616	-0.7	584,848	74.6	202,768	25.4	12.60
2014	790,118	-0.9	585,981	74.2	204,137	25.8	12.44
2015	538,970	-32	407,412	75.6	131,558	24.4	13.16
2016	753,002	40	572,563	76	180,439	24	13.40
2017	940,218	25	760,577	81	179,641	19	12.60
2018	1,173,072	25	969,287	82.63	203,785	17.37	12.40
2019	1,197,191	2.05	995,884	83.19	201,307	16.81	12.70
2020	230,085	-80.7	183,130	79.6	46,955	20.4	15.10
2021	150,962	-34.3	150,625	99.7	337	0.3	15.50
2022	614,869	307.3	592,631	96.4	22,238	3.6	13.1

Source: Nepal Tourism Statistics 2022, Ministry of Culture Tourism and Civil Aviation

Table 2-10 Number of Tourists by Purpose of Visit (2022)

	Holiday Pleasure	Trekking & Mountaineering	Pilgrimage	Others	Total
No. of tourist	397,820	61,692	79,146	76,202	614,869
Percent (%)	64.7	10.0	12.9	12.4	100

Source: Nepal Tourism Statistics 2022, Ministry of Culture, Tourism and Civil Aviation

(5) Logistics

Nepal is a landlocked country with 80% of its land area in mountainous regions and relies on roads for much of the movement of people and goods. Neighboring India accounts for about 60% of Nepal's imports and 80% of its exports. It relies on the Kolkata port in India for much of its ocean freight imports. Goods transported from the Kolkata port are reloaded at dry ports along the border.

Dry ports (also called inland ports) are inland terminals directly connected to seaports by road or rail and serve as transshipment centers for land/ocean freight to inland destinations. The major logistics hubs in Nepal are the five dry ports ⁴(Birgunj, Biratnagar, Bhairahawa, Kakarbhitta (Mecha), and Chobhar (Kathmandu Inland Clearance Depot (ICD)) shown in **Figure 2-15**. In particular, the share of export and import amounts at Birgunji is large. Goods from Birgunj dry port are transported to Kathmandu

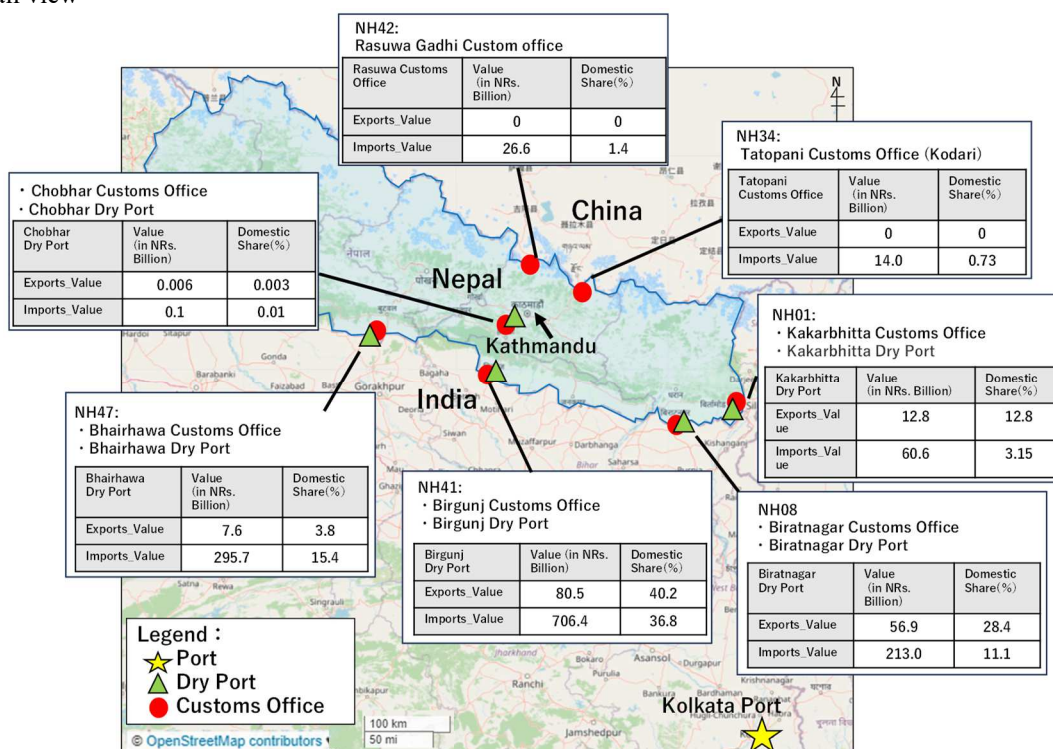
⁴ The Nepal Intermodal Transport Development Board calls the dry port Inland Clearance Depot (ICD).

through Narayanghat, and Mugling. This highway is an essential highway for overland trade with India. On the other hand, as shown in **Figure 2-16**, the overland highway from Birgunj to the capital Kathmandu is shorter via NH41 Tribhuvan Highway. However, since many sections have less than two lanes, large vehicles such as buses and heavy-duty trucks cannot pass through NH41. The only route available for large vehicles is via Narayanghat and Mugling. The distance between Narayanghat and Mugling is about 300 km, and the time required is about 8 to 10 hours (Source: <https://cuts-citee.org/pdf/field-diary-birgunj.pdf>).

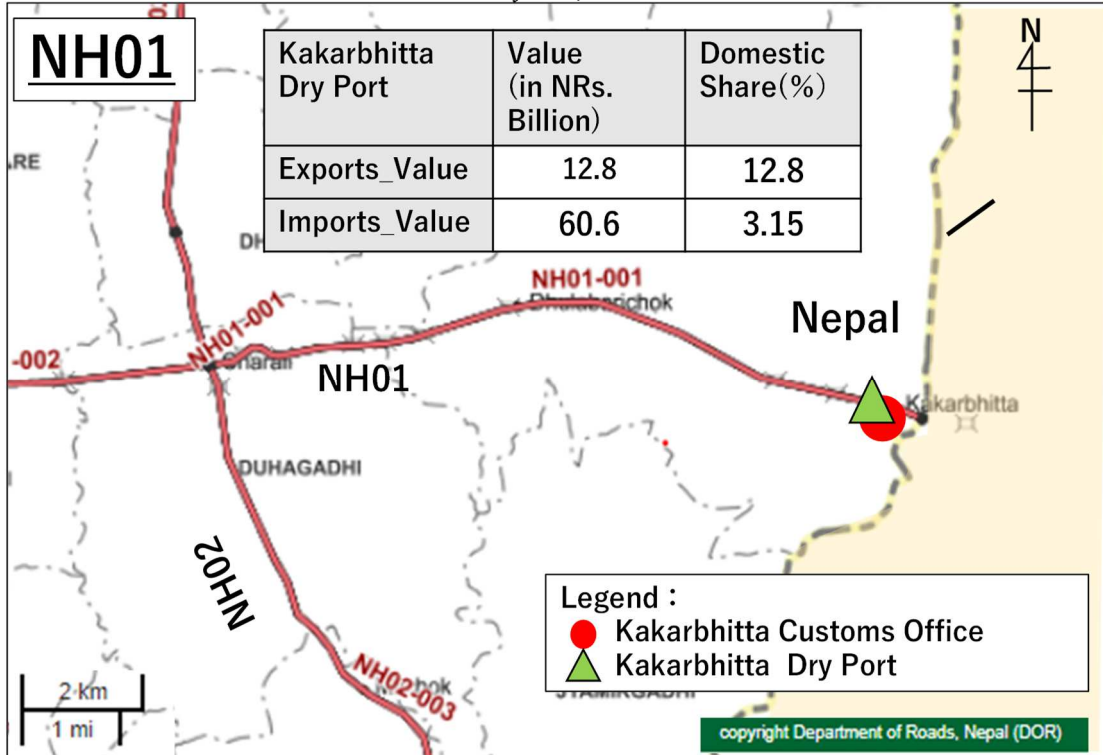
Five dry ports (Birgunj, Biratnagar, Bhairahawa, Kakarbhitta, and Chobhar), as shown in Figure 2-15, are in operation in Nepal. As a landlocked country, Nepal relies on the Indian port of Kolkata for most of its sea freight imports, and the above dry ports serve as transshipment points for transporting exported and imported goods.

Twelve overland NHs are bordering on India and eight NHs bordering on China. Of these, the major overland highways, especially for trade, are shown in **Figure 2-15**. In the north (Chinese side), NH42 and NH34 are the primary land highways; in the south (Indian side), NH47, NH41, and NH08; and in the east (Indian side), NH01 is the major land highway.

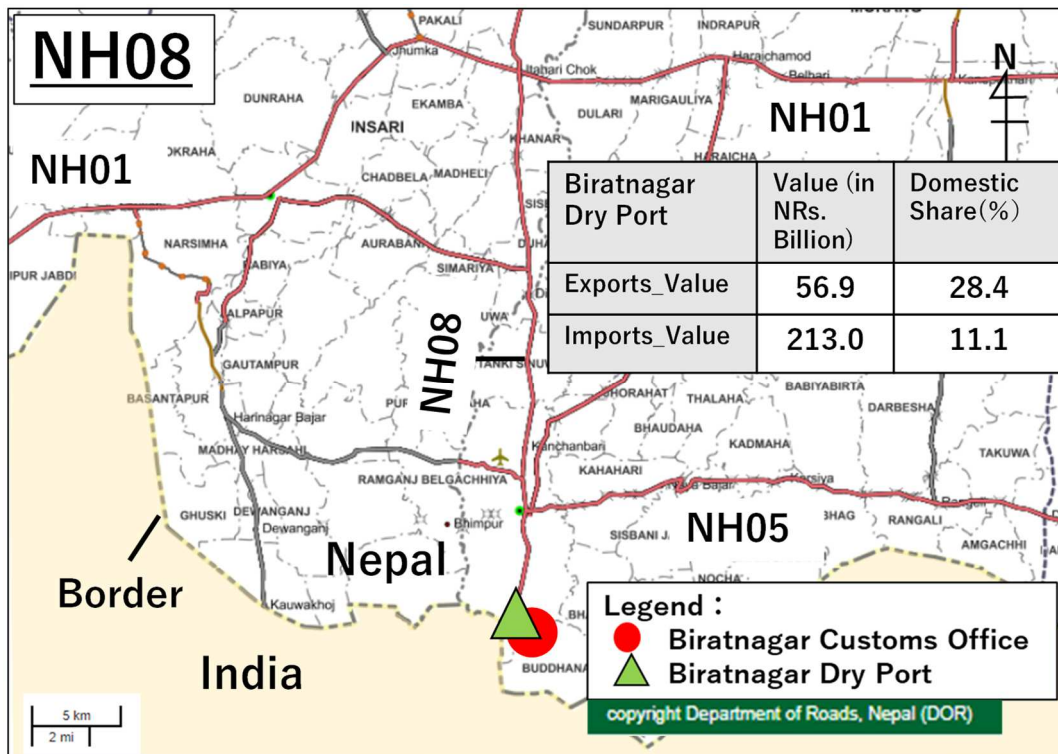
-Overall view-



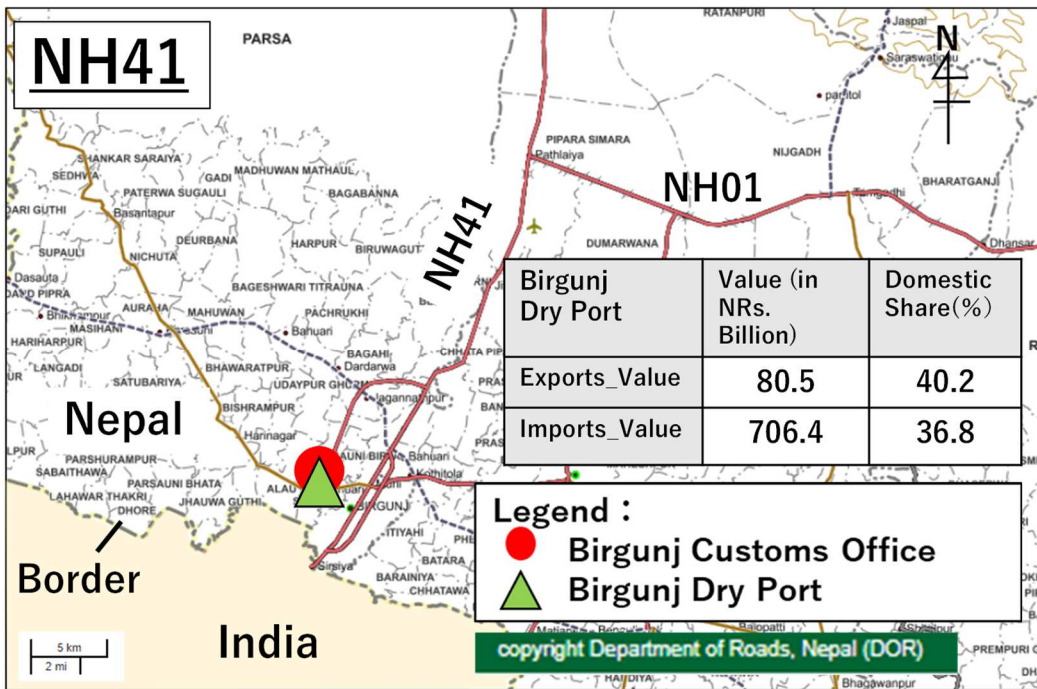
-Kakarbhitta Dry Port, Customs Office-



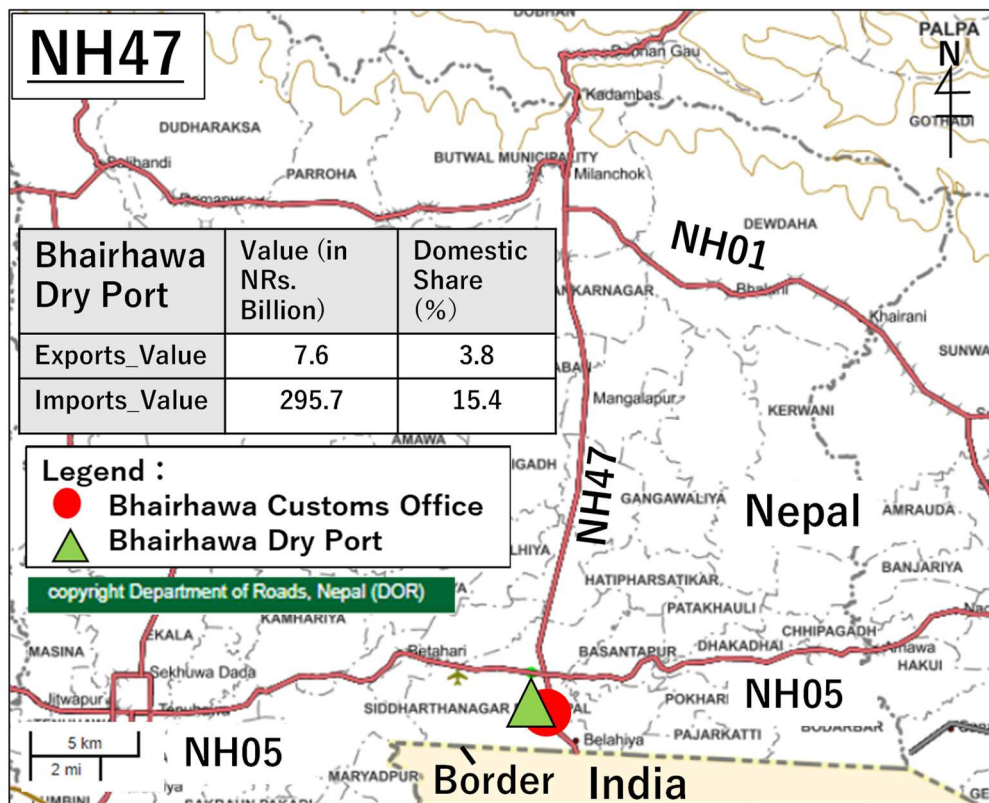
-Biratnagar Dry Port, Customs Office-



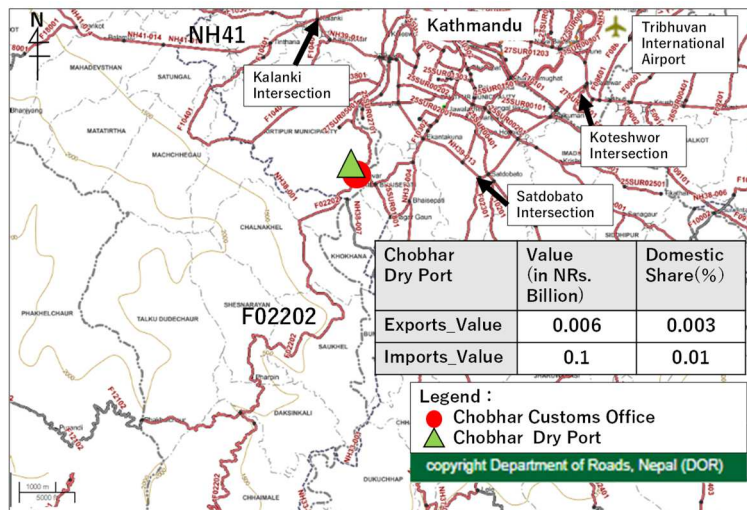
-Birgunj Dry Port, Customs Office-



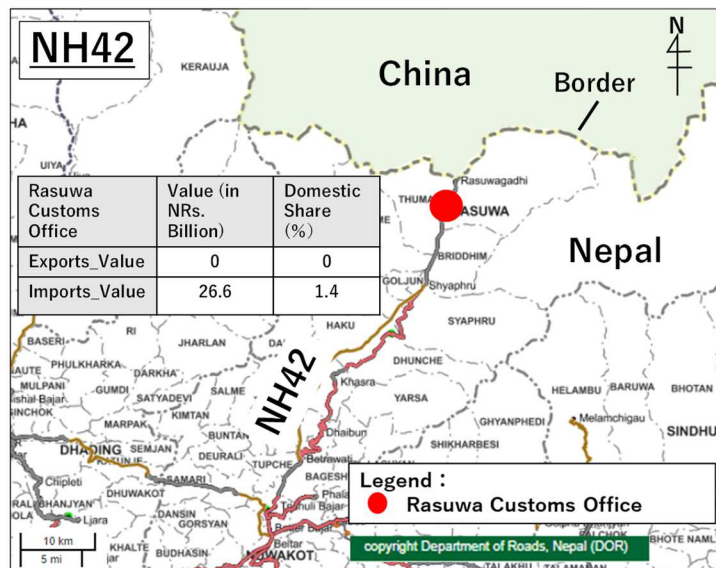
-Bhairahawa Dry Port, Customs Office-



-Chobhar Dry Port, Customs Office-



-Rasuwa Customs Office-



-Tatopani Customs Office-



Source: JICA Survey Team, based on DOR and OpenStreetMap

Figure 2-15 Site of Major NHs, Customs Offices, and Dry Ports for Trade



Source: JICA Survey Team

Figure 2-16 Highway of Goods Transported from Birgunj Dry Port to Kathmandu

Values of exports and imports in Nepal in FY2020/21 and FY2021/22 are shown in **Table 2-11**. Compared to FY2020/21, exports and imports of FY 2021/22 increased by 41.7% and 24.7%, respectively.

Table 2-11 Exports and Imports in FY2020/21 and FY2021/22

	2020/21 (12 months)	2021/22 (12 months)	Rate of change (%)
Exports Value	141,124,080	200,030,962	41.7
Imports Value	1,539,837,068	1,920,448,349	24.7

Unit: thousand NRs

Source: Department of Customs, MOF

Table 2-12 and **Table 2-13** show the major export and import partners. India accounts for the major portions of both exports (77.6%) and imports (62.5%). The U.S.A (9.0%) and Germany (2.1%) follow India in exports. As for imports, China (13.8%) and Indonesia (2.8%) come after India.

Table 2-12 Major Export Partners in FY2021/22

No.	Country Name	Export Value (thousand NRs)	Percentage (%)
1	India	155,222,304	77.6
2	USA	17,992,059	9.0
3	Germany	4,199,234	2.1
4	Turkey	3,741,701	1.9
5	United Kingdom	3,124,316	1.6

Source: Department of Customs, MOF

Table 2-13 Major Import Partners in FY2021/22

No.	Country Name	Export Value (thousand NRs)	Percentage (%)
1	India	1200,152,728	62.5
2	China	264,783,713	13.8
3	Indonesia	53,318,478	2.8
4	USA	50,050,518	2.6
5	United Arab Emirates	47,910,786	2.5

Source: Department of Customs, MOF

The import and export figures (FY2021/22) of Customs Offices in the five dry ports are shown in **Table 2-14** and **Table 2-15**. Birgunj has the largest share of imports (36.78%) and exports (40.24%), making it Nepal's most major dry port. Regarding export value, Birgunj is followed by Biratnagar (28.44%) and Kakarbhitta (6.4%). Regarding import value, Birgunj is followed by Bhairahawa (15.40%) and Biratnagar (11.09%).

The main transportation highways of goods from each dry port except Birgunj to Kathmandu, based on the results of interviews with former employees of DOR, are shown in **Figure 2-17**. From the Kakarbhitta/Biratnagar Dry Port on the east side of Kathmandu, goods are transported through NH01, Narayanghat, and Mugling. At the Bhairahawa Dry Port west of Kathmandu, goods are transported from NH47 to NH01 on the same highway as above. The Chobhar Dry Port is located within the Kathmandu Valley, allowing importers to complete customs clearance for their goods. This has the advantage that importers do not have to go to the dry ports along the border. However, the Chobhar Dry Port accounts for only a small percentage of total imports. Most of the supplies to Kathmandu are transported from the Birgunj Dry Port.

Regarding export logistics, Birgunj Dry Port is used for goods from Kathmandu, and goods to Biratnagar Dry Port, which accounts for 32% of the export value, are collected from the eastern region.

Table 2-14 Imports by Dry Port (FY2021/22)

No.	Dry Port	Import Value (thousand NRs)	Percentage (%)
1	Birgunj	706,387,967	36.78
2	Bhairahawa	295,671,051	15.40
3	Biratnagar	212,967,750	11.09
4	Kakarbhitta (Mechi)	60,559,263	3.15
5	Chobhar	98,877	0.01

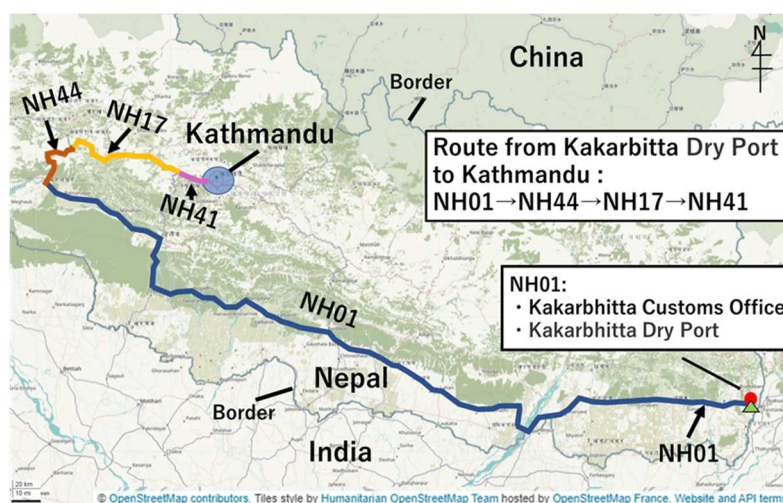
Source: Department of Customs, MOF

Table 2-15 Exports by Dry Port (FY2021/22)

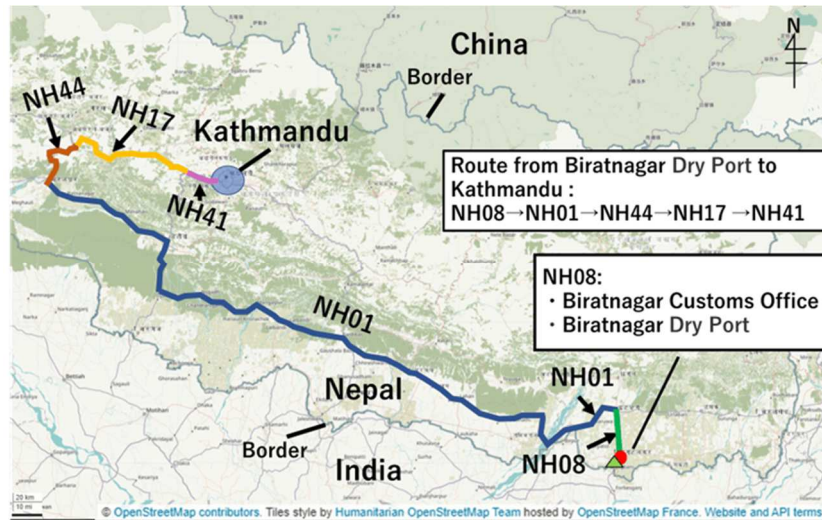
No.	Dry Port	Export Value (thousand NRs)	Percentage (%)
1	Birgunj	80,491,509	40.24
2	Biratnagar	56,880,993	28.44
3	Kakarbhitta (Mechi)	12,805,708	6.40
4	Bhairahawa	7,612,248	3.81
5	Chobhar	5,570	0.00

Source: Department of Customs, MOF

- Transportation route from Kakarbhitta Dry Port to Kathmandu -



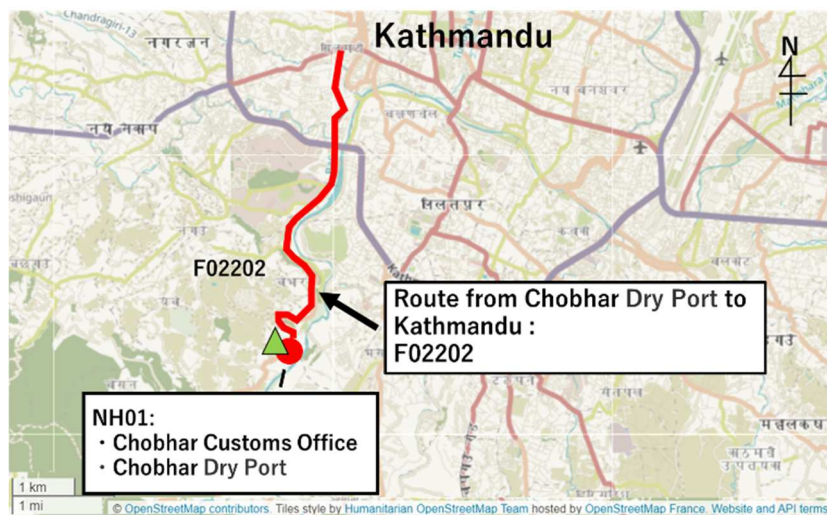
- Transportation route from Biratnagar Dry Port to Kathmandu -



- Transportation route from Bhairahawa Dry Port to Kathmandu -



- Transportation route from Chobhar Dry Port to Kathmandu-



Source: JICA Survey Team, Based on DOR and OpenStreetMap

Figure 2-17 Main Transportation Highways from Each Dry Port to Kathmandu

The proportion of national and regional highways to the total length of the transportation routes from each dry port to Kathmandu is shown in **Table 2-16**. Except for Chobhar Dry Port, transportation from each dry port to Kathmandu needs to go through NH01, NH17, NH41, and NH44. In conclusion, these NHs are important highways for the transportation of goods in Nepal.

Table 2-16 The Proportion of National and Regional Roads to the Total Length of Transportation Routes from Each Dry Port to Kathmandu

Highways	NH01	NH05	NH08	NH17	NH41	NH44	NH46	NH47	F02202 ※1	Total	The total length of the route
Kakarbhitta Dry Port ⇔ Kathmandu	77.1%	0.0%	0.0%	13.5%	3.5%	5.9%	0.0%	0.0%	0.0%	100.0%	612 km
Biratnagar Dry Port ⇔ Kathmandu	69.2%	0.0%	5.4%	15.0%	3.9%	6.5%	0.0%	0.0%	0.0%	100.0%	550 km
Birgunj Dry Port ⇔ Kathmandu	49.4%	0.0%	0.0%	29.8%	7.8%	13.0%	0.0%	0.0%	0.0%	100.0%	277 km
Bhairahawa Dry Port ⇔ Kathmandu	33.6%	8.8%	0.0%	31.7%	8.3%	13.8%	2.4%	1.4%	0.0%	100.0%	260 km
Chobhar Dry Port ⇔ Kathmandu	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%	6 km

※1: This road is shown in Figure 2-17 from the Chobhar Dry Port to Kathmandu.

Source: JICA Survey Team

2.2. Disaster Management-Related Policies and Plans

2.2.1. Policies and Plans for General Disaster Management

In 1982, based upon the Natural Calamity (Relief) Act., the Government of Nepal designated the Ministry of Home Affairs (MOHA) as the central coordinating authority to organize disaster management mechanisms under which the Natural Disaster Relief Committee at the central and regional levels was set up. Since 2005, by the Hyogo Framework for Action (HFA), the purpose of disaster management shifted to focus on “disaster risk reduction (DRR)” and raising “Disaster resilient Nepal” as the conceptual vision. In 2009, the National Strategy for Disaster Risk Management (NSDRM) put up “community development with recovering power” as one of the important objectives.

The Government of Nepal has formulated and updated existing laws and policies in response to the Sendai Framework for DRR 2015-2030. The following policies, laws, and plans are currently operational regarding disaster management.

- River and Water-Induced Disaster Management National Policy December 2023
- The Disaster Risk Reduction and Management (DRRM) Act 2017
- The National Policy for DRR 2018
- The DRR National Strategic Plan of Action 2018-2030

The DRRM Act 2017 was enacted by the government in 2017, replacing the Natural Calamity (Relief) Act 1982 as an international commitment to the Sendai Framework for DRR2015-2030, learning from the experiences of the 2015 earthquake disaster. The National DRRM Authority (NDRRMA) was established as the central agency responsible for disaster management according to the DRRM Act 2017.

The National Policy for DRR 2018 states that the government will conduct and manage necessary research, development, and implementation activities for all types of disasters in Nepal.

The DRR National Strategic Plan of Action 2018-2030 sets the periodic DRR goals targeting the short-term (2020), mid-term (2025), and long-term (2030). Achievement of these goals is monitored by

indexes such as the number of affected people and economic loss, and also the progress of the action plan for the prioritized activities, namely understanding disaster risk, governance in DRR, investment in DRR, and preparedness against disaster.

Under the plan, NDRRMA is to coordinate and promote the surveys, investigations, hazard mapping, monitoring, and projects for DRR. NDRRMA is the coordinating agency for disaster management, and its technical staff for DRR projects consists of officials assigned from other agencies. DRR projects are carried out by the ministries and departments at the federal or provincial level and local governments, depending upon the disaster types.

2.2.2. Policies and Plans for Landslide Risk Reduction

In road landslide risk reduction, Department of Water Resources, and Irrigation (DWRI) under the Ministry of Energy, Water Resources, and Irrigation (MOEWRI) manages landslide that originates outside the road right-of-way, more than 25 meters away from the road. Water Induced Disaster Management Policy 2015 was established by the former Department of Water Resources and Irrigation (DWIDM), which was transformed into the DWRI. This policy has been applied to all river hazard management and landslide management plans, including landslide mitigation in Nepal, since FY2015/16. GON approved the updated new policy “River and Water Induced Disaster Management National Policy” in December 2023.

The DRR National Strategic Action Plan 2018-2030 includes a landslide DRRM plan.

DWRI annually formulates a limited number of landslide management projects in targeted districts.

The Watershed and Landslide Management, Section of the Department of Forest and Soil Conservation (DOFSC) of the Ministry of Forest and Environment (MOFE), has developed the Program Implementation Procedure 2021 and plans to conduct watershed-based small-scale landslide risk reduction, survey, and mapping work.

DOR plans road landslide engineering measures in its annual maintenance plan as specific/preventive maintenance. In addition, road rehabilitation project plans often include landslide engineering measures such as mountain side cutting work for road widening, rock fall engineering measures work, slope stabilization work, and mountain stream debris flow engineering measures.

2.2.3. Budget Related to Landslide Engineering Measures

Based on public information from MOF (<https://www.mof.gov.np/site/publication-category/28>.) and interviews with relevant agencies, the budgets currently allocated to departments involved in landslide engineering measures (DWRI and DOFSC) from FY 2019/20 through FY 2023/24 are as shown in **Table 2-17** and **Table 2-18**. For FY2023/24, approximately NRs.23.1 billion are allocated to DWRI, and NRs.1.9 billion are allocated to DOFSC. DWRI and DOFSC plan to conduct landslide surveys and investigations, prepare landslide maps, perform landslide risk management work, and research works on landslides. The Landslide Management Project of DWRI and the Landslide Section of DOFSC carry out the landslide risk management work. According to interviews with DWRI and DOFSC, however, the landslide risk management budget is not allocated based on the request by DWRI and DOFSC but proposed by MOF in budgeting due process; accordingly, the budget amount needs to meet the actual needs. Considering the budgeting system above, landslide engineering measures are selected and planned based on the request for budget and/or result of a need survey from the local user groups such as irrigation facility within the allocated budget. This situation also means that the central government cannot figure out the demands of engineering measures at a national level because of the lack of landslide hazard maps covering the nation.

On the other hand, since NDRRMA is the central agency responsible for coordinating organizations for disaster management, it is important that it performs its functions by coordinating demands and budgets between local and national governments, and related organizations. NDRRMA intends to promote coordination of this disaster management demand and budget. Still, it does not have a clear coordination function for the budgets of other disaster management-related government agencies, and budget allocation depends on MOF and each ministry and is carried out individually. Regarding the survey of

demand for road landslide management on national highways, NDRRMA is not currently cooperating with DOR.

Table 2-17 Budgets Allocated to Relevant Agencies for Landslide Risk Management (FY2019/20 - FY2023/24)

NRs in million

No.	Institutes, Division, Section/Project	Budget in FY2019/20	Budget in FY2020/21	Budget in FY2021/22	Budget in FY 2022/23	Budget in FY 2023/24
1	DWRI	22,345.0	24,687.5	26,561.2	25,292.1	23,059.6
1a	Water-Induced Disaster Management Division	4549.0	9327.7	10999.5	8683.1	4797.3
1b	Landslide Management Project	103.0	295.5	287.8	21.5	150.3
2	DOFSC	2,585.9	1,807.9	1,557.9	1,687.7	1,863.2
2a	Watershed and Landslide Management Division	144.5	290.0	357.7	416.3	323.6
2b	Landslide Section	1.3	9.6	16.2	17.0	3.5

Source: Created by JICA Survey Team based on publicly available information from MOF and interviews with relevant organizations.

Table 2-18 Implementation Status of Budget Allocated to Relevant Agencies for Landslide Management (FY2019/20 - FY2023/24)

No.	Institutes, Division, Section/Project	Status in FY2019/20	Status in FY2020/21	Status in FY2021/22	Status in FY2022/23	Status in FY2023/24
1	DWRI	58%	76%	90%	*90%	Ongoing
1a	Water-Induced Disaster Management Division	72%	84%	93%	*90%	Ongoing
1b	Landslide Management Section	*90%	*90%	*90%	*90%	Ongoing
2	DOFSC	43%	37%	45%	*45%	Ongoing
2a	Watershed and Landslide Management Division	79%	*82%	86%	*85%	Ongoing
2b	Landslide Section	*100%	*100%	*100%	*100%	Ongoing

Note: "*" means the average of the hearing results from each organization. Because MOF does not release numbers.

Source: Created by JICA Survey Team based on publicly available information from MOF and interviews with relevant organizations.

According to DWRI officials, more than the budget is needed for water-induced disaster management, mainly for flood control (river training works) and landslide management. DWRI's jurisdiction covers medium-sized (perennial) rivers and large-scale landslides (200m x 100m) originating from the Mahabharata and Siwalik mountains. Additionally, 46 rivers other than those mentioned above are under the jurisdiction of DWRI. And 12785.58 ha of land has been reclaimed by constructing 1364.25 km of river embankment works. The total DPR cost for 40 rivers is NRs. 186.15 billion. So, trends have been in decline compared to the allocations budget in this sector for the last five years. There is high demand and requirement, but allocations are only about 30 % of the projected (demand) budget.

According to DOFSC, the annual approved budget must be increased because the demand for landslide treatment and other soil and water conservation measures is very high. Although the budget execution status of DOFSC's overall budget is low, the department's budget mainly consists of the forest conservation budget, which includes the landslide management budget and operating costs. According to FY 2022/23, the approved budget was NRs. 416.3 million, while the demand was NRs. 1145.7 million. This figure shows that the approved budget accounted for only 36.33% of the demand.

The budget execution rate was low in FY2019/20 and FY2020/21 because activities were restricted due to COVID-19. Regarding landslide, the budget utilization rate of DOFSC is over 85%.

In any institution, to increase the budget, which is insufficient to meet demand, it is considered necessary to secure personnel and facilities.

2.3. Summary of Disaster Management

2.3.1. Organizational Structure of Major Organizations Involved in Disaster Management, Budget Allocation/Execution, Project Implementation Status, etc.

The Prime Minister chairs the National Council for DRRM and is the highest authority where the national-level policy and plan are established. Likewise, the Provincial Council for DRRM is formed, which is chaired by the Chief Minister of the Province at the provincial level, where the provincial-level policy and plan are formulated in line with the decision by the National Council for DRRM.

The Minister for the MOHA chairs the National DRRM Executive Committee, which consists of representatives from relevant ministries and other agencies to carry out the policy and plan of the National Council for DRRM. The Province Minister for Internal Affairs and Law chairs the Provincial DRRM Executive Committee. The Chief District Officer chairs the District DRRM Committee, and the Municipality Mayor/ Rural Municipality Chairperson chairs the Local DRRM Committee.

NDRRMA under MOHA is mandated to coordinate and assist in implementing DRRM in Nepal. NDRRMA is responsible for implementing the central level of inter-ministerial coordination, conducting emergency response, relief and recovery, planning recovery and reconstruction, and post-disaster control for the sake of disaster risk management in general.

The Minister of MOHA shall call National DRRM Executive Committee and confirm the scale of the disaster and damage situation. In a severe disaster, the Minister decides on the necessity of international humanitarian assistance. Once the necessity is recognized, the Government of Nepal (Cabinet) appeals for international assistance.

MOHA shall carry out post-disaster rescue and relief operations in cooperation with the military, the Ministry of Defense, the police, and other related organizations such as the Nepal Red Cross Society and NGOs. NDRRMA designates its Risk Reduction, Preparedness, and Recovery Division and National Emergency Operation Center and coordinates the emergency operation with relevant agencies. Accordingly, the Province Minister calls the Province DRRM Executive Committee. Likewise, the Chief District Officer calls the District DRRM Committee and conducts emergency operations. Province, District, and Municipality follow the superior authority's instruction and fulfill the report and request necessary support to them, respectively. In contrast, the superior level authority conducts its operation in response to the report and request from its subordinates, respectively.

NDRRMA is responsible for coordination of implementing pre-disaster preparedness measures, including capacity building, prevention, mitigation, preparedness, and early warning systems.

The relevant agencies technically supporting these activities are as follows.

- Earthquake:
- The National Earthquake Monitoring & Research Centre in the Department of Mines and Geology (DMG), the Ministry of Industry, Commerce and Supply (MOICS) conducts surveys and research for landslides. After the 2015 Gorkha earthquake, DMG conducted geological studies to assess the vulnerability of village areas and recommended relocation for villages with a high risk of earthquakes.
 - The DMG National Earthquake Monitoring & Research Center conducts surveys, research, and knowledge sharing. No specific disaster management measures are being undertaken.
 - The Department of Urban Development and Building Construction (DUDBC), Ministry of Urban Development (MOUD) prepares building codes, guidelines, and rules relating to seismic DRR measures. DUDBC operates urban development projects and a building management information system. These projects and systems include seismic resistance elements.

- Flood:
- DHM of MOEWRI conducts flood forecasting, early warning activities, surveys, research, and knowledge sharing.
 - Water Resources Research and Development Center (WRRDC) is located in the former Disaster Prevention Technical Center (DPTC) building, which used to receive technical cooperation from JICA in conducting research related to water-induced disasters. In August 2021, MOU was signed with the International Center for Water Hazard and Risk Management (ICHARM) to conduct joint research on water resilience and disasters.
 - DWRI of MOEWRI carries out river improvement projects to preserve farmland and irrigation facilities.
- Landslide:
- DWRI conducts research, knowledge sharing, and engineering measures projects for landslides.
 - WRRDC researches landslides and operates a real-time landslide monitoring and warning system.
 - The Landslide Hazard Management Section and Land Use Development Hazard Mitigation Section of DOFSC conduct surveys, research, and knowledge sharing for forest conservation and small-scale landslide DRR projects.
 - The Landslide Hazard Research Division within the DMG Geoscience Department was established in 2016 and conducts scientific surveys, research, and knowledge sharing regarding landslides. The idea is to create a national inventory and landslide risk map, but this has not been realized due to a lack of budget, and the project is looking forward to financial support from development partners. (Assuming 10 million NRs. per province)

The budget allocation, execution, and project implementation status of these institutions are shown in **Table 2-19** and **Table 2-20** as below. NDRRMA's budget is used for rescue, relief, management, investigation, early warning, training, and policymaking for various disasters in Nepal. The DUDBC budget is not included in **Table 2-19** because DRRM budgets cannot be clearly distinguished from the total DUDBC budgets.

**Table 2-19 Budget of Relevant Agencies for Disaster Management
(FY2019/20 - FY2023/24)**

NRs in million

No.	Institutes, Division, Section/Project	Budget in FY2019/20	Budget in FY2020/21	Budget in FY2021/22	Budget in FY2022/23	Budget in FY 2023/24
1	NDRRMA	Not established	249.8	2,368.4	1617.7	188.0
2	DMG	276.9	245.9	371.0	261.6	259.8
2a	Geoscience Survey and Research Division	27.5	20.0	19.9	29.8	29.3
2b	Landslide Research Section	2.5	2.5	2.5	3.2	2.0

Source: Created by JICA Survey Team based on publicly available information from MOF and interviews with relevant organizations.

Table 2-20 Implementation Status of Budget Allocated to Relevant Agencies for Disaster Management (FY2019/20 - FY2023/24)

No.	Institutes, Division, Section/Project	Status in FY2019/20	Status in FY2020/21	Status in FY2021/22	Status in FY2022/23	Status in FY2023/24
1	NDRRMA	Not established	100%	68%	*70%	Ongoing
2	DMG	61%	61%	41%	*61%	Ongoing
2a	Geoscience Survey and Research Division	69%	66%	80%	*80%	Ongoing
2b	Landslide Research Section	100%	100%	100%	*100%	Ongoing

Note: "*" means the average of the hearing results from each organization

Source: Created by JICA Survey Team based on publicly available information from MOF and interviews with relevant organizations.

According to NDRRMA officials, more budget is needed for disaster management. For instance, the NDRRMA with the support of JICA has worked out a budgetary request of around USD 30 million for retrofitting and reconstruction of priority projects in Kathmandu Valley. Similarly, for 13 pilot districts surveyed through a Rapid Visual Survey, funded by WB Group International Development Association (IDA), identifies needs for further investment of USD 300 million. The total cost of the investment in Emergency Preparedness and Response (EPR) is estimated to be NRs. 24,089,700,000, which is equivalent to USD 191.2 million. Similarly, for the Multi-hazard Early Warning System (MHEWS), the cost of USD 515 million is identified.

DMG has conducted many studies regarding landslides from the early days of its establishment. After the Gorkha earthquake in 2015, the rapid geological assessment was conducted to assess the vulnerability of the settlement area in the 18 earthquake-affected districts in two phases in which 475 settlements were at high risk of earthquake-induced geo-hazards, and among them, 193 settlements had been relocated immediately considering the threat of upcoming disasters. DMG also conducted detail assessments in 9 earthquake-affected districts of Central and Eastern Nepal. The investigation was conducted with the objective of categorizing the settlements affected by earthquake into three significant geotechnical risk categories, i.e., safe, controllable, and unsafe. A total of 117 settlements were surveyed, out of which 57 settlements were categorized as unsafe with proper recommendations for relocation. The need for systematic study of landslides was recognized through these circumstances, and the Landslide Research Section was established inside DMG in July 2016. Although DMG has created an inventory for the entire province, landslide risk maps have not yet to be created due to a lack of budget. The preliminary minimum cost is set at NRs.10 million. Still, DMG is seeking a development partner to support the project as it is unlikely to secure funding from MoF due to Nepal's economic recession.

The organizational structure of NDRRMA is shown in **Figure 2-18**. The headquarters has 39 members: 4 executive officers, 29 members of the Policy Planning and Monitoring Division, and six members of the Risk Reduction and Operation Division. 77 local personnel are assigned to the District Emergency Operation Center and 8 to the Humanitarian Support Sites.

DHM and DWRI are the relevant departments for water and landslides under MOEWRI. Under DHM, the Flood Forecasting Division has four staff members and conducts awareness programs on flood forecasting, early warnings, and development to avoid flooding, etc. ICIMOD supports DHM in these activities⁵. The organizational structure of DWRI is shown in **Figure 2-19**. The Water-Induced Disaster Management Division is under DWRI, which has Deputy Director General and three staff members assigned to each of the River Management Section, the Watershed Management and Technology Development Section, and an Emergency Management Project Section. The Landslide Management Section also has three staff members under the Groundwater and Geology Division.

⁵ Enhancing flood early warning systems - SERVIR-HKH (icimod.org)

DOFSC has the Landslide Hazard Management Section and the Land Use Hazard Mitigation Section, with five and three staff members, respectively.

There is the National Earthquake Observation Research Center under DMG with nine staff members and the Landslide Research Section with two staff members in the Department of Geological Sciences.

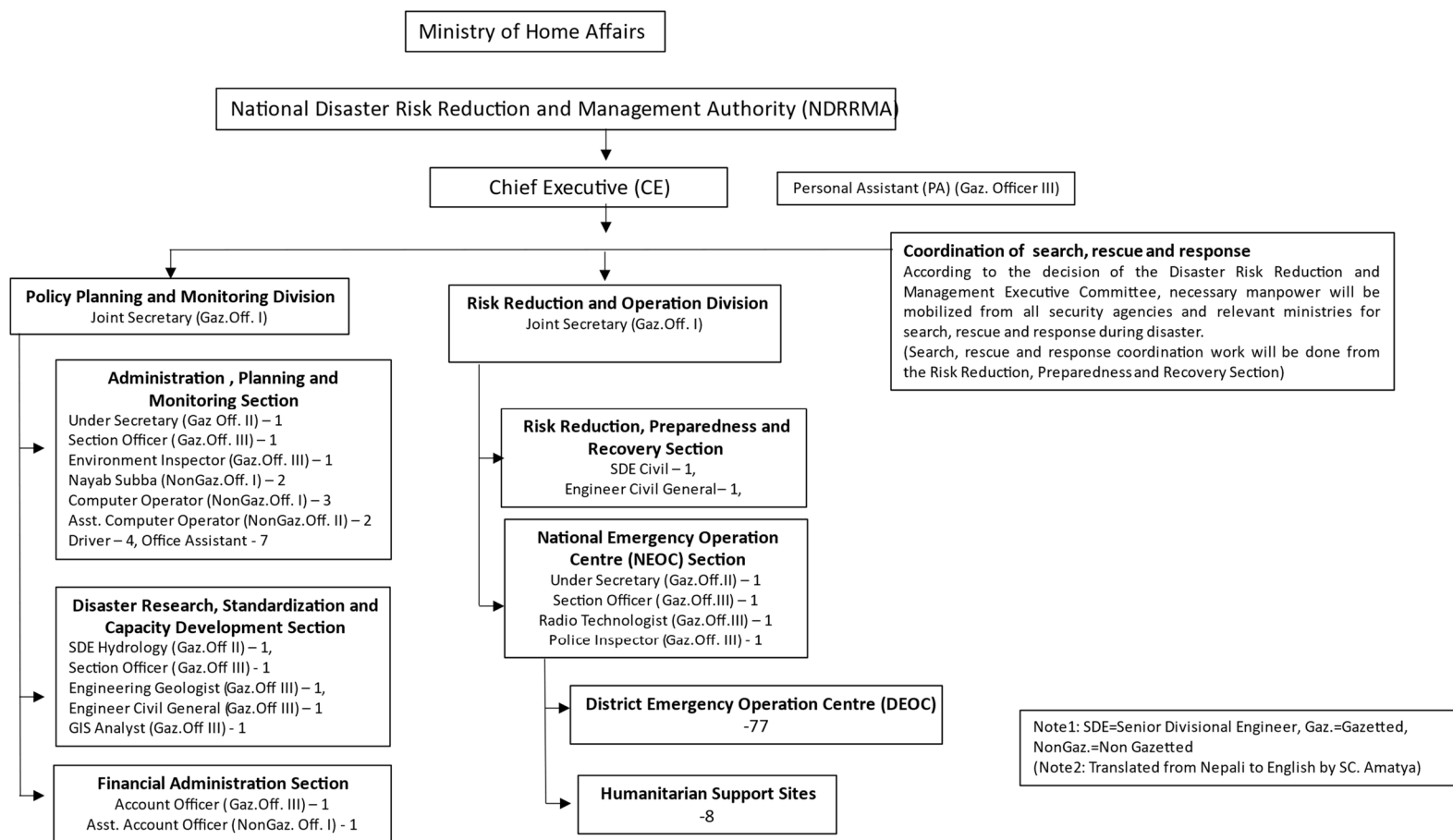
According to interviews with NDRRMA in January 2024, there is a plan to incorporate DHM's meteorological data and road information into the GIS disaster database as national disaster information management data and conduct comprehensive risk assessments considering climate change. The Special Committee on Disaster Risk Assessment task force intends to start discussions on risk assessment methods. For this reason, the government wants to strengthen cooperation with various ministries and agencies.

2.3.2. Organizational Structure of Major Entities Involved in Landslide Management, Budget Allocation/Execution, Project Implementation Status, etc.

The agency with central responsibility for landslide management is NDRRMA. The implementing agencies for landslide management projects are DWRI and DOFSC, and DOR for road landslides. Their budget size and the situations of execution are shown in **Table 2-18**. The details for DOR will be explained in **Chapter.3.2**.

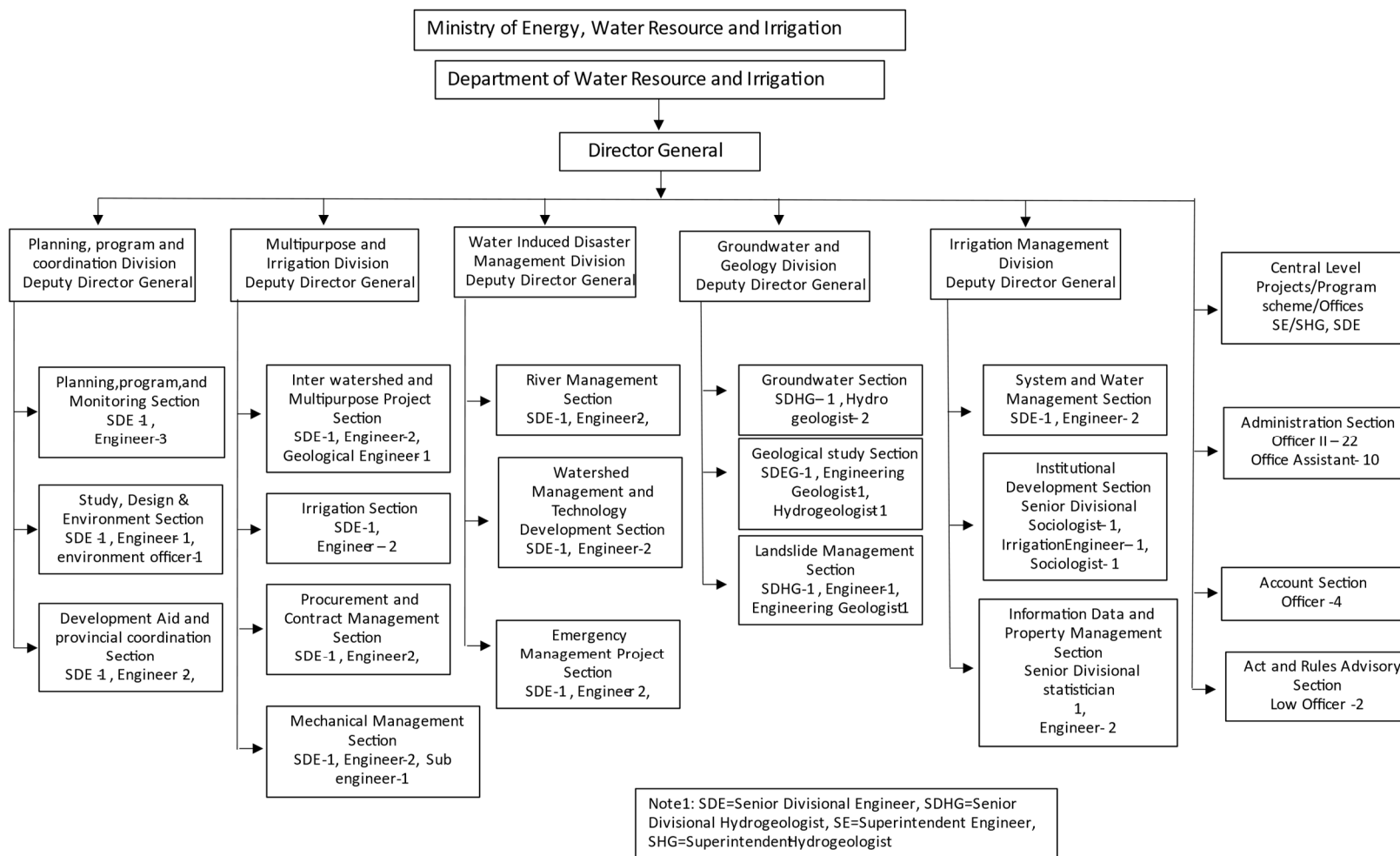
NDRRMA has established a post-event coordination system from the central government to the local regions. Regarding proactive measures, especially for flood forecasting and warnings, collaboration is progressing, and NDRRMA utilizes the warnings issued by DHM, and has achieved outcomes in saving human lives. Prediction and warning of landslides are complex, and although WRRDC is conducting real-time monitoring of landslides in three sites in Katmandu, it is still not widely monitored.

DWRI is responsible for preparing structures in advance of heavy rain and landslides as the central government, while DOR and local governments are also responsible for NHs. DWRI and landslide prevention measures must be improved as personnel are not deployed to rural areas. DWRI's participation in road geohazards risk reduction projects could be more robust.



Source: NDRMMA

Figure 2-18 Organizational Structure of NDRMMA



Source: DWRI

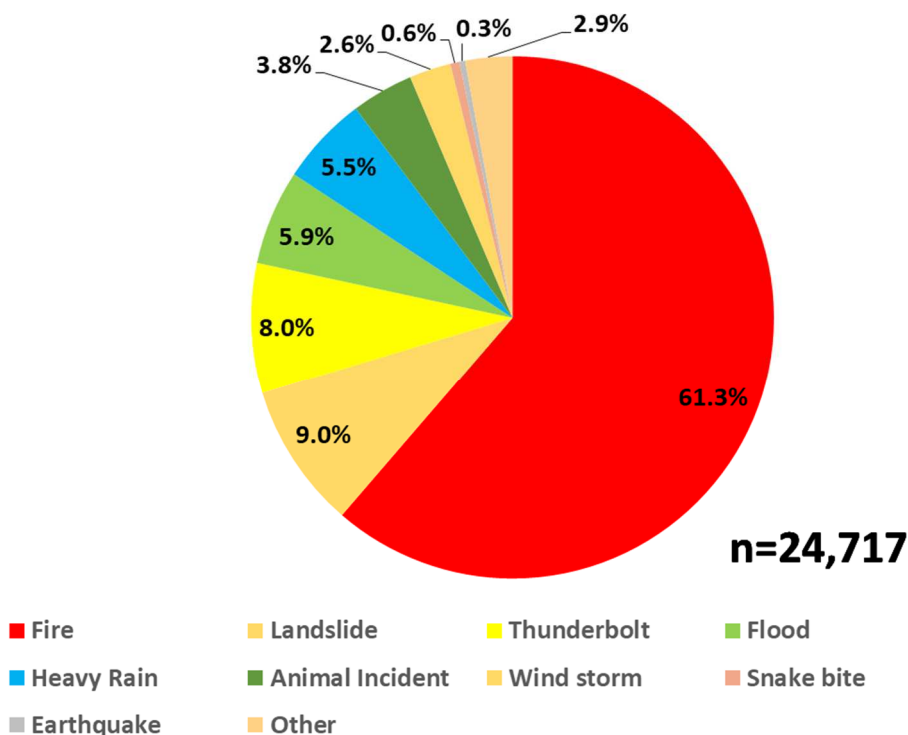
Figure 2-19 Organizational Structure of DWRI

2.4. Summary of Disaster Occurrence and Risks

2.4.1. Occurrence and Risk by Disaster Type

Figure 2-20, Figure 2-21, and Figure 2-22 show the percentages of occurrences, casualties, and the size of disaster damage by disaster type from 2013 to 2022 based on the MOHA) data. Nepal is prone to disasters such as earthquakes, floods, and landslides (Not limited to roadside damage) due to its geographical features: 24,717 disasters occurred in a decade from 2013 to 2022, causing total damages of NRs 39.4 billion (approx. JPY41.2 billion) and 13,262 fatalities. The number of landslides, floods, and heavy rain occurrences (including those of sectors other than the road sector) during the same period was 5,041, causing the damage cost of NRs19.7 billion (approx. JPY20.7 billion) and 2,017 deaths. Landslides accounted for the second largest number of events after fires, with 2,228 (9.0%), followed by thunderbolts with 1,988 (8.0%), floods with 1,452 (5.9%), and heavy rains with 1,361 (5.5%).

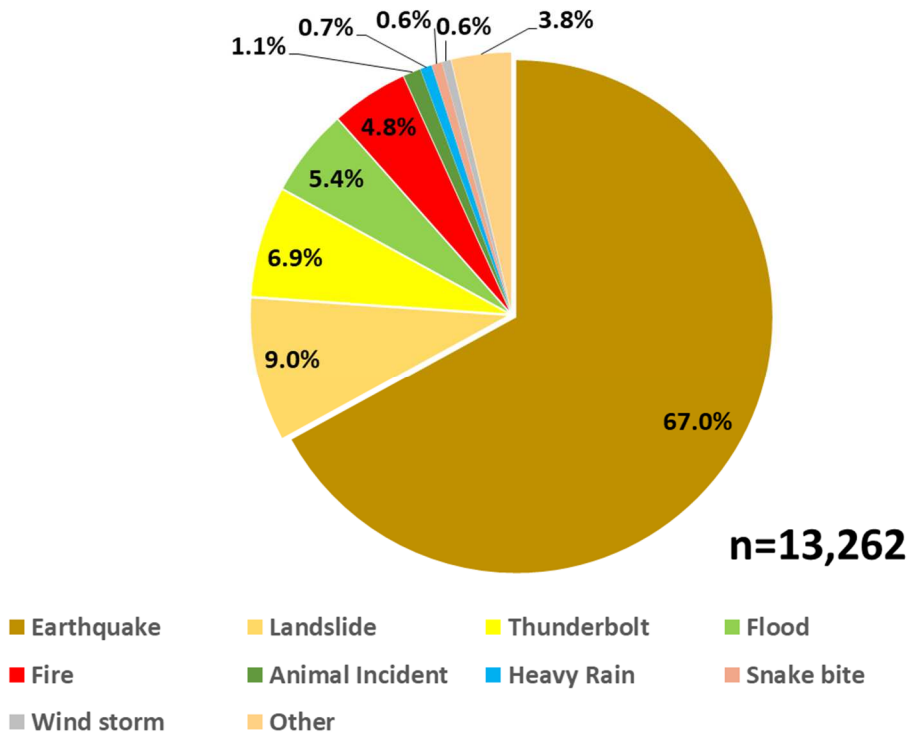
Regarding the earthquake in 2015, publicly available data by MOHA includes the number of events as 70 and the number of deaths as 8,891. However, the data on the total amount of damage on a monetary basis is not available. According to WB, the damage caused by the Nepal earthquake is estimated at \$7.1 billion (about NRs 930 billion)⁶.



Source: Created by JICA Survey Team Based on Publicly Available Data from MOHA.

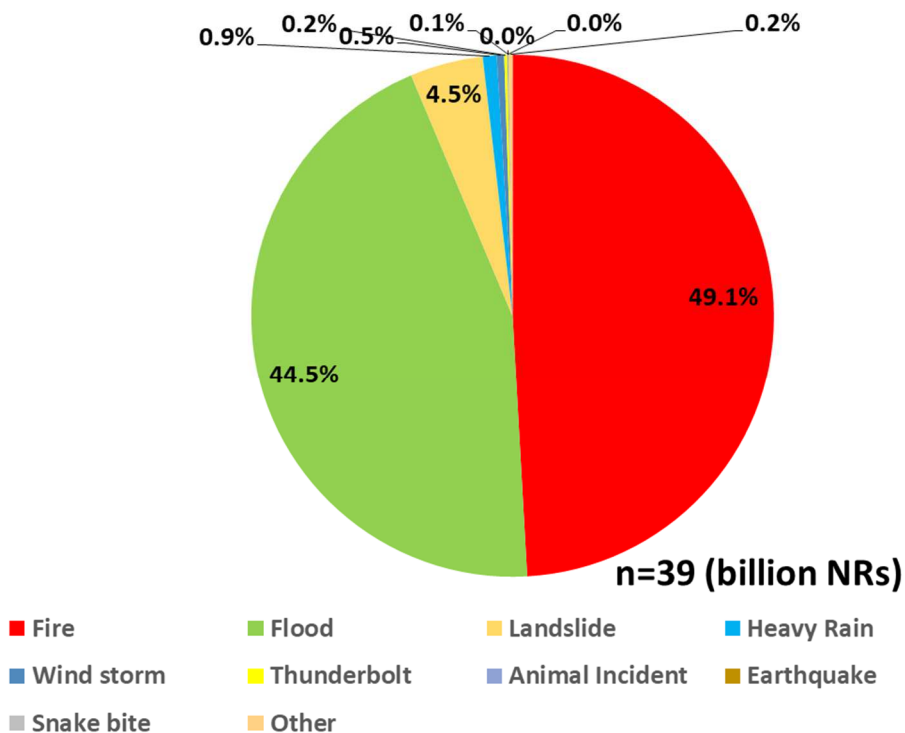
Figure 2-20 Percentage of the Number of Disasters Occurring in 10 Years by Disaster Type (2013-2022)

⁶ <https://blogs.worldbank.org/endpo-vertyinsouthasia/nepalearthquakes-2015-one-year>



Source: Created by JICA Survey Team Based on Publicly Available Data from MOHA.

Figure 2-21 Percentage of Fatalities in 10 Years by Disaster Type (2013-2022)



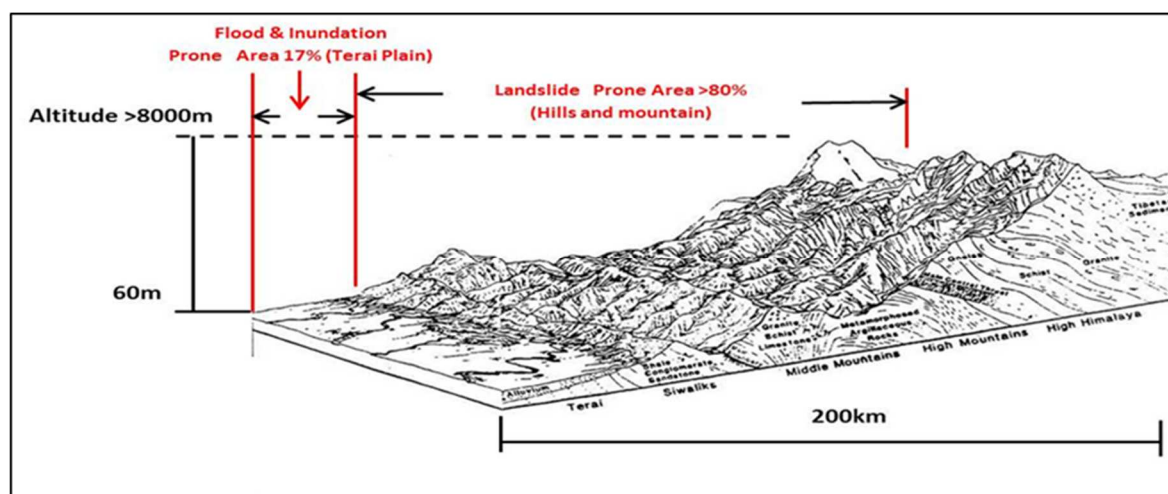
Note: The above figure does not include the amount of damage caused by the 2015 Nepal earthquake.

Source: Created by JICA Survey Team Based on Publicly Available Data from MOHA.

Figure 2-22 Percentage of Damage in 10 Years by Disaster Type (2013-2022)

According to the literature introduced below⁷, economic losses from disasters in Nepal from 1971 to 2017 for 47 years are estimated to have reached 4% of GDP. Considering the size of financial loss caused by the disaster each year, DRR is one of the country's top priorities.

Disasters in Nepal occur mostly in hilly and mountainous areas, which account for more than 80% of the country's total land area. Landslides frequently occur due to steep slopes in hilly areas and unstable geology caused by active crustal movement and triggered by heavy rain. In the southern plains, which consist of 17% of the area of the total Nepal land, there is a high incidence of flooding caused by overflows from rivers and inundation due to the poor drainage of rivers. These water and landslides threaten the country's development by frequently damaging cities, national infrastructure such as roads and bridges, hydropower, irrigation canals, and agricultural land (see **Figure 2-23**).



Source: Physiographic Region of Nepal (Amartya SC and Joshi J., 2015)

Figure 2-23 Frequency Status of Disaster Types in Nepal

The Siwalik Hills, a hilly area bordering the southernmost plains, mainly comprise unconsolidated conglomerates, sandstones, and mudstones. The geology in this area is fragile and prone to erosion, and the risk of landslides is relatively high.

Human-caused disasters have also resulted from expanding residential and agricultural lands into slopes with disaster risks, deforestation, and the dumping of construction debris into valleys during local government and community road construction.

2.4.2. Analysis of Disaster Types to be Prioritized According to Economic Loss Risk

As shown in **Figures 2-20**, landslide events have the second highest number of occurrences and fatalities compared to other types of disasters over the past ten years. Regarding the amount of damage, although MOHA data does not include data on the major earthquake in 2015, landslides are the third highest. The fatalities and economic losses from landslides and floods from 2009/10 to 2022/23 (14 years) were analyzed based on publicly available data from MOHA and shown in **Table 2-21**, **Figure 2-24**, and **Figure 2-25**. According to these figures, it can be seen that although both fatalities and economic losses from floods have been decreasing over the years, both the number of fatalities and economic losses from landslides have been on the rise. Therefore, landslides are a disaster that should be addressed as a priority.

Landslides have caused damage to residential areas, farmland, roads, and other infrastructure. According to Oxford Policy Management 2021's "Political economy of 2020 landslides, road construction and DRR in Nepal," 448 landslide events occurred across Nepal in 2020, resulting in 297 deaths. Of these, 205 (61%) of the 337-landslide event sites that can be confirmed on Google Earth include damage to roads.

⁷ Adhikari, S., & Adhikari, D. (2019). An account of Nepal disasters and economic fallout, [Research Report] Project research and management associates, HAL archives-ouvertes.fr, HAL-01995386, 2019. <https://hal.archives-ouvertes.fr/hal-01995386/document>

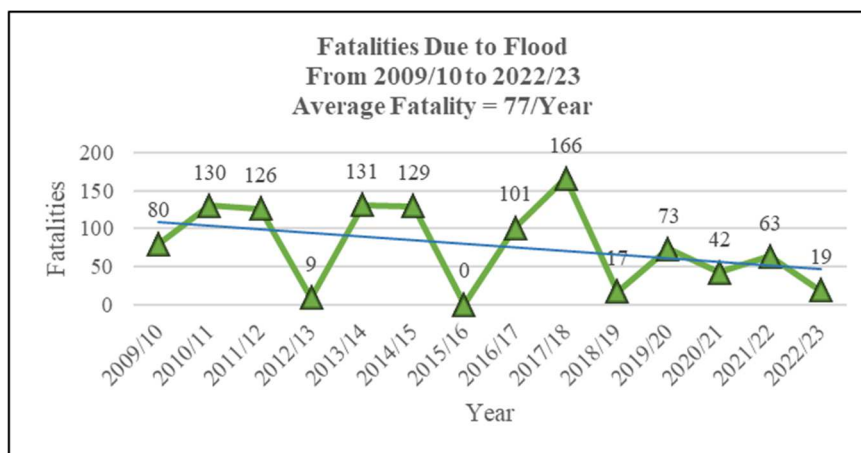
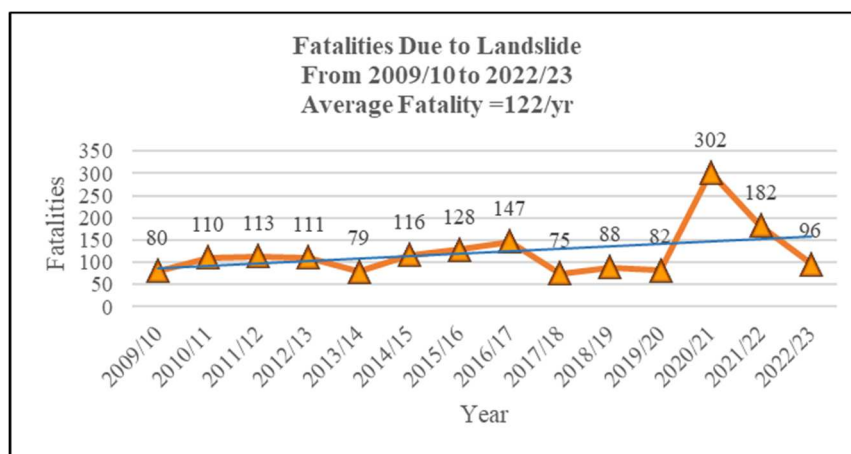
Among the 205 damaged sites on the streets, 179 (87%) events occurred on roads constructed within the past 12 years. The results of this study suggest that most landslide events involve roads and that slope excavation, embankment, and soil disposal due to road construction/widening and new land use along roads are triggers of further landslide events.

Regarding floods, the number of fatalities and economic losses has been decreasing despite population growth, and increasing property values can be evaluated by government flood forecasting, early warnings, and awareness programs for development to avoid flood risks. DHM began providing weather and flood advisory services in 2016 having been preparing since the 2000s. NDRRMA's National Emergency Operation Center and specific individuals will take action to evacuate once they receive the information. Local radio stations also cooperate by reporting warning information. Furthermore, sustainable development measures such as collaboration with local governments and the development of evacuation centers are considered necessary. DWRI manages 46 significant rivers and carries out river training projects to preserve farmland and villages, contributing to the mitigation of disaster damage.

Table 2-21 Landslide and Flood of Fatalities and Economic Losses

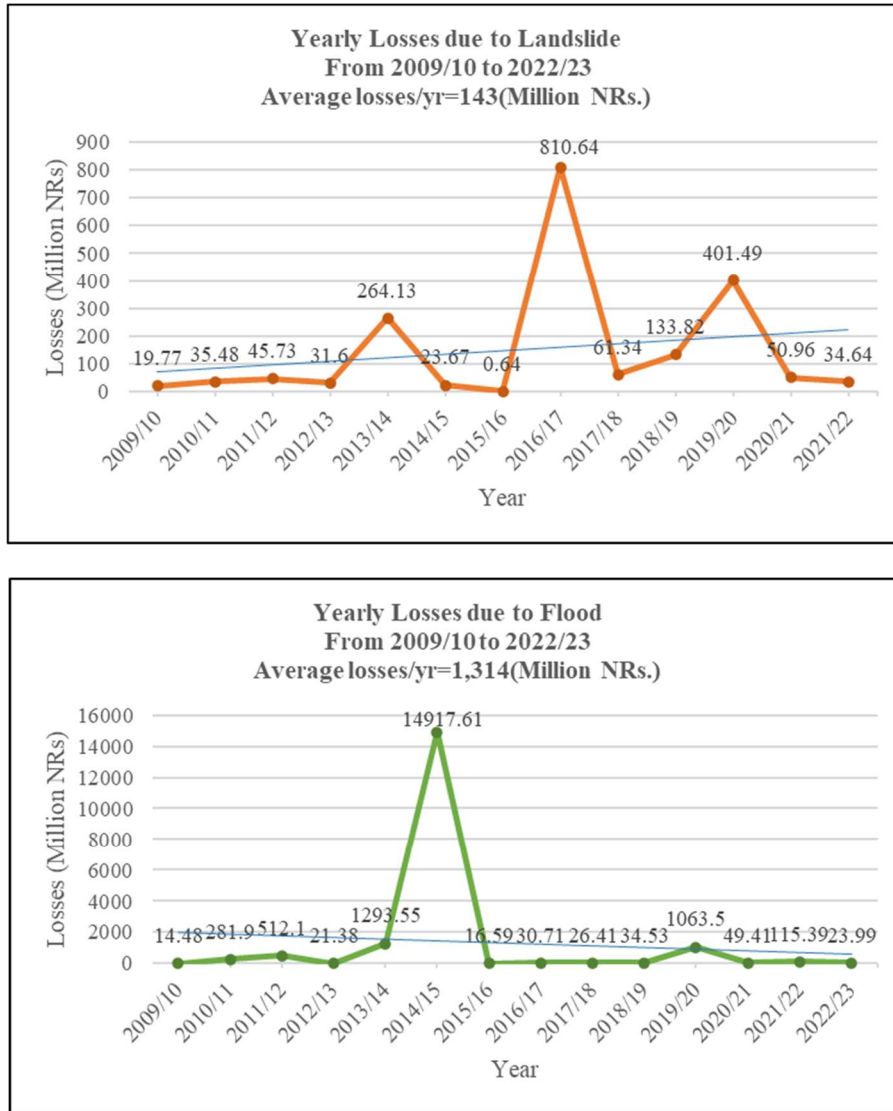
Disaster Type	Average Annual Number of Deaths and Trend of Annual Increase or Decrease from FY2009/10 to 2022/23 (14 years)	Average Annual Economic Losses and Trend of Annual Increase or Decrease from 2009/10 to FY2022/23 (14 years)
Landslide	122 persons/year: Increasing trend	NRs.143 million/year: Increasing trend
Flood	77 persons/year: Decreasing trend	NRs.1,314million/year: Decreasing trend

Source: Created by JICA Survey Team Based on Publicly Available Data from MOHA.



Source: Created by JICA Survey Team Based on Publicly Available Information from MOHA.

Figure 2-24 Fatalities Due to Landslides and Floods



Note: FY2009/10 to FY2022/23 (14 years)

Source: Created by JICA Survey Team Based on Publicly Available Information from MOHA.

Figure 2-25 Economic Losses Due to Landslides and Floods

Chapter 3. Current Issues on Road Geohazards and Landslides

3.1. Summary of Road Geohazards

3.1.1. Causes and Classification of Road Geohazards on NHs

(1) Road Geohazards on NHs

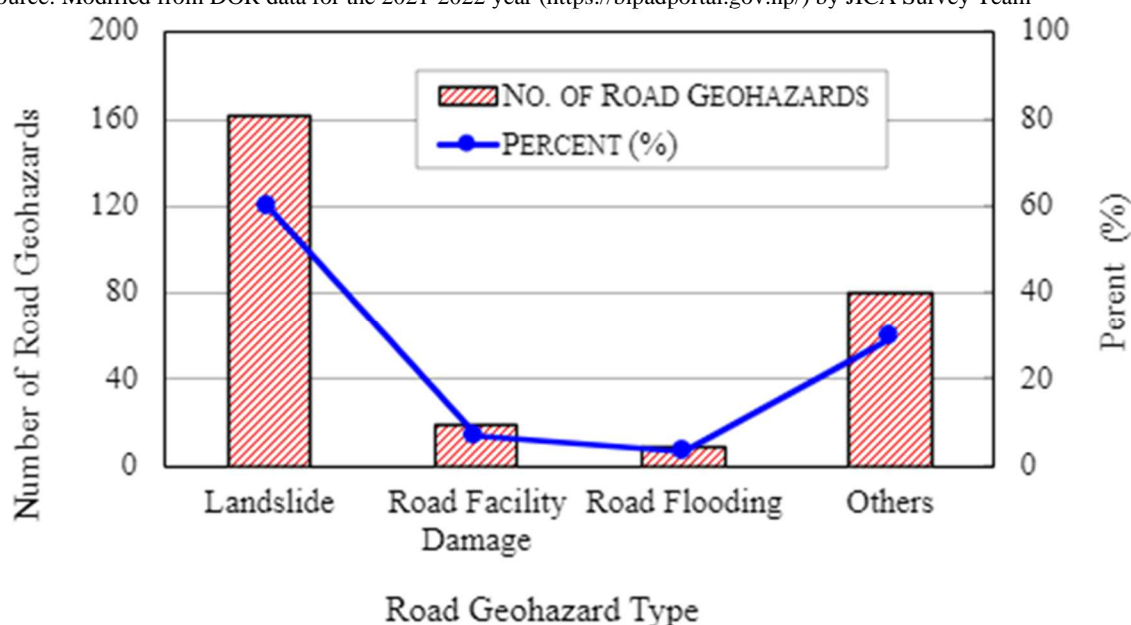
DOR's division road offices (DROs) perform emergency maintenance when a road blockage occurs due to a road geohazard. They are responsible for submitting a road blockage report to the central office of DOR. Based on this report, the DOR Maintenance Office updates the database regarding sites (highway names, distance markers), geohazard types, and road closure times.

The number of road closures by road geohazard type for the two years (2021-2022) in NHs is shown in **Table 3-1** and **Figure 3-1**.

Table 3-1 Classification of Road Geohazards and Their Causes

No.	Road Geohazard Type	Cause and Situation of Road Geohazards	No. of Events
1	Road Landslide	<ul style="list-style-type: none"> · Collapse, slide, flow, etc., caused by heavy rainfall, etc. · Road carriageway collapse and fill slope collapse due to river erosion, etc. · Collapse and road carriageway collapse due to sediment discharge and surface water flow. 	162
2	Road Facility Damage	<ul style="list-style-type: none"> · Culverts and other road structures damaged by sediment discharge of road landslides. · Bridge collapse due to flood and road landslides. · Pier settlement and bridge collapse due to improper construction. 	19
3	Road Flooding	<ul style="list-style-type: none"> · Road flooding due to continuous rainfall or river flooding. 	9
4	Others	<ul style="list-style-type: none"> · Cases with no reference to the classification of road hazards and their causes. · Cases due to factors other than the above (e.g., damage by vehicle hit). 	80

Source: Modified from DOR data for the 2021-2022 year (<https://bipadportal.gov.np/>) by JICA Survey Team



Source: Modified from DOR Data for the 2021-2022 year (<http://bipadportal.gov.np/>) by JICA Survey Team

Figure 3-1 Number of Events of Road Geohazards on NHs (2021-2022)

As shown in **Table 3-1** and **Figure 3-1** above, road landslides are the most common type of road hazard, and road facility damage and road flooding have also occurred. On the other hand, since road landslide events have not been clarified to their further detailed classification, occurrence causes, and the situation of each event from DOR database, the following section analyzes the situations based on the results of the site survey.

Among the road facility damages listed in the above-stated table and figure, five bridge collapses were identified. The probable causes of the collapse of such bridges were flooding in two sites, road landslides in one site, pier settlement in one site, and improper construction during construction in one site. In order to understand the causes of bridge collapses in detail, the bridge damages reported by DOR during mid-April 2021 and early April 2022 were examined and summarized in **Table 3-2**. The data and information were also collected from newspapers online and reviewed to analyze the causes of bridge damage and collapse.

Table 3-2 Bridge Damaged between Mid-April 2021 and Early April 2022

Category of Bridge Collapse/Damage		National Highway			Local Road	National Highway+Local Road	
		No. of Bridge Collapse	Percent (%)	National Highway No. (No. of bridge collapse)	No. of Bridge Collapse	No. of Bridge Collapse	Percent (%)
Bridge collapse/damage due to flooding	Under construction	1	8%	NH55	5	6	21%
	Constructed	0	0%		0	0	0%
	Subtotal	1	8%		5	6	21%
Bridge collapse/damage due to foundation scouring	Under construction	1	8%	NH05	1	2	7%
	Constructed	2	15%	NH01	2	4	14%
	Subtotal	3	23%		3	6	21%
Approach road washed away due to flooding	Under construction	4	31%	NH03, NH05(2), NH53	1	5	17%
	Constructed	3	23%	NH05, NH34, HN53	0	3	10%
	Subtotal	7	54%		1	8	28%
Bridge collapse/damage due to debris flow	Under construction	0	0%		0	0	0%
	Constructed	2	15%	NH25(2)	7	9	31%
	Subtotal	2	15%		7	9	31%
Total	Under construction	6	46%		7	13	45%
	Constructed	7	54%		9	16	55%
	Subtotal	13	100%		16	29	100%

Source: Modified from DOR data by the JICA Survey Team

The causes of bridge damage in Nepal are considered as listed below:

Design:

- Unexpected flood flow rate
- Lack of adequate probabilistic hydrological and rainfall intensity data for flood discharge calculations for the catchment concerned.
- Insufficient scour protection of pier foundations and insufficient erosion protection of abutments.
- Hydraulically inadequate arrangement of piers and abutments.
- Short bridge length relative to flood bed.
- Missing identification of sources of debris flow occurrence in the bridge catchment.
- Lack of adequate probabilistic hydrological and rainfall intensity data for debris flow discharge calculations for the catchment concerned.

Construction skills and methods:

- Inadequate temporary diversion discharge facilities during construction.

Maintenance:

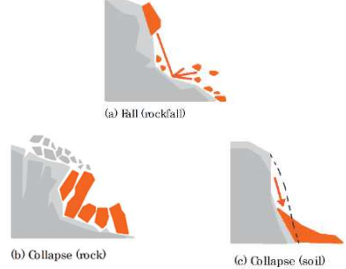
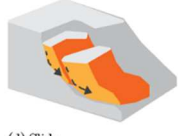


- Flooding erosion of bridge approach roads due to chronological riverbed rise.

(2) Classification and Causes of Road Landslides

Road landslides are classified by simplified from the classification method in the Road Landslide Risk Management Handbook (GFDRR, 2020), as shown in **Table 3-3** and **Figure 3-2**, into four types: collapse, slide, flow, and carriageway collapse.

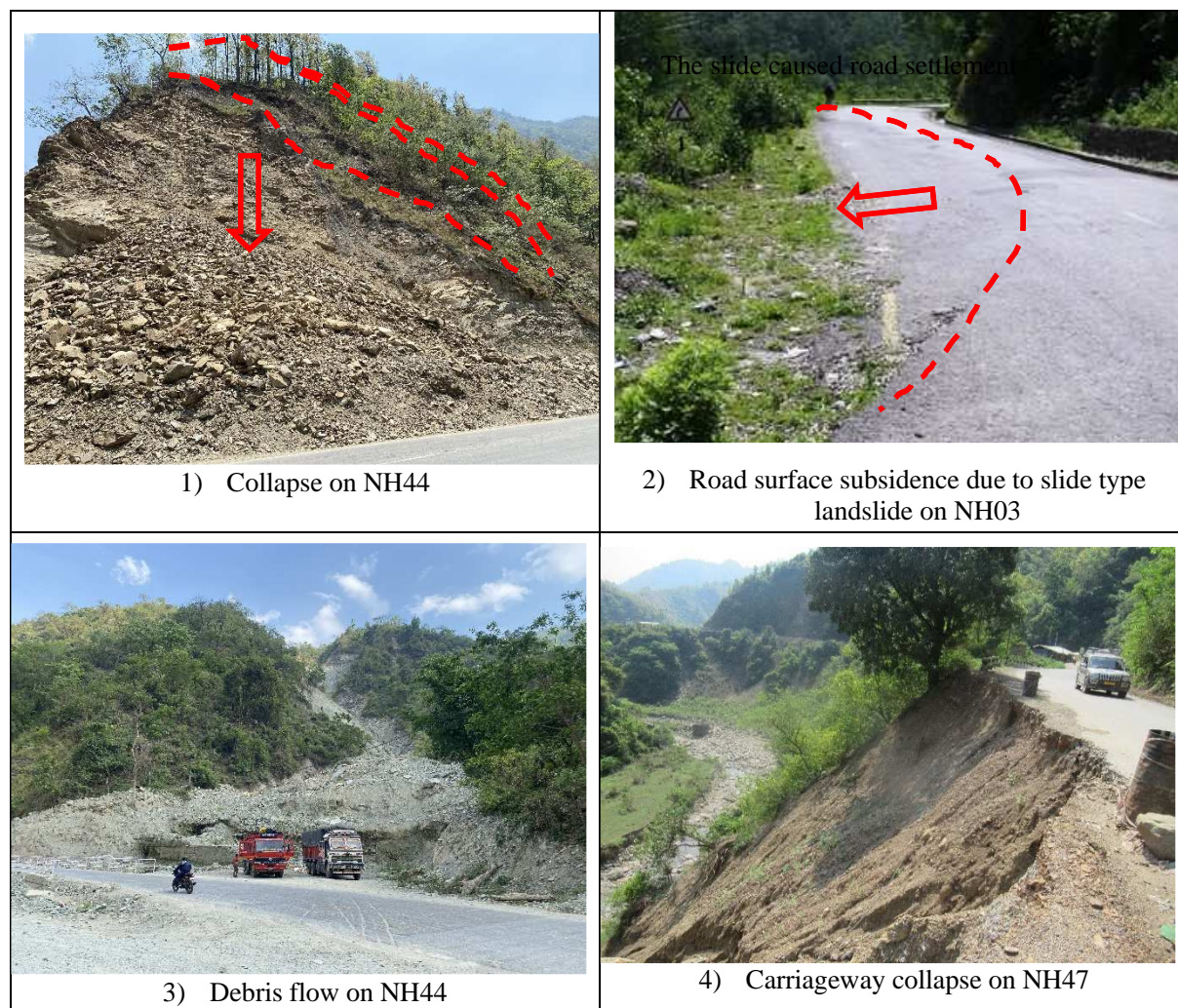
In WB GFDRR 2020, it is classified into (a) Fall (rockfall), (b) Collapse (rock), (c) Collapse (soil), (d) Slide, (e) Flow, and (f) erosion. In this survey, (a) Fall (rockfall), (b) Collapse (rockfall), and (c) Collapse (soil) are unified as a category of Collapse because they often occur in the same place (slope) in combination or gradually. Regarding (f) erosion, the problem is that it causes damage to the road surface as a result. Road surface damage is caused not only by erosion but also by a combination of Collapse and sliding from the road to the valley side, so road collapse (road carriageway collapse) is adopted as the term for the landslide type.

Table 3-3 Classification and Definition of Road Landslides

No.	Type of Road Landslide	Definition and Description	Schematic Image WB GFDRR 2020 classification
1	Collapse	<p>Defined as a downward movement of a mass of soil or rock, which occurs on steep slopes of soils, mainly associated with surficial deposits, or on rock slopes due to fracturing and jointing within the rock mass.</p> <p>Occurs rapidly and suddenly in a short time, mainly due to heavy rainfall.</p> <p>Occurs on a steeper slope on a smaller scale compared with a slide.</p>	 <p>(a) Fall (rockfall)</p> <p>(b) Collapse (rock)</p> <p>(c) Collapse (soil)</p>
2	Slide	<p>Defined as a downward slow movement of a mass of soil or rock on one or more slip surfaces deep in the ground due to heavy rainfall, earthquakes, etc.</p> <p>Has a relatively extensive and peculiar topography - slide landforms in areas with specific geological structures and is often triggered by the effects of groundwater.</p>	 <p>(d) Slide</p>
3	Flow	<p>Defined as a downhill flow movement of a mass of soil and rock accumulated in mountainous streams under the influence of surface water flow.</p> <p>Has a high potential to occur in catchments with numerous collapses, often associated with continuous or heavy rainfalls.</p>	 <p>(e) Flow</p>
4	Carriageway Collapse	<p>Defined as the partial or complete collapse of a road body due to river erosion on the valley side of the road.</p> <p>It can also be caused by sediment discharge and surface water flow from the slope above the road or an riverside slope's collapse due to the slope toe's scouring⁸.</p>	 <p>(f) Erosion (river erosion)</p>

Source: Modified from Road Geohazard Risk Management Handbook (GFDRR, 2020), by JICA Survey Team

⁸ Slope toe scouring is when the lower end of the riverside slope of a road is eroded by running water during a river flood.



Source: JICA Survey Team

Figure 3-2 Examples of 1) Collapse, 2) Slide, 3) Flow, and 4) Carriageway Collapse Occurred on the Target NHs

To clarify the causes of road landslides, such as collapses, slides, and debris flows on the target NHs, and to prioritize road landslide sites at high risk of occurrence, the field surveys were conducted according to the following procedure:

- 1) The field surveys were focused on the road landslide sites listed by DOR and its Division Road Offices (DROs) and conducted by local subcontractors using the modified Site Definition Sheets in Roadside Geotechnical Problems (DOR 2007) to collect road landslide data at sites.
- 2) Google Earth was used to identify the history of the road landslides history and to check the extent/range of collapses, slides, and debris flow source areas, thereby revising and adding the data from the field survey.
- 3) Similarly, topographic maps formulated from 2.5m mesh 3D point cloud data of AW3D were used for topographical interpretation to identify road landslides' extent and topographical characteristics.
- 4) Data on the availability of existing road landslide information, road closure duration/date due to road landslides, and the planning and implementation of emergency and permanent engineering measures were collected through interviews with DROs.

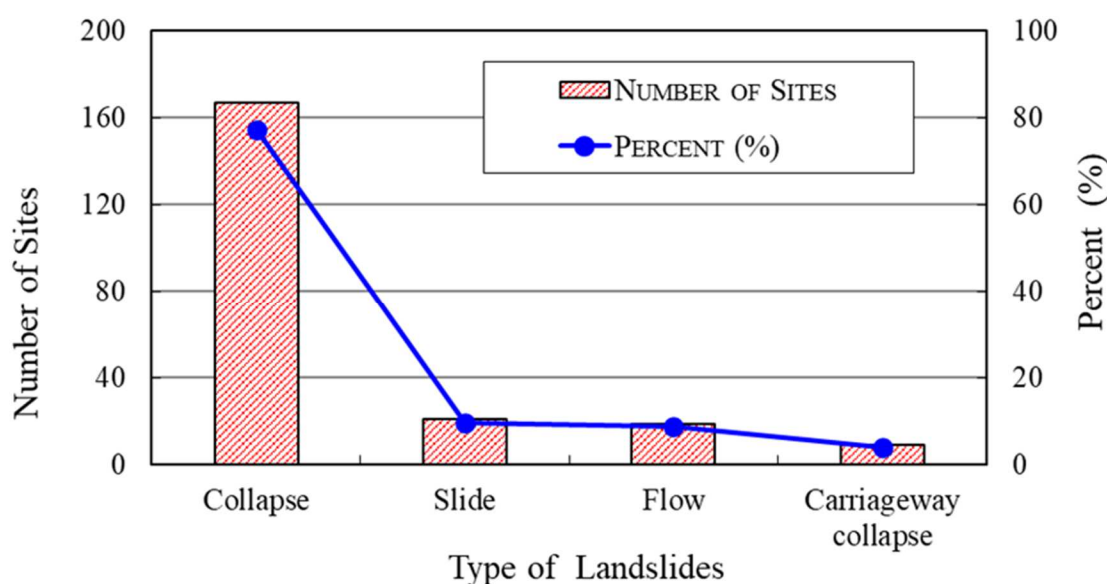
As shown in **Table 3-4**, 216 road landslide sites were surveyed on the selected 10 target NH sections. Collapses were the most common and main type of road landslides, accounting for about 80% of the total, and slides, flows, and carriageway collapses also occurred (**Table 3-4, Figure 3-3**).

Table 3-4 Road Landslide Types of Survey Sites

No.	National Highway No.	Type of Landslides				Subtotal
		Collapse	Slide	Flow	Carriageway Collapse	
1	NH02	3	1	1	0	5
2	NH03 (KH)	20	0	1	1	22
3	NH03 (PB)	28	4	4	4	40
4	NH08	11	0	1	0	12
5	NH25	13	0	1	1	15
6	NH34	25	5	4	0	34
7	NH37	9	4	0	0	13
8	NH41	8	2	0	0	10
9	NH44	7	0	2	2	11
10	NH47	43	5	5	1	54
Subtotal		167	21	19	9	216

Notes: NH03(KH): Khurkot-Halesi Section of NH03, NH03(PB); Pokhara-Baglung Section of NH03

Source: JICA Survey Team



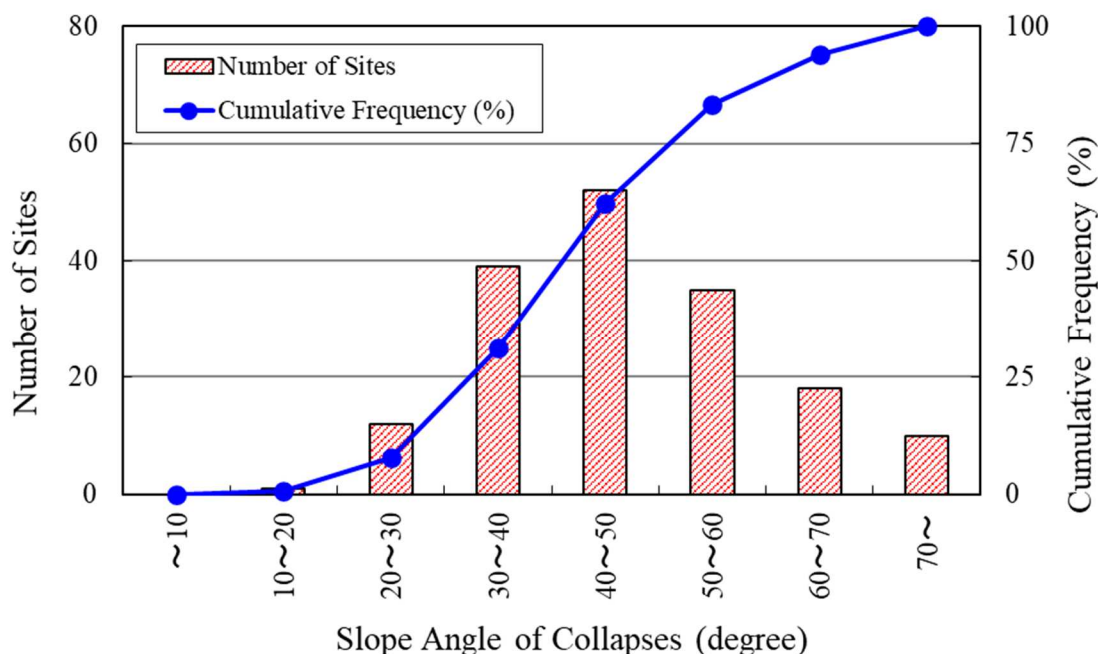
Source: JICA Survey Team

Figure 3-3 Landslide Types of the Field Survey Sites

The main causes of road landslides are summarized based on the results of field surveys at 216 sites and interviews with DROs as follows:

- 1) The target NHs were mainly constructed on steep slopes by excavation on the mountainsides. Collapse frequently occurred on the destabilized slopes of colluvial soils or highly fractured/weathered rocks.
- 2) The cut slopes were steeper than standard slopes related to the slope geological conditions, and therefore, collapses have occurred. Collapses were mainly concentrated on slopes with a slope gradient of 30-70 degrees (**Figure 3-4**).
- 3) Engineering measures works have not been constructed in more than 70% of the inspected sites. Moreover, the constructed engineering measures works are mainly emergency measures, such as masonry and gabion walls, at risk of being damaged again.

