KINGDOM OF BHUTAN
DEPARTMENT OF SURFACE TRANSPORT,
MINISTRY OF INFRASTRUCTURE AND TRANSPORT

PREPARATORY SURVEY FOR THE PROJECT FOR RECONSTRUCTION OF BRIDGES ON PRIMARY NATIONAL HIGHWAY NO. 1 IN MONGAR DISTRICT

FINAL REPORT

APRIL 2024

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey and entrust the survey to Oriental Consultants Global Co., Ltd..

The survey team held a series of discussions with the officials concerned of the Royal Government of Bhutan and conducted a field investigation. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Royal Government of Bhutan for their close cooperation extended to the survey team.

April 2024

TANAKA Hiroo

Director General,

Infrastructure Management Department

Japan International Cooperation Agency

SUMMARY

1. Overview of the Country

Bhutan is located at the southern foot of the Himalayas Mountain range and is surrounded by India and China. Most of its surface area (A=38,394km2) is mountainous with elevation ranging from 100 meters in the south to 7,561 meters in the north.

Major industries include agriculture, forestry, electricity (hydropower), and tourism. Over the 20-year period from 2000 to 2019, Bhutan's GDP growth was strong, averaging 10.1% per year. The economic growth rate then drops significantly to -10.2% in 2020 due to COVID-19 but recovered to 4.4% in 2021. The nominal GDP is USD 2.77 billion in 2021, and GDP per capita is USD 3,560. In 2022, total trade was about BTN 56.9 billion for exports and BTN 61.9 billion for imports, resulting in a trade deficit of about BTN 5.0 billion.

2. Background of the Project

In Bhutan, most of the surface area is mountainous region, and road traffic is the most important mode for transportation. The main road network in Bhutan consists of the Primary National Highway (PNH) No.1, which crosses from east to west of the country, and 4 other highways comprisingthree PNHs and the Asian Highway (AH) which stretches southward to the Indian border from PNH-1. Alternative routes on the roads have hardly developed due to topographical and financial constraints. Therefore, the existing road network serves as an essential infrastructure for the transport of goods, passengers, and emergency cases. Even though PNH-1 is extremely important transport lifeline as aforementioned, especially in the eastern region, bridges on PNH-1 have deteriorated from aging, collapsing by landslides and inadequate technical specifications. Accordingly, and the development of bridges isrequired to ensure stable and firm connectivity.

The Ministry of Infrastructure and Transport (MoIT) established the "Road Sector Master Plan (2007-2027)" in 2006 for implementing maintenance, repair and replacement of bridges, enhancement of feeder road and expansion of road network on the National Highway and Dzongkhag Road for 20 years until 2027.

Under this background, the Royal Government of Bhutan (RGoB) requested reconstruction of bridges on PNH-1 in the eastern area as a Grant Aid cooperation to the Government of Japan (GoJ).

3. Outline of the Project

RGoB initially requested the reconstruction of five bridges. However, two bridges, Namling bridge and Durdari bridge, were selected as the reconstruction on the project as the result of prioritization of five bridges based on the site survey and constraints of Grant Aid budget. On the other hand, the necessary measures to ensure safe traffic near future were discussed for the other three bridges, Pakhadrang bridge, Revidrang bridge, and Rollong bridge. The outline of the project is shown below.

Bridge Name (Bride Type)	Remarks
Namling Bridge (Steel Truss Bridge)	Bridge Length: 44.0m
	Bridge Width: Lane: 3.75m × 2
	Approach Road: Asphalt pavement (327.7m)
	Accessory facility, Others: 1 set
Bridge Name (Bride Type)	Remarks
Durdari Bridge (PC Box-girder Bridge)	Bridge Length: 34.5m
	Bridge Width: Lane: 3.75m × 2
	Approach Road: Asphalt pavement (359.1m)
	Accessory facility, Others: 1 set

Source: JICA Team

4. Project Implementation Period

The project is expected to be implemented in a total of 44 months i.e.13 months for detailed design and bidding, and 31 months for construction.

5. Project Assessment

5-1 Relevance

(1) Comfortability with Superordinate Plan in Bhutan

The Comprehensive National Development Plan (CNDP 2030), which JICA assisted in formulating, sets out a comprehensive and long-term vision of 'Bhutan's identity as a nation', with eight development objectives to be achieved and targets to be achieved by 2030. The development objective relating to the road sector is stated as 'network society for integrated communication', which aims to improve travel times between the eastern and western regions. In addition, the highest priority project for land transport is the 'development of the East-West Road (PNH-1)', and the replacement of the target bridges in the Project is in line with the above-mentioned national high-level plan of Bhutan. Therefore, it is considered highly appropriate for the implementation of the Project.

(2) Importance of PNH-1 in the road network

The road network in Bhutan consists mainly of the Asian Highway (AH) and a network of five major national highways. However, the only road that crosses the country in the east-west direction is currently PNH-1, and there are more than five mountain passes at altitude of more than 3,000 m, which are frequently closed during the rainy season and winter. In the case of road closures, the road is forced to take a diversion route through India, making PNH-1 extremely important as the main east-west road in Bhutan. The Southern East-West Corridor has been planned as an alternative route to PNH-1 and is currently being constructed in sections, but due to a lack of funding and environmental application problems in the national park, only a section in the south-east has been constructed at present. Therefore, it is assumed that the position of PNH-1 as the most important route in the country will remain unchanged in the future.

(3) Breakthrough of technological difficulties

The target bridge is located on a mountain road section with severe terrain and the following technically challenging tasks are expected:

- Design and construction of steel truss bridges and PC bridges with diameters longer than 30 m, which are difficult to cope with the national technical standards of Bhutan.
- Safe execution of work within the limited construction space due to topographical constraints
- Safe demolition and removal of existing bridges (including steel bridges).
- Implementation of slope protection work using crib works and anchor bolts.
- Developing a traffic safety plan to avoid complications between construction vehicles and general vehicles.

Considering the above, it is judged that it is very difficult to carry out the replacement work of the subject bridge with the existing technical capacity of Bhutan. Therefore, it is considered highly appropriate for the implementation of the Project using Japanese technology.

5-2 Effectiveness

Quantitative effects expected from the Project are summarized below:

Index	Standard Value (2023)	Target Value (2031) (3 years after the Project completion)
Days of inaccessibility in the case of the target bridges collapsed (days)	Namling: 14 (year of 2002,2016) Durdari: 14 (year of 2004)	Namling: 0 Durdari: 0
Days of inaccessibility in the case of slope failure of the attached roads (days/year)	Approx. 3 (year of 2018~2022)	0
Traffic volume (vehicles/year)	Namling: 15,435 Durdari: 19,800	Namling: 25,180 Durdari: 32,797
Passengers volume(numbers/year)	Namling: 62,258 Durdari: 68,230	Namling: 110,923 Durdari: 120,832
Traveling time in the case of the target bridges collapsed (between Trashigang and Mongar)	Approx. 12 hours (via Samdrup Jongkher, Nganglam)	Approx. 2.5hours (no bridge collapse)
Traveling time in the case of the target bridges collapsed (between Trashigang and Thimphu)	Approx. 21hours (via Samdrup Jongkher, Gelephu)	Approx. 15hours (no bridge collapse)
Amount of economic loss caused by bridge collapse avoided (USD/times)	0	285,796

Source: JICA Survey Team

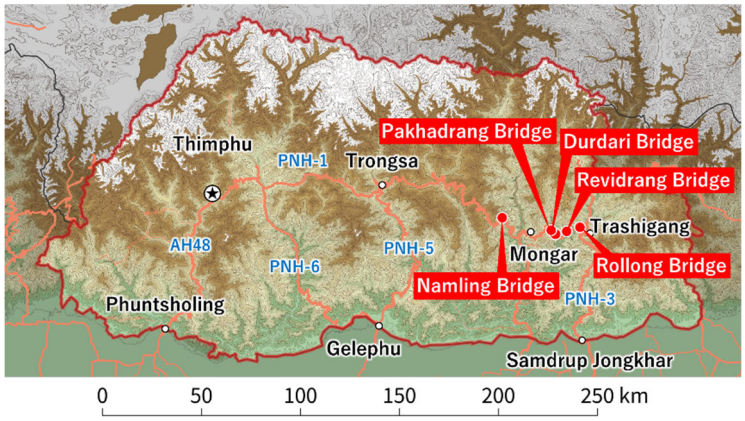
Qualitative effects expected from the grant-aid project are listed below:

Improving bridge safety:	Bridge replacement improves problems such as aging, insufficient width and load-bearing capacity, and improves safety for vehicle travel.
Enhanced access to healthcare and promotion and facilitation of movement of persons and logistics:	The bottleneck of traffic on PNH-1, which supports the economy of the eastern part of Bhutan, will be eliminated, ensuring stable freight transport and patient transport in the event of medical emergencies, thereby contributing to the promotion of logistics and improving safety in the daily lives of the population.
Reducing the risk of damage from natural disasters:	The target bridge has a history of collapse due to landslides in the past, and there is concern about landslides with road closures during the rainy season every year, hindering smooth traffic flow. By moving the new bridge position downstream of the existing bridge and securing the clearance against landslides, the risk of road closures due to landslides can be reduced and the safety of road users can be improved.