- 4) 16% of the reviewed road landslide sites have a history of sediment disposal and domestic waste discharge from the back slopes and valleys above the road (**Table 3-5**). These sediments and domestic waste could be discharged onto the road in the future during heavy rainfall.
- 5) Debris flows have occurred due to collapses in mountain streams crossing the roads, and the road facilities across the roads have low capacity to discharge debris flows. Some parts of major arterial roads were blocked for several days due to the debris flows deposited on the road sections and subsequent removal of the sediment.



Source: JICA Survey Team

Figure 3-4 Frequency Distribution of Slope Angle of the Field Survey Sites of Collapses

Table 3-5 Status of Sediment Disposal on the Slope above the Field Survey Sites

Sediment Disposal on the Slope above the Road	Number of Field Survey Sites for Landslide	Percent (%)
Presence	35	16
Absence	181	84
Total	216	100

Source: JICA Survey Team

3.1.2. Landslide Data on Target NHs

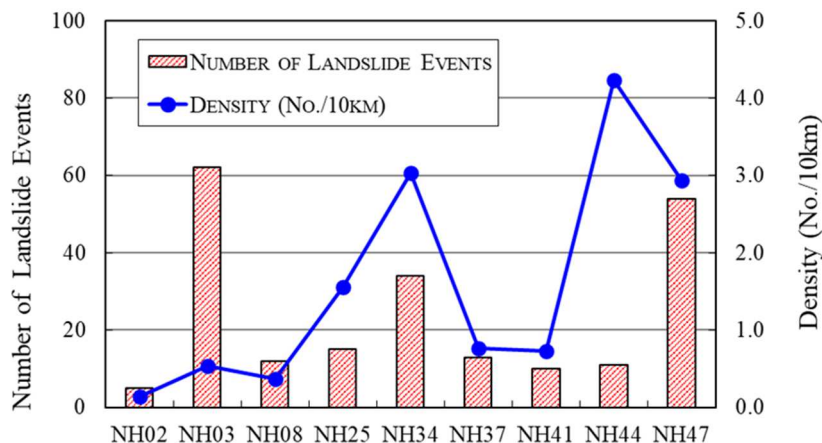
Road landslides are mostly concentrated in the rainy season (June to September) on NHs, and about 90% of road landslides occur on road-cut slopes on the mountainous sides (collapses) and on slopes above roads (slides and debris flows).

The number of road landslides per extension distance on the target NHs varies for each road. As shown in **Figure 3-5**, the density of road landslides on NH34, NH44, and NH47 were higher than others. The possible reasons can be raised as below:

- NH34: The road passes through an area with relatively large annual precipitation, and erosion on the slopes of the road river side has progressed.
- NH44: Collapses associated with new cuttings due to road expansion have occurred.

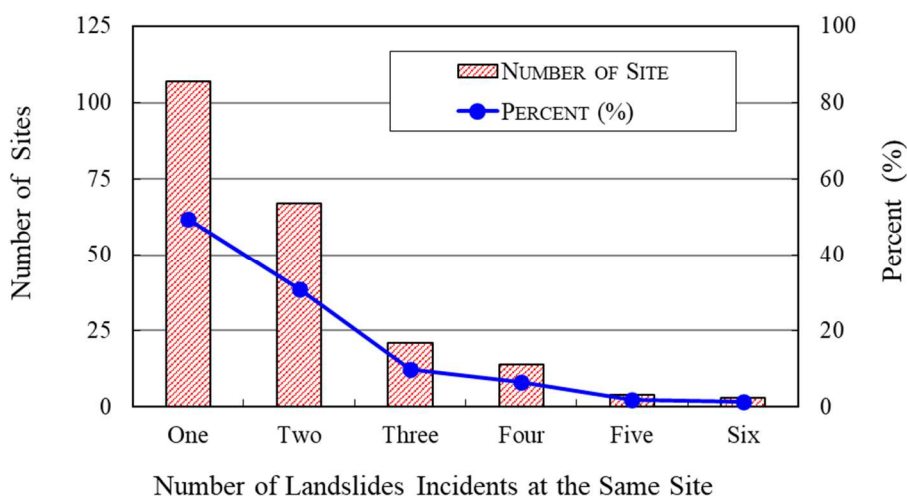
- NH47: The road runs roughly in a north-south direction within Sub-Himalaya, which is bounded by the Main Central Thrust (MCT) in the north and the Main Boundary Thrust (MBT) in the south and is composed of Precambrian to Paleozoic muddy and sandy sedimentary rocks. The geology along the road is particularly vulnerable to landslides.

In addition, these road landslides were found to occur repeatedly at the same site two to six times at surveyed sites (Figure 3-6). The reason for the repeated damage is that no permanent engineering measures have been constructed.



Source: JICA Survey Team (Identified number of landslide events by checking Google Earth satellite images for 20 years since 1992)

Figure 3-5 Density of Road Landslide Events (Number of Events per 10km during 20 Years from 1992)



Source: JICA Survey Team (Identified number of landslide events by checking Google Earth satellite images for 20 years since 1992)

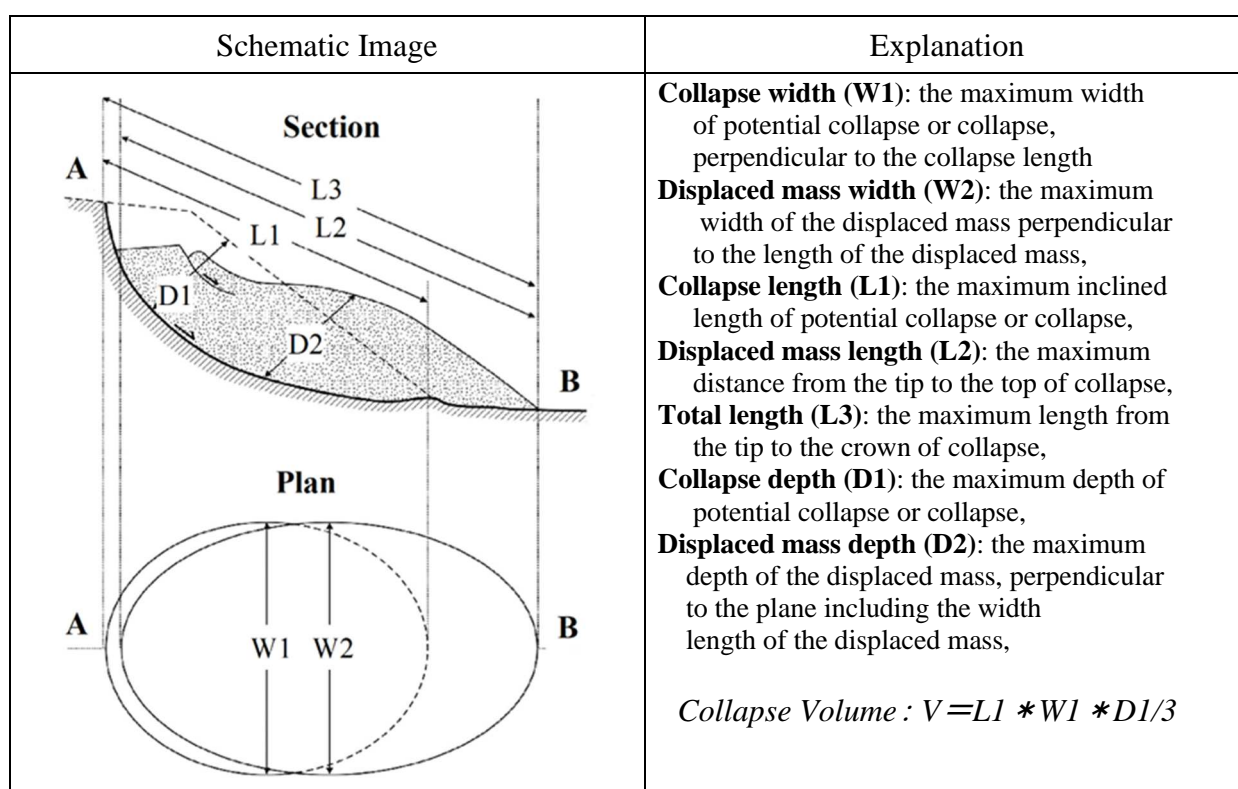
Figure 3-6 Frequency Distribution of Number of Road Landslide Events at the Same Site of the Field Survey Sites during 20 Years from 1992

Collapses are the most common type of road landslide on the target NHs (Figure 3-3 above). The time required to remove the collapsed sediments from the road depends on the size of the collapses, the type and capacity of the backhoe, and the distance between the landslide site and the standby site of the heavy equipment. Of these items the size/scale of the collapsed mass volume (collapse volume) is estimated by visual field measurements and distance meter measurements, using the following formula (see Figure 3-7):

$$\text{Collapse volume, } V = LI(m) (\text{collapse length}) \times WI(m) (\text{collapse width}) \times DI(m) (\text{collapse depth})/3$$

Further, as shown in **Table 3-6**, the scale of the collapsed mass volume is classified, in terms of the impact on road closure and the technical issues of engineering measures design, into four levels as a classification unique to this survey based on the following definitions:

- *Small scale (collapsed mass volume <2,000m³): its scale is defined as 50m (W1) x 50m (L1) x 1-3m (D1) or smaller, and its collapsed mass is expected to close one lane to full width traffic.*
- *Moderate scale (collapsed mass volume =2,000-20,000m³): its scale is defined as 100m (W1) x 100m (L1) x 2-5m (D1) or smaller, and its collapsed mass is expected to close two lanes to full width traffic.*
- *Large scale (collapsed mass volume =20,000-100,000m³): its scale is defined as 200m (W1) x 150m (L1) x 5-10m (D1) or smaller, and its collapsed mass is expected to close part or all the four lanes to traffic.*
- *Super large scale (collapsed mass volume <100,000m³): its scale is defined as 200m (W1) x 150m (L1) x 10m (D1) or larger, and its collapsed mass is expected to close all four lanes to traffic.*



Source: JICA Survey Team

Figure 3-7 Schematic Profile and Plan View of Before and After of Collapse

Table 3-6 Frequency Distribution of Scale of Volume of the Slope Collapse of 167 Field Survey Sites

Collapse Scale Classification	Collapse Volume (m ³)	Number of Collapses	Percent (%)
Small	~2,000	64	38
Moderate	2,000~20,000	80	48
Large	20,000~100,000	20	12
Very Large	100,000~	3	2
Total		167	100

Source: JICA Survey Team

3.1.3. Plan for Road Geohazard Damage Response

The Maintenance Branch of DOR is in charge of road maintenance, including road geohazard damage response. It conducts necessary activities based on the Integrated Annual Road Maintenance Plan (IARMP). IARMP is a compilation of Annual Road Maintenance Plans (ARMPs) for each road section. IARMP/ARMP is created based on data from the National Highway Management Information System (HMIS).

The DOR document “The Definition of Maintenance and Maintenance Activity” sets out road maintenance, including maintenance activities, as described below:

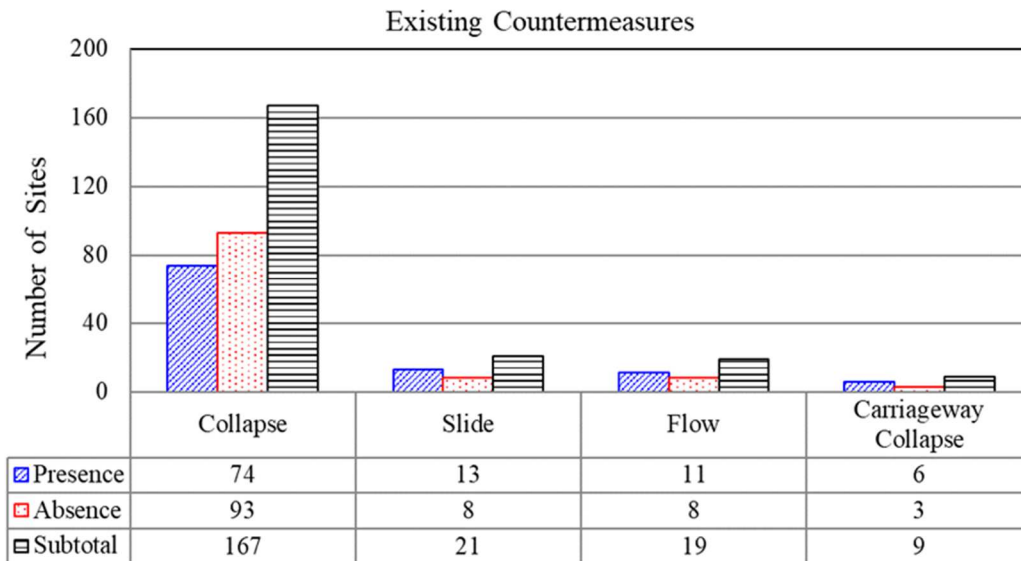
- 1) **Routine Maintenance:** Maintenance required continually throughout the year on each road, regardless of road conditions and traffic volumes. It includes road sweeping/cleaning, drain cleaning, culvert cleaning, grass cutting, etc.
- 2) **Recurrent Maintenance:** Maintenance that must be carried out at intervals of several times a year, depending on traffic volumes. It includes irregular repairs of pavements and road structures (gabion wall, side drain, causeway, etc.).
- 3) **Periodic Maintenance:** Maintenance normally carried out at intervals of several years, including asphalt overlay, road shoulder repair, road sign painting, bridge structure rehabilitation, etc.
- 4) **Emergency Maintenance:** Maintenance is necessary to respond immediately in emergency situations such as road geohazard damage or road closures. It includes removal of debris and other obstacles, installation of warning signs, construction of diversion roads, covering cracks due to slides and collapse, protection works against river erosion, etc.
- 5) **Specific/Preventive Maintenance:** Maintenance required to adapt roads to changing slope and stream conditions. It includes the installation of rockfall prevention nets, gabion walls, check dams, river revetment, bioengineering, etc.

Of the above road maintenance activities, 1) routine maintenance is carried out appropriately according to the manual by the workers directly hired by DOR for every 3 km of road stretch (one worker for every 5 km on flat roads) and one supervisor for every 18 km (one supervisor for every 30km on flat road) of road stretch.

2) Recurrent, 3) periodic, and 5) specific/preventive maintenance activities are outsourced to contractors. There are problems with delays in the execution of works not completed within the contract period by contractors and low construction quality.

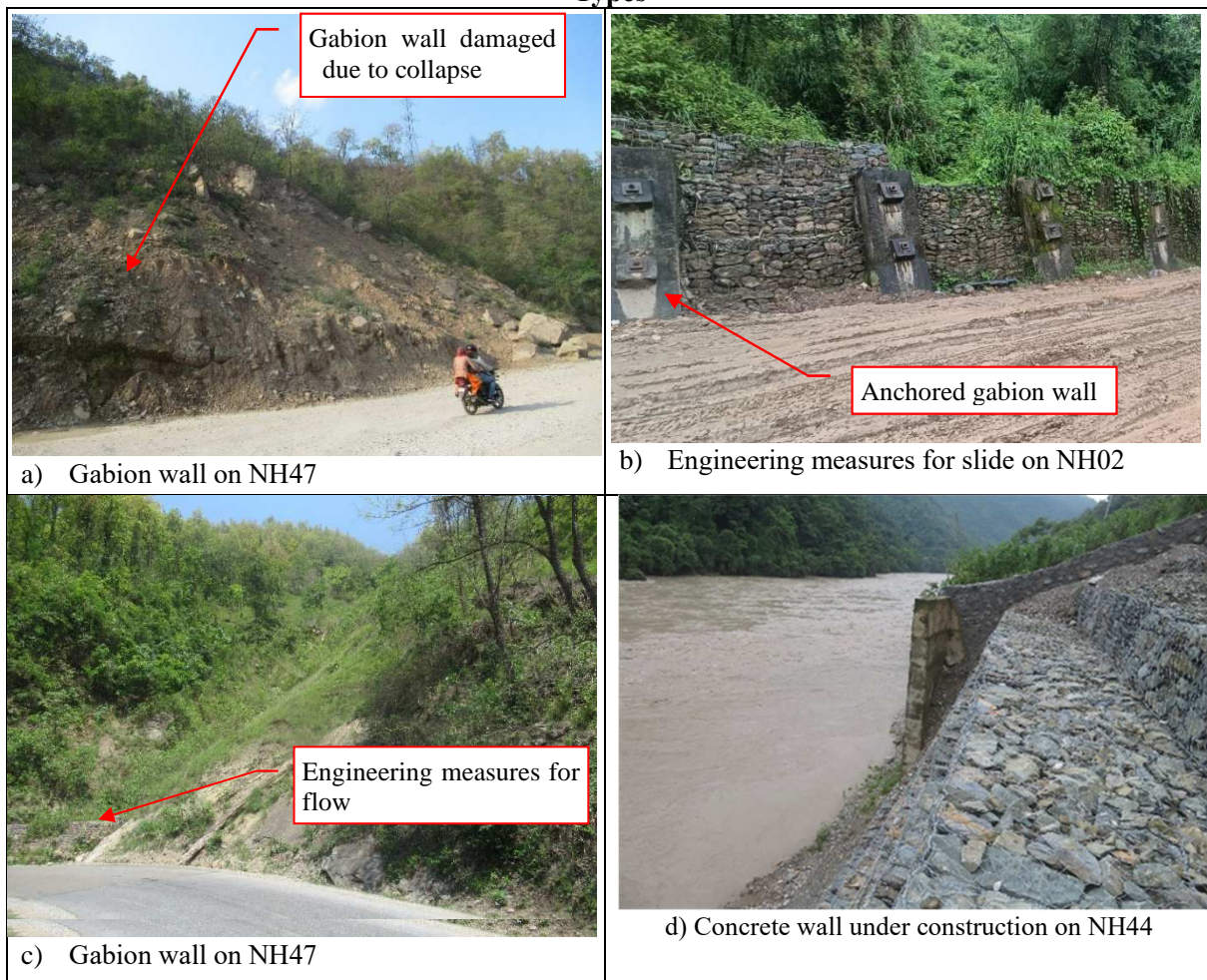
4) Emergency maintenance is carried out by DOR’s permanent employee of works and supervisors, heavy equipment operators from DOR's Mechanical Branch's Heavy Equipment Division, dispatched to geohazard-prone areas with DOR-owned equipment during the rainy season, or by outsourcing. For example, the removal of debris deposited on roads is done by DOR as an emergency response immediately after a landslide event. It is carried out appropriately according to the manual.

As for specific/preventive maintenance, **Figure 3-8** and **Figure 3-9** show the situation of engineering measures implementation at the 216 road landslide sites found by the site survey. The ratio of the sites with implementation of engineering measures works among the surveyed collapse sites was about 40%. The installed engineering measures works were emergency measures such as small-size masonry walls (34%), gabion walls (28%), and concrete retaining walls (10%), as shown in **Figure 3-9** and **Figure 3-10**. Although it is implemented by outsourcing, there are problems with delays in implementing works by external contractors and low work quality.



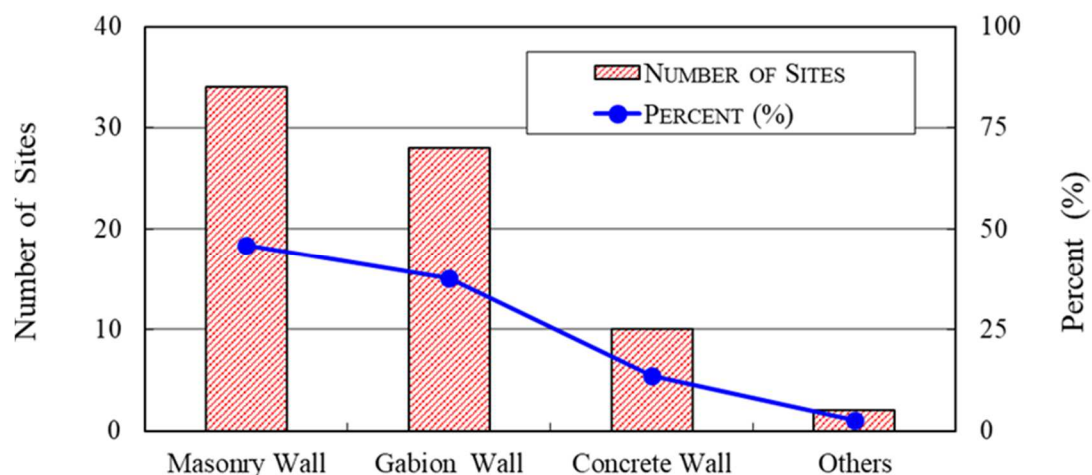
Source: JICA Survey Team

Figure 3-8 Implementation Situation of Existing Engineering Measures for Different Landslide Types



Source: JICA Survey Team

Figure 3-9 Examples of Landslides Engineering Measures on the Target NHs



Source: JICA Survey Team

Figure 3-10 Status of Existing Engineering Measures at the Field Survey Sites of Collapses

Road Board Nepal (RBN), established in 2002, provides the fund for road maintenance activities. The RBN manages a budget financed by fuel taxes, vehicle registration taxes, and road user fees and allocates road maintenance budgets for maintaining NHs managed by DOR and local roads. **Table 3-7** shows the allocated budget for road maintenance for the last five years. The annual budget for FY 2020/21 onwards is about NRs. 10-13.5 billion, double the size of FY2018/19 and FY2019/20 (NRs 4.9 and 6.8 billion, respectively). It reflects the importance of road maintenance and road construction growth (**Table 3-7**). On the other hand, as shown in **Table 3-8**, the allocated budget for road maintenance for FY2022/23 (NRs. 63.3 billion) is only 68% of the budget demand (NRs. 93.0 billion), which left over a 30% budget gap. The reason for this gap is basically that the RBN allocates a limited budget. DOR will reduce the maintenance plan according to the budget determined by RBN. What will be reduced are Recurrent Maintenance, Periodic Maintenance, Specific/Preventive Maintenance, and Rehabilitation /Reconstruction, which are executed as outsourced budgets. Routine and Emergency Maintenance will remain the same because they are carried out by DOR's fixed costs (permanent personnel and equipment). At the time of budget execution, contractors are selected through price competition bidding, so the outsourced costs are lower than the estimated amount. The average difference between the cost estimate and contract amounts is about 30%. DOR can use the remaining budget to revise and execute the annual maintenance plan through outsourcing in the second half of the fiscal year.

Moreover, as per Rule 6 of Roads Board Regulation –Nepal Sambat 2060(2003), RBN allocates budget in following budget heads for maintenance of roads:

- 1) Routine Maintenance
- 2) Recurrent Maintenance
- 3) Periodic Maintenance
- 4) Emergency Maintenance
- 5) Bridge Maintenance (In **Table 3-7**, this is included in Specific/Preventive maintenance.)
- 6) Rehabilitation (This includes pavement repair and road drainage repair.)
- 7) Reconstruction (This includes widening lanes, paving unpaved roads, and improving road alignment.)
- 8) Upgrading (In **Table 3-7**, this is included in Rehabilitation such as lane widening, paving unpaved roads, and improving road alignment.)
- 9) Road Safety (In **Table 3-7**, this is included in Specific/Preventive maintenance such as improving site distance, road safety signs, and installing curved mirrors.)
- 10) Road Maintenance Related Research (In **Table 3-7**, this is included in Specific/preventive maintenance)

Specific/Preventive Maintenance is included in **Table 3-7** which follows DOR's own budget allocation and is not included in **Table 3-8** which follows the classification of Boards Regulation Nepal Sambat

2060 (2003). Specific/Preventive Maintenance is included in items such as Periodic Maintenance, Emergency Maintenance, Bridge Maintenance, Rehabilitation, Road Safety, and Road Inspection Maintenance in the Road Boards Regulation.

Table 3-7 Budget Allocation for Road Maintenance Activities (FY2018/19 to FY2022/23)

Unit: million NRs

No.	Maintenance Activity	2018/2019		2019/2020		2020/2021		2021/2022		2022/2023	
		Allocation	Release	Allocation	Release	Allocation	Release	Allocation	Release	Allocation	Release
1	Routine Maintenance	752	749.11	853.27	840.77	878.18	862.69	890.66	872.4	1095.13	1095.13
2	Recurrent Maintenance	808.29	665.08	1280.21	1095.13	1669.5	1644.84	1738.41	1702.18	1309.41	1309.41
3	Periodic Maintenance	1598.21	1517.68	3480.18	3193.61	4678.63	3136.81	3173.78	3162.58	2565.49	2565.49
4	Emergency Maintenance	129.26	118.62	157.69	156.32	198.5	198.5	357.64	341.92	2372.6	2371.2
5	Specifi/Preventive Maintenance	1090.13	995.51	926.07	813.84	1916.37	1891.57	1854.37	1844.37	2494.85	2494.85
6	Rehabilitation/Reconstructiom	240.78	185.23	89.18	47.6	3857.3	3335.5	2293.2	2283.46	2609.94	2609.94
7	Toll road Maintenance	274.81	230.31	81.4	81.4	328.89	328.89	291.17	241.57	92.52	92.52
Total		4893.49	4461.58	6868.01	6228.67	13527.37	11398.8	10599.24	10448.4	12539.95	12538.5

Note: The budget allocation year starts in mid-July and ends in mid-July of the following year

Source: Prepared by the JICA survey team based on DOR budget data

Table 3-8 Comparison between Requirement and Allocation for Maintenance Activities (FY2022/23)

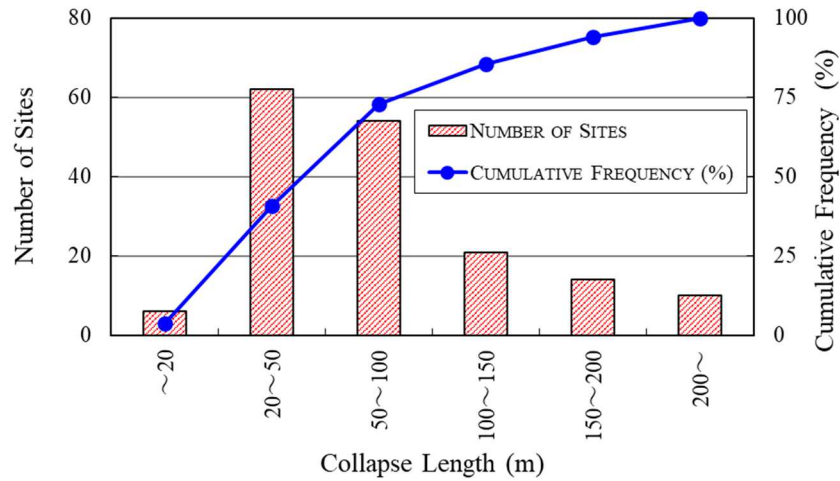
No.	Maintenance Activity	A. Budget Demand (1,000 NRs)	B. Budget Allocation (1000 NRs)	Percent (%) (B/A*100)
1	Routine Maintenace	1,065,579.93	1,064,000.00	100
2	Recurrent Mainenance	2,671,948.65	1,494,660.00	56
3	Periodic Maintenance	3,419,966.18	2,926,100.00	86
4	Eemergency Mainenance	362,520.00	362,520.00	100
5	Reconstruction/Rehabilitation	1,597,364.70	298,600.00	19
6	Upgrading/Widening	0.00	0.00	-
7	Toll Road Maintenance	0.00	0.00	-
8	Road Safety	116,000.00	116,000.00	100
9	Road Research Work	74,000.00	74,000.00	100
Total		9,307,379.46	6,335,880.00	68

Source: Modified from IARMP Nepal Sambat FY2079/80 (FY2022/23), by JICA Survey Team

3.1.4. Occurrence of Road Geohazards

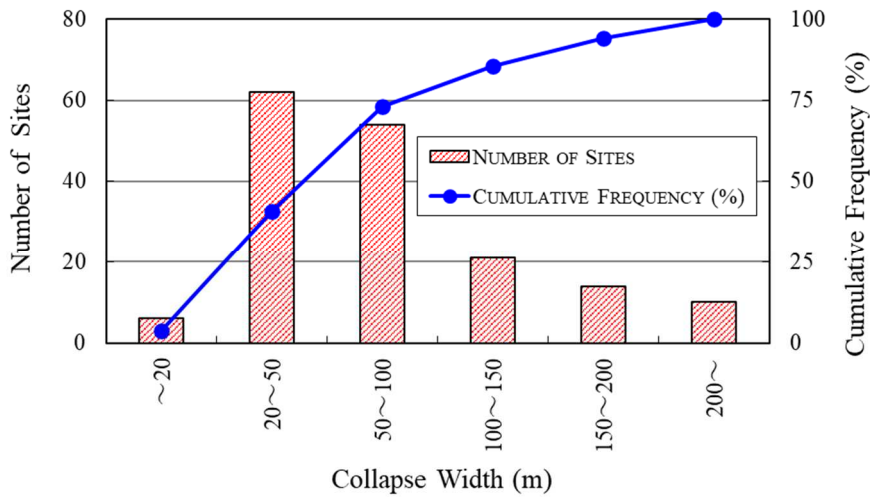
Collapses are the most common type of road landslides on the target NH roads. The occurrence of collapses is summarized in **Figure 3-11** to **Figure 3-13**, showing the following general trends.

- 1) 70% of collapses have a collapse length (see **Figure 3-7** above) between 20-100 m. 30% of the collapses have a collapse length of more than 100 m (**Figure 3-11**).
- 2) The collapse width also shows the same trend as the collapse length: More than 70% of the total cases are with less than 100 m, and about 20% are over 100 m (**Figure 3-12**).
- 3) The collapse depth with less than 3m accounts for approximately 50% of the total cases and 80% with less than 5 m (**Figure 3-13**). In terms of the scale of collapses (see **Table 3-6**), the small-scale collapses accounted for just under 40% of the total, the moderate scale collapses for just under 50% of the total, and the large to very large-scale collapses for over 10% of the total.



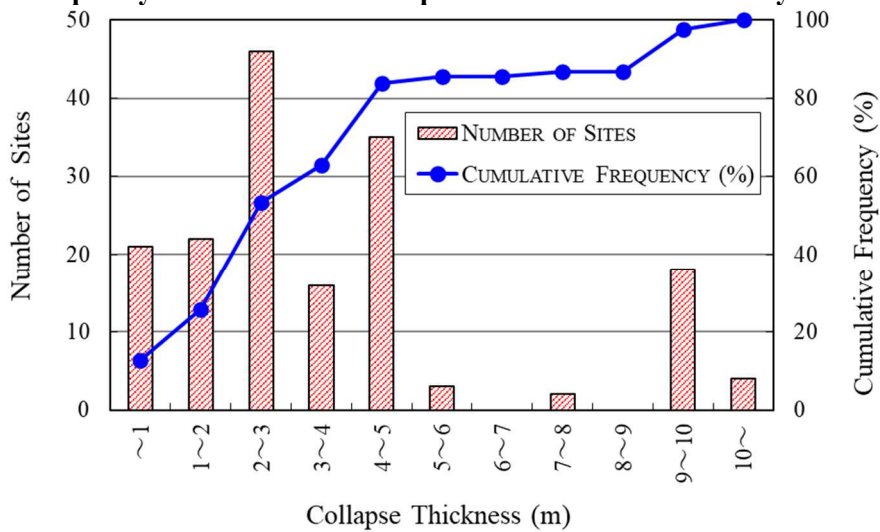
Source: JICA Survey Team

Figure 3-11 Frequency Distribution of Collapse Length at the Field Survey Sites of Collapses



Source: JICA Survey Team

Figure 3-12 Frequency Distribution of Collapse Width at the Field Survey Sites of Collapses



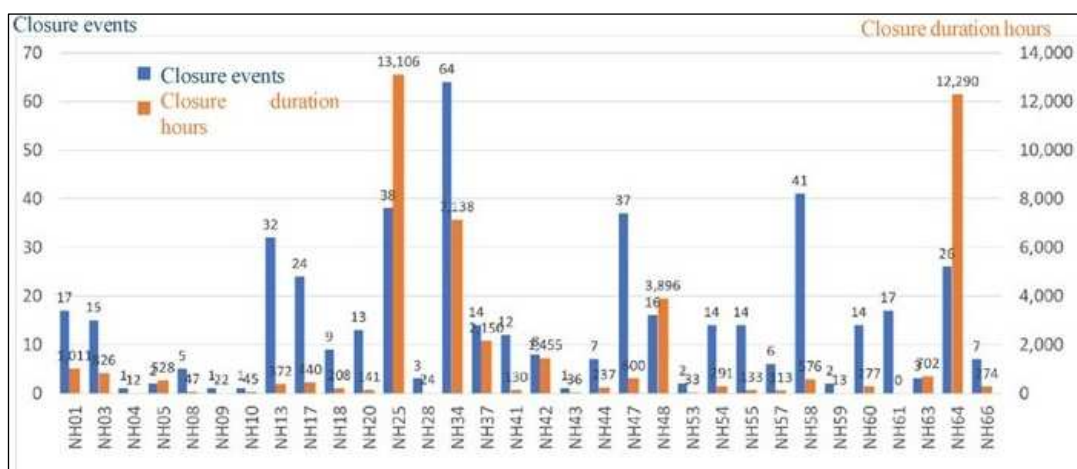
Source: JICA Survey Team

Figure 3-13 Frequency Distribution of Maximum Collapse Depth at the Field Survey Sites of Collapses

3.1.5. Road Damage by Road Landslides

Figure 3-14 shows the results of the road closure history for the past two years (2021 to 2022). The total of road closures was 466 events in two years, and the total closing duration was 47,123 hours. According to the road closure events history, NH34 (64 events), NH58 (41 events), NH25 (38 events), and NH47 (37 events) have the highest number of road closures, and NH25 (13,106 hours), NH64 (12,290 hours) and NH34 (7,138 hours) have the longest closure time. NH25 has the highest road closure duration, with 344 hours per road closure event. It is thought that traffic disturbance losses were generated depending on the road closure period, traffic volume, and detour conditions.

The length of road closure depends on the scale of the geohazard events and the road maintenance and management system, including the deployment of heavy machinery for geohazard damage recovery. Additionally, road carriageway collapses that require road body reconstruction require more time to recover than slope collapses on the mountainside of the road. Significant traffic obstruction losses will occur if the road is closed for a long time, has heavy traffic volume, has no detour, or has a long detour.



Source: Based on DOR data for the 2021-2022 year (<https://bipadportal.gov.np/>)

Figure 3-14 Number and Duration of Road Closures on NHs (2021-2022)

From the surveyed 216 road landslide-prone sites, the most serious damage history of the surveyed road landslide sites was classified as 1) whole road closure, 2) one lane closure, 3) road shoulder/road edge damage (slow down), and 4) almost no impact, as shown in **Table 3-9**.

The following general tendencies are observed (see **Table 3-9**):

- 1) Collapses lead to 63% whole road closure and 14% one-lane closure, significantly impacting road closure.
- 2) Slides result in 80% of whole road closures and reach 100 % when including one-lane road closures. There are no cases where the damage is minimized.
- 3) Debris flows have a high rate of whole road closures at 79%, and not many cases cause minor damage to road closures.
- 4) The rate of whole road closure caused by carriageway collapses is relatively low at 44%. However, even if the damage is minor, reconstructing the road takes many days and costs a lot. This is because it is necessary to construct a structure instead of removing earth and sand.

Table 3-9 Actual Damage Extent on Roads by Road Landslide Type

Types of Road Landslides	Whole Road Closure		1 Lane Closure		Damage to Road Edge		No Impact		Sub-total
	No. of Landslides	Percent (%)	No. of Landslides	Percent (%)	No. of Landslides	Percent (%)	No. of Landslides	Percent (%)	
Collapse	109	63	14	8	44	25	6	3	173
Slide	12	80	3	20	0	0	0	0	15
Flow	15	79	2	11	1	5	1	5	19
Carriageway Collapse	4	44	3	33	2	22	0	0	9
Subtotal	140	65	22	10	47	22	7	3	216

Source: JICA Survey Team

3.1.6. Issues on Road Geohazard Damage Response

Based on the results of the site survey and other analyses, the following issues can be identified as problems in understanding the actual situation of road geohazards and reducing the damage by road geohazards:

- 1) Insufficient data collection and accumulation on road geohazards result in the lack of opportunities to reflect on past experiences and incomplete understanding of road geohazard sites, types/modes of occurrence, actual damage, etc. In this situation, it is difficult to formulate effective preventive measures plans. Data collection methods on road geohazards are provided in Guide to Road Slope engineering measures (DOR, 2003) and Roadside Geotechnical Problems (DOR, 2007) with data collection sheets on road hazards. However, they are not fully utilized. DOR's geohazard data currently collected and accumulated mainly includes road closure times. However, it lacks an analysis of the occurrence mechanism and causative factors for road landslides.
- 2) The main causes of frequent collapses on the target NHs include cut slopes with slope angles steeper than those with stable and suitable ones matched with the geological characteristics of the sites and the lack of cut slope protection and slope drainage.
- 3) Preventive maintenance and management against road geohazards mainly consist of simple measures. In addition, some engineering measures are deformed or damaged. Given this current situation, it is considered that DOR's preventive maintenance budget is insufficient. Another issue is the selection of the appropriate engineering measures and the quality of construction by contractors.
- 4) DWRI has technical knowledge, and a track record of engineering measures for debris flows across roads and river erosion on road valley slopes related to road collapse, which are related to road geohazard engineering measures. These geohazard measures often contribute to road preservation and the preservation of farmland and houses along the road. It is necessary to hold collaborative discussions between DOR and DWRI regarding road DRR and to establish a project and budget system that integrates road maintenance and roadside geohazard risk reduction.

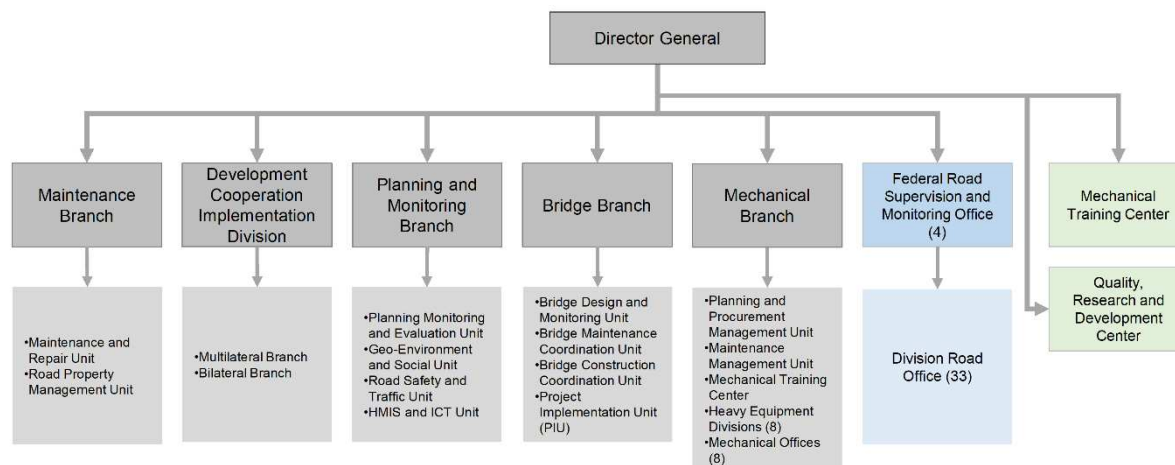
3.2. Geohazard Management of DOR

3.2.1. Role, Structure, Budget Allocation, and Execution Related to Geohazard Management and Recovery of DOR

(1) Outline of DOR

DOR is an influential administrative agency that supports the country's economic infrastructure by maintaining and managing the road network throughout Nepal. The total length of the NHs managed by DOR is 11,100 km, including over 6,800 km of paved roads, 1,100 km of gravel roads, and 3,200 km of unpaved roads.

The technical component of DOR consists of five main Branches/Divisions, the Federal Road Supervision and Monitoring Office (FRSMO) with four offices in the country, and a training and research institute. These organizations are under the direction of the Director General of DOR and are represented by Gazetted First Officers. **Figure 3-15** shows the organizational chart of the main divisions, and **Table 3-10** shows a summary of the main divisions.



Source: JICA Survey Team based on DOR Information

Figure 3-15 Organization Chart of DOR Technical Division

Table 3-10 Summary of DOR's Five Major Departments

Divisions/Branches	Summary
Maintenance Branch	Responsible for the maintenance and repair of roads and property management of road-related facilities.
Development Cooperation Implementation Division (DCID)	Serve as a point of contact for bilateral or multilateral international cooperation. It has the role of contributing to the economy and society through the construction and maintenance of roads and bridges.
Planning and Monitoring Branch	Responsible for preparing budgets for implementation plans, compiling the progress of various plans in project-related work, reviewing and reporting to relevant agencies, and conducting research and design related to road and bridge projects.
Bridge Branch	Responsible for all work related to bridge projects, supervising and monitoring surveys and designs.
Mechanical Branch	Support DOR's construction and maintenance activities through the management of construction equipment.

Source: JICA Survey Team

(2) Departments in Charge of Geohazard Management and Recovery

The Maintenance Branch and Mechanical Branch are the primary departments at DOR related to geohazard management and recovery. In addition, FRSMO and the 33 Road Division Offices (DROs) responsible for the maintenance and management of roads in each region work together to respond to road geohazards.

The Maintenance Branch consists of the Maintenance and Repair Unit and the Road Property Management Unit. The main activities are as follows.

1. Instruct the policy directions and supervise the execution of FRSMO's mandate.
2. Develop policies and plans for road maintenance and management.
3. Develop and implement an evidence-based priority list for road maintenance and bridge maintenance.
4. Develop a program of maintenance and management projects to be implemented with foreign assistance in cooperation with DCID.

5. Maintain the structures such as roads and bridges, arrange personnel, and decide methods that do not disturb traffic.
6. Formulate policy programs related to tree planting and signages of roadsides.
7. Develop an Integrated Annual Road Maintenance Plan (IARMP)
8. Organize training related to road maintenance and management.

The main activities of the Mechanical Branch are as follows.

1. Advise on policy development related to equipment maintenance and vehicle management.
2. Develop operational plans for heavy vehicles (planning, procurement, operation, maintenance, auctions, etc.)
3. Human resource management, including skill development.
4. Provide operational support of construction heavy vehicles mainly after road geohazards (landslides, floods, earthquakes, etc.)

The Heavy Equipment Division (HED) under the Mechanical Branch has eight offices and owns the equipment and heavy vehicles used in road construction and maintenance.

The staffing of each HED office is as shown below.

Table 3-11 Staffing of HED

	SDE / Engineer	Operator / Technician	Office Staff	Total
HED Itahari	4	44	11	59
HED Janakpur	3	38	5	46
HED Hetauda	3	46	3	52
HED Kathmandu	5	36	12	53
HED Pokhara	1	37	2	40
HED Butwal	2	42	11	55
HED Nepalgunj	3	28	5	36
HED Godawari	2	33	13	48
Total	23	304	62	389

Source: JICA Survey Team Based on DOR Information

The Chief of FRSMO in charge of NHs is considered a Gazetted First Class, equivalent to a Deputy Director General of a major department. It plays an important role in road geohazard risk management and rehabilitation. FRSMO comprises four branches, which supervise the maintenance and rehabilitation work carried out by each DRO and allocate equipment for maintenance and rehabilitation.

FRSMOs and DROs under their supervision are shown in **Table 3-12**.

Table 3-12 Name of FRSMO and Each DRO

Federal Road Supervision and Monitoring Office (FRSMO)	Damak	Kathmandu	Pokhara	Surkhet
Road Division Office (DRO)	<ul style="list-style-type: none"> · Damak · Ilam · Biratnagar · Dhankuta · Lahan · Tumlingtar · Harkapur 	<ul style="list-style-type: none"> · Charikot · Janakpur · Chandranigahapur · Hetauda · Bharatpur · Kathmandu · Bhaktapur · Lalitpur · Nuwakot · Khurkot 	<ul style="list-style-type: none"> · Damauli · Pokhara · Palpa · Baglung · Butwal · Shivapur · Dang · Pyuthan 	<ul style="list-style-type: none"> · Surkhet · Jumla · Chaurjahari · Nepalgunj · Doti · Baitadi · Sappebagar · Mahendranagar

Source: JICA Survey Team Based on DOR Information

(3) Budget of DOR

The budget of DOR is developed and compiled as ARMP and IARMP. The amount of allocated budget is calculated based on the extension and Surface Distress Index (SDI) and International Roughness Index (IRI) of each road segment. The project budget allocated for road management corresponds to a single-year plan. Securing the funding is a top priority for DOR. In addition to the budget allocated by the national government, the DOR budget is sourced from the RBN budget, which is allocated to road maintenance.

DOR's budget per maintenance levels for FY2022/23 is shown in **Table 3-13**. DOR's budget and expenditure for the last six years are shown in **Table 3-14**.

Table 3-13 DOR FY2022/23 ARMP Budget (RBN Budget)

ARMP Category	Cost (NRs. thousands)	%	Length km	Per km (NRs. thousands)	Per km (USD)
Routine Maintenance	924,079	11.10%	8,253.72	112	883
Reactive/Recurrent Maintenance	1,128,379	13.60%	4,958.77	228	1,795
Combined Maintenance*1	137,784	1.70%	355.53	388	3,058
Periodic Maintenance	2,602,331	31.40%	687.39	3,786	29,870
Responsive Maintenance*2	0	0.00%	63.00	NA	NA
Roadside Maintenance	1,533,069	18.50%	4,060.52	378	2,979
Emergency Maintenance	154,958	1.90%	Based on experience, a Lump sum amount for each division		
Bridge Routine Maintenance	47,862	0.60%	NA	NA	NA
Bridge Maintenance	164,112	2.00%	NA	NA	NA
Rehabilitation	1,597,364	19.30%	450.74	3,544	27,961
Reconstruction	0	0.00%	0.00	NA	NA
Upgrading	0	0.00%	0.00	NA	NA
Total	8,289,943	100.00%	-	-	-

Note: *1A maintenance budget combining Routine Maintenance and Reactive/Recurrent Maintenance, includes maintenance and management costs that are difficult to classify.

*2 Responsive maintenance is a maintenance item that does not require an emergency to repair malfunctioning road facilities. Normally, it is not budgeted because it is not urgent.

Source: DOR

Table 3-14 Emergency Maintenance Budget Allocation and Release for the Last 6 Years, FY2017/18-FY2022/23 (RBN Budget)

Unit: million NRs.

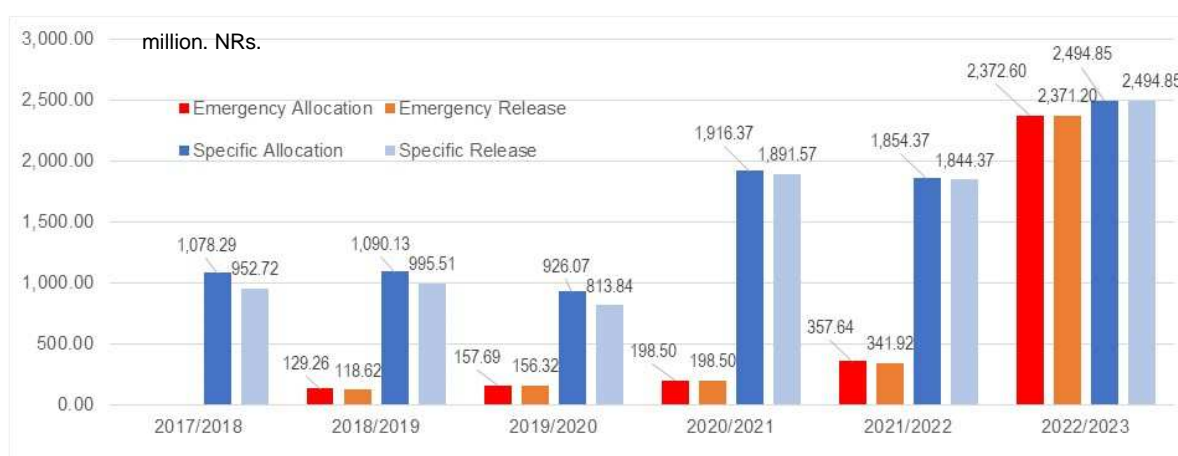
	2017/2018		2018/2019		2019/2020		2020/2021		2021/2022		2022/2023	
	Allocation	Release	Allocation	Release	Allocation	Release	Allocation	Release	Allocation	Release	Allocation	Release
Routine	768.81	768.81	752	749.11	853.27	840.77	878.18	862.69	890.66	872.4	1095.13	1095.13
Recurrent	869.23	742.49	808.29	665.08	1280.21	1095.13	1669.5	1644.84	1738.41	1702.18	1309.41	1309.41
Periodic	1700.17	1426.07	1598.21	1517.68	3480.18	3193.61	4678.63	3136.81	3173.78	3162.58	2565.49	2565.49
Emergency			129.26	118.62	157.69	156.32	198.5	198.5	357.64	341.92	2372.6	2371.2
Specific	1078.29	952.72	1090.13	995.51	926.07	813.84	1916.37	1891.57	1854.37	1844.37	2494.85	2494.85
Rehabilitation	575.72	566.63	240.78	185.23	89.18	47.6	3857.3	3335.5	2293.2	2283.46	2609.94	2609.94
Toll road	107.15	131	274.81	230.31	81.4	81.4	328.89	328.89	291.17	241.57	92.52	92.52
Total	5099.36	4587.76	4893.49	4461.58	6868.01	6228.67	13527.37	11398.81	10599.24	10448.44	12539.95	12538.53

Source: DOR and RBN

The DOR Maintenance Manual defines Emergency Maintenance as emergency measures to clear roadblocks during geohazard events such as floods, landslides, and earthquakes, including removing debris and sediment, installing warning signs, and securing detour highways. In Nepal, the following events generally require Emergency Maintenance of roads.

- Sediment flows into the road due to slope landslide
- Road collapse
- Reduction of road width due to river scour
- Damage to bridges and drainage structures.
- Loss of road structures due to flooding
- Roadblocks caused by vehicle accidents.
- Road subsidence

Apart from the emergency maintenance, the budget for roadside engineering measures construction as a pre-geohazard event investment will be secured as the Specific Maintenance budget. As shown in **Figure 3-16**, the budget for geohazard risk management activities has been increasing over the past six years in response to the increase in geohazard damage to prevent repeated damages. The Emergency Maintenance budget for FY2022/23 stands out as an exceptional case due to the continuous occurrence of road geohazards on the Karnali Highway in the far west of Nepal.



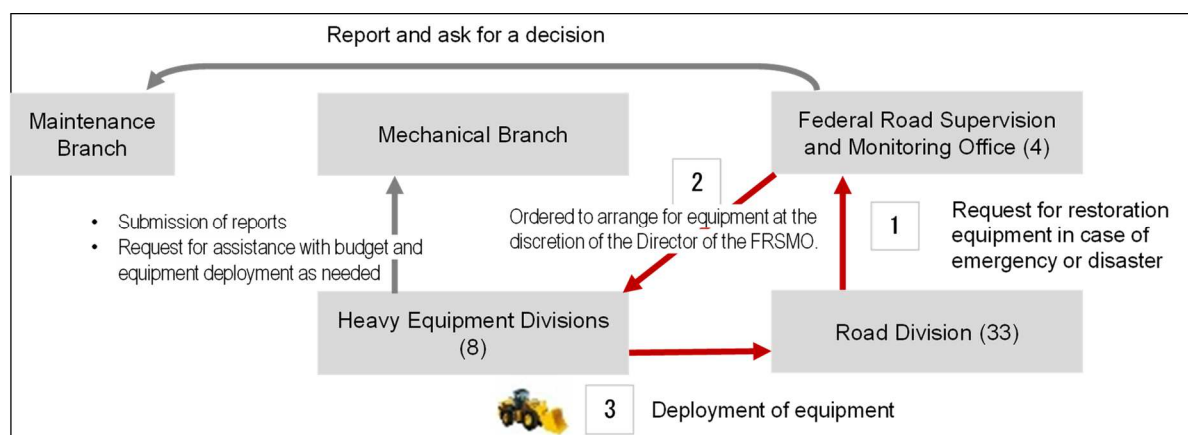
Source: JICA Survey Team Edited with information by DOR and RBN

Figure 3-16 Budget for Geohazard Management for Six Years

3.2.2. Implementation System for Restoration and Emergency Measures Projects for Road Geohazard

When a road geohazard event occurs, as shown in **Figure 3-17**, the related departments of DOR coordinate and conduct each task to open the road and rehabilitate the structures. DRO requests FRSMO to arrange recovery equipment, and FRSMO issues an order to HED to send the equipment to the site based on the equipment's deployment and maintenance status. In response, HED sends restoration equipment to the DROs and performs the temporary restoration. According to DOR, there have been cases where equipment requests overlap, and sufficient deployment faced difficulties. HED has been requesting the Mechanical Branch to increase its budget to stock additional equipment in preparation for such cases.

Then, DOR will plan and request budget for full-scale engineering measures and implement DRR project as specific/preventive maintenance.



Source: JICA Survey Team Based on Hearing From DOR

Figure 3-17 Geohazard Damage Recovery System and Implementation Flow

3.2.3. Abnormal Inspection and Monitoring Data

(1) Highway Condition Reporting System (HCRS)

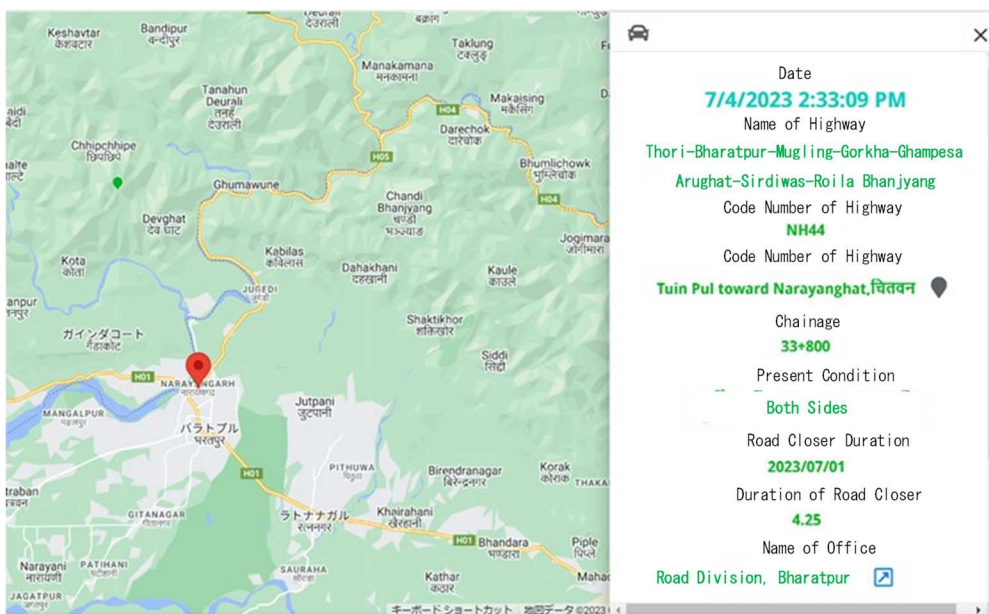
HCRS, an information reporting system for road closures, manages information for Emergency Maintenance. In this system, after DRO personnel identify an anomaly on the road, they register information such as the time of the event and information on whether the road is passable in the system via a Google form. The registered information is scrutinized by HMIS and uploaded to the website. Users can view and edit the information with a browser and report and share road conditions seamlessly and in real time.

The information that can be registered in the system is as follows.

1. Serial Number	10. Road closer duration: (Date- Hrs.- min)
2. Date	11. Tentative time for road opening (Date - Hrs. - min)
3. Name of Office	12. Present condition
4. Code number of Highway	13. Time of road open (Date- Hrs.- min)
5. Name of Highway	14. Duration of Road Closer (Hrs.)
6. District	15. Tentative loss by damage/ road closer (Rs)
7. Site	16. Tentative description of damage (cause of failure)
8. Chainage	17. Contact Person (Name and Mobile number)
9. Co-ordinates (Easting- Northing)	18. Activities carried to the open road
	19. Remarks

Data accuracy and real-time performance depend on the skill and judgment of each engineer in charge of the highway and the communication network. In some cases, up-to-date detailed information is not always reflected. DOR recognizes the need for improvements in the data collection process, and the following enhancements are under consideration.

- Outsource data updates and software maintenance to system operators.
- Data collection, review, and designation of information reported by general road users.



Source: DOR

Figure 3-18 HCRS System Screen

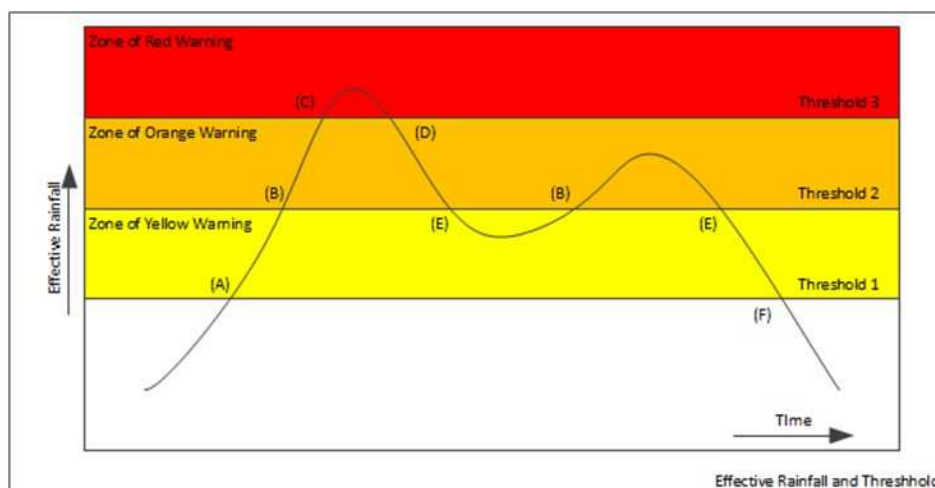
(2) Emergency Information System (EIS)

The Emergency Information System (EIS) was developed and implemented as part of “The Project for Operation and Maintenance of the Sindhuli Road” (JICA, 2016), which was conducted as a technical cooperation by JICA to improve and enhance the management capacity of DOR with the target of NH13 Sindhuli Road. The system consists of a central server, rain gauges, road information boards along the road, battery equipment, and communication equipment. The service helps users obtain real-time information on road conditions such as heavy rainfall, floods, landslides, traffic accidents, traffic congestion, and road closures. The service can also disseminate information on traffic rules, regulations, and driving manners. EIS can be updated and viewed on the DOR website and smartphones. The warning criteria for the original EIS rainfall observation are designed to issue three levels of warnings based on rainfall levels, as shown in the conceptual diagram in Figure 3-19.



Source : DOR (http://eis.softavi.com/main/public_home)

Figure 3-19 System Screen of EIS



Source : DOR (http://eis.softavi.com/main/public_home)

Figure 3-20 Alert Level Based on Rainfall

Figure 3-20 shows effective rainfall, a rainfall index calculated assuming hourly rainfall is halved every 12 hours, to evaluate the increase in surface soil water content. Based on experience, the system has set three thresholds for issuing warnings when the rainfall index value increases, and the risk of landslides increases.

3.2.4. Technical Level and Project Implementation Capability for Road Geohazard Risk Management and Recovery

About 1,800 technical personnel (including 500 engineer class) are engaged in road construction and maintenance under DOR. DOR has no specialized road geohazard risk management and rehabilitation response unit but provides design and construction supervision for slope protection measures based on each DRO's experience. For this reason, it isn't easy to clearly express the technical level of construction work that DOR can cover. Still, it can generally indicate whether measures can be taken depending on the scale of the damage.

DOR can perform emergency earth removal to open roads after a geohazard event, construct mountain retaining walls, build erosion control dams, etc., in the event of damage, and carry out such tasks at the field level, and the equipment for this purpose is also available. DOR is also conducting site management and detour construction to ensure general traffic safety until restoration work is carried out.

On the other hand, as shown in **Table 3-15**, DOR's ability to handle road geohazard events that require advanced technology and high costs, such as large-scale slope failure and landslide restoration work, anchor work, and slope construction, is limited. It is difficult to do it alone. For this reason, research is often outsourced to research institutions or external experts, or consultations are sought from foreign support organizations. As equipment further deteriorates and road length increases, support for strengthening equipment and capacity will become even more necessary.

Table 3-15 Capacity of Engineering Measures Works

Category/ Group	Countermeasure Works		DoR capacity			
			Collapse	Landslide	Debris Flow	Road carriageway failures
CONTROL MEASURES						
Earthwork	Earthwork	Cutting	Adequate	Adequate	-	-
		removal	-	-	Adequate	-
		Filling	Adequate	Adequate	-	-
		Embankment	-	-	-	Adequate
Vegetation	Vegetation	Hydro seeding	Support needed	Support needed	Support needed	Support needed
		Re-Vegetation	Adequate	Adequate	Adequate	Adequate
Water Management	Surface Drainage	Drain Ditch	Adequate	Adequate	Adequate	Adequate
		Cascade, Culverts	Adequate	Adequate	-	Adequate
	Subsurface Drainage	Horizontal Drain Hole	-	Support needed	-	-
		Sub surface drains	Adequate	Adequate	-	Adequate
		Horizontal Drilled Drain	Support needed	-	-	Support needed
	Water Way	Stone Pitching, Stone riprap	-	-	Adequate	-
		Concrete Pitching	-	-	Adequate	-
RESTRAINT MEASURES						
Slope Work	Pitching Work	Stone Pitching	Adequate	-	-	Adequate
		Shotcrete Work	Shotcrete (mortar)	Support needed	-	Support needed
	Shotcrete (concrete)		Support needed	-	Support needed	-
	Frame Work	Frame work	Support needed	Support needed	Support needed	Support needed
Anchoring	Anchoring	Soil Nail	Support needed	-	-	Support needed
		Rock Bolt	Support needed	Support needed	-	-
		Ground Anchor	Support needed	Support needed	-	Support needed
Wall and Resisting Structures	Retaining Wall	Gabion Wall, Crib Wall	Adequate	Adequate	Adequate	Adequate
		Stone Pitching Wall	Adequate	-	Adequate	Adequate
		Concrete Block Wall	Adequate	-	-	Adequate
		Cement Masonry Wall	-	Adequate	-	Adequate
		Frame Wall	-	-	-	Support needed
	Pile Wall	-	-	-	Support needed	
	Catch Work	Catch Concrete Wall	Adequate	-	-	-
Pile Work	Pile Work	Steel Pipe Pile	Support needed	-	-	-
		Steel Pile (H section)	Support needed	Support needed	-	-
		Shaft Work or Bore Pile	-	Support needed	-	-
Protection Work	Sabo (Check) Dam	Check Dam (Sabo Dam)	-	-	Adequate	-
ALT. WORK						
Realignment of Road		Diversion, Bridge and/or Tunnel	-	Support needed	-	-
		Bridge, Culvert, Causeway,	-	-	Adequate	-
		Route Relocation	-	Adequate	Adequate	-

Source: DOR

3.2.5. Implementation Status of Engineering Measures Construction

Preventive maintenance in areas at high risk of road hazards on the roadside is classified as Roadside Maintenance because it is performed along roads. It is a maintenance activity such as road slopes, retaining walls, and planting to prevent possible risks of damage to the road itself. Roadside Maintenance accounts for about 18.5% of the total annual budget for maintenance performed by DOR, but it is insufficient for the demand. The increased budget and other measures, such as extending the durability of road structures, may be necessary. The following are examples of engineering measures works, by landslide type, implemented after the road has been restored.

- Collapse: Frame works, networks, and bioengineering works are being constructed.
- Slides: Ground/surface water works, and anchoring works are being implemented.
- Flow: Check dams are being constructed.
- Carriageway Collapse: In principle, the road should be restored to its original condition, but if similar landslide risks remain, the road should be reconstructed by shifting its alignment.

3.2.6. Equipment for Road Geohazard Risk Management and Recovery

(1) Ownership, Management and Maintenance System of Equipment

Heavy equipment for road construction is managed by DOR's Mechanical Branch through HED and utilized by DOR personnel to perform Emergency Maintenance. Nationwide, 572 pieces of heavy equipment are deployed in the field or stored at eight HEDs. The total number of heavy vehicles is shown in **Table 3-16**.

In addition to the heavy equipment stored at HED, there is also heavy equipment in operation on each roadway or temporarily stored along the highway in preparation for requests. The deployment status of each type of heavy equipment is shown in **Figure 3-21**. Most wheel loaders and backhoe loaders are deployed on-site. Many other machines are on standby in the HED.

Table 3-16 Total Number of Heavy Vehicles Owned by DOR

S.N.	Type of Equipment	Total	S.N.	Type of Equipment	Total
1	Asphalt Plant	6	17	Backhoe Loader	62
2	Asphalt Paver	4	18	Skid Steer Loader	4
3	Bridge Inspection Machine	1	19	Truck Mounted Pothole Patcher	1
4	Chip Spreader	11	20	Roller Three Wheel	24
5	Crane Mobile	7	21	Roller Pneumatic	29
6	Dozer Track	9	22	Roller Pedestrian Vibratory	24
7	Bitumen Distributor	10	23	Roller, Asphalt	8
8	Hydraulic Hammer Drill	1	24	Roller Vibratory, Self-prop	21
9	Mini Dumper	11	25	Simulator	2
10	Excavator	50	26	Crane Mounted Truck	13
11	Mini-Excavator	6	27	Flat Bed Truck	19
12	Forklift Truck	4	28	Tipper Truck	75
13	Wheeled Excavator/Breaker	4	29	Trailer, Tractor	18
14	Long Reach Excavator	1	30	Water Tanker	20
15	Grader Motor	38	31	Mobile Workshop	6
16	Wheel Loader	82	32	Street Sweeper	1
				Total	572

Source: DOR

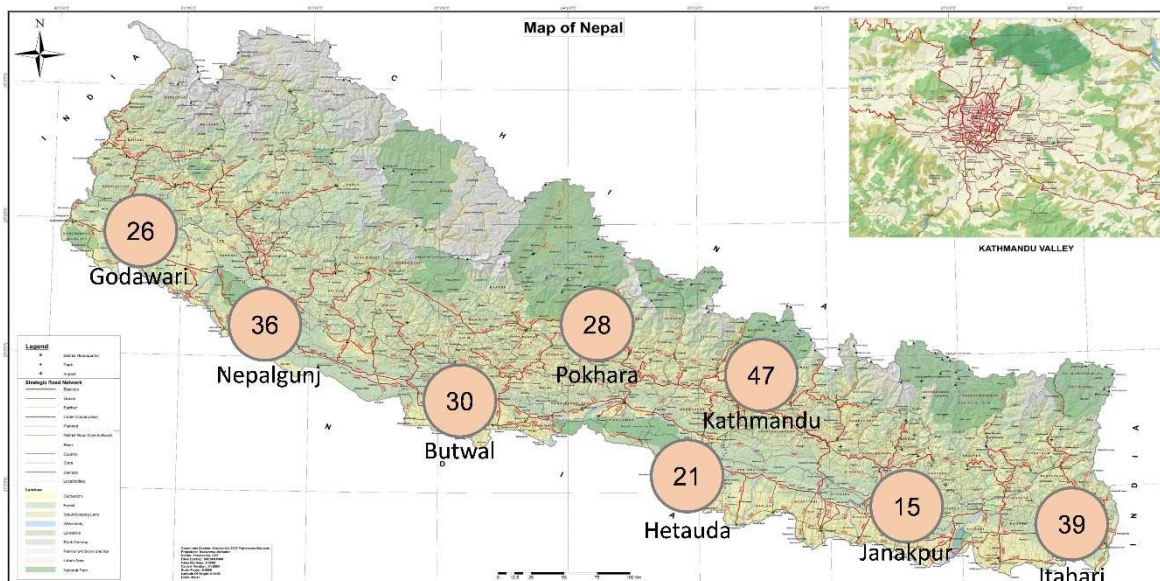


Source: DOR

Figure 3-21 Total Number of Heavy Vehicles Deployed/Standby on Site by Type of Vehicle

The sites of eight HEDs are shown in **Figure 3-22**. The numbers in the figure represent the number of heavy equipment owned by each HED (including the number already deployed along the roads under its responsibility); the HED located in the Min Bhawan district of Kathmandu has 47 heavy equipment, which is the largest followed by Itahari HED and Nepalgunj HED.

Table 3-17 shows the total number, including field deployments of each HED and the total number of standbys at the HED.



Source: DOR

Figure 3-22 Sites of Eight HED

Table 3-17 Total Number of Heavy Vehicles of HED (Field Deployment/Standby, FY2023/24)

Description of Equipment	HED Itahari		HED Janakpur		HED Hetauda		HED Ktm.		HED Pokhara		HED Butwal		HED Nepalgunj		HED Godawari		No. of Total Equipments		
	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Site	Std-by	Total
Backhoe Loader	7		2	1	2		6	7	6		1	2	9	2	4	2	37	14	51
Dozer Track		1				1	1	1		1		1		1			1	6	7
Excavator Track		6		2		3	4	4	3	2	1	4	3	3	4	1	15	25	40
Excavator Wheel						1		1				1	1				1	3	4
Wheel Loader	8	1	2	2	6	2	8	3	6	1	5	4	8		6		49	13	62
Air Compressor								2									0	2	2
Crane Mounted Truck		1						2		2		2		1		1	0	9	9
Flat Bed Truck		2		1								2		1			0	6	6
Mobile Crane												1					0	1	1
Tipper Truck	1	8	2	2		4		5	3	2		2	1	4	5		12	27	39
Transporter	0	4		1		2		3		2		4	1	1		3	1	20	21
Total	16	23	6	9	8	13	19	28	18	10	7	23	23	13	19	7	116	126	242
Grand Total	39		15		21		47		28		30		36		26				

Note: [Site] Total number of heavy equipment deployed to facilities along the road

[Std-by] Total number of heavy equipment on standby at HED's facility

Source: JICA Survey Team Based on DOR Information

(2) Collaboration and Division of Roles with the Private Sector

DOR utilizes its equipment for emergency work such as soil removal. On the other hand, permanent work related to restoration and engineering measures for road geohazard is often outsourced to private contractors, and some private resources are involved voluntarily, with or without a contract.

In Japan, about half of all construction equipment is owned by leasing companies, but in Nepal, most are owned by government organizations or private construction companies.

DOR's heavy vehicles are primarily used for new road construction and maintenance of existing roads, but also rental the equipment to private contractors during periods of non-use. Conversely, DOR may temporarily borrow equipment from private contractors for emergency restoration.

(3) Interview Result about DOR's Needs for Heavy Equipment Provision

In August 2023, the JICA Survey Team interviewed the Mechanical Branch of DOR about its equipment provision needs.

- DOR owns equipment made by HYUNDAI and DOOSAN from South Korea, JCB from India, and VOLVOs manufactured in India and China. DOR also owns equipment manufactured by Kawasaki, but the manufacturer has ceased production of backhoe loaders.
- DOR has a total of 572 number of heavy construction equipment, of which 242 are deployed to HED for road geohazard damage recovery.
- Every year, DOR auctions some equipment for maintenance and renewal, and purchases about the same number of new pieces of equipment. As a result, the total amount of equipment owned by the DOR has remained almost the same each year, and the amount of equipment available for geohazard restoration tends to be insufficient to deal with the increasing number of road geohazard events.
- Heavy equipment made by Japanese manufacturers is regarded as high-quality, and low-cost from a long-term perspective. High durability is important because moving equipment long distances for repair can lead to loss of operational opportunities in the geohazard events. DOR stated that Japanese manufacturers are more reliable than those from other countries. The following list of needs is presented in **Table 3-18**.

Table 3-18 DOR's Needs of Heavy Equipment

No.	Heavy Equipment	Capacity	Quantity
1	Backhoe Loader	1.1m ³ Loader 0.3 m ³ Backhoe	32
2	Wheel Loader	4.0m ³	8
3	Mini Excavator	1t	16
4	Transport Truck	25t	5
5	Motor Grader	14 ft	8
6	Soil Compactor	12t-14t	5

Source: Mechanical Branch of DOR

The number of equipment requested from DOR is based on the number of local HED and maintenance offices. Since the geohazards damage sites changed from time to time, the requested equipment sites are not assumed for specific areas or routes. Equipment No 1 to 4 in the needs list are general-purpose equipment used mainly for emergency road clearing in the damaged site. And No 5 and 6 are frequently used for road construction. DOR is requesting the provision of the equipment for road construction in addition to the equipment for recovery from damage.

3.2.7. Implementation Status of Training

Quality Research and Development Center (QRDC) is responsible for planning and implementing skill development programs for DOR staff. QRDC includes the Road Sector Skill Development Unit (RSSDU) and the Study and Research Section (SRS). Each year, RSSDU organizes training for young DOR engineers at the request of chapters within DOR, including seminars, workshops, and on-demand programs such as training in and out of Nepal.

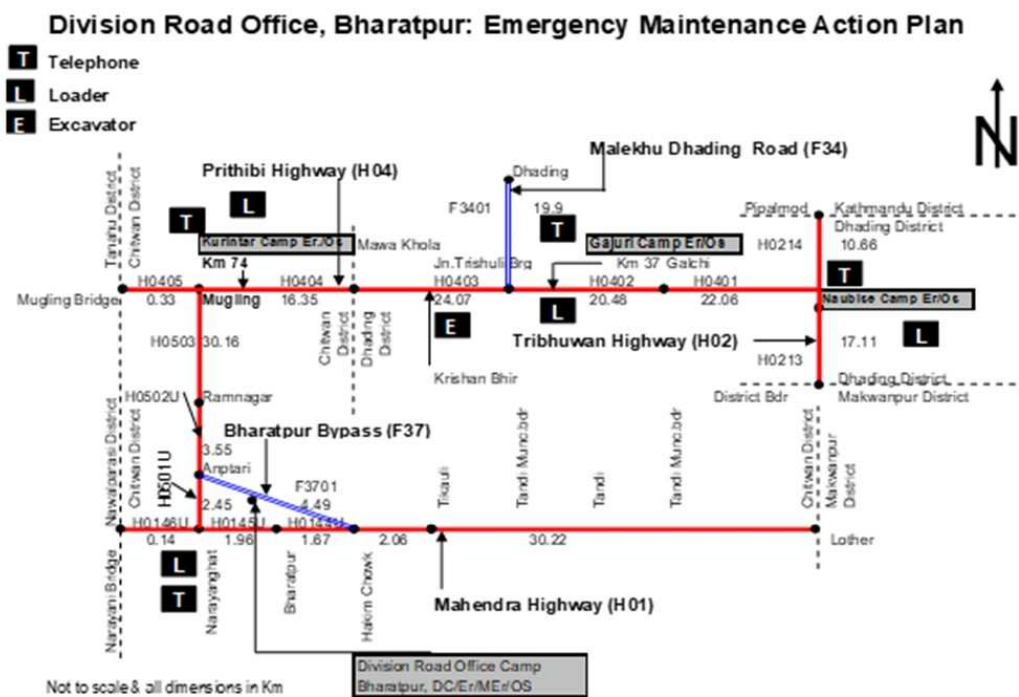
In addition, the Mechanical Training Center in Lalitpur is the responsible organization to manage heavy vehicles. It provides training to improve the capabilities of DOR's mechanical workers involved in maintaining and operating heavy equipment. In addition to the ILO and UNDP, various international aid agencies, including the WB/IDA, cooperate to establish this mechanical training center. It also involves consulting firms such as Crown Agents of England, SUMAC Consulting of Australia, and Royal Haskoning DHV of the Netherlands to provide equipment and materials. Since 2001, the training center has also offered free training programs to non-DOR government agencies, non-governmental organizations, and other interested individuals.

3.2.8. DOR's Future Policy on Road Landslide Management

In Nepal, traffic is increasing rapidly as the road network expands, and the traffic volume is rapidly increasing. The demand for heavy equipment is increasing, especially for damage recovery along the NH03 Mid Hill Highway and the roads running through the north-south axis. Therefore, the Mechanical Branch is required to install equipment and strengthen its human resources to ensure that it can supply adequate restoration equipment. The Mechanical Branch has developed the following plans to address future challenges.

- Prioritize deployment of equipment for post-road damage recovery work and increase equipment.
- Maintain heavy vehicles continuously.
- Review of the scale and configuration of the equipment.
- Conduct HED and Maintenance Office workshops.
- Implement a skills development program to train heavy vehicle operators and mechanics.
- Proactive introduction of new technologies
- Expansion of the scope of jurisdiction of the Mechanical Branch

In addition, DOR develops an Emergency Action Plan each year to minimize the economic loss and duration of road closures. The policy is to deploy heavy equipment, personnel, and construction materials in areas with potential risk. **Figure 3-22** shows the emergency action plan prepared by DRO, Bhaktapur. It shows the plan for road deployment of telephone equipment, loaders, and excavators.



Source: DOR

Figure 3-23 Example of an Emergency Action Plan (DRO, Bhaktapur)

3.2.9. Guidelines for Landslide

Several reference documents exist in Nepal, including technical papers, reports, and guidelines on road slope issues. Geo-Environmental Social Unit (GESU), DOR 2007: Road-side Geotechnical Problems: A Practical Guide to Their Solution, developed in 2007, describes how to act after a road landslide damage, which is not mentioned in previous literature.

Table 3-19 Major Literature Related to Slope Hazards and Their Applicability as Road Geohazard Risk Management Guidelines

Name	Issued by	Year	Summary and Applicability as Geohazard Response
Road-side Geotechnical Problems: A Practical Guide to their Solution	DOR	2007	The guideline provides a decision-making framework for dealing with geotechnical and slope problems based on appropriate procedures, primarily for road engineers at the DRO level. This guideline presents a three-step problem-solving process by 1) defining the problem, 2) evaluating and analyzing the problem, and 3) presenting options for applicable technical solutions, with support from DOR and GESU.
Landslide Risk Assessment in the Rural Access Sector	Scott Wilson	2004	It summarizes the landslide risk assessment procedure, emphasizing geomorphological and geotechnical remote sensing and mapping. It also describes basic planning and highway alignment for road engineers on local roads.
Guide to Road Slope engineering measures	GESU/ DOR	2003	A joint compilation by DOR's DRO and GESU provides guidance and recommendations for continued general maintenance of roadside slopes. Geohazard response is not covered.
Overseas Road Note 16	Traffic Research Laboratory, TRL	1997	General geotechnical and geotechnical elements of mountain road construction are summarized. Guidance is provided on solution options such as slope design and protection work but does not focus on field response.
Mountain Risk Engineering Handbook	ICIMOD	1991	Extensive information on road engineering on mountain roads is presented in two volumes. However, it is not edited so that engineers in the field can easily use it as a working guideline.

Source: Road-side Geotechnical Problems A Practical Guide to their Solution 2007

3.2.10. Road Inspection

(1) Inspection of road landslide risk sites

DOR's GESU developed an input application for smartphones and computers, the following site-specific inspection format used by DRO, specified in DOR's road geohazard risk management guideline, "Roadside Geotechnical Problems: A Practical Guide to Their Solution, June 2007." The app was developed using the DOR budget and outsourced to a Nepalese information system company. The purpose of developing the app is to inspect sites with landslide problems and determine whether they can be dealt with simple non-structural and structural measures and whether it is necessary to plan full-scale structural measures.

Below are the titles of the inspection forms stored in the Annex of "DOR/GESU 2007 Roadside Geotechnical Problems: A Practical Guide to Their Solution, June 2007".

Annex A: Geotechnical Problem Definition

A1 Site Definition

A1.1 Site Definition Data Sheet

A1.2 Site Definition - Decisions and Recommendations

A2 Slope Problems

A2.1 Slope Problem Data Sheet

A2.2 Slope Problem - Decisions

A2.3 Slope Problem - Actions

A3 Erosion Problems

A3.1 Erosion Problem Data Sheet

A3.2 Erosion Problem - Decisions and Actions

DRO staff inspect landslide risk sites by the format and the superior engineer approves the inspection result. As of February 2024, the app is currently dealing with minor issues, and no data has been entered, and no paper-based data has been collected. The app cannot digitize sketches recorded on paper but can add that function if necessary.

The format has not been used since the Guide was published in 2007. As of February 2024, DOR cannot start using the app because there is no personnel to perform inspections or data input, and there is no budget, so it is necessary to train the person of DOR mainly DRO. DOR has a department in charge of staff training, but there is no budget for road landslide inspection training, so DOR is hoping for support from JICA.

(2) Pavement/Road Structure Inspection

The following format from DOR's road geohazard risk management guideline, "Roadside Geotechnical Problems: A Practical Guide to Their Solution, June 2007," are also not used. An input application is planned to be developed to facilitate their use.

DOR plan to develop the following A4. Pavement Problems and A5. Structural Problems in the Future.

A4 Pavement Problems

A4.1 Pavement Problem Data Sheet

A4.2 Pavement Problem - Decisions and Actions

A5 Structural Problems

A5.1 Structure Problem Data Sheet

A5.2 Structure Problem - Decisions and Actions

(3) Bridge inspection

DOR has already developed a bridge inspection app separately.

Bridge Management System (BMS): Data entry into the bridge register began in 2012, and by 2022, data for 2,127 bridges have been entered. It has not been updated since 2023.

(http://bms.softavi.com/dashboard/guest_report_bi/0)

Bridge Site Monitoring (BSM): Bridge inspection forms have a search function for inspection data since 2014, but no data has been stored.

(<http://bsm.softwel.com.np/>)

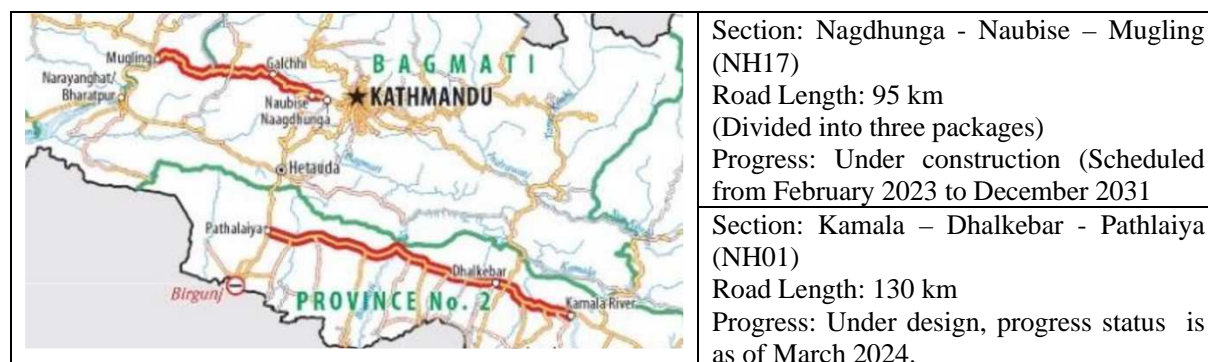
3.3. Status of Geohazard Risk Management Assistance International Organizations and Other Donors

Various donor agencies are actively supporting the government of Nepal in road geohazard risk management. The involvement of these diverse donor countries in ongoing initiatives is described in the following sections:

3.3.1. WB

WB has supported the development of NH17 Nagdhunga-Naubise-Mugling Section (95 km) and NH17 Kamala-Dhalkebar-Pathlaiya Section (130km length). WB also assisted Narayanghat-Mugling with 36 km of road widening as Phase 1 which was completed in 2021. The works included several cutting works and slope engineering measures. A landslide occurred at the 17 km station from Narayanghat due to river erosion, and engineering measures were designed, including 16 m depth concrete piles. At the 21 km station, the Mauri Bridge had a debris outflow in 2022. The elimination of debris under the bridge was conducted after the debris flow event. According to the interviews with WB, although WB continues to support these projects, there appears to be little resistance to other donors providing additional support to address the remaining risks along the highway.

At present, WB operates the Strategic Road Connectivity and Trade Improvement Project (SRCTIP), from 2020~ currently being implemented, total USD 450 million, which covers two separate sections as presented below:



Source: Edited by JICA Survey Team based on the information by WB

Figure 3-24 Target Sections and Progress of SRCTIP

Given the high geo-hazard risk, the project has been designed to implement a comprehensive approach mainstreaming resilience in the civil works and the institutional strengthening aspects of the project. Adaptation measures are summarized below.

Table 3-20 Project Components and Response to Climate Change

Components	Adaptation Measures
Component 1. Trade Facilitation	
Sub-component (a): Provision of equipment and training, and construction and/or renovation of lab buildings at key border sites with the target of achieving international accreditation in selected parameters	Cross-border facilities will be designed considering climate risks (earthquakes). In addition, the design of the 4.5 km access road will integrate climate resilient features, in particular slope protection measures and drainage reinforcement where needed.
Component 2: Regional Road Connectivity Improvement	
Sub-component (a): Improvement of the existing Nagdhunga-Naubise-Mugling (NNM) road to a two-lane standard with one-meter paved shoulders	This subcomponent will support the adoption of engineering measures to improve the climate resilience of the corridor section. Green and resilient technology has been mainstreamed in the design and will be strictly applied during construction and maintenance. All roadsides and water crossing sites will be provided adequate drainage facilities and bioengineering solutions to the highest resilience standard possible.
Sub-component (b): Upgrading of the Kamala-Dhalkebar-Pathlaiya (KDP) road from two lanes to four lanes.	This subcomponent will similarly support the adoption of engineering measures to improve the climate resilience of the corridor section. Green and resilient technology has been mainstreamed in the design and will be strictly applied during construction and maintenance. All roadsides and water crossing sites will be provided adequate drainage facilities and bioengineering solutions to the highest resilience standard possible.
Sub-component (c): Implementation of a safe corridor demonstration program, covering a length of 250-300 km of the Strategic Road Network (NH) including the NNM and KDP roads, for which the program will include support for enhanced enforcement of traffic rules and post-crash response.	<p>Contingency planning is critical to help build resilience. This subcomponent will thus support both preventions, with warning signage for landslide and flooding risks, and action in case of emergency/major road geohazards, with the establishment of emergency response crews to clear landslide blockage, rescue victims, and repair damaged spots.</p> <p>Contingency measures will be implemented along the proposed Safe Corridor Demonstration Program (SCDP) roads. It includes ICT-based measures to support communication messages utilizing variable message signs (VMS) systems/strategy towards the road users before (based on weather forecasts when possible) and during geohazard events.</p>

Source: WB (SRCTIP)

Disaster management supported by WB apart from SRCTIP is shown below.

Strengthening Resilience to Geohazards in Transport⁹: WB GFDRR held the Second Annual South-to-South Learning Workshop on Strengthening Resilience to Geohazards in Transport in November 2017. During this session, technology was shared regarding the Geohazard Risk Assessment for Banepa (Dhulikhel)-Sindhuli-Bardibas Road, provided by Japan's grant aid. In addition, an action plan was developed to pilot the Road Geohazard Risk Management Handbook drafted by WD GFDRR with DOR, the Department of Water Induced Disaster Management (DWIDM) at the time, and the Department of Local Infrastructure Development & Agricultural Roads (DoLIDAR) at the time.

⁹ <https://documents1.worldbank.org/curated/zh/536711527089370922/pdf/126508-WP-P160578-PUBLIC-Nepal-v17-SP.pdf>

Mitigating Geohazard Risk to Help Save Lives in Nepal¹⁰: Supported the establishment of a geohazard early warning unit under the National Emergency Operation Center of NDRRMA. The Geohazard early warning unit disseminates landslide warning information via social media such as SMS, TV, etc.

The Green, Resilient, and Inclusive Development (GRID)¹¹: The Government of Nepal signed the Katmandu Declaration on GRID in 2021, supported by WB. Sixteen development partners, including ADB, ICIMOD, and UN Nepal, participated, and USD7.4 billion in ongoing and future support has been identified. The GRID strategic action plan includes Transition 2: Disaster Risk Management, Preparedness, and Social Protection: Build an early warning system, layer disaster risk financing, and enhance social protection systems to make them shock responsive. Transition 4: Resilient Roads and Sustainable Transport; Resilient roads, including geotechnical, biophysical, hydrological, and metrological and engineering input in design, improve residence planning at the network level, plan for redundancies and promote landscape-level and nature-based solutions.

3.3.2. ADB

(1) South Asia Subregional Economic Cooperation

The East-West Corridors¹²: From 2019 to 2022, the project cost: USD256 million, mainly bridge on the NH01 East-West Highway were renewed and maintained in cooperation with the WB.

Mugling-Pokhara Highway Improvement Phase 1 Project¹³: Implemented in May 2021, the project cost: USD195.5 million, funding for the NH17 4-lane expansion project between Mugling and Pokhara (however, the 8km section west of Mugling is not included in project). The 88.33km road development project from Aambukairani to Pokhara has already started, and the remaining 8.256km is in the procurement stage.

(2) Disaster Management Technical Assistances

ADB projects that include technical assistance for disaster management are listed below.

Rural Connectivity Improvement Project¹⁴: In progress since 2017, project cost: USD101million, this project supports the construction of rural roads in Nepal, including slope protection measures to reduce the risk of landslides.

Strengthening Capacity for Livable and Resilient Cities¹⁵: Currently being implemented from July 10, 2023, to May 31, 2027, Project cost: USD 3.6 million, this project supports developing climate-resilient infrastructure in Nepal, including slope protection measures.

ADB is developing a report for the proposed National Highway Network (NHN) Expansion Plan prepared under the Technical Assistance project - Master Plan for Road Connectivity. The objectives of the technical assistance are to support Nepal in the development of a road masterplan and, in particular, (i) development of the National Highway Network (NHN) expansion plan, (ii) preparation of the Priority Investment Plan (PIP) for 2023–2033.

¹⁰ <https://blogs.worldbank.org/en/endpovertyinsouthasia/mitigating-geohazard-risk-help-save-lives-nepal>

¹¹ <https://thedocs.worldbank.org/en/doc/5f3ac1d71583fab500da942caea11dac-0310012023/original/GRID-Flyer-Nepal.pdf>

¹² <https://www.adb.org/sites/default/files/publication/159827/nep-sasec-road-connectivity-project-brief.pdf>

¹³ <https://www.adb.org/projects/52097-002/main>

¹⁴ <https://www.adb.org/projects/48218-003/main>

¹⁵ <https://www.adb.org/projects/57058-001/main>

3.3.3. The Swiss Agency for Development and Cooperation (SDC)

SDC is implementing the following projects for disaster management.

The Integrated Watershed Management Project in the Sindhupalchok District: This project is helping to improve the management of the Sindhupalchok watershed by investing in slope protection measures, improving drainage systems, and promoting sustainable land use practices.

The Landslide Risk Management Project in the Gorkha district: This project is helping to reduce the risk of landslides in the Gorkha district by strengthening the country's early warning system, improving slope stabilization measures, and raising awareness of landslide risks among the public.

The Community-Based Natural Resource Management Project in the Rasuwa district: This project is helping to improve the management of natural resources in the Rasuwa district by investing in slope protection measures, promoting sustainable land use practices, and raising awareness of environmental issues among the public.

The Siddhababa Tunnel Project: the rockfall Hazard along the Siddhababa Section of Siddhartha Highway (NH 47) design is assisted by SDC.

These projects are funded by the SDC's **Climate Change and DRR** program. The program is committed to helping Nepal reduce its vulnerability to climate change and disasters and improve the safety of its people.

3.4. Review of Technical Cooperation, ODA Loan, and Grant Aid Projects Related to Disaster or Road Geohazard Risk Reduction

3.4.1. Grant Aid "Slope Engineering Measures on Sindhuli Road" in Nepal

A Summary of the project is shown in **Table 3-21**.

Table 3-21 Summary of Rehabilitation of Sindhuli Road Affected by Earthquake

	Summary
Project Name	The Project for the Rehabilitation of Sindhuli Road Affected by Earthquake
Project Period	October, 2018~February, 2021
Project Section	Nepal, Sindhuli road (NH13, 3 sites of Sindhuli Bazar – Khurkot section, two places of Khurkot – Nepalthok section)
Project Cost	1,047 million JPY
Summary of Construction	Landslide protection works at five sites on the road damaged by the 7.8 magnitude earthquake that occurred on April 25, 2015.

Source: JICA Survey Team

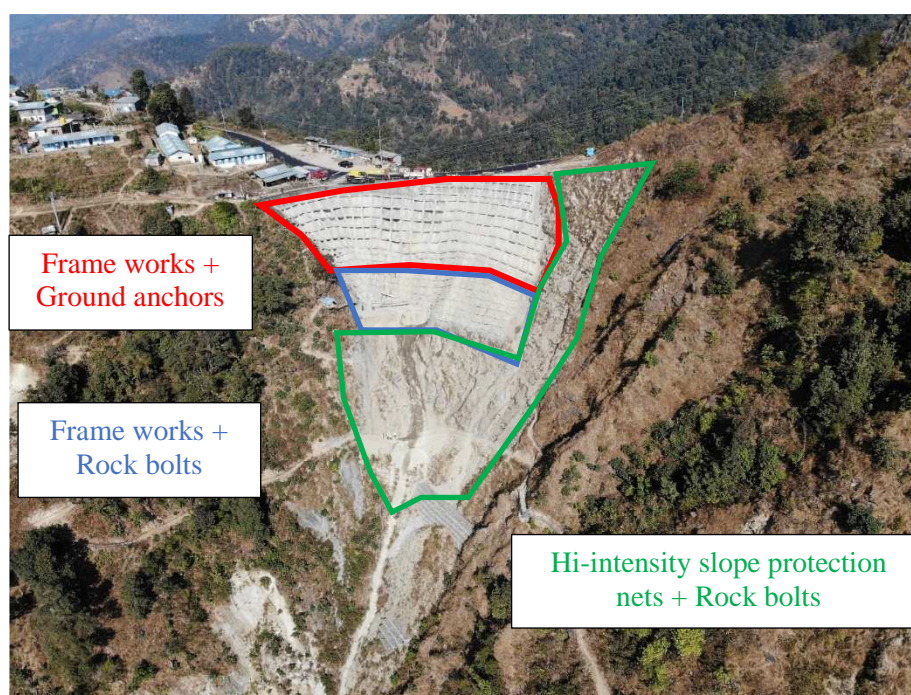
Sindhuli Bazar - Khurkot section Sta. 17+400 is the site where the slope collapse occurred. The slope surface tensioning work using mortar, stones, and reinforcing bars had been constructed adjacent to the road on this slope. Still, the 2015 earthquake widened minor cracks in the slope protection work, and there were concerns that the road body would collapse due to deterioration of the slope protection work. Therefore, the "slope work + anchor work" and "slope work + rock bolt work," which have a proven track record in Japan, were applied as methods with high strength and durability against large-scale slope collapse. In addition, "high-strength netting + rock bolting" was used to prevent erosion on the side and lower slopes, where there were concerns that the extent of collapse would increase.

Table 3-22 shows a summary of the slope stabilization works.

Table 3-22 Sindhuli Bazar - Khurkot Sta.17+400 Summary of Slope Stabilization Works

Works	Detail of Slope Stabilization Works
Frame works + Ground anchors	Frame works 1,270m ² , height/ width 50cm
	158 Ground anchors, total length of ground anchors 1887m (Average length approx.20m)
Frame works + Rock bolts	Frame works 1062m ² , Height/ width 30cm
	300 Rock bolts, length 3m
High-intensity slope protection nets+ Rock bolts	High-intensity slope protection nets, 2800m ²
	300 Rock bolts, length 3m
Scaffolding	Scaffolding by single-pipe
Bioengineering	1352 sandbags with seeds
Gabion retaining wall	Gabion 345m ³
Pavement works	Asphalt pavement 419m ²

Source: JICA Survey Team



Source: JICA Survey Team

Figure 3-25 Engineering Measures at Sta.17+400 in Sindhuli Bazar - Khurkot

Before Construction	After Construction
	
<p>Date of shooting: May 3, 2017, whole view: Situation before project implementation</p>	<p>Date of shooting: January 29, 2022, full view: Situation after completion</p>
	
<p>Date of shooting: May 3, 2017; frame works + ground anchors construction: Situation before project implementation</p>	<p>Date of shooting: January 29, 2022; frame works + ground anchors: Status after completion</p>
	
<p>Date of shooting: May 3, 2017, frame works + ground anchor construction (from below): Situation before project implementation</p>	<p>Date of shooting: January 29, 2022, frame works + ground anchor construction (from below): Status after completion</p>

Source: JICA Survey Team

Figure 3-26 Before and After Construction of Engineering Measures at Sta.17+400 in Sindhuli Bazar - Khurkot

Table 3-23 shows the advantages of the applied slope stabilization engineering measures compared to concrete and stone lining and concrete shotcrete. Both tensioning and concrete shotcrete are effective in preventing erosion, but they do not deter surface collapse.

Table 3-23 Advantages of Adopted Slope Stability Engineering Measures

Type of Slope Engineering Measures	Advantages
Frame works	<p>To deter surface collapse to some extent.</p> <p>An uneven slope surface is less likely to become weak structural points, and the frame works can be adjustable and constructed without filling a certain degree of unevenness of the slope surface. It reduces the soil required for slope preparation by cutting it before construction.</p> <p>The frame adheres well to the ground and is resistant to scouring during heavy rains.</p> <p>The greening of the inside of the frame is possible and is highly harmonized with the natural environment.</p>
High-intensity slope protection nets	<p>Protected from rock falling.</p> <p>Suitable for construction in high places because it does not require large equipment.</p> <p>Because of the simplicity of construction, even on the mountainside slopes of roads, in many cases, construction can be done without traffic control, using only simple protection facilities such as barricades.</p> <p>CO² emissions in comparison with concrete structures can be significantly reduced. Because cement generates large amounts of CO² during its manufacturing process, and this method does not require foundation excavation and soil disposal transportation, resulting in it can be reduced the CO² emission.</p> <p>The entire area to be treated can be greened, and CO² absorption can be expected.</p>
Ground anchors	To deter landslides deeper than 2m.
Rock bolts	Adding or reinforcing the surface collapse prevention by attaching to slopes and high-strength nets.

Source: JICA Survey Team

The features of the areas where slope engineering measures were implemented are as follows:

- This area's slope is steep and uneven, and the geology is weathered and fractured due to a derived fault.
- Anchor and rock bolt works were constructed using temporary scaffolding to cope with the steep terrain, and the frame work that could be adjustable for the uneven slope surface was adopted for areas where the frame work could not be placed due to large uneven slope surfaces, manual excavation, and concrete padding were used.
- The high-intensity netting can be installed with ropework because the drilling machine is lightweight, and ropework was used in this area.

Frame works, anchor works, rock bolting, and high-intensity netting have been used in similar steep terrain conditions and fragile geological conditions in Japan and can be adapted to similar conditions in Nepal.

The procurement method of materials for the adopted engineering measures method is summarized in **Table 3-24**. The workability and durability are the advantages of Japanese products.

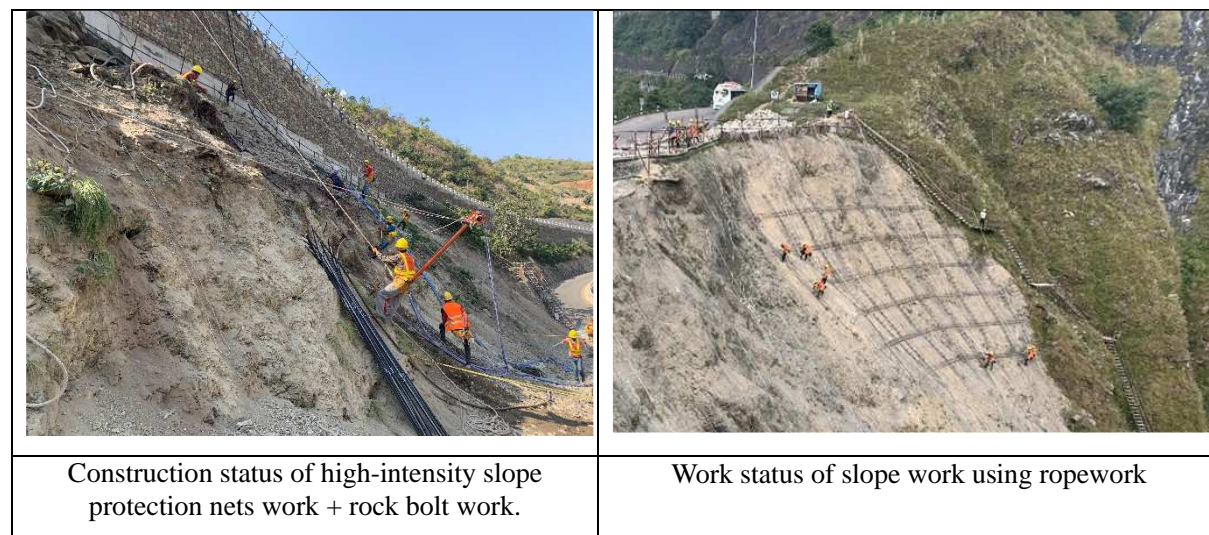
Table 3-24 Procurement Method of Materials Used for Slope engineering measures

Materials	Import Source	Description
Ground anchors	Japan	Products with double corrosion protection are only made in Japan.
Rock bolts	Japan	The threaded joint deformed steel bar is only made in Japan (it is possible to tighten the lock nut on the front and has excellent workability)
Frame work	Japan	The product that includes a simple frame work and is easily adjustable for uneven slope surfaces is only made in Japan.
Wire mesh	Japan	A diamond-shaped wire mesh suitable to adjust for uneven slope surfaces is used (recently, it is also available in Nepal).
High-intensity slope protection net	Japan	At that time, high-strength nets were only made in Japan (recently, French and Italian products have also been available in Nepal).
Single pipe	India	Since it will be used in large quantities, it was decided to use Indian-made products, which have a low total cost, including transportation costs (there is the disadvantage of being heavier than Japanese-made products).

Source: JICA Survey Team

The local contractor has worked as a subcontractor for Japanese contractors for many years in the Sindhuli road construction project. The technology transfer to the foreman class workers is being carried out reliably, and the instructions from the foreman to the local workers are being given appropriately. The technical level and safety management ability are high.

Nepalese people are highly adaptable to slope work, especially rope work (see **Figure 3-27**). Initially, they were afraid of ropes. However, once they understood that ropes are reliable (cannot be cut), they could perform tasks like Japanese skilled workers, although there were individual differences. As mentioned in the above section, if proper guidance and management are provided, the quality and safety of Nepalese workers can be ensured.



Source: JICA Survey Team

Figure 3-27 Implementation Status of Slope Protection Work by Nepalese Worker

In Japan, local workers have several safety measures to prevent accidents. These include safety meetings, toolbox talks, and training sessions. By following these safety measures, even the most challenging projects can be completed without incident. It is believed that repeatedly learning about safety objectives, precautions, and accident cases can instill a safety culture among employees.



Source: JICA Survey Team

Figure 3-28 Safety Management Status

Based on the above, slope works, anchor works, rock bolting, and high-strength netting are evaluated as recommended technologies that can be applied in Nepal.

Findings from this project and responses include the following.

- Frame work and high-intensity slope protection nets are useful in Nepal. It is considered possible for Nepalese contractors to perform the work through training, and the technology dissemination is recommendable. Small-scale collapse-prone slopes are recommended to adopt the simple frame work, although it is less stable, and to use it as a starting point for its widespread.
- Although not all of the frame work, ground anchors, rock bolting, and high-intensity slope protection nets are Japanese technologies, it is necessary to publicize the superiority of Japanese products in terms of workability and durability and that they contribute to a reduction of construction and maintenance costs. However, Japanese products are not usually selected based on comparisons of equipment and material costs only. Therefore, it is necessary to promote that Japanese products contribute to reducing maintenance costs. It is desirable to specify performance and quality requirements in procurement specifications so that products of inferior quality and workability are not adopted in procuring contractors and equipment.
- In this case, the local contractor, the first-tier subcontractor in Nepal, had good technical and safety management skills at the highest level in Nepal. Careful selection of the contractor is necessary.
- The risk of accidents in slope construction is high, and safety meetings and toolbox meetings (TBMs, pre-work meetings) must be well conducted.
- Training in special operations on steep slopes is also essential.
- A self-registering weather meter should be installed in the construction management field office to visually determine from a safe site whether there are any slope anomalies, such as work stoppage due to rainfall before work resumes.

3.4.2. Technical Cooperation, Technical Development, etc.

(1) Technical Cooperation Nepal "The Project for Construction of a Water Induced Disaster Prevention Technical Center (DPTC)" in Nepal

A summary of the project is shown in **Table 3-25**.

Table 3-25 Summary of Technical Cooperation "The Project for Construction of a Water Induced Disaster Prevention Technical Center (DPTC)"

	Summary
Project Name	The Project for Construction of a Water Induced Disaster Prevention Technical Center (DPTC)
Project Period	October 1991 - March 1999
Project Cost	Total JPY6.33billion (Equipment hand over JPY3.95 billion, Local activity JPY2.38 billion)
Support Summary	Research, testing, training, and database development related to erosion control, landslides, and rivers
Experts	Long-term experts 16persons, Short-term experts 66 persons
Number of Trainees	37 persons

Source: JICA Survey Team

This project is a technical cooperation with the Government of Nepal's Disaster Prevention Technical Center (DPTC) as a counterpart(C/P).





DPTC has conducted many studies and research through this technical cooperation, trial construction, training, and database formulation as a technical center in flood and sediment control.

DPTC, through the Department of Water Induced Disaster Prevention/Management (DWIDP/ DWIDM), is transitioning the Flood Control Division to DHM and DWRI and the Sediment Control Division to DWRI. The disaster database has been transferred to MOHA. Disaster awareness and education have been transferred to NDRRMA. The results of the technical cooperation have been transferred to the 10-member Water Hazard Management Division within DWRI and the 3-member Landslide Management Section within the Groundwater and Geology Division. DWRI is cooperating with NDRRMA for disaster awareness and education. The results of the technical cooperation have been also handed over to the four members of the Flood Forecasting Division within the DHM, which implements awareness programs on flood forecasting, early warning, and flood-avoidance development. Although the Nepalese government has changed its structure, the technical materials prepared in this project have been utilized in the disaster management administration in Nepal, and the activities are continuing.

Debris flow control works were carried out in the erosion control field model areas. We visited one of these districts, the Nall Khola area, guided by two C/P members at the time. Although the engineering measures are functioning, the structures must be repaired and reinforced. It is considered necessary to establish a system in which DWRI provides technical guidance for the maintenance of small-scale engineering measures to disaster in such areas based on requests from local governments and funded by local government budgets.

Nallu Khola (Gabion Check-dam) Constructed in 2003

14 check dams were installed to control soil erosion. Most are functioning properly, but one dam is leaning and will likely collapse. Foundation erosion is possible cause. Possible engineering measures include filling the eroded portion with cobblestone filled with mortal, or soil cement. The gabion wire in the water passage was also partially corroded. Using a high zinc plating wire is necessary for the gabion wire in the water passage. At the check dam on the upstream side, leveling concrete was applied to the paddy field tapping part, functioning effectively.

	
<p>The situation of the downstream check dam. The sediment prevention function is maintained.</p>	<p>Enlargement of the drainage part. The gabion wire has corroded and partially disappeared.</p>
	
<p>The status of the upstream check dam. It is sedimented, and the sediment runoff prevention function is maintained.</p>	<p>Leveling concert of the water passage part. Wear, etc., is not recognized.</p>

Source: JICA Survey Team

Figure 3-29 Nallu Khola Field Survey Photo

(2) Development of Erosion Control and Landslide Investigation Technology using Remote Sensing

A summary of the project is shown in **Table 3-26**.

Table 3-26 Summary of Development of Erosion Control and Landslide Investigation Technology using Remote Sensing

Summary	
Project Name	Development of erosion control and landslide investigation technology using remote sensing
Project Period	Reported on March 1996
Support Summary	In response to the June 1993 landslide in the Ratu River in the Siwalik region, Japanese expert used satellite remote sensing technology and geographic information systems to understand the actual situation of ground erosion and landslides.
Experts	Japan Society of Erosion Control Engineering

Source: JICA Survey Team

This research was part of the “Flood Control and Sabo Technology Center Project.” An erosion model was created using aerial photographs, helicopter photographs, field reconnaissance data, and satellite remote sensing data obtained from DPTC. The Japan Society for Erosion Control includes university officials and private consultants.

This research was a major achievement at the time, serving as a technical document that sounded the alarm about the increasing number of farmers living on the mountainsides, causing deforestation and erosion of mountains. As a lesson learned, although we collaborated with DPTC in data acquisition, creating a manual for the analysis method became an issue for the future.

(3) Technical Cooperation “Disaster Mitigation Support Program Project” in Nepal

A summary of the project is shown in **Table 3-27**.

Table 3-27 Summary of Technical Cooperation Nepal “Disaster Mitigation Support Program Project”

Summary	
Project Name	Disaster Mitigation Support Programme Project
Project Period	September 1999 - August, 2004
Support Summary	Improving awareness of local disaster prevention by developing low-cost disaster prevention methods tailored to regional characteristics and promoting community-participatory disaster prevention activities and education.
Project Cost	Equipment hand of JPY0.92 billion
Experts	Long-term experts: 14 persons; Short-term experts: 40 persons
Number of Trainees	26 persons

Source: JICA Survey Team

This project is a technical cooperation carried out with the Department of Water-Induced Disaster Prevention (DWIDP), a successor agency of DPTC, as a C/P

The results of this technical cooperation of development of low-cost engineering measures to disaster tailored to regional characteristics and disaster management activities with community participation are currently being passed on to DWRI. They are being carried out in the guidance on low-cost engineering measures in response to the requests of local government. Currently, NDRRMA is the implementation body for raising awareness of local disaster management through promoting community-participatory disaster management activities and education, and DWRI is providing technical cooperation.

One of the successful lessons learned from the inability to obtain sufficient funds for engineering measures is that the development of low-cost engineering measures for disaster was made possible by allowing residents to participate.

To strengthen the disaster recovery system, DWIDP, as the secretariat of the Disaster Investigation Committee, which is made up of eight related organizations, has created a system to select model areas from among disaster recovery candidate sites requested by related organizations and local governments. A system has been established to advise residents on disaster prevention and mitigation. These can also be cited as fruitful lessons. NDRRMA is currently taking over the aggregation of disaster recovery requests.

DWIDP has experience in implementing disaster risk reduction projects by forming projects based on the results of this project at the request of the DOR regarding road geohazard risk reduction, engineering measures for debris flow for road-crossing mountain streams, and roadside river erosion. DWRI has taken over this function, and new projects are expected to be implemented.

Two engineering measures were implemented to slide-type landslides, and flow-type landslides including debris flow, mainly using gabion, and bioengineering in this technical cooperation project. The JICA Survey Team conducted field inspection for the two sites of engineering measures conducted in 2003 with the two former C/P members of the project, and the effects and challenges lesson learned of the engineering measures were extracted.





Dahachok (Bioengineering Work + Check Dam by Gabion) Constructed in 2003

The valley was deep and overgrown with bioengineering, so it was impossible to confirm the facilities' condition directly. However, according to an interview survey of the residents, no soil erosion has been observed since the construction, and the engineering measures are said to be effective.

Soil cement was used to improve the subgrade to prevent erosion of the gabion retaining wall. It can be assumed that this had a positive effect. In addition, the area where bioengineering work is successfully grown, and no erosion was found. It was confirmed that the bioengineering work was effective.

Dhapakhel (Check Dam with Gabion) Constructed in 2003

Two check dams were constructed in the area to prevent sediment runoff. Sediment has accumulated upstream of the check dams, and it is evaluated that the purpose of preventing sediment runoff has been achieved. However, the gabion wire is rusty, and part has disappeared. Therefore, paying attention to the material selection and the amount of zinc plating used for rust prevention for long-term performance maintenance is necessary. In addition, the front foundation part of the check dam is eroding. It is necessary to consider erosion prevention work.

	
<p>Status of upstream check dam</p>	<p>Expansion of the upstream check dam. Gabion wires are corroded and partially missing.</p>
	
<p>Downstream check dam situation. The front foundation is eroded.</p>	<p>Downstream check dam situation. Gabion wires are corroded and partially missing.</p>

Source: JICA Survey Team

Figure 3-30 Dhapakhel Field Survey Photos

(4) The Study on Disaster Risk Management for Narayanghat Mugling Highway

A summary of the project is shown in **Table 3-28**.

Table 3-28 Summary of “The Study on Disaster Risk Management for Narayanghat Mugling Highway”

	Summary
Project Name	The Study on Disaster Risk Management for Narayanghat Mugling Highway
Project Period	September 2007 - February, 2009
Support Expenditures	JPY 120 million (consultant contract)
Support Summary	Formulation of a disaster prevention management plan for the Narayanghat-Mugling Highway that was affected by the torrential rains on July 30, 2003
Experts	Short-term experts: 14 persons; Short-term experts: 40 persons

Source: JICA Survey Team

This study clarified the risk of road landslides in the study area, formulated an essential strategy for risk management, and confirmed the validity of landslide engineering measures projects based on the basic strategy. The study team transferred technology and knowledge and provided engineering measures guides to the C/Ps, the Department of Water-induced Disaster Protection (DWIDP) of the Ministry of Water Resources, and the then DOR, Ministry of Physical Planning and Works (ministry name now changed into MOPIT) at that time.

A steering committee chaired by the Under Secretary of the Ministry of Water Resources and composed of DWIDP, DOR, WB, ADB, etc., was held at the start and end of the study. The study policy was approved at the beginning, and the basic strategy was adopted at the end of the study.

DWIDP and DOR each selected five engineers as C/P team members.

A technical working group of nine C/P members assisted the steering committee. The team worked collaboratively with Japanese experts, and face-to-face discussions were influential in advancing technical cooperation.

Investigations under the above structure strengthened the DOR and DWIDP (currently DWRI) collaborative relationship regarding road DRR. It was confirmed that DWIDP will support DOR's DRR project or will be the project owner for road debris flow engineering measures for areas beyond 25 m from the center of the road, riverbank protection measures on the river side of the road, and landslide engineering measures. DWIDP carried out road DRR projects on Narayanghat Mugling Highway and Sindhuri Road as a project entity, and the results of this technical cooperation were put to good use. Flood control and erosion control technology has been handed down from DWIDP to DWRI, and there is a need to promote collaboration between DWRI and DOR.

A risk assessment survey was conducted at 305 sites along the road (134 mountainside slopes, 78 mountain stream crossings, and 93 riverside slopes). The risk was calculated using the annual potential loss amount as a quantitative index. This calculation method was later used in other JICA projects and incorporated into the Road Geohazard Risk Management Handbook (WB GFDRR 2020).

Based on this method, an analyst can conduct a cost-effectiveness analysis of risk reduction measures for road landslides using NPV, an index of the effectiveness of road landslide risk reduction measures. It is believed that an analysis will provide a better explanation for selecting priority projects for landslides.

DOR has since used the results of this study to improve the safety of the route by implementing landslide engineering measures as part of the road repair project with WB funding. There are still some technically complex areas regarding remaining risks, and Japan's support is necessary to reduce risks efficiently.

Landslide risk management education, including evacuation drills and simple soil preservation work, was conducted as a pilot to preserve both the road and farmland on the upper slope of the road in the village for residents in Kabilash village along the Narayanghat-Mugling Highway (18 people died and 69 houses collapsed due to heavy rains in 2003). Landslide risk management education was carried out at the elementary school and was widely recognized within the village. As a village leader, we learned that it is adequate to discuss landslide risk management policy with teachers and spread geohazard risk reduction education through classes and village events. The construction work to prevent sediment runoff was also accomplished by procuring materials using the village's budget and carrying out the construction work by villagers. This experience has been passed down from DWIDP to DWRI.

(5) Technical Cooperation Nepal “The Project for the Operation and Maintenance of Sindhuli Road”

A summary of the project is shown in **Table 3-29**.

Table 3-29 Summary of Technical Cooperation Nepal “The Project for the Operation and Maintenance of Sindhuli Road”

Item	Summary
Project Name	The Project for the Operation and Maintenance of Sindhuli Road
Project Period	December 2011 - January 2016
Project Cost	JPY646 million (consultant contract)
Support Summary	Assistance to the DOR and DWIDP to strengthen their operation and maintenance capabilities, including implementing landslide engineering measures such as road restoration.
Experts	Short-term experts: 16 persons, Short-term experts: 95.9 persons-months
Number of Trainee	Nine persons

Source: JICA Survey Team

The experts supported the strengthening of the DOR of the Ministry of Public Infrastructure and Transport (MOPIT) and the DWIDP of the Ministry of Irrigation (MOI) at the time by providing operational and maintenance management skills, including how to implement slope engineering measures and landslide engineering measures such as road restoration.

In the project, it is agreed that DOR would carry out landslide engineering measures works for road landslides within 25 m of road right-of-way width, and if the width exceeded that, DWIDP would carry out landslide engineering measures works. This collaborative relationship continues between the current DOR and DWRI. It is necessary to encourage the promotion of actual project development.

Road landslide engineering measures were implemented at 35 sites within the project. DOR implemented measures against collapse, rockfall, road collapse, and the 2015 large-scale earthquake, while DWIDP implemented measures against debris flows, landslides, and river erosion. Of these, DOR was in charge of 26 sites (15 with JICA funds and 11 with DOR funds), and DWIDP was in the order of 9 sites (3 with JICA funds and 6 with DWIDP funds).

The following are the challenges and lessons learned from this project regarding implementing road landslide risk reduction works.

Immediately after the river revetment and riverbed protection work began, strong requests were received from the local community regarding the problem of erosion of farmland on the opposite bank. DWIDP agreed to undertake the engineering measures using its funds and carried them out. This incident indicates the importance of sufficient attention to be paid to local explanations and consensus building from the planning stage to prevent from major dispute with local communities after the commencement of the construction work. River engineering measures for road erosion protection also involve riverbank erosion and water use issues such as irrigation, so the current participation of DWRI is essential.

The project has a track record of horizontal drilling for water drainage during landslide prevention work to a depth of 50m using a small excavator that can be carried out in Nepal to avoid cutting down trees. In this way, construction methods and the use of small-sized equipment should be considered to minimize the amount of felling required during construction.

(6) Technical Cooperation “Project for Capacity Development on Flood Control for Disaster Risk Reduction in Sunsari and Morang Districts” in Nepal

A summary of the project is shown in **Table 3-30**.

Table 3-30 Summary of Technical Cooperation Nepal “Project for Capacity Development on Flood Control for Disaster Risk Reduction in Sunsari and Morang Districts”

Summary	
Project Name	Project for Capacity Development on Flood Control for Disaster Risk Reduction in Sunsari and Morang Districts
Project Period	January 2024 – ongoing
Support Summary	Support to the DWRI of the Ministry of Energy, Water Resources and Irrigation (MOEWRI) in developing flood control plans and projects that contribute to risk reduction for flood disasters and in strengthening project implementation capacity
Experts	Approximate 46 person-months

The project targets three river watersheds (Kesharia River, Singhiya River, and Lohandra River) in Sunsari and Morang Divisions. These objectives are:

- Facilitate the preparation of hazard and risk maps for flooding
- Facilitate the development of flood control plans for flood risk reduction through engineering and non-engineering measures
- Facilitate investment in disaster risk reduction for implementing flood control plans
- Establish a mechanism to conduct planning, implementation, and maintenance of flood control projects, including coordination among related agencies.
- Develop flood control plans and projects that contribute to risk reduction in the river watersheds covered by the DWRI/MOEWRI
- Strengthen the capacity to implement projects
- Contribute to risk reduction for future flood and integrated community development

In the river watersheds targeted by this project, it has been confirmed that the bridge has caused a reduction in flow capacity at the time of the bridge. DWRI, the C/P of this project, needs to monitor and coordinate road and bridge construction projects as the main management agency. It will acquire the authority and capacity to coordinate and consult with road managers and other relevant agencies for the effective implementation of the flood control plan.

3.4.3. ODA loan "Nagdhunga Tunnel Construction Project" in Nepal

It is a tunnel construction project under construction in Nepal. A summary of the project is shown in **Table 3-31**.

Table 3-31 Summary of ODA Loan Project “Nagdhunga Tunnel Construction Project”

Summary	
Project Name	Nagdhunga Tunnel Construction Project
Project Period	December 2016, Ongoing
Project Section	Nagdhunga Pass (Kathmandu - Naubise)
Provision Amount	JPY16.636 billion
Summary of Construction	Tunnel Construction, access, and bridge construction Tollgate, Management Office, Michi-no-eki construction, utility construction

Source: JICA Survey Team

Procurement of most materials for construction in the Nepalese domestic market with a few exceptions, and the cement produced in Nepal is of good quality. The main imported materials are H steel (Thailand), explosives and diesel oil (India), and geotextile reinforcement (Japan).

The challenges and lessons learned from the survey, detailed design, bidding, and construction stages of projects in Nepal were as follows.

[Detailed design]

To determine the support pattern for the tunnel, it was necessary to conduct a seismic wave survey. However, using explosives required time to obtain a permit for the use of explosives from the Nepal Army and to obtain an agreement for the participation of the Nepal Army. It resulted in a delay in the survey. The client government should select stakeholders appropriately before starting the survey and forming a consensus.

[Tender and bidding]

The consultant who conducted the preparatory survey considered utilizing Japanese technology by adopting AGF (All Ground Fastening Method: small-diameter long-length steel pipe pre-receiving work). However, there are similar construction methods in other countries, and it was difficult to explain to the client government that there is no experience with AGF in the bidding evaluation. It is necessary to select a construction method that confirms the superiority of Japanese technology.

It was difficult to confirm foreign companies' work history and experience in their bidding documents. One of the evaluation items was "Tunnel construction experience within 2D below the operational two-lane road." The coordinates of the construction site were requested in the bid document submission form, but it was impossible to confirm them on the Web. It is particularly difficult to confirm the construction record of underground structures such as AGFs mentioned above. It would also be effective to establish a system in which a third-party organization confirms and certifies the facts of construction results.

[Construction]

Due to a slope collapse that occurred in 2021, another collapse occurred at the west portal area and engineering measures work has been required. However, it was hard to obtain the consent of the landowner of land above the slope and it took time for coordination of land acquisition. It resulted in affecting the progress of the entire project. To ensure smooth implementation of the project, it is necessary to foresee the possible risks and the possibility of additional acquisition and explain to the project proponent to obtain their prior understanding.

3.5. Basic Information on Academia in Nepal Based on Industry-Government-Academia Collaboration

3.5.1. Tribhuvan University

Tribhuvan University was established in 1959 as the first university in Nepal and is the largest comprehensive university in Nepal, with over 150,000 students. The university places importance on research and exchanges with other universities and institutions in Nepal and abroad. Concerning landslides, it has agreements with Kyoto University, Ehime University, etc., and it collaborates through activities such as study abroad programs and academic conferences and building cooperative relationships.

Research related to landslides is mainly conducted in the Graduate School of engineering and the Central Faculty of Geology.

The Graduate School of engineering was established in 1972, and it has four campuses and ten private colleges affiliated with the Graduate School: The affiliate schools receive visiting lectures from the Graduate School. The Central Campus is located at Pulchowk Campus.

The Graduate School of Engineering has 12 graduate schools. Three of these graduate schools are under the Department of Civil Engineering and conduct research related to landslides: (1) Disaster Risk Management Course, (2) Geological Engineering Course, and (3) Water Resources Engineering Course. There are 16 staff members, including professors, and 24 students in each of course of grade. Courses in each faculty are (1) Water Induced Disaster I and II, (2) Headworks and Sedimentation Engineering, (3) River and Sedimentation Engineering, (4) Physical Environmental and Natural Hazards, (5)

Landslides, (6) Mountain Risk Engineering, (7) Rock Slope Engineering, (8) Ground Improvement Techniques (9) Geographic Information System (GIS).

The faculty of Geology was established in 1968 for the bachelor's program and in 1976 for the master's program and is located at the Kirtipur campus.

Many papers on landslide have been published based on the Activities in Nepal.

- Jiang, H., Xu, C., Adhikari, B.R., Liu, X., Tan, X. and Yuan, R., 2023. Editorial: Environmental change driven by climate change, tectonism and landslides.
- Adhikari, B.R. and Gautam, S., 2022. A review of policies and institutions for landslide risk management in Nepal. *Nepal Public Policy Review*, v. 2, pp. 93-112.
- Sharma, S., Talchabhadel, R., Nepal, S., Ghimire, G.R., Rakhali, B., Panthi, J., Adhikari, B.R., Pradhanang, S.M., Maskey, S and Kumar, S., 2022. Increasing risk of cascading hazards in the central Himalayas, *Natural Hazards*, <https://doi.org/10.1007/s11069-022-05462-0>
- Adhikari, B.R., Gautam, S., and Paudel, B., 2022. Landslide, landcover and land use changes in its impacts in Nepal: In: Sarkar, R., Shaw, R. and Pradhan B. (eds) *Impact of Climate Change, Land use and Land Cover, and Socio-economic Dynamics on landslides*. Springer, Singapore. pp. 149-164.
- Chen, F., Adhikari, B.R. and Tian, B. 2020, Identification of Landslide Susceptible Areas For The Proper Settlement Planning In The Kali Gandaki Road Corridor, Nepal. *IEEE International Geoscience and Remote Sensing Symposium*, 5238-5241.
- Gnyawali, K. R., Zhang, Y., Wang, G., Miao, L., Pradhan, A.M.S., Adhikari, B.R., Xiao, L., 2019, Mapping the susceptibility of rainfall and earthquake triggered landslides along China-Nepal Highways, *Bulletin of Engineering Geology and the Environment*, 79, pp. 587-601.
- Thapa, P.S. and Adhikari, B.R., 2019. Development of community-based landslide early warning system in the earthquake-affected areas of Nepal, *Journal of Mountain Science*, 16 (12), pp. 2701-2713.
- McAdoo, B.G., Quak, M., Gnyawali, K.R., Adhikari, B.R., Devkota, S., Rajbhandari, P.L., Sudmeier-Rieux, K., 2018, Roads and landslides in Nepal: how development affects environmental risk, *Nat. Hazards Earth Syst. Sci.* vol. 18, pp. 3203-3210.
- Adhikari, B.R., Nidal, N., Yadav, B.K. and Awasthi, S., 2017, Landslide risk assessment of the Patleket landslide, Myagdi district, Nepal, *Journal of the Institute of Engineering*, vol. 13 (1), pp. 78-89.
- Gnyawali, K.R. and Adhikari, B.R., 2017, Spatial Relations of Earthquake Induced Landslides Triggered by 2015 Gorkha Earthquake $M_w=7.8$, *Landslide research and risk reduction for advancing culture of living with natural hazards, Advancing Culture of Living with landslides*, M. Mikos et al. (eds.) Springer Publication, pp-85-93

Tribhuvan University are also currently researching identifying landslides using AI or others.

- Does machine learning adequately predict earthquake induced landslides? *Soil Dynamics and Earthquake Engineering*, 2023. [<https://doi.org/10.1016/j.soildyn.2023.107994>] [SCI]
- Sustainable rural infrastructure: guidelines for roadside slope excavation. *Geoenvironmental Disasters*, 2023. [<https://doi.org/10.1186/s40677-023-00240-x>] [ESCI]
- Evaluation of Different Landslide Susceptibility Analysis Methods: A Case Study of Bagmati Rural Municipality, *Journal of Engineering Technology and Planning*, 2022. [<https://doi.org/10.3126/joetp.v3i1.49607>]

And the Graduate School of Engineering has a track record of many collaborative projects with the Nepalese government. Multi-hazard risk assessment (Landslides, Flood and Drought) as a part of dry land management (DCRL) project being implemented by Department of Forests and Soil Conservation and UNDP with funding support from global environmental facility (GEF).

- Information technology disaster resource center (ITRDC)-KOCHI University -JICA Partnership Project (Project for Penetration in Nepal of Local Adaptation-Based Gabion Techniques Serving Both Disaster Management and Environmental Protection)

The DOR and the Graduate School of Engineering have an agreement on technical assistance. The main technical assistance includes 1) geophysical exploration and ground surface inclinometer of road slopes, and 2) site visits to complex slope hazard areas and elucidation of their mechanisms of occurrence. This is an intergovernmental agreement, and those activities are funded by the DOR budget.

3.5.2. International Center for Integrated Mountain Development (ICIMOD)

ICIMOD is a regional intergovernmental learning and knowledge-sharing center established in Nepal in 1983 to promote regional cooperation and knowledge sharing in the Hindu Kush Himalayan (HKH) region of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. It is working to strengthen international cooperation.

ICIMOD influences regional policies to enable HKH's diverse countries and communities to transition to greener, more inclusive, and climate-resilient development. Its mission is to build and share knowledge that inspires action and attracts investment. Headquartered in Lalitpur, Nepal, it has 142 staff.

Various agencies fund ICIMOD's programs and activities. These include all governments of HKH and the governments of Australia, Austria, Norway, Sweden, and Switzerland. Program donors include ADA (Austrian Development Agency), BMZ (German Federal Ministry of Economic Cooperation and Development), EU (European Union), BMU (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), SIDA (Swedish International Development Cooperation Agency), IDRC (Canadian International Research Center), IFAD (International Fund for Agricultural Development), the Norwegian Ministry of Foreign Affairs, the Norwegian Embassy, USAID (U.S Agency for International Development). According to the annual report, the revenue for 2021 is USD 13.7 million, and the expenditure is USD 14.7 million.

Investigation, research, and knowledge sharing on disaster risk management are part of ICIMOD activities. It provides a regional platform for experts, planners, policymakers, and practitioners to exchange ideas and perspectives toward sustainable mountain development and encourages industry-academia-government collaboration.

The activities and results of ICIMOD are published at the following URL. <https://lib.icimod.org/>, DOR 2007 Roadside Geotechnical Problems, A Practical Guide to their Solution references ICIMOD's Mountain Risk Engineering Handbook.

ICIMOD is currently working on providing HKH flood risk maps and disaster risk management education.

3.5.3. Ehime University / Professor Netra Prakash Bhandary

As of July 2023, Ehime University has accepted one privately financed international student from DOR, a third-year doctoral student, on the theme of "Earthquake-resistant design of bridge foundations." Furthermore, from September 2023, the current project manager of NH37 Kanti highway was accepted as a privately funded international student in the doctoral course. His research theme includes "Geological and Geotechnical Characterization of Cut Slope-induced Landslides on Lesser Himalayan Zone of Nepal: A Case of Kanti National Road."

Professor Netra Prakash Bhandary is a professor of civil engineering and construction engineering at the Faculty of Social Co-Creation at Ehime University. In 2006, he co-authored "Risk management and hazard map of the most important road in Nepal" in the Journal of the Japan Landslide Society, Vol. 43 (6). He has been working on disaster prevention research related to the 2015 Nepal earthquake in recent years.

3.5.4. Nepal-Japan Friendship Association for Water-Induced Disaster Prevention

The Nepal-Japan Friendship Association for Water-Induced Disaster Prevention (NFAD) was established as an NGO in July 1993 and was certified as an NPO in November 2000. The association aims to assist the development and enlightenment of Nepal's flood control and erosion control technology, promote information exchange between Japan and Nepal, educate and disseminate disaster prevention knowledge, and foster the next generation of human resources. The members consist of the Ministry of Land, Infrastructure, and Tourism, prefectures of Japan, university professors, and private sector officials, including current and retired members. The C/P on the Nepal side is mainly WRRDC and DWRI, but there are no registered members.

As activities of FY 2023, The Nepal-Japan Friendship Association digitalized technical materials developed by the former DPTC and exchanged the memorandums in December 2023 with WRRDC related to storing the technical materials at the WRRDC.

3.6. Review of Information Collection of the Latest Technology on Landslide Engineering Measures

3.6.1. Aerial Photography Using Drones and Creation of 3D Terrain Models

Orthoimage creation through drone aerial photography and the generation of topographical figures from photographs have become widely adopted practices. Japan utilizes aerial photography with thermal infrared cameras to identify spring water sources and detect deteriorated slope areas. However, conventional aerial photography using optical images cannot grasp the terrain beneath dense tree cover. Laser surveying technology, which will be described later, is a technology that can grasp the terrain beneath trees. The laser surveying technology described in the next section makes this possible.

In 2023, local private consultants in Nepal are utilizing aerial photography and expertise to facilitate the road widening project for NH17 Prithvi Highway with the support of the WB to aid in the design process. In addition, some consultant companies in Kathmandu specialize in utilizing aerial photographs and 3D digital information technology.

3.6.2. Laser Survey Technology

Light Detection and Ranging (LiDAR) is an advanced technology that utilizes laser pulses to precisely measure the distance and size of objects, even from considerable distances. With LiDAR, acquiring terrain data under trees by passing through branches and leaves is possible, even in environments with thick trees.

In October 2021, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) in Japan introduced the "Guidelines for identifying road slope hazard areas using 3D point cloud data (draft)". These guidelines emphasize the role of laser survey technology in the field of road geohazard risk management. To further promote advancements in this area, the Geospatial Information Authority of Japan published the "Public Survey Manual Using Lidar SLAM Technology" in June 2022. This manual outlines the application of SLAM (Simultaneous Localization and Mapping) with laser-based sensors, allowing for use of the technology for public surveys.

LiDAR-based topographic figures have been developed using aeronautical LiDAR using fixed-wing aircraft and helicopters. A terrestrial LiDAR uses a tripod to fix equipment and take measurements from the ground. Currently, digital 3D services are available worldwide using satellite LiDAR, and the digital 3D ground table model provides an accuracy of 0.5m in urban areas and 5m in general areas. This Japanese technology provides the highest resolution image worldwide. In addition, the development of miniaturization technology and available Japanese technology has progressed, and drone LiDAR has become possible.

Table 3-32 shows measurement distances and point cloud densities for general LiDAR survey technology.

Table 3-32 Measurement Distance and Point Cloud Density of Laser Survey Technology

Items	Satellite LiDAR	Aviation LiDAR	Drone LiDAR	Terrestrial LiDAR
Distance measurement	700 km	0.15 - 2 km	0.01 - 0.15 km	0.001 - 0.15 km
Point Cloud Density	0.04 - 4/m ²	10 - 30/m ²	100 - 300/m ²	100 - 3000/m ²

Source: JICA Survey Team

The Survey Department, the Ministry of Land Management, Cooperatives and Poverty Alleviation (DOSMLCA) in Nepal announced a seven-year plan in 2019 to develop aerial LiDAR measurements and digital 3D ground table models (<https://www.telecomkhabar.com/2019/09/lidar-survey-started-by-survey-department-of-nepal/>). The Survey Department has already completed the LiDAR survey of the western Terai region (around 20,000 sq. km). The plans for expansion to other regions is not clear.

The Transmission Directorate has a track record of working with the Nepal Electric Authority (NEA) to create digital 3D ground table models. The two organizations collaborated to develop a model of a 150 km² area using LiDAR imaging from a helicopter.

There are several LiDAR geodetic companies in Nepal, and drone LiDAR can also be used for aerial photography.

3.6.3. Landslide Susceptibility Evaluation Using Point Cloud Data

The road subcommittee of the social infrastructure development council of the Ministry of Land, Infrastructure, Transport, and Tourism created "Guide to identify road landslide risk areas using 3-dimensional point cloud data (draft)" for efficient grapes of a wide area of landslide risk, planning and implementation of engineering measures. The subcommittee has begun revising the "Guide to road earthwork structure inspection" and " Guide to Road Risk Assessment."

(https://www.mlit.go.jp/policy/shingikai/road01_sg_000576.html)

The following four points are listed as points of the " Guide to identify road landslide risk areas using 3-dimensional point cloud data (draft)". Using point cloud data with an accuracy of 4 points or more per square meter makes it possible to easily interpret topographical features and minimize individual differences, enabling highly accurate stability evaluations.

1. Utilize 3D point cloud data to narrow down inspection points for road landslide inspection guidelines
 - Aerial laser survey results and microtopographic representation maps are used to extract hazard areas.
2. Determine the range from the ridge to the valley of the slope along the highway
 - Using high-precision (more than 4 points per square meter) point cloud data, almost all hazard causes on slopes can be extracted.
3. Perform terrain interpretation that covers terrain information related to hazard factors
 - Post the latest interpretation information, such as bedrock creep
4. Utilize laser survey topographic maps for inspection records
 - Make records compatible with future data linkage

Source : <https://www.mlit.go.jp/policy/shingikai/content/001428664.pdf>

Ministry of Land, Infrastructure, Transport and Tourism Japan (MLIT Japan) edited "Road landslide inspection guidelines (2006)" and "Extraction guidelines for road landslide areas using 3D point cloud data (draft)".

In Nepal, a Japanese researcher has created a landslide topography map using a 3D service of satellite LiDAR.

In Nepal, it is possible to acquire point cloud data with high precision (4 points or more per square meter) by Nepalese contractors. Therefore, transferring and disseminating landslide risk assessment technology based on point cloud data is possible.

3.6.4. Slope Remote Monitoring System

A remote landslide monitoring system has been developed in Japan. The measurement equipment is fitted with communication, landslide detection, and alarm functions. One can remotely check landslide data at dangerous sites or distant sites.

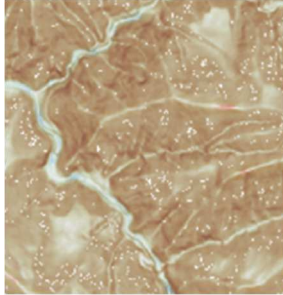
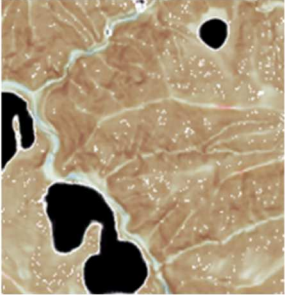
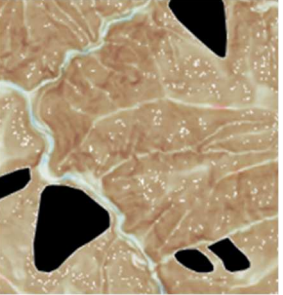
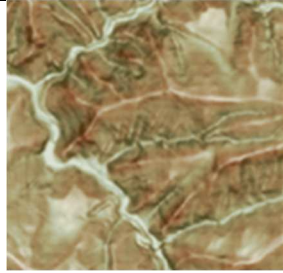
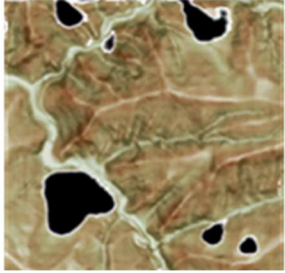
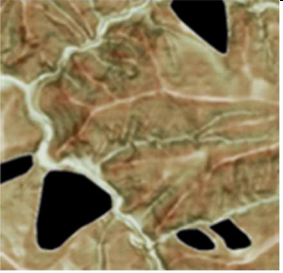
- Data monitoring using small solar panels, measurement equipment powered by commercially available batteries, and the cloud: In case of a landslide occurs in a mountainous area where infrastructure is not well-developed, small solar panels, commercially available batteries, and cloud monitoring can be used to check observation data anytime, anywhere, and receive alerts in case of abnormalities. It can help prevent secondary landslides and ensure the long-term safety of residents. These systems were introduced after the Kii peninsula flood disaster that occurred in August 2011.
- Observation of landslide dynamics using a scattering-type inclinometer (NETIS registration number: SK-160012-VE): A scattering-type inclinometer has many sensors equipped with wireless devices placed on the slope, and the measurement data is sent to the data logger via wireless communication. Collecting and recording the data allows for tracking its deformation over time. Data can be obtained more reliably even in mountainous areas where landslides have occurred because communication uses a mesh-type specific low-power radioresistant to obstacles.

It is challenging to apply this Japanese measurement equipment in Nepal because it is necessary to change the language of the table, and the equipment manufacturer needs to establish a maintenance and management system in Nepal.

Nepal has a track record of remote monitoring of landslides using GPS, CCTV, radar, borehole sensors, etc. DHM and ICIMOD operate a remote landslide monitoring system in the Glacial Lake Outburst Flood (GLOF) study area. Since 2021, ICIMOD has been developing an earth observation (EO)-based landslide monitoring and prediction system as joint research with USAID and NASA. It aims to monitor a large-scale landslide and predict sequential risks and earthquake-induced landslides by rainfall and rainfall forecast by satellite image analysis. These Nepalese applications are project-based assistance from international donors through ICIMOD. There will be challenges in maintaining the slope remote monitoring system in the future.

3.6.5. Landslide Susceptibility Prediction Using AI

In Japan, a technology that uses AI and deep learning to improve the accuracy of predicting the site of landslides is being developed. Using the figure created by the terrain interpretation technician based on the numerical terrain information as the training data, AI can learn the traces of soil movement that the technician reads during terrain interpretation with deep learning, and landslide terrain and erosion terrain can be extracted at a specific rate. (See **Figure 3-24**).

	Image	AI extraction sliding terrain	Training data provided by topographical interpretation engineers
CS solid figure CS: Curvature and Slope			
CS sharpening			

CS solid figure: A combination of curvature and slope enables visual and intuitive topographic interpretation.

CS sharpening: Processes to enhance the edges while preserving the original image's shading, improving the image's sharpness. The dark area in the center photo is the landslide extracted by AI, and the dark area on the right photo is the landslide terrain distribution provided as training data by terrain interpretation engineers.

Source: JICA Survey Team

Figure 3-31 Output Image by AI

The Australian government is developing potential landslide extraction software called AI-Landslide in 2021.

The use of AI for landslide prediction and application in Nepal is expected to be effective in practice as Nepal's digital 3D data is being developed using LiDAR and other technologies.

3.7. Examination of the Applicability of Japanese Technology

Japanese technology is considered superior in quality and performance for engineering measures for roads slopes in mountainous areas. Information on the applicable methods for landslide in Nepal, including the types of hazards they address, the construction methods, specific construction details, technical names, and their features/functions, have been compiled.

3.7.1. Engineering Measures for Slope-Collapse Hazard

(1) Engineering measures at the Source of Hazard

- **Frame Works Construction Method:** This method involves creating a continuous frame on cut slopes and natural slopes by utilizing the characteristics of a wire mesh-type frame and the advantages of the spraying application method. Harmony with the natural environment can be achieved by implementing slope stabilization measures and incorporating greenery works. This method has been successfully applied in Nepal along the Sindhuli road. Some countries have similar technology, but only Japanese products include simplified formwork, filling uneven slope surfaces. There is a construction method association in which several Japanese companies participate.
- **Rope Net Construction:** This is an engineering measure against the initial movement of floating and rolling stones scattered on slopes. It involves arranging wire ropes in a grid pattern and restraining the stones in their current positions. Some specifications include a tough-coated paint on the plated surface. Other countries have similar technologies. But Japanese products have advantages like tough-coated products, excellent resistance to

peeling abrasion, and strong adhesion. Several manufacturers and construction method associations are organized in Japan.

- **Footless Rock Bolt Method:** As it does not require scaffolding, it allows for minimal traffic regulations and enables construction without slope excavation and cutting down trees in forested areas. It has been adopted on the Sindhuli road in Nepal. There are no similar technologies in other countries. There are several manufacturers and construction method associations in Japan.
- **Continuous Long Fiber Reinforced Soil Stabilization:** Sand, cement, and continuous long fibers (polypropylene) are sprayed to reinforce the cut soil surface, and then the vegetation is applied to the slope surface. There is an example of providing equipment and training to El Salvador for this type of construction. In Japan, two companies are registered with NETIS, and there are two construction method associations.
- **Non-frame Ground Reinforcement Method:** The method stabilizes slopes without cutting down trees and grading the ground while preserving the landscape and natural environment. The method uses secondary products, which leads to shorter construction periods and cost savings. The method does not apply to slopes where the average depth of the assumed collapse surface is more than 3 m. No similar technology exists in other countries. There are two similar construction methods in Japan.
- **High-intensity Slope Protection Net:** A slope protection technique designed for overall slope stability using reinforcing materials and prevention of collapse of soil blocks by a highly durable net. This method significantly reduces carbon dioxide emissions compared to conventional slope protection methods, mainly based on retaining walls. Moreover, due to its fully open design, it allows for more green areas, promoting the absorption of carbon dioxide. This technique has been successfully applied on the Sindhuli Road in Nepal. It isn't easy to show the significance of Japanese-made products because other countries have similar technologies. Five types are registered in the MLIT's New Technology Information System (NETIS).
- **Unstable Bedrock Fixing Wire Roping:** A method that uses a lattice of wire ropes or several wire ropes to prevent the initial movement of individual or multiple floating stones and rolling stones. Since it targets individual or multiple floating stones and rolling stones, it can accommodate even large ones. Since other countries have similar technologies, Japanese products are not advantageous. There are several manufacturers in Japan.

(2) High-Energy Absorption Type Rockfall Protection Work

- **High-energy Absorption Type Rockfall Protection Barriers:** Different types of fall protection fences are available from manufacturers. Some of these fences can withstand up to 1000kJ of falling rock energy and have been successfully used in El Salvador. Similar products exist in other countries.
- **The Ring Net:** It was introduced to Japan from Switzerland and spread as a Japanese manufacturer's product. It can absorb high energy up to 3000 kJ. Other countries have similar technologies. In Japan, several companies participate in a construction method association.
- **High-energy Absorption Rockfall Protection Nets:** They have been applied in El Salvador. A rope type that can withstand up to 2700 kJ is now available. Other countries have similar technologies. In Japan, several companies participate in a construction method association.

(3) Rock Fall Protection Wall

- **Reinforced Earth Protection Wall (geo-rock wall):** A retaining wall of reinforced soil that uses special fibers to protect against rockfalls and collapses. It is economical because it can use locally available materials, and bioengineering can be applied to the wall to blend in with the surrounding landscape. It also has a large energy absorption capacity and has a proven track record in Bhutan. No similar technology exists in other countries. In Japan, several companies participate in a construction method association.
- **Protective Earthworks (Rock Geobank Construction Method):** It is a method of constructing a reinforced earth wall using geogrid and placing Terrace (geocell) with a three-

dimensional honeycomb structure made of high-density polyethylene resin as a buffer (impact surface of falling rocks) and using single particle crushed stone with high buffering effect as the filling material. This method can withstand up to 4500 kJ of falling rock energy. No similar technology exists in other countries. In Japan, several companies participate in a construction method association.

3.7.2. Engineering Measures for Slide

(1) Restoration Work

- **Ground Anchor with Wedge and Nut Anchoring System:** The head structure can be selected according to the purpose of use, such as a simple adjustment type that is easy to re-tension and a load adjustment type that is easy to adjust. It is highly corrosion-resistant and adhesive. It can be assembled on-site or in the factory. Even on-site, reliable, and high-quality tendon processing can be performed and adapted to length changes on-site. It was used in Nepal along the Sindhuli Road. No similar technology exists in other countries. One Japanese manufacturer is registered with NETIS.
- **The Steel Pipe Pile Gyro Press Method (Rotational Cutting Penetration) System:** A method of installing steel pipe piles that utilizes the advantages of the pressure injection principle, including no vibration and noise. The system uses a special bit at the tip of the pile to minimize cutting, which results in almost no excavated soil and minimal environmental impact. Additionally, all machinery can operate on the completed pile, making it possible to complete the entire process of pile transportation, installation, and pressure injection without any temporary structures, such as temporary wharves or roads. It is known as "temporary-free construction". There is no similar technology in other countries. It is considered a registered trademark in Japan.
- **Steel Pipe Pile Screw Joint Material:** A screw joint for steel pipe piles that do not require on-site welding and can be connected quickly. This solves various problems related to on-site welding joint pile work, such as welding taking a long time and interfering with the process. Maintaining welding quality is difficult due to the thickening of the steel pipe piles. No similar technology exists in other countries. One Japanese manufacturer is registered with NETIS.
- **Tensile Ground Anchors:** Tensile ground anchors are a type of landslide prevention anchor that can be easily modified in length on-site and are economical. They have been used effectively on the Sindhuli Road in Nepal. Other countries have similar technologies. There are several manufacturers in Japan.
- **Steel Pipe:** Pile work is a method of preventing landslides by inserting steel pipes or H beams into a large-diameter boring hole that has been cut and drilled vertically in advance and then filling the hole with grout to adhere the pipes to the ground and resist sliding force. This waiting-type method first deforms and exerts resistance when the landslide-moving layer is displaced. Ground anchors may also be used to prevent the displacement of the pile head. This method has been used successfully in Honduras and Mauritius. Other countries have similar technologies. There are several manufacturers in Japan.
- **Anchored Steel Pipe Pile:** An anchored steel pipe pile is a method used to restore roads that landslides have damaged. It is not a method of stopping landslides altogether, but it is the minimum standard required to protect the road, which is the target of conservation and is economical. By using anchors, the displacement of the pile head can be suppressed. Other countries have similar technologies. There are several manufacturers in Japan.

(2) Control Work

- **Permanent Water Collection Boring Casing (Rust-proof):** This is a permanent water collection boring casing that is not easily broken in unstable landslide soil blocks, has a long lifespan (coating life of 80 to 100 years) due to its high corrosion resistance, and is strong against soil pressure. It is made of steel water drainage casing and uses molten zinc plating that is not easily corrupted, so it can also be used in permanent methods. No similar technology exists in other countries. There is only one Japanese manufacturer.

- **Underground Water Extraction Well Liner Plate:** Underground water extraction well liner plate is a method of lowering the groundwater level by digging a well with a diameter of 3.5 to 4 m in the landslide, moving soil block, and then placing a water collecting boring of 40 to 50 m from it and drawing the groundwater level into the well. The liner plate is used to protect the borehole wall, and it is lightweight, easy to install, low noise, and highly corrosion resistant. It has been applied in Honduras. Other countries have similar technologies. There are several manufacturers in Japan.
- **Lightweight Embankment:** The lightweight embankment method is employed in various situations, such as widening embankments on soft ground, embankments at the head of landslides requiring deformation and safety measures, reducing earthwork in road construction in mountainous areas, and mitigating soil pressure on bridge piers. This technique has been successfully implemented in Sri Lanka. Other countries have similar technology. In Japan, there are several manufacturers.

(3) Reinforced Embankment

- **Geotextile Reinforced Soil Wall Construction Material:** This material is a composite of high-strength polyester fibers bundled together as the core material and coated with polypropylene resin as the covering material, joined in a grid-like pattern. It possesses sufficient strength, minimal elongation, excellent creep properties, impact resistance, durability against temperature and chemicals, frictional characteristics with soil, and easy workability. It has been applied on the Sindhuli Road in Nepal, and Honduras. Similar technology exists in other countries. In Japan, there are several manufacturers.

3.7.3. Engineering Measures for Debris Flow

- **Permeable Steel Erosion Control Dam:** This dam has a large opening (slit) in the water passage section, allowing harmless sediment to flow downstream during normal and small to moderate water outflows. It has the advantage of minimizing its impact on the environment. Additionally, it is highly effective in capturing floating debris like driftwood. Other countries have similar technologies. In Japan, there are several manufacturers.
- **Sabo Soil-Cement:** Sabo soil-cement is an intermediate material between concrete and soil materials, and it can be widely applied by appropriately adjusting the mixture according to the specific purpose. It allows for a broad range of applications. Using locally available soil materials, including excavated earth from construction sites, reduces the need to transport soil off-site, leading to cost reductions in transportation and disposal. There is a successful track record of its application in Brazil. Other countries have similar technologies. In Japan, there are several manufacturers.
- **Basket Frame:** A Simple Type of Steel Gabion Works. It utilizes welded wire mesh and crushed stones as filling material. This panel-type gabion work enhances the rigidity of the simple steel gabion works and combines the excellent features of traditional basket works with the functionality of a permanent structure. It can be used for steel retaining walls and various slope stabilization and erosion control projects, including small check dams and hillside works. Other countries have similar technologies. In Japan, there are several manufacturers.

3.7.4. Erosion Control and Foundation of Bioengineering

- **Curing Mat (multifunctional filter):** A curing mat protects the slope from various environmental stresses by laying it on the slope. It is made by processing ultra-fine polyester fibers, similar to plant capillary roots, into the non-woven fabric and layering it with a reinforcing net of chemical fibers (turtle shell-like metal mesh). It protects against rain, wind, freezing, and drought and prevents small rockfalls (turtle shell-like metal mesh specification) when attached to the slope. It has been applied in Honduras and El Salvador. Other countries have similar technologies. In Japan, there are several manufacturers.

Chapter 4. Market Situations of the Road Sector

4.1. Procurement Situation of Similar Projects in Nepal

4.1.1. General Circumstances for Bidding and Contracting for General Civil Works

Nepal's construction industry contributes to the development of transportation, mainly roads (including bridges and tunnels), hydropower, irrigation, and architecture. The GDP contribution by the construction industry is about 10% and accounts for about 35% of the government budget's spending allocation. The construction sector is estimated to create jobs for about one million people, second largest after the agricultural sector in Nepal.

Public works procurement needs to be economical, reasonable, and transparent. The procurement process should ensure good governance by maintaining competitiveness, fairness, integrity, accountability, and credibility. The following laws and guidelines conduct construction bidding and contracting in Nepal.

- Public Procurement Act 2007, Procurement Regulation Nepal 2007
- Developing Partner's Procurement Guidelines (Document name and year of publication varies by development partner)

4.1.2. Situation of Local Consultants

The Government of Nepal once initiated the involvement of private engineers in small construction projects around the 1970s to introduce engineering services. In the 1990s, the Society of Consulting Architectural & Engineering Firms (SCAEF) was established and registered as a national organization to ensure a healthy environment for the consulting industry. A law issued by the monarchy in January 2002 made it mandatory for consulting firms to register with a legitimate organization for being short-listed as bidders of public works projects. As of 2023, more than 250 consulting firms in the country are registered with SCAEF to provide consulting services in construction projects.

4.1.3. Situation of Local Contractor

According to the Federation of Contractors' Associations of Nepal (FCAN), about 60 % of the country's development budget is spent on the works with the involvement of contract builders. The contractor industry is expanding, especially after the 2015 earthquake. The relevant industries, such as the construction equipment and materials market, doubled.

Public construction contractors in Nepal are classified into four categories: Classes A, B, C, and D, according to the scale of their enterprise. According to FCAN, a registered association of contractors in Nepal established in the 1990s, the number of registered contractors as of 2023 is 228 in Class A, 282 in Class B, 1,158 in Class C, and 10,740 in Class D.

According to the Construction Business Act, Nepal Sambat 2055 (1999), the classes of contractors that can be procured depending on the scale of the public construction project are as follows.

- Construction works exceeding NRs. 20 million Class A
- NRs. 6 million to NRs.30 million construction: Class B
- NRs. 2 million NRs to NRs.10 million construction: Class C
- NRs. Under 3 million constructions: Class D

Note: Amounts are estimates.

Despite the industry's size, the work in the field of road landslide engineering measures is limited, and the number of experienced constructors is small. To understand the general situation of local contractors' capacity (track records, number of construction equipment, etc.), we surveyed two companies that have experience in slope protection work using a questionnaire to determine the following points: (1) experience in slope protection work, (2) slope protection construction machinery owned by the company, (3) procurement status of slope protection construction machinery, and (4) procurement status of materials required for slope protection work.

Although the local contractors had little experience in slope engineering measures, they had experience in Japanese grant aid and WB funding projects. The machinery and materials required for slope engineering measures can be imported from India or China. The quality of the material is adequate to be applied according to the survey results that there is no information regarding any particular material problems, such as cement or reinforcing bars.

Table 4-1 Interview Survey from Local Contractors

	Contractor A	Contractor B
(1) Experience in slope protection	Has experience as a subcontractor of ODA. No experience of a project of GoN	Has experience in WB founding project from Mugling – Narayanghat Highway section rehabilitation.
(2) Slope protection construction machinery owned by the company	Rotary percussion drill, rock bolt machine, machines for horizontal drilling work, drilling machine for cast-in-place pile (Currently not owned but can be procured in Nepal if needed.)	Rotary percussion drill (2 units), Rock bolt machine (4 units), machines for horizontal drilling work (2 units), and drilling machine for cast-in-place pile (1 unit).
(3) Procurement status of machinery for slope protection construction	Available in Nepal with the following standards. Rotary percussion drill (under 50m) Rock bolt machine (under 10m) Machines for horizontal boring work (under 50m) Drilling machine for cast-in-place pile (25-30m)	Available in Nepal with the following standards. Rotary percussion drill (under 40m) Rock bolt machine (under 10m) Machines for horizontal drilling work (under 50m) Drilling machine for cast-in-place pile (under 25m)
(4) Procurement status of materials required for slope protection work	Available in Nepal: Construction scaffold, H beams, chain link wire netting, wire gabion baskets Available in India: Rock bolt, Anker, high-performance net, steel pipe pile, rockfall protection fence	Available in Nepal: Construction scaffold, wire gabion baskets Available in India: Rock bolt, Anker, high-performance net, H beams, steel pipe pile, chain link wire netting, rockfall protection fence

Source: JICA Survey Team

4.1.4. Circumstances of Procurement of Required Materials and Equipment

Procurement of materials and equipment in Nepal is carried out based on the Public Procurement Act, Procurement Regulation Nepal, or procurement guidelines of respective development donors. The Public Procurement Regulation 2007 (Revised Version) (PPR) defines the procurement method for materials and equipment as follows.

(1) Sealed Bidding

• International Competitive Bidding (ICB)

The scale and scope of the contract depend on the nature of the project. For large projects that require the procurement of multiple types of goods and where domestic manufacturers and suppliers may not be able to handle sufficient capacity and resources, the ICB procedure will be adopted. ICB is designed to give all bidders an equal opportunity to bid by informing them of the project requirements at a fixed time and by appropriate means.

• National Competitive Bidding (NCB)

NCB is recommended in the following situations.

- When locally produced goods are reasonably priced and can be delivered quickly.
- When a foreign manufacturer/supplier is unlikely to be interested in bidding because the contract amount is small compared to the effort and expense involved in bidding and entering the contract.
- When the nature of the materials favors local manufacturers/suppliers.

- When the project specifies a special NCB application.

The tender announcement is only publicized via national newspapers, so only domestic bidders can participate in the bidding. There are some exception cases where the foreign bidders are allowed to participate following the laws and regulations.

• Limited Tender (LT)

If there are three or fewer suppliers of material/equipment, limited competitive bidding of public notice of 15 days prior will be applied.

This method is appropriate for the following situations.

- When there are only a few well-known manufacturers/suppliers. (e.g., complex industrial plants, specialized equipment, or technology)
- For small quantities (e.g., communication facilities or airfield lighting.)

All procedures in **(5) Bidding Methods and Contract Terms and Conditions**, except for short-term public notice and prequalification, will apply to this bidding process.

(2) Catalog Shopping

Catalog shopping purchases goods based on rates published by authorized manufacturers or distributors. Under this method, enclosed quotations are solicited from the firms designated on the public entity's permanent registration list. Usually, a written request is distributed to the firms, and quotations are submitted within 7 to 15 days for the equipment.

The equipment to be cataloged shopping under the Public Procurement Monitoring Office (PPMO) guidelines, and their annual purchase limits per organization are as follows.

Table 4-2 Catalog Shopping Equipment and Limit in Annual Amount

	Type of Equipment	The maximum allowable amount for each year (NRs.)
A	Heavy Vehicles	6 million
B	Vehicles	6 million
C	Tools	2.5 million
D	Machinery	2.5 million
E	Devices	2.5 million
F	Medical Equipment (X-ray, MRI, etc.)	4 million

Source: PPMO Guideline for Catalogue Shopping, 2074

(3) Sealed Quotations

Purchases of general materials and equipment under NRs. 2 million (in the case of medical equipment like X-ray units, up to 5 million) will be made by submitting a sealed quotation from a qualified domestic registered supplier/manufacturer by Rule 84 of PPR. Requests for quotation submissions will be posted on the website and in national newspapers. It will take 14 days to prepare and submit quotations. Goods manufactured in Nepal will be given a 15% preference over foreign goods in price comparison by Rule 17 of PPR.

(4) Direct Purchase

Materials and equipment valued at less than NRs. 1 million can be purchased directly from local suppliers and stores.

(5) Bidding Methods and Contract Terms and Conditions

In Nepal, standard bidding documents issued by the Public Procurement Monitoring Office (PPMO) are used for public funds construction projects. In the case of internationally supported financial assistance projects, the terms and conditions of the contract issued or agreed upon by FIDIC or the donor agency

will apply depending on the requirements of each donor. The Public Procurement Regulation 2007 (Revised Version) (PPR) defines six general procurement modalities for works.

- Sealed bidding
- Sealed quotations
- Direct purchase
- Force account
- Public tender (Procurement in exceptional circumstances by Article 66 of the Public Procurement Act)
- User or Consumer Commission

The terms of the procurement contract will be selected considering the following.

- Type and quantity of procurement
- Procurement method of similar procurements adopted previously
- Risk diversification between the employer and the contractor
- Procurement Contract Supervision Methods

The main steps involved in the procurement of materials and equipment and the standard number of days for each step are shown in **Table 4-3**.

Table 4-3 Procedures for Procurement of Materials and Equipment

Step	Activity	Responsibility	Estimated time in days		
			ICB/LT	NCB	Sealed Quotation
1	Establishment of Procurement Strategy	Preparation: Project Manager or Consultant Approval: Competent Authority (Same as for acceptance of bids)	60	30	15
2	Prequalification and post Qualification		Large and complex civil works contracts and contracts for technically complex plants. [Normally, ICB requires PQ]		Not required
2.1	Preparation of Prequalification Documents	Preparation: Project Manager or Consultant Approval of Criteria: Director General (DG)	30	15	0
2.2	Invitation for pre-qualification	Preparation: Project Manager or Consultant	15	15	0
2.3	Submission of Prequalification Documents	Prospective Bidders	60	30	0
2.4	Analysis of Prequalification Documents & Selection of Prequalified Bidders	Preparation: Project Manager or Consultant Approval: Competent Authority (same as for acceptance of bids)	60	30	0
2.5	Donor No Objection (If required in 2.1 and 2.4)	Donor	Additional 15 days each for 2.1 and 2.4		NA
2.6	Notification to Applicants	Project Manager or Consultant	15	7	0
	Total of 2		195	111	0
3	Preparation of Bid Documents (Excluding Specification Documents)	Preparation: Project Manager or Consultant Approval: Competent Authority (same as for the acceptance of bids)	30	30	15
4	Bidding Period				
4.1	Arrange Notice	Project Manager or Consultant	14	14	7
4.2	Issue of Bid Documents	Project Manager or Consultant	14	14	7
4.3	Site Visit by Bidders	Project Manager, Consultant, and Prospective Bidders	Time included in 4.5		
4.4	Bidders Queries a) Written b) Pre-bid Meeting	Project Manager, Consultant and Prospective Bidder	Complete by 15 days before the bid submission deadline	Complete by ten days before the bid submission deadline	
4.5	Preparation and Submission of Bids	Bidders	45 from the first notice	30 from the first notice	15 from the first notice
	Total of 4		73	58	29
5	Opening of bids	Project Manager	Immediately after submission, on the same day		
6	Evaluation of Bids				

6.1	Preliminary Examination of Bids	The Bid Evaluation Committee and Consultant	Included in 6.2	Included in 6.2	Included in 6.3
6.2	Detailed Evaluation of Bids	The Bid Evaluation Committee and Consultant	28	21	7
6.3	Bid Evaluation Report	The Bid Evaluation Committee and Consultant	14	14	7
6.4	Donor No Objection (If required)	Donor	14	14	Not Required
6.5	Selection of bid for approval	Competent Authority	7	7	Not Required
6.6	Issue of intention to award notice	Project Manager and Consultant	7	7	Not Required
6.7	Complain to Intention to award	Bidder	7	7	Not Required
6.8	Approval	Competent Authority	7	7	7
	Total of 6 excluding 6.7		84	77	21
7	Award of Contract				
7.1	Letter of Acceptance	Project Manager	7	7	Not required
7.2	Provision of Performance Security	Successful Bidder	15	15	7
7.3	Signing of Contract Agreement	Signing: Competent Authority and Successful Bidder	7	7	7
	Total of 7		29	29	14
8	Bid Validity and Bid Security Periods				
8.1	Bid Validity Periods	Specify: Project Manager Comply: Bidders	120	120 for estimated amount >NRs. 100 million and 90 for up to NRs. 100 million	45
8.2	Bid Security Periods	Specify: Project Manager Comply: Bidders	150	150 for estimated amount > NRs.100 million and 120 for up to NRs. 100 million	65
	Total excluding 8		471	335	94

Source: DOR

4.2. Selection of Consultant

4.2.1. Type of Consultant Contracts

The consultant contract for the construction work will be made in the following contract.

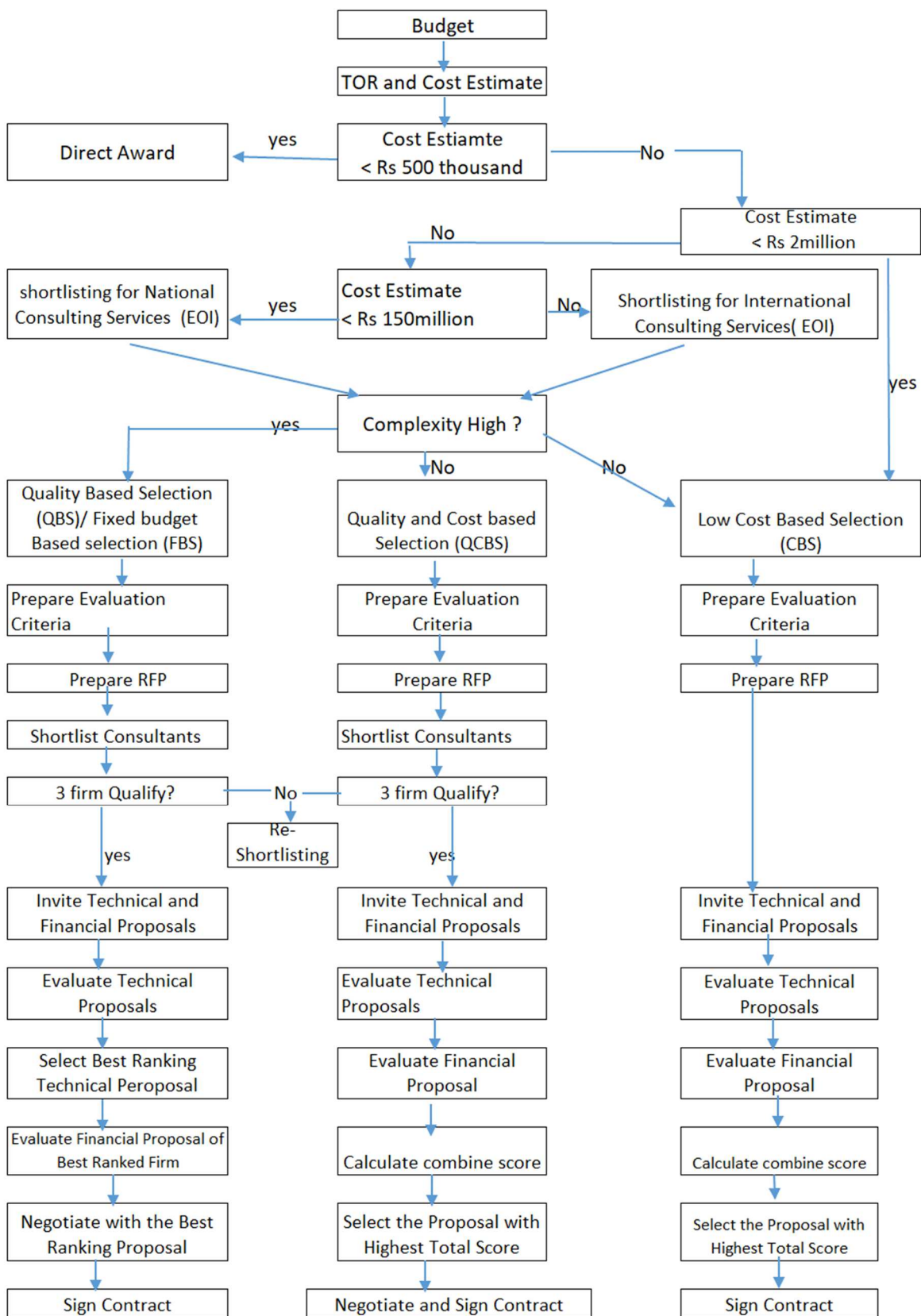
- Lump sum contract
- Time-based contract
- Performance-based fee-paying contract
- Percentage based contract
- Indefinite service period contract

4.2.2. Short Listing Process

Article 31(4) of the Public Procurement Act 2007 (Revised Edition) stipulates four standard procurement methods for short-listed firms through the qualification examination related to the construction work from SCAFE-registered consultants.

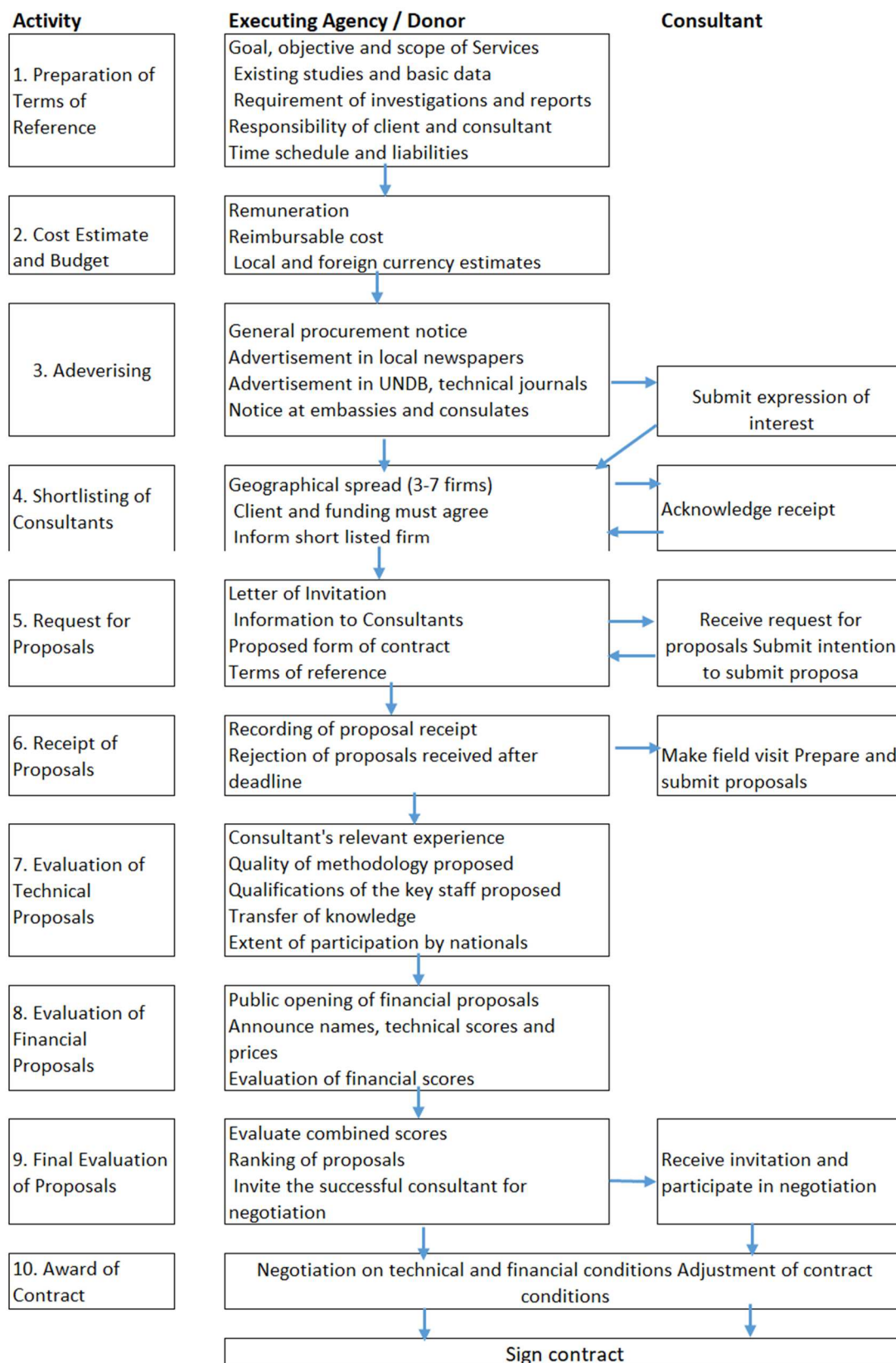
- Quality and Cost Based Selection (QCBS)
- Quality Based Selection (QBS)
- Fixed Budget Based (FBS)
- Least Cost Selection (LCS)

Figure 4-1 shows the standard consultant selection process. **Figure 4-2** shows the traditional consultant selection process in the case of the QCBS application.



Source: DOR

Figure 4-1 The Selection Process for Consultant



Source: DOR

Figure 4-2 QCBS Contract Selection Process

4.2.3. Evaluation Methods and Their Approval Authority and Process of Consultants

The evaluation method and approval authority for the consultant selection are as follows.

Table 4-4 Evaluation Methods and Their Approval Authority and Process of Consultants

Step	Activity	Responsibility	Time
1	Preparation of Terms of Reference and Cost Estimate	Preparation: Project Manager Approval: <u>higher authority</u> for international Consultants, <u>The officer in charge Gazetted 3rd class: up to cost NRs. 2 million,</u> <u>The officer in charge Gazetted 2nd class: up to cost NRs. 5 million</u> <u>Officer-in-charge Gazetted 1st class: up to cost NRs. 10 million</u> <u>Department Head > cost NRs. 10 million</u>	30 days
2	Advertising	Preparation: Project Manager	15 days
3	Shortlisting of Consultants	Recommendation: Tender Evaluation Committee Approval: <u>The officer in charge Gazetted 3rd class: up to cost NRs. 2 million,</u> <u>Officer in charge Gazetted 2nd class: up to NRs. 10 million</u> <u>Officer in charge Gazetted 1st class: up to NRs. 50 million</u> <u>Director General > NRs. 50 million</u>	35 days
4	Request for Proposals	Preparation: Project Manager Approval: Same as step 3.	15 days
5	Receipt of Proposals	Project Manager	15 days up to cost NRs. 2 million, 30 days for cost > NRs. 2 million
6	Evaluation of Technical Proposals	Tender Evaluation Committee	15 days to 30 days
7	Notice for Financial opening	Project Manager	7 days for National Consultants and 15 days for International Consultants
8	Evaluation of Financial Proposals	Tender Evaluation Committee	Three days
9	Final Evaluation of Technical and Financial Proposals	Tender Evaluation Committee	3 days
10	Negotiation and Award of Contract	Tender Evaluation Committee and Project Manager	15 days to 30 days
11	Special Requirements of Donor-Assisted Projects	Executing Agency and Donor	30 days
	Total Elapsed time		183 days - 236 days (6-8 months)

Source: DOR

4.3. Selection of Contractor

4.3.1. Contractual Arrangements for Contractors

The terms and conditions of the Contractor's Agreement for the construction work will be selected, considering the following. Standard bidding documents for each type of contract for contractor contracts are shown in **Table 4-5**.

- Properties and quantities of construction work to be procured
- Procurement method of similar procurements adopted previously
- Risk diversification between the employer and the contractor
- Procurement Contract Supervision Methods

The form of the Contractor Agreement is as follows.

- Unit rate contract
- Lump sum contract
- Cost-reimbursement contract
- Time and material rate contract
- Design and Build a contract
- Management contract
- Performance-based maintenance or management contract
- Piece work contract
- Build Operate and Maintenance contract
- Turnkey contract
- Engineering, Procurement and Construction (EPC) Contract

4.3.2. The Selection Process for Contractors

The standard procedure for contractor procurement and the general time required for each step are shown in **Table 4-6**. This procedure is like that described in FIDIC's "Bidding Procedures, 2nd Edition 1994".

Table 4-5 Standard Bidding Documents for Each Type of Contract for Contractor Contracts

No	Procurement Method	Contract Size in NRs.	Recommended Standard Bidding Document (available in ppmo.gov.np)	Remarks
1	Pre- Qualification (PQ)		Prequalification of Bidders - August 2019	For the large and complex nature of works
2	Engineering, Procurement and Construction (EPC)		EPC SBD ICB	For the large and complex nature of works. The Procuring Entity intends to select a Bidder (a Contractor) for the Procurement of Works under Open Tendering following the Single Stage Two Envelope system without having a pre-qualification procedure.
3	Engineering, Procurement and Construction (EPC)		EPC SBD NCB	For the large and complex nature of works
4	International Competitive Bidding (ICB)	>5 billion	SBD for Procurement of works ICB Two Envelope revised on July-22-2022	In case of Pre-qualification, this document is issued to the pre-qualified bidder
5	National/Local Competitive Bidding (NCB/LCB)	>20 million to < 5 billion	NCB Works, Single Stage Two Envelope for above 20 Million September-30-2022	In case of Pre-qualification, this document is issued to pre-qualified bidder [PQ only in special circumstances]
6	National/Local Competitive Bidding (NCB/LCB)	<20 million	NCB Works, Qualification not Required for up to 20 Million, final - September-30-2022	
7	Limited International Bidding (LIB)	For highly specialized works only	SBD for Procurement of works ICB Two Envelope revised on July -22-2022 or specialized document	
8	Sealed Quotation	< 2 million	Sealed Quotation Works - August 2019	
9	Direct Purchase	< 1 million	Procurement of Works, Direct Purchase	Issue letter to the firms registered in the standing list
10	Force Account	< 0.1 million	None	
11	Public Bidding	In an emergency or other special circumstances	Sealed Quotation Works - August 2019	As specified in Rule 145, PPR 2007
12	Users' Committee	< 50 million		Competition among user committee

Source: DOR

Table 4-6 The Process of Contracts Agreement for Contractor

Step	Activity	Responsibility	Estimated time in days		
			ICB/LIB	NCB	Sealed Quotation
1	Establishment of Procurement Strategy	Preparation: Project Manager or Consultant Approval: Same as for acceptance of bids			
2	Prequalification		Large and complex civil works contracts and contracts for technically difficult plants. [Normally, ICB requires PQ]		Not required
2.1	Preparation of Prequalification Documents	Preparation: Project Manager or Consultant Approval of Criteria: Director General (DG)	30	15	0
2.2	Invitation for pre-qualification	Preparation: Project Manager or Consultant	15	15	0
2.3	Submission of Prequalification Documents	Prospective Bidders	60	30	0
2.4	Analysis of Prequalification Documents & Selection of Prequalified Bidders	Preparation: Project Manager or Consultant Approval: Competent Authority (same as for acceptance of bids)	60	30	0
2.5	Donor No Objection (If required in 2.1 and 2.4)	Donor	Additional 15 days each for 2.1 and 2.4		NA
2.6	Notification to Applicants	Project Manager or Consultant	15	7	0
	Subtotal of step 2		210	127	0
3	Preparation of Bid Documents (Excluding Design Work)	Preparation: Project Manager or Consultant Approval: Competent Authority (same as for the acceptance of bids)	30	30	15
4	Bidding Period				
4.1	Arrange Notice	Project Manager or Consultant	14	14	7
4.2	Issue of Bid Documents	Project Manager or Consultant	14	14	7
4.3	Site Visit by Bidders	Project Manager, Consultant, and Prospective Bidders	Time included in 4.5		
4.4	Bidders Queries a) Written b) Pre-bid Meeting	Project Manager, Consultant and Prospective Bidder	Complete by 15 days before the bid submission deadline	Complete by ten days before the bid submission deadline	
4.5	Preparation and Submission of Bids	Bidders	45 from the first notice	30 from the first notice	15 from the first notice
	Subtotal of step 4		73	58	29
5	Opening of bids	Project Manager	Immediately after submission, on the same day		
6	Evaluation of Bids				
6.1	Preliminary Examination of Bids	The Bid Evaluation Committee and Consultant	Included in 6.2	Included in 6.2	Included in 6.3

6.2	Substantial Responsiveness of Bids	Bid Evaluation Committee and Consultant	14	7	Included in 6.3
6.3	Detailed Evaluation of Bids	Bid Evaluation Committee and Consultant	28	21	7
6.4	Bid Evaluation Report	Bid Evaluation Committee and Consultant	14	14	7
6.5	Donor No Objection (If required)	Donor	14	14	Not Required
6.6	Re-bidding (If required)	Project Manager and Consultant	21	15	15
6.7	Selection of bid for approval	Competent Authority	7	7	Not Required
6.8	Issue of intention to award notice	Project Manager and Consultant	7	7	Not Required
6.9	Complain to Intention to award	Bidder	7	7	Not Required
6.10	Approval	Competent Authority	7	7	7
	Subtotal of step 6 excluding 6.6 and no complaints as per 6.9		98	84	21
7	Award of Contract				
7.1	Letter of Acceptance	Project Manager	7	7	Not required
7.2	Provision of Performance Security	Successful Bidder	15	15	7
7.3	Signing of Contract Agreement	Signing: Competent Authority and Successful Bidder	7	7	7
	Subtotal of 7		29	29	14
8	Bid Validity and Bid Security Periods				
8.1	Bid Validity Periods	Specify: Project Manager Comply: Bidders	120	120 for estimated amount >NRs.100 million and 90 for up to NRs. 100 million	45
8.2	Bid Security Periods	Specify: Project Manager Comply: Bidders	150	150 for estimated amount >NRs100 million and 120 for up to NRs. 100 million	65
	Subtotal excluding 8		440	328	79

Source: DOR

4.3.3. Setting of PQ (Pre-Qualification) Conditions

In the Prequalification of Bidders (August 2019) issued by the PPMO, terms and conditions for satisfactory performance of the vendor contract in the Pre-Qualification (PQ) are established concerning the following items.

- Eligibility
- Nationality
- Conflict of Interest
- Government of Nepal / Department of Eligibility
- Government-Owned Entity
- United Nations Eligibility
- VAT and PAN Registration
- Pending Litigation
- Historical Financial Performance
- Average Annual Construction Turnover
- Experience
- General Construction Experience
- Contracts of Similar Size and Nature
- Construction Experience in Key Activities
- Personnel
- Equipment
- Domestic Preference

4.3.4. Concept of Bid Packages (Orders by Construction Work Type, Scale of Order)

Construction work may be performed under a single contract or by splitting the package into multiple packages. Splitting should be considered in the following situations.

- ✓ When the project scale is too large for a single contractor to take on, given the technical, administrative, and financial capabilities of the contractors that could be procured.
- ✓ The construction project comprises various disciplines such as civil, mechanical, electrical, etc., and there is no suitable contractor.
- ✓ Where construction packages are physically separated from each other, and separate site management is required for construction work.
- ✓ The construction work requires a variety of plant and equipment that a single contractor cannot manage.
- ✓ The construction work requires various skills and expertise that no single contractor can possess.

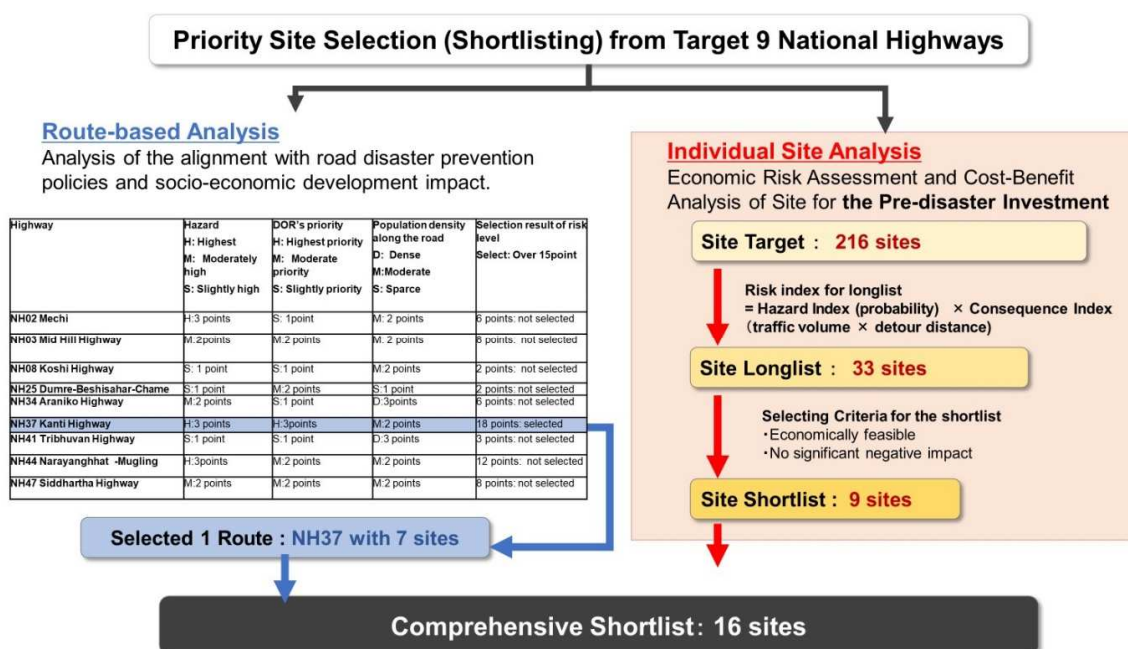
The executing agency must consider all possible combinations of contract packages and decide on the most favorable combination based on the opinions of consultants and experts, considering the management cost advantages and disadvantages.

In the case of Nepal, if the construction work is complex and requires advanced technology and equipment, ICB should be applied, but if the construction work is not difficult, NCB may be applied by keeping the project cost below NRs. 5 billion. In the case of landslide, if the construction work is not complicated and the estimated project cost is less than NRs.5 billion, the single package should be applied to a single line.

Chapter 5. Methodology of Selection of Priority Sites

A list was created to identify priority sites for landslides on Nepal's NHs based on the occurrences of road landslides and the social situation mentioned above.

This survey combined route-based and site-based analyses to conduct a multifaceted evaluation. In the route-based analysis, important routes were selected by a simple method using indicators such as risk, DOR's priority, and population density for each route, considering the validity of government policies and their impact on economic development. A shortlist of route-based analysis was created for those parts of the targeted routes that are high risk and for which DOR has requested assistance. On the other hand, for site-based analysis, firstly, high-risk sites were extracted as a longlist based on on-site surveys of several recurrent damaged sites. Then, a cost-benefit analysis for engineering measures was conducted for available benefits, and economically feasible sites were selected as shortlist of individual site analysis. We processed these two evaluation methods in parallel, organized the risk sites extracted by each method into a comprehensive shortlist, and selected 16 sites as candidate sites for priority engineering measures projects.



Source: JICA Survey Team

Figure 5-1 Policy of the Priority Site Selection (Route-based Analysis and Individual Site Analysis)

Table 5-1 shows the selection results of priority sites for engineering measures as a comprehensive shortlist. The technical difficulties shown in the table are defined as follows.

Difficulty: DOR will need technical support from Japan and other sources for risk assessment, planning, investigation, design, cost estimation, and construction supervision. In planning, it may be economically more effective to change the road alignment by building tunnels, bridges, etc., rather than taking measures against slopes.

Moderate: Not at a level that DRO can handle; technical support from GESU is required, and technical support from Japan is also considered effective.

Easy: Planning, designing, and managing construction at DRO is possible with simple technical advice.

Table 5-1 Selection Result of Priority Sites for Engineering Measures (Comprehensive Shortlist)

NH	Chainage	Inventory No.	Risk Index Ranking for Longlist	DOR's priority Ranking (October 10, 2023)	Route-based Analysis	Site-based Analysis	Technical Difficulty
NH25	45+150	L21	16	23		✓	Medium
NH37	42+000	K9	68	3	✓		Medium
NH37	46+000	K8	73	4	✓		Medium
NH37	56+420	K7	63	2	✓		Medium
NH37	61+627	K6	119	7	✓		Difficult
NH37	63+885	K5	62	1	✓		Difficult
NH37	66+565	K4	85	6	✓		Difficult
NH37	69+365	K3	84	5	✓		Difficult
NH44	20+000	L5	34	N.A.*		✓	Difficult
NH44	21+500	L2	1	N.A.		✓	Difficult
NH44	31+400	L25	4	N.A.		✓	Medium
NH44	33+150	L24	14	N.A.		✓	Medium
NH44	33+800	L26	15	N.A.		✓	Medium
NH47	35+500	SH03	9	9		✓	Easy
NH47	46+400	SH09	29	14		✓	Easy
NH47	87+400	SH18	12	12		✓	Medium

*N.A.: Not Applicable

Source: JICA Survey Team

Chapter 6. Route-Based Analysis for Selecting Priority Sites

6.1. Result of Route-Based Analysis of Priority Sites

The NHs are evaluated using three criteria, which indicate the situations of the highway (i.e., route-based analysis). The analysis is done based on the scores aggregating individual scores of three criteria, namely (i) hazard level (risk level of the route evaluated by the density of the hazards and the number of human life loss and injury), and two criteria of consequence level (ii) DOR's policy priority and (iii) population density of along the routes). The result is shown in **Table 6-1**.

Table 6-1 The Result of the Route-Based Analysis for Selecting Priority Project Sites

Highway	Hazard level H: Highest M: Moderately high S: Slightly high	DOR's priority H: Highest M: Moderate S: Slightly	Population density along the road D: Dense M: Moderate S: Sparse	Analysis result of risk level: Rating multiplier for each assessment
NH02 Mechi	H:3 points	S: 1point	M: 2 points	6 points
NH03 Mid Hill Highway	M:2points	M:2 points	M: 2 points	8 points
NH08 Koshi Highway	S: 1 point	S:1 point	M:2 points	2 points
NH25 Dumre-Beshisahar-Chame	S:1 point	M:2 points	S:1 point	2 points
NH34 Arniko Highway	M:2 points	S:1 point	D:3points	6 points
NH37 Kanti Highway	H:3 points	H:3points	M:2 points	18 points
NH41 Tribhuvan Highway	S:1 point	S:1 point	D:3 points	3 points
NH44 Narayanghat-Mugling	H:3points	M:2 points	M:2 points	12 points
NH47 Siddhartha Highway	M:2 points	M:2 points	M:2 points	8 points

Route danger: Highest: 3 points, Medium-high: 2 points, slightly high: 1 point

DOR priority: Highest: 3 points, medium priority: 2 points, low priority: 1 point

Roadside population density: Dense: 3 points, Medium: 2 points, Low: 1 point

Source: JICA Survey Team

As a result of the route-based analysis, NH37 Kanti Highway was selected as the highest-risk route. Seven priority sites on NH37 Kanti Highway were listed in DOR's priority list on October 10, 2023, and the survey team assessed the high risk of seven road landslide sites by site survey and selected the Comprehensive Shortlist Sites, as shown in **Table 6-2**.

Table 6-2 Comprehensive Shortlist Site Based on the Route-Based Analysis

DOR Priority	National Highway Code	Chainage	Risk Index Ranking for longlist	Road Section	Type
1	NH37	63+885	62	Kanti Highway	collapse
2		56+420	63	Kanti Highway	slide
3		42+000	68	Kanti Highway	slide
4		46+000	73	Kanti Highway	collapse
5		69+365	84	Kanti Highway	collapse
6		66+565	85	Kanti Highway	collapse
7		61+627	119	Kanti Highway	collapse

Source: JICA Survey Team

6.2. Evaluation of the Hazard Level by the Routes

The hazard level by route was evaluated based on the density of the sites with landslides (216 sites that were repeatedly damaged more than once were assessed based on the request of DRO in this survey) per 10km and the number of human life losses and injuries on the whole route. as shown in **Table 6-3**. The route density of landslides more than 0.5nos./10km is categorized as “Moderately high,” and those with more than 6.0nos./10km and with human life loss and/or injury as “Slightly high”.