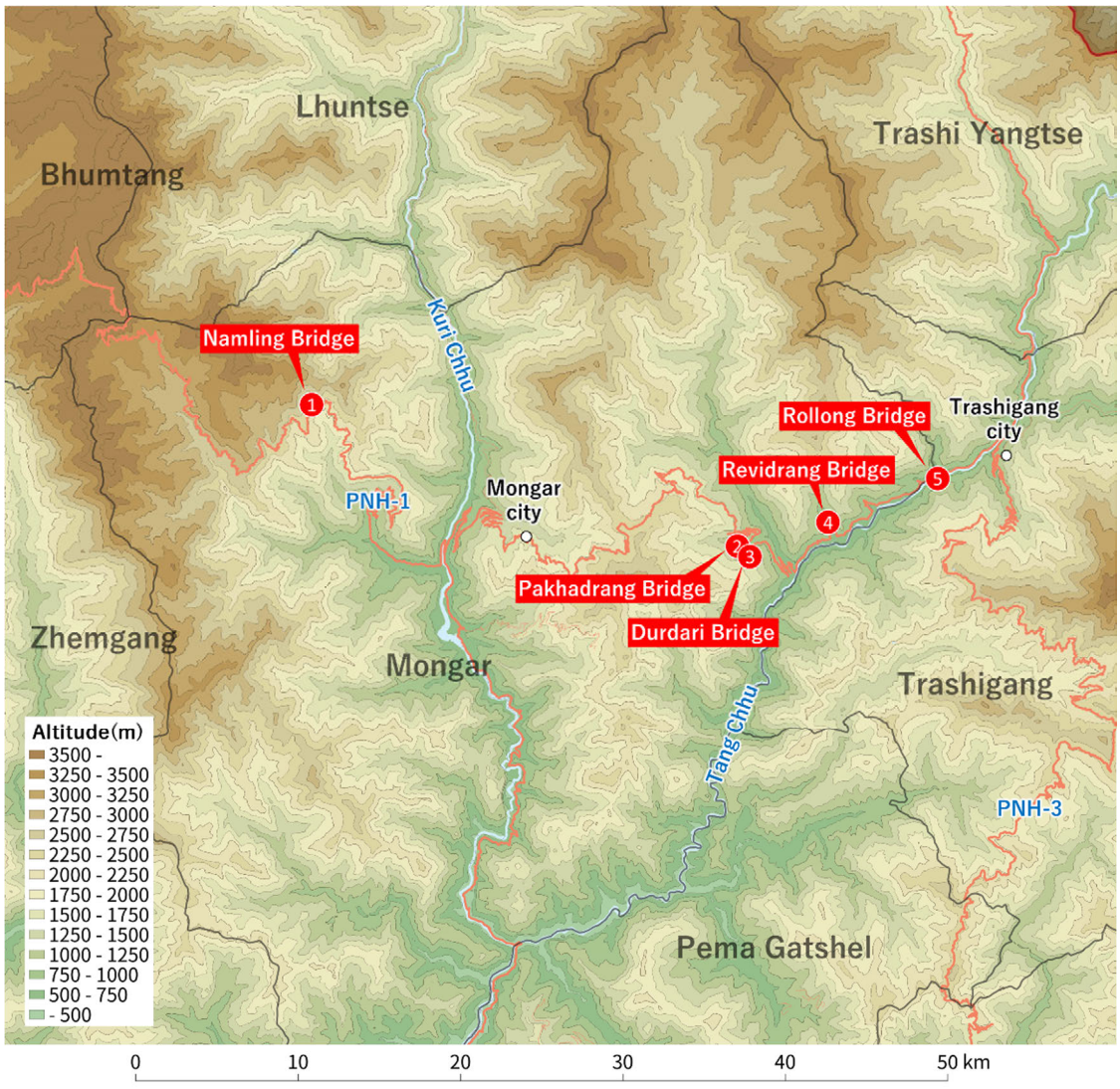
Source: JICA Survey Team

Location Map

Map of South Asia



Map of Bhutan



Project Site Map

Perspectives

Namling Bridge

Durdari Bridge

PREPARATORY SURVEY FOR THE PROJECT FOR RECONSTRUCTION OF BRIDGES ON PRIMARY NATIONAL HIGHWAY NO. 1 IN MONGAR DISTRICT

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Abbreviations

Abbreviation	Meaning
A/P	Authorization to Pay
ADB	Asian Development Bank
AH	Asian Highway
AH48	Asian Highway No.48
B/A	Bank Arrangement
BHU	Basic Health Unit
BMS	Bridge Management System
CBR	California Bearing Ratio
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNDP	Comprehensive National Development Plan for Bhutan
DANTAK	Indian Border Roads Organization
DD	Detailed Design
DEC	Dzongkhag Environment Commission
DoST	Department of Surface Transport
DTA	Department of Treasury and Accounts
E/N	Exchange of Notes
EC	Environmental Clearance
EIA	Environmental Impact Assessment
FAB DEM	Forest And Buildings removed Copernicus DEM
G/A	Grant Agreement
GDP	Gross Domestic Product
GOI	Government of India
GoJ	Government of Japan
GSMaP	Global Satellite Mapping of Precipitation
HEC	Hydraulic Engineering Circular
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
IBA	Important Bird and Biodiversity Areas
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IRC	Indian Road Congress
IUCN	International Union for Conservation of Nature

Abbreviation	Meaning
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
KBA	Key Biodiversity Areas
M/D	Minute of Discussion
MIGA	Multilateral Investment Guarantee Agency
MoF	Ministry of Finance
MoIT	Ministry of Infrastructure and Transport
NCHM	National Centre for Hydrology and Meteorology
NEC	National Environment Commission
Nu	Ngultrum
OD	Outline Design
OD Survey	Origin Destination Survey
ORC	Outreach Clinic
PHC	Primary Health Centre
PNH	Primary National Highway
PNH-1	Primary National Highway No.1
PC Bridge	Pre-stressed Concrete Bridge
PQ	Pre-qualification
RAP1	Rural Access Project 1
RAP2	Rural Access Project 2
RGoB	Royal Government of Bhutan
ROW	Right of Way
RQD	Rock Quality Designation
RSMP	Road Sector Master Plan
SCS-CN	Soil Conservation Service - Curve Number
STIs	Sexually transmitted infections
TSS	Total suspended solid
UNODC	United Nations Office on Drugs and Crime
USACE	U.S. Army Corps of Engineers
WB	World Bank

1. Background of the Project

1-1 Background of the Grant Aid Project

1-1-1 Background of the Grant Aid Project

In Bhutan, the most part of the national land (Area is 38,394 km^2) is mountainous region, and road traffic is the most important for transportations. The main road network in Bhutan consists of the Primary National Highway (PNH) No.1, which crosses from east to west of the nation, and 4 other highways, which are three PNHs and one Asian Highway (AH) stretched southward to the Indian border from PNH-1. Alternative routes on the roads hardly developed due to topographical and financial constraints, therefore, the road network serves as an essential infrastructure for the transport of goods, passengers, and emergency cases.

Even though PNH-1 is extremely important transport lifeline as aforementioned, especially in the eastern region, bridges on PNH-1 are suffered from aging, collapsing by landslide and inadequate in current specifications. For these reasons, Improvement and development of bridges are required to ensure the stable and firm connectivity.

Ministry of Infrastructure and Transport (MoIT) has established "Road Sector Master Plan (2007-2027)" in 2006 and been implementing maintenance, repair and replacement of bridges, enhancement of feeder road and expansion of road network on the National Highway and Dzongkhag Road for 20 years until 2027.

Under such conditions, the Royal Government of Bhutan (RGoB) requested reconstruction of bridges on PNH-1 in eastern area as a grant aid cooperation to the Government of Japan (GoJ).

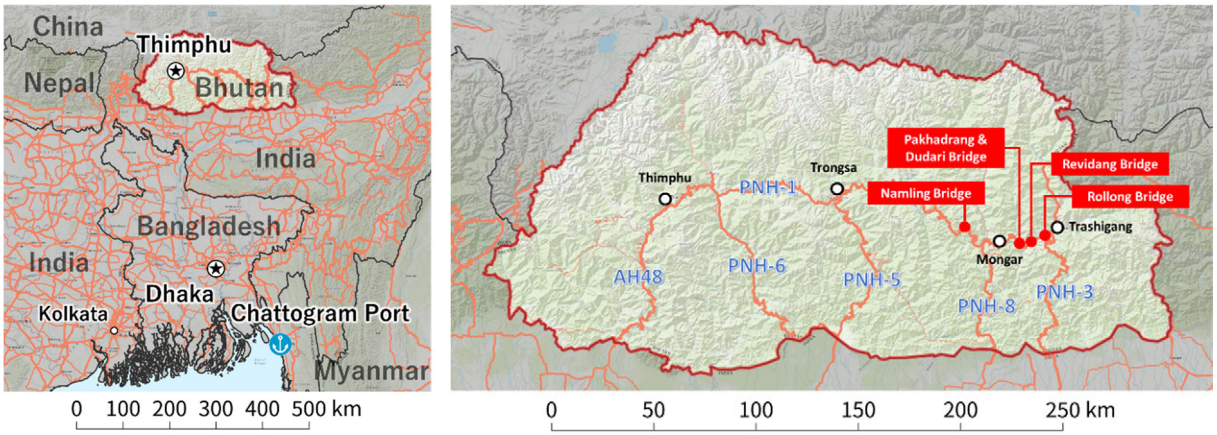
1-1-2 Outline of the Project

The project aims to achieve human safety, economic stability, and sustainable development in Bhutan by improving the safety and accessibility of national roads through the reconstruction of bridges with insufficient loading capacity and the risk of collapse. RGoB initially requested the reconstruction of five bridges. However, two bridges, Namling bridge and Durdari bridge, were selected as the reconstruction on the project by the result of prioritization of five bridges based on the site survey and constraint of GoJ budget. On the other hand, the necessary measures to ensure safe traffic near future were discussed for other three bridges, Pakhadrang bridge, Revidrang bridge, and Rollong bridge. The details of measures are desribed in "4. Study of Bridge Repair Method for Bridge not selected for Japanese Assistance". Outline of the project is shown in Table 1-1-1.

Table 1-1-1 Outline of the reconstruction of bridges

Bridge Name (Bride Type)	Remarks
Namling Bridge (Steel Simple Truss Bridge)	Bridge Length: 44.0m
	Bridge Width: Lane: 3.75mx2
	Approach Road: Asphalt pavement (327.7m)
	Accessory facility, Others: 1 set
Durdari Bridge (PC Simple Box-girder Bridge)	Bridge Length: 34.5m
	Bridge Width: Lane: 3.75mx2
	Approach Road: Asphalt pavement (359.1m)
	Accessory facility, Others: 1 set

Source: JICA Survey Team



Remarks: Number of PNH is referred to Road Classification & Network Information of Bhutan (2020)

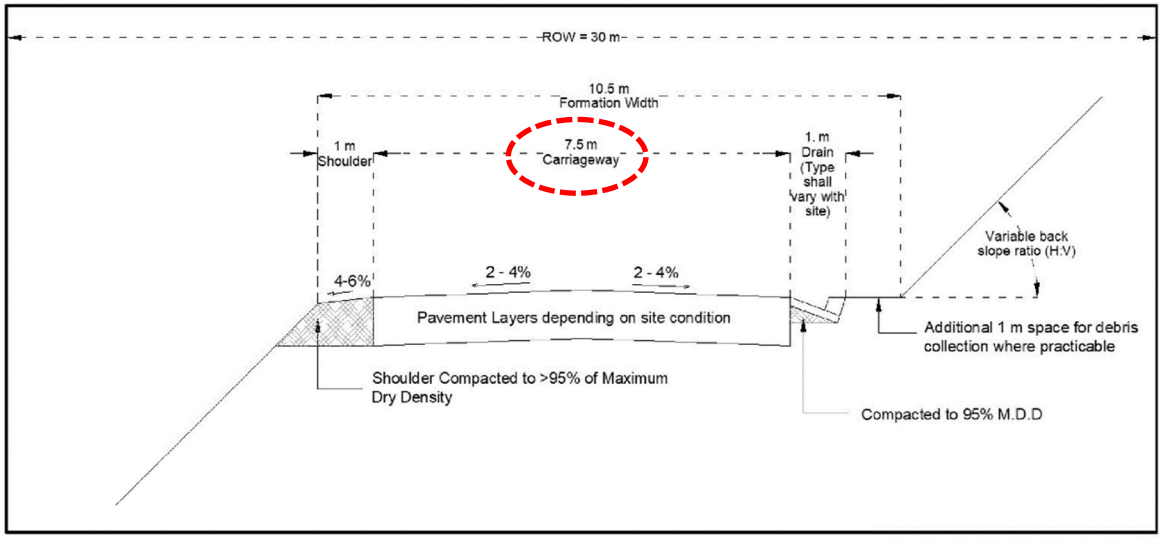
Source: JICA Survey Team

Figure 1-1-1 Location Map

1-2 Situation of the Project Site and Surround Area

1-2-1 Relevant infrastructure at the project site

DoST is currently implementing road widening works on the PNH-1 under Indian Fund. According to Road Classification and Network Information of Bhutan 2020 prepared by DoST, road with of PNH is specified with 7.5m (Refer to Figure 1-2-1). As of March 2023, road widening work had been completed on approximately 90% on thePNH-1. After completion of works, road widening works on PNH-5 is considered.



Source: Road Classification and Network Information of Bhutan 2020

Figure 1-2-1 Width configuration of the PNH

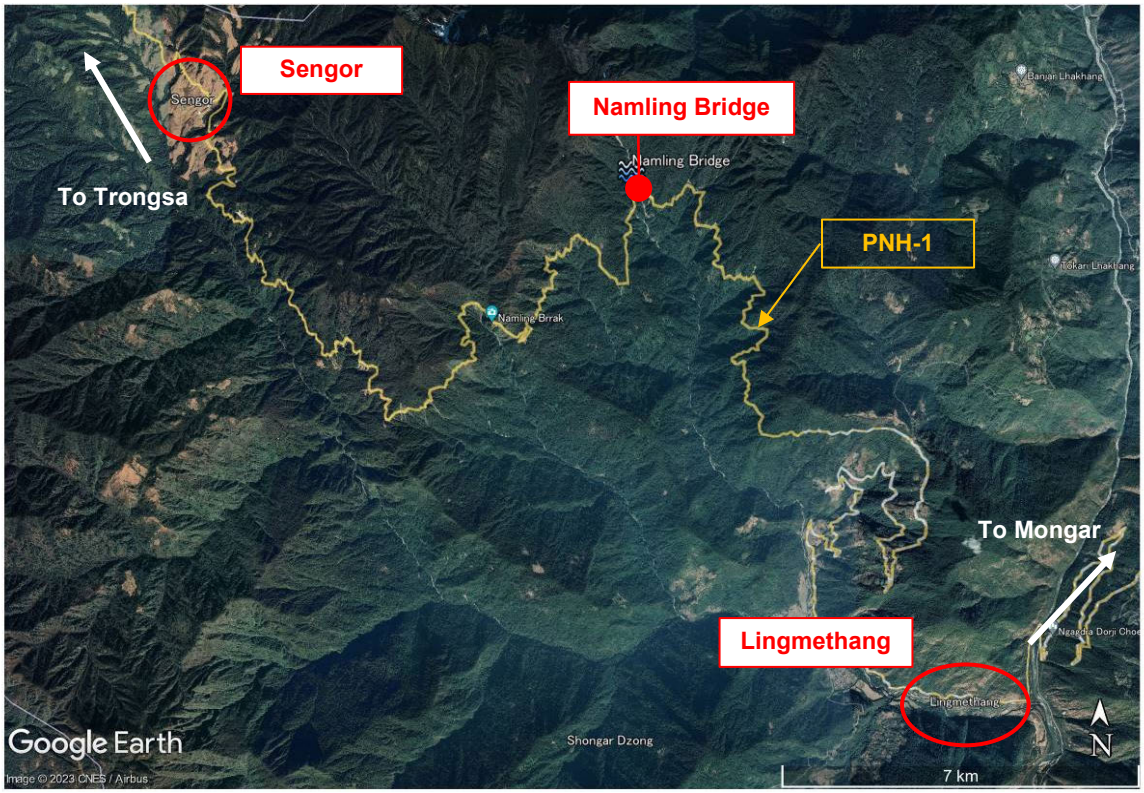
1-2-2 Current situation of the site

(1) Scope of the project

Target bridges of the project are five bridges located in Mongar Dzongkhag. Name of five bridges are Namling Bridge, Pakhadrang Bridge, Durdari Bridge, Revidrang Bridge, and Rollong Bridge from the East. Namling Bridge is under Lingmethang regional office and other bridges are under Trashigang regional office.