Table 6-3 The Result of the Route-Based Hazard Level

National Highway No.	Cumulative Number of Landslides	Inspected Road Length (km)	Hazard Level (nos./10km)	Recorded Fatality or Casualty	Hazard Level
NH02	12	352	0.3		Slightly high
NH03	92	1155	0.8		Moderately high
NH08	13	320	0.4		Slightly high
NH25	38	96	4.0		Slightly high
NH34	67	112	6.0		Moderately high
NH37	33	49	6.7	2-person causality	Highest
NH41	13	136	1.0		Slightly high
NH44	32	26	12.3	4-person fatality	Highest
NH47	98	184	5.3	Several person fatalities	Moderately high

Source: JICA Survey Team

6.3. DOR’s Policy Priority

DOR shared the list of the priority sites for implementing landslide engineering measures shown in the JICA Survey Team on 10 October 2023. The priority was determined based on the analysis of the expected improvement of the usefulness of the route upon the implementation of engineering measures on the hazardous sites. NH37, with the highest priority, was scored as “H (highest priority),” and others on the list as “M(moderate).”

Table 6-4 DOR List of Priority Sites for Landslide Engineering Measures (as of 10th October 2023)

DOR Priority	NH Code	Chainage	Risk Index Ranking for longlist	Road Section	Landslide Type	Priority Category
1	NH37	63+885	62	Kanti Highway	collapse	H: Highest
2		56+420	63	Kanti Highway	slide	
3		42+000	68	Kanti Highway	slide	
4		46+000	73	Kanti Highway	collapse	
5		69+365	84	Kanti Highway	collapse	
6		66+565	85	Kanti Highway	collapse	
7		61+627	119	Kanti Highway	collapse	
8	NH44	33+000	6	Narayanghat- Mugling	collapse	M: Moderate priority
9	NH47	35+500	2	Siddartha Highway	slide	
10		48+600	8	Siddartha Highway	collapse	
11		56+200	11	Siddartha Highway	slide	
12		87+400	12	Siddartha Highway	collapse	
13		39+600	28	Siddartha Highway	road shoulder collapse	
14		46+400	29	Siddartha Highway	collapse	
15		49+800	30	Siddartha Highway	slide	
16		NH03	37+900	25	Pokhara- Baglung	
17	36+400		26	Pokhara- Baglung	slide	
18	26+200		27	Pokhara- Baglung	slide	
19	51+500		33	Pokhara- Baglung	collapse	
20	NH25	45+150	16	Dumre-Besisahar-Chame	collapse	
21		61+100	18	Dumre-Besisahar-Chame	collapse	
22		62+500	19	Dumre-Besisahar-Chame	collapse	
23		101+800	31	Dumre-Besisahar-Chame	collapse	
24	NH03	4+000	201	Khurkot-Halesi	collapse	

Source: JICA Survey Team

6.4. Population Density along the Routes

Table 6-5 shows the size of the population and the number of households that benefitted from landslide risk reduction project inwards where the NHs pass. The population, number of households, area width, and population density of each ward are reviewed. The data on the population and the number of households are based on the National Population and Housing Census 2021. The population density was categorized as “Sparse” when the density is below 100 persons/ km², “Moderate” when 100 to 500 persons/ km², and “Dense” when over 500 persons/km².

Table 6-5 Population, Number of Household, and Population Density along the Routes

Route	District	Population	Household	Area(km ²)	Population density (population/km ²)	Population density
NH02 Mechi	Ilam	82,744	21,358	298	278	M: Moderate
	Jhapa	143,771	35,297	226	636	
	Panchthar	51,141	12,952	224	228	
	Taplejung	46,859	11,853	1941	24	
	Total/Average for population density	324,515	81,460	2689	121	
NH03 Mid Hill Highway	Sindhuli	24,883	5,750	272	92	M: Moderate
	Udayapur	2,323	552	31	75	
	Okhaldhunga	10,767	2,391	82	131	
	Khotang	13,383	3,009	108	124	
	Ramechhap	10,543	2,855	112	94	
	Baglung	9,410	2,651	26	363	
	Kaski	2,362	654	6	412	
	Parbat	38,046	10,715	80	478	
Total/Average for population density	111,717	28,577	716	156		
NH08 Koshi Highway	Bhojpur	7,365	1,782	87	84	M: Moderate
	Dhankuta	43,555	11,471	175	250	
	Morang	228,114	53,359	87	2,609	
	Sankhuwasabha	53,574	13,846	1,308	41	
	Sunsari	264,271	67,331	143	1,851	
	Total/Average for population density	596,879	147,789	1,801	331	
NH25 Dumre - Beshisahaar -Chame	Lamjung	34,246	9,503	428	80	S: Sparce
	Manang	2,688	786	416	6	
	Total/Average for population density	36,934	10,289	843	44	
NH34 Araniko Highway	Bhaktapur	214,336	55,394	44	4,866	D: Dense
	Kabhrepalanchok	89,006	22,608	143	621	
	Kathmandu	335,466	92,065	219	1,529	
	Sindhuripalchok	69,690	18,988	508	137	
	Total/Average for population density	708,498	189,055	914	775	
NH37 Kanti Highway	Lalitpur	13,703	3,330	56	243	M: Moderate
	Makawanpur	21,097	4,681	178	118	
	Total/Average for population density	34,800	8,011	235	148	
NH41 Tribhuvan Highway	Dhading	26,951	6,477	75	357	D: Dense
	Kathmandu	265,510	71,559	33	8,030	
	Makawanpur	43,778	10,973	228	192	
	Total/Average for population density	336,239	89,009	337	999	
NH44 Narayanghat-Mugling Highway	Chitwan	21,993	5,248	144	153	M: Moderate
	Tanahu	11,509	3,051	103	112	
	Total/Average for population density	33,502	8,299	247	136	
NH47 Siddhartha Highway	Rupandehi	34,727	8,954	13	2,719	M: Moderate
	Palpa	26,247	6,738	188	139	
	Total/Average for population density	60,974	15,692	201	303	

Source: JICA Survey Team Based on the National Population and Housing Census 2021

Chapter 7. Individual Site Analysis for Priority Sites

7.1. Risk Index for Longlist Selection for Priority Sites

The risk level indexes were calculated for the 216 sites on 9 target NHs that were surveyed on-site. Landslides have repeatedly damaged the 216 sites and require engineering measures by DRO as priority. The top high-risk sites were selected as priority sites for landslide risk reduction and to create a longlist for consideration.

Risk was assessed as the product of the likelihood and consequence of damage at each site.

$$\text{Risk} = \text{likelihood of damage} \times \text{consequence of damage}$$

Risk was calculated by the following formula to be a quantitative index.

$$\text{Risk index (\% vehicles km/year/day)} =$$

$$\begin{aligned} & \text{Quasi-annual exceedance probability of damage of whole-width road closure (\%/year)} \times \\ & \text{Annual average daily traffic excluding motorcycles (vehicle/day)} \times \\ & \text{Detour distance (km)} \end{aligned}$$

Each item of this calculation formula is explained below.

Quasi-annual exceedance probability of damage of whole-width road closure (%/year)

- Annual exceedance probability is the probability of being affected by damage in one year expressed as a percentage. It is the reciprocal of the probability year, which indicates the probability of being affected once in how many years.

$$\text{Annual exceedance probability (\%/year)} = 1/\text{probability year (year)}$$

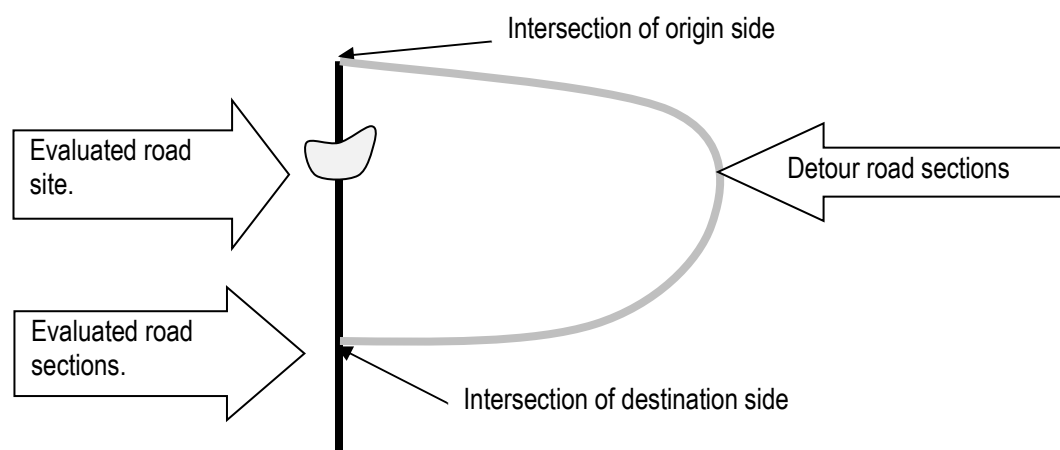
- Because it is not calculated by statistical or numerical analysis and is assumed based on the damage history of each risk site, it is called a quasi-annual exceedance probability or a quasi-probability year of damage. In the concept of probability, the annual exceedance probability should not be 100% or more. The probability year should be one year at maximum. Still, in the assessment of the quasi-damage probability, the sites that are likely to be affected n times in a year are $n \times 100\%$ annual exceedance probability, and $1/n$ probability year is set.
- Based on satellite imagery evidence, the number of damages in the past 20 years is estimated, and the quasi-annual exceedance probability of whole-width road closure is calculated based on the evidence of satellite images over the past 20 years. If the damage caused by whole-width road closures is not acknowledged, the quasi-damage annual exceedance probability was evaluated as the following as an experiential estimation of the unique setting for this assessment.
- If the damage is less severe than the road shoulder damage, the quasi-annual exceedance probability year of whole-width road closure is considered 1/5. If one lane is closed, it is evaluated as 1/2. In other words, the quasi-probability year of whole-width road closure is assessed by multiplying it by two if the damage is less severe than the road shoulder damage and by five if one lane is closed.

Annual average daily traffic (AADT) excluding motorcycles (vehicle/day)

- Considering the degree of social impact caused by road landslides, it is necessary to select sites with a high-risk level of damaged sites that should be prioritized, so we prioritize logistics transportation, which has a high social impact; the risk index is calculated using the annual average daily traffic volume excluding motorcycle traffic (AADT_{emc}). However, the annual average daily traffic volume, including motorcycles (AADT), will also be calculated as a reference index.

Detour Distance (km)

- The concept of a detour highway is shown in **Figure 7-1**. For roads with two or more lanes, two or more lanes are considered detour highways. For roads with more than 1.5 lanes, more than 1.5 lanes are considered detour highways. For paved roads, unpaved roads are not considered detour highways.
- With the above settings, the longest detour route is 390km. For a site with no detour, calculations are made using a detour distance of 500km, which can be differentiated from 390km of the longest detour distance of a site to avoid the risk index from infinity.



Source: World Bank-GFDRR 2020: Road Landslide Risk Management Handbook Operation Manual

Figure 7-1 The Concept of Setting Detours

7.2. Selection Criteria for Longlist

The following risk indexes were calculated for 216 sites surveyed on the target NHs, as described in "**5.2. Road Landslide Risk Assessment**" (**Annex A.1. List of 216 sites**). The top high-risk sites were selected as priority candidates for risk reduction projects and to create a longlist.

Risk was calculated by the following formula to be a quantitative index.

Risk index (% vehicles km/year/day) =

Quasi-annual exceedance probability of damage of whole-width road closure (%/year) X
Annual average daily traffic excluding motorcycles (vehicle/day) X
Detour distance (km)

The threshold for selection was defined as sites with a risk index of 100,000 (% vehicles km/year/day) or greater. This selection criteria were set on a scale where the number of selected sites exceeds 30, and the estimated overall project cost exceeds NRs. 10 billion. Furthermore, it is assumed that the number of sites will be selected during shortlist selection.

7.3. Formulation of Longlist

33 sites with risk index values exceeding 100,000 (% vehicles/km/year/day) were selected for the longlist. **Table 7-1** summarizes the sites selected for the longlist, and its detailed indexes are presented in **Table 7-2**. The selected sites are shown in **Figure 7-2** to **Figure 7-6**. The 216 sites surveyed are ranked in order of priority by the risk index calculated, and the index values are shown in **Annex A.2. Risk index ranking**.

The items listed in **Table 7-2** are explained below.

Type of Landslide: Type of landslide, See **Table 3-3**.

Historical Failure Volume: See **Figure 3-7** and its explanation.

Annual Exceedance Probability Damage to the Whole Road Width (%/year): Quashi annual landslide damage probability (%/year)

Measures for the hazard itself: Measures to stabilize sources of collapse, landslides, debris flows, and erosion.

Road protection measures from hazards: Road protection measures include catch works from collapse, landslide, debris flow, or erosion.

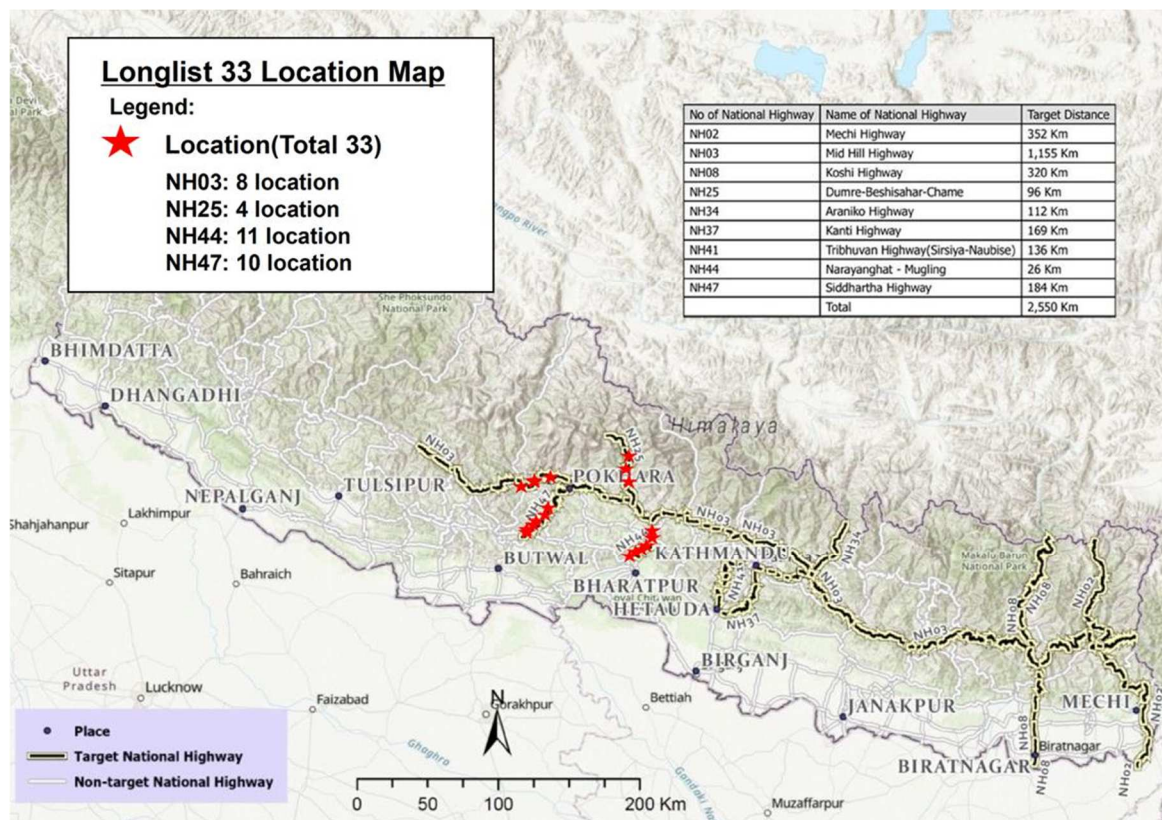
Hazard avoidance by shifting road alignment: Avoidance by shifting the road away from sources of collapse, landslides, debris flows, and erosion.

Table 7-1 Summary of Priority Sites of Nine Target NHs

NH Code	Highway Name		DOR Priorities	No. of Inspected sites	No. of Selected site	Percentage in longlist
NH02	Mechi Highway			5	0	0%
NH03	Mid Hill Highway	Khurkot - Halesi	✓	22	0	0%
		Pokhara - Baglug	✓	40	8	20%
NH08	Koshi Highway			12	0	0%
NH25	Dumre-Beshisahar-Chame		✓	15	4	27%
NH34	Araniko Highway			34	0	0%
NH37	Kanti Highway		✓	13	0	0%
NH41	Tribhuvan Highway			10	0	0%
NH44	Narayanghat-Mugling		✓	11	11	100%
NH47	Siddhartha Highway		✓	54	10	19%
			Total	216	33	15%

Source: JICA Survey Team

A summary of the selected sites is shown in **Figure 7-2**.



Source: JICA Survey Team

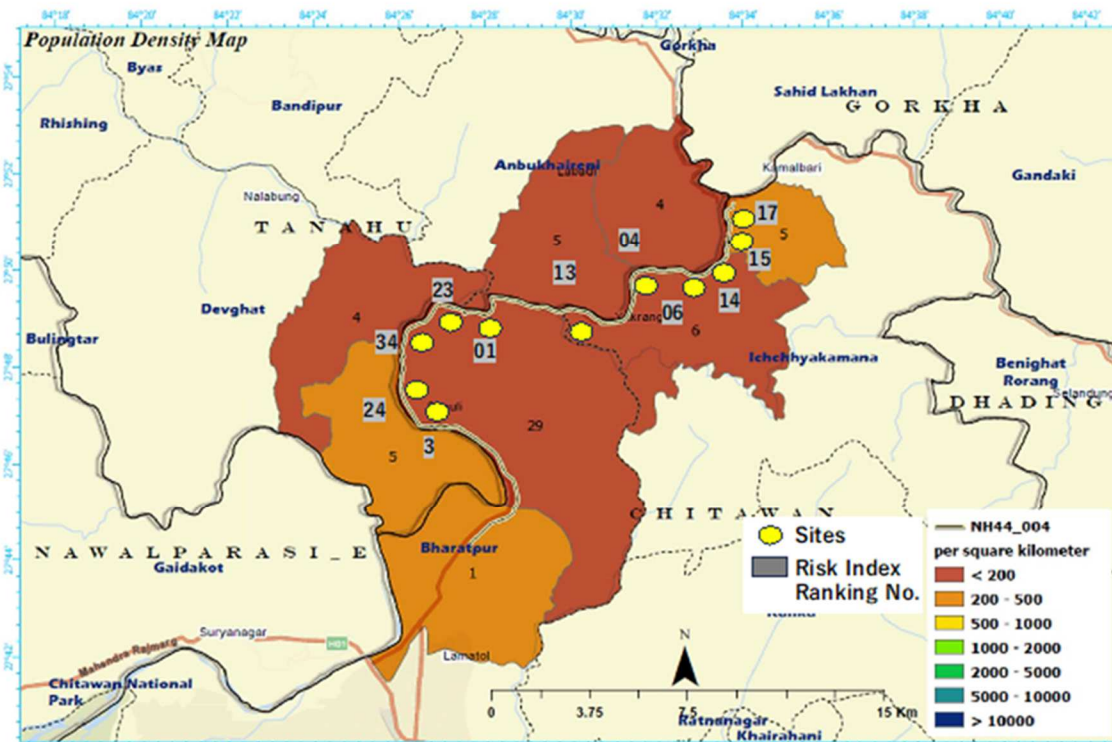
Figure 7-2 Map of Priority Sites on the Longlist

Table 7-2 Longlist of Priority Sites of Target Nine NHs

Risk Index Ranking	Landslide Site					Type of Landslide	Historical Failure Volume V=L*W*D/3	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment				
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No.										AAEP	AADT _{exc}	DR	=AAEP*AADT _{exc} *DR
1	NH44	Narayanghat-Mugling	21+500	Mauri Bridge	L2	Flow	25,000	25	7,607	500	950,875	Frame work with rock bolt	Check dams	Bridge				
2	NH47	Siddhartha Highway	35+500	Jhumsa	SH03	Slide	18,012	30	7,211	366	791,768	Earth work, subsurface drainage	Catch works	Reinforced Earth				
3	NH44	Narayanghat-Mugling	15+100	Bhangadi	L3	Collapse	5,350	20	7,607	500	760,700	Surface drainage	Retaining and breast walls					
4	NH44	Narayanghat-Mugling	31+400	Namshi Khola	L25	Collapse	5,600	20	7,607	500	760,700	Frame work with ground anchor, surface drainage						
5	NH47	Siddhartha Highway	39+500	Hiyeude Khola	SH06	Flow	20,833	25	7,211	366	659,807	Frame work rock bolt, surface drainage	Check dams					
6	NH44	Narayanghat-Mugling	33+000	Nyanse River	L7	Collapse	13,120	15	7,607	500	570,525	Frame work rock bolt, surface drainage	rockfall protection barriers					
7	NH47	Siddhartha Highway		Siddhababa area	SH01	Collapse	32,375	20	7,211	366	527,845							
8	NH47	Siddhartha Highway	48+600	Near Dumre Bazar	SH10	Collapse	15,000	20	7,211	366	527,845	Cutting, reinforced earth wall						
9	NH47	Siddhartha Highway	38+000		SH05	Collapse	6,600	15	7,211	366	395,884	Cutting, reinforced earth wall						
10	NH47	Siddhartha Highway	56+000	from Bartung Bazar	SH13	Slide	5,885	15	7,211	366	395,884	Earth work, subsurface drainage	Catch works	x				
11	NH47	Siddhartha Highway	56+200	from Bartung	SH14	Slide	9,333	15	7,211	366	395,884	Earth work, subsurface drainage	Catch works	x				
12	NH47	Siddhartha Highway	87+400	Randi -1	SH18	Collapse	20,000	15	7,211	366	395,884	Frame work with ground anchor						
13	NH44	Narayanghat-Mugling	26+500		L6	Carriageway Collapse	7,000	10	7,607	500	380,350	Frame work with ground anchor						
14	NH44	Narayanghat-Mugling	33+150	23June 2017 police killed, 1 truck buried	L24	Collapse	20,000	10	7,607	500	380,350	Cutting work, frame work with ground anchor						
15	NH44	Narayanghat-Mugling	33+800	Tuin khola	L26	Collapse	14,000	10	7,607	500	380,350	Frame work with rock bolt						
16	NH25	Dumre-Besisahar-Chame	45+150		L21	Collapse	126,000	25	1,673	500	209,125	High-intensity net with bioengineering						
17	NH44	Narayanghat-Mugling	34+500	Tuin Khola	L23	Collapse	11,117	5	7,607	500	190,175	Frame work, surface drainage						
18	NH25	Dumre-Besisahar-Chame	61+100		L12	Collapse	17,000	20	1,673	500	167,300	Frame work, surface drainage	Rockfall protection wall					
19	NH25	Dumre-Besisahar-Chame	62+500		L20	Collapse	12,500	20	1,673	500	167,300	Frame work, surface drainage						
20	NH03	Pokhara-Baglung	58+700	Nayapool Flow, Kushma	PB03	Flow	87,780	20	1,597	500	159,700		Check dams, bank protection					
21	NH03	Pokhara-Baglung	57+400	Amadi 1, Kushma	PB04	Collapse	1,085	20	1,597	500	159,700	Frame work						
22	NH03	Pokhara-Baglung	52+500	Damkare khola, Kushma	PB11	Flow	31,680	20	1,597	500	159,700		Check dams					
23	NH44	Narayanghat-Mugling	21+300	Dobhan (Seti & Trisuli)	L1	Collapse	2,125	4	7,607	500	152,140	Frame work with rock bolt	Masonry wall, Flow protection wall					
24	NH44	Narayanghat-Mugling	16+000	Dasdhunga	L4	Carriageway Collapse	820	4	7,607	500	152,140	Crib-walls						
25	NH03	Pokhara-Baglung	37+900	Nayapool 4, Kaski	PB36	Slide	125,000	10	3,017	500	150,850	Earth work, subsurface drainage	Catch works	x				
26	NH03	Pokhara-Baglung	36+400	Nayapool 5, Kaski	PB37	Slide	40,000	10	3,017	500	150,850	Earth work, subsurface drainage	Catch works	x				
27	NH03	Pokhara-Baglung	26+200	Pandung, Kaski	PB38	Slide	1,350,000	10	3,017	500	150,850	Earth work, subsurface drainage	Catch works	x				
28	NH47	Siddhartha Highway	39+600	Near Hiyeude	SH07	Collapse	6,000	5	7,211	366	131,961	Frame work						
29	NH47	Siddhartha Highway	46+400	Near Charchure	SH09	Collapse	8,400	5	7,211	366	131,961	Cutting, bioengineering, breast wall, surface drainage						
30	NH47	Siddhartha Highway	49+800	Lower Dumre	SH12	Slide	17,000	5	7,211	366	131,961	Earth work, subsurface drainage	Catch works	x				
31	NH-25	Dumre-Besisahar-Chame	101+800		L19	Collapse	80,000	15	1,673	500	125,475		Reinforced earth wall					
32	NH03	Pokhara-Baglung	58+700	Saharshadhara 2, Kushma	PB02	Collapse	14,405	15	1,597	500	119,775	Cutting work, gabion wall						
33	NH03	Pokhara-Baglung	51+500	Paradi Slide, Kushma	PB21	Collapse	66,667	15	1,597	500	119,775	Reinforced earth						
34	NH44	Narayanghat-Mugling	20+000	Gaighat	L5	Flow	200	3	7,607	500	114,105	Surface drainage	Check dams					

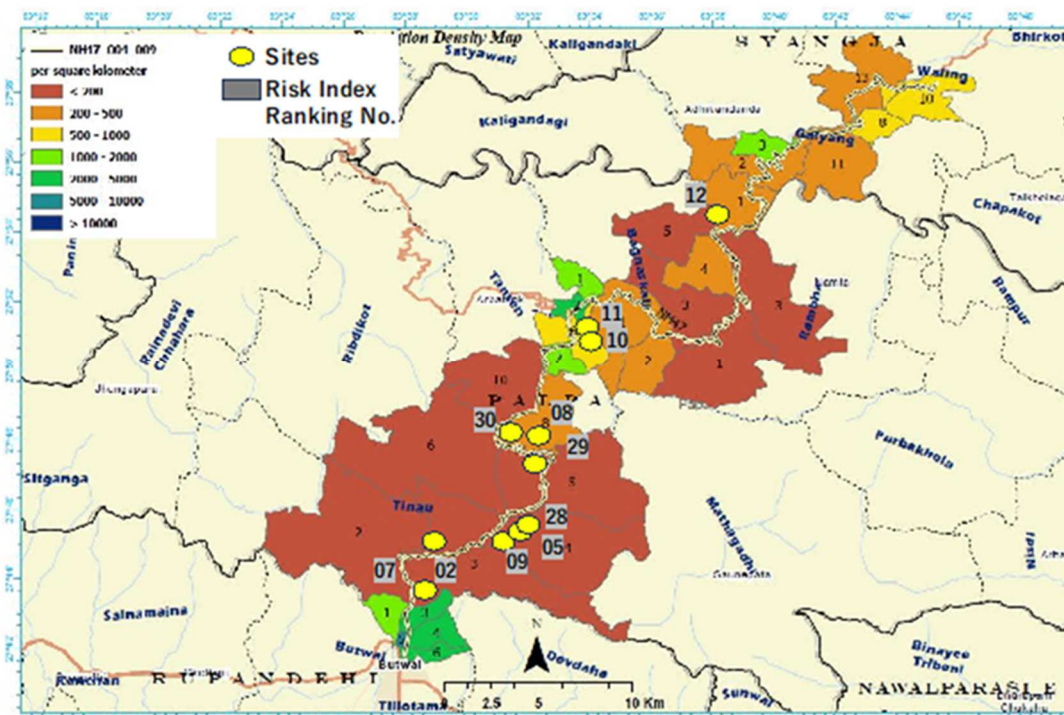
Note: DOR plans engineering measures to NH47 Siddhartha Highway, Siddhababa area, risk index ranking of 7, and not included in longlist. Detailed tables are shown in B.1. Longlist sites and the other assessment sites
Source: JICA Survey Team

Figures 7-2 to 7-6 show the selected sites by route. The numbers written alongside each map are the Risk Index Ranking.



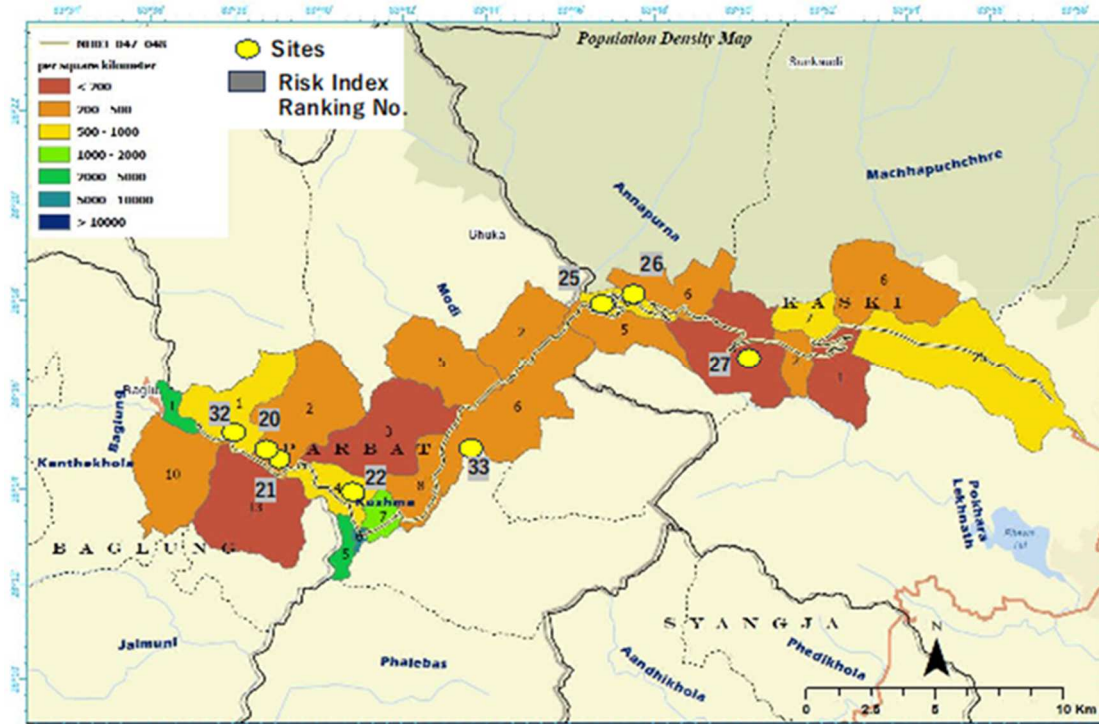
Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

Figure 7-3 Map of Priority Sites on the Longlist (NH44, Narayanghat-Mugling)



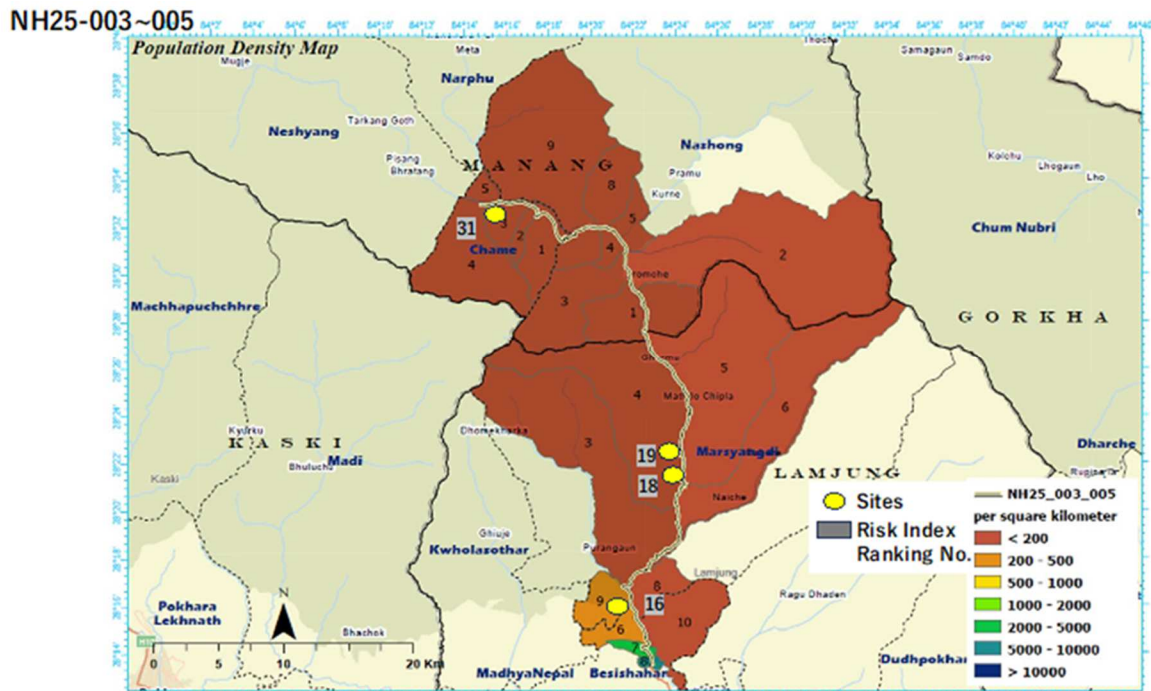
Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

Figure 7-4 Map of Priority Sites on the Longlist (NH47, Siddhartha Highway)



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

Figure 7-5 Map of Priority Sites on the Longlist (NH03, Pokhara - Baglung)



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

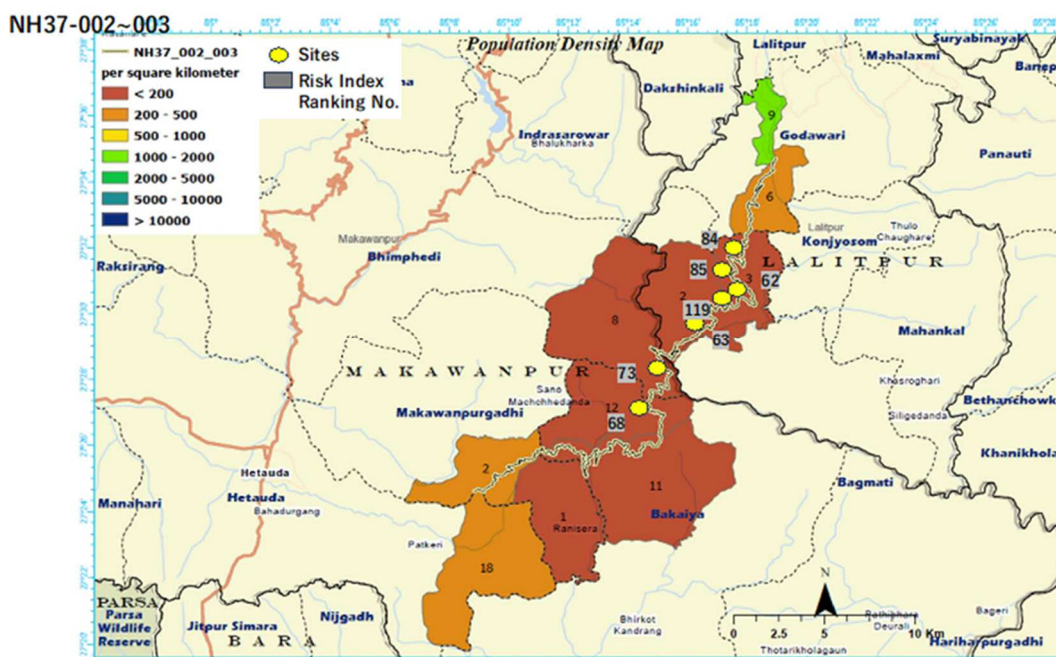
Figure 7-6 Map of Priority Sites on the Longlist (NH25, Dumre-Beshisaha-Chame)

Although the two highways with DOR’s priority sites listed on 10th October 2023 below were not selected for the longlist, they were also reviewed. priority sections of the DOR: The sites with relatively high-risk indexes and sites where DOR expected assistance were selected as priority consideration sites. The details are shown in **Table 7-3, Table 7-4, Figure 7-7, and Figure 7-8**. As with the sites selected for the longlist, Engineering measures is also proposed to provide technical advice to DOR.

- NH37 Kanti Highway, 7 sites.
- NH03 Mid Hill Highway (Khurkot – Halesi Section), 4 sites.

Table 7-3 List of Sites of Engineering Measures Planning (NH37: Kanti Highway 7 sites)

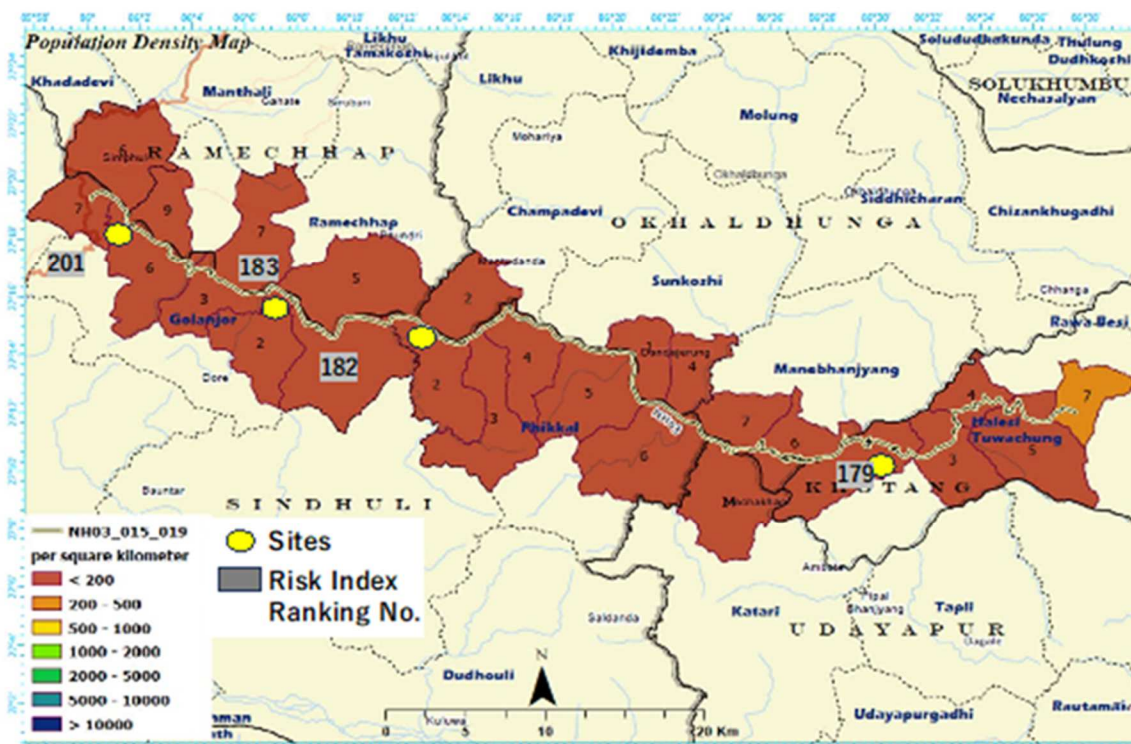
Risk Index Ranking	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	Type of Geohazard	Historical Failure Volume V=L*W*D/3	Annual Exceedance Probability Damage to the Whole Road Width (%/year)		Detour Road Sections (km)	Risk Index	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment
								AAEP	AAETemc					
84	NH37	Kanti Highway	69+365	Narayanghat slide	K3	Collapse	44,000	10	2,307	152	35,070		Reinforced earth wall	x
85	NH37	Kanti Highway	66+565	Karukibas slide	K4	Collapse	142,497	10	2,307	152	35,070		Reinforced earth wall	x
62	NH37	Kanti Highway	63+885	23rd September 2020, two people were injured	K5	Collapse	18,957	20	2,307	152	70,140		Reinforced earth wall	x
119	NH37	Kanti Highway	61+627	Chhapeli Slide	K6	Collapse	58,320	5	2,307	152	17,535		Reinforced earth wall	x
63	NH37	Kanti Highway	56+420		K7	Slide	21,900	20	2,307	152	70,140	Earth work, subsurface drainage	Gabion wall	x
73	NH37	Kanti Highway	46+000		K8	Collapse	98,000	15	1,846	152	42,081		Reinforced earth wall	x
68	NH37	Kanti Highway	42+000		K9	Slide	196,000	20	1,846	152	56,108	Earth work, subsurface drainage	Gabion wall	x



Source: JICA Survey Team, OpenStreetMap showing ward population density of the 2021 Census
Figure 7-7 Map of Sites for Engineering Measures Assessment (NH37 Kanti Highway)

Table 7-4 List of Sites with Consideration of Engineering Measures (NH03:MID Hill Highway Khurkot-Halesi)

Risk Index Ranking	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No.	Type of Geohazard	Historical Failure Volume $V = L \times W \times D / 3$	Annual Exceedance Probability Damage to the Whole Road Width (%/year)		AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment
								AAP	AADTinc						
179	NH03	Khurkot-Halesi	15+600 (Ch 0+000 at Hilepani)	Khotang	HK#5	Collapse	1,100	2	897	274	4,916	Shotcrete frame work with rock bolt			
182	NH03	Khurkot-Halesi	28+060(0+00 at Khurkot)	Chyakutar (Photo HK#10)	HK#10	Collapse	800	2	956	191	3,652	Reinforced earth wall (H=5m)			
183	NH03	Khurkot-Halesi	18+600 Kulkuretar 4+000	Kulkuretar	HK#13	Collapse	2,400	2	956	191	3,652	Shotcrete frame work			
201	NH03	Khurkot-Halesi	Haibar(Akkare)	Haibar (Akkare)	HK#15a	Collapse	1,067	1	956	191	1,826				



Source: JICA Survey Team, OpenStreetMap showing ward population density of the 2021 Census

Figure 7-8 Map of Sites for Engineering Measures Assessment (NH03 MID Hill Highway Khurkot-Halesi)

Chapter 8. Natural and Social Conditions of Candidate Priority Sites

8.1. Survey of Natural and Social Conditions

A total of 33 sites were selected to the longlist as individual site analysis, which consisted of 11 sites on NH44, 10 sites on NH47, 8 sites on the Pokhara-Baglung section of NH03, and 4 sites on NH25. Apart from the longlist, DOR requested the survey team to inspect the sites of the two routes that were not selected for the longlist, which required road landslide engineering measures in August 2023 by the survey team experts and provide recommendations regarding engineering measures. DOR requested to add 11 sites, including 4 sites on the Khurkot-Halesi section of NH03, and 7 sites on NH37. **Table 8-1** summarizes the natural and social conditions of the selected longlist sites and sites requested by DOR, based on the results of survey. Natural and social conditions are described based on interviews with DOR regional offices and Google Earth image interpretation over the past 20 years. The statuses of priority sites are shown in **Annex B.3 Photos**.

Table 8-1 Summary of the Natural and Social Conditions for the Selected and Requested Site

NH Code	Risk Index Ranking	Chainage (Inventory No.) Name of Area	Type of Landslide	Natural Condition	Social Condition
Longlist Selected Sites					
NH44	1	21+500 (L2) Mauri Bridge	Flow	Debris flow occurred in 2022 and 2023. Abundant unstable sediments in upstream and steep upper slope.	Ten whole-width road closures in 2022 and one whole-width road closure in 2023 occurred due to debris flow. DOR contracted the Asian Disaster Preparedness Center (ADPS) to conduct the study and design (As of Feb 2024).
	3	15+100 (L3) Bhangadi	Collapse	The collapse has spread to the surrounding area and became debris flow partially.	Road users are at high risk of the landslides.
	4	31+400 (L25) Namshi Khola	Collapse	Large-scale collapse occurred in 2023, unstable parts also observed on its upper slope.	Eleven whole-width road closures occurred in 2023. DOR contracted the ADPC to conduct the study and design (As of Feb 2024).
	6	32+500~ 33+000 (L7) Nyanse River	Collapse	Slope collapses occurred due to road excavation. Dip-slope joints are the cause of the progressing collapse.	Seven whole-width road closures occurred in 2023. Road users are at high risk of collapse. DOR intends to implement engineering measures as part of the bridge project (As of Feb 2024).
	13	26+500 (L6)	Carriageway Collapse	Ground anchors were installed in 2022. After construction, minor settlement was observed in the adjacent section.	There are no problems with drivability under the current conditions.
	14	33+150 (L24)	Collapse	Many small-scale collapses frequently occurred. Unstable soil mass is recognized on upper and surrounding slope.	Eight whole-width road closures occurred in 2023. DOR is planning engineering measures (As of Oct 2023). Four police officers dead in 2017.
	15	33+800 (L26) Tuin Khola	Collapse	Collapse occurred in 2023, unstable parts observed on its upper slope.	Five whole-width road closures occurred in 2023 DOR contracted the ADPC to conduct the study and design (As of Feb. 2024)
	17	34+500 (L23)	Collapse	Slope cutting is completed, and the cut slope is stable.	Slope cutting measures largely decreased causality risk for road users.
	23	221+300 (L1)	Collapse	Small collapses occurred on a gentle slope.	Two whole-width road closures occurred in the 2023 rainy season.

NH Code	Risk Index Ranking	Chainage (Inventory No.) Name of Area	Type of Landslide	Natural Condition	Social Condition
		Dobhan (Seti&Trisuli)			
	24	16+000 (L4) Dasdunga	Carriageway Collapse	Revetment was constructed. No new deformations and collapses are recognized.	Revetment measures largely decreased causality risk for road users.
	34	20+000 (L5) Gaighat	Flow	Unstable parts are observed on upper slopes.	Road users are at high risk of debris flow.
NH47	2	35+500 (SH03) Jhumsa	Slide	Large bedrock has intermittently progressed over the past 40 years.	Road users are at high risk of the landslides.
	5	39+500 (SH06) Hiyeude Khola	Flow	Debris flows frequently occurred. Abundant unstable sediments in upstream and steep upper slope are recognized.	1 whole-width closures in 2023 Existing check dams filled with sediment
	8	48+600 (SH10) Near Dumre Bazar	Collapse	Large shallow collapses occurred.	Road users are at high risk of landslides.
	9	38+000 (SH05)	Collapse	Small collapses/rockfalls frequently occurred.	Road users are at high risk of landslides.
	10	56+000 (SH13) Bartung Bazar	Slide	Sliding is active.	There is a school on the upper slope.
	11	56+200 (SH14) Bartung	Slide	Sliding is active.	There is a school on the upper slope.
	12	87+400 (SH18) Ramdi	Slide	Sliding is active.	Road users are at high risk of landslides.
	28	39+600 (SH07) Near Hiyeude	Collapse	Collapses occurred due to road excavation. Abundant springs are recognized	Reinforced earth wall is under construction as of August 2023.
	29	46+400 (SH09)	Collapse	Collapses occurred due to surface water flow from upper slope	One whole-width road closure occurred in 2023.
	30	49+800 (SH12)	Slide	Slide mass is slightly unstable.	Several people died. Road users are at high risk of landslides.
NH03	20	58+700 (PB03) Nayapool Flow, Kushma	Flow	Debris flows occurred due to land use on the upper slope.	Road users are at high risk of landslides.
	21	57+400 (PB04) Armadi, Kushma	Collapse	Collapses occurred on colluvial slope.	Road users are at small risk of landslides.
	22	52+500 (PB11) Damdare Khola, Kushuma	Flow	Debris deposited on stream outlet above the road is recognized.	Road users are at high risk of landslides.
	25	37+900 (PB36) Nayapool, Kaski	Slide	Large bedrock slides are recognized.	Road users are at high risk of landslides.
	26	36+400 (PB37) Nayapool, Kaski	Slide	Large bedrock slides are recognized.	Road users are at high risk of landslides.
	27	26+200 (PB38) Pandung,	Slide	Clear slide topography is recognized. Deformations on the ground are observed.	Engineering measures implemented by DOR in 2023 (upper slope only)

NH Code	Risk Index Ranking	Chainage (Inventory No.) Name of Area	Type of Landslide	Natural Condition	Social Condition
		Kaski 8			
	32	58+700 (PB02) Saharshadhara Kushma	Collapse	Collapse on dip-slope rock slope were recognized. Retaining wall constructed at toe of cut slope stabilizes the cut slope	Road users are at small risk of collapse.
	33	51+500 (PB21) Paradi Slide, Kushma	Collapse	Existing gabion stabilized the collapse mass.	Road users are at small risk of collapse.
NH25	16	45+150 (L21)	Collapse	Collapses occurred on colluvial slope.	Road users are at high risk of geohazards.
	18	61+100 (L12)	Collapse	Collapses occurred due to surface water flowing from the upper slope.	Road users are at high risk of geohazards.
	19	62+500 (L20)	Collapse	Slightly stable on slope of glacial deposits.	One whole-width road closures occurred in 2023
	31	101+800 (L19)	Collapse	Collapses occurred due to surface water flowing from the upper slope.	Eleven whole-width road closures occurred in 2023
Sites Requested by DOR in August 2023.					
NK37	62	63+885 (K5)	Collapse	Collapses frequently occurred Collapsed occurred at site survey in August 2023.	Collapse is beginning to affect private houses on the upper slopes. There will be seven whole-width road closures in 2023. On September 23, 2020, two people were injured, and the road was blocked for seven days.
	63	56+420 (K7)	Slide	Slide with many cracks on its upper slope (hearing from DOR).	The road shoulder partially collapsed. DOR, GESU carried out electrical exploration in 2022.
	68	42+000 (K9)	Slide	Large slide crossing the road. Abundant springs are recognized.	Two whole-width road closures occurred in 2023. DOR, GESU conducted an electrical exploration in 2022.
	73	46+000 (K8)	Collapse	Cutting slope was collapsed.	Road users are at high risk of landslides.
	84	69+365 (K3)	Collapse	The collapse is extending to the upper slope.	One whole-width road closure in rainy season in 2023. There are houses on the upper slope, and there is a possibility of affection by collapse or further slope excavation.
	85	66+565 (K4)	Collapse	The collapse is extending to the upper slope.	DOR, GESU conducted geotechnical survey in 2023. There are houses on the upper slope, and there is a possibility of affection by collapse or further slope excavation.
	119	61+627 (K6)	Collapse	The collapse is extending to the upper slope.	Impact on houses on upper slope Six whole-width road closure occurred in 2023 rainy season DOR, GESU conducted geotechnical survey in 2023

Source: JICA Survey Team

8.2. Peak Flow Rates of Flood/Debris at Debris Flow Risk Sites

Table 8-2 gives the five flow sites of the longlist. At these debris flow risk sites, the amount of rainfall-runoff within the target safety level of the certain number of probability years and debris flow peak discharge are required. In addition, engineering measures against flows was conducted according to the following Japanese Standards and Guidelines:

- Manual of Technical Standards for Establishing Sabo Master Plans for Debris Flows and Driftwood, by National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure and Transport, Japan, 2016
- Manual of Technical Standards for Designing Sabo Facilities for Debris Flows and Driftwood, by National Institute for Land and Infrastructure Management (NILIM), Ministry of Land, Infrastructure and Transport, Japan, 2016
- Technical Guidelines for Debris Flow Control Measures, by Sediment Control Department (SCD), River Bureau, Ministry of Construction, Japan, 2000
- Guideline for Survey of Debris-Flow-Prone Streams and Survey of Debris Flow Hazard Areas, by Sediment Control Department (SCD), River Bureau, Ministry of Construction, Japan, 1999

Table 8-2 List of Selected 5 Debris Flow Sites

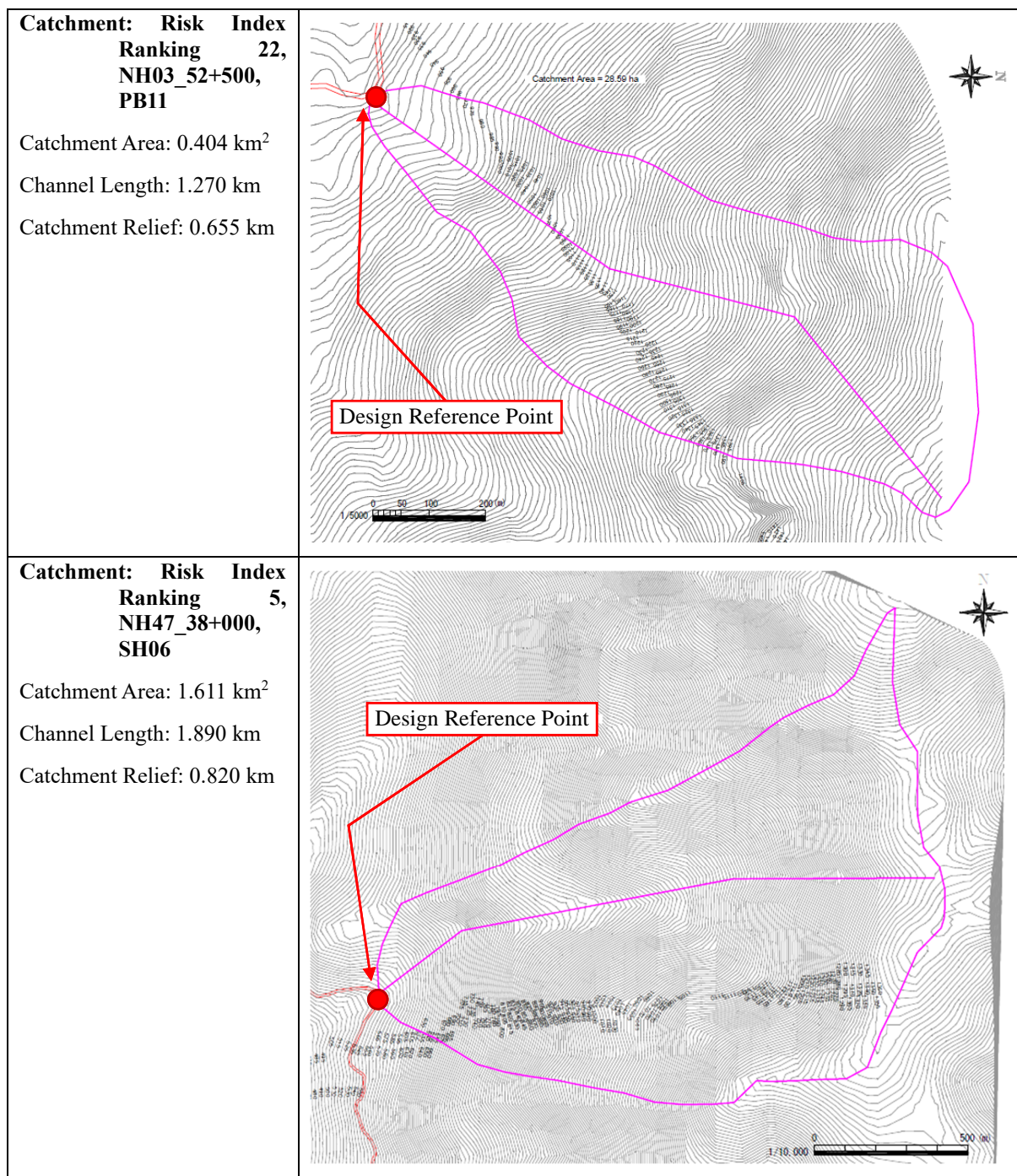
Risk Index Ranking	National Highway Code	Road Section	Chainage	Inventory No:	GPS Coordinate (WGS84) and Elevation		
					Latitude (North)	Longitude (East)	Elevation (m)
1	NH44	Narayanghat-Mugling	21+500	L2	27°49'3.74"N	84°27'46.35"E	232.0
5	NH47	Siddhartha Highway		SH06	27°46'2.50"N	83°31'16.94"E	452.3
20	NH03	Pokhara-Baglung	58+700	PB03	28°14'43.96"N	83°38'14.98"E	692.9
22	NH03	Pokhara-Baglung	52+500	PB11	28°13'43.64"N	83°40'38.53"E	868.4
34	NH44	Narayanghat-Mugling	20+000	L5	27°48'43.06"N	84°26'1.59"E	200.0

Source: JICA Survey Team

8.2.1. Design Reference Point

Following the Manual of Technical Standards for Establishing Sabo Master Plans for Debris Flows and Driftwood (NILIM, 2016) and Technical Guidelines for Debris Flow Control Measures (SCD, 2000), the design reference point shall be the point where the quantity of sediment and driftwood handled by the sediment control plan is determined. The design reference point was set at the exit where the mountain stream meets the road, just upstream of the road to be preserved. Accordingly, these design reference points for the selected 5 debris flow sites were determined, based on site survey, just at the upstream of the NHs to be protected from debris flows. **Figure 8-1** shows the river basin of each stream, in which the boundary of river basin was delineated by pink line and design reference point by red point.

<p>Catchment: Risk Index Ranking 1 NH44_21+500, L2</p> <p>Catchment Area: 1.406 km² Channel Length: 2.030 km Catchment Relief: 0.875 km</p>	
<p>Catchment: Risk Index Ranking 34 NH44_20+000,L 5</p> <p>Catchment Area: 0.080 km² Channel Length: 0.440 km Catchment Relief: 0.265 km</p>	
<p>Catchment: Risk Index Ranking 20 NH03_58+700, PB03</p> <p>Catchment Area: 0.526 km² Channel Length: 1.320 km Catchment Relief: 0.295 km</p>	



Source: JICA Survey Team, Partially Based Goole Earth Images

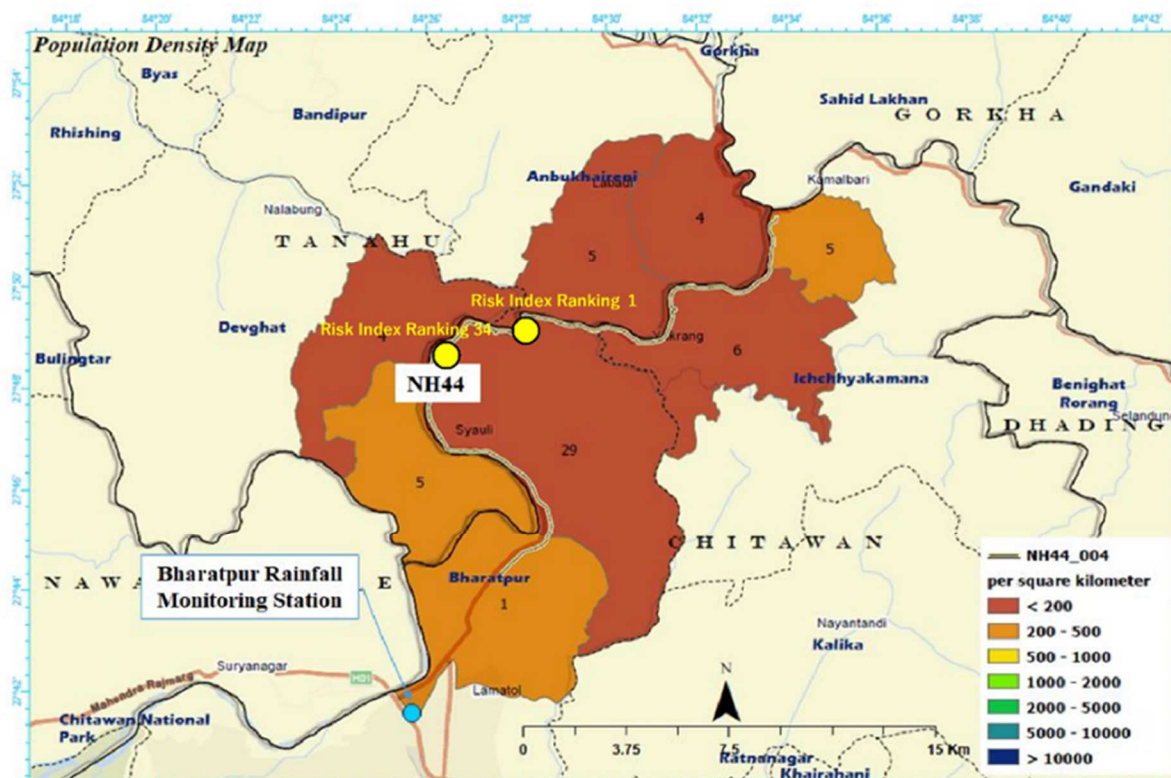
Figure 8-1 River Catchments of Each Debris Flow Stream

8.2.2. Planed Rainfall Intensity

(1) Overview

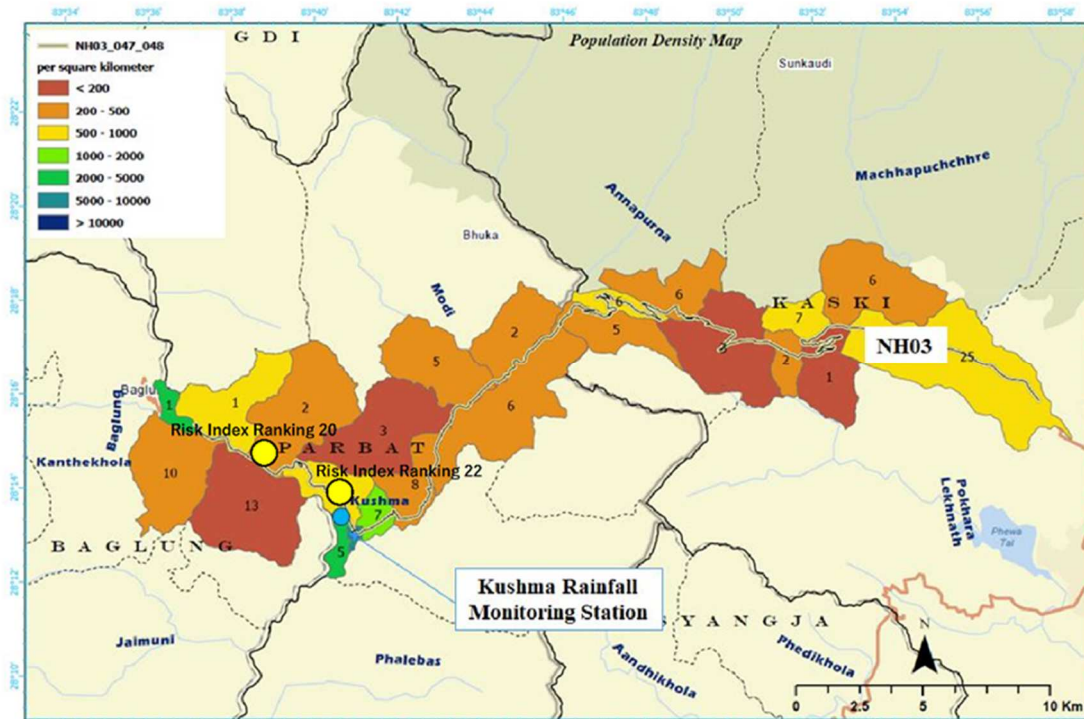
Following the Manual of Technical Standards for Establishing Sabo Master Plans for Debris Flows and Driftwood (NILIM, 2016), in principle, a debris flow including driftwood that is considered highly likely to occur accompanying the exceedance probability of the 24-hour rainfall or daily rainfall were estimated and calculated.

In addition, the daily rainfall records are collected for calculating rainfall intensity, from three rainfall monitoring stations. They are Bharatpur Station (No. 927), which is close to risk index ranking 1 (L2) and risk index ranking 34 (L5) sites on NH44, Kushma Station (No. 614), which is close to risk index ranking 20 (PB03) and risk index ranking 22 (PB11) sites on Pokhara-Baglung Section of NH03, and Tansen Station (No. 702), which is close to risk index ranking 5 (SH06) site on NH47. These rainfall monitoring stations are shown in **Figure 8-2** to **Figure 8-4**.



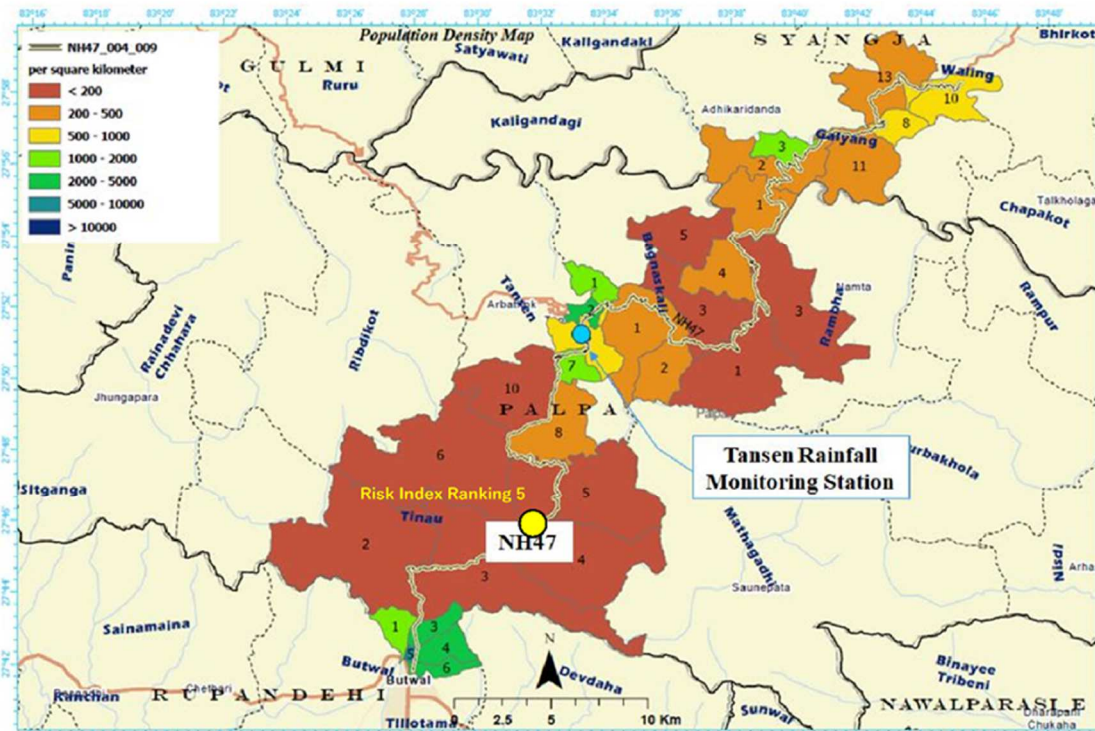
Source: JICA Survey Team, Base map: OpenStreetMap, 2021 Census Ward Population Density Map

Figure 8-2 Location Map of Bharatpur Rainfall Monitoring Station



Source: JICA Survey Team, Base map: OpenStreetMap, 2021 Census Ward Population Density Map

Figure 8-3 Location Map of Kushma Rainfall Monitoring Station



Source: JICA Survey Team, Base map: OpenStreetMap, 2021 Census Ward Population Density Map

Figure 8-4 Location Map of Tansen Rainfall Monitoring Station

(3) Annual Rainfall

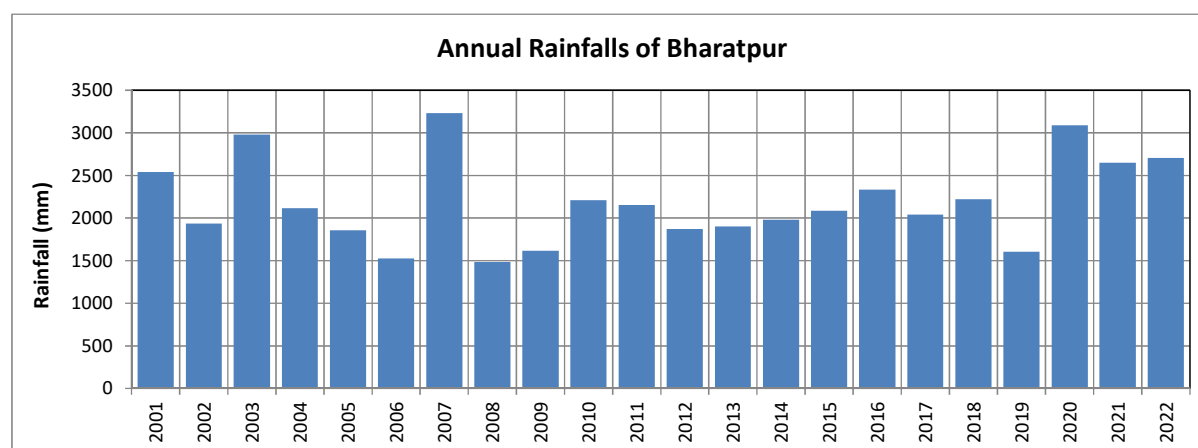
Bharatpur Station

The time series of annual rainfall of Bharatpur Station was developed by analyzing the daily rainfall records from 2001 to 2022. The annual rainfall records of the station are presented in **Table 8-3** and **Figure 8-5**. The result shows that the highest annual rainfall amount is 3232 mm in the year 2007; and the lowest annual rainfall amount is 1485mm in the year 2008. The mean annual rainfall of the station is 2188 mm.

Table 8-3 Annual Rainfall Records of Bharatpur Station

Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)
2001	2540	2007	3232	2013	1903	2019	1607
2002	1936	2008	1485	2014	1981	2020	3092
2003	2981	2009	1615	2015	2083	2021	2650
2004	2117	2010	2210	2016	2333	2022	2705
2005	1856	2011	2152	2017	2041	Mean	2188
2006	1524	2012	1871	2018	2224		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-5 Annual Rainfall Records of Bharatpur Station

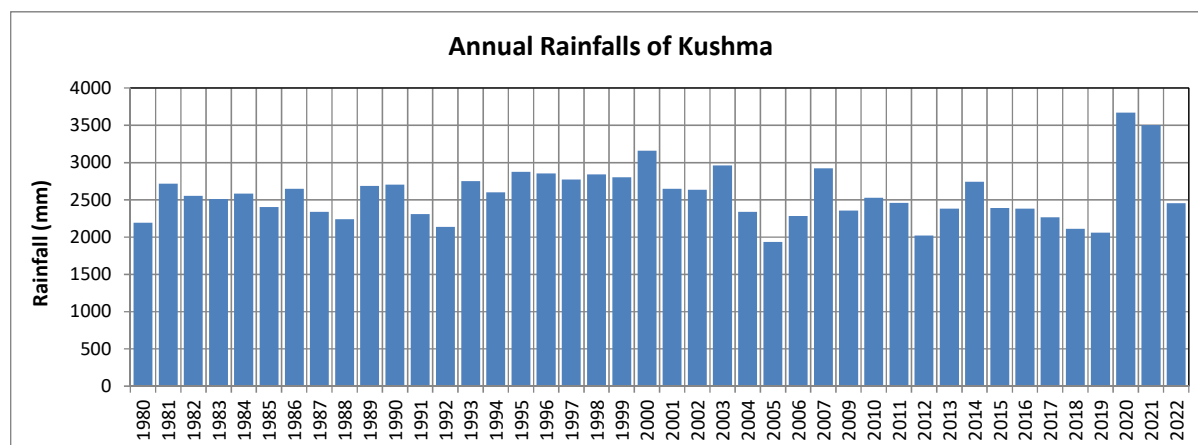
Kushma Station

Similarly, the time series of annual rainfall of Kushma Station was developed by analyzing the daily rainfall records from 1980 to 2022. The annual rainfalls of the station are presented in **Table 8-4** and **Figure 8-6**. The result shows that the highest annual rainfall amount is 3671 mm in the year 2020; and the lowest annual rainfall amount is 1934 mm in the year 2005. The mean annual rainfall of the station is 2566 mm.

Table 8-4 Annual Rainfall of Kushma Station

Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)
1980	2195	1991	2308	2002	2637	2014	2742
1981	2715	1992	2139	2003	2963	2015	2389
1982	2554	1993	2751	2004	2340	2016	2382
1983	2513	1994	2599	2005	1934	2017	2268
1984	2585	1995	2878	2006	2283	2018	2114
1985	2403	1996	2855	2007	2925	2019	2059
1986	2649	1997	2774	2009	2355	2020	3671
1987	2341	1998	2840	2010	2529	2021	3504
1988	2241	1999	2802	2011	2457	2022	2454
1989	2685	2000	3162	2012	2021	Mean	2566
1990	2706	2001	2651	2013	2384		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-6 Annual Rainfalls of Kushma Station

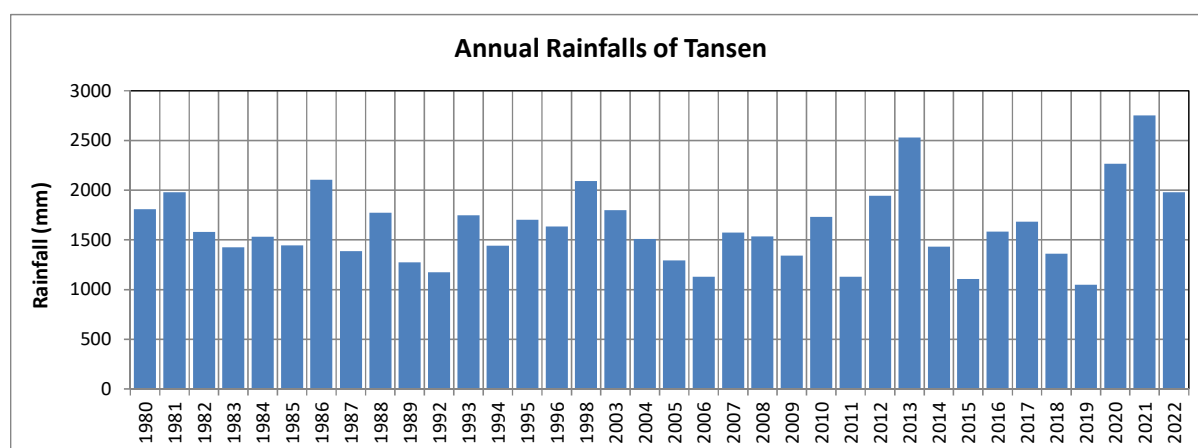
Tansen Station

The time series of annual rainfall of Tansen Station was developed by analyzing the daily rainfall records from 1980 to 2022. The annual rainfalls of the station are presented in **Table 8-5** and **Figure 8-7**. The result shows that the highest annual rainfall amount is 2750 mm in the year 2021; and the lowest annual rainfall amount is 1048 mm in the year 2019. The mean annual rainfall of the station is 1634 mm.

Table 8-5 Annual Rainfall of Tansen Station

Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)
1980	1809	1992	1173	2007	1571	2017	1683
1981	1981	1993	1748	2008	1536	2018	1363
1982	1580	1994	1441	2009	1344	2019	1048
1983	1425	1995	1704	2010	1734	2020	2266
1984	1534	1996	1634	2011	1129	2021	2750
1985	1446	1998	2092	2012	1942	2022	1980
1986	2106	2003	1799	2013	2532	Mean	1634
1987	1387	2004	1509	2014	1431		
1988	1772	2005	1294	2015	1106		
1989	1277	2006	1130	2016	1581		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-7 Annual Rainfalls of Tansen Station

(2) Frequency Analysis

The frequency analysis of annual maximum daily rainfall was performed employing the Gumbel distribution function to determine the design daily rainfall of different return periods. The cumulative distribution function (CDF) of the Gumbel distribution is as presented below:

$$F_x(x) = \exp\left[-\exp\left(-\frac{x-u}{a}\right)\right]$$

$$u = \bar{x} - 0.5772a$$

$$a = \frac{\sqrt{6}S_x}{\pi}$$

Where,

F_x = Cumulative probability

u, a = Parameters of the function

x = Annual maximum daily rainfall

S_x = Standard deviation

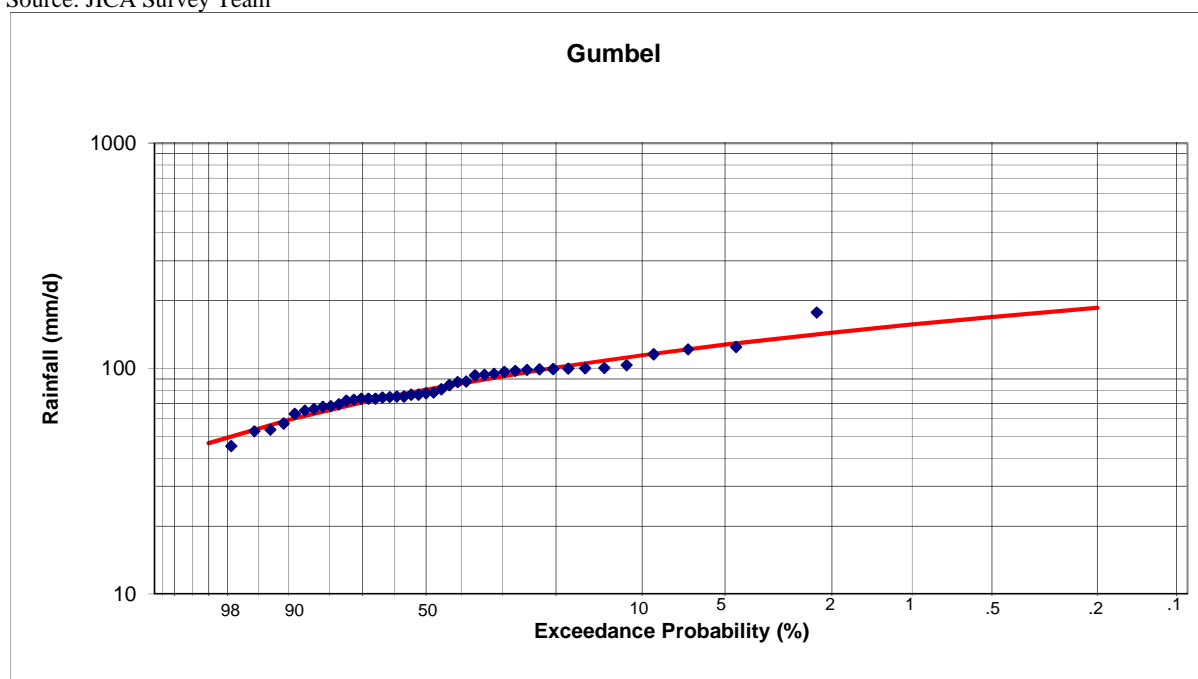
Bharatpur Station

The annual maximum daily rainfalls from 1980 to 2022 at Bharatpur Station (see **Table 8-6**) are used for frequency analysis to determine the design daily rainfall of different return periods. The Gumbel distribution was employed to analyze and fit the curve in the annual maximum daily rainfall of the station. The Gumbel distribution function curve fits well with the observed annual maximum daily rainfalls of the station (**Figure 8-8**). **Table 8-7** gives the design daily rainfalls of the station for different return periods.

Table 8-6 Annual Maximum Daily Rainfall of Bharatpur Station

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1980	100.1	1991	74.2	2002	177	2013	100.5
1981	53.5	1992	45.2	2003	100	2014	93.1
1982	87.6	1993	62.8	2004	74.6	2015	115.5
1983	72	1994	99	2005	68.1	2016	94.6
1984	76.5	1995	73.5	2006	67.7	2017	65
1985	69.3	1996	72.7	2007	52.6	2018	93.6
1986	77.6	1997	87	2008	84.3	2019	103.5
1987	124.4	1998	97.6	2009	76.5	2020	73.5
1988	66	1999	99.4	2010	80.7	2021	121.5
1989	57	2000	98.6	2011	73.4	2022	75.1
1990	78	2001	96.4	2012	75		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-8 Frequency Analysis of Annual Maximum Daily Rainfall of Bharatpur Station**Table 8-7 Design Daily Rainfall of Bharatpur Station**

Return period (years)	2	5	10	20	50	100
Design rainfall (mm/d)	81	101	115	128	144	157

Source: JICA Survey Team

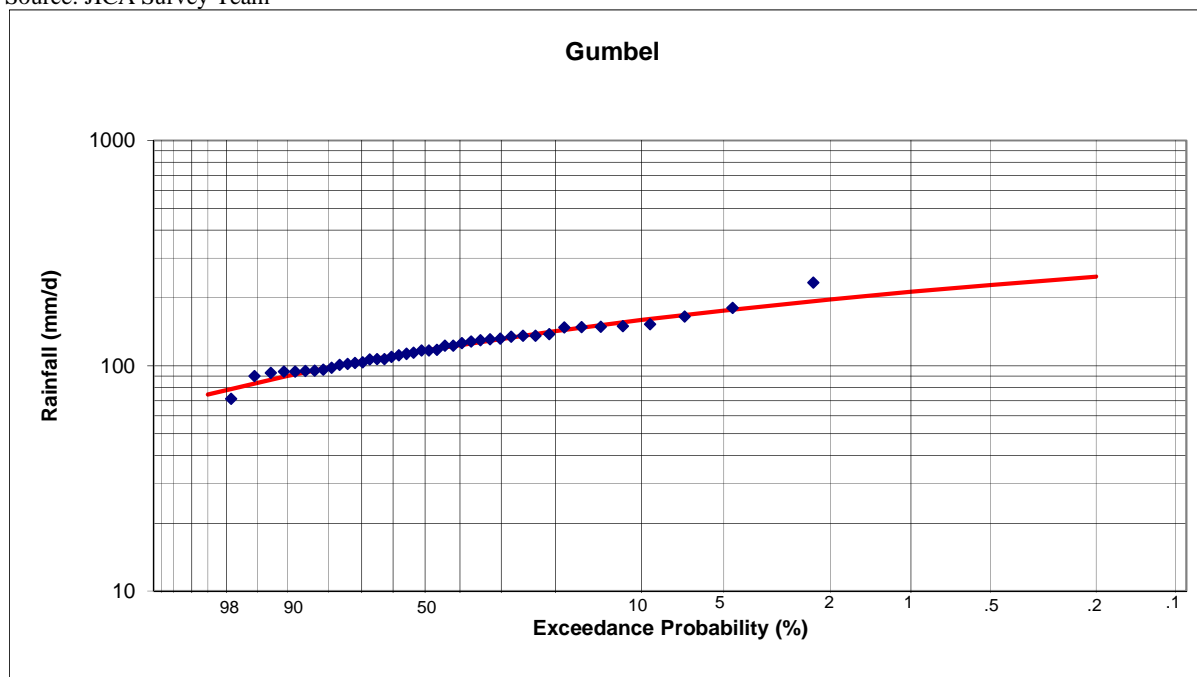
Kushma Station

Similarly, the annual maximum daily rainfalls from 1980 to 2022 at Kushma Station (see **Table 8-8**) are used for frequency analysis to determine the design daily rainfall of different return periods. The Gumbel distribution was employed to analyze and fit the curve in the annual maximum daily rainfall of the station. The Gumbel distribution function curve fits well with the observed annual maximum daily rainfalls of the station (see **Figure 8-9**). **Table 8-9** gives the design daily rainfalls of the station for different return periods.

Table 8-8 Annual Maximum Daily Rainfall of Kushma Station

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1980	165.6	1991	95.0	2002	103.0	2014	98.0
1981	132.0	1992	131.0	2003	136.0	2015	93.0
1982	114.1	1993	106.5	2004	138.0	2016	136.0
1983	111.6	1994	113.0	2005	96.2	2017	103.5
1984	116.8	1995	130.0	2006	107.0	2018	128.4
1985	122.7	1996	148.5	2007	153.0	2019	101.8
1986	101.0	1997	107.0	2009	123.0	2020	234.0
1987	94.9	1998	117.0	2010	94.0	2021	180.4
1988	71.5	1999	148.0	2011	149.0	2022	134.6
1989	109.3	2000	126.0	2012	90.0		
1990	150.0	2001	94.0	2013	118.0		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-9 Frequency Analysis of Annual Maximum Daily Rainfall of Kushma Station

Table 8-9 Design Daily Rainfall of Kushma Station

Return period (years)	2	5	10	20	50	100
Design rainfall (mm/d)	117	143	160	176	197	213

Source: JICA Survey Team

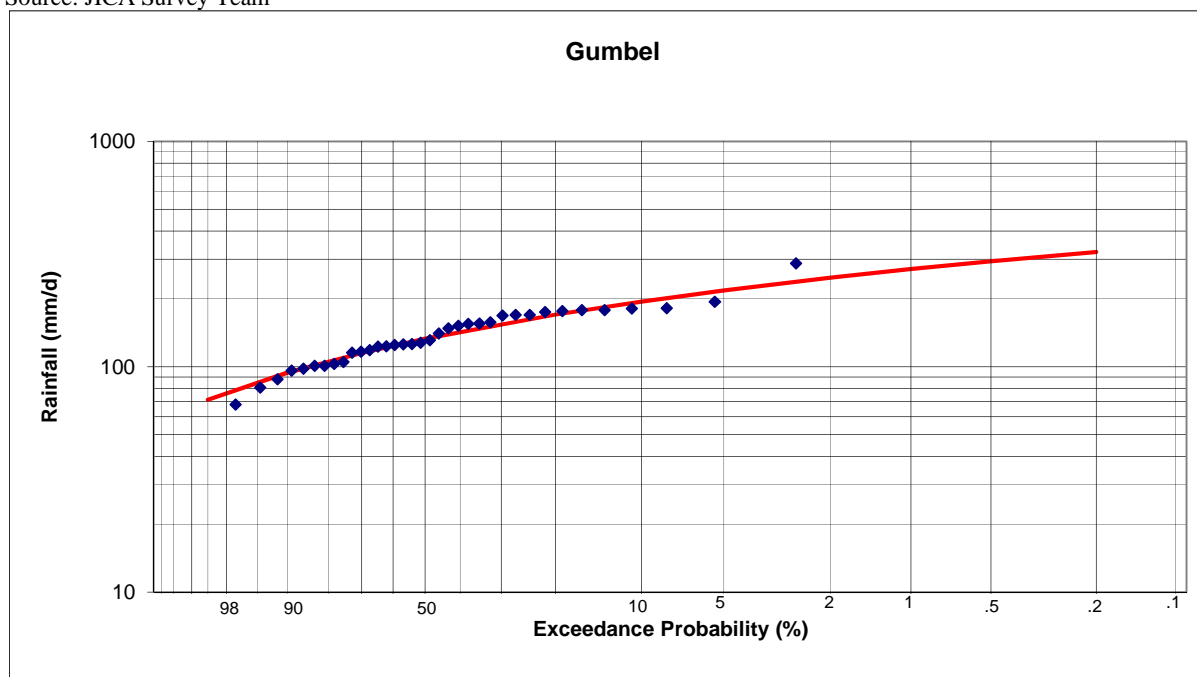
Tansen Station

Similarly, the annual maximum daily rainfalls from 1980 to 2022 at Tansen Station (see **Table 8-10**) are used for frequency analysis to determine the design daily rainfall of different return periods. The Gumbel distribution was employed to analyze and fit the curve in the annual maximum daily rainfall of the station. The Gumbel distribution function curve fits well with the observed annual maximum daily rainfalls of the station (see **Figure 8-10**). **Table 8-11** gives the design of daily rainfalls of the station for different return periods.

Table 8-10 Annual Maximum Daily Rainfall of Tansen Station

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1980	178.0	1992	105.0	2007	96.0	2017	155.0
1981	288.0	1993	115.4	2008	152.0	2018	101.0
1982	125.9	1994	155.6	2009	182.0	2019	81.0
1983	100.7	1995	194.3	2010	103.0	2020	175.0
1984	157.3	1996	169.0	2011	68.0	2021	170.0
1985	123.2	1998	140.5	2012	148.0	2022	178.0
1986	127.8	2003	170.0	2013	181.0		
1987	118.4	2004	98.0	2014	125.5		
1988	88.0	2005	123.0	2015	131.0		
1989	177.0	2006	125.0	2016	116.5		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-10 Frequency Analysis of Annual Maximum Daily Rainfall of Tansen Station

Table 8-11 Design Daily Rainfall of Tansen Station

Return period (years)	2	5	10	20	50	100
Design rainfall (mm/d)	133	170	195	218	248	271

Source: JICA Survey Team

(3) Rainfall Intensity

Rainfall intensity records of the stations are not available. The record of the rainfall intensity of only a few events of rainfall storm in these three stations is available but that is not enough for the analysis of the rainfall intensity of different return periods. Therefore, the most widely used Mononobe's method is employed for rainfall intensity analysis of the stations. The intensity duration frequency (IDF) curves of the rainfall were developed based on the design daily rainfalls of the station. Mononobe's relation for calculating the rainfall intensity of t -hour duration is as presented below.

Where,

i_t = Rainfall intensity of t -hour duration (mm/h)

t = Duration = time of flood concentration (h)

P_{24} = Daily rainfall or 24-h rainfall (mm)

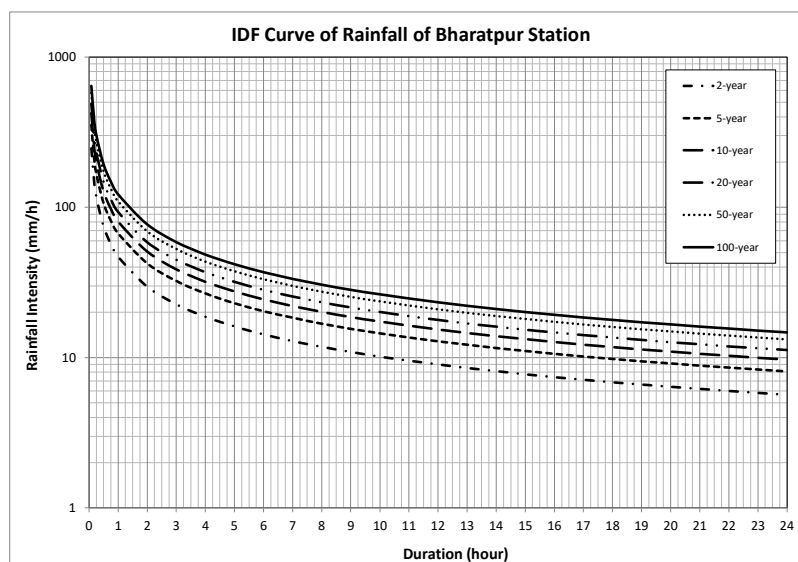
Bharatpur Station

The design rainfall intensity of different time duration and return periods estimated by Mononobe's relation for Bharatpur station are presented in **Table 8-12**; and the intensity duration frequency (IDF) curves of rainfall of the station are presented in **Figure 8-11**.

Table 8-12 Design Rainfall Intensities of t-hour Duration of Bharatpur Station

Duration (h)	Return Period (years)					
	2	5	10	20	50	100
	Rainfall Intensity (mm/h)					
0.083	146.7	183.7	208.2	231.7	262.2	285.0
0.167	92.4	115.7	131.2	146.0	165.2	179.5
0.25	70.5	88.3	100.1	111.4	126.0	137.0
0.5	44.4	55.6	63.1	70.2	79.4	86.3
0.75	33.9	42.5	48.1	53.6	60.6	65.9
1	28.0	35.1	39.7	44.2	50.0	54.4
2	17.6	22.1	25.0	27.9	31.5	34.3
3	13.5	16.9	19.1	21.3	24.0	26.1
4	11.1	13.9	15.8	17.5	19.9	21.6
5	9.6	12.0	13.6	15.1	17.1	18.6
6	8.5	10.6	12.0	13.4	15.1	16.5
7	7.6	9.6	10.9	12.1	13.7	14.9
8	7.0	8.8	9.9	11.1	12.5	13.6
9	6.5	8.1	9.2	10.2	11.6	12.6
10	6.0	7.6	8.6	9.5	10.8	11.7
12	5.3	6.7	7.6	8.4	9.5	10.4
14	4.8	6.0	6.8	7.6	8.6	9.4
16	4.4	5.5	6.3	7.0	7.9	8.6
18	4.1	5.1	5.8	6.4	7.3	7.9
20	3.8	4.8	5.4	6.0	6.8	7.4
22	3.6	4.5	5.1	5.6	6.4	6.9
24	3.4	4.2	4.8	5.3	6.0	6.5

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-11 Intensity Duration Frequency (IDF) Curves of Rainfall of Bharatpur Station

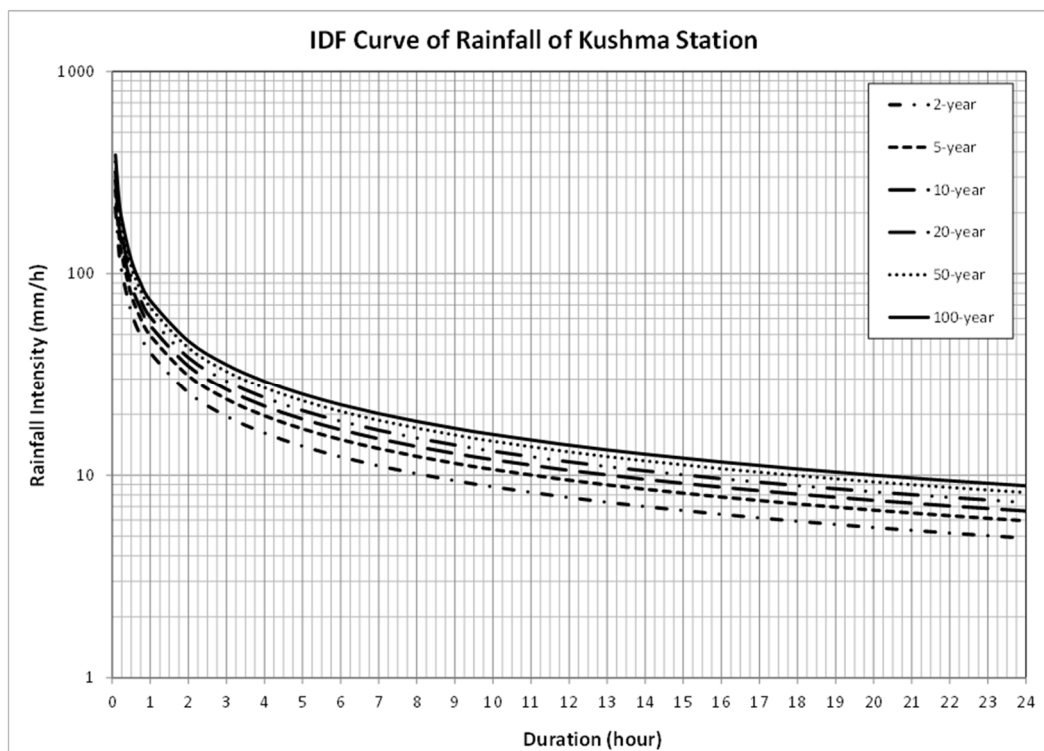
Kushma Station

The design rainfall intensity of different time duration and return periods estimated by Mononobe’s relation for Kushma station are presented in **Table 8-13**; and the intensity duration frequency (IDF) curves of rainfall of the station are presented in **Figure 8-12**.