(2) Surround situation of the target bridges

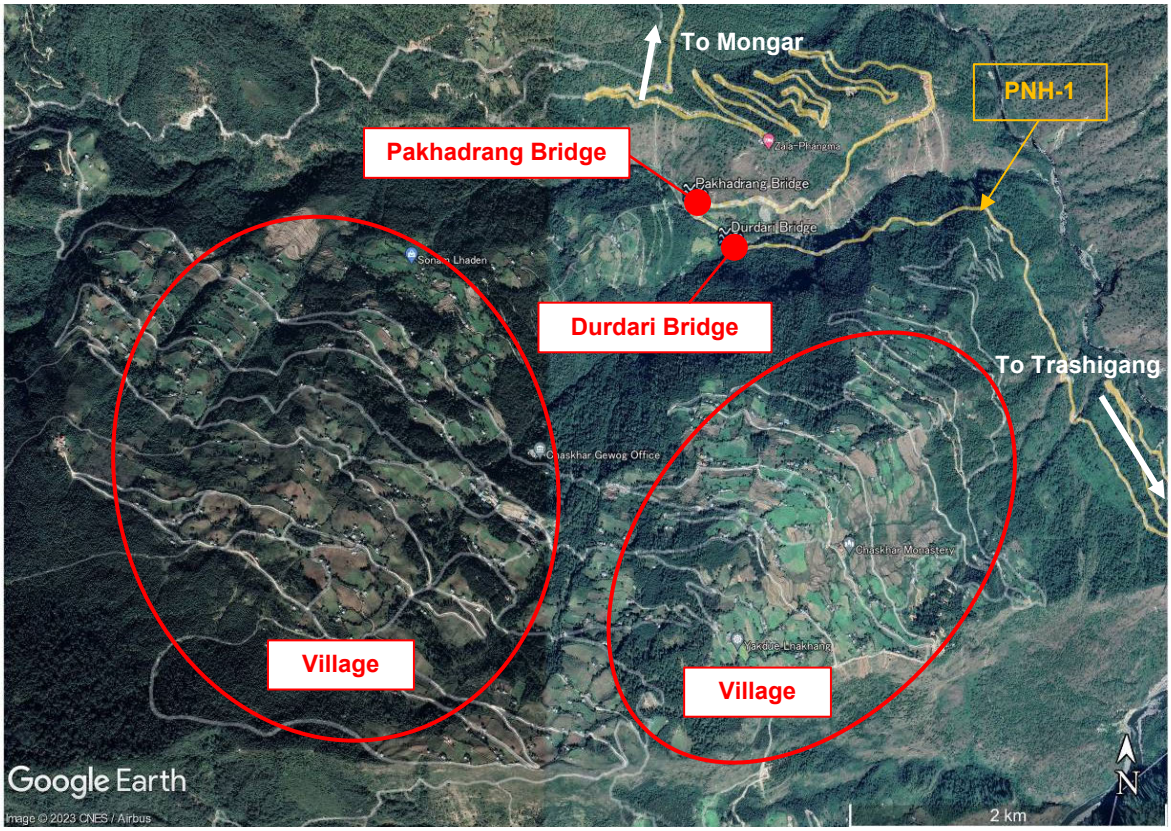
Namling bridge is located in a mountainous area, and its elevation is approximately 2,300m. There is no town near the bridge, and it takes 60 minutes to Sengor town and 45 minutes to Lingmethang town.



Source: prepared by JICA Survey Team based on Google Earth

Figure 1-2-2 Surround situation of Namling Bridge

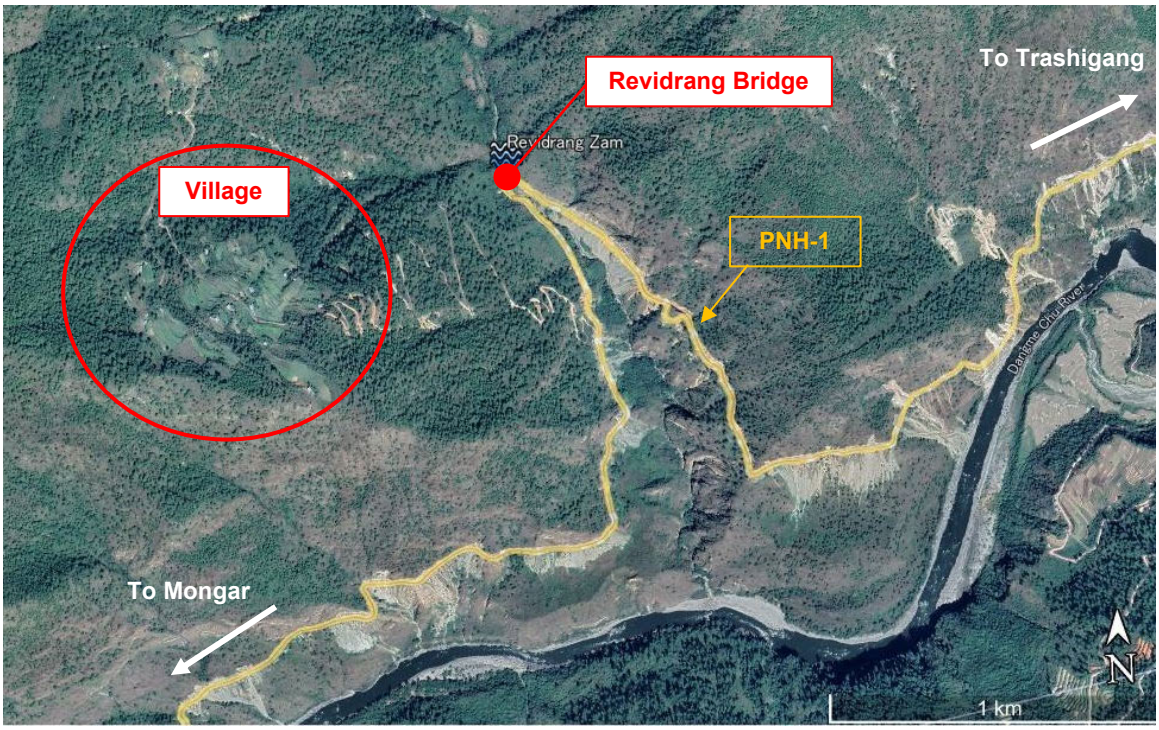
Pakhadrang Bridge is located near to Durdari Bridge and both elevations are approximately 1,000m. Villages exist on the mountain side of the bridges and produce some agricultural products. According to the interview with DoST, residents of the villages circled in red in Figure 1-2-3 sell their agricultural products on the road of PNH-1.



Source: prepared by JICA Survey Team based on Google Earth

Figure 1-2-3 Surround situation of Pakhadrang Bridge and Durdari Bridge

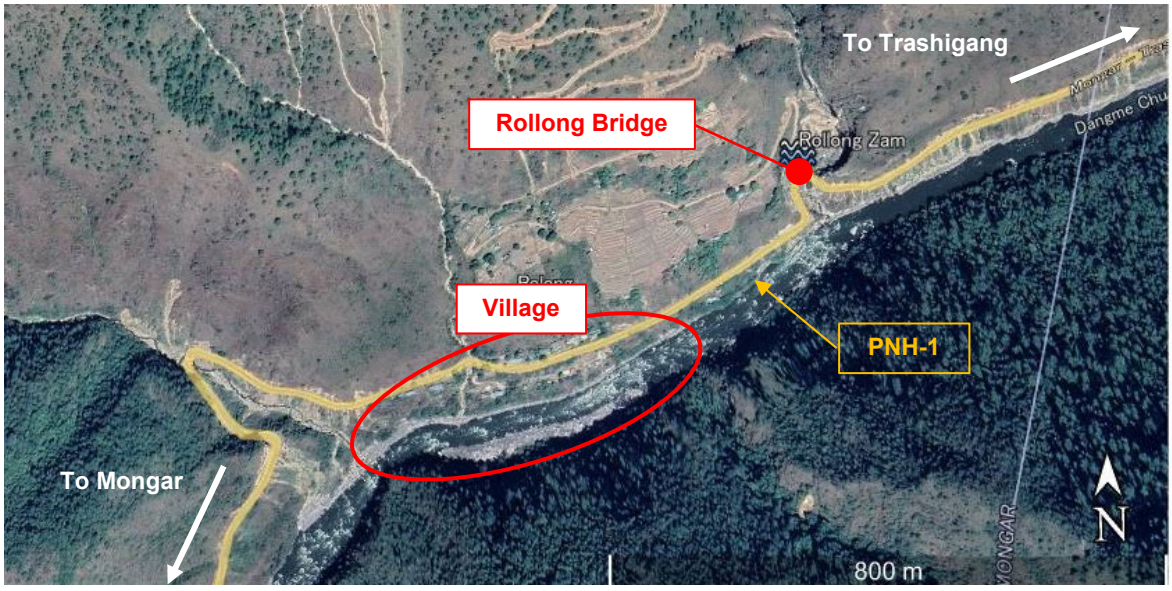
Surround situation of Revidrang bridge is shown in Figure 1-2-4. The bridge is located along with Drangme Chhu (Gongri Chhu) flowed to Manas River (international river). The elevation of the bridge is approximately 800m. Village exists on the mountain side of the bridges and produce some agricultural products as well as aforementioned two bridges (Pakhadrang Bridge and Durdari Bridge).



Source: prepared by JICA Survey Team based on Google Earth

Figure 1-2-4 Surround situation of Revidrang Bridge

Rollong bridge is located along with Drangme Chhu (Gongri Chhu) as well as Revidrang bridge. Residents exist along with the PNH-1 and the river.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-2-5 Surround situation of Rollong bridge

Namling bridge is in a mountainous area with no residents. On the other hand, other four bridges are in the area where villages and residents are existed near bridges. Thus, situations of the target bridges were confirmed.

(3) Current situation and Issues on the Namling Bridge

1) Current Situation

The current existing Namling bridge is baily bridge, and it was built in April 2020. A temporary diversion road was also constructed on the mountain side when the Namlin Bridge was built. The original Namling bridge was a box-culvert bridge, and it was washed by a debris flow occurred in 2002. Both sides of approach road were also damaged by landslides at the same time. Baily type bridge, which is not same as the current existing Namling bridge, was built in 2003 but it was washed by a debris flow occurred in 2016. Basic information for the current existing Namling bridge is shown in Table 1-2-1.

Several times of road closure occurred due to landslides during 2018 to 2020 near the Namling bridge. Road closure for two days, when it happened on 12th and 13th of May 2021, was confirmed by the result of interview form DoST.

Table 1-2-1 Basic information on Namling bridge

Picture	 Existing Bridge  Slope (Right side)  Slope (Left side)		
Location	Mongar Dzongkhag (Lingmithang Regional Office)		
Construction year	2016 (Substructure seems to be constructed in 2003)		
Bridge Type	Baily Type		
Bridge Length	27.4m	Bridge Width	3.27m
Design Speed	20km/h	Loading Capacity	30 ton (Heavy vehicles shall pass the detour on the upstream side)

Source: Prepared by JICA Survey Team based on BMS data and interview from DoST

2) Issues

The superstructure of the current bridge is a baily bridge, which is a temporary bridge, and sagging has been observed in the centre of the bridge under dead load conditions. The bridge is considered to have insufficient loading capacity, so the existing bridge needs to be replaced with a permanent bridge as soon as possible, and slope protection is urgently required as the slope around the area is very steep and rock falls are common.

(4) Current situation and Issues on the Pakhadrang Bridge

1) Current Situation

Pakhadrang Bridge, constructed in 1982, has never been affected by disaster in its lifetime. Basic information on Pakhadrang Bridge is shown in Table 1-2-2 On the other hand, the PNH-1 between Mongar and Trashigang has been closed several times from 2018 to 2020 due to landslides.

2) Issues

Rebar exposure was observed in the deck bottom and main girder. Pakhadrang Bridge is an RC bridge, and rebar corrosion is one of the critical deteriorations. Therefore, the existing bridge needs to be replaced as soon as possible.

Table 1-2-2 Basic information on Pakhadrang Bridge

Picture	 Existing Bridge  Slope (Right side)  Slope (Left side)		
Location	Mongar Dzongkhag (Trashigang Regional Office)		
Construction year	1982		
Bridge Type	RC Bridge (I Type Girder)		
Bridge Length	19.4m	Bridge Width	4.24m
Design Speed	20km/h	Loading Capacity	40 ton

Source: Prepared by JICA Survey Team based on BMS data and interview from DoST

(5) Current situation and Issues on the Durdari Bridge

1) Current Situation

The current existing Durdari Bridge is baily bridge, and it was constructed in April 2004. The original bridge was a box-culvert bridge, and it was washed by a debris flow occurred in 2004. Basic information on Durdari Bridge is shown in Table 1-2-3. The PNH-1 between Mongar and Trashigang has been closed several times from 2018 to 2020 due to landslides.

2) Issues

The superstructure of the current bridge is a baily bridge, which is a temporary bridge, and steel corrosion has been observed. Therefore, the existing bridge needs to be replaced with a permanent bridge as soon as possible.

Table 1-2-3 Basic information on Durdari Bridge

Picture	 Existing Bridge  Slope (Right side)  Slope (Left side)		
Location	Mongar Dzongkhag (Trashigang Regional Office)		
Construction year	2004		
Bridge Type	Baily Type		
Bridge Length	24.4m	Bridge Width	3.26m
Design Speed	20km/h	Loading Capacity	40 ton

Source: Prepared by JICA Survey Team based on BMS data and interview from DoST

(6) Current situation and Issues on the Revidrang Bridge

1) Current Situation

The Revidrang Bridge was reinforced in 2019 by the installation of a support vent at the center span for the countermeasure of bending moment. However, the bridge was closed due to the progress of damage. Vehicles are currently using a diversion road constructed in 2020 after the bridge was closed. Rainfall in the rainy season the same year caused overflow on the diversion road, but impact on traffic was minor. Basic information on the Revidrang Bridge is shown in Table 1-2-4. The PNH-1 between Mongar and Trashigang has been closed several times from 2018 to 2020 due to landslides.

2) Issues

The bridge is currently closed, and overflow on diversion road has been observed during rainy season. Function as the PNH-1 is insufficient. Therefor the existing bridge needs to be replaced with a permanent bridge as soon as possible.

Table 1-2-4 Basic information on Revidrang Bridge

Picture	 Existing Bridge  Slope (Right side)  Slope (Left side)		
Location	Mongar Dzongkhag (Trashigang Regional Office)		
Construction year	1992		
Bridge Type	RC Bridge (I Type Girder)		
Bridge Length	19.1m	Bridge Width	4.3m
Design Speed	20km/h	Loading Capacity	40 ton

Source: Prepared by JICA Survey Team based on BMS data and interview from DoST

(7) Current situation and Issues on the Rollong Bridge

1) Current Situation

Rollong Bridge, constructed in 1968, has no evidence or record of disaster affecting the bridge. The PNH-1 between Mongar and Trashigang has been closed several times from 2018 to 2020 due to landslides.

2) Issues

Rebar exposure was observed in the deck bottom and main girder. Pakhadrang Bridge is an RC bridge, and rebar corrosion is one of the critical deteriorations. Therefore, the existing bridge needs to be replaced as soon as possible.