Table 8-13 Design Rainfall Intensities of t-hour Duration of Kushma Station

Duration (h)	Return Period (years)					
	2	5	10	20	50	100
	Rainfall Intensity (mm/h)					
0.083	213.0	259.4	290.1	319.6	357.7	386.3
0.167	134.2	163.4	182.8	201.3	225.4	243.4
0.25	102.4	124.7	139.5	153.6	172.0	185.7
0.5	64.5	78.6	87.9	96.8	108.3	117.0
0.75	49.2	60.0	67.1	73.9	82.7	89.3
1	40.6	49.5	55.3	61.0	68.2	73.7
2	25.6	31.2	34.9	38.4	43.0	46.4
3	19.5	23.8	26.6	29.3	32.8	35.4
4	16.1	19.6	22.0	24.2	27.1	29.2
5	13.9	16.9	18.9	20.9	23.3	25.2
6	12.3	15.0	16.8	18.5	20.7	22.3
7	11.1	13.5	15.1	16.7	18.7	20.1
8	10.2	12.4	13.8	15.2	17.1	18.4
9	9.4	11.4	12.8	14.1	15.8	17.0
10	8.8	10.7	11.9	13.1	14.7	15.9
12	7.8	9.4	10.6	11.6	13.0	14.1
14	7.0	8.5	9.5	10.5	11.7	12.7
16	6.4	7.8	8.7	9.6	10.7	11.6
18	5.9	7.2	8.1	8.9	9.9	10.7
20	5.5	6.7	7.5	8.3	9.3	10.0
22	5.2	6.3	7.0	7.8	8.7	9.4
24	4.9	5.9	6.7	7.3	8.2	8.9

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-12 Intensity Duration Frequency (IDF) Curves of Rainfall of Kushma Station

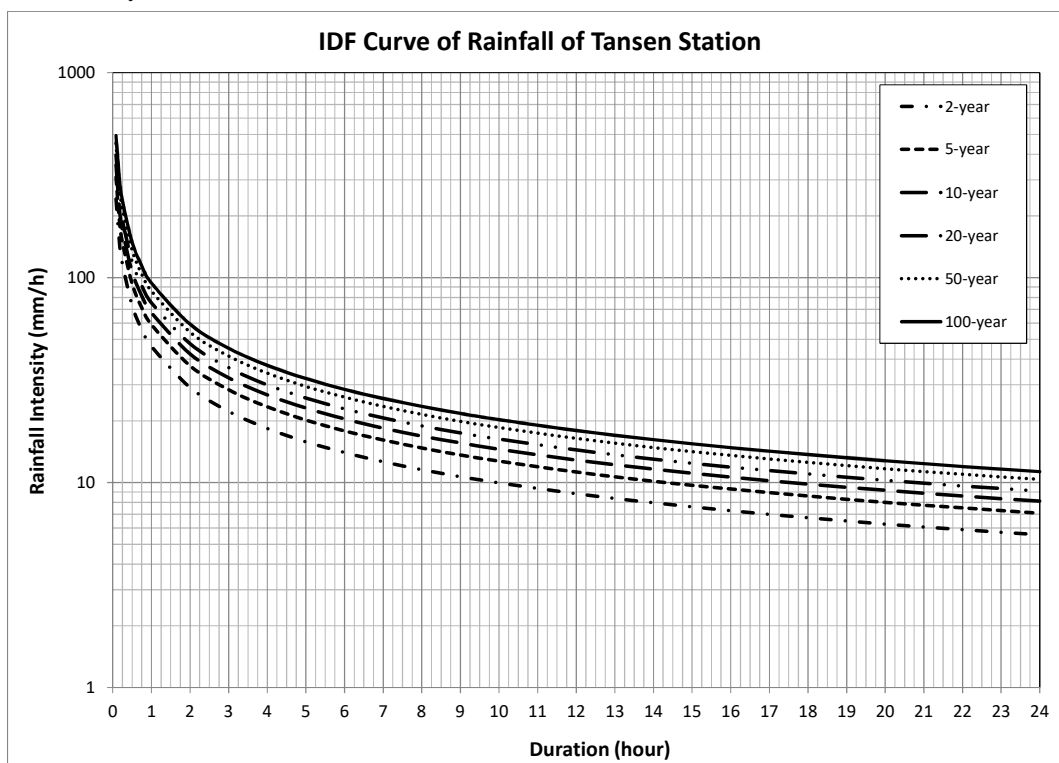
Tansen Station

The design rainfall intensity of different time duration and return periods estimated by Mononobe’s relation for Tansen are presented in **Table 8-14**; and the intensity duration frequency (IDF) curves of rainfall of the station are presented in **Figure 8-13**.

Table 8-14 Design Rainfall Intensities of t-hour Duration of Tansen Station

Duration (h)	Return Period (years)					
	2	5	10	20	50	100
0.083	242.1	309.2	353.7	396.3	451.5	492.9
0.167	152.5	194.8	222.8	249.7	284.4	310.5
0.25	116.4	148.7	170.0	190.5	217.1	236.9
0.5	73.3	93.6	107.1	120.0	136.7	149.3
0.75	55.9	71.5	81.7	91.6	104.4	113.9
1	46.2	59.0	67.5	75.6	86.1	94.0
2	29.1	37.2	42.5	47.6	54.3	59.2
3	22.2	28.4	32.4	36.3	41.4	45.2
4	18.3	23.4	26.8	30.0	34.2	37.3
5	15.8	20.2	23.1	25.9	29.5	32.2
6	14.0	17.9	20.4	22.9	26.1	28.5
7	12.6	16.1	18.4	20.7	23.5	25.7
8	11.5	14.7	16.9	18.9	21.5	23.5
9	10.7	13.6	15.6	17.5	19.9	21.7
10	10.0	12.7	14.5	16.3	18.6	20.3
12	8.8	11.3	12.9	14.4	16.4	17.9
14	8.0	10.2	11.6	13.0	14.8	16.2
16	7.3	9.3	10.6	11.9	13.6	14.8
18	6.7	8.6	9.8	11.0	12.5	13.7
20	6.3	8.0	9.2	10.3	11.7	12.8
22	5.9	7.5	8.6	9.6	11.0	12.0
24	5.6	7.1	8.1	9.1	10.4	11.3

Source: JICA Survey Team



Source: JICA Survey Team

Figure 8-13 Intensity Duration Frequency (IDF) Curves of Rainfall of Tansen Station

8.2.3. Peak Discharge of Debris Flow

(1) Calculation Methods of Debris Flow Peak Discharge

The peak discharge of debris flow is obtained by using one of the following methods.

- Rainfall method - developed by Takahashi (rainfall)¹⁶ or
- Sediment discharge method—developed by Mizuyama¹⁷

In this Survey, the peak discharge of debris flow, Q_{sp} (m^3/s), shall be obtained by using rainfall, as follows, assuming that it has the following relationship between the peak discharges of peak water discharge Q_p (m^3/s):

Where,

Q_{sp} : peak discharge of debris flow (m^3/s)

Q_p : runoff peak discharge (m^3/s)

C_* : volumetric concentration of sediment (0.6)

C_d : density of debris flow

In addition, the density of debris flow shall be obtained by Takahashi's equation shown below:

Where,

C_d : density of debris flow (m^3/s)

C_* : volumetric concentration of sediment (0.6, general value)

s : density of gravel (approx. $2.6 t/m^3$, general value)

r : density of water (approx. $1.2 t/m^3$, general value)

θ : internal friction angle of accumulated sediment (35 degrees, general value)

q : riverbed gradient (degree) (measured from profile section)

The θ is an average inclination between the design reference point and the position about 200 meters upstream of it.

Moreover, when the calculated value (C_d) is larger than $0.9C_*$, debris cannot flow, then $C_d = 0.9C_*$ shall be the maximum value, and when the calculated value (C_d) is smaller than 0.3, debris flow cannot be formed, the flow of bed load is formed, and $C_d = 0.33$ shall be minimum.

(2) Calculated Peak Discharge of Debris Flow

For the five sites selected in the longlist, the calculated rainfall intensity with the traveling time of flood and peak discharge of debris flow for each catchment are summarized in **Table 8-15** and **Table 8-16**, respectively, below.

Table 8-15 Rainfall Intensities within the Traveling Time of Flood

Catchment	Return Period (years)					
	2	5	10	20	50	100

¹⁶ Debris Flow: Mechanics, Prediction and Engineering measures, by T. Takahashi, 2007.

¹⁷ Empirical Prediction of Peak Discharge of Debris Flows, priority field research of the Ministry of Education, Science and Technology Fund, "Predicting natural disasters and prevention of disasters", by T. Mizuyama, 1990, pp. 54-57.

	Catchment Area (km ²)	Traveling Time of Flood (hr)	Rainfall Intensity (mm/h)					
			96.0	137.0	164.1	190.1	223.7	248.9
NH44_L02	1.406	0.380	96.0	137.0	164.1	190.1	223.7	248.9
NH44_L05	0.080	0.342	102.7	146.5	175.5	203.3	239.3	266.3
NH03_PB03	0.526	0.378	83.0	101.1	113.0	124.5	139.4	150.5
NH03_PB11	0.404	0.360	85.7	104.4	116.8	128.6	144.0	155.5
NH47_SH06	1.611	0.377	94.5	120.7	138.1	154.7	176.3	192.4

Source: JICA Survey Team

Table 8-16 Peak Discharge of Debris Flow at Different Return Periods

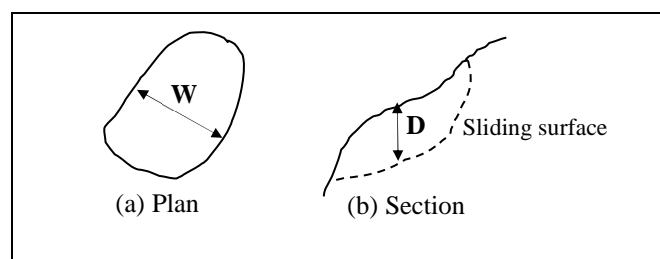
Catchment	Catchment Area (km ²)	Channel Length (km)	Catchment Relief (km)	Return Period (years)					
				2	5	10	20	50	100
				Peak Discharge of Debris Flow (m ³ /s)					
NH44_L02	1.406	2.030	0.875	318.7	454.8	544.8	631.2	742.7	826.4
NH44_L05	0.080	0.440	0.265	19.4	27.7	33.2	38.4	45.2	50.3
NH03_PB03	0.526	1.320	0.295	31.0	37.7	42.1	46.4	52.0	56.1
NH03_PB11	0.404	1.270	0.655	81.8	99.7	111.4	122.7	137.4	148.3
NH47_SH06	1.611	1.890	0.820	359.5	459.1	525.4	588.5	670.7	731.9

Source: JICA Survey Team

In addition, the channel length is measured along the course of the mainstream from the basin outlet (or design reference point) to its source. The catchment relief refers to the difference in elevation between the catchment outlet (design reference point) and the highest point on the catchment area.

8.3. Estimation of Landslide Surface Depth at Landslide Risk Sites

The slide area subject to further slide activity is identified through interpretation of Google Earth Images and subsequently confirmed by site survey from various indications occurring in the slide areas, such as cracks, steps, settlements, bulges, deformation of structures, as well as the micro-topographical conditions, like distribution of depressions, lakes, spring water, etc., and geological conditions, like outcrop of base rock and sliding surface.



Source: JICA Survey Team

Figure 8-14 Schematic Diagram of Slide

In no case of sliding surface survey, like boring survey – by observing core, and monitoring – by pipe strain gauge and borehole inclinometer, the depth of the sliding surface can be roughly estimated based on the following empirical relationship (Guidelines for Landslide Prevention Technologies, Public Works Research Institute (PWRI), 2007):

$$D = W \times 1/7 \sim 1/10$$

where,

D = Depth of sliding surface,

W = Width of slide area

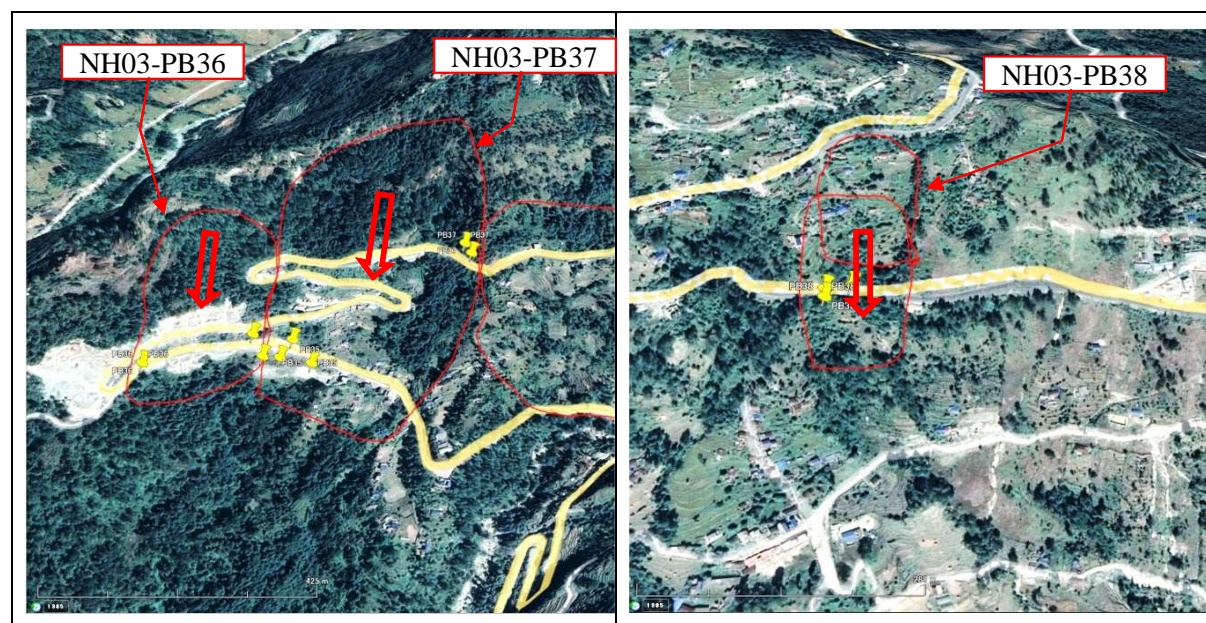
Based on the above empirical relationship, **Table 8-17** shows the slip surface depths of nine sites corresponding to slide-type landslide extracted from the longlist of individual site analysis and priority sites on NH37 which is selected by route-based analysis. The correlation between collapse depth and collapse width is unclear regarding slope collapses, so the collapse depth is not estimated from the collapse width.

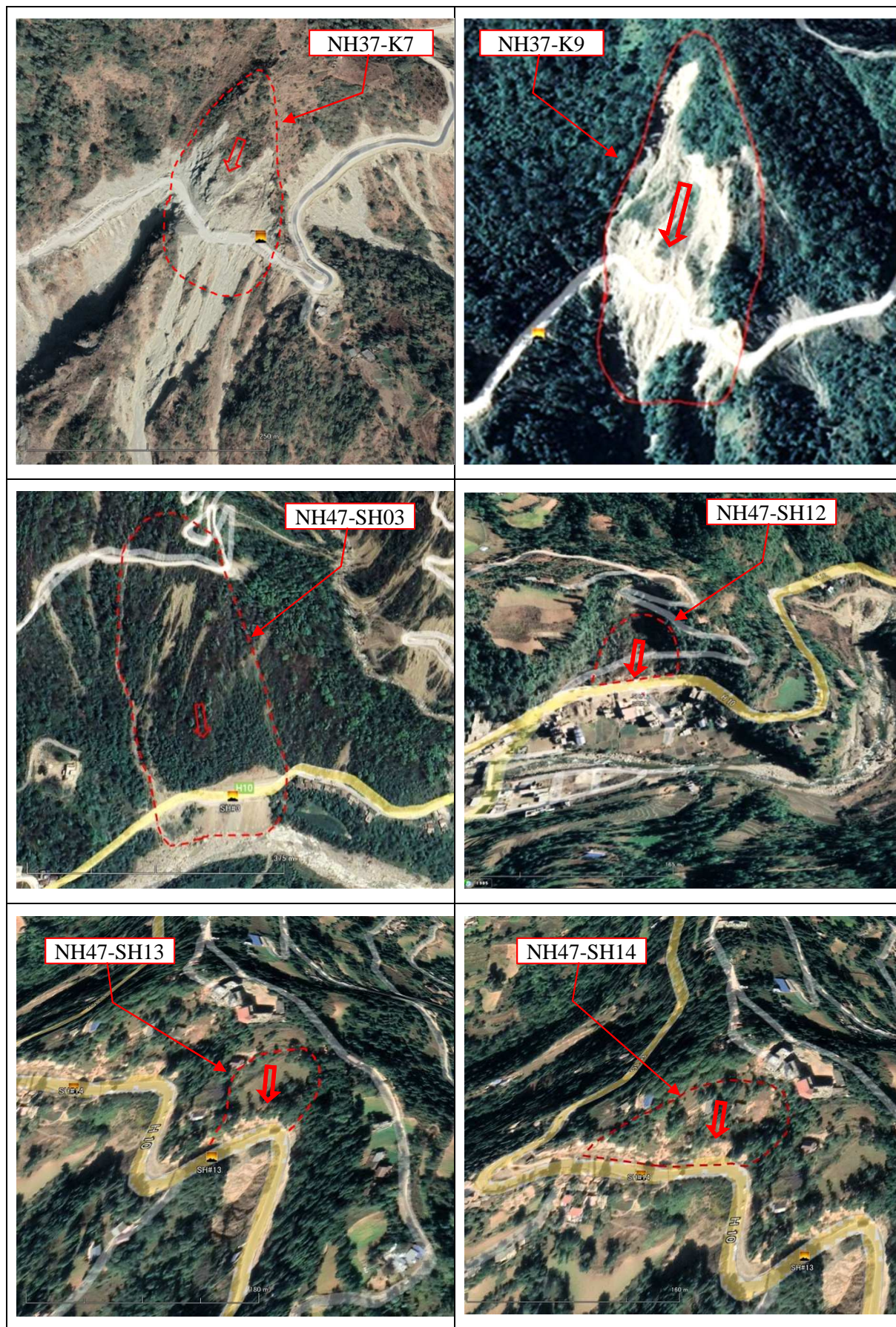
Table 8-17 Summary of Estimated Sliding Surface Depth for Identified Slides Areas

Risk Index Ranking	National Highway Code	Chainage	Inventory No.	Width of Slide Area (m)	Estimated Depth of Sliding Surface (m)
25	NH03	37+900	PB36	200	20 - 30
26	NH03	36+400	PB37	320	30 - 45
27	NH03	26+200	PB38	115	10 - 15
63	NH37	56+420	K7	120	10 - 20
68	NH37	42+000	K9	210	20 - 30
2	NH47	35+500	SH03	215	20 - 30
30	NH47	49+800	SH12	65	5 - 10
10	NH47	56+000	SH13	75	5 - 10
11	NH47	56+200	SH14	145	15 - 20

Source: JICA Survey Team

Figure 8-15 shows the identification of potential slide areas.





Source: JICA Survey Team, Based on Google Earth Images

Figure 8-15 Identified Slide Areas

8.4. Economic Indicators for Cost-Effectiveness Analysis of Road Landslide Risk Reduction Investments

Road economic indicators for cost-benefit analysis of road landslide risk reduction investments are shown below. The calculation of the cost-benefit analysis is based on the calculation tool of World Bank – GFDRR 2020 Road Geohazard Risk Management: Appendix B (Manual Operation Manual).

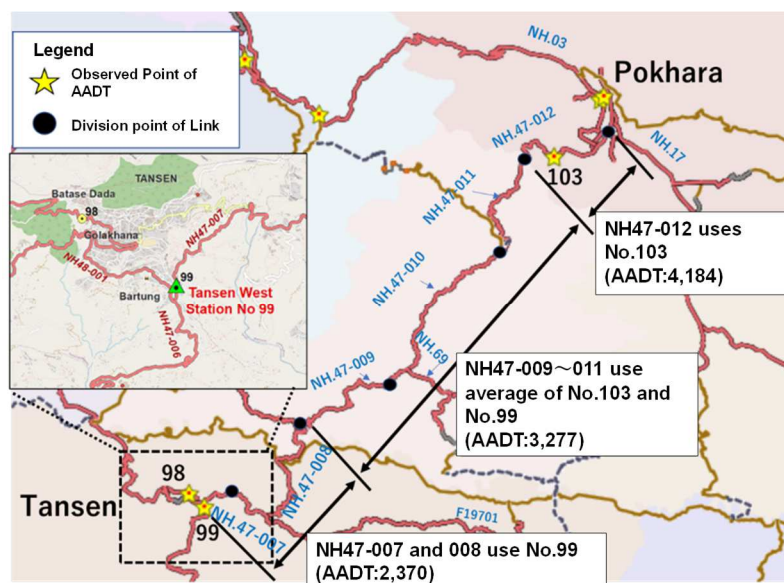
8.4.1. Annual Average Daily Traffic (AADT)

In Nepal, traffic surveys have been conducted by DOR at 160 sites throughout Nepal. The following definitions were used to set AADT for the 33 sites selected in the longlist. NH47 is shown as a specific example.

- 1) In the case where there is an AADT observation point on the road link at the selected site

For risk sites where there is an AADT observation point on the link, use the AADT for that observation point.

Example) AADT observed at No. 99 (Tansen West Station No. 99) is used for the risk sites in the NH.47-007 and NH.47-008 sections shown in **Figure 8-16**.



*AADT was counted value in 2021/2022.

Source: JICA Survey Team Based on "http://ssrn.aviyaan.com/ssrn_map/map"

Figure 8-16 AADT of NH47 (Tansen-Pokhara)

- 2) In the case where there is no AADT observation point on the link but there is an AADT observation point on an adjacent link
 - Use the average of the AADT of the links adjacent to the target link.
 - Example) For risk sites in the interval NH47-009 to NH47-0011, the average AADT observed at No. 99 (Tansen West Station No. 99) and No. 103 (Pokhara South Station No. 103) is used.
- 3) Risk sites with no AADT observation points on the link and no AADT observation points on adjacent links.
 - The AADT was supplemented with link-specific AADT calculated by DOR's software. Note that the calculation method of this software does not estimate the vehicle type breakdown. The specific routes complemented were the NH25 and NH37.

8.4.2. Vehicle Operation Cost Units

Table 8-18 below shows the assumptions for vehicle operation cost by vehicle type and speed. vehicle operation cost assumptions were made based on the projected growth rate of the Consumer Price Index for each year of the analysis period.¹⁸

Table 8-18 Vehicle Operation Cost by Vehicle and Speed Type (as of 2025)

Unit: NRs./km/vehicle

km/hr	Motorcycle	Car /Taxi	Light Truck	Truck	Safa Tempo	Micro Bus	Mini Bus	Bus	Utility
<5	11.19	62.39	87.04	139.29	42.75	79.26	89.85	107.47	58.98
10	10.91	60.1	82.83	132.59	40.98	76.81	87.18	102.25	56.75
15	10.59	57.5	78.53	125.68	39.05	73.95	84.03	96.62	54.27
20	10.23	54.59	74.15	118.54	36.96	70.68	80.38	90.6	51.51
25	9.83	51.36	69.66	111.19	34.71	66.97	76.21	84.24	48.48
30	9.38	47.81	65.05	103.62	32.31	62.82	71.49	77.62	45.18
35	8.87	43.92	60.28	95.84	29.75	58.2	66.19	70.84	41.59
40	8.3	39.7	55.32	87.84	27.05	53.12	60.27	64.05	37.73
45	7.66	35.18	50.09	79.63	24.26	47.56	53.69	57.48	33.63
50	6.93	30.41	44.46	71.21	21.45	41.55	46.42	51.54	29.35
55	6.07	25.67	38.09	62.54	18.98	35.28	38.54	46.93	25.19

Source: Made by JICA Survey Team Based on “The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal, Final Report” (May 2017)

8.4.3. Average Travel Speed

Since there is no actual measured data on average travel speeds at the 33 sites selected in the longlist, we assumed the average speeds at these sites using Google Maps, as defined below.

- Search for a route with a starting point and a destination point 5 km (± 5 km) before and after the risk sites.
- Calculate the speed based on the time required (formula: 10 km/trip time)
- Calculate speeds by period (weekdays, holidays) and by time (peak hour, off-peak hour), and calculate the average of these speeds.

8.4.4. Time Travel Cost Units

Table 8-19 shows assumptions for time travel cost by vehicle type. The time travel cost for motorcycles was assumed to be 51.98 NRs. /hr/unit, while the time travel cost for vehicles was assumed to be 102.65 NRs. /hr/unit. The assumptions of time travel cost were based on the projected GDP per capita growth rate for each year of the analysis period.¹⁹

Table 8-19 Time Travel Cost by Vehicle Type (2025)

Unit: NRs. /hr/vehicle

Motorcycle	Car	Taxi	Light Truck	Heavy Truck
51.98	102.65	102.65	132.87	157.43
Safa Tempo	Micro Bus	Mini Bus	Bus	Utility
355.77	768.56	997.86	1621.69	96.05

Source: Made by JICA Survey Team based on “The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal, Final Report”(May, 2017)

¹⁸ The growth rate of the Consumer Price Index was 6.20%, the average of the past 10 years.

¹⁹ GDP per capita growth rate of 3.38%, the average of the past 10 years, was used.

8.4.5. Average Number of Passengers by Vehicle Type

The average number of passengers by vehicle type were estimated based on data from several traffic surveys, as shown in the table below.

Table 8-20 Average Number of Passengers by Vehicle Type

Average Number of Passengers for Motorcycle, Car, Taxi and Truck					unit: person/vehicle
Motorcycle	Car	Taxi	Light Truck	Heavy Truck	
1.1	1.9	2.0	1.8	1.9	

Source: Results of Roadside Interview Survey by JICA Study Team in 2011

Average Number of Passengers for Bus					unit: person/vehicle
Tempo *1	Microbus *2	Minibus *2	Large Bus *2	Total *3	
7.8	13.5	18.5	33.5	14.4	

Source: Results of Roadside Interview Survey and Home Interview Survey by JICA Study Team in 2011

*1: Based on the Result of Roadside Interview Survey

*2: Estimated by JICA Study Team based on the results of related survey and capacity of each bus type

*3: Calculated by total bus trips(948,464)/total bus operation number(32,835 × 2)

Source: Result of Roadside Interview and Home Interview Survey by JICA Survey Team in 2011

8.4.6. Average Number of Operators by Vehicle Type

The average number of operators by vehicle type was assumed as shown in **Table 8-21**. It is assumed to be 1.5 operators for light truck, heavy truck, and micro bus, 2 operators for minibus and bus, and 1 operator for others.

Table 8-21 Average Numbers of Operators by Vehicle Type

unit: person/vehicle

Motorcycle	Car	Taxi	Light Truck	Heavy Truck
1	1	1	1.5	1.5
Safa Tempo	Micro Bus	Mini Bus	Bus	Utility
1	1.5	2	2	1

Source: Hearing with DOR Staff (OB)

8.4.7. Average New Vehicle Price

Table 8-22 shows the assumed average price of new vehicles in Nepal. The average new vehicle price in 2023 was assumed to be NRs. 297,093 for motorcycles and NRs. 3,292,250 for vehicles. The assumed average new vehicle price was converted to 2025 units using the Consumer Price Index.

Table 8-22 Average New Vehicle Price (2023 unit)

unit: NRs./vehicle

Motorcycle	Car	Taxi	Light Truck	Heavy Truck
297,093	3,292,250	3,292,250	3,423,940	7,901,400
Safa Tempo*	Micro Bus	Mini Bus	Bus	Utility
1,371,370	3,292,250	4,609,150	6,584,500	2,633,800

Note: Converted to price of 2023 by using Consumer Price Index based on “The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal, Final Report”(JICA)(May, 2017)

Source: Nepal Automobile Dealers Association (Average price approximation)

Table 8-23 Average New Vehicle Price (2025 unit)

unit: NRs. /vehicle

Motorcycle	Car	Taxi	Light Truck	Heavy Truck
335,125	3,713,712	3,713,712	3,862,260	8,912,908
Safa Tempo*	Micro Bus	Mini Bus	Bus	Utility
1,546,928	3,713,712	5,199,196	7,427,423	2,970,969

Note: Converted to price of 2025 by using Consumer Price Index based on World Development Indicators

Source: Made by JICA Survey team based on Nepal Automobile Dealers Association (Average price approximation)

8.4.8. Average Years of Use and Depreciation Rate for Vehicles

The average years of use and depreciation rate for vehicles in Nepal are shown in **Table 8-24**. The average year of use is assumed to be 20 years and the depreciation rate for vehicles is assumed to be 15%.

Table 8-24 Average Years of Use and Depreciation Rate for Vehicles

Average years of use	20 years
Depreciation rate	15%

Source: DDG, Mechanical Branch

8.5. Estimated Number of Days to Restore Full Road Closures and Benefits from Reduced Restoration

The answers obtained from the DROs or project offices managing each route (As of 2023) related to the number of days to restore full road closures for six routes, including those with high requests for assistance from the DOR, are shown in **Table 8-25**.

The number of days for restoration was answered as the actual number of days for the rainy season in 2023, if available. Heavy equipment restoring road closure during the rainy season (June–October) in 2023 was placed between 0.1 km and 30.1 km (1.5 km to 17.9 km on average for each route) from the risk areas. For this system, the respondents indicated that traffic would be restored in 0.1 to 2.7 days (0.2 to 1.2 days on average for each route) for full road closures.

In the 2023 rainy season roads, for frequently damaged sites on DOR’s priority routes, DOR has been able to maintain heavy equipment and deployment of personnel within an average of 1 km to 18 km. In addition, DOR has been able to open roads within an average of 0.2 to 1.2 days. However, the current system is considered to have limitations in response to the increasing frequency and scale of landslide damage due to future climate change.

As an indicator to measure effectiveness of this enhanced restoration system, “reduction from hourly restoration time = loss from hourly waiting (2025 value)” was calculated using the following formula. Benefits are larger in NH44 and NH47, where there is more Truck and Bus traffic with higher travel time cost.

Losses from waiting (NRs. /hour) =

Average travel time value at the site (NRs. /unit) × Annual average daily traffic (vehicles/day) /24 (hours)/2

Table 8-25 Estimated Number of Days to Restore Road Closures

Road Section (No. of sites answered)	Estimated number of days to restore road closures (day). Responses from DROs or project offices (as of October 2023)			Distance (km) between site of heavy equipment and risk site of landslide (June-October 2023).			Loss from waiting per hour (2025) (thousand NRs. /hour)
	Min	Max	Average	Min	Max	Average	
NH03 Khurkot - Halesi (4 sites)	0.5	2.4	1.2	6.0	30.1	17.9	179~189
NH03 Pokhara - Baglung (8 sites)	0.2	0.5	0.3	2.0	26.0	10.1	344~586
NH25 Besisahar - Chame (3 sites)	0.5	1.3	0.9	0.5	3.0	1.5	41~83
NH37 Kanti Highway (7 sites)	0.1	0.3	0.2	0.5	21.4	8.2	227~283
NH44 Narayanghat - Mugling (9 sites)	0.1	0.4	0.2	0.1	4.5	2.3	1,687
NH47 Siddhartha Highway (12 sites)	0.1	2.7	0.6	2.0	11.0	7.1	328~2,130

Source: JICA Survey Team

Chapter 9. Engineering Measures According to the Type of Road Landslide

9.1. Preparation of Proposed Engineering Measures

The engineering measures to be taken according to the movement type of landslides (topple, collapse, slide, lateral spread, flow, river erosion, valley side slope erosion/collapse), ground material classification (rock, coarse-grained soil, fine-grained soil), and the scale of the landslides are as summarized in **Table 9-1**.

A type of landslide movement called “Lateral Spread” is a sliding phenomenon of upper strata on liquified, gently sloping, and saturated fine-grained soil layers during an earthquake. It is a rapid sliding phenomenon during an earthquake and difficult to distinguish from "Slide." No cases have been recognized as "Lateral Spread" in Nepal. Therefore, "Lateral Spread" and "Slide" are treated without distinction in **Table 9-1**.

Coarse-grained soil (soil dominated by coarse particles with a diameter of 0.075 mm or more) and fine-grained soil (soil dominated by fine particles with a diameter of less than 0.075 mm) are involved for road slopes and road bodies where engineering measures are being considered. Since they are often distributed in a mixed manner, they are not classified and are treated as soil.

The table was updated while considering engineering measures for longlist etc., and was confirmed by DOR. The engineering measures are based on DOR 2007 Roadside Geotechnical Problems, A Practical Guide to their Solution, Annex C: Standard Geotechnical Solutions, but the following changes were made.

- Added C5.3 “Drainage Well” as a new option.
- Added C12.4 "Protection Barriers," which is a general term for "C12.4.1 Rockfall Protection Barrier" and "C12.4.2 Debris Protection Barrier."
- Changed C13.4 "Wire-netting” to "Slope Protection Netting." A general term for slope engineering measures using wire mesh and wire rope and soil slopes, including "Rockfall Protection Nets", "High-intensity Slope Protection Nets," and "Unstable Bedrock Fixing Wire Roping," "High-intensity Slope Protection Nets," and "Unstable Bedrock Fixing Wire Roping," and "Unstable Bedrock Fixing Wire Roping."

According to confirmation with DOR, the only technology that cannot be applied in Nepal is the "Drainage Well." "Rock Sheds: Rockfall/Debris Flow Covering" has already been designed and is in the construction stage on NH47 Siddhartha Highway, and DOR has experience in it.

The main types of work associated with road widening are "Earthwork: Cutting," "Filling: Embankment," and "Reinforce Earth," which are included in **Table 9-1**.

In accordance with the above-mentioned proposed engineering measures according to the movement type, ground material, and hazard scale for road landslide damages, engineering measures are considered to the following policy.

It was finalized through the process of considering 33 sites on the longlist and 11 sites outside the longlist.

- While aiming for a 100-year probability of damage-free safety level as a major national highway, engineering measures which lower the safety level for economic reasons were also considered.
- The estimated construction cost includes temporary road protection works and temporary detours to ensure traffic safety during construction.
- In addition, if consistent with the Build Back Better concept, the policy should include the following.
 - Include adjacent risk areas, past hazard sources, and areas affected by hazards as target areas of risk reduction.

- Include road alignment and sight distance improvements in the vicinity of the target area, widening narrow spaces and creating flat regions adjacent to the road for effective use.

- To adapt to climate change adaptation, the bridge design will apply 1.1 times the runoff rate based on the 100-year rainfall intensity in accordance with DOR's bridge design standards. Similar considerations should be made for other drainage designs.
- As a climate change adaptation measures, C13.1 Framework: Adopt bioengineering as much as possible, such as using greenery within the frame as a basis for glue frame work. For concrete structures, to reduce CO² emissions during construction, consider applying C13.4.2 High-intensity slope protection net, and soil cement materials to C10. Check dams.

Table 9-1 Engineering Measures according to the Movement Type, Ground Material Classification, and Hazard Scale of Road Landslides

Road Landslide Type		Collapse			Slide		Flow	Road Carriageway Collapse				Technologies available on Nepal side	Cost 2023/24 price including 15% indirect cost for few or no examples applied engineering in Nepal	
Movement Type		Topple	Fall		Slide/Lateral Spread		Flow	River Erosion		Slope Erosion/Collapse				
Material Factors			Bedrock	Soil	Bedrock	Soil	Soil	Bedrock	Soil	Bedrock	Soil			
General Options in DOR 2007 Roadside Geotechnical Problems, A Practical Guide to their Solution, Annex C: Standard Geotechnical Solutions. Bold: Additional countermeasures based on this proposal		Applicable classification for hazard scale	Bedrock	Soil	Bedrock	Soil	Soil	Bedrock	Soil	Bedrock	Soil			
Code	Solutions													
C1	Removal	L, H	◆	◆	◆	◆	◆	◇			◆	◆	Yes	
C2	Realignment	L, H	◆	◆	◆	◆	◆	◇			◆	◆	Yes	
C3	Earthwork	L, H	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C3.1	Cutting	L,H	◆	◆	◆	◆	◆	◇			◆	◆	Yes	
C3.2	Filling	L,H	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C4	Surface Drainage	A	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C4.1	Surface Drains	A	◇	◇	◆	◆	◇			◆	◆		Yes	
C4.2	Cascade Structure	A			◆	◆	◇			◆	◆		Yes	
C4.3	Chute Structure	A					◇			◆	◆		Yes	
C4.4	Channel Lining	A					◇			◇	◇		Yes	
C5	Subsurface Drainage	A	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C5.1	French Drains	A			◇	◆							Yes	
C5.2	Horizontal Drains	A			◇	◆							Yes	
C5.3	Drainage Well	H			◆	◆							No	NRs 22million for 25m depth well of 3.5m diameter
C6	Retaining and Brest Walls	L	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C6.1	Wall Structures	L		◆	◆	◇	◇			◇	◇		Yes	
C6.2	Reinforced Erath	L		◆	◆	◇	◇			◇	◇		Yes	
C6.3	Dry Masonry Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.4	Composite Masonry Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.5	Gabion Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.6	Cantilever Masonry Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.7	Cement Masonry Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.8	Crib-walls	L		◆	◆	◇	◇			◇	◇		Yes	
C6.9	Buttressed or Counterfort Walls	L		◆	◆	◇	◇			◇	◇		Yes	
C7	Tired-Back Walls	L				◆	◆						Yes	
C8	Piles	H				◆	◆						Yes	
C9	Anchors and Bolts	H	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	
C9.1	Soil Nails	H			◆	◆	◆				◆		Yes	
C9.2	Rock Bolts	H	◆	◆	◆	◆				◆			Yes	
C9.3	Ground Anchors	H	◆	◆	◆	◆				◆			Yes	
C10	Check Dams	L, H					◆						Yes	
C11	Bank Protection Work	L, H							◆	◆			Yes	
C11.1	Bank Protection	L, H							◆	◆			Yes	
C11.2	Revetment	L,H					◆	◆	◆				Yes	
C11.3	Spurs/Groynes	L, H							◆	◆			Yes	
C11.4	Launching Aprons	L, H							◆	◆			Yes	
C12	Catch Works	L,H	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	Yes	NRs 0.2~5million/m
C12.1	Trap Walls	L	◇	◆	◆	◇	◇	◆					Yes	NRs 0.2~0.5million/m
C12.2	Rock Sheds	H	◆	◆	◆	◇	◇						Yes	NRs 2~5million/m
C12.3	Catch works reinforced earth	H	◆	◆	◆	◇	◇						Yes	NRs 0.2~2million/m
C12.4	Protection Barriers	L,H											Yes	NRs 0.2~1.0million/m
C12.4.1	Rockfall protection barrier	L,H	◆	◆		◇	◇						Yes	NRs 0.2~0.7million/m
C12.4.2	Debris protection barrier	L,H	◆	◆	◆	◇	◇						Yes	NRs 0.5~1.0million/m
C13	Surface Protection Work	L,H	◆	◆	◆								Yes	
C13.1	Shotcrete Work	L	◇	◇							◆		Yes	
C13.2	Pitching Work	L		◆	◆					◆	◆		Yes	
C13.3	Frame Work	L,H		◆	◆					◆	◆		Yes	NRs 5~12thousand/m2
C13.4	Slope Protection Net	L,H		◆									Yes	NRs 30~40thousand /m2
C13.4.1	High-intensity Rockfall Protection Net	L,H		◆	◆					◆			Yes	NRs 15~40thousand/m2
C13.4.2	Slope Protection Net	L,H		◆	◆					◆	◆		Yes	NRs 30~40thousand/m2
C13.4.3	Unstable bedrock fixing wire roping	L,H		◆	◆					◆			Yes	Varies greatly depending on conditions
C14	Bioengineering	A	◇	◇	◇	◆	◆	◇	◇	◆	◆		Yes	

Applicability to types of geohazards, movements, and ground materials
 ◆: Principal Option to be Considered for Solution of the Hazards
 ◇: Auxiliary Options
 ◇: Can not specific to the generic options

Applicable categories related to the scale of hazard
 H: Options to be applied to large-scale hazards
 L: Options to be applied to small-scale hazards
 A: Auxiliary options applicable to any hazard scale

DOR 2007 Roadside Geotechnical Problems, A Practical Guide to their Solution, Annex C: Standard Geotechnical Solutions
 Changed from "DOR 2007 Roadside Geotechnical Problems A Practical Guide to their Solution, Annex C: Standard Geotechnical Solutions"
 Added C5.3 "Drainage Well" as a new option.
 Added C12.4 "Protection Barriers" as a new option.
 A general term for "12.4.1 Rockfall Protection Barrier" and "Debris Protection Barrier".

C13.4 "Wire-netting" was changed to "Slope Protection Net". A general term for slope protection works using wire mesh and wire rope applied to bedrock and soil slopes, including "Rockfall Protection Net", "High-intensity Slope Protection Net", "Unstable Bedrock Fixing Wire Roping."

9.2. Direction for Considering Engineering Measures

The types of landslides confirmed on site are mainly summarized into four types: Collapse, slide, flow and road carriageway collapse. (See **Table 3-3 Classification and Definition of Road Landslide**).

In considering engineering measures, three typical methods (PLAN I: Permanent, PLAN II: Moderate, and PLAN III: Temporary) are proposed. The Summary of each method is as described below. In addition, **Table 9-2** shows an image of the safety, construction cost, maintenance cost and construction period of the three options.

(1) PLAN I: Permanent

- This is a construction method that completely stabilizes the cause of the landslide through engineering measures.
- This is the safest of the three options and can withstand normal heavy rain and earthquakes.
- The construction cost is the highest and the construction period is the longest among the three options.
- Maintenance costs can be kept to a minimum.
- It is possible to proactively introduce Japan's cutting-edge landslide prevention technologies and construction methods.



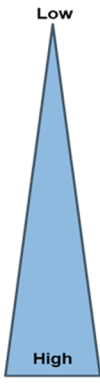
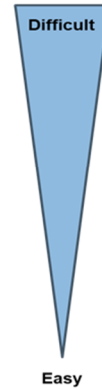
(2) PLAN II: Moderate

- This is a construction method that can suppress the main causes of landslide to some extent through engineering measures.
- Roads may be damaged by secondary events (for example, falling rocks from a cut slope in a collapsed area) or events that are difficult to predict (for example, damage to a bridge due to a large amount of driftwood in a debris flow).
- The construction cost and construction period of the three options are medium.
- The main method is the type currently being used in Nepal, but it is possible to introduce Japan's cutting-edge landslide prevention technology and construction methods into some of the engineering measures works.

(3) PLAN III: Temporary

- Among landslide causes, this method can only deal with small and medium-scale events that occur frequently.
- Safety is the lowest among the three options, and it is not possible to deal with large-scale events, and even after engineering measures are implemented, there is a possibility that landslides will still occur frequently.
- Facilities need to be restored every time a landslide occurs, which increases maintenance and management costs.
- Among the three options, the construction cost is the lowest and the construction period is the shortest.
- The main method is the type currently being used in Nepal, but it is possible to introduce Japan's cutting-edge landslide prevention technology and construction methods into some of the engineering measures works.

Table 9-2 Comparison of Three Options

Option	Mitigation Level	Safety Degree	Construction Cost	Maintenance Cost	Construction Difficulty
PLAN I	Permanent	High 	High 	Low 	Difficult 
PLAN II	Moderate				
PLAN III	Temporary				

Source: JICA Survey Team

9.3. Engineering Measures for Each Landslide Type

Based on the previous chapter, specific engineering measures are proposed for the four types of landslides that are observed on-site: collapse, slide, flow, and road carriageway collapse. **Table 9-3** shows a Summary of engineering measures for each type of landslide.

Table 9-3 Summary of Engineering measures for Each Landslide Type

	Probability year of damage after engineering measures	Collapse	Slide	Flow	Road Carriageway Collapse
PLAN 1 (Permanent)	100 years	Drastic engineering measures such as ground anchors, reinforcing bars, rockfall protection fences, etc.	<i>Design safety factor</i> ²⁰ = 1:1.2 Drastic engineering measures using a combination of groundwater drainage works, earthworks, and ground anchors	Flow engineering measures using debris flow control facilities or bridges that can deal with 1.1 times the 100-year probability debris flow peak flow rate	Drastic measures such as ground anchors and river side erosion control (retaining walls)
PLAN 2 (Moderate)	50 years	Engineering measures by slope cutting and greening to eliminate loose areas	<i>Design safety factor</i> = 1:1.0 Control of sliding through combination of groundwater drainage works and earthworks	Debris flow control facility capable of dealing with 1.1 times the 50-year peak debris flow rate	Engineering measures such as reinforced earth embankments on the road valley side
PLAN 3 (Temporary)	25 years	Engineering measures to separate from collapsed slope by small shift of road alignment	<i>Design safety factor</i> = 1: 1.05 Control of sliding through small-scale groundwater drainage works	Debris flow control facility capable of dealing with 1.1 times the 25-year probability debris flow peak flow rate	Engineering measures using gabion retaining walls on the road valley side

Source: JICA Survey Team

²⁰ Landslide safety factor = Landslide resistance force/Landslide sliding force. "The Japan Road Association Cutting and Slope Stabilization Guidelines 2009 Edition" states that "the safety factor required to stabilize a landslide site after the construction of landslide engineering measures is called the design safety factor, which is the required safety factor, usually set at 1.2, but considering the extent of damage caused by landslides and economic efficiency, it should be set within the range of 1.05 to 1.2".

(1) Collapse

In areas where collapse occurs, the movement includes large-scale collapses, small and medium-sized rock failures, surface failures, rockfalls and erosion by surface water. The following three engineering measures are proposed as typical engineering methods to deal with these events.

Table 9-4 Engineering Measures for Collapse

	Pattern Diagram	Points
PLAN I : Permanent		<ul style="list-style-type: none"> • Mainly supervision works (anchors, reinforcing bars, high-strength nets). • Capable of dealing with all possible landslide causes. • To ensure safety during construction, the road alignment will be shifted to the valley side and a rockfall protection fence will be installed. The shifted road will be left as is and left as a widening section.
PLAN II : Moderate		<ul style="list-style-type: none"> • The main work will be controlling works (cutting), and the cutting surface will be greened. • Although it is possible to deal with all possible collapse causes, the risk of loose rock remaining behind, erosion of surface water, collapse due to aging, and falling rocks remains. • To ensure safety during construction, the road alignment will be shifted to the valley side and a rockfall protection fence will be installed. The shifted road will be left as is and left as a widening section.
PLAN III : Temporary		<ul style="list-style-type: none"> • Slope engineering measures will not be implemented, and a standby structure will be planned on the mountain side of the road. • Capable of dealing with surface failures and rockfalls that occur frequently, but it cannot deal with large and medium-sized rock failures. • Shift road alignment to secure pockets. The shifted road will be left as is and left as a widening section.

Source: JICA Survey Team

(2) Flow

In areas where flows occur, the outflow of sediment and driftwood associated with large to small flows is recognized as a contributing factor to the phenomenon. The following three engineering measures are proposed as typical engineering methods to deal with these events.

Table 9-5 Engineering Measures for Flows

	Pattern Diagram	Points
PLAN I: Permanent		<ul style="list-style-type: none"> • This is a method that combines check dams (soil cement), head and channel construction to prevent debris flows and reinsertion of reinforcing bars to prevent collapse sources. • Capable of dealing with all possible flow causes. • As a climate change adaptation, plan to increase the target flow rate.
PLAN II: Moderate		<ul style="list-style-type: none"> • This is a method that new bridge is constructed on the valley side of the road and debris flows down under the bridge. • Although the expected amount of sediment will be accommodated, there remains a risk that driftwood and large rock blocks may cause river channel blockage and collapse damage. • As a climate change adaptation, plan to increase the target flow rate.
PLAN III: Temporary		<ul style="list-style-type: none"> • Place many small-scale check dams in mountain streams. • Capable of dealing with small-scale debris flows that occur frequently, but large and medium-scale debris flows from upstream areas cannot be controlled. • A conventional method practiced in Nepal for a long time.

Source: JICA Survey Team

(3) Slide

At the slide site, the movement of the landslide soil mass, collapse of the roadside slope (mountain side slop or road shoulder), and erosion by spring water are recognized as hazard factors. The following three engineering measures are proposed as typical engineering methods to cope with these events.

Table 9-6 Engineering Measures for Slide

	Pattern Diagram	Points
PLAN I: Permanent		<ul style="list-style-type: none"> Control works (head removal, water collection wells) will be planned to stop landslides, and deterrent works (anchors) will be installed to prevent roadside collapse. Capable of dealing with all possible slide causes. As water collection wells have no experience in Nepal, Japanese technology²¹ need to introduce. Increase the number of water collection wells as a climate change adaptation²².
PLAN II: Moderate		<ul style="list-style-type: none"> Plan control works (pressing embankment or horizontal drilling) to mitigate landslide movement. Slide movement is mitigated, but it is a possibility to continue. If damage is progressing, additional engineering measures are required. The method is used in Nepal.
PLAN III: Temporary		<ul style="list-style-type: none"> Slide restraint measures will not be implemented, and a standby structure will be planned on the mountain side of the road. Capable of preventing damage from roadside slopes. Shift road alignment to secure pockets.

Source: JICA Survey Team

²¹ The Japanese liner plate, which protects well walls, has excellent durability and workability, and the small rotary percussion drill, which makes it possible to construct water collection and drainage borings inside the well, has excellent workability. Therefore, the introduction of the equipment is recommended.

²² The drainage drillings inside the well should be arranged in a fan shape from the same location, with an interval of 5m to 10m at the end tips of the drillings. The spacing is recommended about 10% closer to 4m to 9m as climate change adaptation.

(4) Road Carriageway Collapse

At sites of road carriageway collapse, landslide movement, colluvium collapse and river erosion are recognized as hazard factors. Here, engineering measures against road carriageway collapse itself are shown, and engineering measures against slide fluctuations and river structures for full-scale river erosion prevention are not included. The following three engineering measures are proposed as typical engineering methods.

Table 9-7 Engineering Measures for Road Carriageway Collapse

	Pattern Diagrams	Points
PLAN I: Permanent		<ul style="list-style-type: none"> • Construct a deterrent work (anchor) on the slope under the road to stabilize the collapsed soil mass. • In case that there is a river at the end of the site, use bank protection to prevent erosion. • Highest stability. <p>HWL²³= High Water Level LWL²⁴= Low Water Level</p>
PLAN II: Moderate		<ul style="list-style-type: none"> • Reinforced soil will be installed on the valley side of the road to ensure road stability. It is important to ensure that the foundation of the reinforced soil is firmly attached to the rock. • There remains a risk that the foundation of the reinforced soil will become unstable due to river erosion in the future.
PLAN III: Temporary	<p>Mitigation Plan III</p>	<ul style="list-style-type: none"> • Gabion will be installed on the road valley side to ensure road width. • In case that there is a river at the end of the site, use bank protection to prevent erosion. • As this construction method does not fundamentally address the cause of the damage, there is a high risk of repeated damage and the need to redo the work each time.

Source JICA Survey Team

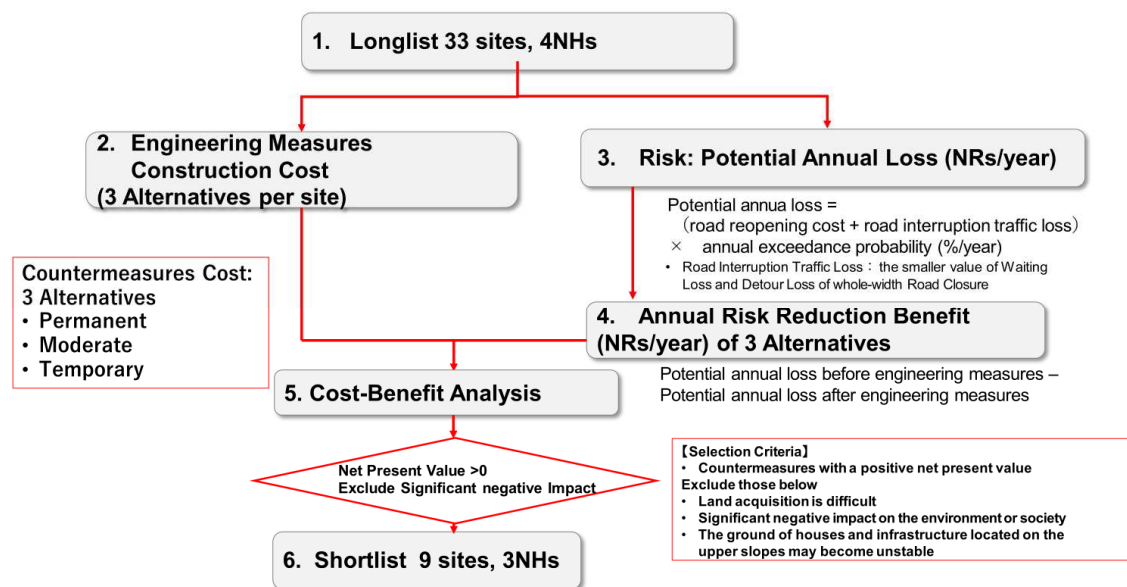
²³ HWL= A water level, is used to evaluate the stability of the slope on the river side of a road and is a flood level that occurs once or twice a year.

²⁴ LWL=The water level does not fall below this level for 275 days in a year.

Chapter 10. Selection Criteria and Creation of Shortlist of Site-based Assessment

10.1. Summary of Site -based Assessment and Shortlist

A cost-benefit analysis was conducted on the 33 sites selected in the longlist, and 9 sites were selected for the shortlist that have a net present value (NPV) over 0. **Figure 10-1** shows the process of shortlist selection.



Source: JICA Survey Team

Figure 10-1 Site-based Assessment and Selection Process of Shortlist

1) Target: 33 sites, in 4NH in longlist.

2) Estimated construction cost (3 plans per site): Three plans (PLAN I: Permanent, PLAN II: Moderate, PLAN III: Temporary) were proposed and the estimated construction cost was calculated for each site based on the approach described in "8.2 Engineering Measures Methods for Each Landslide Type"

3) Potential Annual Loss (NRs. /year):

Potential annual loss is calculated by multiplying the loss due to whole-width road closure by the annual exceedance probability of the road landslide closure events.

The losses associated with road closures are the following two items:

Road reopening cost: The input value confirmed by the district road office (DRO).

Road interruption traffic loss: The smallest value among the standby loss and detour loss.

4) Annual risk reduction benefit: The effect of implementing engineering measures works is calculated as "potential annual loss before engineering measures - potential annual loss after engineering measures. The "potential annual loss after engineering measures" was obtained by considering the "annual exceedance probability of a road landslide closure event after engineering measures" for each of the three plans (PLAN I - III).

5) Net Present Value (NPV): The annual risk reduction benefit and the estimated construction cost were each converted into a present value, and the NPV was obtained as "present value of benefit - present value of cost.

6) Shortlist: The sites on the shortlist were selected based on the NPV being greater than zero, as well as the impact of the land acquisition, environment, private houses, etc.

10.2. Individual Site Analysis for Road Landslide

10.2.1. Calculation Method

The calculation method is based on the "World Bank-GFDRR 2020 Road Geohazard Risk Management Manual, Operation Manual1: Economic Risk Estimation and Cost-Benefit Analysis" (the WB2020-OM1). Details of the method are described as follows.

10.2.2. Evaluation of Annual Exceedance Probability of Road Landslide Event

The number of landslide events over 20 years is estimated based on the damage information obtained from DOR and the traces of damage in satellite images over the past 20 years, and the annual exceedance probability of whole-width road closure damage is calculated. However, suppose multiple landslide events are confirmed in the damage information obtained from DOR from June to September 2023. In that case, it is determined that this reflects the stability of the current situation, and it is considered that multiple landslide events occurred in one year. The number of landslide events per year is evaluated as the annual exceedance probability. When the survey team conducted a field visit in August 2023, if it is evaluated that the measures have been implemented and the level of safety has increased, the annual exceedance probability was reduced according to the stability evaluation.

10.2.3. Estimation of Potential Annual Loss

The potential annual loss due to road closure is calculated as the following:

$$\begin{aligned} \text{Potential annual loss} = & \\ & (\text{road reopening cost} + \text{road interruption traffic loss}) \\ & \times \text{annual exceedance probability of landslide event (\%/year)} \end{aligned}$$

Table 10-1 shows the method for calculating the potential loss.

Table 10-1 Calculation of Potential Damage

Calculation Item	Calculation Policy
Road reopening costs	The amount is input based on the district road office's (DRO) confirmation.
Road interruption traffic loss	It is assumed that road users will make economically rational decisions in the event of a road closure event, and the smaller value of the waiting loss and the detour loss is defined as the road interruption traffic loss. If there is no detour, the waiting loss is treated as the road closure loss.

Source: JICA Survey Team

(1) Road Reopening Costs

The input figure is the cost of damage caused by whole-width road closure at each site confirmed by DRO.

(2) Road Interruption Traffic Loss

Losses related to road closures are calculated.

Road interruption traffic losses are first calculated by waiting for losses and detour losses. If road users make economically rational decisions, the smaller value of the waiting loss and the detouring loss is defined as the road interruption traffic loss. If there is no detour, waiting loss equals road interruption traffic loss.

(3) Waiting Loss

The waiting loss is calculated using the following formula as the loss in the time travel cost of the vehicle when the road is closed.

$$\text{Waiting Loss} = \sum (\text{TTC} \times \text{waiting time})$$

where,

TTC = time travel cost (NRs. /vehicle/hour) = monetary value of time travel when the travel time of a vehicle is reduced by 1 hour

10.2.4. Detour Loss

The detour loss is calculated using the formula below as the sum of the increase in vehicle operation costs and the growth in the TTC of the vehicle when the vehicle takes a detour. The concept of the detour is shown in **Figure 7-1 The Concept of Setting Detours**.

$$\text{Detour loss} = \sum (\text{VOC for a detour section} \times \text{travel distance} - \text{TTC for the evaluated road section} \times \text{travel distance}) + \sum (\text{TTC} \times \text{increases in travel time due to detour})$$

Where,

VOC = vehicle operation cost (NRs. /vehicle/km) = vehicle operation cost when a vehicle travels 1 km.

10.2.5. Calculation of Potential Annual Loss and Annual Risk Reduction Benefit

In case that the engineering measures has been implemented, annual damage reduction benefit are calculated as below:

$$\text{Annual risk reduction benefit} = \text{Potential Annual loss before engineering measures} - \text{Potential Annual loss after engineering measures}$$

The annual loss after engineering measures was calculated by considering the “annual exceedance probability after engineering measures” for three of engineering measures plans (PLAN I-III). The annual exceedance probability after engineering measures is a value that reflects the safety degree of the adopted engineering measures as a technical image after it has been completed.

[Annual exceedance probability after engineering measures]

<Engineering measures works> <Annual exceedance probability after the engineering measures>

- PLAN I: Permanent:100 Year
- PLAN II: Moderate:50 Year
- PLAN III: Temporary : 25 Year

10.2.6. Cost-benefit Analysis of Engineering Measures

A cost-effectiveness analysis will be conducted on each site's three engineering measures alternative plans. The diagram of input and output items for cost-effectiveness analysis is shown in **Figure 10-2**.

Input item		Output item	
Items	Unit	Item	Unit
Engineering measures construction cost	NRs.	Net Present Value (NPV)	NRs.
Annual maintenance cost	NRs. /Year	Benefit cost ratio	Non dimension
Annual risk reduction benefit	NRs. / Year	Economic internal rate of return (EIRR)	%
Discount rate	%		
Evaluation period	Year		

Source: JICA Survey Team

Figure 10-2 Input and Output Items of Cost-Benefit Analysis of Engineering Measures

The input items are as follows.

(1) Engineering Measures Construction Cost

In this assessment, the estimated engineering cost is the direct construction cost plus 15% of the contractor's indirect costs. However, the estimated project cost is the amount that includes 40% of

expenses (24% of contingencies, 13% of design and supervision costs, and 3% of other expenses). The 24% contingencies are stipulated in Nepal's Public Procurement Rules Nepal Sambat 2064 (2007). Since this assessment does not cover all the benefits, it will consider the estimated construction costs, excluding project cost, approximately 40% of the expenses. Benefits not covered include those that are difficult to calculate, such as loss of affected persons, loss of vehicles, moving costs of heavy equipment and machinery, and fixed costs (labor costs and expenses) of restoration workers.

(2) Maintenance and Operation Cost

For technologies that do not require special maintenance and management, 0.1% of the construction cost will be set as the annual maintenance and management cost, as additional construction is not assumed within the target safety level of probability years of a landslide event. For bridges and groundwater drainage works, 1% of the construction cost will be allocated for painting, repairing, and reinforcing bridges and engineering measures for clogging groundwater drainage holes. For debris flow dams, 5% of the construction cost will be allocated for dam repair and sediment removal. These coefficients are set empirically for initial cost-effectiveness evaluation. The DOR's maintenance department has confirmed that it is generally appropriate.

(3) Annual Risk Reduction Benefit

The Annual Risk Reduction Benefit estimation is shown in **10.2.5 Calculation of Potential Annual Loss and Annual Risk Reduction Benefit**. The following values are input for the estimation.

- Annual increase in AADT: 6% (the general value used in DOR's planning)
- The annual increase rate of time travel cost 3.4% (annual GDP increase, 10-year average from WB2013/14 to 2022/23)
- The annual rate of increase in vehicle operation costs: 6.2% (annual price increase rate, 10-year average from WB2013/14 to 2022/23)
- Discount rate: 12% (The discount rate applied to the WB funded improvement project of NH17 Prithivi Highway, Nagdhunga-Naubise-Mugling road, which is also connected to the road subject to this assessment, will be applied)
- Evaluation period: 30 years (apply the evaluation period used in the WB funding road rehabilitation project of NH17 Prithivi Highway, Nagdhunga-Naubise-Mugling road, which is also connected to the road targeted for this assessment)

(4) Net Present Value (NPV)

The NPV is calculated using the equation below. If the NPV is positive, the larger the positive value, the more valuable the investment is and the higher the return on investment.

$$\text{Net Present Value} = \text{Present Value of Benefits} - \text{Present Value of Costs}$$

(5) Cost-Benefit Ratio

The Cost-Benefit Ratio is calculated using the equation below. In case that the Cost-Benefit Ratio exceeds 1, it is worth investing in. However, even if a small-scale investment is efficient, if the risk reduction benefit is small, it will not be consistent with the objective of a significant risk reduction benefit, so it will not be used as an indicator for selecting engineering measures.

$$\text{Benefit-Cost Ratio} = \text{Present Value of Benefit} / \text{Present Value of Cost}$$

(6) Economic Internal Rate of Return (EIRR)

EIRR is the discount rate at which the present benefit value equals the cost value. The higher the EIRR is, the more profit can be obtained quickly. Since this is an indicator used in investment decision-making by the Nepali government, engineering measures with a high EIRR will be selected.

10.3. Site-based Shortlist Selection Criteria and Listing

10.3.1. Site-based Shortlist Selection Criteria

For the 33 sites on the longlist, the sites and engineering measures (PLANI, II, III) that would be cost-effective were selected as candidates for selection. In cases where multiple engineering measures methods were appropriate at a single site, the engineering measures method with the highest EIRR was finally selected.

[Shortlist Selection Criteria] *Net present value (NPV) > 0*

What should be noted is, sites and engineering measures that are difficult to implement as below have been excluded.

- Land acquisition is difficult.
- Significant negative impact on the environment or society.
- There are houses or other structures on the upper slopes, which may be affected.

10.3.2. Selection of Site-based Shortlist

Based on the selection criteria, nine sites were selected from the 33 sites on the longlist.

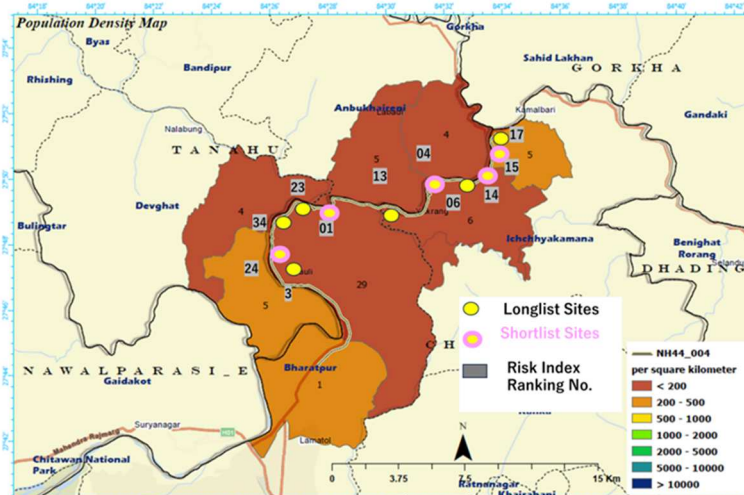
The breakdown is as follows.

- Five sites from NH44 Narayanghat Mugling Highway
- Three sites from NH47 Siddhartha Highway
- One site from NH25 Dumre-Besisahar-Charme Highway

Except for two proposed bridge alignment changes, the target safety level of damage has been lowered to 50 or 25 probability years.

(1) NH44 Narayanghat Mugling Highway

Five sites were selected from the 11 longlisted sites on NH44 Narayanghat Mugling Highway based on the selection criteria. Details of the engineering measures are shown in **Chapter 11**.



Source: JICA Survey Team, base map: OpenStreetMap showing ward population density of the 2021 census



Figure 1044 Narayanghat Mugling Highway Assessment Sites Map




Table 10-2 Selected Shortlist Sites on NH44 Narayanghat Mugling Highway

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Selected Alternative Engineering Measures Plan	The Target Safety Level of Probability Years of Damage Event	NPV BCR EIRR
1	21+500 L2	Flow	Downstream of the newly constructed bridge on the valley side, Bridge length: 40m	100 years	NPV=110 BCR=2.26 EIRR=21%
34	20+000 L5	Flow	Downstream of the newly constructed bridge on the valley side, bridge length 35m	100 years	NPV=18 BCR=1.15 EIRR=13%
4	31+400 L25	Collapse	Slope cutting	50 years	NPV=709 BCR=7.93 EIRR=50%
14	33+150 L24	Collapse	Slope cutting	50 years	NPV=24 BCR=1.18 EIRR=13%
15	33+800 L26	Collapse	Slope cutting	50 years	NPV=262 BCR=2.39 EIRR=21%

Source: JICA Survey Team

Table 10-3 Summary of Proposed Shortlist Extraction for NH44 Narayanghat Mugling Highway

	<p>Risk Index Ranking of Longlist 1, 21+500, L2: Mauri Bridge, Flow Probability year of whole-width damage event: 1.0 years Reopening duration from whole-width road closure: 0.4 days Road closures will be observed in 2022 and 2023. DOR and GESU are planning and designing an erosion control weir and bioengineering project in the watershed under a WB-funded Asian Disaster Preparedness Center (ADPC) contract. A bridge risk avoidance plan (PLAN II for debris flow) with the highest EIRR is selected after a comparison with the two watershed erosion control alternative planes (PLAN I and PLAN III). If the safety level is reduced, the water erosion control project obtains a positive NPV. Currently, new bridge is being constructed, but it will be a linear shift of the new bridge (L=40m) further into the valley side.</p>
	<p>Risk Index Ranking of Longlist 34, 20+500, L5, Flow Probability year of whole-width damage event: 0.2 years Reopening duration from whole-width road closure 0.1 days DOR has no plan for engineering measures. A bridge risk avoidance plan (PLAN II for debris flow) with the highest EIRR is selected after a comparison with the two watershed erosion control alternative planes (PLAN I and PLAN III). All alternative plan (PLAN I, II, III) have positive NPVs. The realignment by bridge to the road valley side is selected for the 100 probability years of peak debris flow rate x 1.1 that flow debris flow safely.</p>

	<p>Risk Index Ranking of longlist 4, 31+400, L25, Collapse. Probability year of whole-width damage event: 0.2 years Reopening duration from whole-width road closure: 0.1 days DOR and GESU are planning and designing slope engineering measures projects in the watershed under a WB-funded ADPC contract. DOR's DRO is in the process of planning and designing engineering measures. After comparing the frame work with the lockbolt, realignment by reinforced earth, the slope cut plan is selected with the highest EIRR and target safety level of 50 probability years.</p>
	<p>Risk Index Ranking of longlist 14, 33+150, L24, Collapse. Probability year of whole-width damage event: 0.1 years Reopening duration from whole-width road closure: 0.1 days DOR's DRO is in the process of planning and designing engineering measures. After comparing the frame work with the lockbolt and realignment with reinforced earth, the slope cut plan with a high EIRR and target safety level of 50 probability years is selected.</p>
	<p>Risk Index Ranking of longlist 15, 33+800, L26, Collapse. Probability year of whole-width damage event: 0.2 years Reopening from whole-width road closure: 0.2 days DOR and GESU are planning and designing slope engineering measures projects in the watershed under a WB-funded ADPC contract. After comparing the results with the frame work with lockbolt and realignment with reinforced earth, the slope cut plan with a high internal return rate and target safety level of 50 probability years probability is selected.</p>

Source: JICA Survey Team

■ Reference: Sites not selected for site-based shortlisting in NH44

The sites that were not selected for the shortlist in NH44 and the reasons are shown in **Table 10-4**. The "three engineering measures plans" in the table refer to PLAN I: Permanent, PLAN II: Moderate, and PLAN III: Temporary of the engineering measures plans in Annex B.5: Risk assessment, engineering measures plan and benefit and cost analysis. For details, please refer to **Chapter 9**.

Table 10-4 Reasons for Non-selection of NH44 Narayanghat Mugling Highway Sites

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Reason for non-selection	Response by DOR
3	15+100 L3	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	No special note
24	16+000 L4	Flow	• The revetment was installed in August 2023, so no additional measures should be taken, and observation is appropriate.	Construction support
23	21+300 L1	Collapse	• NPVs of all three alternative plans of engineering measures are negative .	No special note
13	26+500 L6	Carriageway Collapse	• The ground anchor was installed in 2022 and is stable. The road surface of 26+800 adjacent to the area of engineering measures needs to be monitored as minor settlement is observed.	No special note
6	32+500 (modified from 33+000) L7	Collapse	• NPVs of all three alternative plans of engineering measures are negative. • The threat to road users is high, so implementation of engineering measures is recommended. The slope cut proposal is unacceptable because it destabilizes the upper slope. Frame work with rock bolt and ground anchor with a target of damage event of 100 years probability is recommended.	8th on DOR's priority list of requests to Japan (10 th October 2023). DRO is planning and designing engineering measures
17	34+500	Collapse	• The soft rock slopes cut in 2023 are stable, and additional measures are not a priority.	Construction support

Source: JICA Survey Team

Table 10-5 NH44 Narayanghat Mugling Highway

Risk Index Ranking 13, Carriageway Collapse



Ground anchors have been taken to measure landslides and road collapse in 2022. Minor road surface subsidence is observed at 15+300 adjacent to the road but can be addressed by visual monitoring.

Risk Index Ranking 24, Carriageway Collapse



June 2023



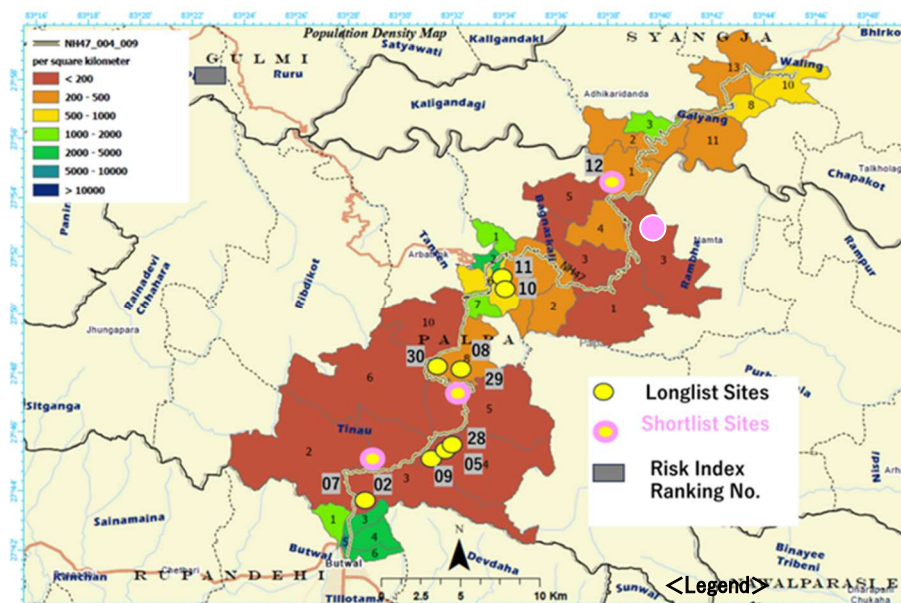
August 2023

A concrete foundation footing revetment was installed on the river side of the road from June to August 2023. It has been functioning since its installation.

Source: JICA Survey Team

(2) NH47 Siddhartha Highway

Ten sites were selected from 10 longlist sites on NH47 Siddhartha Highway based on the selection criteria. Details of the engineering measures are shown in Chapter 11.



Source: JICA Survey Team, Base Map: OpenStreetMap showing ward population density of the 2021 Census




Figure 10-3 NH47 Shidharth Highway Assessment Site Map

Table 10-6 Selected Shortlist Sites of Site-based Analysis on NH47 Siddhartha Highway

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Selected Alternative Engineering Measures Plan	The Target Safety Level of Probability Years of Damage Event	NPV BCR EIRR
2	35+500 SH03	Slide	Drainage lateral boring	25 years	NPV=3,414 BCR=10.57 EIRR=94%
29	46+400 SH09	Collapse	Slope cut	50 years	NPV=29 BCR=1.17 EIRR=13%
12	87+400 SH18	Collapse	Slope cut	50 years	NPV=62 BCR=2.53 EIRR=22%

Source: JICA Survey Team

Table 10-7 Summary of Proposed Shortlist Extraction from NH47 Siddhartha Highway

 <p>Google Earth Image, Dec.2022</p>	<p>Risk Index Ranking of Longlist 2, Slide Probability year of whole-width damage event: 3years Reopening duration for whole-width road closure: 2.7 days 9th of DOR's priority list of requests to Japan (10th October 2023) After comparison with the plans of engineering measures, including drainage wells, the horizontal subsurface drain is selected with the highest EIRR, less cutting of standing trees, and target safety level of 25 probability years.</p>
	<p>Risk Index Ranking of Longlist 29, Collapse Probability year of whole-width damage event: 10 years Reopening duration for whole-width road closure: 0.5 days 13th of DOR's priority list of requests to Japan (10th October 2023). After comparing the frame work with the rock bolt, the slope cut is selected with the highest internal return rate and target safety level of 50 probability years.</p>
	<p>Risk Index Ranking of longlist 12, Collapse. Probability year of whole-width damage event: 7 years Reopening duration for whole-width road closure:1.6 days. 12th of DOR's priority list of requests to Japan. As a result of comparison with the frame work with anchor and high intensity rockfall protection barrier, the slope cut is selected with the highest EIRR and the target safety level of 50 probability years.</p>

Source: JICA Survey Team

■ Reference: Sites not selected for site-based shortlisting in NH47

The sites that were not selected for the short list in NH47 and the reasons are shown in **Table 10-8**. The "three options for engineering measures" in the table refer to PLAN I: Permanent, PLAN II: Moderate, and PLAN III: Temporary, and are described in detail in **Chapter 9**.

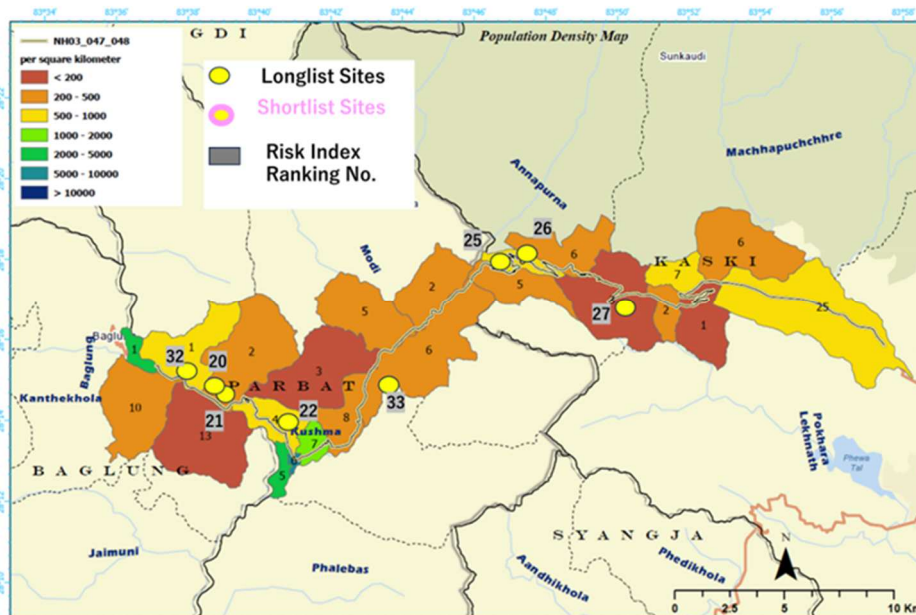
Table 10-8 Reasons for Non-selection of NH47 Siddhartha Highway Sites

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Reason for non-selection	Response by DOR
9	38+000 SH05	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	No special note
5	39+500 SH06	Flow	• NPVs of all three alternative plans of engineering measures are negative. • The cost of the bridge measures is somewhat high for a curved bridge with a length of 45m.	Repeatedly construct valley side embankment
28	39+600 SH07	Collapse/Carriageway Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
8	46+400 SH09	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
30	49+800 SH12	Slide	• NPVs of all three alternative plans of engineering measures are negative. • The landslide control embankment on the road valley side is not feasible due to the difficulty of expropriating land for residential use.	
10	56+000 SH13	Slide	• NPVs of all three alternative plans of engineering measures are negative.	
11	56+200 SH14	Slide	• NPVs of all three alternative plans of engineering measures are negative.	

Source: JICA Survey Team

(3) NH03 Pokhara-Baglung Highway

Based on the selection criteria, none of the eight longlisted sites on the NH03 Pokhara-Baglung Highway are selected because they have negative NPVs.



Source: JICA Survey Team, Base map: OpenStreetMap showing ward population density of the 2021 census NH03-408 is the road link number, and AADT is the 2021/22 value.

Figure 10-4 NH03 Pokhara Baglung Highway Assessment Site Map

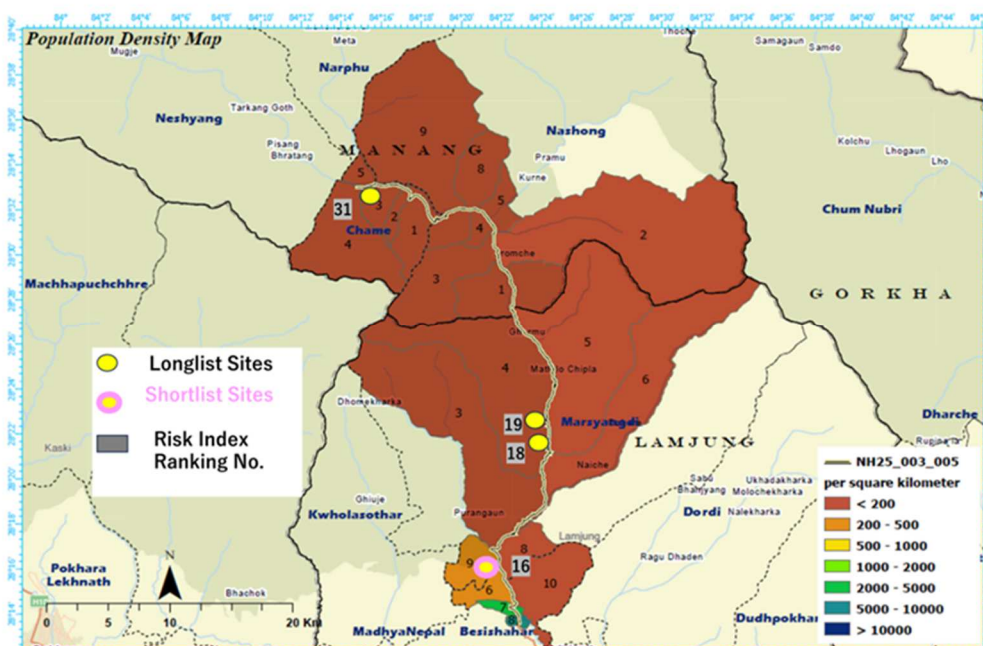
Table 10-9 Reasons for Non-selection of NH03 Pokhara-Baglung Highway Sites

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Reason for non-selection	Response by DOR
32	58+700 PB02	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
20	58+880 PB03	Flow	• NPV of all alternative plans of engineering measures are negative.	
21	57+400 PB04	Collapse	• NPV of all three alternative plans of engineering measures are negative.	
22	52+500 PB11	Flow	• NPV of all three alternative plans of engineering measures are negative.	
33	51+500 PB21	Collapse	• NPV of all three alternative plans of engineering measures are negative.	
25	37+900 PB36	Slide	• NPV of three all alternative plans of engineering measures are negative.	
26	36+400 PB37	Slide	• NPV of all three alternative plans of engineering measures are negative.	
27	26+200 PB38	Slide	• NPV of all three alternative plans of engineering measures are negative.	

Source: JICA Survey Team

(4) NH25 Dumre-Besisahar-Charme Highway

One site was selected from the four longlisted sites on the NH25 Dumre-Beshisahar-Charme Highway based on the selection criteria. Details of the engineering measures works are shown in **Chapter 11**.




Source: JICA Survey Team, Base map: OpenStreetMap showing ward population density of the 2021 census
Figure 10-5 N25 Dumre-Besisahar-Charme Highway Assessment Site Map

Table 10-10 Selected Shortlist Sites by Site-based Analysis on NH25 Dumre-Beshisahar-Charme Highway

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Selected Alternative Engineering Measures Plan	The Target Safety Level of Probability Years of Damage Event	NPV BCR EIRR
16	45+150 L21	Collapse	Realignment of the road with reinforced earth embankment and gabion catch works	25 years	NPV=668 BCR=2.15 EIRR=20%

Source: JICA Survey Team

Table 10-11 Summary of Proposed Shortlist Extraction from NH25 Dumre-Banshidhar-Charme Highway

	<p>Risk Index Ranking of Longlist 16, Collapse Probability year of whole-width damage: 3 years Reopening duration from whole-width road closure: 5.8 days 23rd DOR's priority list requests to Japan on 10th October 2023.</p> <p>The assessment results of the alternative plans of engineering measures with slope bioengineering and high energy debris protection barrier all have positive NPV. Plan III for the gabion catch works and road realignment with reinforced earth was selected, because of the highest EIRR among alternative Plan I, II, and III for collapse. The selected Plan III has a target safety level of 25 probability years.</p> <p>Since the project is in the Annapurna Nature Reserve, it is necessary to comply with regulations regarding tree cutting, bioengineering, etc.</p>
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Collapse in 2022

Source: JICA Survey Team

■ Reference: Sites not selected for site-based shortlisting in NH25

The sites that were not selected for the shortlist in NH25 and the reasons are shown in **Table 10-12**. The "three options for engineering measures" in the table refer to PLAN I: Permanent, PLAN II: Moderate, and PLAN III: Temporary, and for details, please refer to **Chapter 9**.

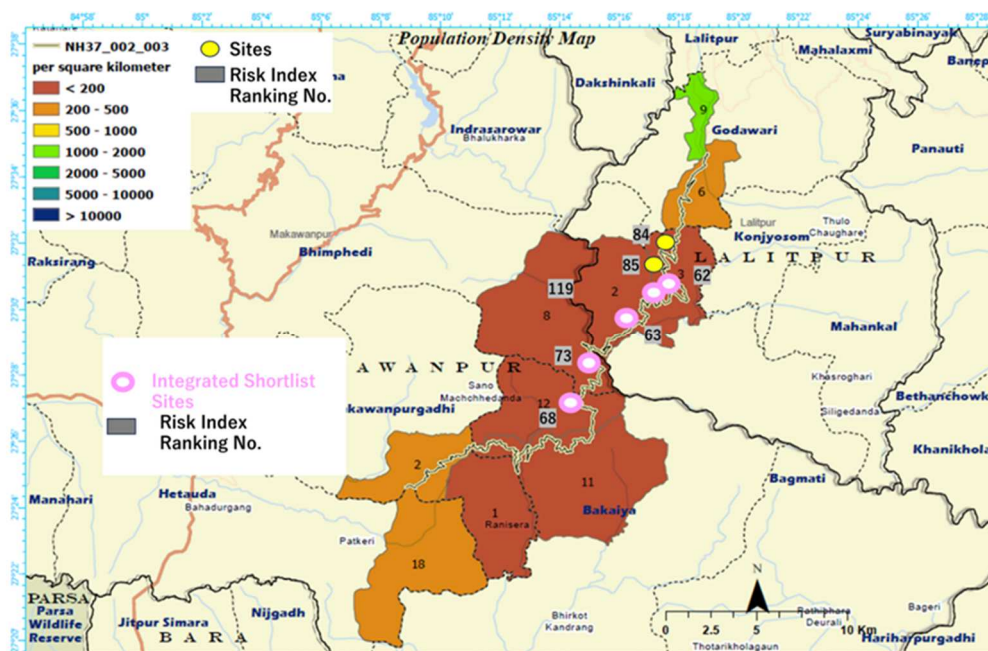
Table 10-12 Reasons for Non-selection of NH25 Dumre-Beshisahar-Charme Highway Sites

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Reason for Non-selection	Response by DOR
18	61+100 L12	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
31	101+800 L19	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
19	62+500 L20	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	

Source: JICA Survey Team

(5) NH37 Kanti Highway (Referential Assessment outside of the Site-based Analysis)

The section of NH37 Kanti Highway was not included in the longlist, but the engineering measures work was considered, and cost-effectiveness analysis was performed for reference due to the strong request for assistance from the DRO. In both analysis, the NPV is negative.



Source: JICA Survey Team, Base Map: OpenStreetMap showing ward population density of the 2021 census

Figure 10-6 NH37 Kanti Highway Assessment Site Map

The sites that were not selected in site based short list in NH37 and the reasons are shown in **Table 10-13** below. The "three options for engineering measures" in the table refer to PLAN I: Permanent, PLAN II: Moderate, and PLAN III: Temporary, and for details, please refer to **Chapter 9**.

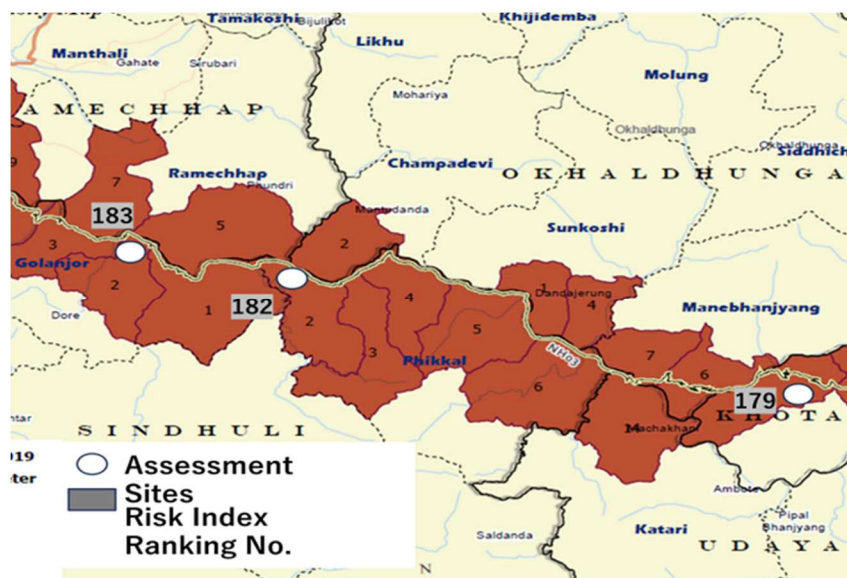
Table 10-13 Engineering Measures Works and Study Sites for Cost-effectiveness on NH37 Kanti Highway

Risk Index Ranking	Chainage Inventory No.	Landslide Type	Cost-effectiveness of Engineering measures Works	Response by DOR
84	69+365 K3	Collapse	• NPV of all three alternative plans of engineering measures are negative.	
85	66+565 K4	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	Geotechnical investigation conducted in 2023.
62	63+885 K5	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
119	61+627 K6	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	Geotechnical investigation conducted in 2023.
63	56+420 K7	Slide	• NPVs of all three alternative plans of engineering measures are negative.	Electrical prospecting conducted in 2022.
73	46+000 K8	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	
68	42+000 K9	Slide	• NPVs of all three alternative plans of engineering measures are negative.	Electrical prospecting conducted in 2022.

Source: JICA Survey Team

(6) NH03 Khurkot-Halesi (Reference Assessment Outside of the Site-based Analysis)

Although the NH03 Khurkot-Halesi section is not included in the longlist, there is DRO's priority route for landslide (July 2023). In addition to the top three sections in the DOR Longlist Risk Index Ranking, we also prepared three engineering measures construction plans, including one section requested by the DRO at the time of the survey team's inspection in early August 2023, and examined their cost-effectiveness.



Source: JICA Survey Team, Base Map: OpenStreetMap showing ward population density of the 2021 census



Figure 10-7 NH03 Khurkot-Halesi Assessment Site Map

Table 10-14 Economically Promising Sites on the NH03 Khurkot-Halesi Section

Risk Index Ranking	Chainage Inventory No.	Landslide Type Probability of Damage	Selected Alternative Engineering Measures Plan	The Target Safety Level of Probability Years of Damage Event	NPV BCR EIRR
183	18+600 HK13	Collapse	Slope cut	50 years	NPV=16 BCR=1.66 EIRR=17%
201	4+000 HK15	Collapse	Slope cut	50 years	NPV=463 BCR=5.67 EIRR=38%

Source: JICA Survey Team

Table 10-15 Summary of Economically Viable Site on NH03 Khurkot-Halesi Section

	<p>Risk Index Ranking 183, Collapse. The probability of whole-width failure: 1.5 years Reopening for whole-width blockage failure: 0.8 days. There is no priority of the DOR request. After a comparative study with slope frame work with rock bolt and gabion catch works, the slope cut plan with the highest EIRR and target safety level of 50 probability years is promising.</p>
	<p>Risk Index Ranking 201, Collapse Probability year of whole-width failure: 1 Recovery duration of whole-width closure: 2.4 days 24th on DOR's priority list of requests to Japan. After comparison with the frame work with rock bolt and gabion catch work, the slope cut plan with the highest EIRR and target safety level of 50 probability years is promising.</p>

Source: JICA Survey Team

Table 10-16 Summary of Other Assessment Sections in NH03 Khurkot-Halesi

Longlist Risk Index Ranking	Chainage Inventory No.	Landslide Type	Cost-effectiveness of Engineering Measures Works	Response by DOR
179	15+600 HK05	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	No special note
182	101+800 HK10	Collapse	• NPVs of all three alternative plans of engineering measures are negative.	No special note

Source: JICA Survey Team

10.4. Selection Results of the Comprehensive Shortlist

Seven sites selected by route-based analysis and nine sites evaluated by site-based analysis are listed in **Table 10-17**. For seven sites (NH 37: Kanti Highway) selected through the route-based analysis, the economic justification of the project may be obtained by considering the benefits of widening the road from 1.5 to 2 lanes and pavement improvement, in addition to the benefits of reducing landslides risk.

Table 10-17 Selection of Comprehensive Shortlist

NH	Chainage	Risk Index Ranking (Inventory No.)	Route-based Analysis Selection	Individual Site Analysis	Landslide Type (Technical Difficulty)	Selected Alternative Countermeasures Plan	Target Safety Level of Probability Years of Damage Incident	Benefit Cost Indicators: NPV: Net Present Value (million Rs.) BCR: Benefit Cost Ratio EIRR: Economic Internal rate of Return	Remark
NH25 Besisahar-Charme	45+150	16 (L21)		✓	Collapse (M: Medium)	Realignment, Reinforced earth embankment + Trap gabion wall	25 years	NPV=668, BCR=2.2, EIRR=20%	
NH37 Kanti Highway	42+000	68 (K9)	✓		Slide (M: Medium)	Earth removable of slide head, drainage wall, horizontal subsurface drainage	100 years	NPV=-2,060 BCR=0.0, EIRR=-	By adding to the benefits of reducing travel time and travel costs due to widening from 1.5 lanes to 2 lanes and paving, the countermeasure works may be economically appropriate for both individual slopes and routes. Since countermeasures against slopes would be very difficult, a possible avoidance option by tunnel could also be considered. In such a case, economic benefits are expected due to the shortening of the distance presentation.
	46+000	73 (K8)	✓		Collapse (M: Medium)	Frame work with ground anchors, high-intensity slope protection net, alignment shift by reinforced earth embankment	100 years	NPV=-1,461, BCR=0.0, EIRR=-	
	56+420	63 (K7)	✓		Slide (M: Medium)	Earth removable of slide head, frame work with ground anchors, horizontal subsurface drainage, alignment shift by reinforced earth embankment	100 years	NPV=-747, BCR=0.0, EIRR=-	
	61+627	119 (K6)	✓		Collapse (D: Difficult)	Frame work with ground anchors, high-intensity slope protection net, alignment shift by reinforced earth embankment	100 years	NPV=-2,646, BCR=0.0, EIRR=-	
	63+885	62 (K5)	✓		Collapse (D: Difficult)		100 years	NPV=-1024, BCR=0.1, EIRR=-	
	66+565	85 (K4)	✓		Collapse (D: Difficult)		100 years	NPV=-661, BCR=0.0, EIRR=-	
	69+365	84 (K3)	✓		Collapse (D: Difficult)		100 years	NPV=-593, BCR=0.0, EIRR=-	
NH44 Narayanghat - Mugling	20+000	34 (L5)		✓	Flow (D: Difficult)	Realignment by Bridge (length: 35m)	100 years	NPV=18, BCR=1.2, EIRR=13%	
	21+500	1 (L2)		✓	Flow (D: Difficult)	Realignment by Bridge (length: 40m)	100 years	NPV=158, BCR=2.3, EIRR=21%	
	31+400	4 (L25)		✓	Collapse (M: Medium)	Slope cutting Bioengineering	50 years	NPV=709, BCR=7.9., EIRR=50%	
	33+150	14 (L24)		✓	Collapse (M: Medium)		50 years	NPV=24, BCR=1.2, EIRR=13%	
	33+800	15 (L26)		✓	Collapse (M: Medium)		50 years	NPV=262, BCR=2.4, EIRR=21%	
NH47 Siddhartha Highway	35+500	2 (SH03)		✓	Slide (E: Easy)	Horizontal subsurface drain, gabion breast wall	25 years	NPV=3,414, BCR=10.6, EIRR=94%	
	46+400	29 (SH09)		✓	Collapse (E: Easy)	Slope cutting Bioengineering	50 years	NPV=29, BCR=1.2, EIRR=13%	
	87+400	12 (SH18)		✓	Collapse (M: Medium)		50 years	NPV=62, BCR=2.5, EIRR=22%	

Source: JICA Survey Team

Chapter 11. Proposal and Schedule for Engineering Measures for Site-based Analysis Selected Shortlist

11.1. Engineering Measures

11.1.1. Slope Engineering Measures

(1) Shortlist for Landslide Engineering Measures

Table 11-1 shows the selected shortlist sites by site-based analysis and the landslide engineering measures, which include two slide sites and seven collapse sites. The methods of selecting engineering measures according to the types of road landslides are explained in **Chapter 9. Engineering Measures according to the Type of Road Landslide** and **10.3.2 Selection of Site-based Shortlist**.

Table 11-1 List of the Selected Site-based Shortlist and the Slope Engineering Measures

NH Code	Risk Index Ranking	Inventory No.	Chainage	Type of Geohazard	Remarks
NH44	4	L25	31+400	Collapse	<ul style="list-style-type: none"> • Collapse completely blocked the road • Selected engineering measures: Cutting work and Bioengineering
	14	L24	33+150	Collapse	<ul style="list-style-type: none"> • Selected engineering measures: Cutting work and Bioengineering
	15	L26	33+800	Collapse	<ul style="list-style-type: none"> • Selected engineering measures: Cutting work and Bioengineering
NH47	2	SH03	35+500	Slide	<ul style="list-style-type: none"> • Continuous movement over past 20 years • Selected engineering measures: Subsurface drain – Horizontal drain
	12	SH18	87+400	Slide	<ul style="list-style-type: none"> • Active slide • Selected engineering measures: Cutting work and Bioengineering
	29	SH09	46+400	Collapse	<ul style="list-style-type: none"> • Selected engineering measures: Cutting work and Bioengineering
NH25	16	L21	45+150	Collapse	<ul style="list-style-type: none"> • Selected engineering measures: Avoidance – Realignment

Source: JICA Survey Team

(2) Design Consideration

In general, there are three basic strategies to reduce the risk of a landslide to the road:

- (1) Prevention or stabilization engineering measures,
- (2) Protection engineering measures, and
- (3) Avoidance engineering measures.

Prevention engineering measures seek to address one or more key mechanisms and causes of landslides and improve stability of the road slope and landslide areas. The latter two engineering measures allow landslide occurrence and seek to avoid, protect against, or limit the associated impacts on the road and traffic safety.

Prevention Measures

Prevention measures for a landslide along roads (such slides and collapses) are directly implemented on the respective slopes to improve their stability to the required safety levels. Typical prevention engineering measures include cutting or grading of the unstable portion of the slope to a lower or stable

gradient, construction of anchoring/slope reinforcements, retaining walls, improving drainage conditions, and increasing forces to resist sliding or collapse.