Table 1-2-5 Basic information on Rollong Bridge

Picture	 Existing Bridge  Slope (Right side)  Slope (Left side)		
Location	Mongar Dzongkhag (Trashigang Regional Office)		
Construction year	1968		
Bridge Type	RC Bridge (I Type Girder)		
Bridge Length	13.5m	Bridge Width	4.03m
Design Speed	20km/h	Loading Capacity	40 ton

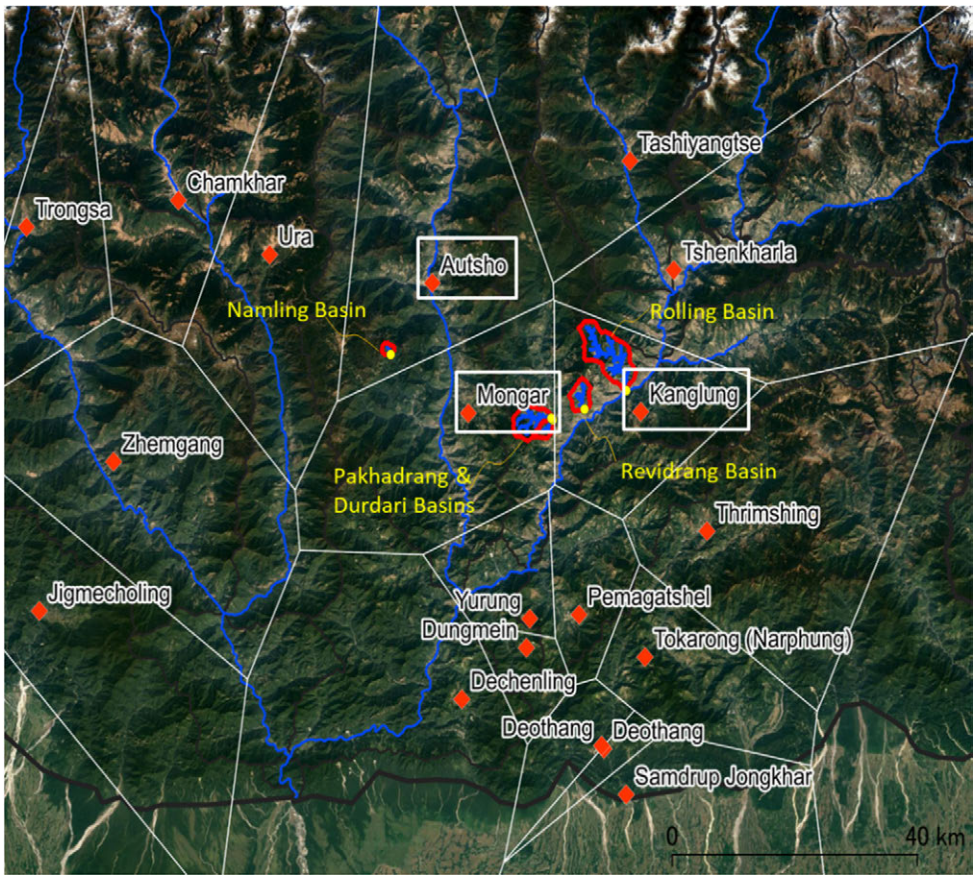
Source: Prepared by JICA Survey Team based on BMS data and interview from DoST

1-3 Natural Conditions

1-3-1 Meteorology

Meteorological data was collected from the National Centre for Hydrology and Meteorology (NCHM). The climate in the basin of the five surveyed bridges is classified as a subtropical highland climate (Cwb) according to Köppen's climate classification. And it is characterized by the differentiation of "summer rainy season" and "winter dry season", due to the influence of the monsoon in the mid-latitude high-pressure zone. The four seasons are relatively distinct: spring from March to May, summer from June to September, autumn from October to November, and winter from December to February. Periodic impacts from the remnants of cyclones that occasionally cross India from the Bay of Bengal, bring relatively heavy rainfall, especially in the eastern regions.

There are 40 weather stations under the jurisdiction of NCHM in Bhutan. In order to obtain average meteorological (average-rainfall over watershed) data within the basin, targeted stations that can represent as the average data of the bridge basins under study were selected, by using the Thiessen polygon method from these stations. The Thiessen polygon map is shown in Figure 1-3-1. The Namling Bridge basin is represented by the Autsho Station, the Pakhadrang Bridge and Durdari Bridge basins are represented by the Mongar Station, and the Revidrang Bridge and Rolling Bridge basins are represented by the Kanglung Station, and then these meteorological data were collected.



Source: National Centre for Hydrology and Meteorology (NCHM), Google Earth

Figure 1-3-1 Thiessen Polygon around Target Basins of Meteorological Stations in Bhutan

Table 1-3-1 List for Collected Meteorological Stations

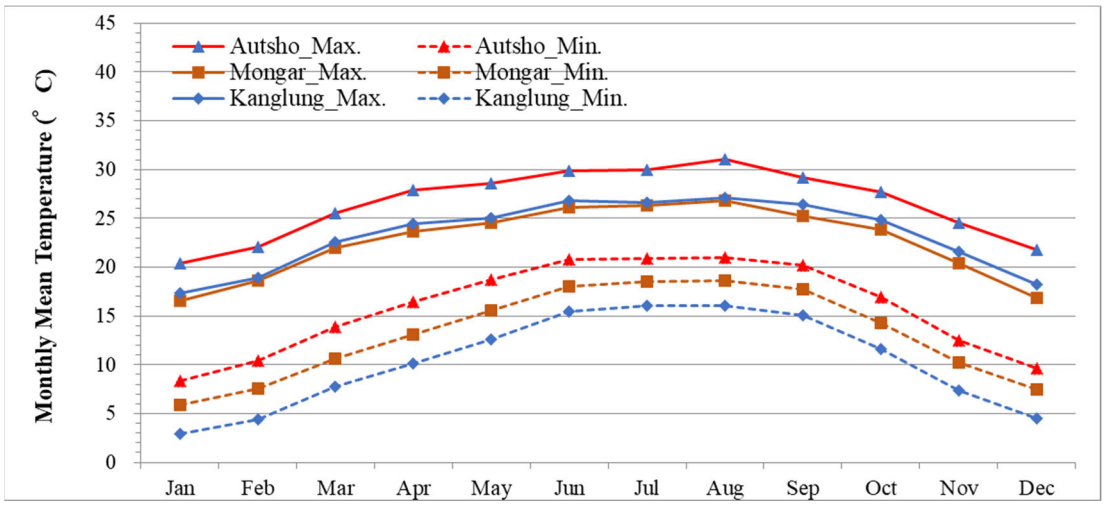
Sl. no.	Name	station ID	Station Type	Auto / Manual	Dzongkhag	Latitude	Longitude	Elevation (m)	Remarks
1	Kanglung	17480046	Class A	Manual	Trashigang	27.2780	91.5016	1,987	Revidrang, Rolling
2	Mongar	16300046	Class A	Manual	Mongar	27.2793	91.2357	1,564	Pahhadrang, Durdari
3	Autsho	16400046	Class C	Manual	Lhuntse	27.4400	91.1700	863	Namling

Source: National Centre for Hydrology and Meteorology (NCHM)

(1) General Climate

1) Temperature

Monthly average temperature varies depending on the altitude of the station, with a maximum temperature of 17 to 31 °C and a minimum temperature of 3 to 21 °C.

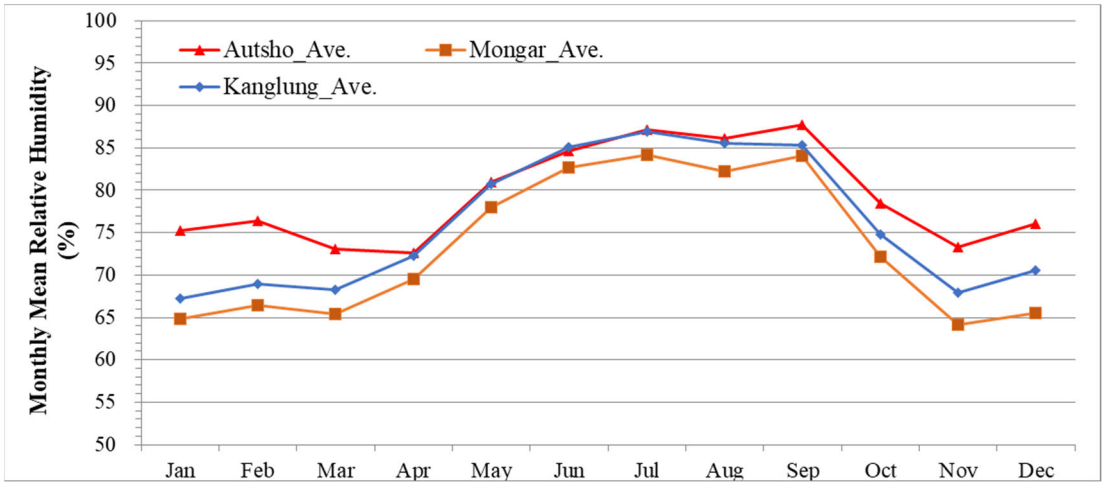


Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-2 Monthly Mean Temperature (2013 - 2022)

2) Relative Humidity

Relative humidity is high in the rainy season and low in the dry season, changing between 64% and 87% throughout the year.