Protection Measures

Protection measures protect road and traffic from landslides by controlling and stopping moving or diverting earth or debris mass caused by landslides. The protection measures include catch walls, protection fences/nets, and check dams.

Avoidance Measures

Avoidance measures are permanent solutions to landslides without maintenance which involve relocation or placing of the highway to more stable sites. Avoidance measures mainly include realignment of the road away from the landslide site, tunnels, bridges and rock sheds that allow passage of landslide materials above and beneath the roads.

In designing the landslide engineering measures, the following points should be considered in the planning of the overall layout,

- Mechanism and dimension of landslides,
- Damage and situation of the road sections due to landslides,
- Site specific topographic and geologic conditions,
- Land use constraints and right-of-way for each site,
- Safety of construction personnel and traffic during construction,
- Availability of construction material and equipment,
- Environmental and social effects during construction, and
- Engineering experience and judgments.

In addition, climate change adaptation is incorporated into landslide engineering measures, which are as summarized below:

- The cut slopes will be protected with bioengineering (vegetation) to prevent erosion from surface water flow,
- Surface drains with a larger drain section (1.2 times larger) will be provided for all site to improve drainage and control surface erosion,
- Subsurface drain or horizontal drain is provided for large-scale slide site (for example, site of Risk Index Ranking 2 (SH03) at NH47 31+500, which is cited within the forested land, not only improving underground water drainage, but also slope minimize deforestation, for example, for construction of access road and cutting work),
- As an alternative engineering measures against debris flows will be designed to accommodate a debris flow accompanying the 100-year exceedance probability of the 24-hour rainfall.

Accordingly, as shown in **Table 11-1** above, from the selected shortlist sites, the engineering measures are selected mainly as follows:

- (1) Prevention - Cutting works with bioengineering for Risk Index Rankings 4, 14 and 15 on NH44, Risk Index Rankings 12 and 29 on NH47,
- (2) Prevention - Subsurface drains – Horizontal drain work for Risk Index Ranking 2 on NH47, and
- (3) Avoidance – Realignment for Risk Index Ranking 16 on NH25,
- (4) Avoidance – Bridges for Risk Index Rankings 1 and 34 on NH44, and 5 on NH47. The design of Bridges will be given in Section 11.1.2 below.

The cutting work is intended to remove the presently unstable and potentially unstable part of the target slopes with stable or standard gradient (see **Table 11-2**). Standard gradient is generally determined according to the geology of cut slopes. The gentler the slope gradient is, the more stable (safe) the cut slope is, and where steeper than the standard gradient, the more dangerous the cut slope is.

The gradient of cut slopes at the target slopes were determined from geological and rock mass observation at each site. In addition, the cut slopes shall be protected with bioengineering to prevent surface erosion and to improve environmental impact by excavation.

Table 11-2 Standard Gradient of Cut Slopes

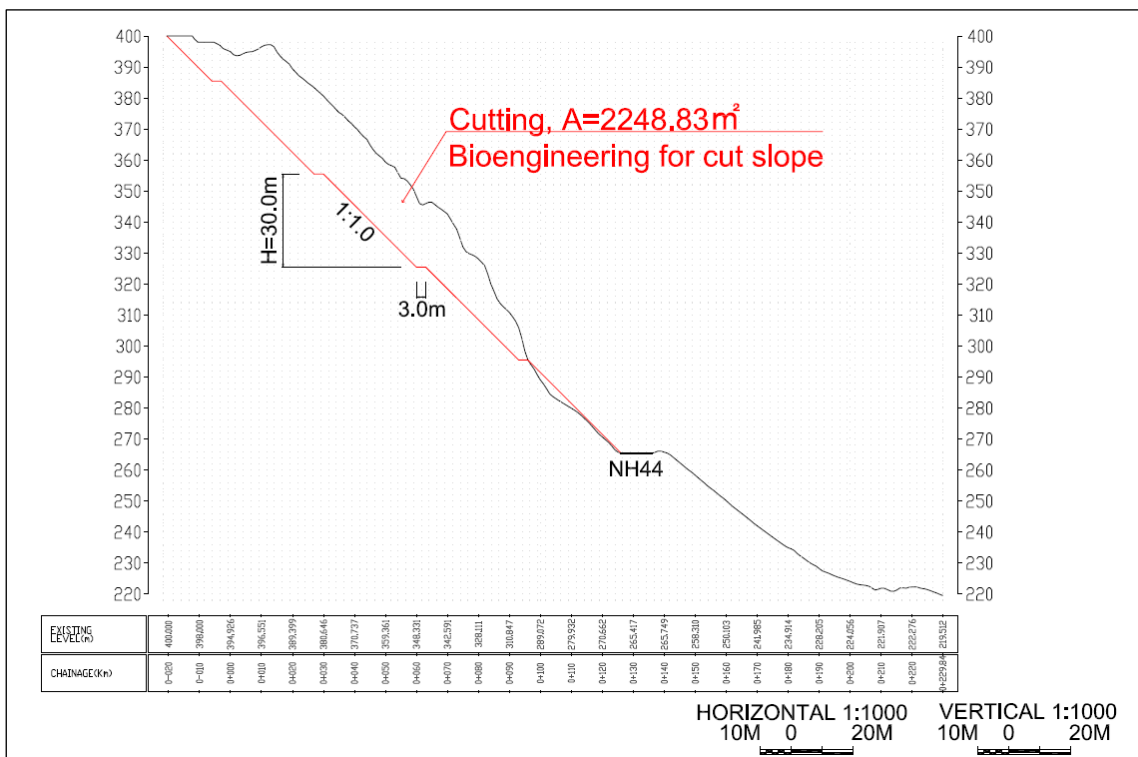
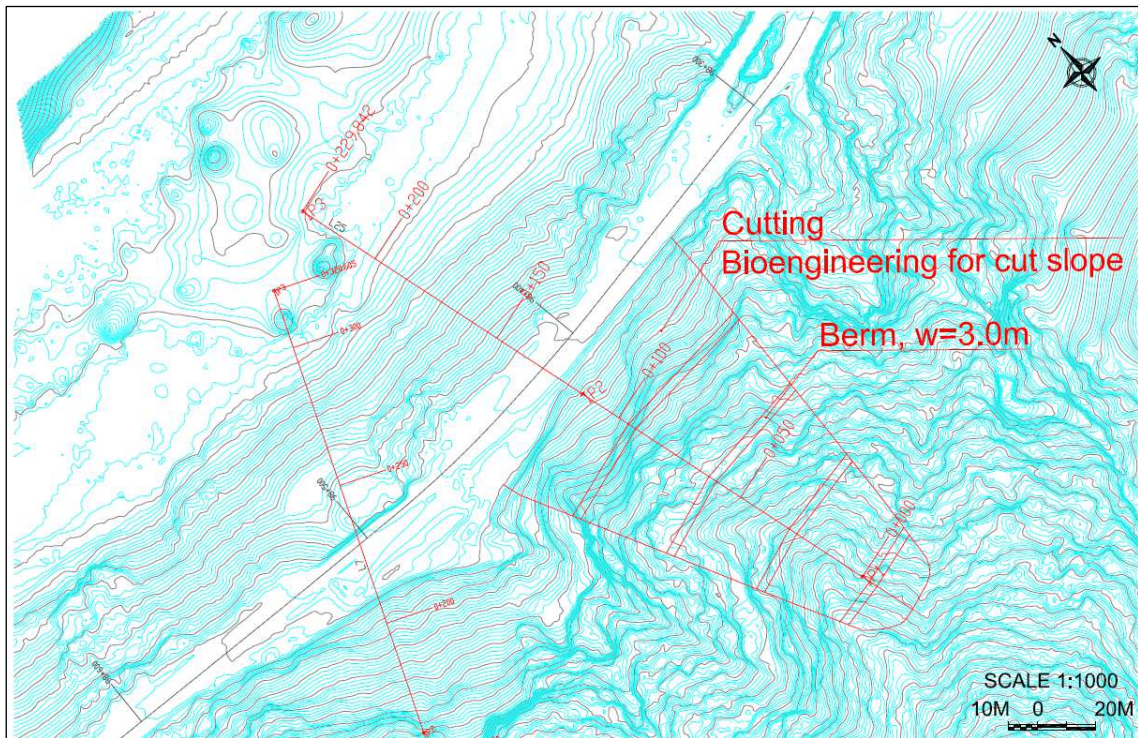
Classification and Soils and Rocks		Cut Slope Height	Gradient (i=V:H)	Cut Slope Angle
Hard rock			1:0.3 to 1:0.8	73° to 51°
Soft rock			1:0.5 to 1:1.2	63° to 39°
Sand	loose, poorly graded		1:1.5 or steeper	33 or bigger
Sandy soil	Dense	Less than 5m	1:0.8 to 1:1.0	51° to 45°
		5 - 10m	1:1.0 to 1:1.2	45° to 39°
	Not dense	Less than 5m	1:1.0 to 1:1.2	45° to 39°
		5 - 10m	1:1.2 to 1:1.5	39° to 33°
Sandy soil mixed with gravel or rock block	Dense, well graded	Less than 10m	1:0.8 to 1:1.0	51° to 45°
		10 - 15m	1:1.0 to 1:1.2	45° to 39°
	Not dense or poorly graded	Less than 10m	1:1.0 to 1:1.2	45° to 39°
		10 - 15m	1:1.2 to 1:1.5	39° to 33°
Cohesive soil		Less than 10m	1:0.8 to 1:1.2	51° to 39°
Clayey soil mixed with rock or cobble stones		Less than 5 m	1:1.0 to 1:1.2	45° to 39°
		5 - 10 m	1:1.2 to 1:1.5	39° to 33°

Source: Modified by JICA Survey Team from Manual for Slope Protection, Japan Road Association, 2009. This table is referenced in the DOR 2003 Guide to Slope Protection, DOR 2007 Roadside Geotechnical Problems.

The subsurface drain – horizontal drain for Risk Index Ranking 2 (SH03) at NH47 37+500 is intended to first stop slide movement by lowering the groundwater level and improving slope stability of slide. Abundant springs were observed at site survey, and therefore, horizontal drain is expected to significantly increase the slope stability of slide. After construction of horizontal drain, its effectiveness can be observed and confirmed through monitoring of groundwater level configuration, and thereby, further engineering measures, like cutting at the upper slope of slide, or piling work on the middle slope just above the road, will be considered.

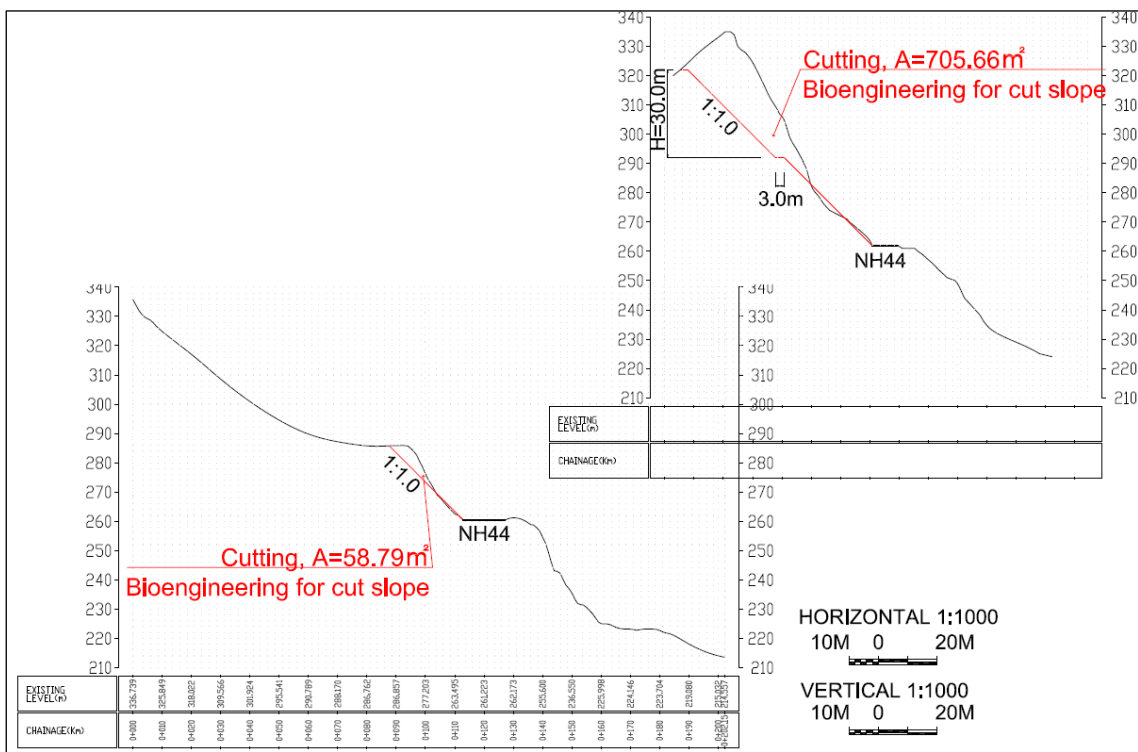
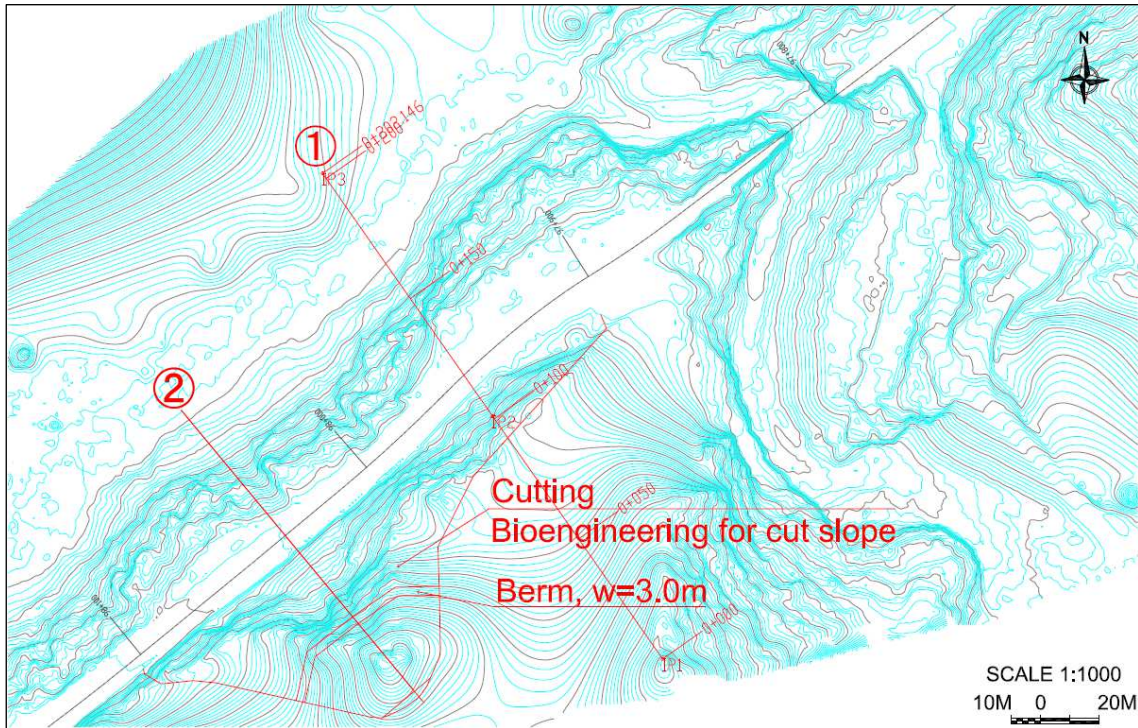
The avoidance – realignment is intended to shift the road into valley side and trap wall will be installed on the existing road to catch collapsed debris. However, maintenance – regular removal of debris behind trap wall may be required.

The general plans and typical sections of the designed engineering measures for each site are shown in **Figure 11-1** to **Figure 11-7**.



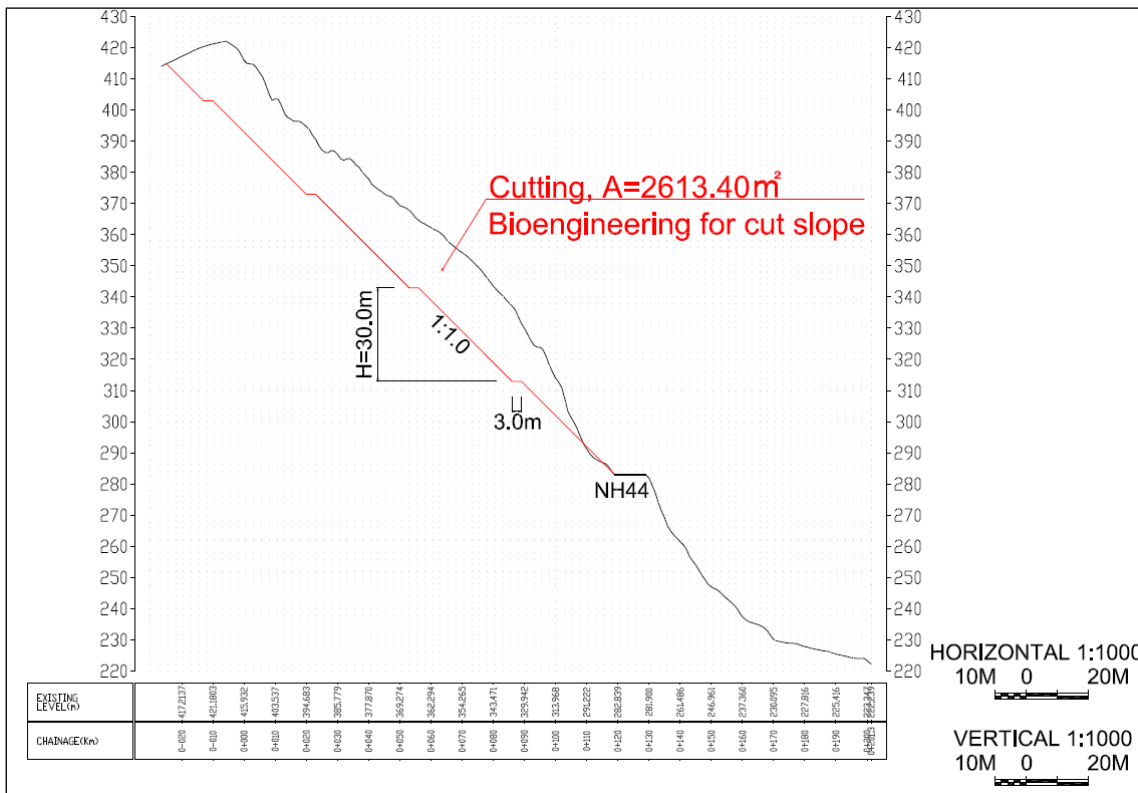
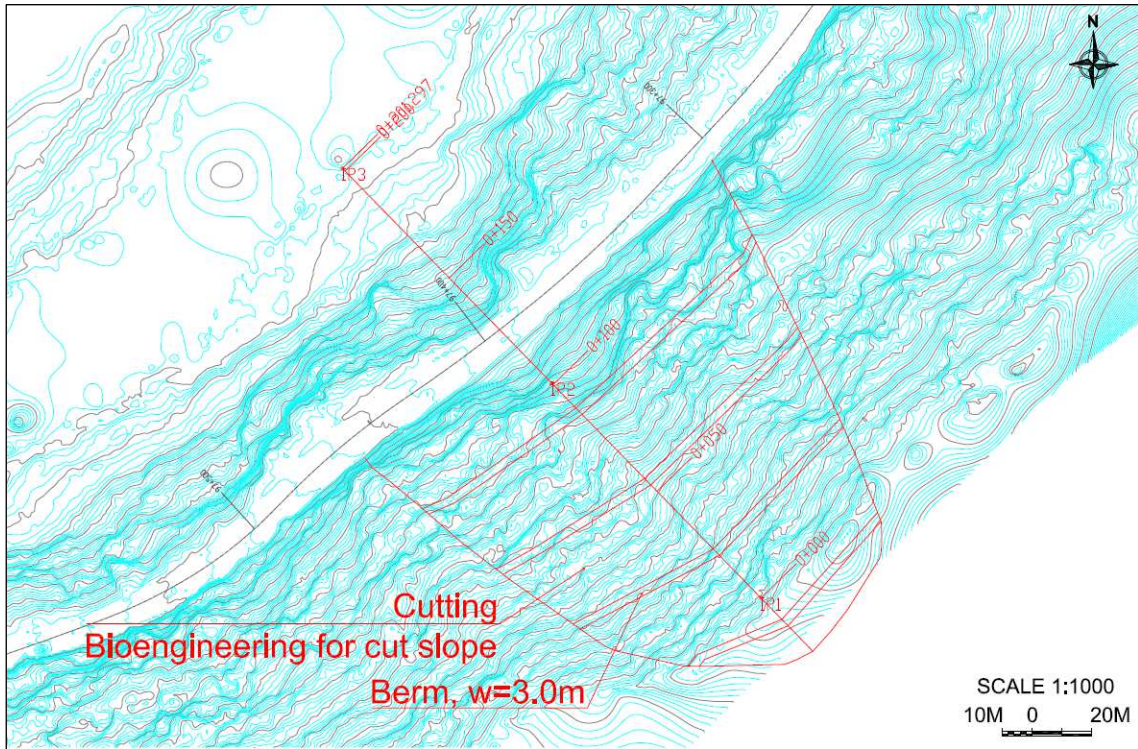
Source: JICA Survey Team

Figure 11-1 General Plan and Typical Section of Engineering Measures for NH44 31+400, Risk Index Ranking 4 (L25)



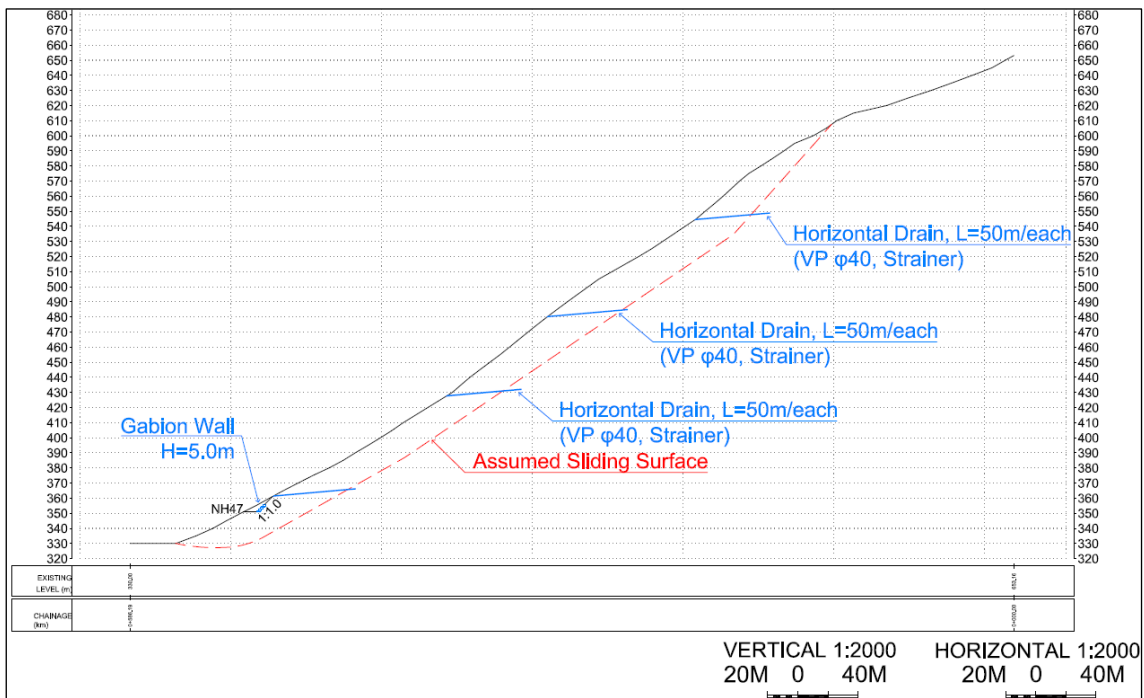
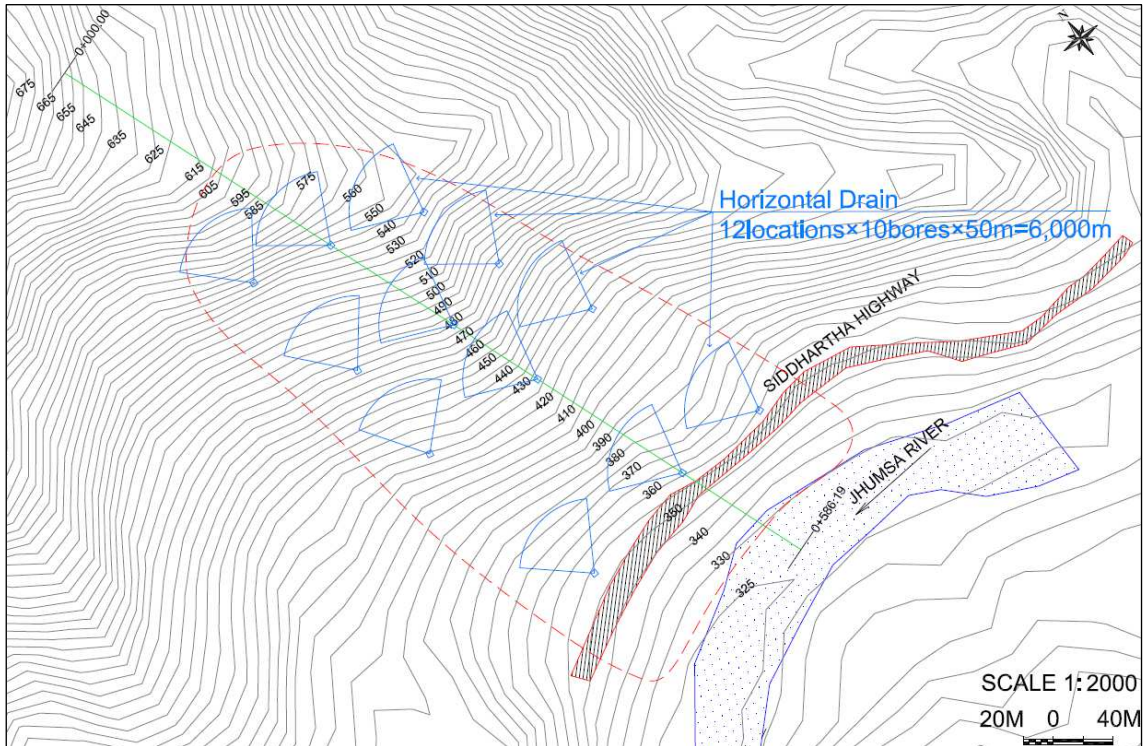
Source: JICA Survey Team

Figure 11-2 General Plan and Typical Section of Engineering Measures for NH44 33+150, Risk Index Ranking 14 (L24)



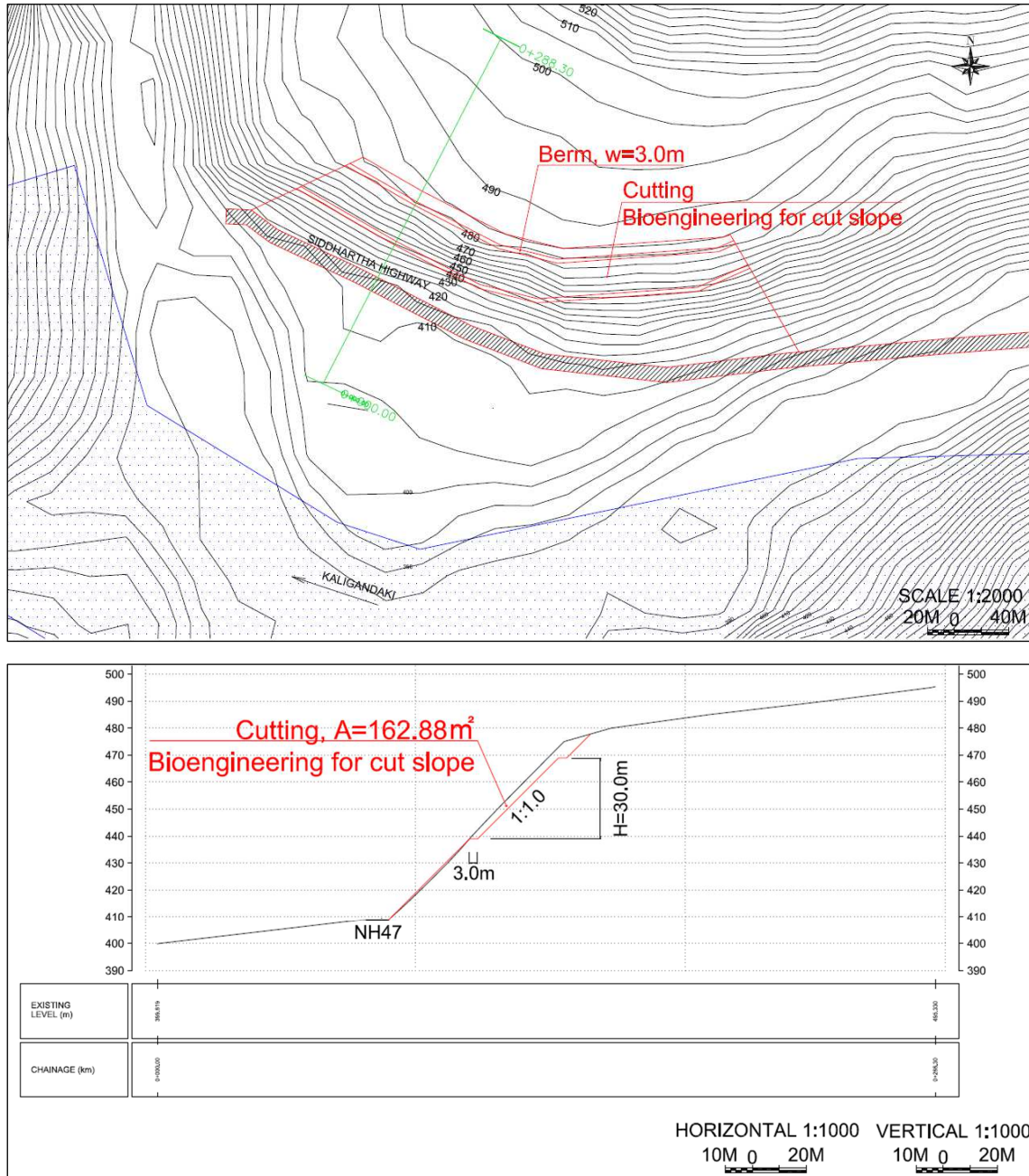
Source: JICA Survey Team

Figure 11-3 General Plan and Typical Section of Engineering Measures for NH44 33+800, Risk Index Ranking 15 (L26)



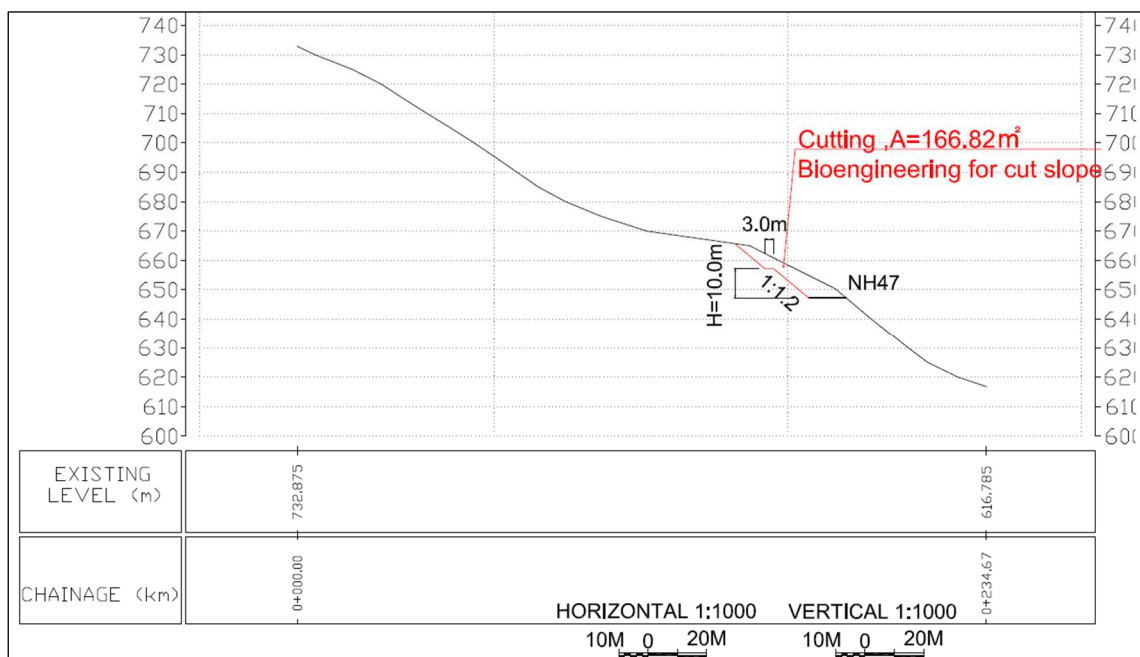
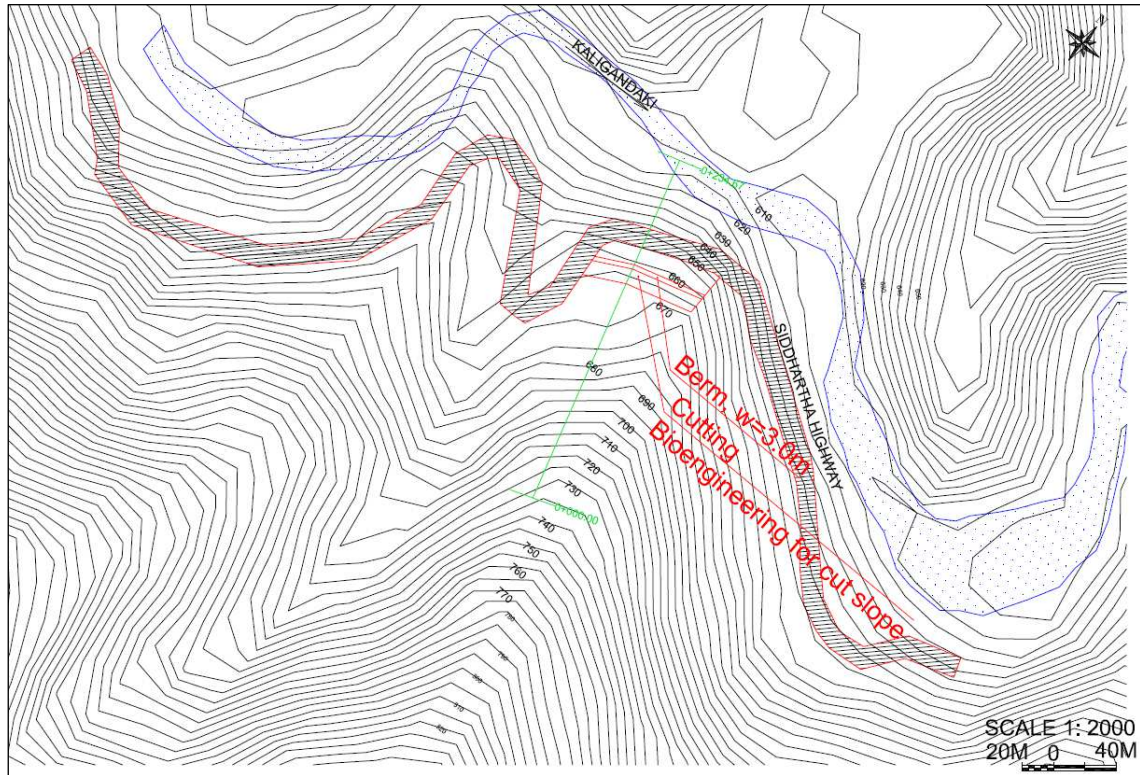
Source: JICA Survey Team

Figure 11-4 General Plan and Typical Section of Engineering Measures for NH47 35+500, Risk Index Ranking 2 (SH03)



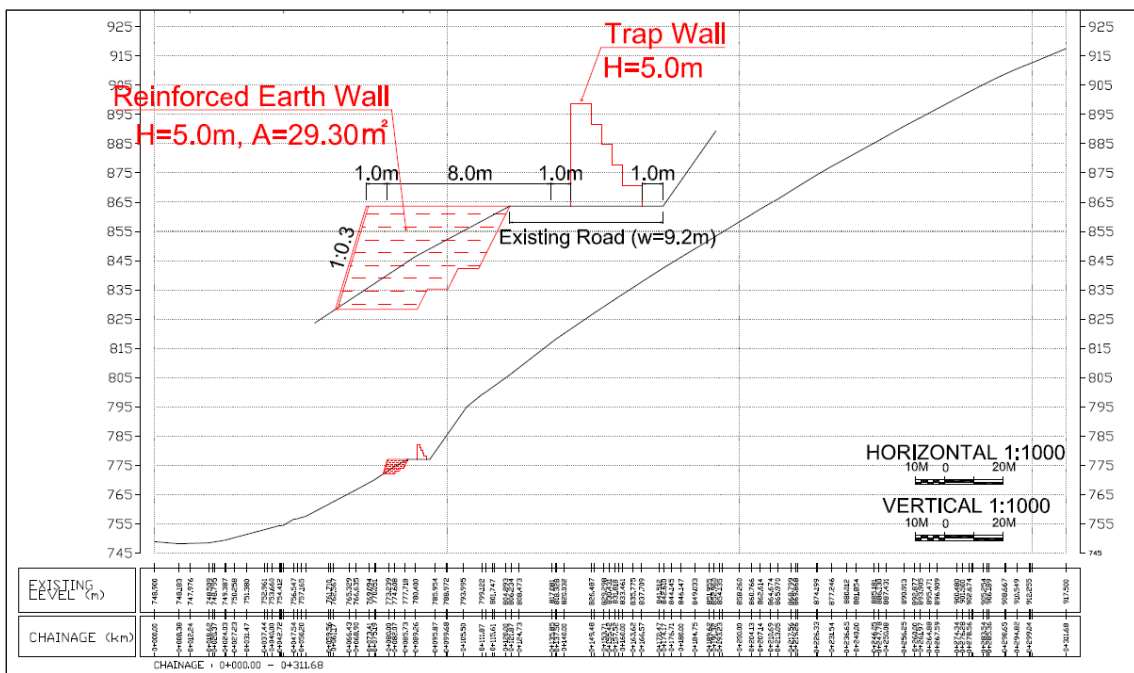
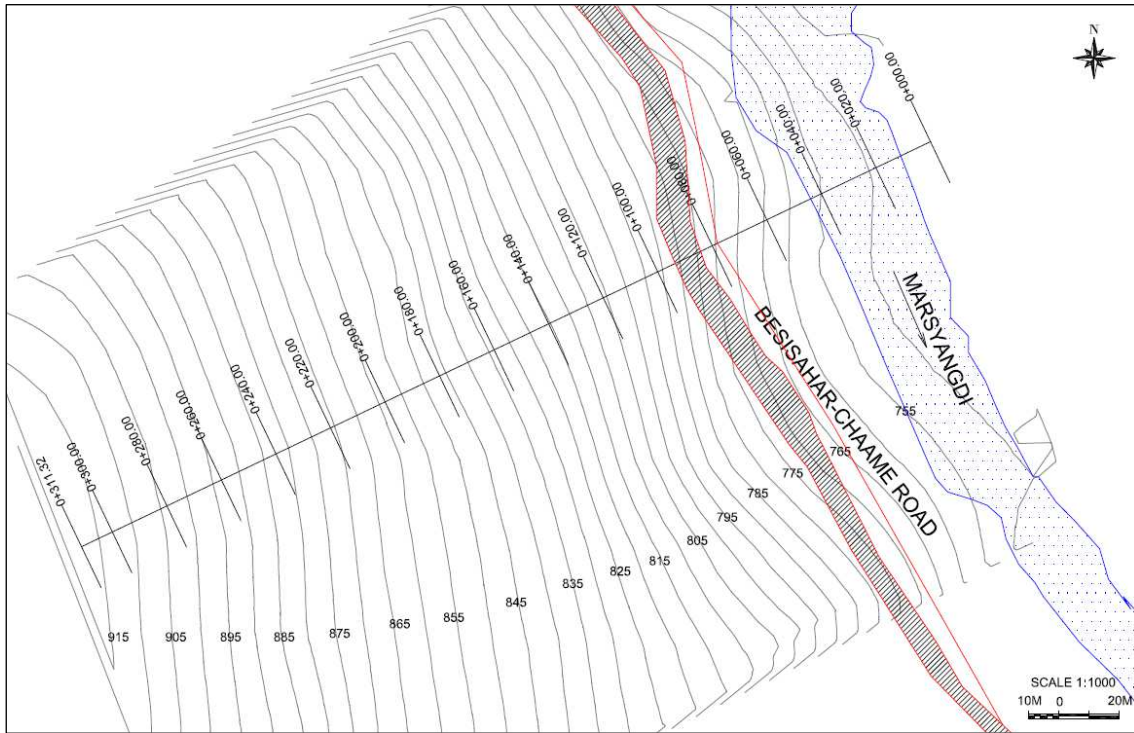
Source: JICA Survey Team

Figure 11-5 General Plan and Typical Section of Engineering Measures for NH47 87+400, Risk Index Ranking 12 (SH18)



Source: JICA Survey Team

Figure 11-6 General Plan and Typical Section of Engineering Measures for NH47 46+400, Risk Index Ranking 29 (SH09)



Source: JICA Survey Team

Figure 11-7 General Plan and Typical Section of Engineering Measures for NH25 45+150, Risk Index Ranking 16 (L21)

(3) Consideration for Construction

These engineering measures mainly include cutting works in areas where landslides are active or where the potential for landslides is high. Accordingly, construction should be avoided during the rainy season, from June to October.

11.1.2. Bridge Works

(1) Target Area of Bridge Works

The sites include bridge work as engineering measures is shown in **Table 11-3**. Risk Index Ranking 1 (L2) 21+500 and Risk Index Ranking 34 (L5) 20+000 on NH44 are two of the sites on the shortlist. Risk Index Ranking 5 (SH06) 39+500 on NH47 was a curved bridge, so the estimated construction cost was high. As a result, the net present value was negative, and it was not selected for the site evaluation shortlist. As the project was considered promising, a design study was conducted to estimate the approximate construction cost. The cost-benefit cost is 0.7, and the internal rate of return is 9%. This report describes this as a promising area where risk reduction investment may be appropriate depending on examining costs and risk reduction benefits.

Table 11-3 Summary of Bridge Planning Sites

Code	Road Section	Chainage	Inventory No.	Site Name
NH44	Narayanghat - Mugling Highway	21+500	L2	Mauri Bridge
		20+000	L5	Gaighat
NH47	Siddhartha Highway	39+500	SH06	Hiyeude Khola

Source: JICA Survey team

(2) Conditions for Design

The proposed bridges involve an alignment shift from the current road to the valley side. The following geometric condition values were applied based on the assumption that the bridge would connect smoothly to the existing road at both the beginning and ending sections.

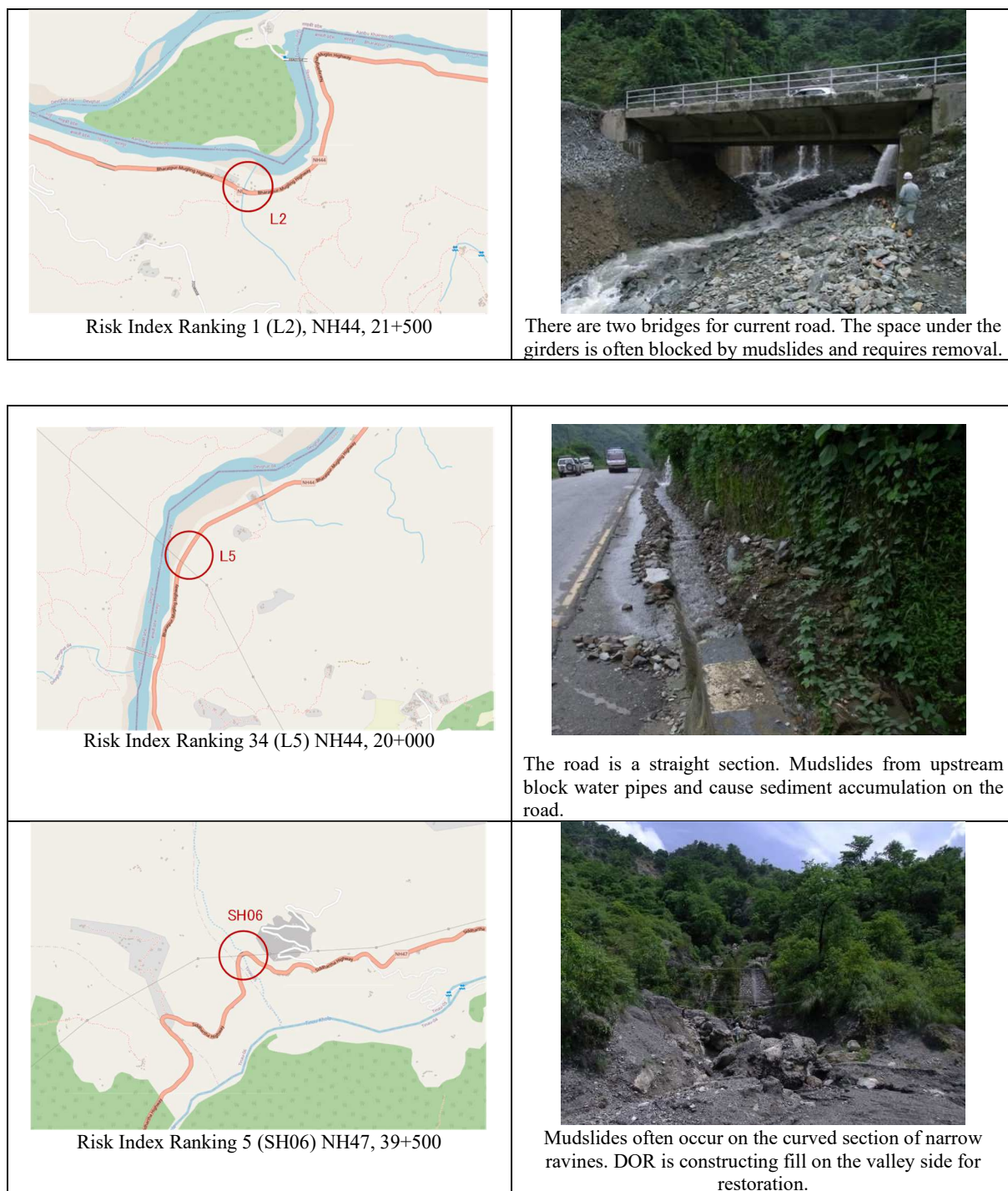
Table 11-4 Geometric Criteria of Alternative Alignment for Bridge

Design Conditions		Nepal Standard	Japan Standard	Applied Value
Design Speed		60km/h	50km/h	60km /h
Minimum Curve Radius		$R \geq 110m$	$R \geq 100m$	100m
Minimum Curve Length		N/A	80m	80 m
Maximum Gradient		$i \leq 7\%$	$i \leq 6\%$	7.0 %
Minimum Vertical Curve Radius	Crest	N/A	800m(1,200m)	800 m
	Sag	N/A	700m(1,000m)	700 m
Minimum Vertical Curve Length		N/A	40m	40m
Road Width				10 m

Source: JICA Survey Team Based on the Standards of Nepal and Japan

(3) Existing Site Conditions

Figure 11-8 shows the three site conditions as of August 2023 at the three sites where bridges are planned.



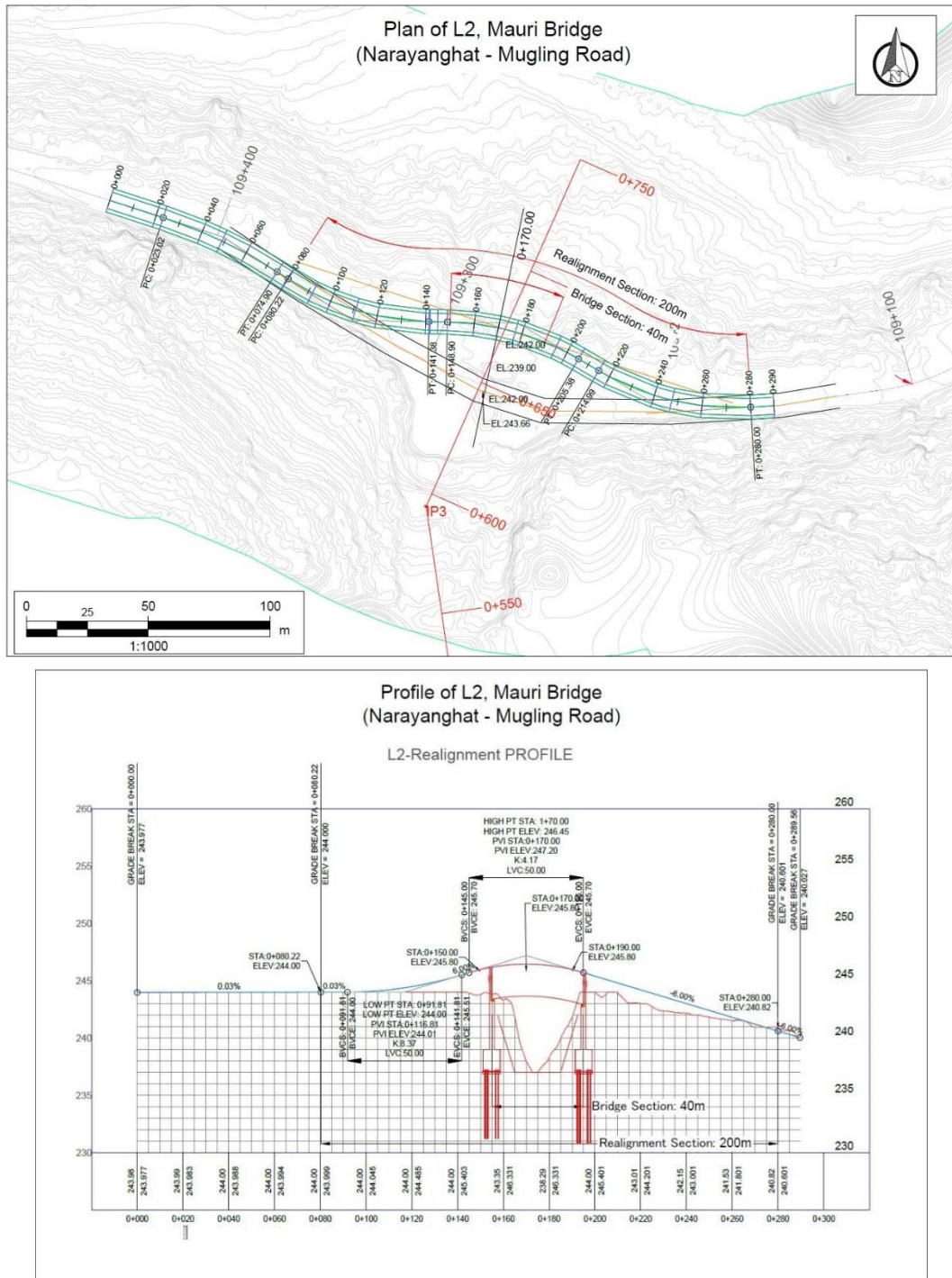
Source: JICA Survey Team

Figure 11-8 Site Situation Around the Bridge Target Area

(4) Consideration of Alternatives

Risk Index Ranking 1, NH44 21+500 (L2)

Debris peak flow is estimated to be about 990 m³/s based on 100-year probability rainfall of design standards of Nepal. And it is evaluated at 1.1 times to account for the effects of climate change. The required span length is 35m and the required riverbed height is 4.8m determined from the discharge and channel height, and the bridge is planned as a 40 m long PC ribbed deck bridge. The road longitudinal alignment is set by adding 2.7m of girder height to the channel height. The length of the road section affected by the change in longitudinal alignment is approximately 200m.

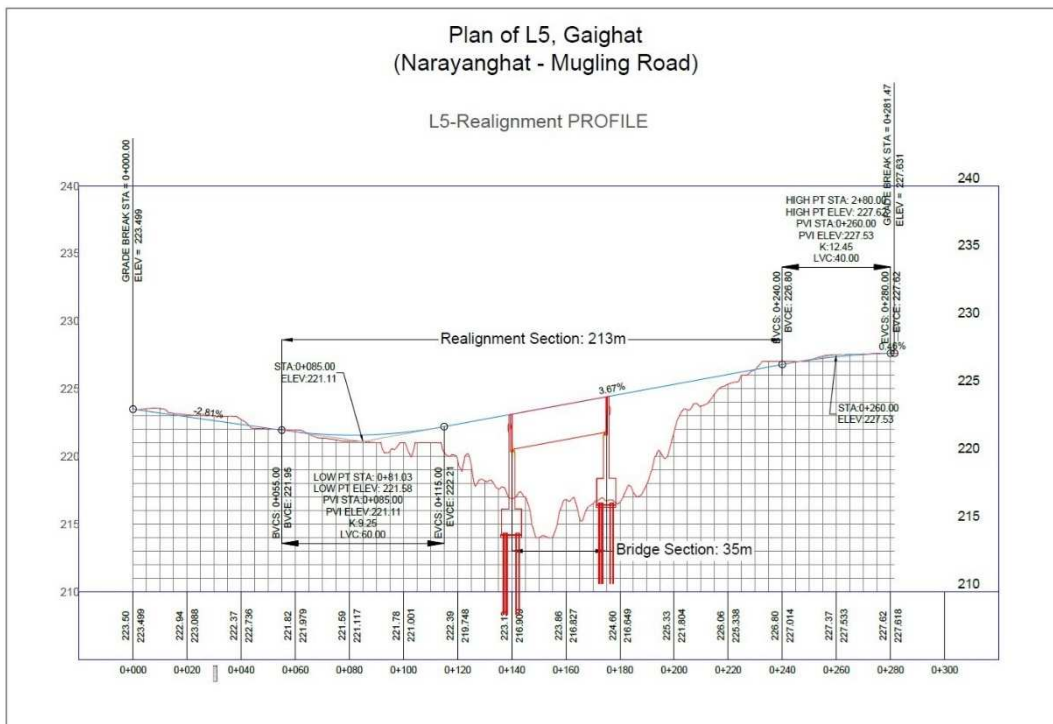
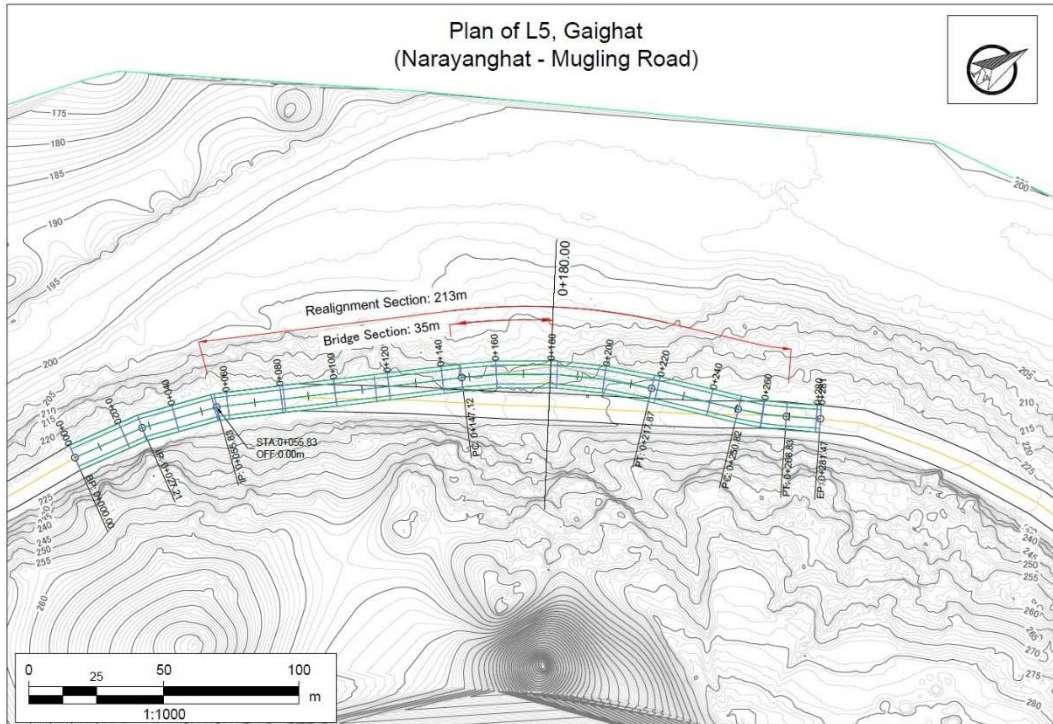


Source: JICA Survey Team

Figure 11-9 General Plan of Engineering Measures for Risk Index Ranking 1, NH44 21+500 (L2)

Risk Index Ranking 34, NH44 20+000 (L5)

Debris peak flow is estimated to be about 60 m³/s based on 100-year probability rainfall of design standards of Nepal. And it is evaluated at 1.1 times to account for the effects of climate change. The required span length is 23m, and the required riverbed height is 1.9 m, determined from the flow rate and channel height, and the bridge is planned as a PC ribbed deck bridge with a bridge length of 35 m and a girder height of 2.4 m. The length of the road section affected by the change in longitudinal alignment is for approximately 213m.

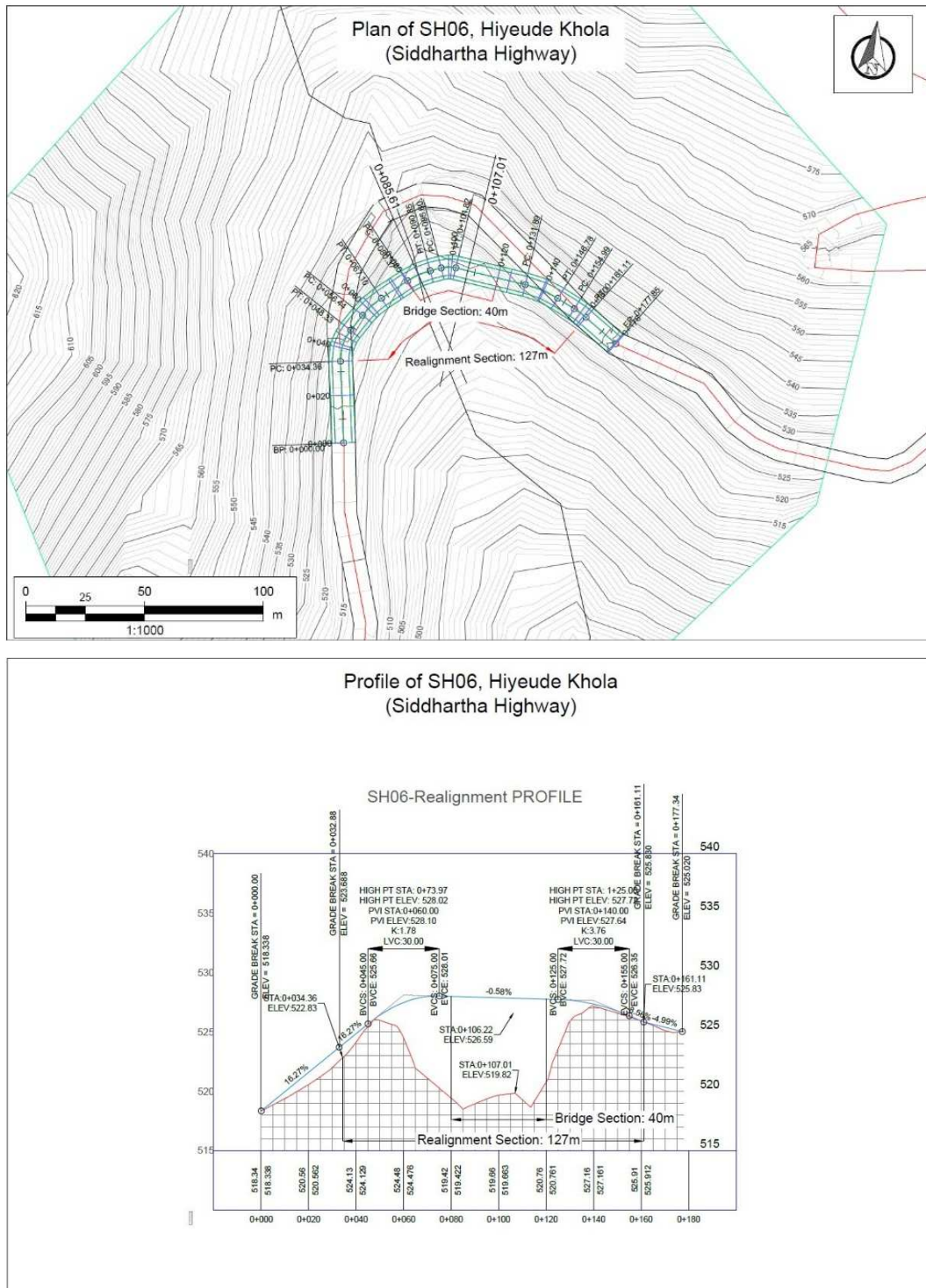


Source: JICA Survey Team

Figure 11-10 General Plan of Engineering Measures for Risk Index Ranking 34, NH44 20+000 (L5)

Risk Index Ranking 5, NH47 39+500 (SH06)

Mudflow peak flow is estimated to be about 900 m³/s based on 100-year probability rainfall of design standards of Nepal. And it is evaluated at 1.1 times to account for the effects of climate change. The required span length is 40m and the required riverbed height is 4.0 m determined from the flow rate and channel height, and the bridge is planned as a curved PC box girder bridge with a bridge length of 45 m and a girder height of 2.7 m. The length of the road section affected by the change in plane and longitudinal alignment is for approximately 127m.



Source: JICA Survey Team

Figure 11-11 General Plan of Engineering Measures for Risk Index Ranking 5, NH47 39+500 (SH06)

11.2. Environmental and Social Consideration

11.2.1. Purpose and Methodology of Analysis

This section Summary background and identifies critical issues relevant to environmental and social considerations for the planning and implementation of JICA assistance projects for landslide engineering measures.

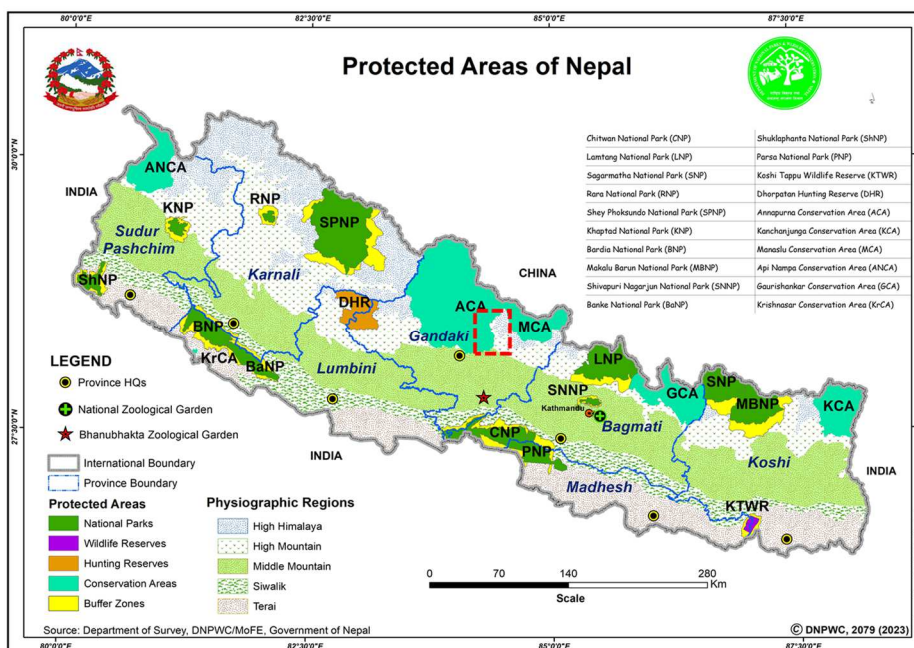
The analysis is done based on the information obtained through the review of the prior studies of the related fields and similar projects, interviews with the government agencies in charge, and the quick review of possible environmental and social impacts of the project on the areas around the longlisted sites. The observation is to assess the possible impact of the project and identify the sites with factors which indicate the possible necessity of further studies according to the JICA Environmental and Social Consideration Guideline. Upon the decision of the project sites and the decision on possible methods of landslide engineering measures thorough analysis on the environmental and social consideration of each site is required.

11.2.2. Background and Conditions of the Studied Sites

The general conditions of the sites on the longlist based on sites-based analysis and other DOR requested sites are reviewed to estimate the required procedures for environmental and social consideration. The following points are reviewed; land use and natural conditions, the existing houses and buildings, cultivated areas and other facilities of economic activities, other buildings and objects in the proximity and other factors which may require the attention. The review is based on the observation of satellite imagery and partial site visits by the JICA Survey Team and the sub-contractor.

Most studies sites are forest and the areas along rivers. Some areas are in proximity to villages with houses, other buildings, and cultivated areas. As for forests, the required procedures may be different depending on the site and the width of the areas for cutting trees. Upon the confirmation of the sites and the technical methods to be applied to each site, the estimate amount of the necessity of tree cutting and the status of the site in the Forest Act should be confirmed to decide the necessity of the procedures for environmental consideration.

As explained later in the chapter, the laws and regulations as well as the relevant guidelines of Nepal do not categorize the projects for slope engineering measures as those with requirements of environmental consideration procedures. However, in case the project site is in the conservation areas, the project shall be required the Environmental Impact Assessment (EIA). The sites of conservation areas are shown in the map below. Two sites on NH25 along the studied sites are in the conservation area: risk index ranking .18, 19 and 31 on the list are in Annapurna Conservation Area (see **Figure 11-3**. The area where these 3 sites are located and shown in **Figure 11-13** is indicated in a red-dotted square).



Source: Department of National Park and Wildlife Conservation, Ministry of Forests and Environment

Note: The area of 3 sites in the long lists located in the Annapurna Conservation Area are indicated in the red dotted square. The same site is shown in **Figure 11-13**.

Figure 11-12 Conservation Areas of Nepal



Source: JICA Survey Team

Note: Three longlisted sites are as shown in the red-dotted circles in the Annapurna Conservation Area (hatched in blue)

Figure 11-13 Annapurna Conservation Area and the Long-Listed Project Sites

11.2.3. Review of the Studied Sites

Table 11-5 below shows the results of the review of the studied sites. All sites are reviewed on the following points namely (i) houses and villages in the neighboring areas, and (ii) existing cultivated areas in the neighboring areas, and (iii) other issues to be noted regarding environmental and social considerations.

Table 11-5 Factors Relevant to Environmental and Social Consideration in the Areas around the studied Sites

NH Code	Long-List Ranking	Site Name	Inventory No.	Type of Geohazard	Conditions of the Surrounding Area Related to the Environmental and Social Consideration
NH44	1	Mauri Bridge	L2	Flow	No house and cultivated areas observed in the neighboring area.
	3	Bhangadi	L3	Collapse	A residential area observed in the neighboring area. Another residential area also observed above the slope.
	4	Namshi Khola	L25	Collapse	The cultivated areas observed on the slope near the site and residential areas below the slope.
	6	Nyanse River	L7	Collapse	A cultivate area observed in the neighboring area. Another cultivated area observed above the slope with geohazard.
	13	—	L6	Carriageway Collapse	A residential and cultivated areas observed above the slope with geohazard.
	14	Kali Khola	L24	Collapse	A residential area observed in the neighboring area. Another residential area below the slope with geohazard.
	15	Tuin khola	L26	Collapse	No residential and cultivated areas observed in the neighboring area.
	17	Tuin Khola	L23	Collapse	No residential and cultivated areas observed in the neighboring area.
	23	Dobhan (Seti & Trisuli)	L1	Collapse	No house and cultivated areas observed in the neighboring area. Buildings and roads observed above the slope with geohazard.
	24	Dasdhunga	L4	Carriageway Collapse	No residential and cultivated areas observed in the neighboring area.
	34	Gaighat	L5	Flow	No residential and cultivated areas observed in the neighboring area.
NH47	2	Jhumsa Idsl	SH03	Collapse	A residential area observed in the neighboring area.
	5	Hiyeude Khola	SH06	Flow	A residential area observed in the neighboring area.
	8	Near Dumre Bazar	SH10	Collapse	A cultivate area observed above the slope with geohazard.
	9	—	SH05	Collapse	No house and cultivated areas observed in the neighboring area.
	10	5km down from Bartung Bazar	SH13	Collapse	Multiple houses observed in the neighboring area. Some type of land use observed above the slope with geohazard.
	11	4.8km down from Bartung Bazar	SH14	Collapse	Multiple houses observed in the neighboring area. Some type of land use observed above the slope with geohazard.
	12	Ramdi -1	SH18	Slide	A residential and cultivated areas observed in the neighboring area.
	28	Near Hiyeude khola	SH07	Collapse	A residential area observed in the neighboring area.
	29	Near Charchare	SH09	Collapse	No residential and cultivated areas observed in the neighboring area.
	30	Lower Dumre	SH12	Collapse	A residential and cultivated areas observed across the street of the slope with geohazard.
NH03	20	Nayapool Flow, Kushma	PB03	Flow	No residential and cultivated areas observed in the neighboring area.
	21	Armadi 1, Kushma	PB04	Collapse	No residential and cultivated areas observed in the neighboring area. A residential and cultivate area observed above the slope with geohazard.

NH Code	Long-List Ranking	Site Name	Inventory No.	Type of Geohazard	Conditions of the Surrounding Area Related to the Environmental and Social Consideration
	22	Damdare khola, Kushuma	PB11	Flow	A residential and cultivated area observed in the neighboring area.
	25	Nayapool 4, Kaski	PB36	Slide	No residential and cultivated areas observed in the neighboring area.
	26	Nayapool 5, Kaski	PB37	Slide	The site is located in the residential and cultivated areas.
	27	Pandung, Kaski	PB38	Slide	A cultivated area observed in the neighboring area.
	32	Saharshadhara 2, Kushhuma	PB02	Collapse	A residential area observed in the neighboring area.
	33	Paradi Slide, Kushma	PB21	Collapse	Buildings observed in the neighboring area of the slope with geohazard.
	179	Khotang	HK#5	Collapse	No residential and cultivated areas observed in the neighboring area.
	182	—	HK# 10	Collapse	No residential and cultivated areas observed in the neighboring area.
	183	—	HK# 13	Collapse	No residential and cultivated areas observed in the neighboring area.
	201		HK#15a	Collapse	No residential and cultivated areas observed in the neighboring area.
NH25	16	—	L21	Collapse	No residential and cultivated areas observed in the neighboring area.
	18	—	L12	Collapse	Located in the conservation area: EIA is mandatory. No residential and cultivated areas observed in the neighboring area.
	19	—	L20	Collapse	Located in the conservation area: EIA is mandatory. No residential and cultivated areas observed in the neighboring area.
	31	—	L19	Collapse	Located in the conservation area: EIA is mandatory. No residential and cultivated areas observed in the neighboring area.
NH37	62	—	K5	Collapse	No residential and cultivated areas observed in the neighboring area.
	63	—	K7	Slide	No residential and cultivated areas observed in the neighboring area.
	68	—	K9	Slide	No residential and cultivated areas observed in the neighboring area.
	73	—	K8		Residential and cultivated areas observed in the neighboring area.
	84	—	K3		Residential and cultivated areas observed in the neighboring area.
	85	—	K4		Residential and cultivated areas observed in the neighboring area.
	119	—	K6		Residential and cultivated areas observed in the neighboring area.

Source: JICA Survey Team

Note: Yellow-hatched sites are observed as requiring attentions regarding environmental and social consideration depending on the protection methods and size of the construction works. Two sites located in Annapurna Conservation Area are bolded.

11.2.4. Institutional and Legal Framework of Environmental and Social Consideration Policies and Laws and Regulations of Nepal

(1) Environmental Protection Act 2076 (2019), Environmental Protection Rules 2077 (2020)

Environmental Protection Act 2076 (2019 A.D) (EPA2019) was originally enacted in 1997 and revised in 2019. The Environmental Protection Rules 2077 (2020), (EPR 2020) are the regulations for implementing the EPA 2019, which were also revised in 2020 in line with the stipulations of EPA 2019. The revised EPA in 2019 introduced the Brief Environmental Study (BES) as the more simplified

process than the Initial Environmental Examination (IEE). EPR was also revised in 2022 and necessary rules on the implementation of BES was added.

Slope protection projects are not listed in the categories mandated for environmental consideration processes in EPR2020. However, the process is required if it is implemented in the following conditions, namely (i) if the project uses more than certain width of the land in the forests, forest reserves, and Environmental Conservation Area, or (ii) if the project is to be implemented in the wildlife reserves. The criteria of environmental consideration processes are as shown in **Table 11-6**.

Table 11-6 Criteria and the Required Environmental Consideration Processes

	Criteria	Reference in EPR2020
BES	Use up to 1 ha of land in forest, forest conservation area, Environmental Protection Area, and the buffer zones for other use.	Annex 1
IEE	Use more than 1 ha up to 5 ha of land in forest, forest conservation area, Environmental Protection Area, and the buffer zones for other use.	Annex 2
EIA	Use more than 5 ha of land in forest, forest conservation area, Environmental Protection Area, and the buffer zones for other use. Implemented in the National Parks, Wildlife Reserves, and Hunting Reserve Areas.	Annex 3

Source: JICA Survey Team Based on EPR2020

Note: Environmental Conservation Area is mentioned in EPR, but there has not been designated according to DOR.

In case the project needs to cut down trees outside of RoW, it is required to take necessary measures stated in the Forests Act.

It should be noted that EPA were under the process of another amendment to change the approving entity for EIA to the Department of Environment at the time of the Survey²⁵.

(2) Public Road Act 2031(1974)

The Public Road Act 2031(1974) includes various provisions related to the slope protection projects. Section 3 of the act prohibits the construction of permanent structures within the distance prescribed therein for different roads. The act empowers GON to acquire the lands or other property for public roads after compensating the owners of the land or property (Section 4). The act also stipulates that DOR has the power of acquiring land temporarily for the purposes such as establishing construction material depots, supervisors' offices and residence, and detour routes with the compensation following the designated procedures (Section 14 and 15). The act obliges DOR to plant trees along both sides of the road (Section 16). The act also endorses DOR's power of acquiring quarries and borrowing pits and other facilities during the construction with reasonable compensation (Section 17). Section 27 also provides the authority of DOR to decide the amount of compensation. The section also has the provision on the petition against the decided compensation in case of disagreement.

(3) Forest Act 2076 (2019)

Forest Act 2076(2019) provides regulatory framework on management and utilization of forest in the country comprising Government managed forests, forest conservation areas, community forest, leased forest, and religious forest and the protection of natural resources, both flora and fauna, in these forests. In case there are no alternative areas, the act allows the implementation of national priority projects in forest area by applying the methods with limited impacts on the environment. In such case, tree planting is instructed to the extent possible in the area near the project adjoining to the national forest and the same geographical and ecological belt with the project site (Section 42).

²⁵ Based on the interview with GESU.

(4) National Parks and Wildlife Conservation Act 2029 (1973)

National Parks and Wildlife Conservation Act 2029 (1973) provides the rules on conservation areas such as national parks and wildlife conservation areas, protection, and handlings of wildlife and so on. The conservation areas defined and regulated by the act are shown in **Table 11-7**.

Table 11-7 Definition of the Conservation Areas in Nepal

Conservation Area	Definition
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 for allowing hunters to hunt them
Conservation Area	An area to be managed according to an integrated plan for the conservation of natural environment and balanced utilization of natural resources

Source: National Parks and Wildlife Conservation Act 2029 (1973)

The act has the provisions on national parks, conservation areas and the buffer zones located in the fringe areas of conservation areas which allows the use by communities etc. The areas and boundary of the conservation areas and buffer zones are notified by the Nepal Gazette. The Schedule 1 of the act also provide the list of the mammal, reptile, and bird species which need to be preserved.

(5) Land Acquisition Act 2034 (1977)

Land Acquisition Act 2034(1977) provides the procedures on land acquisition and compensation for public works. The act stipulates the compensation to be done in cash basis in principle and the amount shall be decided by the Compensation Fixation Committee (Section 13). In case a whole land of a person is acquired, the person may be entitled to claim the compensation for the land (Section 14).

(6) Environmental and Social Considerations of the Road Sector and the Relevant Laws and Regulations

“Environmental Assessment in the Road Sector of Nepal” developed in 2000 by DOR comprises basic explanation, ways to apply EIA matched with the nature of the road sector projects, actual procedures, issues to be fulfilled, and checklists. Moreover, as explained in the later part, the Environmental and Social Management Framework (ESMF) was developed in 2007. ESMF compiled the procedures on environmental and social consideration for the road sector projects. The first edition was published in 2007 with the support of the WB. ESMF encompasses the rules and instructions in order to fulfill the requirement of the project financed by international financial institutions such as the WB and ADB by supplementing the provisions in the domestic laws and regulations. The contents include basic matters and premises of environmental and social considerations, comparison and the gap analysis between domestic laws and regulations and donors’ policies, procedures on reviews and studies (screening, IEE, EIA, Social Impact Assessment (SIA), land acquisition and resettlement action plan (RAP)), evaluation, alternatives, and the process and procedures for monitoring. The latest version of EMSF at the time of this Survey was the revised edition in 2013: DOR was revising the contents in accordance with EPA2019/EPR2020.

11.2.5. Comparison between JICA Guidelines for Environmental and Social Considerations and Nepal’s Domestic Laws and Institutions

This Survey assumes that the slope protection projects reviewed under the Survey should pursue the implementation with the support of JICA where the JICA Guidelines for Environmental and Social Considerations (January 2022, hereinafter referred to as “the JICA Guidelines”) are to be applied.

The Guidelines sets out the basic principles as below:

While project proponents bear the ultimate responsibility for the environmental and social considerations of project, JICA supports and reviews appropriate environmental and social considerations undertaken by the project proponents. This is to avoid or to minimize impacts on the environment and local communities caused by development projects, and to prevent the occurrence of unacceptable adverse impacts. JICA thus promote sustainable development in developing countries.

(1) Environmental and social considerations

Table 11-8 shows the results of the review of the JICA Guidelines and the laws and regulations of Nepal on differences and gaps of basic principles and procedures regarding environmental and social consideration. No major differences and gaps were observed. However, EPA and ESMF are in the process of revising at the time of this Survey as mentioned in the previous section. Therefore, the thorough review of the updated situation of the laws and regulations of Nepal should be done upon the confirmation of the details of the projects in the future.

Table 11-8 Comparison between the JICA Guidelines and Laws and Regulations of Nepal on Environmental and Social Considerations

Item	JICA Guidelines	Laws and Regulations of Nepal	Gaps & Items for measuring
Sectors for review and categorization	The sensitive sectors, characteristics and areas are listed in Appendix 3. The sectors listed are those fallen under Category A or B. Category A projects are required the submission of EIA report, while Category B projects are required the survey based on the narrower scope and areas based on the information provided by the government of the proponent country (IEE level). The sensitive sectors listed in Appendix 3 includes “(8) Road, railways and bridges”. Sensitive characteristics includes (1) Large-scale involuntary resettlement, (4) Large-scale logging. Sensitive areas include (1) National parks and nationally designated protected areas.	Slope protection projects are not mandated to undertake procedures of environmental considerations. However, the projects implemented in conservation areas require BES, IEE or EIA as per instructed in EPR2020.	The required measures are the same in documents of both sides. It is necessary to conduct analysis again upon the decision on the project sites with clearer plans on engineering measures for slope stabilization and the size of the construction.
Basic principles	Environmental and social considerations must be implemented from an early stage of the project planning until monitoring stage. Environmental and social considerations is reviewed in accordance with the mitigation hierarchy (avoidance of environmental impact, minimization, reduction, mitigation of impacts and compensation if not avoidable.)	EPA 2019 states that the proposed project shall not be allowed to be implemented unless the environmental study report prescribed by the same law is submitted. EPA 2019 also mandates an environmental management plan (EMP) to be in place prior to the commencement of the project.	No significant gaps. As for mitigation measures, ESMF provides some instruction for the road sector projects comprising avoidance, rectification and abatement, and compensation. If the needs arise, necessary measures should be taken in accordance with the JICA Guidelines.
Impact to be assessed and the scope	Air, water, soil, wastes, accidents, water use, climate change, biodiversity, and	EPR2020 lists the impacts to be reported in IEE as biological impacts on	No major gap is observed. It is necessary to conduct thorough analysis upon the

Item	JICA Guidelines	Laws and Regulations of Nepal	Gaps & Items for measuring
	ecosystem services, including transboundary or global scale impacts. Impacts include environmental and social impacts such as involuntary resettlements, migration of population and local economy.	people and flora and fauna, physical impact such as those on the land, atmosphere, water, noise, and man-made objects and those on human health and social, economic, and cultural spheres. ESMF instructs to include socio-economic impact analysis in an environmental and social consideration report. ESMF also explains the procedures of the analysis.	decision on the project sites with clearer plans on Engineering measures for slope stabilization and the size of the construction . (Note: Reviews regarding involuntary resettlement and gender are to be explained in the next section.)
Information disclosure and accountability	JICA proactively encourage the project proponents to disclose and present information about environmental and social considerations of their projects to local stakeholders.	Rule 7 of EPR2020 explains the information disclosure to local stakeholders, EIA scoping, and other reports.	No major gap is observed.
Participation of stakeholders	In principle, the project proponents take initiatives to consult with local stakeholders to a reasonable extent.	ESMF confirms participation of local stakeholders is an important factor. The proposed procedures encourage communication at the time of IEE and EIA prior to the project.	The JICA Guidelines define the procedures to ensure the meaningful participation of the local stakeholders. If the needs arise, necessary measures should be taken in accordance with the JICA Guidelines.
Monitoring	The Guidelines instruct that "during the project implementation, project proponents monitor whether any unforeseeable situations occur, and the performance and effectiveness of the planned mitigation measures. Project proponents take appropriate measures based on the results of such monitoring." It further instructs the information disclosure of monitoring results to the local stakeholders and the necessity of building consensus on problem resolution in case the third parties point out the insufficiency of environmental and social considerations.	EPA2019 states that the Environmental Inspector or the alternate is mandated to conduct monitoring based on the EIA report. ESMF mentions development of Environmental Management Plan (EMP), monitoring procedures across the project life and monitoring specific to the social considerations.	No major gaps observed. ESMF covers most of the JICA Guidelines requirement. However, as the grievance redress mechanism is not well covered in the existing rules and regulations in Nepal except ESMF covering the issue of resettlement. It may be necessary to take measures in accordance with the principles of JICA Guidelines upon the implementation of the project.
Grievance redress mechanism	The Guidelines states "A mechanism for handling concerns and grievances from people and communities affected by the project's environmental and social impact must be in place".	There is no rules and regulations handling the grievance redress mechanism. ESMF provides instructions on consultation and grievance mechanism in the part of the	ESMF fulfills the requirements for resettlement. It is still necessary to request setting up the necessary mechanism to cover other areas in accordance with

Item	JICA Guidelines	Laws and Regulations of Nepal	Gaps & Items for measuring
		resettlement policy framework.	the principles of JICA Guidelines upon the implementation of the project.

Source: JICA Survey Team Based on the JICA Guidelines for Environmental and Social Considerations (January 2022) and Relevant Laws and Regulations of Nepal.

(2) Land Acquisition and Resettlement

Table 11-9 shows the results on the review of the JICA Guidelines and the laws and regulations of Nepal on differences and gaps of basic principles and procedures regarding land acquisition and resettlement. The Environmental and Social Standards 5 (ESS5) of the WB were also reviewed as the JICA Guidelines also refer to the ESS5 on the issue of land acquisition and resettlement. The major points are observed to be covered by ESMF. However, the revised ESMF shall be reviewed and checked upon the decision of project implementation.

Table 11-9 Comparison between the JICA Guidelines and Laws and Regulations of Nepal on Land Acquisition and Resettlement

Item	JICA Guidelines	Laws and Regulations of Nepal	Gaps & Items for measuring
Basic principle	The Guidelines mentions the necessity of taking effective measures to minimize impacts and to compensate for losses upon agreement with the affected people in case of unavoidable involuntary resettlement and loss of means of livelihood.	ESMF has the similar principle.	No major gaps observed in ESMF
Eligibility of compensation and measures	The Guidelines states that “Project affected people, such as people to be resettled involuntarily and/or people who may lose their livelihoods by the project, must be provided sufficient compensations and supports by the project proponents in a timely manner”. The Guidelines further defines that compensation should be at least for restoring the living standards, income opportunities and production levels to the pre-project levels. It also states that the measures may include providing land or monetary compensations for losses of land or assets, supporting for alternative sustainable livelihoods, supporting for expenses necessary for relocations and supporting for re-establishment of communities at resettlement sites.	ESMF endorses the rights of project affected people to receive various compensation to restore their level of livelihood to the pre-project time.	ESMF encompasses the measures to match with the requirements by development partners’ policy such as the policy of the WB after the gap analysis of the domestic rules and regulations.
Compensation standards	The Guidelines states that compensation standards should be disclosed and consistently	ESMF explains that the project affected persons are eligible for various	No major gap observed, but the pre-decided compensation may

	applied. The Guideline also provides the following principles namely: the project affected persons need to be aware of the standards; the compensation contents should be agreed and explained in writing; and the contents should be also available for confirmation by the projected affected persons anytime.	compensations to recover their livelihood to the level before the project implementation.	require some adjustment based on the actual situation.
Resettlement Action Plan (RAP)	A resettlement action plan shall be developed in advance in case of large-scale involuntary resettlement is unavoidable.	ESMF covers preparation of RAP.	ESMF fulfills requirements.
Participation of the project affected people and community	“Appropriate participation of project affected people and their communities must be promoted in planning, implementation, and monitoring of measures against involuntary resettlement and loss of livelihood”.	ESMF includes the parts explaining the approaches and measures to ensure the participation of the project affected people, community and local stakeholders.	ESMF fulfills requirements.
Confirmation of affected population	In order to confirm the number of project affected persons, land and assets in advance, World Bank, ESS5 maintains the necessity of the early stage baseline surveys including population census, land and asset inventory surveys, and socio-economic analysis of the project implemented areas. ESS5 also states that the information on the cut-off date shall be well documented and will be disseminated through the project areas.	ESMF set the cut-off date as the time of the population census.	No significant issues to be noted, but it is necessary to check the previous examples for confirmation.
Support in the transition period between displacement and livelihood restoration	The needs of support during the transition period are mentioned.	No rules and regulations in Nepal handle this matter.	When needs arise, examining and taking necessary measures may be requested.
Considerations on vulnerable social groups	Need of particular attention on vulnerable social groups are stressed. Vulnerable social group includes women, children, elderly people, people in poverty, indigenous people, persons with disabilities, refugees, internally displaced persons, and minorities.	ESMF clarifies the entitled rights including vulnerable groups.	ESMF fulfills the requirements.

Source: JICA Survey Team

11.2.6. Relevant Organizations to Environmental and Social Consideration of the Road Sector

(1) Ministry of Physical Infrastructure and Transport (MOPIT)

MOPIT is the higher authority of the project implementation organization such as DOR. It carries the responsibility of compliance with the laws and regulations in the areas of environmental and social considerations and approves BES and IEE.

(2) Department of Roads (DOR)

DOR is the organization which can be an implementing organization of the projects for slope protection reviewed under this Survey. It is responsible for confirmation on the issues on environmental and social considerations, conducting the surveys, developing reports, and obtaining approvals.

(3) Geo-Environment and Social Unit (GESU)

The unit supervises the surveys and procedures for environmental and social considerations in DOR for the implementation of Strategic Road Network (SRN) program. The tasks carried out by GESU are as listed below:

- Develop of guidelines for internal use in DOR
- Participate in the screening for the project for which DOR is to be the proponent.
- Develop IEE and EIA reports
- Review F/S reports regarding the alternative and mitigation measures, and adoption of technologies with environmental considerations. Compile the review results.

GESU is also in charge of developing EMAPs, RAPs, conducting monitoring activities, collaboration with other organizations, and environmental and social audit after project completion.

(4) Ministry of Forest and Environment (MOFE)

MOFE is in charge of implementation and enforcement of the law and regulations for environmental protection by EPA/EPR which endorse the power and authority of MOFE for policy formulation, implementation and approval of environmental considerations studies and procedures. The following tasks are performed by MOFE:

- Approve EIA scoping, TOR, and the report
- Confirm the implementation of EMP
- Conduct environmental and social audit after the project implementation

(5) Department of Forest and Soil Conservation

The Department of Forest and Soil Conservation is one of the departments under MOFE. In case there is a need of cutting trees or the project with the certain size is to be implemented in a forest area, it is necessary to consult with the department. Tree cutting is obliged to acquire a prior permission from the department.

Chapter 12. Proposed Equipment List and Procurement Process for Elimination of Road Obstacles after Geohazards Events/Construction

12.1. Equipment Provision Record from Japan in Recent Year

After the flooding caused by heavy rains in August 2017, the Japanese Government provided geohazard risk reduction and recovery equipment manufactured in Japan to Nepal under the Economic and Social Development Program, a grant aid of 700 million yen. The equipment provided was as follows.

- Soil Compactor: 5 units
- Asphalt roller: 4 units
- Static pneumatic tired roller: 4 units
- Vibration roller: 5 units

12.2. Procurement of Equipment

Major construction equipment is not manufactured in Nepal and imported from abroad. The sources of imports depend on the type of equipment, but India and China are the most common. Some of the equipment is procured from South Korea and Japan. Major brands and distributors of heavy equipment in Nepal are listed in the **Table 12-1**.

Table 12-1 Main Manufactures and Distributor of Construction Equipment

Manufactures of Equipment	Distributor	Site
JCB	MAW Earthmovers Pvt. Ltd	Lalitpur
Komatsu	Continental Traders Pvt. Ltd	Kathmandu
Hyundai	Construction Solutions Pvt, Ltd	Kathmandu
Doosan	Infrastructure leasing Services	Kathmandu
Kobelco	Pooja Construction Pvt. Ltd	Kathmandu
XCMG	United Heavy Equipment and Earthmovers Pvt. Ltd	Kathmandu
Volvo	Explore Earthmovers Pvt. Ltd	Lalitpur

Source: Mechanical Branch of DOR

As most construction equipment is not manufactured in Nepal and imported from abroad, it is expected to be procured from India or Japan. In case of transportation from Japan, the shipment by RORO or containers can be arranged through the container company of Inland Depot in Birgunj, Nepal, and transported by sea from Japan to Kolkata Port in India. Cargo is transported by trailer truck from Kolkata port to Kathmandu. Cargo that can fit into containers can be transported by railway to Birgunj and then by trailer to Kathmandu. Cargo from India is transported by trailer truck.

12.3. Required Time for Procurement and Shipment

In case of shipment from Japan, it estimated to take 20 to 40 days for the consignment to arrive at Kolkata port and further 5 days to Kathmandu by road except the time for custom clearance and administrative process at the border point.

12.4. List of Equipment Required by DOR

Based on interviews with HED of DOR in August 2023, the need for heavy equipment was confirmed. **Table 12-2** summarizes the approximate costs and procurement conditions for the candidate equipment based on interviews with Japanese trading companies and manufacturers.

Table 12-2 List of Equipment Required by DOR

No.	Equipment
1	Backhoe Loader
2	Wheel Loader
3	Mini Excavator
4	Transport Truck
5	Motor Grader
6	Soil Compactor

Source: JICA Survey Team

12.5. Maintenance Support of Equipment

Due to the increased demand for mobilization of heavy equipment related to increased geohazards events, priority is to maintain the heavy equipment to effectively utilized over the long term. Further strengthening of human resources and technology related to equipment maintenance is required. DOR have a training center for heavy equipment that provides training for its technical staff, and they have a certain level of maintenance skills. However, support and technical assistance by manufacturers for specific equipment maintenance is considered more effective.

In the interviews with Japanese manufacturers, it is confirmed that, in addition to the provision of equipment, there are also examples of provision of training component for maintenance by local agents to staff in the opportunity of equipment provision. In addition, after-sales services such as repair support for equipment by experienced and qualified personnel and quality guarantees for 1,000 hours of equipment parts are also considered effective.

Chapter 13. Workshops for Awareness Building of Road Landslide Risk Reduction

The workshops were held with the participants from DOR and other relevant stakeholders in order to share the progress and the results of the Survey and to raise the understanding of the stakeholders on pre-disaster investment, Build Back Better, and the necessity of landslide risk reduction. The outlines of three workshops are as summarized as below. The details of the presentation and discussion are as recorded in the reports in Annex.

13.1. First Workshop

The outline and the contents of the First Workshop is as summarized in **Table 13-1**. After the presentations of JICA Survey Team and DOR, questions and answers session and discussion were held. Some questions and opinions raised by the participants are also listed in the table below.

Table 13-1 Outline of the First Workshop

Date and Time	9 June 2023 13:00-16:30
Venue	DOR Conference Room
Participants	<ul style="list-style-type: none"> · Relevant officials from DOR, DWRI, MOPIT, RBN · Officials of JICA HQs and the Nepal Office · JICA Survey Team members (Total: 45 participants)
Program	After the presentations listed below, the discussion was held on landslide Engineering measures, the process of the Survey and other issues. <ul style="list-style-type: none"> · Presentation: Road landslide risks in Nepal · Pre-disaster investment and Build Back Better · Sharing the experience of road landslide risk reduction through the case of the construction of Sindhuli Road
Questions and Answers Opinions	<ul style="list-style-type: none"> · A participant asked JICA Survey Team how to incorporate the impact of the climate change in the risk analysis. There was also a question from a participant to DOR about the plans and consideration on the climate change adoption measures. · Other participant expressed his opinion on the necessity of disaster risk reduction plans taking into account of the impact of the climate change. · Some participants asked JICA Survey Team the types of data used for the Survey and the way to handle the data on human life loss. JICA Survey Team responded according to their Survey plan.

Source: JICA Survey Team

13.2. Second Workshop

The outline and the contents of the Second Workshop is as summarized in the **Table 13-2**. After the presentations of JICA Headquarters, JICA Survey Team and DWRI, questions and answers session and discussion were held. Some questions and opinions raised by the participants are also listed in **Table 13-2**.

Table 13-2 Outline of the Second Workshop

Date and Time	4 August 2023 13:00~16:30
Venue	DOR Conference Room
Participants	<ul style="list-style-type: none"> · Relevant officials from DOR、DWRI、MOPIT、RBN、NDRRMA · Officials of JICA HQs and the Nepal Office · JICA Survey Team members (Total: 34 participants)
Program	After the presentations listed below, the questions-and-answers on the disaster risk assessment and the economic analysis, and the discussion on the longlist of the project sites as well as the significance of the pre-disaster investment were held. Presentation: <ul style="list-style-type: none"> · Methodology of landslide disaster risk assessment, the process of developing the longlist of the engineering measures sites and the progress of the Survey · The explanation of JICA Global Agenda and the concept of pre-disaster investment and Build Back Better · The explanation on landslide engineering measures · DWRI's road geohazard risk management and climate change adaptation
Questions and Answers Opinions	<ul style="list-style-type: none"> · Regarding the disaster risk analysis, some participants expressed the opinions on the appropriate level of safety applied to the risk analysis and importance of including the aspects of economic development policies. · A participant expressed the opinion on the demerit of the pre-disaster investment as the high initial cost. However, the importance of evaluating projects from the aspect of life-cycle cost was also pointed out. · On the other hand, another participant expressed the opinion that the proper cost analysis may not be easy due to the complex nature of the ground.

Source: JICA Survey Team

13.3. Third Workshop

The outline and the contents of the Third Workshop are summarized in **Table 13-3**. After the presentations of JICA Survey Team, questions and answers session and discussion were held. Some questions and opinions raised by the participants are also listed in **Table 13-3** below.

Table 13-3 Outline of the Third Workshop

Date and Time	7 February 2024 10:30~14 : 30
Venue	DOR Conference Room
Participants	<ul style="list-style-type: none"> · Relevant officials from DOR, DWRI, MOPIT, RBN, NDRRMA · Officials of JICA HQs and the Nepal Office · JICA Survey Team members (Total: 50 participants)
Program	After the presentations listed below, the questions-and-answers and discussion on the disaster risk assessment and the method of the economic analysis were held. Presentations: <ul style="list-style-type: none"> · Risk assessment and prioritization · Engineering measures methods selection by the hazard scale and types of landslides · Environmental and social consideration and Nepal’s domestic laws and regulation and JICA Guidelines
Questions and Answers Opinions	<ul style="list-style-type: none"> · A participant asked the consideration of life cycle costs in the economic analysis. He also expressed his opinion that low-cost measures such as bioengineering should be applied considering the large cost incurred by slope protection. The JICA Survey Team responded that the economic cost evaluation applied for a 30-year evaluation period. The JICA Survey Team also explained that the bio-engineering methods should be applied along with other hard measures based on the site’s specific requirements. · ”A participants suggested that” the assessment of potential damage loss should also include loss of human capital. · DOR introduced their initiative of a bridge management system and in the process of implementing comprehensive management systems for slopes using the mobile application. · Both DOR and DWRI officials emphasized the potential advantage of collaborating with other agencies for slope protection.

Source: JICA Survey Team

Chapter 14. Conclusion, Issues and Recommendations

14.1. Conclusion and Issues

14.1.1. Hypothesis and Verification related to Evaluation Method

(1) Significance of Cost-benefit Analysis of Road Geohazard Risk Reduction as a Public Works

Cost-benefit analysis of road investment is commonly performed internationally. The benefit items commonly used are "benefits of reduced travel time," "benefits of reduced travel costs," and "benefits of reduced traffic accidents."

Cost-benefit analyses of road geohazards risk reduction investments are generally not performed. Road supervisors determine the target safety level of risk sites and calculate engineering measures costs but do not estimate risk reduction benefits. To calculate the risk reduction benefit, first, calculate the risk as the annual potential damage amount by multiplying the potential damage amount before and after countermeasures and the damage probability, and then estimate the difference between the annual potential damage amount before and after the countermeasure as risk reduction benefit = annual damage reduction benefit. This calculation method is written in the Road Geohazard Risk Management Handbook of WB-GFDRR 2020, but it is not generally implemented because it is complicated and involves many assumptions. This survey was limited to the extent that it could be estimated. Road managers generally evaluate road geohazard risk reduction projects by identifying sites that require countermeasures and the number of risk sites and using the number of risk sites where engineering measures have been completed as an output indicator. Suppose the validity of road geohazards risk reduction investment is shown as an outcome of cost-benefit indicators. In that case, the explainability of the project's validity will be improved, and it will be possible to understand financial decision-makers who place importance on the internal rate of return (EIRR). This is considered a driving force for investment in road disaster risk reduction. For this reason, the estimation is considered to be highly significant.

(2) Issues with the method of route-based risk assessment applied to the Survey

This time, we first selected nine target NH routes. These are (i) sections that include sites where road landslide events have frequently occurred in recent years, (ii) road sections that include sites that DOR deems necessary for road landslide risk management, and (iii) Sections that other development partners do not support. This method is consistent with (i) and (ii) in Chapter 2: Selection of inspection target sections (first narrowing down) of Japan's "Road Geohazards Risk Reduction Inspection Guidelines 2006 Edition"²⁶. The Japanese proposal emphasized selecting road sections with a high traffic volume of large freight vehicles as important routes for logistics under current conditions. Still, the survey respected (ii) road sections that include sites that DOR deems necessary for road landslide risk management. Therefore, NH03, NH25, and NH37, which have relatively low traffic volumes, were included as the target NHs.

For the target NHs, the route-based assessment is multiplying the three scores of (a) the hazard level of the route (density of hazardous sites, presence or absence of human loss history), the importance (consequence level) of (b) DOR priority, and (c) population density by the route. The main limitations and challenges of this selection method are:

- The accuracy of road closure landslide history records for evaluating route-based assessment is low, and there is no record of personal loss history, which needs to be extracted from past news reports.
- DOR priorities lack objectivity of priority reasons.
- Population density by route indicates the necessity of a road as a community road, but it is not an indicator of the importance of a wide-area logistics route.

²⁶ <https://www.zenchiren.or.jp/geocenter/lec-road/docs/guideline.pdf>

(3) Issues with the method of economic risk assessment for individual sites applied to the Survey

The following two documents were used as references for this survey's cost-effectiveness analysis of road geohazard risk reduction investment.

- Public Works Research Institute Material No. 3926 “Road slope disaster risk analysis and management support manual (draft)”²⁷
- The World Bank, Global Facility for Disaster Reduction and Recovery (GFDRR) 2020 Road Geohazard Risk Management Handbook, Operation Manual 1 (OM1) Economic Risk Estimation and Cost-Benefit Analysis (The limitations and issues of the cost-effectiveness analysis method applied to the Survey are as listed as follows:
 - The items for evaluating benefits are the measurable road restoration costs and the benefit of reducing road closure losses. The items which are difficult to quantify for various reasons cannot be included. The examples of cost items which reductions were not included into the benefit were the following; human life losses, vehicle losses, moving costs of heavy equipment/damage to machinery, and fixed costs for recovery workers (personnel costs and other expenses). The benefits of mitigating losses to roadside assets, residents, and infrastructure are not included.
 - DOR's deployment of heavy equipment and personnel near landslide risk sites can reduce road closures to several hours, significantly reducing the economic losses borne by road closures in many cases. For this reason, the benefits of structural measures were minor according to the calculation method applied to the Survey. Therefore, it was found that there were many cases in which the investment in structural measures was not justifiable.
 - For the road landslide risk assessment, DOR discloses only the damage history data dated after April 14, 2021; some records do not contain complete information. The accuracy of the Survey has to be compromised because the damage history was evaluated based on interviews with the DROs and traces of collapse ruins from satellite images.
 - Road landslide risk assessments do not consider the increasing frequency and augmenting scale of disasters due to increased rainfall intensity caused by climate change.

14.1.2. Analysis of DOR's Capability and the System for Conducting Risk Assessment

DOR's initial landslide risk assessment method is based on DOR's road geohazard risk management guidelines, "Roadside Geotechnical Problems: A Practical Guide to Their Solution, June 2007(https://dor.gov.np/uploads/publication/publication_1472792371.pdf)". In this guide, DROs are to prepare the inspection sheets of Site Definitions, Slope Problems, Erosion Problems, Pavement Problems, and Structural Problems. The purpose of this inspection sheet is to record the DROs' recognition of roadside geotechnical problems and decisions on how to deal with them. If it is determined that it is difficult for a DRO to deal with them, a request will be sent to GESU for investigation and designing of the engineering measures.

However, since the guide was established in 2007, it has not been used in practice, and most DRO staff members are unaware of its existence.

GESU, which developed the guide, aims to promote its use by developing and introducing the data input of site definitions, slope problems, and erosion problem sheets from smartphones and computers. They plan to build applications for pavement problems and structural problems sheets in the future. However, the application does not have the function of digitizing and storing plans and cross-sectional views. Additionally, GESU recognizes that the data preparation will first require the training of DRO staff members. Still, the budget has not been secured, and there is no timetable for data preparation to begin.

Due to the above-mentioned situation, although the system has been developed, there are still the problems of the capacity and organizational development and securing budget to conduct the risk assessment as well as the appropriate system operation and management.

²⁷ (https://thesis.pwri.go.jp/public_detail/100503/)

GESU orders survey and design work at the request of DRO. At the workshops held under this Survey, the opinion was expressed that the safety measures at the safety level of 100-years damage probability are an excessive investment and that the first step is to promote the application of low-cost engineering measures such as bioengineering. It is necessary to transfer the risk assessment technique to develop roads with higher safety levels while taking economic efficiency into account simultaneously.

14.2. Recommendations

14.2.1. Assessment Methods with Validation and Issues to be Considered for Data Collection

It is felt that the frequency and extent of road geohazards caused by climate change have increased in recent years. For this reason, in road geohazard risk assessments to be conducted by DOR in future, it is recommended that the frequency and extent of geohazards the increase coefficient over the next 30 years by 1.1, considering the latest three-year history of geohazard events obtained from 2021 and the remaining risks at the site (Nepal's bridge design guidelines already stipulate that the 1.1 times larger amount of rainfall runoff with a 100-year probability should be applied considering the climate change).

Regarding the benefit of reducing restoration costs, the Survey used the restoration cost per time of full road closure based on the information collected by interviews with DROs. As the improvement upon the analysis of restoration costs in the future, it is necessary to include equipment maintenance costs and delivery costs related to the deployment of heavy equipment and personnel near geohazards risk sites, as well as costs related to annual training of related personnel. Furthermore, it is recommended that those restoration costs calculated above should be used as annual benefits incurred through reducing those costs in the 30-year evaluation period in the cost benefit analysis.

As for the benefit, the reduction in the damage to assets, residents' casualty loss, access to workplaces, schools and medical services, and damage to physical infrastructure along the route should be included.

In connection with geohazard risk reduction measures and restoration, if there are bottlenecks or unpaved roads in areas where geohazards events frequently occur, improvement and restoration projects will be carried out to secure road lanes along with restoration. The reduced driving time and costs will be recorded as the benefits because of the improvement.

Among the road geohazard engineering measures projects financed by DOR's budget, the structural measures should be actively promoted by prioritizing those against the disasters with a higher probability of human life loss, such as rock failures, rockfalls, and flow. Economic efficiency should not be the only factor determining the adequacy of implementing engineering measures against these critical hazards. The method of prioritization and the financing system should be developed to serve such needs of engineering measures in the future.

14.2.2. Positioning DOR's Priority Routes of NH37

(1) Current Status of NH37

According to the information provided by DOR in September 2023, the 79km route (Hetauda – Tikabhairab) is to be widened to 2 lanes (7m-width) and asphalted. The work is being implemented with a multi-year budget (FY2023-2025) of 680 million NRs. and more than 98% of the planned section will be completed by the middle of July 2025. However, the Engineering measures on the slopes with landslide risks, including 6 large-scale collapses (road length: 1478m), are not budgeted as the design and cost estimates have yet been done. Therefore, 963m of road length (1.2% of the entire length) are left for the sections of un-widen and 1,138m (1.4% of the whole length) are left for non-pavement. DOR plans to widen these sections while implementing slope protection measures. Asphalt pavement will also be done after the widening and slope protection.

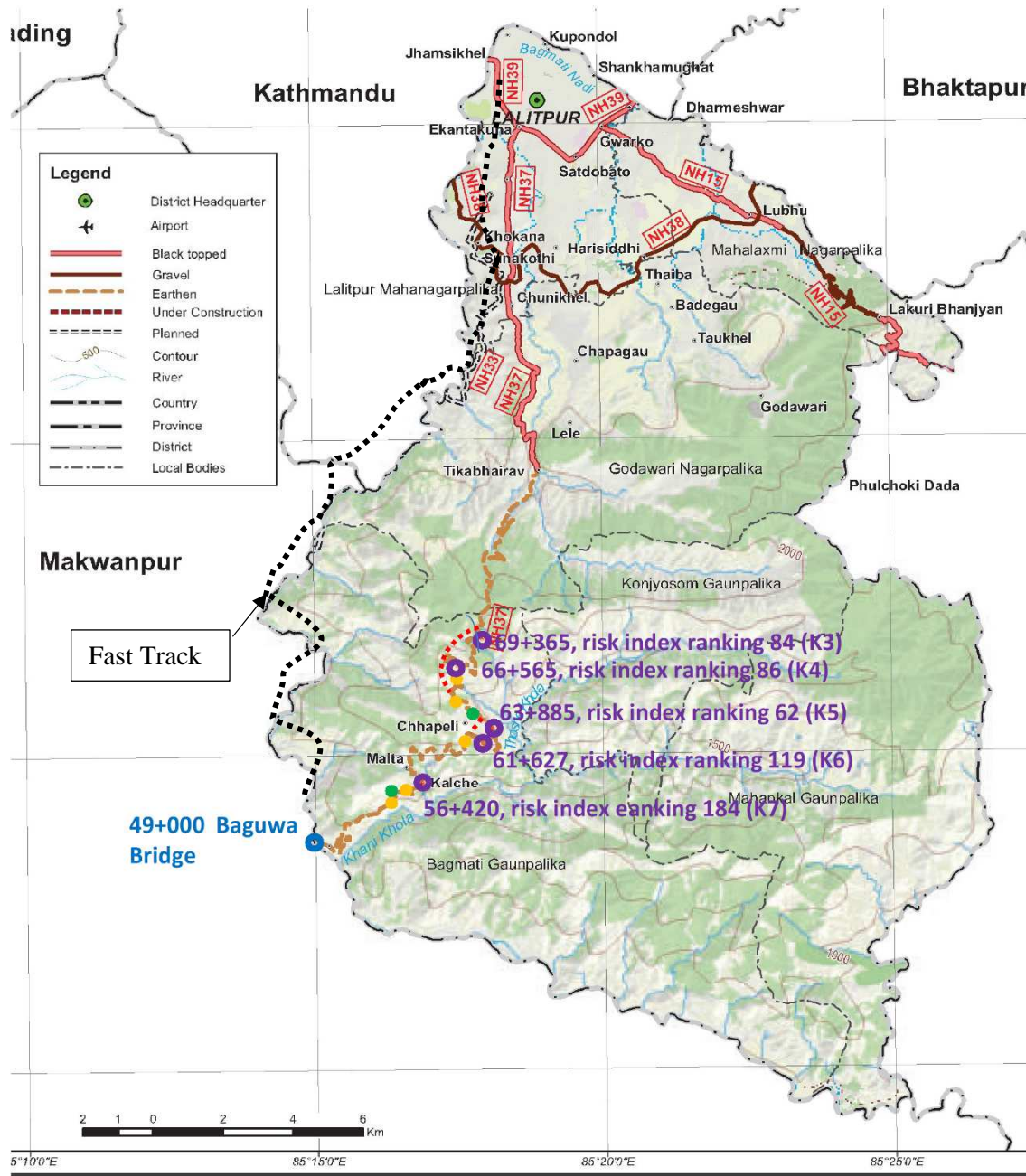
The survey considered risk assessments that include the benefits of risk reduction at seven locations, including one additional location in addition to these six locations.

Table 14-1 DOR Plan for NH37 Development

Situation of road widening with 2 lanes (As of September 2023)		To be completed by mid-July 2025	
The section with less than 2 lanes (road width :7m) out of 79km	23 small sections Total road length: 2,608m 3.3% of 79km	Planned to be completed by mid-July 2025	19 small sections Total road length:1,645m
		The sections left for road widening after August 2025 (estimated)	Total road length of unwidened: 963m 1.2%
Progress of asphalt pavement (As of early September 2023)		Progress of asphalt pavement (As of early August 2023)	
The section without pavement in NH37	35 small sections Total road length: 5349m 6.8% of 79km	Planned to be completed by mid-July 2025	30 small sections Total road length: 4211m
		The sections left for asphalt pavement after August 2025 (estimated)	Total road length non pavement: 1138m 1.4%

Source: JICA Survey Team based on the information provided by DOR

As of 5 February 2024, it was confirmed that some parts of the sections reported as widened and paved were left with less than 7m width.



Project Location	
Symbol	Description
	Sites affected by large-scale landslides where DOR expects support
	Road widening by mountain slope cutting + asphalt paving
	Asphalt pavement (road widening by cutting the mountain side slope has been completed)
	Bridge Replacement
	Landslide avoidance plan using tunnels

Source: JICA Survey Team based on the information provided by DOR

Figure 14-1 Map of the Sites of Large Scale Landslides and Road Improvement Projects (Lalitpur District)



Symbol	Description
●	Sites affected by large-scale landslides where DOR expects support
●	Road widening by mountain slope cutting + asphalt paving
●	Asphalt pavement (road widening by cutting the mountain side slope has been completed)
●	Bridge Replacement
●	Landslide avoidance plan using tunnels

Source: JICA Survey Team based on the information provided by DOR

Figure 14-2 Map of the Sites of Large-Scale Landslides and Road Improvement Projects (Makwanpur District)

(2) Cost and Benefit Analysis of Landslide Prevention Project Involving NH37 Road Improvement Work

The projects on seven sites in the comprehensive shortlist may be evaluated as “feasible” if the projects are re-packaged as the landslide engineering measures and road improvement project with road widening to 2 lanes and pavement work. The benefit to be generated through the reduced travel time and cost through improved roads is expected to increase the adequacy of the project. In this case, it is necessary to obtain the data by measuring the actual speed at the unpaved point with narrow road width due to the problem of landslide hazards and the traffic volume in the rainy and dry seasons. The data on actual speed measurements at the section with similar curvature and gradient with seven sites may also be necessary to evaluate the expected speed after the road widening to 2 lanes and pavement.

The alternative to the project to the landslide engineering measures and road improvement project may be the construction of tunnels and shortening the road length, as shown in **Figure 14-1**. Four sites with large-scale collapses require extensive and technically difficult measures in the case of the construction of physical structures. The concerned four sites are listed below:

- 61+627 risk index ranking 119 (K6)
- 63+885 risk index ranking 62 (K5)
- 66+565 risk index ranking 86 (K4)
- 69+365 risk index ranking 84 (K3)

(3) Cost-Benefit Analysis of the Project for Road Widening to 2 Lanes and Asphalt Pavement of 7 Sites on NH37

By implementing landslide engineering measures with road widening to 2 lanes and pavement of 7 sites on NH37, the entire project as a road improvement has a possibility to be evaluated as efficient with the benefit-cost analysis.

Through road improvement, NH37 is expected to contribute to transport cost reduction as the shortest route between Katmandu and Birgunji, the logistics hub at the border with India. However, it should be noted that the relations and the roles among the available routes, including the 4-lane toll road under construction by the government finance (the Fast-Track highway), should be clarified.

The cost and benefit items included in the analysis are listed below:

Cost items :

The total cost of landslide engineering measures of 7 sites (road length: 1478m) + road width widening to 2 lanes (7m width) and asphalt pavement

Benefit items :

Benefit generated by the reduced landslide risk + travel time reduction benefit + vehicle operation cost reduction benefit + diversion traffic benefit as a result of improved NH37 (travel time reduction benefit + vehicle operation cost reduction benefit)

To evaluate the benefit of conversion traffic due to the improvement of NH37, data collection and analysis, as shown in **Table 14-2**, are proposed.

Table 14-2 Outline of the Additional Survey for Calculating Benefit of Widening to 2 Lanes and Asphalt Paving of NH37 (Proposal)

	Changes in the traffic volume of the section between Birgunj and Kathmandu Calculation of route share based on the network analysis covering wide areas	Research on usability of NH37 Survey on driver's preference for routes
Outline	<ul style="list-style-type: none"> • Collect the data on Traffic volume between Birgunji and Katmandu as the origin/destination traffic volume. • Allocate traffic volume between Birgunji and Katmandu to the currently used route, NH37, and Fast Track after NH37 is paved to two lanes and before and after Fast Track construction. 	Conduct the drivers' questionnaire survey to understand the usage status of NH37 after the opening of the fast track.
Data to be collected	Road network (link length, traffic capacity, traffic volume-speed formula (Q-V formula)) Economic indicators: population, number of vehicles possessed per person	Route selection intention of drivers starting and ending at Katmandu and Birgunji after being presented with the current route used, fast track, NH37 passing speed, and toll road fees.
Utilization of the result	Evaluate the traffic conversion rate to NH37 between Birgunj and Kathmandu and evaluate the benefits of reduced travel time and travel costs associated with diverted traffic.	

Source: JICA Survey Team

(3) Technical Cooperation for Landslide Engineering Measures of NH37

Technical cooperation support for landslide engineering measures on NH37 could include advice on lowering the cost of engineering measures projects and shifting road alignment through tunnels, etc. to avoid landslide risks.

14.2.3 Actions for Climate Change Issues in Landslide Risk Reduction

(1) Climate Change Adaptation Measures

DOR's standard for road drainage design is based on the rainfall projection of 50-year, 33-year, or 25-year return period, depending on the traffic volume projection for 20 years. This standard level is sufficiently high compared with Japan's standards of general national highways with 7- to 10-year return period rainfalls. However, the standard for drainage design does not consider climate change adaptation. The drainage work has not been done on most slopes along the roads. The standards for the road bridges and culverts require sufficient flow capacity to maintain hydraulic safety for the precipitation, with a level of 1.1 times larger than the 100-year return period to adapt to climate change.

First, the rainfall intensity should be calculated at various stations to promote road slope drainage. The road slope drainage should then be designed by applying the formula from the nearest sites and the current standard of flow capacity.

If frequent overflow phenomena are observed in existing drainage facilities, the amount of drainage should be corrected by at least 1.1 times, considering climate change.

Groundwater drainage works require the installation of adequate drainage drilling in principle with a good understanding of the situations on slip lines and groundwater levels during the rainy seasons. The draining holes should be densely located, considering the effects of climate change.

(2) Climate Change Mitigation Measures

To reduce GHG emissions such as CO² at the time of implementation of engineering measures, the following methods are recommended:

- Change the types of engineering measures from the one with cement with significant CO² emission at the time of production to those with reduced emission (framework, high-intensity protection net, check dams with soil cement)
- Promote the use of cement aggregate produced in nearby sites such as soil cement in order to reduce CO² emission while transporting earth sand and other materials,
- Promote CO² absorption by applying methods that enable greening, such as using a high-intensity protection net, which can allow greening of all the areas inside the frame.
- Use the high-intensity slope protection net and leave a part of existing trees uncut in order to minimize the amount of tree cutting,

14.2.4 Necessity of System Manuals

DOR has the following guidelines related to road landslides:

- "Roadside Geotechnical Problems: a Practical Guide to their Solution, June 2007" URL: https://dor.gov.np/uploads/publication/publication_1472792371.pdf
- "Guide to Slope engineering measures, June 2003"

URL: <https://dor.gov.np/home/publication/gesu-publication/guide-to-road-slope-engineering-measures>

“Roadside Geotechnical Problems” was developed incorporating “Guide to Slope engineering measures,” which is developed using the Japanese guidelines as a reference (English translation of the title: “The Guidelines of Road Civil Engineering Construction: Guidelines of Slope Stabilization”)

It has been 16 years since “Roadside Geotechnical Problems” was published. Revision of the guidelines should be desirable to introduce and adjust to the recent developments in survey techniques and engineering methods.

As explained in 14.1.2 on DOR’s capacity and structure for risk assessment, DOR has developed the system to input and manage the information on the sites under the responsibility of DROs using the sheets of Site Definition, Slope Problem, and Erosion Problems. The data can be entered via applications on smartphones or computers. Further training, especially for DRO staff members, is necessary to utilize the preliminary risk assessment system. The problem with the current system is that it carries too many data items, which requires a long time for data entry. For the sustainable utilization of the system, simplification of the system may also be necessary.

14.2.5 Strengthen Cooperation with Other Organizations

(1) Cooperation with DWRI

DWRI (previously DWIDP before the organizational restructuring) implemented the sediment control projects on Narayanghat Mugling Highway in 2007 and Sindhuli Road in 2012 with non-project grant assistance from the Japanese government. At that time, DWRI and DOR agreed that the area beyond the 25m line from the center of the road is under the jurisdiction of DWRI.

During the JICA Project for the Operation and Maintenance of Sindhuli Road (2012-2015), DWIDP implemented the sediment control projects of the streams impacting on Sindhuli Road and the engineering measures of erosions of the adjacent rivers by its budget. DWIDP was merged into DWRI at the time of the organizational restructuring. Currently, DWRI is responsible for managing 46 rivers, developing and managing irrigation facilities, and implementing flood protection measures to protect farmlands and villages. DWRI has 19 local offices to undertake these tasks. However, technical personnel in charge of landslide risk reduction such as geotechnical engineers and hydrogeologists are not deployed. Many of the personnel in charge of land slide risk reduction have been transferred to local governments.

DWRI is responsible for the issues related to landslides, including protecting assets and infrastructure of roads and outside of RoW. It has accumulated technical capacity for geohazard management and management of large-scale landslides, flows caused by the streams crossing roads, and erosions caused by the rivers adjacent to roads. Therefore, it is necessary to reinforce the cooperation with the DWRI

Landslide Section and River Management Section again in collaboration with the engineers of the local governments.

(3) Cooperation with NDRRMA

NDRRMA takes the position as summarized below. As DOR has an idea of sharing the data, further actions for cooperation are expected.

- Landslides cause damage not only on the roads but also to other assets, such as farmlands and houses. Therefore, it is essential to conduct the risk assessment incorporating multiple factors in addition to the roads. NDRRMA considers incorporating the factor of climate change into their analysis by using DHM data as a GIS database. By adding information on the road sector, the system may be used to calculate the road geohazard risks. The meetings for road geohazard risk reduction with the participation of NDRRMA are necessary.
- The benefit to cost can be larger by including broader types of benefits. Pre-disaster investment should be considered from the aspects of national security and political issues.
- NDRRMA finds the national guideline for disaster risk evaluation is necessary. It is necessary for the risk evaluation special committee to define the risk evaluation. For that purpose, NDRRMA established the taskforce.

(4) Cooperation with Tribhuvan University

DOR and Tribhuvan University Department of Civil Engineering have a technical cooperation agreement. The primary contents of the cooperation are (i) geophysical exploration on road slopes and measurement of ground inclinometers and (ii) investigations at the sites with complicated landslides and research on the causes of the landslides. This is the agreement between governmental organizations and the DOR budget for activities. Continuous cooperation is expected to be effective.

14.2.6 Necessity of Capacity Building of Local Technical Personnel

As DOR mainly transfers its personnel between the central and other areas, the technical and skill levels are assumed not to have significant differences. However, the locally deployed engineers are conducting various tasks on the sites, such as daily observation of the situations, road clearance during landslides, emergency operations, and permanent measures. Therefore, the need for capacity building for local technical personnel is high.

14.3. Organizing the Direction of Japan's Cooperation

14.3.1. Technical Cooperation Project Related to Road Landslide Risk Reduction

(1) Technical Issues Expected from the Affected Site

The types of damage confirmed at the site are mainly summarized into four types: collapse, slide, flow, and road carriageway collapse (see **Table 10-1**). In all types of road landslides, it was observed that there were places where the local response was not necessarily sufficient, consequently leading to damage. The following common phenomena were observed on-site in the affected sites where sufficient measures had not been taken.

[Phenomena common to affected sites where adequate measures have not been taken]

i. Causes of damage:

The causes of collapse, slide and road carriageway collapse were found to differ depending on the affected site. For example, in terms of road carriageway collapse, it is observed that cases associated with landslide deformation, colluvial collapse and river erosion. When considering engineering measures. It is necessary to understand the cause of the occurrence, and then adopt engineering measures appropriate to the cause. According to information from C/Ps, however, sufficient investigations have not necessarily been conducted in some affected sites.

ii. Secondary events:

In collapse and slide, multiple types of secondary events are recognized to occur simultaneously, for example, erosion by spring water or surface water, falling rocks/rock collapse, partial surface collapse are the cases. When considering engineering measures, it is necessary to deploy comprehensive engineering measures that also deal with these multiple secondary events, which makes the response complex.

iii. Frequency of landslide events:



Frequently damaged road landslide sites have ongoing phenomena (causes) that make it difficult to respond technically. Several C/Ps at the site said, ‘‘In the last four or five years, the number of landslides has increased rapidly, and we are now experiencing repeated landslide events.’ It is assumed that this is clearly caused by an increase in rainfall amount and rainfall intensity due to climate change. Considering this trend, it is necessary to formulate engineering measures that consider the effects of Climate change.

iv. Impact of landslide:

In places where the impact of disaster is large, engineering measures need to be large-scale, making it economically difficult to deal with.

v. Maintenance and management:

In this survey, the survey team analyzed 216 sites , and it is assumed that similar issues exist in areas other than these landslide-affected sites. Currently, standards and management methods for properly maintaining and managing these facilities have not been established. To implement responses in sequence, it is necessary to establish an appropriate management method for road landslide risk reduction that focuses on the landslide types recognized on site.

	
<p>Road carriage collapse has occurred due to landslide movement within a large-scale landslide.</p> <p>NH03 37+900 (Risk Index Ranking 25)</p>	<p>The road lies on top of the colluvium, and road carriage collapse occurs due to the collapse and movement of colluvium.</p> <p>NH47 39+600(Risk Index Ranking 28)</p>

Source: JICA Survey Team

Figure 14-3 Damage Patterns of Road Carriageway Collapse

(2) Basic Direction of Pilot Project for Capacity Building

A pilot project is proposed with the aim of strengthening the capability to resolve i) to iii) and v) based on technical reasons among the common phenomena in landslide-affected sites that have been confirmed on site in the previous section and for which sufficient measures have not been taken.

[Basic Direction]

- I. Strengthen the capability to conduct appropriate investigations to clarify the causes of landslides.
- II. Strengthen the capability to formulate comprehensive engineering measures considering multiple secondary events caused by landslides.
- III. Strengthen the capability to formulate engineering measures considering changes in rainfall due to climate change.
- IV. Strengthen capabilities regarding maintenance and management methods focusing on landslide risk reduction.

(3) Types of Landslides Targeted in Pilot Projects

Based on the above basic direction, the landslide types covered include collapse, slide, and road carriageway collapse, which are the main damage types confirmed on investigated site covered in this survey. Flow is excluded because they are a simple phenomenon, the survey and engineering measures are spread over a wide area throughout the basin, so there are cost and land acquisition issues, and in addition, flow is not included in the C/P's requested sites, which will be explained later.

[Targeted types of Landslides]

- Collapse
- Slide
- Road Carriageway collapses

(4) Issues to be Handled in the Pilot Project and Proposed Technical CooperationStrengthening Survey Capabilities

Surveys to clarify the causes of landslide damage are carried out through the steps of planning, surveying, reconnaissance survey, investigation and analysis. Furthermore, specific implementation items will vary depending on the landslide type. In the pilot project, based on the common flow of the survey, the specific survey items necessary for each landslide type will be implemented. For specific survey items, Japan's know-how and technology will be actively introduced into each survey items. The following is a draft list of technical cooperation support items related to survey capacity building. The specific support items to be adopted will be determined depending on the pilot project sites as well as budget size.

Table 14-3 Proposed Items for Assistance in Technical Cooperation for Strengthening Survey Capacity (Tentative)

Items	Issues	Proposed assistance items for Technical Cooperation
Planning	<ul style="list-style-type: none"> • There are many sites where the scale of damage is large, and it is difficult to grasp the complete situation. • There are many sites that have been repeatedly damaged by landslides, but the damage history is not fully understood, and conventional measures based on experience are taken accordingly. 	<ul style="list-style-type: none"> • Extract landslide risk sites and areas by interpreting microtopography using high-resolution topographic maps. • Carry out a landslide history survey using satellite engineering images.
Surveying	<ul style="list-style-type: none"> • There are many places where the causes and phenomena of the landslide extend beyond the area under road management. In Nepal's road improvement project, aerial optical images are taken by a drone approximately 100 meters from the 	<ul style="list-style-type: none"> • Set the range for aerial photography using a drone, considering the collapse source and slide area, and carry out photography. In forest areas, drone LiDAR aerial image, which is also possible in Nepal, may be considered as a pilot activity. Using the created topographic map with 1m elevation line

Items	Issues	Proposed assistance items for Technical Cooperation
	center of the road, but there are some areas that are not fully covered.	intervals, topographical analysis to identify areas where collapse, slide and road carriageway collapse are expected will be conducted.
Reconnaissance Survey	<ul style="list-style-type: none"> The most basic item in the reconnaissance survey is the field survey. However, sufficient field surveys have not been conducted. 	<ul style="list-style-type: none"> Establish the scope of survey, estimating the causes of damage, a reconnaissance survey planning and setting priorities regarding landslide phenomena through field survey.
Investigation	<p><Collapse></p> <ul style="list-style-type: none"> When formulating engineering measures, it is necessary to understand the extent of sagging in the ground, but no investigation method has been established. Rockfalls and bedrock collapses are recognized as secondary events, but if the scale of the collapse is large, it is not possible to enter the collapse area and grasp the scale. 	<p><Collapse></p> <ul style="list-style-type: none"> Conduct in-hole logging and borehole cameras in survey boreholes to understand loose areas. Conduct handheld 3D ground laser surveying to understand the scale of rockfalls and collapses.
	<p><Slide></p> <ul style="list-style-type: none"> In general survey boring, it is difficult to collect cores from fractured areas, and the slide surface cannot be identified in many cases. Slope stability analysis is conducted based on ground strength based on test values, but there is a possibility that accurate strength cannot be determined. Instrumental observations have not been carried out, and data-based analysis has not been carried out accordingly. 	<p><Slide></p> <ul style="list-style-type: none"> Grasp the slide surface by observing pipe strain gauges inside the borehole (install strain gauges on the pipes and measures with data loggers). As an introduction to cutting-edge technology, cores will be collected using high-quality boring (a hybrid construction method, which is currently under examination in Indonesia) for the fracture classification to determine the landslide mass boundaries. Conduct groundwater level observation (measured with a data logger) and ground extensometer observation (measured with a data logger) and analysis of the results.
	<p><Road carriageway collapse></p> <ul style="list-style-type: none"> It is important to understand the depth at which bedrock appears and at the same time grasp the physical properties of the ground through survey boring. 	<p><Road carriageway collapse></p> <ul style="list-style-type: none"> Easily estimate physical property values using the standard penetration test results (N value) commonly carried out in survey boreholes.
Analysis	<p><Collapse></p> <ul style="list-style-type: none"> Many cases were observed in the field where gabions were installed as a measures against collapse. However, many cases of damage were observed 	<p><Collapse></p> <ul style="list-style-type: none"> The scale of collapse that occurs within the loosened area identified through the survey will be determined through trial arc calculations and will be used as a condition for selection and

Items	Issues	Proposed assistance items for Technical Cooperation
	due to colluvium, falling rocks and rock collapse.	design of construction methods. Regarding rockfalls and rock collapses, the rockfall energy is calculated and used as a condition for the scale of engineering measures.
	<Slide> <ul style="list-style-type: none"> In the affected sites, slide events (range, thickness, fluctuation status, groundwater level) were not accurately understood, and there were areas where slide movement had not been suppressed. 	<Slide> <p>A slide analysis model will be set up based on instrumental observation results. The items to be determined in the analytical model are the slip surface, slip surface strength, groundwater level, initial safety factor and planned safety factor. Using the analytical model, perform stability analysis using a simplified method and set design conditions for engineering measures design.</p>
	<Road carriageway collapse> <ul style="list-style-type: none"> Multiple cases were recognized as the cause of the road carriageway collapse, and in some cases, there were affected sites where the basement rock appeared at a deep depth, making it difficult to deal with. 	<Road carriageway collapse> <ul style="list-style-type: none"> The scale of the collapse will be determined through trial arc calculations based on the physical property values obtained through the survey and will be used as conditions for selection and design of construction methods.

Source: JICA Survey Team

Strengthening Capability to Formulate Engineering Measures

At the site, it was confirmed that the following construction methods have been introduced as slope engineering measures. On the other hand, even if slope engineering measures were implemented, there were cases in which the effects were not achieved because appropriate construction methods were not adopted to deal with the phenomenon. It is proposed that the pilot project aims to introduce Japan's know-how and technology to deal with landslides. Possible construction methods for each landslide type are shown in **Table 14-4**.

Planning large-scale earthworks (slope cut) poses the following technical challenges for Nepali engineers.

Applying an appropriate cutting slope and placing berms according to the ground conditions is necessary. Although this is stated in the DOR guide, it is often not applied appropriately. The actual distribution of soil and rock on the ground of a road slope is complex, and the cut slope gradient requires comprehensive judgment, including the presence of spring water and the erosion resistance of the soil.

If houses or infrastructure are distributed on the upper slope, it is necessary to avoid destabilizing the upper slope due to the slope cut. It is necessary to carry out the slope reinforcement by frame work, rock bolting, and ground anchoring.

Since large-scale earthworks (slope cut) involve large-scale felling and transportation of waste soil, it is desirable to reduce the scale of cutting from the viewpoint of CO² absorption by bioengineering and control of CO² emissions. In this case, it is necessary to consider a retaining wall, slope protection net, soil nailing, framework, and ground anchor. The introduction of slope bioengineering is also recommended.

The cutting mentioned above reinforcement method has few applications in Nepal, so it is necessary to obtain technical support.

Countermeasures against slope failure and rockfall include source and standby countermeasures, and the distinction between these measures depends on cost efficiency. Suppose there is a separation space between the road and the slope on the mountainside of the road. In that case, it can be used as a buffer zone to absorb rockfall energy, so if it can cope with the largest expected rockfall, it is economically more cost-effective to take standby measures. Conceivable. If a rockfall is expected that cannot be dealt with standby measures, remove the floating rocks or boulders at the source or secure the source with slope protection netting, ropes, etc. In recent years, high-energy absorption rockfall protection fences (standby protection) and high-energy absorption rockfall protection nets (standby protection type, source protection type) have been developed in Japan, and their application may be considered. It is necessary to obtain technical support regarding application conditions and design concepts.

Landslide countermeasures include suppression works (landslide head waste soil, landslide foot embankment, groundwater drainage works, etc.) and deterrent works (ground anchor works, deterrent pile works, etc.). First, control works are planned, and once the slipperiness of the landslide has been suppressed to a certain extent, restraint works are planned to ensure the desired level of safety. In Nepal, the first option is to plan and implement relatively inexpensive control works. Alternatively, if the negative environmental and social aspects associated with restraining works are large, such as large-scale deforestation or relocation of residents, and if the sliding force of the landslide is of a scale that can be handled with anchors or restraining piles, restraining works may be adopted. Conceivable. It is necessary to obtain technical support regarding application conditions and design concepts.

In addition to the above-mentioned landslide phenomenon, road collapse is often associated with river erosion near the road. In this case, it is necessary to understand whether the slope is directly hit by river water and the water level during floods and then take measures to prevent erosion if there is a risk of the road being flooded.

Table 14-4 Proposed Items for Assistance in Technical Cooperation for Strengthening Capacity of Formulating Engineering Measures (Tentative)

	Measures	Proposed Assistance Items for Technical Cooperation
Common issue	<ul style="list-style-type: none"> • Performance standard 	<ul style="list-style-type: none"> • In Japan, the concept of "performance-based contract" has been introduced as a flexible standard that allows for the rapid introduction of new design methods, new technologies, and new construction methods to cope with the diversification of needs for structures and landscapes as well as further cost reductions. In the pilot project, it is possible to teach the concept of performance standard. Performance standard for slope engineering measures assumes the concept of temporary emergency measures and permanent measures, as well as the concept of a planned safety factors for permanent measures.
Collapse	<ul style="list-style-type: none"> • Massive collapse measures • Engineering measures against falling rocks and rockfall 	<ul style="list-style-type: none"> • Teach the design flow, concepts, and design methods for designing large-scale earthworks (cutting works). • There are two types of measures against falling rocks and rockfall: source measures and standby measures. In the pilot project, it is possible to teach how to use both works and the method of each design.
Slide	<ul style="list-style-type: none"> • Control works²⁸ • Restraint works²⁹ 	<ul style="list-style-type: none"> • Slide engineering measures include control works and restraint works. This pilot project may target control works that are highly feasible in Nepal (water collection wells, horizontal borings, embankments, earth removal).
Road carriageway collapse	<ul style="list-style-type: none"> • Engineering measures against collapse 	<ul style="list-style-type: none"> • During the field survey, multiple causes of the road carriageway collapse were confirmed. In the pilot project, it is possible to consider engineering measures targeting road carriage collapse due to colluvium collapse, which is the most recognized cause.

Source: JICA Survey Team

Strengthening the Capability to Cope with Climate Change

The effects of climate change are recognized in increased precipitation and rainfall intensity, which cause road landslides such as frequent collapses, expansion of the scale of collapses and activation of slides.

Climate change engineering measures can be divided into adaptation measures and mitigation measures. In road landslide risk reduction project, adaptation measures include strengthening the functionality of surface water treatment and groundwater drainage works, and mitigation measures include slope bioengineering.

[Climate change engineering measures in road landslide risk reduction]

Adaptation measure:

Strengthening of works related to surface water treatment (channel works, berm drainage, etc.)

Reinforcement of groundwater drainage works (drainage well, horizontal boring, culvert)

Mitigation measures:

Slope bioengineering

²⁸ Control works: A method of stopping or mitigating slide movement by changing the natural conditions such as the topography of the site and the state of groundwater to improve the balance between the sliding force and resistance of the slide.

²⁹ Deterrence works: A construction method that uses the resistance of a structure to stop part or all of the slide movement.

It is proposed that the pilot project will focus on groundwater drainage works for landslides, which are among the climate change engineering measures mentioned above and the technology for which is still immature in Nepal. An example of a specific method is shown below.

[Example of consideration of slide prevention works considering increase in precipitation due to climate change]

- 1) Understand current groundwater level fluctuations through instrumental observation (groundwater observation in boreholes)
- 2) Understanding the relationship between rainfall and groundwater level
- 3) Construction of a ground model through reproduction analysis using seepage flow analysis
- 4) Prediction of groundwater level when precipitation increases
- 5) The effect of lowering the groundwater level due to groundwater drainage works (water collection wells, horizontal borings)

Strengthening Maintenance and Management Capacity

DOR's road landslide risk reduction guidelines are as follows.

- DOR 2007: Roadside Geotechnical Problems: A Practical Guide to their Solution (<https://dor.gov.np/home/publication/gesu-publication/road-side-geo-technical-problems-a-practical-guide-to-their-solutions>)
- GESU: Geo Environmental Social Unit/DOR 2003: Guide to Road Slope Protection Work (<https://dor.gov.np/home/publication/gesu-publication>)

The pilot project will utilize these guidelines and provide supplementary materials and data to improve the capacity of Nepali C/Ps. The knowledge gained from the pilot project is preferable to be compiled as supplementary material to the above guide.

(5) Identification of C/P

The C/Ps are expected to be DOR (Maintenance Division, GESU) and Groundwater and Geology Division of DWRI.

(6) Extraction of Candidate Sites for Pilot Projects

In a technical cooperation project, the C/P may decide on a model section (pilot project site), and an expert may be involved to provide comments and advice. On the other hand, DOR has set a priority list of 24 sites as of October 10, 2023, where support is needed (see **Table 14-5**).

Selection Criteria

The survey team proposes that the target sites for the pilot project be selected from among the sites indicated by DOR. Selection was carried out based on the following criteria.

[Selection Criteria]

- Select from the priority list of 24 sites indicated by DOR on 10th October 2023.
- Select from routes relatively close to Kathmandu (NH37, NH44, NH47: 15 sites).
- Exclude the sites on the short list (5 sites).
- Exclude dangerous sites (4 sites) where collapses and rockfalls occur frequently.
- Covers three landslide types (collapse, slide, and road carriageway collapse).

As a result of the considerations, seven candidate sites were selected.

[Candidate sites for pilot projects]

- Collapse: 3 sites: NH37 46+000(73), NH44 33+000(6), NH47 48+600(8)
- Slide: 3 sites: NH37 56+420(63), NH37 42+000(68), NH47 49+800(30)
- Road carriageway collapse: 1 site: NH47 39+600(28)

*(): Risk Index Ranking

All the above candidate sites are suitable for implementing the capability strengthening assistance in Technical Cooperation shown in the previous section, 10.4 Implementation Contents. Three sites each for collapse and slide were listed, and if it is necessary to narrow down to one site for each landslide type, the sites would be located on NH37, which is highly requested by DOR, relatively close to Kathmandu, and relatively small and easy to handle. The following sites were selected.

[Final candidate sites for pilot project]

- Collapse: 1 site: NH37 46+000, Risk Index Ranking 73
- Slide: 1 site: NH37 56+420, Risk Index Ranking 68
- Road carriageway collapse: 1 site: NH47 39+600 28

Table 14-5 Priority Sites Presented by DOR (October 10, 2023)

White-colored cells are pilot project candidate sites, and red text is the final candidate sites.

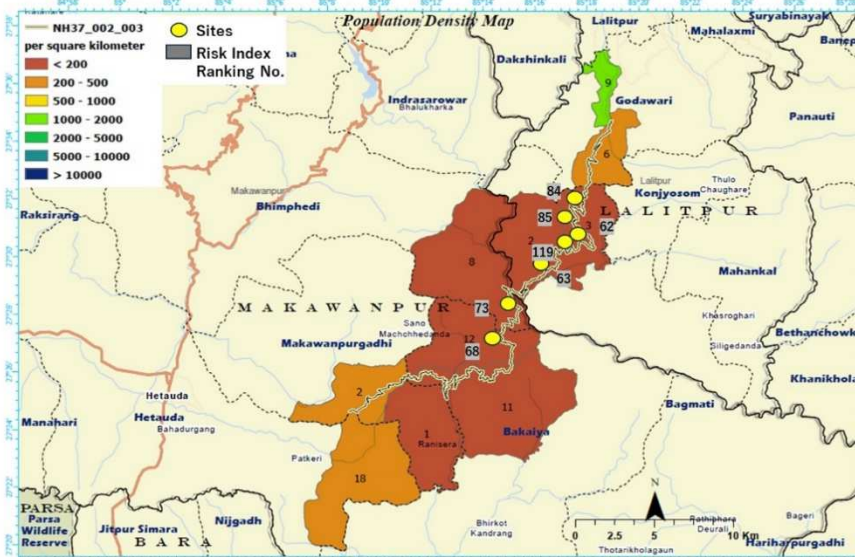
DOR's Priority Ranking on 10 October 2023	National Highway Code	Risk Index Ranking	Road Section	Chainage	Inventory No.	Type	Shortlist	Danger
1	NH37	62	Kanti Highway	63+885	K5	collapse		x
2	NH37	63	Kanti Highway	56+420	K7	slide		
3	NH37	68	Kanti Highway	42+000	K9	slide		
4	NH37	73	Kanti Highway	46+000	K8	collapse		
5	NH37	84	Kanti Highway	69+365	K3	collapse		x
6	NH37	85	Kanti Highway	66+565	K4	collapse		x
7	NH37	119	Kanti Highway	61+627	K6	collapse		x
8	NH44	6	Narayanghat- Mugling	33+000	L7	collapse		
9	NH47	2	Siddartha Highway	35+500	SH03	slide	x	
10	NH47	8	Siddartha Highway	48+600	SH10	collapse		
11	NH47	11	Siddartha Highway	56+200	SH14	slide	x	
12	NH47	12	Siddartha Highway	87+400	SH18	collapse	x	
13	NH47	28	Siddartha Highway	39+600	SH07	road shoulder collapse		
14	NH47	29	Siddartha Highway	46+400	SH09	collapse	x	
15	NH47	30	Siddartha Highway	49+800	SH12	slide		
16	NH03	25	Pokhara- Baglung	37+900	PB36	slide		
17	NH03	26	Pokhara- Baglung	36+400	PB37	slide		
18	NH03	27	Pokhara- Baglung	26+200	PB38	slide		
19	NH03	33	Pokhara- Baglung	51+500	PB21	collapse		
20	NH25	16	Dumre-Besisahar-Chame	45+150	L21	collapse	x	
21	NH25	18	Dumre-Besisahar-Chame	61+100	L12	collapse		
22	NH25	19	Dumre-Besisahar-Chame	62+500	L20	collapse		
23	NH25	31	Dumre-Besisahar-Chame	101+800	L19	collapse		
24	NH03	201	Khurkot-Halesi	4+000	HK15	collapse		

Source: Edited by the survey team based on information provided by DOR

Selected Idea

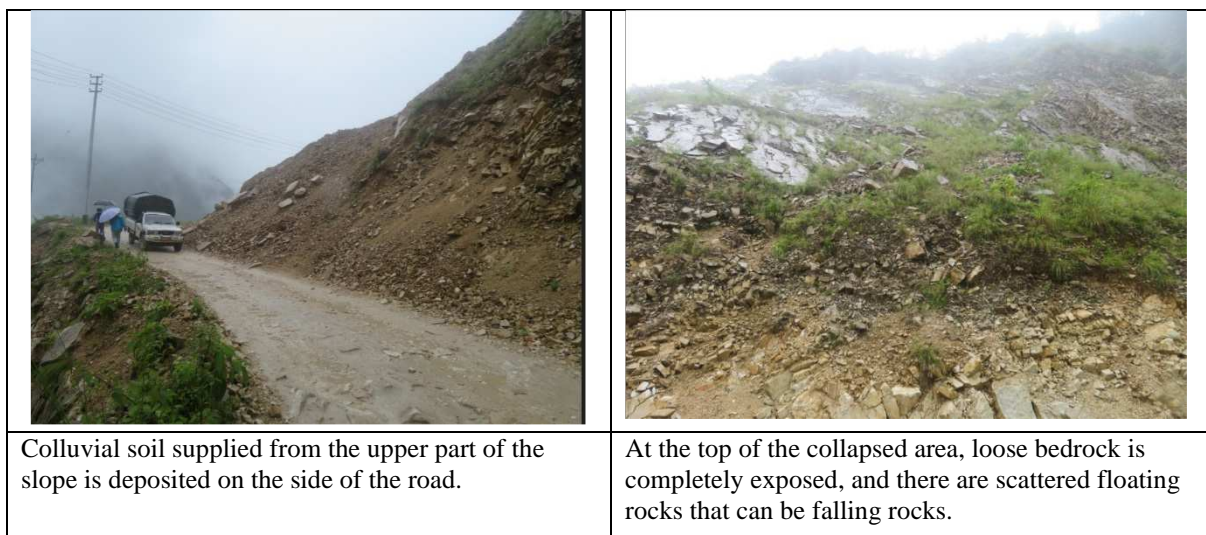
NH 37 46+000, Risk index ranking 73 (K8), collapse (4th Place in DOR request ranking on 10th October 2023)

This is a collapsed area with a slope height of approximately 100 m and a slope gradient of approximately 40° to 60°. There are places where colluvial soil generated at the top of the slope is thickly deposited from the middle to the bottom of the slope, and there are also places where weathered rock is exposed and overhangs the entire surface. Collapses, rock collapses, and rockfalls occur from areas where the surface layer is loose. Focusing on two types of phenomena, collapses and falling rocks in collapsed areas, methods of investigation, analysis, and design appropriate for each will be proposed.



Source: JICA Survey Team, Location map showing ward population density of the 2021 Census

Figure 14-4 Proposed Site of NH37 46+000, Risk Index Ranking 73 (K3)

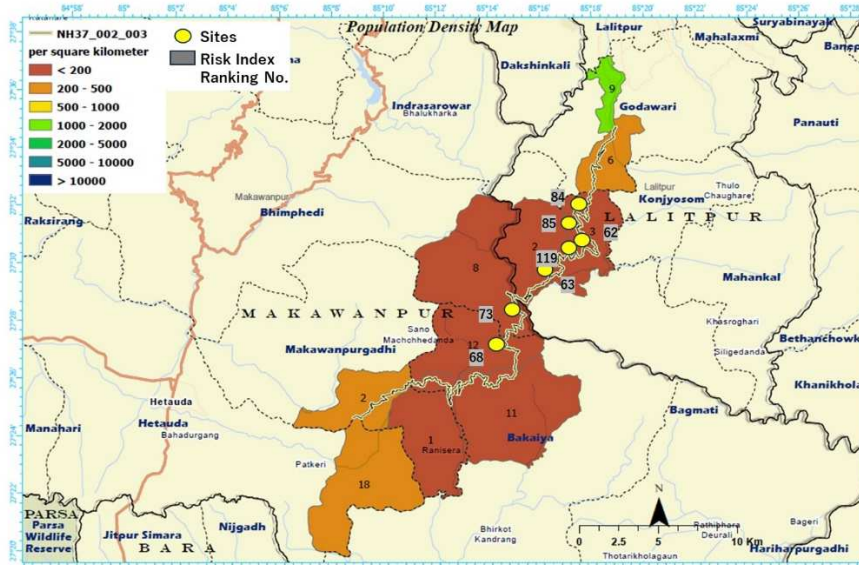


Source: JICA Survey Team

Figure 14-5 Site Photos of Proposed Site of NH37 46+000, Risk Index Ranking 73 (K3)

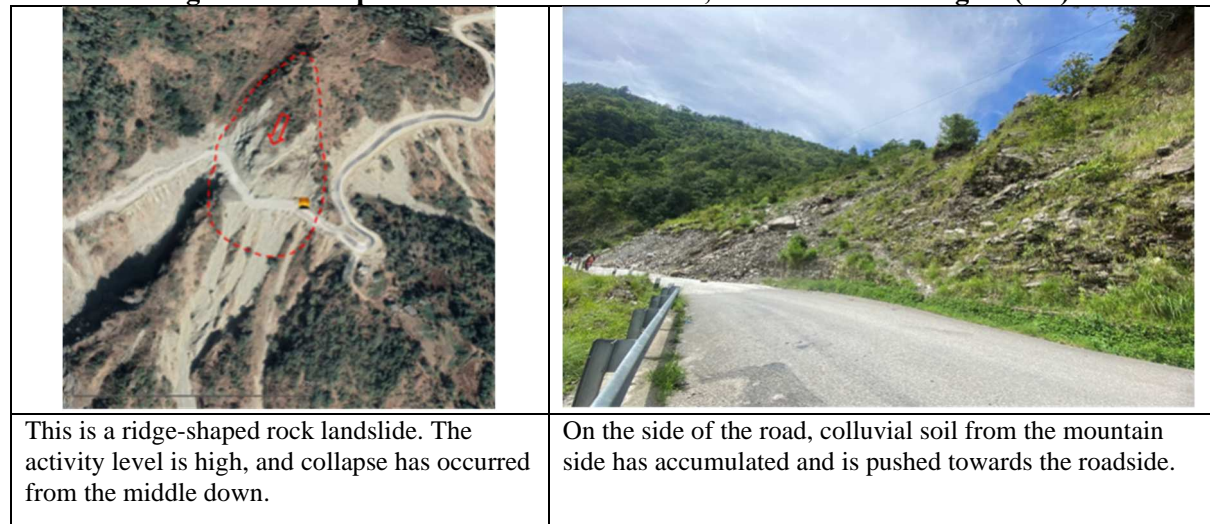
Proposed site of NH37 56+420, risk index ranking 63 (K7), slide (2nd place in DOR request ranking on 10th October 2023)

The landslide was 100m wide and large-scale., In 2023, GESU conducted the investigation and stability analysis which are one boring hole to the depth of 12m and the two-dimensional electrical resistivity survey on the halfway of the slope of the road mountain side. In the pilot project, it is conceivable that survey borings will be placed, and the depth of the landslide will be determined through groundwater observation and strain meter measurements inside the borehole, and these will be used for planning and designing engineering measures.



Source: JICA Survey Team, Location map showing ward population density of the 2021 Census

Figure 14-6 Proposed Sites of NH37 56+420, Risk Index Ranking 63 (K7)

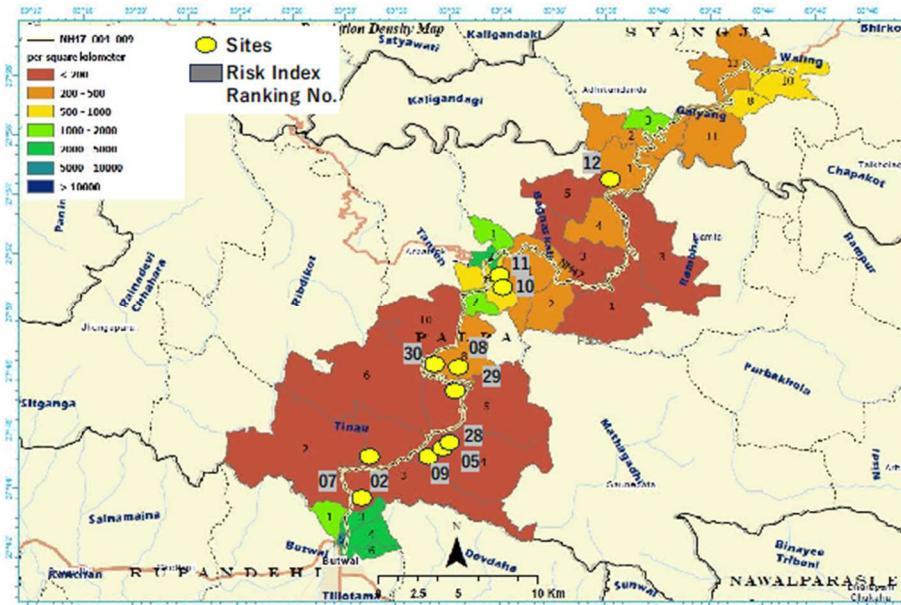


Source: JICA Survey team

Figure 14-7 Site Photos of NH37 56+420, Risk Index Ranking 63 (K7)

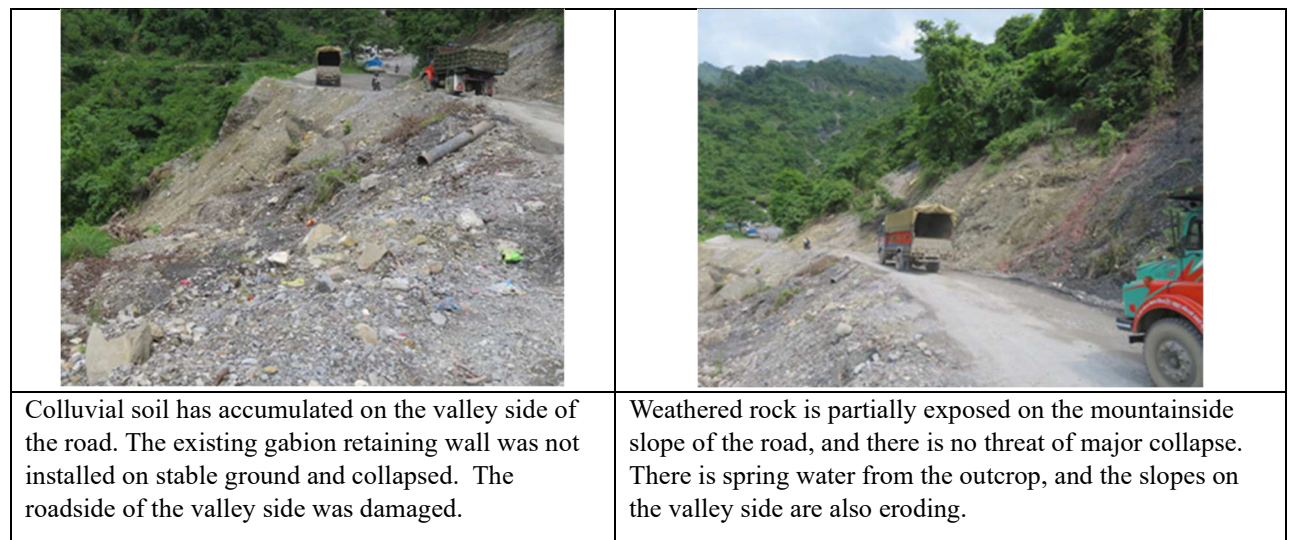
NH47 39+600 (SH07), risk index ranking 28, road carriageway collapse (17th place DOR request ranking on 10th October 2023)

The gabion retaining wall on the road valley side has collapsed. It is thought that the road will be stabilized by carrying out survey boring to confirm the bedrock and constructing the valley side retaining wall by ensuring that it is firmly embedded in the bedrock, and this is considered appropriate as technical cooperation for the DOR’s current capability.



Source: JICA Survey Team, Location map showing ward population density of the 2021 Census

Figure 14-8 Propose Site of NH47 39+600, Risk Index Ranking 28 (SH07)



Source: JICA Survey team

Figure 14-9 Site Photos of NH47 39+600, Risk Index Ranking 28 (SH07)

14.3.2. Technical Cooperation Project related to Mountain Road Improvement Project

The government of Nepal is prioritizing investment in road development over road landslide risk reduction. When constructing, widening, or changing the alignment of mountain roads, it is considered adequate to transfer technology on how to build roads that are resistant to landslides, such as road alignment that avoids hazards such as collapse, landslides, debris flows, and erosion, extensive slope cutting and embankments. Targets include national highways managed by DOR and local roads managed by the Ministry of Urban Development's Department of Rural Infrastructure (DOLI). Regarding local roads, there have been cases in which sediment from road construction is disposed of in valleys, causing sediment to flow downstream to other roads, residential areas, and farmland. Technical cooperation is needed to prevent new landslides due to road construction.

Support items for technical cooperation related to mountain road projects include the following:

- Creation of landslide hazard mapping for new road planning area
- Road alignment planning for landslide-resistant road construction
- Benefit-cost analysis related to road development
- Benefit-cost analysis for road improvement
- Geotechnical investigation, hydrological and hydraulic investigation
- Landslide risk management planning
- Structural measures for risk sites
- Maintenance of engineering measures
- Awareness for road landslide
- Emergency information collection method
- Road emergency information systems, including early warning or precautionary road closure

14.3.3. Proposed ODA Lone Projects related to Road Landslide Risk Reduction

The necessity and appropriateness of implementing ODA loan projects for the shortlisted areas are summarized as follow.

(1) NH25 Besisahar-Charne section

Although one site has been selected, the scale of the project is relatively small, and the level of technical difficulty is medium, so that DOR can handle it with technical cooperation. As landslide occur frequently, early engineering measures are recommended without relying on Japanese loans.

(2) NH37 Kanti Highway

Seven sites have been selected. Site-based evaluation has not determined the validity of landslide risk reduction investment. The application of Japanese loans is based on the premise that landslide prevention and road improvement projects, including two-lane paving, are economically viable. For the four technically difficult slopes, it is necessary to consider ways to avoid the risk of landslides, such as changing the road alignment, in addition to implementing engineering measures.

Suppose the economic validity of the above project is achieved. In that case, the necessity of the Japanese loan project will be moderate to high since the project scale is large and the level of technical difficulty is moderate to high.

(3) NH44 Narayanghat-Mugling Highway

Five sites have been selected, but none are included in DOR's priority list of requests for Japan's cooperation on 10th October 2023. Investigation and design of engineering measures have already been commissioned at three sites.

Although the scale of the project is relatively small and the level of technical difficulty is medium to high, it can be handled by DOR with technical cooperation. As landslides occur frequently, early engineering measures are recommended without relying on Japanese loans.

(4) NH47 Siddhartha Highway

Three sites have been selected. Although the scale of the project is relatively small and the level of technical difficulty is low to medium, it can be handled by DOR with technical cooperation. Early engineering measures are recommended regardless of Japanese loans.

Annex

Annex A. 216 Survey Sites.

- A.1. List of 216 sites
- A.2. Risk index ranking

Annex B. Longlist sites and the other assessment sites

- B.1. Longlist sites and the other assessment sites
- B.2. Traffic indicators
- B.3. Photos
- B.4. Road closure status

Annex A. 216 Survey sites

A.1. List of 216 sites

Annex A-1. List of 216 sites

National Highway Code	Road Section	Chainage	Landslide Sites					Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L1*W1*D1/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	
			Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation												Risk Index AADT	Risk Index AADT
					Latitude (North)	Longitude (East)	Elevation (m)											
												AAEP	AADT	AADT	DR	=AAEP*AADT*DR	=AAEP*AADT*DR	
NH02	Kanchhi Dokan			NH02#1	27°5'24.07"N	87°47'23.46"E	2,202.6	Flow	2		7,575	1	15	2523	1,145	500	85,875	189,225
NH02	Puwa Bhanjyang/Gumbba Dada			NH02#2	27°37'98"N	87°48'24.84"E	2,282.5	Collapse	2		250	0	1	2523	1,145	500	5,725	12,615
NH02	Pangre ko bhir			NH02#3	27°32'62"N	87°48'43.84"E	2,127.9	Collapse	2		13,650	0	15	2523	1,145	500	85,875	189,225
NH02	Dhapatar			NH02#4	27°2'15.00"N	87°50'15.93"E	2,107.5	Collapse	2		2,100	0	3	2523	1,145	500	17,175	37,845
NH02	Golkharka-Rajduwali			NH02#5	26°53'4.7"N	87°55'34.75"E	502.6	Landslide	1	4	750,000	1	10	3531	1,825	500	91,250	176,550
NH03	Khurkot-Halesi		Khotang	HK#1	27°11'24.14"N	86° 34'32.65"E	1,232.0	Collapse	2		153	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK#2	27°11'46.64"N	86° 33'56.02"E	1,123.8	Collapse	2		2,667	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK#3	27°11'38.32"N	86° 33'21.78"E	1,148.8	Collapse	2		150	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK#4	27°10'10.92"N	86° 18'20.88"E	1,000.0	Collapse	1	1	175	0	1	1,827	956	274	2,619	5,006
NH03	Khurkot-Halesi	15+600	Khotang (Ch 0+0000 at Hilepani Khotang)	HK#5	27°10'18.48"N	86° 30'00"E	828.6	Collapse	2		1,100	0	2	1,725	897	274	4,916	9,453
NH03	Khurkot-Halesi		Khotang	HK#5a	27°10'18.50"N	86° 30'21.50"E	769.5	Collapse	2		2,667	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK#5b	27°11'19.30"N	86° 30'19.60"E	793.2	Collapse	2		350	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK#6	27°10'61.40"N	86° 29'25.80"E	603.3	Collapse	1	1	3,733	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Khotang	HK# 6	27°10'14.16"N	86° 30'10.84"E	938.6	Carriageway Collapse	1	1	267	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Okhaldhunga	HK# 7	27°10'40.26"N	86° 25'14.74"E	466.5	Flow	2		533	0	1	1,725	897	274	2,458	4,727
NH03	Khurkot-Halesi		Udaypur	HK# 8	27°10'22.84"N	86° 23'56.80"E	335.4	Collapse	2		500	0	1	1,827	956	274	2,619	5,006
NH03	Khurkot-Halesi		Udaypur	HK# 8a	27°10'18.41"N	86° 24'00.36"E	305.2	Collapse	2		600	1	1	1,827	956	274	2,619	5,006
NH03	Khurkot-Halesi		Udaypur	HK# 8b	27°10'21.79"N	86° 23'58.92"E	332.8	Collapse	2		1,600	0	1	1,827	956	274	2,619	5,006
NH03	Khurkot-Halesi			HK# 9	27°12'33.77"N	86°20'21.80"E	345.5	Collapse	2		400	0	1	1,827	956	191	1,826	3,490
NH03	Khurkot-Halesi	28+060	(Ch 0+000 at Khurkot)	HK# 10	27°14'44.63"N	86° 12'21.89"E	391.9	Collapse	1	2	800	0	2	1,827	956	191	3,652	6,979
NH03	Khurkot-Halesi			HK# 11	27°15'6.84"N	86°10'37.27"E	383.3	Collapse	2		1,250	0	1	1,827	956	191	1,826	3,490
NH03	Khurkot-Halesi			HK# 12	27°14'35.09"N	86° 9'9.61"E	400.0	Collapse	2		750	0	1	1,827	956	191	1,826	3,490
NH03	Khurkot-Halesi	18+600	Kukhuretar	HK# 13	27°16'10.45"N	86° 9'52.81"E	408.0	Collapse	1	2	2,400	0	2	1,827	956	191	3,652	6,979
NH03	Khurkot-Halesi			HK# 14	27°15'50.04"N	86° 2'29.4"E	407.3	Collapse	2		1,400	0	1	1,827	956	191	1,826	3,490
NH03	Khurkot-Halesi	4+000	Habar (Akare)	HK# 15a	27°18'27.79"N	86° 1'27.41"E	425.4	Collapse	2		1,067	0	1	1,827	956	191	1,826	3,490
NH03	Khurkot-Halesi	4+000	Habar (Akare)	HK# 15b	27°18'28.44"N	86° 1'19.80"E	430.6	Collapse	2		5,200	1	5	1,827	956	191	9,130	17,448
NH03	Khurkot-Halesi	4+000	Habar (Akare)	HK# 15c	27°18'30.67"N	86° 1'15.38"E	436.1	Collapse	2		5,200	1	5	1,827	956	191	9,130	17,448
NH03	Pokhara- Baglung	58+700	Saharshadhara 1, Kushma	PB01	28°14'49.80"N	83°38'4.75"E	699.6	Collapse	1	1	5,918	0	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung	58+500	Saharshadhara 2, Kushma	PB02	28°14'51.04"N	83°38'0.61"E	684.7	Collapse	1	1	14,405	1	15	2,819	1,597	500	119,775	211,425
NH03	Pokhara- Baglung	57+440	Nayapool Flow, Kushma	PB03	28°14'43.96"N	83°38'14.98"E	692.9	Flow	1	2	87,780	1	20	2,819	1,597	500	159,700	281,900
NH03	Pokhara- Baglung	57+400	Armadi 1, Kushma	PB04	28°14'24.47"N	83°38'47.42"E	721.0	Collapse	2		1,085	1	20	2,819	1,597	500	159,700	281,900
NH03	Pokhara- Baglung	57+300	Armadi 2, Kushma	PB05	28°14'21.24"N	83°38'52.71"E	724.8	Collapse	1	2	3,899	1	2	2,819	1,597	500	15,970	28,190
NH03	Pokhara- Baglung	56+050	Armadi 3, Kushma	PB06	28°14'32.38"N	83°39'24.42"E	748.0	Collapse	1		257	0	2	2,819	1,597	500	15,970	28,190
NH03	Pokhara- Baglung	54+350	chamar Ke dil, Kushma	PB07	28°14'14.09"N	83°39'48.79"E	830.4	Collapse	1	2	1,800	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung	53+600	Dulepani, Kushma	PB08	28°14'3.26"N	83°40'9.08"E	848.0	Collapse	1	1	1,200	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung	53+400	Gupteshwor Campus area, Kushuma	PB09	28°13'59.73"N	83°40'12.38"E	857.1	Carriageway Collapse	1	1	800	0	3	2,819	1,597	500	23,955	42,285
NH03	Pokhara- Baglung	53+450	Gupteshwor Campus area, Kushuma	PB10	28°13'58.19"N	83°40'11.35"E	847.3	Carriageway Collapse	1	2	10,400	1	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung	52+500	Damdare khola, Kushuma	PB11	28°13'43.64"N	83°40'38.53"E	868.4	Flow	1	2	31,680	1	20	2,819	1,597	500	159,700	281,900
NH03	Pokhara- Baglung		Near Kushma Gate1, Kushma	PB12	28°13'20.92"N	83°41'33.51"E	866.8	Collapse	1	2	267	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Near Kushma Gate2, Kushma	PB13	28°13'22.93"N	83°41'35.69"E	858.9	Collapse	1	2	400	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Near Kushma Gate3, Kushma	PB14	28°13'24.37"N	83°41'39.61"E	856.8	Collapse	1	1	533	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Near Kushma Gate4, Kushma	PB15	28°13'27.90"N	83°41'43.44"E	856.8	Collapse	1	1	292	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Police Station, Kushma	PB16	28°13'29.30"N	83°41'47.90"E	848.3	Collapse	1	2	4,500	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB17	28°13'57.45"N	83°42'41.16"E	760.0	Collapse	1	1	7,200	0	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung		Damadi khola, Kushma	PB18	28°13'33.68"N	83°41'48.98"E	848.3	Flow	1	2	18,667	1	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung		Chuha landslide, Kushma	PB19	28°13'34.22"N	83°42'27.22"E	804.6	Collapse	2		1,000	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Ambot, Kushma	PB20	28°15'5.79"N	83°42'54.46"E	773.8	Collapse	2		800	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung	51+500	Paradi landslide, Kushma	PB21	28°14'20.24"N	83°42'39.22"E	744.8	Collapse	1	2	66,667	0	15	2,819	1,597	500	119,775	211,425
NH03	Pokhara- Baglung		Slope erosion, Kusma	PB22	28°14'16.09"N	83°42'38.69"E	735.6	Collapse	2		2,310	0	1	2,819	1,597	500	7,985	14,095
NH03	Pokhara- Baglung		Sundare khola, Kushma	PB23	28°14'2.95"N	83°42'35.63"E	761.3	Flow	1	2	16,973	1	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB24	28°13'57.72"N	83°42'41.03"E	782.0	Collapse	1	1	9,000	0	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB25	28°13'55.71"N	83°42'41.23"E	768.0	Collapse	1	1	5,500	0	5	2,819	1,597	500	39,925	70,475

Annex A-1. List of 216 sites

National Highway Code	Road Section	Chainage	Landslide Sites				Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L1*W1*D1/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)		
			Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation											Risk Index AADT	Risk Index AADT	
					Latitude (North)	Longitude (East)												Elevation (m)
											AAEP	AADT	AADT _{excl.}	DR	=AAEP*AADT _{excl.} *DR	=AAEP*AADT*DR		
NH03	Pokhara- Baglung		Ambot landslide, Kushma	PB26	28°15'38.75"N	83°43'13.93"E	782.7	Collapse	1	2	6,750	0	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung		Near lasting resort, Kushma	PB27	28°15'49.73"N	83°43'38.68"E	795.3	Collapse	1	2	5,600	0	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung		Patichaur, Kushma	PB29	28°16'23.85"N	83°44'28.34"E	851.5	Collapse	2		5,400	0	5	2,819	1,597	500	39,925	70,475
NH03	Pokhara- Baglung		Near Modi Khola Bridge, Kushma	PB30	28°16'25.71"N	83°44'29.40"E	885.8	Collapse	2		8,880	0	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung		Dinuwa, Kushma	PB31	28°16'43.12"N	83°44'50.49"E	851.2	Collapse	2		8,250	0	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung		Dinuwa (Mahabhir), Kushma	PB32	28°16'43.03"N	83°44'54.62"E	867.9	Collapse	2		5,333	0	10	2,819	1,597	500	79,850	140,950
NH03	Pokhara- Baglung	41+700	Nayapool 1, Kaski	PB33	28°17'55.04"N	83°46'17.26"E	1,047.2	Landslide	1	2	47,667	0	5	6,594	3,017	500	75,425	164,850
NH03	Pokhara- Baglung	41+600	Nayapool 2, Kaski	PB34	28°17'51.98"N	83°46'27.67"E	1,231.2	Carriageway Collapse	2		4,800	0	2	6,594	3,017	500	30,170	65,940
NH03	Pokhara- Baglung	38+000	Nayapool 3, Kaski	PB35	28°18'5.21"N	83°46'52.09"E	1,233.8	Carriageway Collapse	1	2	1,500	0	2	6,594	3,017	500	30,170	65,940
NH03	Pokhara- Baglung	37+900	Nayapool 4, Kaski	PB36	28°18'6.86"N	83°46'43.31"E	1,273.2	Landslide	1	2	125,000	0	10	6,594	3,017	500	150,850	329,700
NH03	Pokhara- Baglung	36+400	Nayapool 5, Kaski	PB37	28°18'5.30"N	83°47'4.31"E	1,625.4	Landslide	2		40,000	0	10	6,594	3,017	500	150,850	329,700
NH03	Pokhara- Baglung	26+200	Pandung, Kaski	PB38	28°17'9.04"N	83°49'59.17"E	1,610.0	Landslide	2		1,350,000	0	10	6,594	3,017	500	150,850	329,700
NH03	Pokhara- Baglung		Ghattekholo landslide, Kaski	PB39	28°17'12.83"N	83°51'39.70"E	1,172.2	Collapse	1	1	7,500	0	5	6,594	3,017	500	75,425	164,850
NH03	Pokhara- Baglung		Phedi 1, Kaski	PB40	28°17'15.70"N	83°51'55.69"E	1,137.9	Collapse	1	1	4,267	0	2	6,594	3,017	500	30,170	65,940
NH03	Pokhara- Baglung		Phedi 2, Kaski	PB41	28°17'16.67"N	83°51'59.56"E	1,124.2	Collapse	1	1	5,867	0	5	6,594	3,017	500	75,425	164,850
NH08	Pool Dada			NH08#1	27°16'5.33"N	87°12'38.20"E	276.7	Collapse	1	3	960	0	1	748	364	500	1,820	3,740
NH08	Sano Akkare			NH08#2a	27°13'51.29"N	87°13'39.31"E	267.3	Collapse	1	2	805	0	1	746	364	500	1,820	3,730
NH08	Sano Akkare			NH08#2b	27°13'42.22"N	87°13'44.00"E	249.4	Collapse	1	2	18,000	0	5	746	364	500	9,100	18,650
NH08	Thulo Akkare			NH08#3a	27°11'58.65"N	87°14'31.34"E	242.5	Collapse	2		233	0	1	746	364	500	1,820	3,730
NH08	Thulo Akkare			NH08#3b	27°11'52.33"N	87°14'51.95"E	232.7	Collapse	2		350	0	1	746	364	500	1,820	3,730
NH08	Kewa Besi			NH08#4	27°11'4.37"N	87°15'33.02"E	242.4	Collapse	2		1,500	0	1	746	364	500	1,820	3,730
NH08	Dhankuta			NH08#5	26°25'40.69"N	87°20'14.42"E	996.0	Collapse	1	2	200	0	1	746	364	500	1,820	3,730
NH08	Dhodeni			NH08#6a	26°57'33.31"N	87°19'23.98"E	661.7	Collapse	2		1,833	0	1	2498	1126	500	5,630	12,490
NH08	Dhodeni			NH08#6b	26°57'32.36"N	87°19'27.54"E	663.5	Collapse	2		1,833	0	1	2498	1126	500	5,630	12,490
NH08	Dhodeni			NH08#7	26°51'9.98"N	87°17'55.39"E	759.2	Collapse	2		1,042	0	1	4056	1691	485	8,201	19,672
NH08	Nisane Khola			NH08#8	26°50'54.96"N	87°18'1.38"E	688.6	Flow	1	4	8,000	0	10	4056	1691	485	82,014	196,716
NH08	Piluwa Khola			NH08#9	27°12'58.80"N	87°14'30.22"E	256.0	Collapse	2		2,083	0	1	746	364	500	1,820	3,730
NH25	Dumre-Besisahar-Chame	45+030		L8	28°15'14.20"N	84°22'6.93"E	756.0	Collapse	1	3	60,735	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	57+000		L9	28°19'17.29"N	84°23'57.35"E	991.0	Collapse	2		61,439	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	58+000		L10	28°19'44.97"N	84°23'54.81"E	953.0	Flow	2		125,000	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	58+880		L11	28°20'15.06"N	84°23'50.65"E	972.0	Collapse	2		50,000	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	61+100		L12	28°21'10.98"N	84°24'12.39"E	1,049.0	Collapse	2		17,000	0	20	3,931	1,673	500	167,300	393,100
NH25	Dumre-Besisahar-Chame	63+500		L13	28°22'29.07"N	84°24'6.76"E	1,086.0	Collapse	2		39,600	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	72+500		L14	28°26'4.81"N	84°23'31.62"E	1,357.0	Collapse	1	3	18,250	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	80+900		L15	28°29'19.60"N	84°21'55.40"E	1,695.0	Collapse	2		5,865	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	83+600		L16	28°30'25.81"N	84°21'27.51"E	1,797.0	Carriageway Collapse	2		5,000	1	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	85+400		L17	28°31'57.09"N	84°20'44.91"E	1,871.0	Collapse	1	2	17,767	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	88+200		L18	28°32'1.95"N	84°20'9.09"E	2,077.0	Collapse	2		1,461,500	0	10	3,931	1,673	500	83,650	196,550
NH25	Dumre-Besisahar-Chame	101+800		L19	28°33'3.07"N	84°15'18.11"E	2,599.0	Collapse	1	1	80,000	0	15	3,931	1,673	500	125,475	294,825
NH25	Dumre-Besisahar-Chame	62+500		L20	28°21'45.08"N	84°24'8.60"E	1,150.0	Collapse	2		12,500	0	20	3,931	1,673	500	167,300	393,100
NH25	Dumre-Besisahar-Chame	45+150		L21	28°15'23.26"N	84°22'0.56"E	776.0	Collapse	1	2	126,000	0	25	3,931	1,673	500	209,125	491,375
NH25	Dumre-Besisahar-Chame	32+800		L22	28°10'51.32"N	84°25'44.10"E	666.0	Collapse	1	2	58,067	0	10	3,931	1,673	500	83,650	196,550
NH34	Amiko Highway	114+100	Liping Bridge	AH01	27°58'9.83"N	85°57'33.91"E	1,677.1	Flow	2		3,750,000	0	20	1908	658	500	65,800	190,800
NH34	Amiko Highway	113+200	Near Kodari	AH02	27°57'38.05"N	85°57'24.34"E	1,576.0	Collapse	1	2	8,000	1	10	1908	658	500	32,900	95,400
NH34	Amiko Highway	111+600	Koplang Subsidence area	AH03	27°57'33.50"N	85°57'25.46"E	1,598.6	Collapse	1	1	3,500	1	2	1908	658	500	6,580	19,080
NH34	Amiko Highway	112+500	Ghatte Khola	AH04	27°57'23.54"N	85°57'15.92"E	1,545.2	Flow	2		10,000	1	10	1908	658	500	32,900	95,400
NH34	Amiko Highway	110+300	Damsite	AH05	27°56'24.46"N	85°56'43.55"E	1,417.4	Flow	2		45,500	1	30	1908	658	500	98,700	286,200
NH34	Amiko Highway	109+000	Larcha Bridge	AH06	27°55'55.60"N	85°56'12.43"E	1,357.9	Flow	2		166,667	1	25	1908	658	500	82,250	238,500
NH34	Amiko Highway		Near Bhansar Bridge	AH07	27°55'42.65"N	85°56'9.72"E	1,359.8	Collapse	2		10,000	0	10	1908	658	500	32,900	95,400
NH34	Amiko Highway	105+300	Hindi Area	AH08	27°54'16.15"N	85°55'9.40"E	1,319.5	Landslide	1	1	20,000	0	5	1908	658	500	16,450	47,700
NH34	Amiko Highway		Hindi Area	AH09	27°53'59.97"N	85°55'1.43"E	1,272.7	Collapse	1	1	1,250	0	2	1908	658	500	6,580	19,080
NH34	Amiko Highway		Hindi Area	AH10	27°53'58.58"N	85°54'58.84"E	1,279.6	Collapse	1	1	3,000	0	2	1908	658	500	6,580	19,080
NH34	Amiko Highway		Daklang	AH11	27°54'1.66"N	85°55'2.59"E	1,254.5	Collapse	1	2	5,700	0	10	1908	658	500	32,900	95,400

Annex A-1. List of 216 sites

National Highway Code	Road Section	Chainage	Landslide Sites				Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L1*W1*D1/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)		
			Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation											Risk Index AADT	Risk Index AADT	
					Latitude (North)	Longitude (East)												Elevation (m)
																=AAEP*AADT*DR	=AAEP*AADT*DR	
NH34	Armiko Highway		Near Kholsi	AH12	27°53'47.46"N	85°54'54.64"E	1,250.6	Collapse	1	2	6,300	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		About 50m ahead Kholsi	AH13	27°53'44.31"N	85°54'54.22"E	1,238.8	Collapse	1	2	11,000	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		Gully erosion+ Side bank erosion	AH14	27°53'32.78"N	85°54'52.93"E	1,253.8	Collapse	1	2	13,300	0	5	1908	658	500	16,450	47,700
NH34	Armiko Highway		Chaku Khola	AH15	27°52'57.52"N	85°54'46.79"E	1,172.9	Collapse	1	2	13,417	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		Another slide near Chaku Khola	AH16	27°52'55.40"N	85°54'41.33"E	1,151.2	Collapse	2		17,158	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		Mahabhir	AH17	27°52'38.68"N	85°54'3.69"E	1,150.6	Collapse	2		6,400	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		Side Gulkote Pahiro	AH18	27°52'33.53"N	85°53'53.97"E	1,124.2	Collapse	1	4	7,200	0	5	1908	658	500	16,450	47,700
NH34	Armiko Highway		Bahrabise landslide	AH19	27°47'9.76"N	85°53'58.80"E	818.4	Collapse	1	1	1,500,000	0	15	1908	658	500	49,350	143,100
NH34	Armiko Highway		Main Gulkote Pahiro	AH20	27°52'34.07"N	85°53'51.59"E	1,124.7	Collapse	1	2	166,667	0	5	1908	658	500	16,450	47,700
NH34	Armiko Highway		Near Hydro Camp	AH21	27°50'35.77"N	85°52'49.70"E	956.1	Collapse	1	4	35,000	0	5	1908	658	500	16,450	47,700
NH34	Armiko Highway		Balefi landslide	AH22	27°43'46.96"N	85°46'44.86"E	642.1	Collapse	1	3	37,500	0	10	4199	2233	226	50,466	94,897
NH34	Armiko Highway		Wall Crack at Near Balefi Bazar	AH23	27°44'4.57"N	85°46'56.93"E	650.3	Landslide	1	1	8,000	1	5	4199	2233	226	25,233	47,449
NH34	Armiko Highway		Creeping at Near Balefi Bazar	AH24	27°44'5.75"N	85°46'59.68"E	652.7	Landslide	1	2	21,000	1	5	4199	2233	226	25,233	47,449
NH34	Armiko Highway		Jure landslide	AH25	27°45'49.52"N	85°52'26.04"E	787.9	Collapse	1	3	1,091,667	1	20	1908	658	500	65,800	190,800
NH34	Armiko Highway		Subsidence area3	AH26	27°46'32.24"N	85°53'17.65"E	837.3	Landslide	1	2	7,000	0	5	1908	658	500	16,450	47,700
NH34	Armiko Highway		Subsidence area4	AH27	27°46'49.36"N	85°53'34.09"E	837.3	Landslide	1	2	2,432,000	0	10	1908	658	500	32,900	95,400
NH34	Armiko Highway		Subsidence area5	AH28	27°44'27.82"N	85°48'1.13"E	696.6	Collapse	2		26,667	0	5	4199	2233	226	25,233	47,449
NH34	Armiko Highway		Subsidence area6	AH29	27°44'19.98"N	85°47'53.57"E	698.4	Collapse	2		8,000	1	5	4199	2233	226	25,233	47,449
NH34	Armiko Highway		Subsidence area7	AH30	27°44'14.26"N	85°47'46.18"E	708.3	Collapse	2		3,150	1	1	4199	2233	226	5,047	9,490
NH34	Armiko Highway		Chehere landslide	AH31	27°40'28.37"N	85°43'49.48"E	584.1	Collapse	2		333	0	2	4199	2233	226	10,093	18,979
NH34	Armiko Highway		Simle	AH32	27°39'35.42"N	85°42'56.22"E	672.2	Collapse	2		2,333	0	1	4199	2233	226	5,047	9,490
NH34	Armiko Highway		Near Dolalghat	AH33	27°38'57.97"N	85°41'8.98"E	636.8	Collapse	2		5,167	0	5	4199	2233	226	25,233	47,449
NH34	Armiko Highway	37+500	Dhulikhel Khawa	AH34	27°37'51.86"N	85°36'8.36"E	1,052.8	Collapse	2		2,730	0	1	9495	5534	500	27,670	47,475
NH37	Kanti Highway	74+800		K1	27°33'26.06"N	85°18'5.56"E	1,726.0	Collapse	2		7,055	0	10	3914	2,307	152	35,070	59,493
NH37	Kanti Highway	72+800		K2	27°32'58.05"N	85°17'50.96"E	1,865.0	Collapse	2		12,125	0	10	3914	2,307	152	35,070	59,493
NH37	Kanti Highway	69+365		K3	27°31'46.08"N	85°17'36.34"E	1,925.0	Collapse	2		44,000	0	10	3914	2,307	152	35,070	59,493
NH37	Kanti Highway	66+565		K4	27°31'29.07"N	85°17'11.65"E	1,741.0	Collapse	2		142,497	0	10	3914	2,307	152	35,070	59,493
NH37	Kanti Highway	63+885		K5	27°30'30.29"N	85°17'50.08"E	1,568.0	Collapse	2		18,957	0	20	3914	2,307	152	70,140	118,986
NH37	Kanti Highway	61+627		K6	27°30'15.21"N	85°17'45.26"E	1,481.0	Collapse	2		58,320	0	5	3914	2,307	152	17,535	29,746
NH37	Kanti Highway	56+420		K7	27°29'27.25"N	85°16'28.52"E	1,177.0	Slide	1	2	21,900	0	20	3914	2,307	152	70,140	118,986
NH37	Kanti Highway	46+000		K8	27°28'3.27"N	85°15'12.61"E	934.0	Collapse	2		98,000	0	15	3131	1,846	152	42,081	71,387
NH37	Kanti Highway	42+000		K9	27°26'56.12"N	85°14'24.21"E	1,152.0	Slide	2		196,000	0	20	3131	1,846	152	56,108	95,182
NH37	Kanti Highway	36+300		K10	27°25'34.56"N	85°14'3.72"E	1,078.0	Collapse	2		9,960	0	10	3131	1,846	152	28,054	47,591
NH37	Kanti Highway	32+200		K11	27°25'42.70"N	85°13'6.13"E	850.0	Landslide	2		10,833	0	10	3131	1,846	152	28,054	47,591
NH37	Kanti Highway	25+700		K12	27°25'38.55"N	85°12'10.07"E	944.0	Collapse	2		7,583	0	15	3131	1,846	152	42,081	71,387
NH37	Kanti Highway	25+500		K13	27°25'42.20"N	85°11'54.15"E	981.0	Landslide	2		8,000	0	5	3131	1,846	152	14,027	23,796
NH41	Hetauda-Sim Bhanjyang	127+900		T1	27°27'45.74"N	85° 2'33.40"E	554.0	Landslide	1	2	1,583	0	2	5754	3038	154	9,357	17,722
NH41	Hetauda-Sim Bhanjyang	121+800		T2	27°30'12.88"N	85° 2'51.46"E	597.0	Collapse	2		1,144	0	1	5754	3038	154	4,679	8,861
NH41	Hetauda-Sim Bhanjyang	112+800		T3	27°31'59.79"N	85° 2'30.22"E	930.0	Collapse	1	1	1,500	0	1	5754	3038	154	4,679	8,861
NH41	Hetauda-Sim Bhanjyang	109+500		T4	27°32'6.43"N	85° 2'9.27"E	1,091.0	Landslide	2		5,500	0	5	5754	3038	154	23,393	44,306
NH41	Sim Bhanjyang - Plaung-Tistung	57+000		T5	27°39'35.22"N	85° 5'58.69"E	1,978.0	Collapse	2		20,000	0	5	748	354	74.7	1,322	2,794
NH41	Sim Bhanjyang - Plaung-Tistung	54+500		T6	27°40'17.16"N	85° 5'48.68"E	1,968.0	Collapse	2		480	0	2	748	354	74.7	529	1,118
NH41	Sim Bhanjyang - Plaung-Tistung	51+ 500		T7	27°40'53.28"N	85° 5'1.79"E	1,814.0	Collapse	1	3	3,400	0	2	748	354	74.7	529	1,118
NH41	Palung - Tistung- Naubise	50+100		T8	27°41'12.26"N	85° 5'28.09"E	1,740.0	Collapse	1	2	1,250	1	1	748	354	74.7	264	559
NH41	Palung - Tistung- Naubise	44+200		T9	27°41'59.03"N	85° 5'46.01"E	1,572.0	Collapse	2		5,250	1	5	748	354	74.7	1,322	2,794
NH41	Palung - Tistung- Naubise	31+500		T10	27°43'16.37"N	85° 6'47.35"E	1,111.0	Collapse	1	3	5,333	0	5	748	354	74.7	1,322	2,794
NH44	Narayanghat-Mugling	21+300	Dobhan (Seti & Trisuli)	L1	27°49'9.80"N	84°27'14.20"E	238.0	Collapse	1	1	2,125	0	4	9,692	7,607	500	152,140	193,840
NH44	Narayanghat-Mugling	21+500	Marui Bridge	L2	27°49'3.74"N	84°27'46.35"E	232.0	Flow	1	1	25,000	0	25	9,692	7,607	500	950,875	1,211,500
NH44	Narayanghat-Mugling	15+100	Bhangadi	L3	27°46'50.94"N	84°26'16.75"E	199.0	Collapse	1	1	5,350	0	20	9,692	7,607	500	760,700	969,200
NH44	Narayanghat-Mugling	16+000	Dasdhunga	L4	27°47'50.91"N	84°25'54.00"E	209.0	Carriageway Collapse	1	3	820	0	4	9,692	7,607	500	152,140	193,840
NH44	Narayanghat-Mugling	20+000	Gaighat	L5	27°48'43.06"N	84°26'1.59"E	200.0	Flow	1	2	200	0	3	9,692	7,607	500	114,105	145,380
NH44	Narayanghat-Mugling	26+500		L6	27°49'4.33"N	84°30'15.63"E	259.0	Carriageway Collapse	1	4	7,000	0	10	9,692	7,607	500	380,350	484,600
NH44	Narayanghat-Mugling	33+000	Nyanse River	L7	27°49'50.46"N	84°32'48.64"E	255.0	Collapse	1	1	13,120	0	15	9,692	7,607	500	570,525	726,900