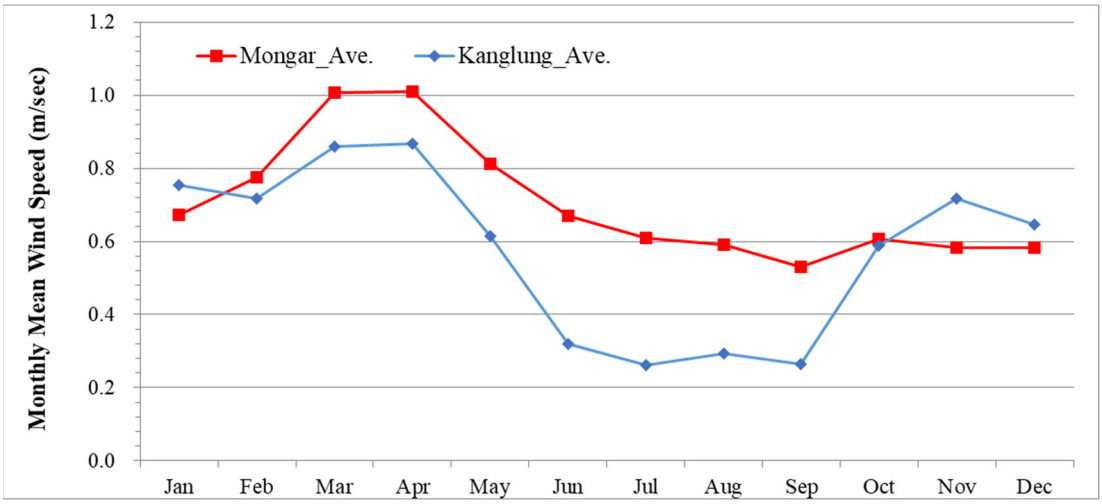
Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-3 Monthly Mean Relative Humidity (2013-2022)

3) Wind Speed

NCHM only collects daily average wind speed readings. (See Figure 1-3-4. Wind speed is not measured at Autsho Station.)

Although the maximum wind speed value is unknown, Bhutan is not the area where strong winds occur, although it is affected by the remnants of cyclones that occur in the Bay of Bengal. According to the 'Compendium of Climate and Hydrological Extremes in Bhutan', strong winds of 50-60 km/hr (13.9-16.7 m/sec) occurred in the Thimphu Valley in April 1996.



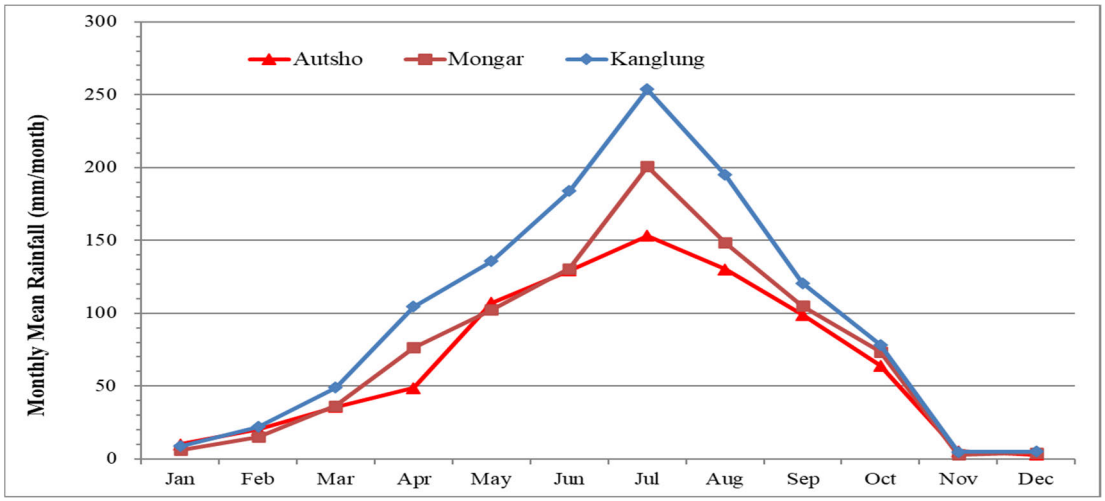
Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-4 Monthly Mean Wind Speed (2013-2022)

(2) Characteristics of Rainfall

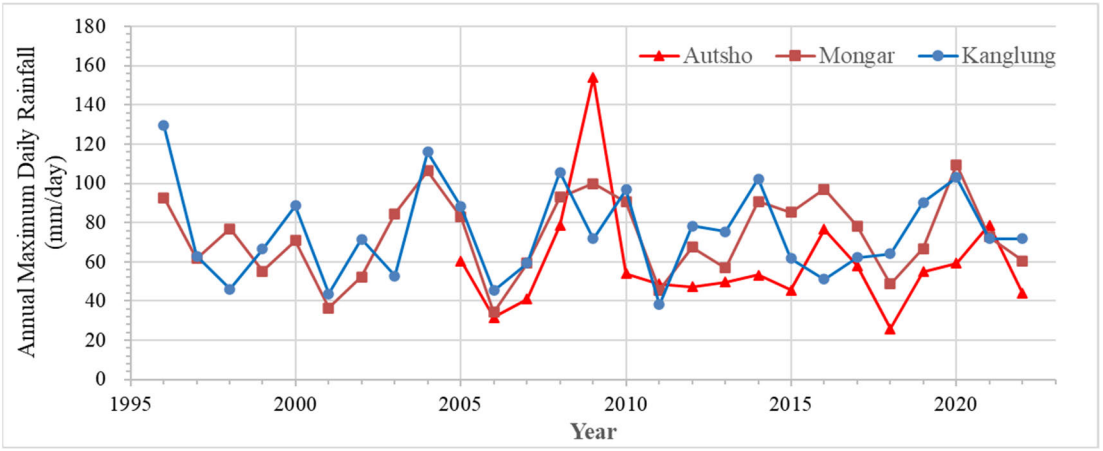
1) Annual, Monthly and Daily Rainfall

Figure 1-3-5 shows the monthly average precipitation of the 3 rainfall stations, and Figure 1-3-6 shows the annual precipitation fluctuation of them. Among the target bridges, the average annual precipitation at the Kanglung Station near the easternmost Rolling Bridge is 1,162 mm, and at the Autsho Station near the westernmost Namling Bridge, it is 806 mm. Due to the influence of the monsoon, the rainy season from May to September accounts for more than 76% of the total annual rainfall, with July being the heaviest, followed by August. Although annual precipitation fluctuates with large variations, there is no noticeable trend of significant annual variation not indicating a slight increase in precipitation due to climate change. Daily precipitation data from NCHM was collected for 27 years (1996-2022) at Kanglung and Mongar Stations, and for 18 years (2005-2022) at Autsho station. The daily precipitation at each rainfall station is shown in Figure 1-3-7 to Figure 1-3-9. On the other hand, in order to understand short-term rainfall characteristics such as hourly rainfall, we attempted to obtain hourly rainfall, but nearby rainfall stations only have data for the past five years since observation, and the data is quite unreliable as a statistical quantity. Furthermore, we obtained the hourly rainfall near each bridge since March 2000 from Japan's JAXA satellite rainfall (GSMaP) distribution data, but the annual rainfall was only about 40 to 60% of the rainfall at rainfall stations. Therefore, it was determined that there was a problem with reliability and the decision was made not to adopt it.