Annex A-1. List of 216 sites

National Highway Code	Road Section	Chainage	Landslide Sites				Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L1*W1*D1/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)		
			Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation											Risk Index AADT	Risk Index AADT	
					Latitude (North)	Longitude (East)												Elevation (m)
											AAEP	AADT	AADT	DR	=AAEP*AADT*DR	=AAEP*AADT*DR		
NH44	Narayanghat-Mugling	33+500	Tuin Khola	L23	27°50'33.88"N	84°33'31.29"E	298.0	Collapse	2		11,117	0	5	9,692	7,607	500	190,175	242,300
NH44	Narayanghat-Mugling	32+500	Kali Khola	L24	27°49'59.47"N	84°33'8.11"E	262.0	Collapse	2		20,000	0	10	9,692	7,607	500	380,350	484,600
NH44	Narayanghat-Mugling	31+400	Namshi khola	L25	27°49'57.88"N	84°31'37.33"E	403.0	Collapse	1	3	5,600	0	20	9,692	7,607	500	760,700	969,200
NH44	Narayanghat-Mugling	33+800	Tuin khola	L26	27°50'08.55"N	84°33'23.41"E	336.0	Collapse	2		14,000	0	10	9,692	7,607	500	380,350	484,600
NH47	Siddhartha Highway		Siddhababa area	SH01	27°43'29.58"N	83°28'9.51"E	201.5	Collapse	1	3	32,375	0	20	15,845	7,211	366	527,845	1,159,854
NH47	Siddhartha Highway		Near Siddhababa area	SH02	27°44'28.89"N	83°27'52.39"E	215.0	Collapse	1	1	333	0	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway	35+500	Jhumsa Idsl	SH03	27°45'4.90"N	83°30'4.61"E	299.0	Collapse	1	2	18,012	1	30	15,845	7,211	366	791,768	1,739,781
NH47	Siddhartha Highway			SH04	27°45'9.95"N	83°30'24.90"E	331.2	Collapse	2		100	1	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway	38+000		SH05	27°45'14.78"N	83°30'48.88"E	371.0	Collapse	2		6,600	0	15	15,845	7,211	366	395,884	869,891
NH47	Siddhartha Highway	39+500	Hiyeude khola	SH06	27°46'2.50"N	83°31'16.94"E	452.3	Flow	1	4	20,833	0	25	15,845	7,211	366	659,807	1,449,818
NH47	Siddhartha Highway	39+600	Near Hiyeude khola	SH07	27°46'0.80"N	83°31'21.43"E	475.0	Collapse	2		6,000	1	5	15,845	7,211	366	131,961	289,964
NH47	Siddhartha Highway		Charchare	SH08	27°47'43.62"N	83°32'9.44"E	584.1	Carriageway Collapse	2		250	0	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway	46+400	Near Charchare	SH09	27°47'45.91"N	83°32'6.32"E	605.3	Collapse	2		8,400	0	5	15,845	7,211	366	131,961	289,964
NH47	Siddhartha Highway	48+600	Near Dumre Bazar	SH10	27°47'55.51"N	83°31'33.56"E	645.0	Collapse	2		15,000	0	20	15,845	7,211	366	527,845	1,159,854
NH47	Siddhartha Highway		Dumre	SH11	27°47'52.95"N	83°31'9.25"E	637.4	Collapse	2		1,600	0	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway	49+800	Lower Dumre	SH12	27°48'1.78"N	83°30'56.25"E	635.6	Collapse	1	3	17,000	1	5	15,845	7,211	366	131,961	289,964
NH47	Siddhartha Highway	56+000	5km down from Bartung Bazar	SH13	27°51'4.55"N	83°33'22.24"E	960.6	Collapse	2		5,885	0	15	15,845	7,211	366	395,884	869,891
NH47	Siddhartha Highway	56+200	4.8km down from Bartung Bazar	SH14	27°51'6.90"N	83°33'17.09"E	960.1	Collapse	1	1	9,333	1	15	15,845	7,211	366	395,884	869,891
NH47	Siddhartha Highway		Aryabhanjyang	SH15	27°51'6.16"N	83°36'48.65"E	1,053.5	Collapse	2		400	0	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway		Near Aryabhanjyang(towards Walin)	SH16	27°50'58.87"N	83°37'32.34"E	1,048.7	Collapse	2		50	0	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway		100m down Aryabhanjyang	SH17	27°51'0.50"N	83°38'1.05"E	975.9	Collapse	2		105	1	1	15,845	7,211	366	26,392	57,993
NH47	Siddhartha Highway	87+400	Ramdi -1	SH18	27°54'10.61"N	83°38'3.31"E	429.9	Landslide	2		20,000	1	15	15,845	7,211	366	395,884	869,891
NH47	Siddhartha Highway		On the way to Palpa from Butwal	SH19	27°51'20.09"N	83°38'13.48"E	813.0	Collapse	2		67	0	1	2,370	1,242	500	6,210	11,850
NH47	Siddhartha Highway		Kerabari	SH20	27°46'2.79"N	83°31'38.17"E	494.1	Flow	2		81,667	0	10	2,370	1,242	500	62,100	118,500
NH47	Siddhartha Highway		Siddhababa area	SH21	27°44'15.26"N	83°27'54.51"E	228.0	Collapse	2		7,200	0	15	2,370	1,242	82	15,202	29,009
NH47	Siddhartha Highway		Siddhababa area	SH22	27°44'19.33"N	83°27'53.65"E	247.1	Collapse	1	1	300	0	2	2,370	1,242	82	2,027	3,868
NH47	Siddhartha Highway		Dovan landslide	SH23	27°44'45.50"N	83°27'48.86"E	257.8	Collapse	1	1	200	0	1	2,370	1,242	82	1,013	1,934
NH47	Siddhartha Highway		Erosion	SH24	27°45'14.78"N	83°30'25.57"E	900.8	Flow	1	1	1,000	0	6	2,370	1,242	82	6,081	11,604
NH47	Siddhartha Highway		Birauta	SH25	27°51'15.85"N	83°37'58.46"E	813.0	Collapse	2		2,133	1	1	2,370	1,242	82	1,013	1,934
NH47	Siddhartha Highway		Way to Ramdi 1	SH26	27°52'33.20"N	83°38'41.40"E	884.3	Collapse	1	2	9,160	0	10	2,370	1,242	82	10,135	19,339
NH47	Siddhartha Highway		Way to Ramdi2	SH27	27°52'50.16"N	83°38'37.57"E	542.3	Flow	1	2	5,000	0	10	2,370	1,242	82	10,135	19,339
NH47	Siddhartha Highway		Near Ramdi landslide	SH28	27°54'0.82"N	83°37'52.49"E	507.5	Collapse	1	1	1,380	0	5	3,277	1,591	390	31,025	63,902
NH47	Siddhartha Highway		Kaligandaki	SH29	27°54'15.63"N	83°39'0.61"E	345.4	Collapse	1	3	1,020	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 46	SH30	27°54'33.76"N	83°39'20.80"E	382.4	Flow	1	2	6,000	1	5	3,277	1,591	390	31,025	63,902
NH47	Siddhartha Highway		Mark 47	SH31	27°55'22.51"N	83°39'3.51"E	459.7	Collapse	2		123	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 48	SH32	27°55'41.41"N	83°39'13.52"E	524.2	Collapse	2		300	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 49	SH33	27°55'39.56"N	83°39'44.03"E	737.6	Collapse	1	1	1,140	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 50	SH34	27°57'0.49"N	83°41'14.24"E	679.8	Collapse	1	2	2,333	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 51	SH35	27°57'16.08"N	83°42'35.81"E	731.1	Collapse	2		368	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 52	SH36	27°57'14.32"N	83°42'31.00"E	726.2	Collapse	2		800	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 53 (Towards Walin from Butwa	SH37	27°58'19.94"N	83°43'1.48"E	734.9	Collapse	1	1	7,482	0	2	3,277	1,591	390	12,410	25,561
NH47	Siddhartha Highway		Mark 54	SH38	27°58'23.13"N	83°43'22.46"E	721.7	Collapse	2		480	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 55	SH39	27°58'22.25"N	83°43'22.74"E	682.3	Collapse	1	1	331	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 56	SH40	27°58'21.99"N	83°43'24.33"E	684.7	Collapse	1	1	27	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 57	SH41	27°58'19.75"N	83°43'27.70"E	686.9	Collapse	2		250	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 58	SH42	27°58'17.30"N	83°43'34.40"E	689.3	Collapse	2		3,088	0	2	3,277	1,591	390	12,410	25,561
NH47	Siddhartha Highway		Mark 59 (Towards Walin from Butwa	SH43	27°58'18.23"N	83°44'20.08"E	687.9	Collapse	1	1	2,467	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 61 (Towards Walin from Butwa	SH44	27°58'18.99"N	83°44'37.81"E	706.7	Collapse	2		35,500	0	10	3,277	1,591	390	62,049	127,803
NH47	Siddhartha Highway		Mark 62	SH45	27°59'6.35"N	83°45'57.95"E	706.2	Collapse	1	1	3,533	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 63	SH46	27°59'16.15"N	83°46'26.77"E	679.6	Collapse	2		3,750	0	1	3,277	1,591	390	6,205	12,780
NH47	Siddhartha Highway		Mark 65	SH47	27°59'42.96"N	83°46'50.78"E	687.0	Collapse	2		1,500	0	1	3,277	1,591	320	5,091	10,486
NH47	Siddhartha Highway		Mark 66	SH48	27°59'54.04"N	83°47'1.34"E	708.1	Collapse	2		1,100	0	1	3,277	1,591	320	5,091	10,486
NH47	Siddhartha Highway		Mark 67	SH49	28° 0'6.28"N	83°46'55.13"E	696.9	Collapse	1	2	17,500	0	10	3,277	1,591	320	50,912	104,864

A.2. Risk index ranking

Annex A-2. Risk index ranking

Risk Index Ranking	Landslide Sites								Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D1/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	Ancillary Risk Index (2021/22)
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation													
						Latitude (North)	Longitude (East)	Elevation (m)											
	AAEP	AADT	AADT _{emc}	DR	=AAEP*AADT _{emc} *D	=AAEP*AADT*DR													
1	NH44	Narayanghat-Mugling	21+500	Mauri Bridge	L2	27°49'3.74"N	84°27'46.35"E	232.0	Flow	1	25,000	0	25	9,692	7,607	500	950,875	1,211,500	
2	NH47	Siddhartha Highway	35+500	Jhumsa	SH03	27°45'4.90"N	83°30'4.61"E	299.0	Slide	1	18,012	1	30	15,845	7,211	366	791,768	1,739,781	
3	NH44	Narayanghat-Mugling	15+100	Bhangadi	L3	27°46'50.94"N	84°26'16.75"E	199.0	Collapse	1	5,350	0	20	9,692	7,607	500	760,700	969,200	
4	NH44	Narayanghat-Mugling	31+400	Namshi khola	L25	27°49'57.88"N	84°31'37.33"E	403.0	Collapse	1	5,600	0	20	9,692	7,607	500	760,700	969,200	
5	NH47	Siddhartha Highway	39+500	Hiyende khola	SH06	27°46'2.50"N	83°31'16.94"E	452.3	Flow	1	20,833	0	25	15,845	7,211	366	659,807	1,449,818	
6	NH44	Narayanghat-Mugling	33+000	Nyanse River	L7	27°49'50.46"N	84°32'48.64"E	255.0	Collapse	1	13,120	0	15	9,692	7,607	500	570,525	726,900	
7	NH47	Siddhartha Highway		Siddhababa area	SH01	27°43'29.58"N	83°28'9.51"E	201.5	Collapse	1	32,375	0	20	15,845	7,211	366	527,845	1,159,854	
8	NH47	Siddhartha Highway	48+600	Near Dumre Bazar	SH10	27°47'55.51"N	83°31'33.56"E	645.0	Collapse	2	15,000	0	20	15,845	7,211	366	527,845	1,159,854	
9	NH47	Siddhartha Highway	38+000		SH05	27°45'14.78"N	83°30'48.88"E	371.0	Collapse	2	6,600	0	15	15,845	7,211	366	395,884	869,891	
10	NH47	Siddhartha Highway	56+000	5km down from Bartung Bazar	SH13	27°51'4.55"N	83°33'22.24"E	960.6	Slide	2	5,885	0	15	15,845	7,211	366	395,884	869,891	
11	NH47	Siddhartha Highway	56+200	4.8km down from Bartung Bazar	SH14	27°51'6.90"N	83°33'17.09"E	960.1	Slide	1	9,333	1	15	15,845	7,211	366	395,884	869,891	
12	NH47	Siddhartha Highway	87+400	Ramdi -1	SH18	27°54'10.61"N	83°38'3.31"E	429.9	Collapse	2	20,000	1	15	15,845	7,211	366	395,884	869,891	
13	NH44	Narayanghat-Mugling	26+500		L6	27°49'4.33"N	84°30'15.63"E	259.0	Carriageway Collapse	1	7,000	0	10	9,692	7,607	500	380,350	484,600	
14	NH44	Narayanghat-Mugling	32+500	Kali Khola	L24	27°49'59.47"N	84°33'8.11"E	262.0	Collapse	2	20,000	0	10	9,692	7,607	500	380,350	484,600	
15	NH44	Narayanghat-Mugling	33+800	Tuin khola	L26	27°50'08.55"N	84°33'23.41"E	336.0	Collapse	2	14,000	0	10	9,692	7,607	500	380,350	484,600	
16	NH25	Dumre-Besisahar-Chame	45+150		L21	28°15'23.26"N	84°22'0.56"E	776.0	Collapse	1	126,000	0	25	3,931	1,673	500	209,125	491,375	
17	NH44	Narayanghat-Mugling	33+500	Tuin Khola	L23	27°50'33.88"N	84°33'31.29"E	298.0	Collapse	2	11,117	0	5	9,692	7,607	500	190,175	242,300	
18	NH25	Dumre-Besisahar-Chame	61+100		L12	28°21'10.98"N	84°24'12.39"E	1,049.0	Collapse	2	17,000	0	20	3,931	1,673	500	167,300	393,100	
19	NH25	Dumre-Besisahar-Chame	62+500		L20	28°21'45.08"N	84°24'8.60"E	1,150.0	Collapse	2	12,500	0	20	3,931	1,673	500	167,300	393,100	
20	NH03	Pokhara- Baglung	58+700	Nayapool Flow, Kushma	PB03	28°14'43.96"N	83°38'14.98"E	692.9	Flow	1	87,780	1	20	2,819	1,597	500	159,700	281,900	
21	NH03	Pokhara- Baglung	57+400	Armadi 1, Kushma	PB04	28°14'24.47"N	83°38'47.42"E	721.0	Collapse	2	1,085	1	20	2,819	1,597	500	159,700	281,900	
22	NH03	Pokhara- Baglung	52+500	Damdare khola, Kushuma	PB11	28°13'43.64"N	83°40'38.53"E	868.4	Flow	1	31,680	1	20	2,819	1,597	500	159,700	281,900	
23	NH44	Narayanghat-Mugling	21+300	Dobhan (Seti & Trisuli)	L1	27°49'9.80"N	84°27'14.20"E	238.0	Collapse	1	2,125	0	4	9,692	7,607	500	152,140	193,840	
24	NH44	Narayanghat-Mugling	16+000	Dasdhunga	L4	27°47'50.91"N	84°25'54.00"E	209.0	Carriageway Collapse	1	820	0	4	9,692	7,607	500	152,140	193,840	
25	NH03	Pokhara- Baglung	37+900	Nayapool 4, Kaski	PB36	28°18'6.86"N	83°46'43.31"E	1,273.2	Slide	1	125,000	0	10	6,594	3,017	500	150,850	329,700	
26	NH03	Pokhara- Baglung	36+400	Nayapool 5, Kaski	PB37	28°18'5.30"N	83°47'4.31"E	1,625.4	Slide	2	40,000	0	10	6,594	3,017	500	150,850	329,700	
27	NH03	Pokhara- Baglung	26+200	Pandung, Kaski	PB38	28°17'9.04"N	83°49'59.17"E	1,610.0	Slide	2	1,350,000	0	10	6,594	3,017	500	150,850	329,700	
28	NH47	Siddhartha Highway	39+600	Near Hiyende khola	SH07	27°46'0.80"N	83°31'21.43"E	475.0	Collapse	2	6,000	1	5	15,845	7,211	366	131,961	289,964	
29	NH47	Siddhartha Highway	46+400	Near Charchare	SH09	27°47'45.91"N	83°32'6.32"E	605.3	Collapse	2	8,400	0	5	15,845	7,211	366	131,961	289,964	
30	NH47	Siddhartha Highway	49+800	Lower Dumre	SH12	27°48'1.78"N	83°30'56.25"E	635.6	Slide	1	17,000	1	5	15,845	7,211	366	131,961	289,964	
31	NH25	Dumre-Besisahar-Chame	101+800		L19	28°33'3.07"N	84°15'18.11"E	2,599.0	Collapse	1	80,000	0	15	3,931	1,673	500	125,475	294,825	
32	NH03	Pokhara- Baglung	58+700	Saharshadhara 2, Kushma	PB02	28°14'51.04"N	83°38'0.61"E	684.7	Collapse	1	14,405	1	15	2,819	1,597	500	119,775	211,425	
33	NH03	Pokhara- Baglung	51+500	Paradi Slide, Kushma	PB21	28°14'20.24"N	83°42'39.22"E	744.8	Collapse	1	66,667	0	15	2,819	1,597	500	119,775	211,425	
34	NH44	Narayanghat-Mugling	20+000	Gaighat	L5	27°48'43.06"N	84°26'1.59"E	200.0	Flow	1	200	0	3	9,692	7,607	500	114,105	145,380	
35	NH34	Araniko Highway	110+300	Damsite	AH05	27°56'24.46"N	85°56'43.55"E	1,417.4	Flow	2	45,500	1	30	1,908	658	500	98,700	286,200	
36	NH02	Golkharka-Rajduwali			NH02#5	26°53'4.7"N	87°55'34.75"E	502.6	Slide	1	750,000	1	10	3,531	1,825	500	91,250	176,550	
37	NH02	Kanchhi Dokan			NH02#1	27°5'24.07"N	87°47'23.46"E	2,202.6	Flow	2	7,575	1	15	2,523	1,145	500	85,875	189,225	
38	NH02	Pangre ko bhir			NH02#3	27°3'2.62"N	87°48'43.84"E	2,127.9	Collapse	2	13,650	0	15	2,523	1,145	500	85,875	189,225	
39	NH25	Dumre-Besisahar-Chame	45+030		L8	28°15'14.20"N	84°22'6.93"E	756.0	Collapse	1	60,735	0	10	3,931	1,673	500	83,650	196,550	
40	NH25	Dumre-Besisahar-Chame	57+000		L9	28°19'17.29"N	84°23'57.35"E	991.0	Collapse	2	61,439	0	10	3,931	1,673	500	83,650	196,550	
41	NH25	Dumre-Besisahar-Chame	58+000		L10	28°19'44.97"N	84°23'54.81"E	953.0	Flow	2	125,000	0	10	3,931	1,673	500	83,650	196,550	
42	NH25	Dumre-Besisahar-Chame	58+880		L11	28°20'15.06"N	84°23'50.65"E	972.0	Collapse	2	50,000	0	10	3,931	1,673	500	83,650	196,550	
43	NH25	Dumre-Besisahar-Chame	63+500		L13	28°22'29.07"N	84°24'6.76"E	1,086.0	Collapse	2	39,600	0	10	3,931	1,673	500	83,650	196,550	
44	NH25	Dumre-Besisahar-Chame	72+500		L14	28°26'4.81"N	84°23'31.62"E	1,357.0	Collapse	1	18,250	0	10	3,931	1,673	500	83,650	196,550	
45	NH25	Dumre-Besisahar-Chame	80+900		L15	28°29'19.60"N	84°21'55.40"E	1,695.0	Collapse	2	5,865	0	10	3,931	1,673	500	83,650	196,550	
46	NH25	Dumre-Besisahar-Chame	83+600		L16	28°30'25.81"N	84°21'27.51"E	1,797.0	Carriageway Collapse	2	5,000	1	10	3,931	1,673	500	83,650	196,550	
47	NH25	Dumre-Besisahar-Chame	85+400		L17	28°31'57.09"N	84°20'44.91"E	1,871.0	Collapse	1	17,767	0	10	3,931	1,673	500	83,650	196,550	
48	NH25	Dumre-Besisahar-Chame	88+200		L18	28°32'1.95"N	84°20'9.09"E	2,077.0	Collapse	2	1,461,500	0	10	3,931	1,673	500	83,650	196,550	
49	NH25	Dumre-Besisahar-Chame	32+800		L22	28°10'51.32"N	84°25'44.10"E	666.0	Collapse	1	58,067	0	10	3,931	1,673	500	83,650	196,550	
50	NH34	Arniko Highway	109+000	Larcha Bridge	AH06	27°55'55.60"N	85°56'12.43"E	1,357.9	Flow	2	166,667	1	25	1,908	658	500	82,250	238,500	

Risk Index Ranking	Landslide Sites																	Risk Index (2021/22)	Ancillary Risk Index (2021/22)
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation			Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1=Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)		
						AAEP	AADT	AADT _{exc}						DR	=AAEP*AADT _{exc} *D	=AAEP*AADT*DR			
51	NH08	Nisane Khola			NH08#8	26°50'54.96"N	87°18'1.38"E	688.6	Flow	1	4	8,000	0	10	4056	1691	485	82,014	196,716
52	NH03	Pokhara- Baglung	58+700	Saharshadhara 1, Kushma	PB01	28°14'49.80"N	83°38'4.75"E	699.6	Collapse	1	1	5,918	0	10	2,819	1,597	500	79,850	140,950
53	NH03	Pokhara- Baglung		Damadi khola, Kushma	PB18	28°13'33.68"N	83°41'48.98"E	848.3	Flow	1	2	18,667	1	10	2,819	1,597	500	79,850	140,950
54	NH03	Pokhara- Baglung		Sundare khola, Kushma	PB23	28°14'2.95"N	83°42'35.63"E	761.3	Flow	1	2	16,973	1	10	2,819	1,597	500	79,850	140,950
55	NH03	Pokhara- Baglung		Near Modi Khola Bridge, Kushma	PB30	28°16'25.71"N	83°44'29.40"E	885.8	Collapse	2		8,880	0	10	2,819	1,597	500	79,850	140,950
56	NH03	Pokhara- Baglung		Dinuwa, Kushma	PB31	28°16'43.12"N	83°44'50.49"E	851.2	Collapse	2		8,250	0	10	2,819	1,597	500	79,850	140,950
57	NH03	Pokhara- Baglung		Dinuwa (Mahabhir), Kushma	PB32	28°16'43.03"N	83°44'54.62"E	867.9	Collapse	2		5,333	0	10	2,819	1,597	500	79,850	140,950
58	NH47	Siddhartha Highway		Mark 74(Bhalupahad)	SH54	28° 8'29.39"N	83°51'42.89"E	979.0	Collapse	2		5,200	0	15	3,277	1,591	320	76,368	157,296
59	NH03	Pokhara- Baglung	41+700	Nayapool 1, Kaski	PB33	28°17'55.04"N	83°46'17.26"E	1,047.2	Slide	1	2	47,667	0	5	6,594	3,017	500	75,425	164,850
60	NH03	Pokhara- Baglung		Ghattekhol Slide, Kaski	PB39	28°17'12.83"N	83°51'39.70"E	1,172.2	Collapse	1	1	7,500	0	5	6,594	3,017	500	75,425	164,850
61	NH03	Pokhara- Baglung		Phedi 2, Kaski	PB41	28°17'16.67"N	83°51'59.56"E	1,124.2	Collapse	1	1	5,867	0	5	6,594	3,017	500	75,425	164,850
62	NH37	Kanti Highway	63+885		K5	27°30'30.29"N	85°17'50.08"E	1,568.0	Collapse	2		18,957	0	20	3914	2,307	152	70,140	118,986
63	NH37	Kanti Highway	56+420		K7	27°29'27.25"N	85°16'28.52"E	1,177.0	Slide	1	2	21,900	0	20	3914	2,307	152	70,140	118,986
64	NH34	Arniko Highway	114+100	Liping Bridge	AH01	27°58'9.83"N	85°57'33.91"E	1,677.1	Flow	2		3,750,000	0	20	1908	658	500	65,800	190,800
65	NH34	Arniko Highway		Jure Slide	AH25	27°45'49.52"N	85°52'26.04"E	787.9	Collapse	1	3	1,091,667	1	20	1908	658	500	65,800	190,800
66	NH47	Siddhartha Highway		Kerabari	SH20	27°46'2.79"N	83°31'38.17"E	494.1	Flow	2		81,667	0	10	2,370	1,242	500	62,100	118,500
67	NH47	Siddhartha Highway		Mark 61 (Towards Walin from Butwal)	SH44	27°58'18.99"N	83°44'37.81"E	706.7	Collapse	2		35,500	0	10	3,277	1,591	390	62,049	127,803
68	NH37	Kanti Highway	42+000		K9	27°26'56.12"N	85°14'24.21"E	1,152.0	Slide	2		196,000	0	20	3131	1,846	152	56,108	95,182
69	NH47	Siddhartha Highway		Mark 67	SH49	28° 0'6.28"N	83°46'55.13"E	696.9	Collapse	1	2	17,500	0	10	3131	1,591	320	50,912	100,192
70	NH47	Siddhartha Highway		Mark 70 (the way to Pokhara from Syangja)	SH50	28° 7'36.94"N	83°52'4.03"E	959.4	Collapse	1	1	10,200	0	10	3,277	1,591	320	50,912	104,864
71	NH34	Arniko Highway		Balefi Slide	AH22	27°43'46.96"N	85°46'44.86"E	642.1	Collapse	1	3	37,500	0	10	4199	2233	226	50,466	94,897
72	NH34	Arniko Highway		Baharise Slide	AH19	27°47'9.76"N	85°53'58.80"E	818.4	Collapse	1	1	1,500,000	0	15	1908	658	500	49,350	143,100
73	NH37	Kanti Highway	46+000		K8	27°28'3.27"N	85°15'12.61"E	934.0	Collapse	2		98,000	0	15	3131	1,846	152	42,081	71,387
74	NH37	Kanti Highway	25+700		K12	27°25'38.55"N	85°12'10.07"E	944.0	Collapse	2		7,583	0	15	3131	1,846	152	42,081	71,387
75	NH03	Pokhara- Baglung	53+400	Gupteshwar Campus area, Kushuma	PB10	28°13'58.19"N	83°40'11.35"E	847.3	Carriageway Collapse	1	2	10,400	1	5	2,819	1,597	500	39,925	70,475
76	NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB17	28°13'57.45"N	83°42'41.16"E	760.0	Collapse	1	1	7,200	0	5	2,819	1,597	500	39,925	70,475
77	NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB24	28°13'57.72"N	83°42'41.03"E	782.0	Collapse	1	1	9,000	0	5	2,819	1,597	500	39,925	70,475
78	NH03	Pokhara- Baglung		Near Sundare khola, Kushma	PB25	28°13'55.71"N	83°42'41.23"E	768.0	Collapse	1	1	5,500	0	5	2,819	1,597	500	39,925	70,475
79	NH03	Pokhara- Baglung		Ambot Slide, Kushma	PB26	28°15'38.75"N	83°43'13.93"E	782.7	Collapse	1	2	6,750	0	5	2,819	1,597	500	39,925	70,475
80	NH03	Pokhara- Baglung		Near lasting resort, Kushma	PB27	28°15'49.73"N	83°43'38.68"E	795.3	Collapse	1	2	5,600	0	5	2,819	1,597	500	39,925	70,475
81	NH03	Pokhara- Baglung		Patichaur, Kushma	PB29	28°16'23.85"N	83°44'28.34"E	851.5	Collapse	2		5,400	0	5	2,819	1,597	500	39,925	70,475
82	NH37	Kanti Highway	74+800		K1	27°33'26.06"N	85°18'5.56"E	1,726.0	Collapse	2		7,055	0	10	3914	2,307	152	35,070	59,493
83	NH37	Kanti Highway	72+800		K2	27°32'58.05"N	85°17'50.96"E	1,865.0	Collapse	2		12,125	0	10	3914	2,307	152	35,070	59,493
84	NH37	Kanti Highway	69+365		K3	27°31'46.08"N	85°17'36.34"E	1,925.0	Collapse	2		44,000	0	10	3914	2,307	152	35,070	59,493
85	NH37	Kanti Highway	66+565		K4	27°31'29.07"N	85°17'11.65"E	1,741.0	Collapse	2		142,497	0	10	3914	2,307	152	35,070	59,493
86	NH34	Arniko Highway	113+200	Near Kodari	AH02	27°57'38.05"N	85°57'24.34"E	1,576.0	Collapse	1	2	8,000	1	10	1908	658	500	32,900	95,400
87	NH34	Arniko Highway	112+500	Ghatte Khola	AH04	27°57'23.54"N	85°57'15.92"E	1,545.2	Flow	2		10,000	1	10	1908	658	500	32,900	95,400
88	NH34	Arniko Highway		Near Bhansar Bridge	AH07	27°55'42.65"N	85°56'9.72"E	1,359.8	Collapse	2		10,000	0	10	1908	658	500	32,900	95,400
89	NH34	Arniko Highway		Daklang	AH11	27°54'1.66"N	85°55'2.59"E	1,254.5	Collapse	1	2	5,700	0	10	1908	658	500	32,900	95,400
90	NH34	Arniko Highway		Near Kholsi	AH12	27°53'47.46"N	85°54'54.64"E	1,250.6	Collapse	1	2	6,300	0	10	1908	658	500	32,900	95,400
91	NH34	Arniko Highway		About 50m ahead Kholsi	AH13	27°53'44.31"N	85°54'54.22"E	1,238.8	Collapse	1	2	11,000	0	10	1908	658	500	32,900	95,400
92	NH34	Arniko Highway		Chaku Khola	AH15	27°52'57.52"N	85°54'46.79"E	1,172.9	Collapse	1	2	13,417	0	10	1908	658	500	32,900	95,400
93	NH34	Arniko Highway		Another slide near Chaku Khola	AH16	27°52'55.40"N	85°54'41.33"E	1,151.2	Collapse	2		17,158	0	10	1908	658	500	32,900	95,400
94	NH34	Arniko Highway		Mahabhir	AH17	27°52'38.68"N	85°54'3.69"E	1,150.6	Collapse	2		6,400	0	10	1908	658	500	32,900	95,400
95	NH34	Arniko Highway		Subsidence area4	AH27	27°46'49.36"N	85°53'34.09"E	837.3	Slide	1	2	2,432,000	0	10	1908	658	500	32,900	95,400
96	NH47	Siddhartha Highway		Near Ramdi Slide	SH28	27°54'0.82"N	83°37'52.49"E	507.5	Collapse	1	1	1,380	0	5	3,277	1,591	390	31,025	63,902
97	NH47	Siddhartha Highway		Mark 46	SH30	27°54'33.76"N	83°39'20.80"E	382.4	Flow	1	2	6,000	1	5	3,277	1,591	390	31,025	63,902
98	NH03	Pokhara- Baglung	41+600	Nayapool 2, Kaski	PB34	28°17'51.98"N	83°46'27.67"E	1,231.2	Carriageway Collapse	2		4,800	0	2	6,594	3,017	500	30,170	65,940
99	NH03	Pokhara- Baglung	38+000	Nayapool 3, Kaski	PB35	28°18'5.21"N	83°46'52.09"E	1,233.8	Carriageway Collapse	1	2	1,500	0	2	6,594	3,017	500	30,170	65,940
100	NH03	Pokhara- Baglung		Phedi 1, Kaski	PB40	28°17'15.70"N	83°51'55.69"E	1,137.9	Collapse	1	1	4,267	0	2	6,594	3,017	500	30,170	65,940

Risk Index Ranking	Landslide Sites																								
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation			Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1=Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	Ancillary Risk Index (2021/22)						
						Latitude (North)	Longitude (East)	Elevation (m)												AAEP	AADT	AADT _{excl}	DR	=AAEP*AADT _{excl} *DR	=AAEP*AADT*DR
101	NH37	Kanti Highway	36+300		K10	27°25'34.56"N	85°14'3.72"E	1,078.0	Collapse	2		9,960	0	10	3131	1,846	152	28,054	47,591						
102	NH37	Kanti Highway	32+200		K11	27°25'42.70"N	85°13'6.13"E	850.0	Slide	2		10,833	0	10	3131	1,846	152	28,054	47,591						
103	NH34	Arniko Highway	37+500	Dhulikhel Khawa	AH34	27°37'51.86"N	85°36'8.36"E	1,052.8	Collapse	2		2,730	0	1	9495	5534	500	27,670	47,475						
104	NH47	Siddhartha Highway		Near Siddhababa area	SH02	27°44'28.89"N	83°27'52.39"E	215.0	Collapse	1	1	333	0	1	15,845	7,211	366	26,392	57,993						
105	NH47	Siddhartha Highway			SH04	27°45'9.95"N	83°30'24.90"E	331.2	Collapse	2		100	1	1	15,845	7,211	366	26,392	57,993						
106	NH47	Siddhartha Highway		Charchare	SH08	27°47'43.62"N	83°32'9.44"E	584.1	Carriageway Collapse	2		250	0	1	15,845	7,211	366	26,392	57,993						
107	NH47	Siddhartha Highway		Dumre	SH11	27°47'52.95"N	83°31'9.25"E	637.4	Collapse	2		1,600	0	1	15,845	7,211	366	26,392	57,993						
108	NH47	Siddhartha Highway		Aryabhanjyang	SH15	27°51'6.16"N	83°36'48.65"E	1,053.5	Collapse	2		400	0	1	15,845	7,211	366	26,392	57,993						
109	NH47	Siddhartha Highway		Near Aryabhanjyang(towards Walin)	SH16	27°50'58.87"N	83°37'32.34"E	1,048.7	Collapse	2		50	0	1	15,845	7,211	366	26,392	57,993						
110	NH47	Siddhartha Highway		100m down Aryabhanjyang	SH17	27°51'0.50"N	83°38'1.05"E	975.9	Collapse	2		105	1	1	15,845	7,211	366	26,392	57,993						
111	NH47	Siddhartha Highway		Mark 73(Bhalupahad)	SH53	28° 8'28.07"N	83°51'43.20"E	983.6	Collapse	2		6,160	0	5	3,277	1,591	320	25,456	52,432						
112	NH34	Arniko Highway		Wall Crack at Near Balefi Bazar	AH23	27°44'4.57"N	85°46'56.93"E	650.3	Slide	1	1	8,000	1	5	4199	2233	226	25,233	47,449						
113	NH34	Arniko Highway		Creeping at Near Balefi Bazar	AH24	27°44'5.75"N	85°46'59.68"E	652.7	Slide	1	2	21,000	1	5	4199	2233	226	25,233	47,449						
114	NH34	Arniko Highway		Subsidence area5	AH28	27°44'27.82"N	85°48'1.13"E	696.6	Collapse	2		26,667	0	5	4199	2233	226	25,233	47,449						
115	NH34	Arniko Highway		Subsidence area6	AH29	27°44'19.98"N	85°47'53.57"E	698.4	Collapse	2		8,000	1	5	4199	2233	226	25,233	47,449						
116	NH34	Arniko Highway		Near Dolalghat	AH33	27°38'57.97"N	85°41'8.98"E	636.8	Collapse	2		5,167	0	5	4199	2233	226	25,233	47,449						
117	NH03	Pokhara- Baglung	53+400	Gupteshwor Campus area, Kushuma	PB09	28°13'59.73"N	83°40'12.38"E	857.1	Carriageway Collapse	1	1	800	0	3	2,819	1,597	500	23,955	42,285						
118	NH41	Hetauda-Sim Bhanjyang	109+500		T4	27°32'6.43"N	85° 2'9.27"E	1,091.0	Slide	2		5,500	0	5	5754	3038	154	23,393	44,306						
119	NH37	Kanti Highway	61+627		K6	27°30'15.21"N	85°17'45.26"E	1,481.0	Collapse	2		58,320	0	5	3914	2,307	152	17,535	29,746						
120	NH02	Dhaptar			NH02#4	27°2'15.00"N	87°50'15.93"E	2,107.5	Collapse	2		2,100	0	3	2523	1,145	500	17,175	37,845						
121	NH34	Arniko Highway	105+300	Hindi Area	AH08	27°54'16.15"N	85°55'9.40"E	1,319.5	Slide	1	1	20,000	0	5	1908	658	500	16,450	47,700						
122	NH34	Arniko Highway		Gully erosion+ Side bank erosion	AH14	27°53'32.78"N	85°54'52.93"E	1,253.8	Collapse	1	2	13,300	0	5	1908	658	500	16,450	47,700						
123	NH34	Arniko Highway		Side Gulkote Pahiro	AH18	27°52'33.53"N	85°53'53.97"E	1,124.2	Collapse	1	4	7,200	0	5	1908	658	500	16,450	47,700						
124	NH34	Arniko Highway		Main Gulkote Pahiro	AH20	27°52'34.07"N	85°53'51.59"E	1,124.7	Collapse	1	2	166,667	0	5	1908	658	500	16,450	47,700						
125	NH34	Arniko Highway		Near Hydro Camp	AH21	27°50'35.77"N	85°52'49.70"E	956.1	Collapse	1	4	35,000	0	5	1908	658	500	16,450	47,700						
126	NH34	Arniko Highway		Subsidence area3	AH26	27°46'32.24"N	85°53'17.65"E	837.3	Slide	1	2	7,000	0	5	1908	658	500	16,450	47,700						
127	NH03	Pokhara- Baglung	57+300	Armadi 2, Kushma	PB05	28°14'21.24"N	83°38'52.71"E	724.8	Collapse	1	2	3,899	1	2	2,819	1,597	500	15,970	28,190						
128	NH03	Pokhara- Baglung	56+050	Armadi 3, Kushma	PB06	28°14'32.38"N	83°39'24.42"E	748.0	Collapse	1		257	0	2	2,819	1,597	500	15,970	28,190						
129	NH47	Siddhartha Highway		Mark 71	SH51	28° 7'40.36"N	83°51'59.08"E	971.0	Collapse	1	1	1,837	0	3	3,277	1,591	320	15,274	31,459						
130	NH47	Siddhartha Highway		Siddhababa area	SH21	27°44'15.26"N	83°27'54.51"E	228.0	Collapse	2		7,200	0	15	2,370	1,242	82	15,202	29,009						
131	NH37	Kanti Highway	25+500		K13	27°25'42.20"N	85°11'54.15"E	981.0	Slide	2		8,000	0	5	3131	1,846	152	14,027	23,796						
132	NH47	Siddhartha Highway		Mark 53 (Towards Walin from Butwal)	SH37	27°58'19.94"N	83°43'1.48"E	734.9	Collapse	1	1	7,482	0	2	3,277	1,591	390	12,410	25,561						
133	NH47	Siddhartha Highway		Mark 58	SH42	27°58'17.30"N	83°43'34.40"E	689.3	Collapse	2		3,088	0	2	3,277	1,591	390	12,410	25,561						
134	NH47	Siddhartha Highway		Mark 72(Bhalupahad)	SH52	28° 8'26.33"N	83°51'43.70"E	973.2	Collapse	2		1,333	0	2	3,277	1,591	320	10,182	20,973						
135	NH47	Siddhartha Highway		Way to Ramdi1	SH26	27°52'33.20"N	83°38'41.40"E	884.3	Collapse	1	2	9,160	0	10	2,370	1,242	82	10,135	19,339						
136	NH47	Siddhartha Highway		Way to Ramdi2	SH27	27°52'50.16"N	83°38'37.57"E	542.3	Flow	1	2	5,000	0	10	2,370	1,242	82	10,135	19,339						
137	NH34	Arniko Highway		Chehere Slide	AH31	27°40'28.37"N	85°43'49.48"E	584.1	Collapse	2		333	0	2	4199	2233	226	10,093	18,979						
138	NH41	Hetauda-Sim Bhanjyang	127+900		T1	27°27'45.74"N	85° 2'33.40"E	554.0	Slide	1	2	1,583	0	2	5754	3038	154	9,357	17,722						
139	NH03	Khurkot-Halesi			HK# 15b	27°18'28.44"N	86° 1'19.80"E	430.6	Collapse	2		5,200	1	5	1,827	956	191	9,130	17,448						
140	NH03	Khurkot-Halesi			HK# 15c	27°18'30.67"N	86° 1'15.38"E	436.1	Collapse	2		5,200	1	5	1,827	956	191	9,130	17,448						
141	NH08	Sano Akkare			NH08#2b	27°13'42.22"N	87°13'44.00"E	249.4	Collapse	1	2	18,000	0	5	746	364	500	9,100	18,650						
142	NH08	Dhodeni			NH08#7	26°51'9.98"N	87°17'55.39"E	759.2	Collapse	2		1,042	0	1	1691	1691	485	8,201	8,201						
143	NH03	Pokhara- Baglung	54+350	chamar Ke dil, Kushma	PB07	28°14'14.09"N	83°39'48.79"E	830.4	Collapse	1	2	1,800	0	1	2,819	1,597	500	7,985	14,095						
144	NH03	Pokhara- Baglung	53+600	Dulepani, Kushma	PB08	28°14'3.26"N	83°40'9.08"E	848.0	Collapse	1	1	1,200	0	1	2,819	1,597	500	7,985	14,095						
145	NH03	Pokhara- Baglung		Near Kushma Gate1, Kushma	PB12	28°13'20.92"N	83°41'33.51"E	866.8	Collapse	1	2	267	0	1	2,819	1,597	500	7,985	14,095						
146	NH03	Pokhara- Baglung		Near Kushma Gate2, Kushma	PB13	28°13'22.93"N	83°41'35.69"E	858.9	Collapse	1	2	400	0	1	2,819	1,597	500	7,985	14,095						
147	NH03	Pokhara- Baglung		Near Kushma Gate3, Kushma	PB14	28°13'24.37"N	83°41'39.61"E	856.8	Collapse	1	1	533	0	1	2,819	1,597	500	7,985	14,095						
148	NH03	Pokhara- Baglung		Near Kushma Gate4, Kushma	PB15	28°13'27.90"N	83°41'43.44"E	856.8	Collapse	1	1	292	0	1	2,819	1,597	500	7,985	14,095						
149	NH03	Pokhara- Baglung		Police Station, Kushma	PB16	28°13'29.30"N	83°41'47.90"E	848.3	Collapse	1	2	4,500	0	1	2,819	1,597	500	7,985	14,095						
150	NH03	Pokhara- Baglung		Chuwa Slide, Kushma	PB19	28°13'34.22"N	83°42'27.22"E	804.6	Collapse	2		1,000	0	1	2,819	1,597	500	7,985	14,095						

Risk Index Ranking	Landslide Sites											Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	Ancillary Risk Index (2021/22)	
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation			Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1=Masonry 2=Gabion 3=Concrete wall 4=Others								Historical Failure Volume V=L*W*D/3
						Latitude (North)	Longitude (East)	Elevation (m)											
						AAEP	AADT	AADT _{excl}											
151	NH03	Pokhara- Baglung		Ambot, Kushma	PB20	28°15'5.79"N	83°42'54.46"E	773.8	Collapse	2		800	0	1	2,819	1,597	500	7,985	14,095
152	NH03	Pokhara- Baglung		Slope erosion, Kusma	PB22	28°14'16.09"N	83°42'38.69"E	735.6	Collapse	2		2,310	0	1	2,819	1,597	500	7,985	14,095
153	NH34	Arniko Highway	111+600	Koplang Subsidence area	AH03	27°57'33.50"N	85°57'25.46"E	1,598.6	Collapse	1	1	3,500	1	2	1908	658	500	6,580	19,080
154	NH34	Arniko Highway		Hindi Area	AH09	27°53'59.97"N	85°55'1.43"E	1,272.7	Collapse	1	1	1,250	0	2	1908	658	500	6,580	19,080
155	NH34	Arniko Highway		Hindi Area	AH10	27°53'58.58"N	85°54'58.84"E	1,279.6	Collapse	1	1	3,000	0	2	1908	658	500	6,580	19,080
156	NH47	Siddhartha Highway		On the way to Palpa from Butwal	SH19	27°51'20.09"N	83°38'13.48"E	813.0	Collapse	2		67	0	1	2,370	1,242	500	6,210	11,850
157	NH47	Siddhartha Highway		Kaligandaki	SH29	27°54'15.63"N	83°39'0.61"E	345.4	Collapse	1	3	1,020	0	1	3,277	1,591	390	6,205	12,780
158	NH47	Siddhartha Highway		Mark 47	SH31	27°55'22.51"N	83°39'3.51"E	459.7	Collapse	2		123	0	1	3,277	1,591	390	6,205	12,780
159	NH47	Siddhartha Highway		Mark 48	SH32	27°55'41.41"N	83°39'13.52"E	524.2	Collapse	2		300	0	1	3,277	1,591	390	6,205	12,780
160	NH47	Siddhartha Highway		Mark 49	SH33	27°55'39.56"N	83°39'44.03"E	737.6	Collapse	1	1	1,140	0	1	3,277	1,591	390	6,205	12,780
161	NH47	Siddhartha Highway		Mark 50	SH34	27°57'0.49"N	83°41'14.24"E	679.8	Collapse	1	2	2,333	0	1	3,277	1,591	390	6,205	12,780
162	NH47	Siddhartha Highway		Mark 51	SH35	27°57'16.08"N	83°42'35.81"E	731.1	Collapse	2		368	0	1	3,277	1,591	390	6,205	12,780
163	NH47	Siddhartha Highway		Mark 52	SH36	27°57'14.32"N	83°42'31.00"E	726.2	Collapse	2		800	0	1	3,277	1,591	390	6,205	12,780
164	NH47	Siddhartha Highway		Mark 54	SH38	27°58'23.13"N	83°43'22.46"E	721.7	Collapse	2		480	0	1	3,277	1,591	390	6,205	12,780
165	NH47	Siddhartha Highway		Mark 55	SH39	27°58'22.25"N	83°43'22.74"E	682.3	Collapse	1	1	331	0	1	3,277	1,591	390	6,205	12,780
166	NH47	Siddhartha Highway		Mark 56	SH40	27°58'21.99"N	83°43'24.33"E	684.7	Collapse	1	1	27	0	1	3,277	1,591	390	6,205	12,780
167	NH47	Siddhartha Highway		Mark 57	SH41	27°58'19.75"N	83°43'27.70"E	686.9	Collapse	2		250	0	1	3,277	1,591	390	6,205	12,780
168	NH47	Siddhartha Highway		Mark 59 (Towards Walin from Butwal)	SH43	27°58'18.23"N	83°44'20.08"E	687.9	Collapse	1	1	2,467	0	1	3,277	1,591	390	6,205	12,780
169	NH47	Siddhartha Highway		Mark 62	SH45	27°59'6.35"N	83°45'57.95"E	706.2	Collapse	1	1	3,533	0	1	3,277	1,591	390	6,205	12,780
170	NH47	Siddhartha Highway		Mark 63	SH46	27°59'16.15"N	83°46'26.77"E	679.6	Collapse	2		3,750	0	1	3,277	1,591	390	6,205	12,780
171	NH47	Siddhartha Highway		Erosion	SH24	27°45'14.78"N	83°30'25.57"E	900.8	Flow	1	1	1,000	0	6	2,370	1,242	82	6,081	11,604
172	NH02	Puwa Bhanjyang/Gumbba Dada			NH02#2	27°37'98"N	87°48'24.84"E	2,282.5	Collapse	2		250	0	1	2523	1,145	500	5,725	12,615
173	NH08	Dhodeni			NH08#6a	26°57'33.31"N	87°19'23.98"E	661.7	Collapse	2		1,833	0	1	2498	1126	500	5,630	12,490
174	NH08	Dhodeni			NH08#6b	26°57'32.36"N	87°19'27.54"E	663.5	Collapse	2		1,833	0	1	2498	1126	500	5,630	12,490
175	NH47	Siddhartha Highway		Mark 65	SH47	27°59'42.96"N	83°46'50.78"E	687.0	Collapse	2		1,500	0	1	3,277	1,591	320	5,091	10,486
176	NH47	Siddhartha Highway		Mark 66	SH48	27°59'54.04"N	83°47'1.34"E	708.1	Collapse	2		1,100	0	1	3,277	1,591	320	5,091	10,486
177	NH34	Arniko Highway		Subsidence area7	AH30	27°44'14.26"N	85°47'46.18"E	708.3	Collapse	2		3,150	1	1	4199	2233	226	5,047	9,490
178	NH34	Arniko Highway		Simle	AH32	27°39'35.42"N	85°42'56.22"E	672.2	Collapse	2		2,333	0	1	4199	2233	226	5,047	9,490
179	NH03	Khurkot-Halesi		Khotang	HK#5	27°10'18.48"N	86° 30'00"E	828.6	Collapse	2		1,100	0	2	1,725	897	274	4,916	9,453
180	NH41	Hetauda-Sim Bhanjyang	121+800		T2	27°30'12.88"N	85° 2'51.46"E	597.0	Collapse	2		1,144	0	1	5754	3038	154	4,679	8,861
181	NH41	Hetauda-Sim Bhanjyang	112+800		T3	27°31'59.79"N	85° 2'30.22"E	930.0	Collapse	1	1	1,500	0	1	5754	3038	154	4,679	8,861
182	NH03	Khurkot-Halesi			HK# 10	27°14'44.63"N	86° 12'21.89"E	391.9	Collapse	1	2	800	0	2	1,827	956	191	3,652	6,979
183	NH03	Khurkot-Halesi			HK# 13	27°16'10.45"N	86° 9'52.81"E	408.0	Collapse	1	2	2,400	0	2	1,827	956	191	3,652	6,979
184	NH03	Khurkot-Halesi		Khotang	HK#4	27°10'10.92"N	86° 18'20.88"E	1,000.0	Collapse	1	1	175	0	1	1,827	956	274	2,619	5,006
185	NH03	Khurkot-Halesi		Udaypur	HK# 8	27°10'22.84"N	86° 23'56.80"E	335.4	Collapse	2		500	0	1	1,827	956	274	2,619	5,006
186	NH03	Khurkot-Halesi		Udaypur	HK# 8a	27°10'18.41"N	86° 24'00.36"E	305.2	Collapse	2		600	1	1	1,827	956	274	2,619	5,006
187	NH03	Khurkot-Halesi		Udaypur	HK# 8b	27°10'21.79"N	86° 23'58.92"E	332.8	Collapse	2		1,600	0	1	1,827	956	274	2,619	5,006
188	NH03	Khurkot-Halesi		Khotang	HK#1	27°11'24.14"N	86° 34'32.65"E	1,232.0	Collapse	2		153	0	1	1,725	897	274	2,458	4,727
189	NH03	Khurkot-Halesi		Khotang	HK#2	27°11'46.64"N	86° 33'56.02"E	1,123.8	Collapse	2		2,667	0	1	1,725	897	274	2,458	4,727
190	NH03	Khurkot-Halesi		Khotang	HK#3	27°11'38.32"N	86° 33'21.78"E	1,148.8	Collapse	2		150	0	1	1,725	897	274	2,458	4,727
191	NH03	Khurkot-Halesi		Khotang	HK#5a	27°10'18.50"N	86° 30'21.50"E	769.5	Collapse	2		2,667	0	1	1,725	897	274	2,458	4,727
192	NH03	Khurkot-Halesi		Khotang	HK#5b	27°11'19.30"N	86° 30'19.60"E	793.2	Collapse	2		350	0	1	1,725	897	274	2,458	4,727
193	NH03	Khurkot-Halesi		Khotang	HK#6	27°10'61.40"N	86° 29'25.80"E	603.3	Collapse	1	1	3,733	0	1	1,725	897	274	2,458	4,727
194	NH03	Khurkot-Halesi		Khotang	HK# 6'	27°10'14.16"N	86° 30'10.84"E	938.6	Carriageway Collapse	1	1	267	0	1	1,725	897	274	2,458	4,727
195	NH03	Khurkot-Halesi		Okhaldhunga	HK# 7	27°10'40.26"N	86° 25'14.74"E	466.5	Flow	2		533	0	1	1,725	897	274	2,458	4,727
196	NH47	Siddhartha Highway		Siddhababa area	SH22	27°44'19.33"N	83°27'53.65"E	247.1	Collapse	1	1	300	0	2	2,370	1,242	82	2,027	3,868
197	NH03	Khurkot-Halesi			HK# 9	27°12'33.77"N	86°20'21.80"E	345.5	Collapse	2		400	0	1	1,827	956	191	1,826	3,490
198	NH03	Khurkot-Halesi			HK# 11	27°15'6.84"N	86°10'37.27"E	383.3	Collapse	2		1,250	0	1	1,827	956	191	1,826	3,490
199	NH03	Khurkot-Halesi			HK# 12	27°14'35.09"N	86° 9'9.61"E	400.0	Collapse	2		750	0	1	1,827	956	191	1,826	3,490
200	NH03	Khurkot-Halesi			HK# 14	27°15'50.04"N	86° 2'29.4"E	407.3	Collapse	2		1,400	0	1	1,827	956	191	1,826	3,490
201	NH03	Khurkot-Halesi			HK# 15a	27°18'27.79"N	86° 1'27.41"E	425.4	Collapse	2		1,067	0	1	1,827	956	191	1,826	3,490
202	NH08	Pool Dada			NH08#1	27°16'5.33"N	87°12'38.20"E	276.7	Collapse	1	3	960	0	1	746	364	500	1,820	3,730
203	NH08	Sano Akkare			NH08#2a	27°13'51.29"N	87°13'39.31"E	267.3	Collapse	1	2	805	0	1	746	364	500	1,820	3,730
204	NH08	Thulo Akkare			NH08#3a	27°11'58.65"N	87°14'31.34"E	242.5	Collapse	2		233	0	1	746	364	500	1,820	3,730
205	NH08	Thulo Akkare			NH08#3b	27°11'52.33"N	87°14'51.95"E	232.7	Collapse	2		350	0	1	746	364	500	1,820	3,730
206	NH08	Kewa Besi			NH08#4	27°11'4.37"N	87°15'33.02"E	242.4	Collapse	2		1,500	0	1	746	364	500	1,820	3,730

Risk Index Ranking	Landslide Sites											Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	Ancillary Risk Index (2021/22)		
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No:	GPS Coordinate (WGS84) and Elevation			Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1=Masonry 2=Gabion 3=Concrete wall 4=Others							Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence
						Latitude (North)	Longitude (East)	Elevation (m)											
													AAEP	AADT	AADTemc	DR	=AAEP*AADTemc*D	=AAEP*AADT*DR	
207	NH08	Dhankuta			NH08#5	26°25'40.69"N	87°20'14.42"E	996.0	Collapse	1	2	200	0	1	746	364	500	1,820	3,730
208	NH08	Piluwa Khola			NH08#9	27°12'58.80"N	87°14'30.22"E	256.0	Collapse	2		2,083	0	1	746	364	500	1,820	3,730
209	NH41	Sim Bhanjyang - Plaung-Tistung	57+000		T5	27°39'35.22"N	85° 5'58.69"E	1,978.0	Collapse	2		20,000	0	5	748	354	74.7	1,322	2,794
210	NH41	Palung - Tistung- Naubise	44+200		T9	27°41'59.03"N	85° 5'46.01"E	1,572.0	Collapse	2		5,250	1	5	748	354	74.7	1,322	2,794
211	NH41	Palung - Tistung- Naubise	31+500		T10	27°43'16.37"N	85° 6'47.35"E	1,111.0	Collapse	1	3	5,333	0	5	748	354	74.7	1,322	2,794
212	NH47	Siddhartha Highway		Dovan Slide	SH23	27°44'45.50"N	83°27'48.86"E	257.8	Collapse	1	1	200	0	1	2,370	1,242	82	1,013	1,934
213	NH47	Siddhartha Highway		Birauta	SH25	27°51'15.85"N	83°37'58.46"E	813.0	Collapse	2		2,133	1	1	2,370	1,242	82	1,013	1,934
214	NH41	Sim Bhanjyang - Plaung-Tistung	54+500		T6	27°40'17.16"N	85° 5'48.68"E	1,968.0	Collapse	2		480	0	2	748	354	74.7	529	1,118
215	NH41	Sim Bhanjyang - Plaung-Tistung	51+ 500		T7	27°40'53.28"N	85° 5'1.79"E	1,814.0	Collapse	1	3	3,400	0	2	748	354	74.7	529	1,118
216	NH41	Palung - Tistung- Naubise	50+100		T8	27°41'12.26"N	85° 5'28.09"E	1,740.0	Collapse	1	2	1,250	1	1	748	354	74.7	264	559

Note: DOR plans to engineering measures on NH47 Siddhartha Highway, Siddhababa area, risk index ranking of 7, 130, and 196.

Annex B. Longlist sites and the other assessment sites

B.1. Longlist sites and the other assessment sites

Annex B.1. Longlist sites and the other assessment sites

(1) Longlist sites

Risk Index Ranking	Landslide Site								Type of Landslide	Existing Engineering Measures 1=Y, 2=N	Type of Existing Engineering Measures 1= Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22)	Extension of roads with a history of damage(m)	Extension of roads targeted for measures (m)	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment	Build Back Better		
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No.	GPS Coordinate (WGS84) and Elevation																		Measures for adjacent risk sections	Road function improvement (alignment improvement, elimination of bottlenecks)	
						Latitude (North)	Longitude (East)	Elevation (m)																		
														AAEP	AADT	AADTexc	DR	=AAEP*AADT exc*DR								
1	NH44	Narayanghat-Mugling	21+500	Mauri Bridge	L2	27°49'3.74"N	84°27'46.35"E	232.0	Flow	1	1	25,000	0	25	9,692	7,607	500	950,875	25	30	Frame work with rock bolt	Check dams	Bridge		Bridge	
2	NH47	Siddhartha Highway	35+500	Jhumsa	SH03	27°45'4.90"N	83°30'4.61"E	299.0	Slide	1	2	18,012	1	30	15,845	7,211	366	791,768	100	200	Earth work, subsurface drainage	Catch works	Reinforced Earth	x		
3	NH44	Narayanghat-Mugling	15+100	Bhangadi	L3	27°46'50.94"N	84°26'16.75"E	199.0	Collapse	1	1	5,350	0	20	9,692	7,607	500	760,700	30	40	Surface drainage	Retaining and breast walls		x		
4	NH44	Narayanghat-Mugling	31+400	Namshi Khola	L25	27°49'57.88"N	84°31'17.33"E	403.0	Collapse	1	3	5,600	0	20	9,692	7,607	500	760,700	70	80	Frame work with ground anchor, surface drainage			x		
5	NH47	Siddhartha Highway	39+500	Hiyeude Khola	SH06	27°46'2.50"N	83°31'16.94"E	452.3	Flow	1	4	20,833	0	25	15,845	7,211	366	659,807	30	30	Frame work	Check dams				
6	NH44	Narayanghat-Mugling	33+000	Nyanse River	L7	27°49'50.46"N	84°32'48.64"E	255.0	Collapse	1	1	13,120	0	15	9,692	7,607	500	570,525	80	100	Frame work with rock bolt, surface drainage	Brest wall with rockfall protection barriers		x		
7	NH47	Siddhartha Highway		Siddhababa area	SH01	27°43'29.58"N	83°28'9.51"E	201.5	Collapse	1	3	32,375	0	20	15,845	7,211	366	527,845	-							
8	NH47	Siddhartha Highway	48+600	Near Dumre Bazar	SH10	27°47'55.51"N	83°31'33.56"E	645.0	Collapse	2		15,000	0	20	15,845	7,211	366	527,845	40	200	Cutting, reinforced earth wall			x		
9	NH47	Siddhartha Highway	38+000		SH05	27°45'14.78"N	83°30'48.88"E	371.0	Collapse	2		6,600	0	15	15,845	7,211	366	395,884	10	20	Cutting, reinforced earth wall			x		
10	NH47	Siddhartha Highway	56+000	5km down from Bartung Bazar	SH13	27°51'4.55"N	83°33'22.24"E	960.6	Slide	2		5,885	0	15	15,845	7,211	366	395,884	20	80	Earth work, subsurface drainage	Catch works	x	x		
11	NH47	Siddhartha Highway	56+200	4.8km down from Bartung Bazar	SH14	27°51'6.90"N	83°33'17.09"E	960.1	Slide	1	1	9,333	0	15	15,845	7,211	366	395,884	40	120	Earth work, subsurface drainage	Catch works	x	x		
12	NH47	Siddhartha Highway	87+400	Ramdi -1	SH18	27°54'10.61"N	83°38'3.31"E	429.9	Collapse	2		20,000	0	15	15,845	7,211	366	395,884	20	350	Frame work with ground anchor			x		
13	NH44	Narayanghat-Mugling	26+500		L6	27°49'4.33"N	84°30'15.63"E	259.0	Carriageway Collapse	1	4	7,000	0	10	9,692	7,607	500	380,350	60	350	Frame work with ground anchor			x		
14	NH44	Narayanghat-Mugling	33+150	Kali Khola, 23June 2017 police killed, 1 truck buried	L24	27°49'59.47"N	84°33'8.11"E	262.0	Collapse	2		20,000	0	10	9,692	7,607	500	380,350	150	150	Cutting work, frame work with ground anchor					
15	NH44	Narayanghat-Mugling	33+800	Tuin khola	L26	27°50'08.55"N	84°33'23.41"E	336.0	Collapse	2		14,000	0	10	9,692	7,607	500	380,350	70	80	Frame work with rock bolt			x		
16	NH25	Dumre-Besisahar-Chame	45+150		L21	28°15'23.26"N	84°22'0.56"E	776.0	Collapse	1	2	126,000	0	25	3,931	1,673	500	209,125	135	150	High-intensity net with bioengineering			x		
17	NH44	Narayanghat-Mugling	34+500	Tuin Khola	L23	27°50'33.88"N	84°33'31.29"E	298.0	Collapse	2		11,117	0	5	9,692	7,607	500	190,175	46	70	Frame work, surface drainage			x		
18	NH25	Dumre-Besisahar-Chame	61+100		L12	28°21'10.98"N	84°24'12.39"E	1,049.0	Collapse	2		17,000	0	20	3,931	1,673	500	167,300	85	90	Frame work, surface drainage	Rockfall protection wall		x	Widening with reinforced earth embankment	
19	NH25	Dumre-Besisahar-Chame	62+500		L20	28°21'45.08"N	84°24'8.60"E	1,150.0	Collapse	2		12,500	0	20	3,931	1,673	500	167,300	30	50	Frame work, surface drainage			x		
20	NH03	Pokhara- Baglung	58+700	Nayapool Flow, Kushma	PB03	28°14'43.96"N	83°38'14.98"E	692.9	Flow	1	2	87,780	0	20	2,819	1,597	500	159,700	57	60		Check dams, bank protection		x		
21	NH03	Pokhara- Baglung	57+400	Armadi 1, Kushma	PB04	28°14'24.47"N	83°38'47.42"E	721.0	Collapse	2		1,085	0	20	2,819	1,597	500	159,700	31	40	Frame work			x		
22	NH03	Pokhara- Baglung	52+500	Damdare khola, Kushuma	PB11	28°13'43.64"N	83°40'38.53"E	868.4	Flow	1	2	31,680	0	20	2,819	1,597	500	159,700	40	40		Check dams				
23	NH44	Narayanghat-Mugling	21+300	Dobhan (Seti & Trisuli)	L1	27°49'9.80"N	84°27'14.20"E	238.0	Collapse	1	1	2,125	0	4	9,692	7,607	500	152,140	25	40	Frame work with rock bolt	Masonry wall, Flow protection wall		x		
24	NH44	Narayanghat-Mugling	16+000	Dasdhunga	L4	27°47'50.91"N	84°25'54.00"E	209.0	Carriageway Collapse	1	3	820	0	4	9,692	7,607	500	152,140	12	30	Crib-walls			x		
25	NH03	Pokhara- Baglung	37+900	Nayapool 4, Kaski	PB36	28°18'6.86"N	83°46'43.31"E	1,273.2	Slide	1	2	125,000	0	10	6,594	3,017	500	150,850	150	150	Earth work, subsurface drainage	Catch works	x			
26	NH03	Pokhara- Baglung	36+400	Nayapool 5, Kaski	PB37	28°18'5.30"N	83°47'4.31"E	1,625.4	Slide	2		40,000	0	10	6,594	3,017	500	150,850	100	400	Earth work, subsurface drainage	Catch works	x	x		
27	NH03	Pokhara- Baglung	26+200	Pandung, Kaski	PB38	28°17'9.04"N	83°49'59.17"E	1,610.0	Slide	2		1,350,000	0	10	6,594	3,017	500	150,850	300	300	Earth work, subsurface drainage	Catch works	x			
28	NH47	Siddhartha Highway	39+600	Near Hiyeude khola	SH07	27°46'0.80"N	83°31'21.43"E	475.0	Collapse	2		6,000	0	5	15,845	7,211	366	131,961	150	180	Frame work			x		
29	NH47	Siddhartha Highway	46+400	Near Charchare	SH09	27°47'45.91"N	83°32'6.32"E	605.3	Collapse	2		8,400	0	5	15,845	7,211	366	131,961	350	350	Cutting, bioengineering, breast wall, surface drainage					
30	NH47	Siddhartha Highway	49+800	Lower Dumre	SH12	27°48'1.78"N	83°30'56.25"E	635.6	Slide	1	3	17,000	0	5	15,845	7,211	366	131,961	10	100	Earth work, subsurface drainage	Catch works	x	x		
31	NH-25	Dumre-Besisahar-Chame	101+800		L19	28°33'3.07"N	84°15'18.11"E	2,599.0	Collapse	1	1	80,000	0	15	3,931	1,673	500	125,475	160	180		Reinforced earth wall		x	Widening with reinforced earth embankment	
32	NH03	Pokhara- Baglung	58+700	Saharshadhara 2, Kushma	PB02	28°14'51.04"N	83°38'0.61"E	684.7	Collapse	1	1	14,405	0	15	2,819	1,597	500	119,775	40	60	Cutting work, gabion wall			x		
33	NH03	Pokhara- Baglung	51+500	Paradi Slide, Kushma	PB21	28°14'20.24"N	83°42'39.22"E	744.8	Collapse	1	2	66,667	0	15	2,819	1,597	500	119,775	250	250	Reinforced earth					
34	NH44	Narayanghat-Mugling	20+000	Gaighat	L5	27°48'43.06"N	84°26'1.59"E	200.0	Flow	1	2	200	0	3	9,692	7,607	500	114,105	10	20	Surface drainage	Check dams		x		

The sites of risk ranking of 7 omit the longlist because DOR plans to engineering measures the site on the Siddhababa area, NH 47 Siddhartha Highway.

(2) NH37 Kanti Highway 7 sites

Risk Index Ranking	Geohazard Location					Type of Geohazard	Existing Countermeasure Works 1=Y, 2=N	Type of Existing Countermeasure Works 1=Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22) =AAEP*AADT*DR	Extension of roads with a history of damage(m)	Extension of roads targeted for measures (m)	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment	Build Back Better				
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No.																GPS Coordinate (WGS84) and Elevation			Measures for adjacent risk sections	Road function improvement (alignment improvement, elimination of bottlenecks)
																					Latitude (North)	Longitude (East)	Elevation (m)		
84	NH37	Kanti Highway	69+365	Narayanghat slide	K3	27°31'46.08"N	85°17'36.34"E	1,925.0	Collapse	2		44,000	0	10	3914	2,307	152	35,070	135	160		Reinforced earth wall	x	x	Widening, pavement
85	NH37	Kanti Highway	66+565	Karukibas slide	K4	27°31'29.07"N	85°17'11.65"E	1,741.0	Collapse	2		142,497	0	10	3914	2,307	152	35,070	335	370		Reinforced earth wall	x	x	Widening, pavement
62	NH37	Kanti Highway	63+885	23rd September 2020, two people were injured	K5	27°30'30.29"N	85°17'50.08"E	1,568.0	Collapse	2		18,957	0	20	3914	2,307	152	70,140	115	150		Reinforced earth wall	x	x	Widening, pavement
119	NH37	Kanti Highway	61+627	Chhapeli Slide	K6	27°30'15.21"N	85°17'45.26"E	1,481.0	Collapse	2		58,320	0	5	3914	2,307	152	17,535	273	300		Reinforced earth wall	x	x	Widening, pavement
63	NH37	Kanti Highway	56+420		K7	27°29'27.25"N	85°16'28.52"E	1,177.0	Slide	1	2	21,900	0	20	3914	2,307	152	70,140	50	100	Earth work, subsurface drainage	Gabion wall	x	x	Widening, pavement
73	NH37	Kanti Highway	46+000		K8	27°28'3.27"N	85°15'12.61"E	934.0	Collapse	2		98,000	0	15	3131	1,846	152	42,081	400	450		Reinforced earth wall	x	x	Widening, pavement
68	NH37	Kanti Highway	42+000		K9	27°26'56.12"N	85°14'24.21"E	1,152.0	Slide	2		196,000	0	20	3131	1,846	152	56,108	220	250	Earth work, subsurface drainage	Gabion wall	x	x	Widening, pavement

(3) NH03 Khurkot-Haleshi 4 sites

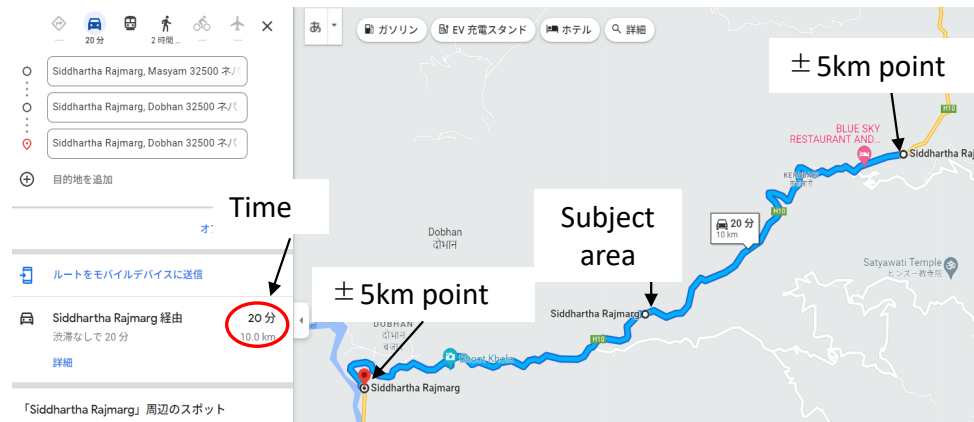
Risk Index Ranking	Geohazard Location					Type of Geohazard	Existing Countermeasure Works 1=Y, 2=N	Type of Existing Countermeasure Works 1=Masonry 2=Gabion 3=Concrete wall 4=Others	Historical Failure Volume V=L*W*D/3	Presence or Absence of Sediment Disposal on the Slope above the Road 1=Presence, 0=Absence	Annual Exceedance Probability Damage to the Whole Road Width (%/year)	AADT (2021/22)	AADT excl. MC, Rickshaws (2021/22)	Detour Road Sections (km)	Risk Index (2021/22) =AAEP*AADT*DR	Extension of roads with a history of damage(m)	Extension of roads targeted for measures (m)	Measures for the hazard itself (collapse source measures, Slide prevention/control, erosion measures)	Road protection measures from hazards (falling rocks and collapse catch works)	Hazard avoidance by shifting road alignment	Build Back Better					
	National Highway Code	Road Section	Chainage	Location Name/Description	Inventory No.																GPS Coordinate (WGS84) and Elevation			Measures for adjacent risk sections	Road function improvement (alignment improvement, elimination of bottlenecks)	
																					Latitude (North)	Longitude (East)	Elevation (m)			
179	NH03	Khurkot-Halesi	15+600 (Ch 0+000 at Hilepani)	Khotang	HK#5	27°10'18.55"N	86°30'19.32"E	828.6	Collapse	2		1,100	0	2	1,725	897	274	4,916	55	60		Shotcrete frame work with rock bolt			x	
182	NH03	Khurkot-Halesi	28+060(0+00 at Khurkot)	Chyakutar (Photo HK#10)	HK# 10	27°10'43.87"N	86°12'34.56"E	391.9	Collapse	1	2	800	0	2	1,827	956	191	3,652	40	120		Reinforced earth wall (H=5m)			x	
183	NH03	Khurkot-Halesi	18+600 Kukuretar	Kukhuretar	HK# 13	27°16'8.51"N	86°6'54.01"E	408.0	Collapse	1	2	2,400	0	2	1,827	956	191	3,652	60	120		Shotcrete frame work			x	
201	NH03	Khurkot-Halesi	4+000 Haibar(Akkare)	Haibar (Akkare)	HK# 15a	27°18'27.79"N	86°1'27.41"E	425.4	Collapse	2		1,067	0	1	1,827	956	191	1,826	150	400					x	

B.2. Traffic indicators

Reference

- **Derive of Travel speed**
Method of derivation

- I. After entering the latitude and longitude of the subject point in Google Maps, search for a route with the starting point and destination set at 5 km (± 5 km) before and after the point.
 - II. Derive the time required from the starting point to the destination (10 km).
 - III. Calculate the speed from the time required (formula: 10 km/time required)
 - IV. Calculate speeds by **period** and **time**, then calculate the average of those speeds.
- ✂ **Period** : weekdays (10/8~10/13, 2023)
 holidays : Saturdays in October (10/7.14.21.28, 2023)
- ✂ **Time** : The peak and off-peak hours are set for each target location by checking the hourly traffic volume in the traffic volume survey results conducted by DOR.



Example : Derivation of Travel speed

- **AADT (Annual Average Daily Traffic)**

Annual Average Daily Traffic Volume. The average daily traffic volume at a given point on a road, summed over a year and divided by the number of days in the year.

Source: General Incorporated association, Japan Society of Traffic Engineers, glossary Traffic Engineers

- **AADT (without motorcycle)**

In this case, Motorcycle and Rickshaw were excluded from the aggregate.

- **VOC (Vehicle Operating Cost)**

The cost of one vehicle traveling one kilometer.
speed.

179,358
179,358
188,870
188,870

ding on vehicle type and

- **TTC (Travel Time Cost)**

Monetary equivalent of the time value of a one-minute reduction in driving time of one vehicle.

Annual increase rate

The AADT 2025 value is calculated based on the 2021/22 value of DOR and the annual increase rate is 6% according to the DOR designation.

VOC is based on the value of the 2017 “The Project on Urban Transport Improvement for Kathmandu Valley in the Federal Democratic Republic of Nepal, Final Report” (May 2017). The annual increase rate is 6.20% based on the variation of average consumer price index over the past 10 years up to 2022.

TTC is based on the value of the 2017 “The Project on Urban Transport Improvement for Kathmandu Valley in the Federal Democratic Republic of Nepal, Final Report” (May 2017). The annual increase rate 3.38% is based on the GDP variation over the past 10 years up to 2022.

NH44-004 Traffic indicators for each site

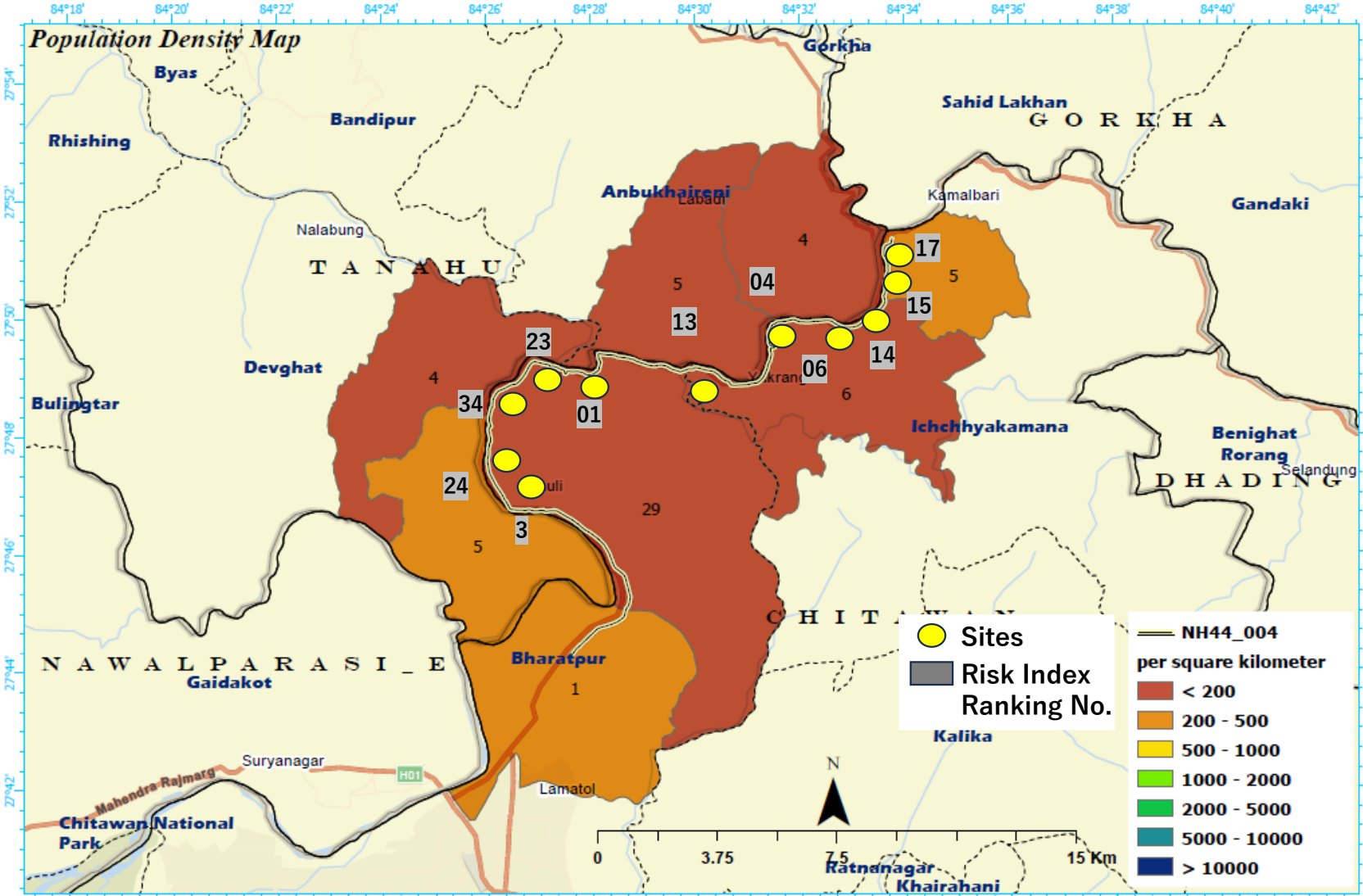
Risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluate sections (km/h)	VOC									AADT (2021/22)	AADT (2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motor cycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
1:Mauri Bridge	42.6	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
3:Bhangadi	45.0	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
4:Namshi Khola	36.1	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
6	32.4	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
13	41.3	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
14	32.4	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
15	32.4	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
17	29.9	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
23	42.4	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
24	42.5	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537
34	42.2	38.7	8.87	43.92	43.92	60.28	95.84	58.2	66.19	70.84	29.75	9,692	11,524	292.70	1,686,537

※1TTC: Travel Time Cost

※ 2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT / 2

Source: Estimated by the JICA Survey Team based on "The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal, Final Report", JICA, May 2017

NH44-004



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

NH47-004~005 Traffic indicators for each site

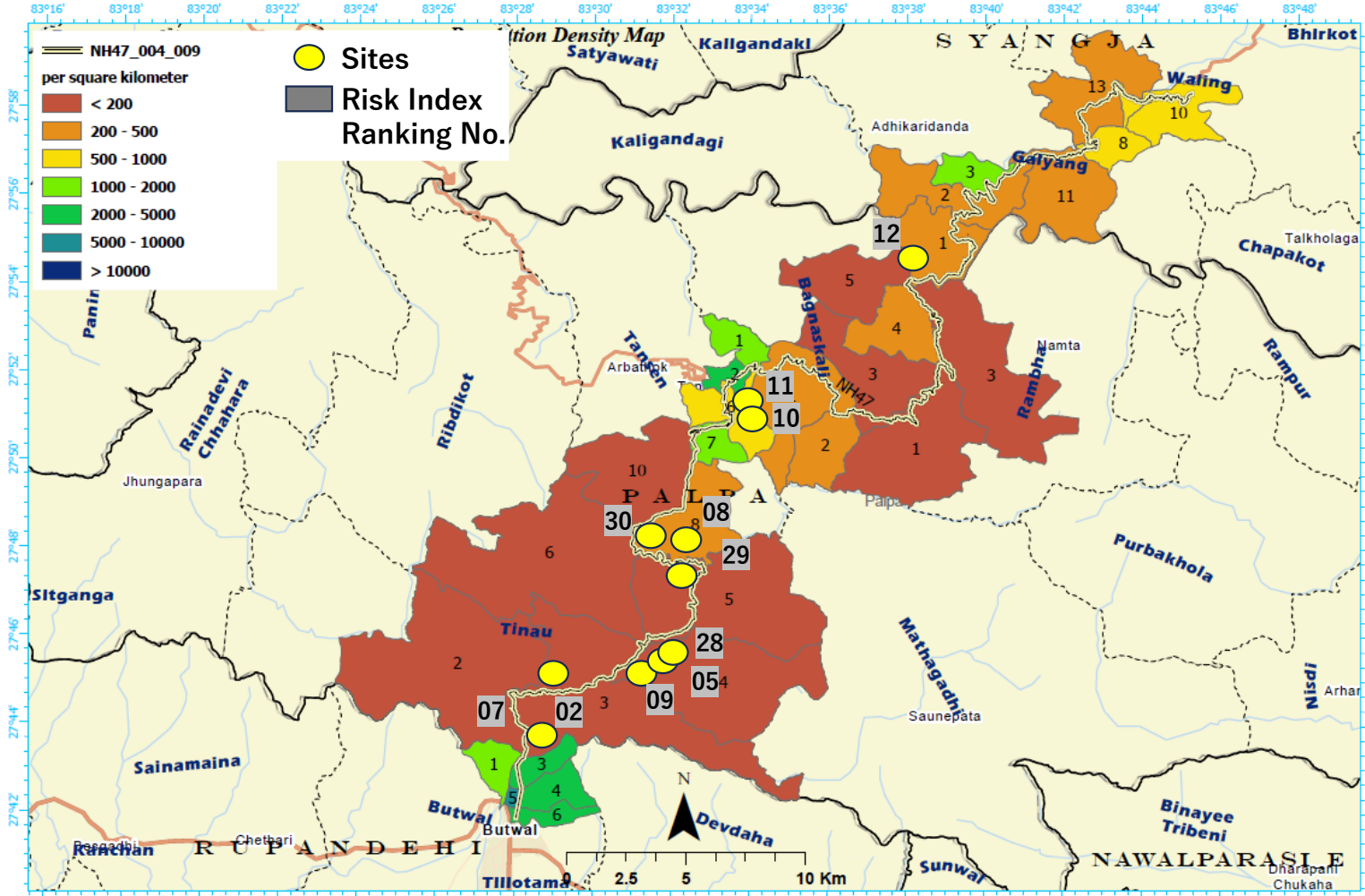
Risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluate sections (km/h)	VOC									AADT (2021/22)	AADT(2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motorcycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
2:Jhumsa Idsl	27.95	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
5:Hiyeude Khola	29.55	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
7	24.82	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
8:Near Dumre Bazar	30.00	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
9	29.09	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
10	33.33	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
11	33.33	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
12	33.19	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	3,277	3872	169.22	327,610
28	29.55	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
29	29.09	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395
30	30.83	30.7	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	15,845	18,770	227.00	2,130,395

※1TTC: Travel Time Cost

※ 2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT /2

Source: Estimated by the JICA Survey Team based on "The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal, Final Report", JICA, May 2017

NH47-004~005



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

NH03-048 Traffic indicators for each site

Geographic risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluative sections (km/h)	VOC									AADT (2021/22)	AADT (2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motorcycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
20:Nayapool Debris Flow, Kushma	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	2819	3,230	212.85	343,753
21:Armadi 1, Kushma	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	2819	3,230	212.85	343,753
22:Damdare khola, Kushuma	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	2819	3,230	212.85	343,753
25	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	6594	7,761	150.95	585,761
26	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	6594	7,761	150.95	585,761
27	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	6594	7,761	150.95	585,761
32	37.5	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	2819	3,230	212.85	343,753
33	42.9	36.8	8.87	43.92	60.28	95.84	58.2	66.19	70.84	41.59	29.75	2819	3,230	212.85	343,753

※1TTC: Travel Time Cost

※ 2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT /2

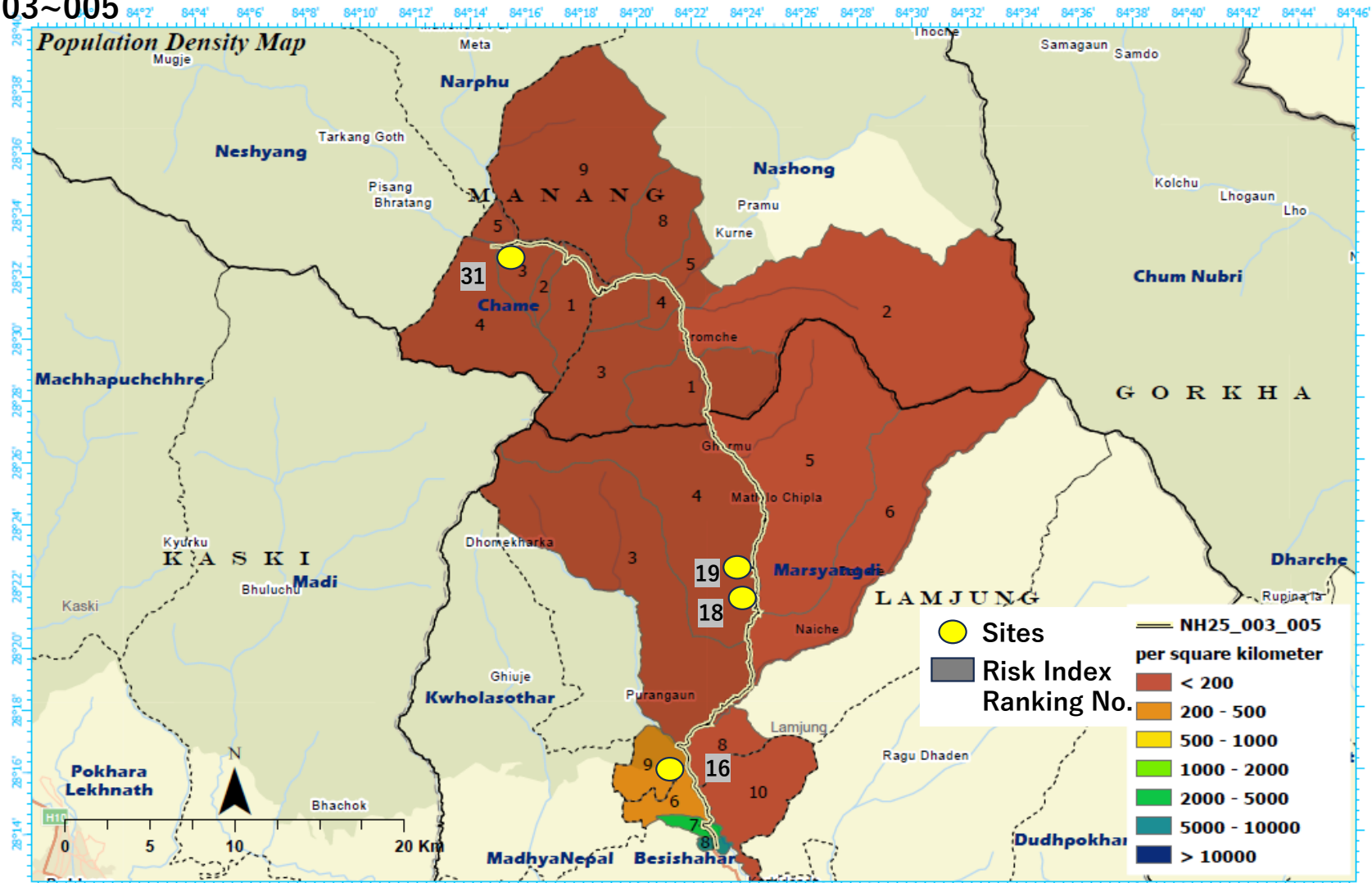
NH25-003~005 Traffic indicators for each site

Risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluative sections (km/h)	VOC									AADT (2021/22)	AADT (2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motorcycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
16	17.14	20.1	10.23	54.59	54.59	74.15	118.54	70.68	80.38	90.6	36.96	841	976	169.65	82,789
18	15.0	20.1	10.23	54.59	54.59	74.15	118.54	70.68	80.38	90.6	36.96	632	733	169.65	62,177
19	15.0	20.1	10.23	54.59	54.59	74.15	118.54	70.68	80.38	90.6	36.96	632	733	169.65	62,177
31	20.0	20.1	10.23	54.59	74.15	118.54	70.68	80.38	90.6	51.51	36.96	421	488	169.65	41,395

※1TTC: Travel Time Cost

※ 2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT / 2

NH25-003~005



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census

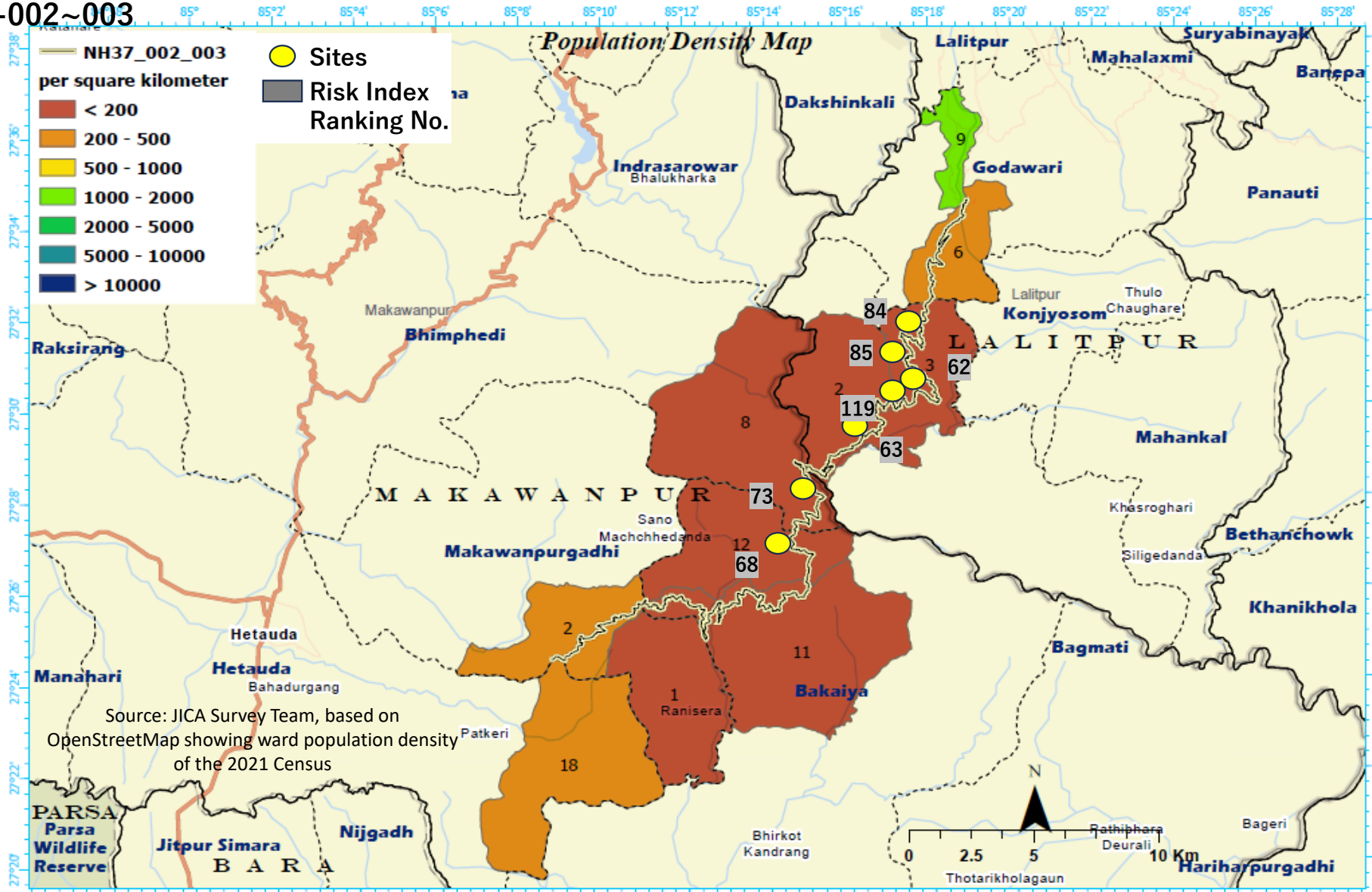
NH37-002~003 Traffic indicators for each site

Risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluate sections (km/h)	VOC									AADT (2021/22)	AADT (2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motorcycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
62	23.08	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,914	4,050	139.92	283,338
63	25	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,914	4,050	139.92	283,338
68	27.27	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,131	3,240	139.92	226,670
73	25	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,131	3,240	139.92	226,670
84	25	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,914	4,050	139.92	283,338
85	25	26.6	9.83	51.36	51.36	69.66	111.19	66.97	76.21	84.24	34.71	3,914	4,050	139.92	283,338
119	25	26.6	9.83	51.36	51.05	69.66	111.19	66.97	76.21	84.24	34.71	3,914	4,050	139.92	283,338

※1TTC: Travel Time Cost

※2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT / 2

NH37-002~003



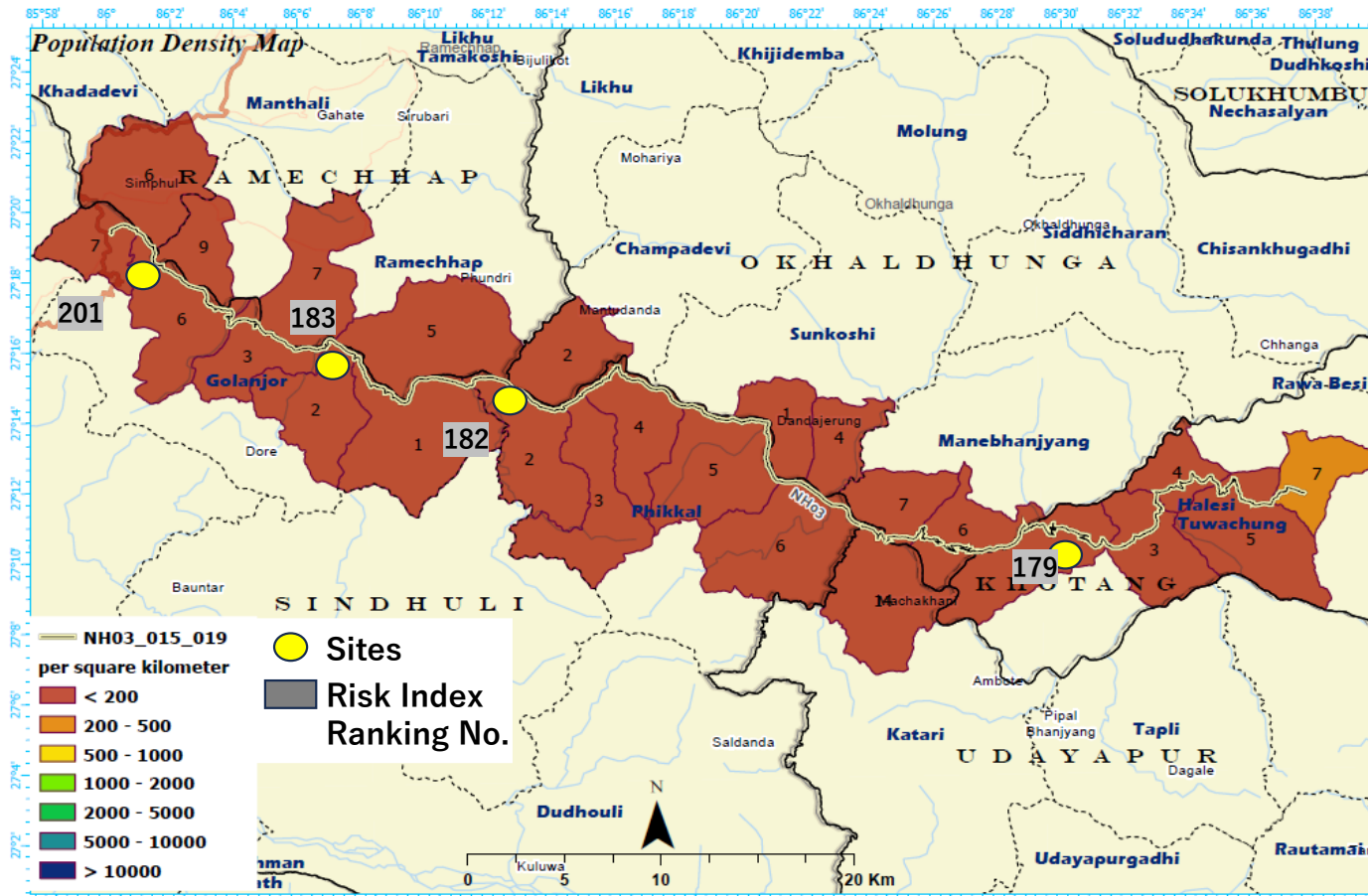
NH03-015~019 Traffic indicators for each location

Risk index ranking number : Place name	Travel speed at place (km/h)	Travel speed at evaluate sections (km/h)	VOC									AADT (2021/22)	AADT (2025)	Average TTC (2025) ※1 (NRs/h)	Waiting loss of a site of one-day whole-width closure (2025) ※2 (NRs/hour)
			Motorcycle	Car	Taxi	Light Truck	Truck	Micro Bus	Mini Bus	Bus	Safa Tempo				
179	25	33.0	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	1725	2,013	178.20	179,358
182	27.3	33.0	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	1725	2,013	178.20	179,358
183	25	33.0	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	1827	2,134	177.01	188,870
201	33.3	33.0	9.38	47.81	47.81	65.05	103.62	62.82	71.49	77.62	32.31	1827	2,134	177.01	188,870

※1TTC: Travel Time Cost

※ 2 Waiting loss of a site of one-day whole-width closure = Average TTC × AADT / 2

NH03-015~019



Source: JICA Survey Team, based on OpenStreetMap showing ward population density of the 2021 Census