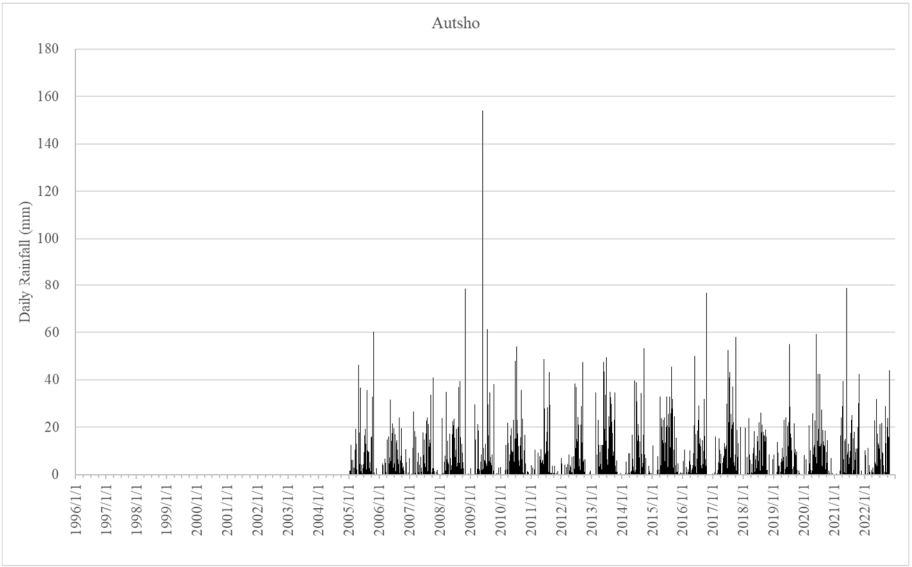
Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-5 Monthly Mean Rainfall at 3 Stations (-2022)



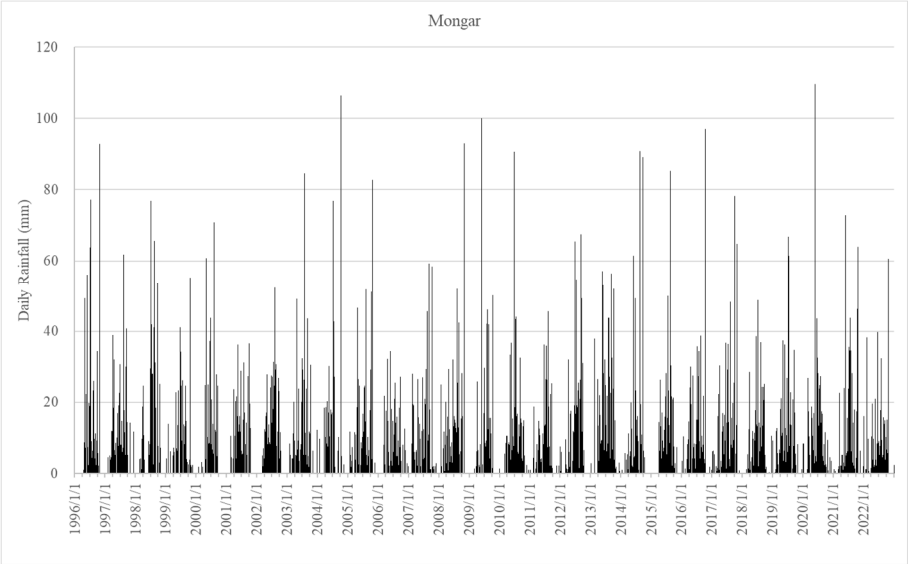
Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-6 Change of Annual Rainfall at 3 Stations (-2022)



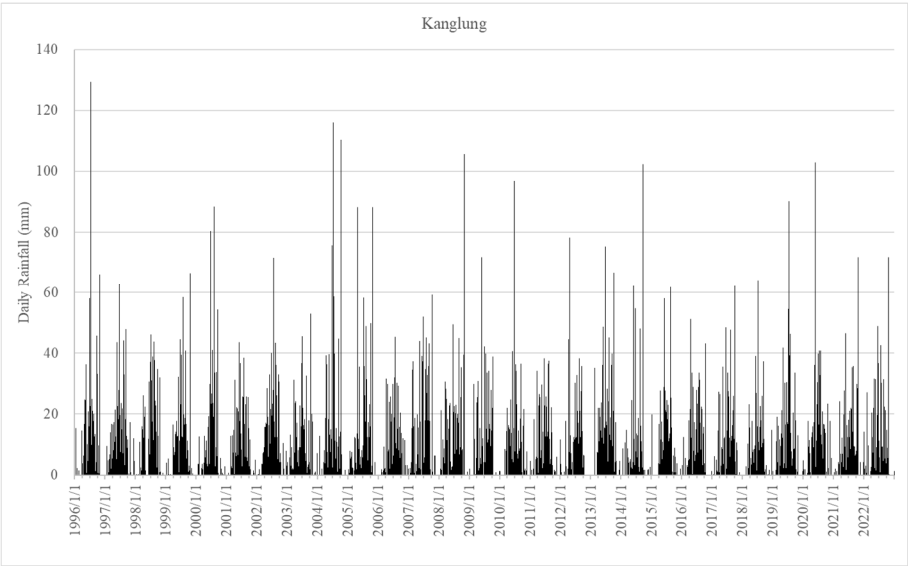
Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-7 Daily Rainfall at Autsho Station (2005-2022, Namling Bridge)



Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-8 Daily Rainfall at Mongar Station (1996-2022, Pakhadrang and Drdari Bridges)



Source: National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-9 Daily Rainfall at Kanglung Station (1996-2022, Revidrang and Rolling Bridges)

2) Annual Maximum Daily Rainfall (Extreme Values)

The extreme values (annual maximum daily rainfall) required for rainfall statistical analysis are summarized in Table 1-3-2.

Table 1-3-2 Annual Extreme Values (Annual Maximum Daily Rainfall)

Year	Kanglung		Mongar		Autsho		Remarks
	ID	19116	ID	19001	ID	19016	
	X	91.50160	X	91.23570	X	91.17000	
	Y	27.27800	Y	27.27930	Y	27.44000	
	R24max	Date	R24max	Date	R24max	Date	
Data No.	27		27		18		years
1996	129.4	1996/7/12	92.8	1996/10/29			
1997	62.8	1997/6/17	61.8	1997/8/10			
1998	46.2	1998/7/6	76.8	1998/7/5			
1999	66.5	1999/10/19	55.2	1999/10/18			
2000	88.5	2000/8/2	70.8	2000/8/2			
2001	43.6	2001/5/29	36.6	2001/10/1			
2002	71.6	2002/7/23	52.4	2002/8/5			Namling washed away.
2003	52.9	2003/10/9	84.6	2003/7/26			
2004	116.0	2004/7/9	106.4	2004/10/7			Durdari washed away
2005	88.2	2005/4/23	82.8	2005/10/20	60.4	2005/10/22	
2006	45.4	2006/7/25	34.4	2006/5/28	31.6	2006/5/13	
2007	59.2	2007/10/9	59.2	2007/9/6	41.0	2007/10/10	
2008	105.6	2008/10/27	93.0	2008/10/28	78.6	2008/10/28	
2009	71.8	2009/5/25	100.0	2009/5/26	154.0	2009/5/26	Cyclone Aila
2010	96.8	2010/6/26	90.6	2010/6/26	54.0	2010/7/11	
2011	38.2	2011/6/16	45.6	2011/8/6	48.8	2011/6/1	
2012	78.2	2012/4/19	67.4	2012/9/2	47.4	2012/9/13	
2013	75.4	2013/6/25	57.0	2013/5/23	49.6	2013/6/27	
2014	102.4	2014/9/21	90.8	2014/8/14	53.4	2014/9/21	
2015	61.8	2015/8/19	85.2	2015/8/19	45.6	2015/8/19	
2016	51.2	2016/4/17	97.0	2016/10/12	76.6	2016/10/12	Namling washed away.
2017	62.2	2017/9/29	78.2	2017/9/29	58.2	2017/9/29	
2018	64.2	2018/7/3	48.8	2018/7/3	26.0	2018/7/30	
2019	90.2	2019/7/10	66.8	2019/7/7	55.0	2019/7/8	
2020	103.0	2020/5/21	109.6	2020/5/21	59.4	2020/5/21	
2021	71.8	2021/10/19	72.8	2021/5/26	78.8	2021/5/26	
2022	71.8	2022/10/24	60.6	2022/10/24	44.0	2022/10/24	
2023							
Max	129.4	1996/7/12	109.6	2020/5/21	154.0	2009/5/26	
Average	74.6		73.2		59.0		
Min	38.2		34.4		26.0		

Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

3) Rainfall Intensity Curve (IDF Curve)

The rainfall intensity curve, IDF curve, that is, the rainfall Intensity (Intensity) - rainfall Duration (Duration) - rainfall Frequency (Frequency) curve, is determined by statistical processing of the extreme values for each rainfall duration, but this time, the rainfall data is based on daily rainfall data. Hence, since only daily rainfall is available, the short-term rainfall distribution was reasoned by analogy using the Japanese Mononobe equation.

Table 1-3-4 shows the probable rainfall amount at each rainfall station and bridge basin determined from hydrological statistical calculations. (The probability values for each duration estimated from JAXA's hourly rainfall are also attached for reference, but are not adopted as design values.) Figure 1-3-10 to Figure 1-3-12 show the rainfall intensity curves (IDF curves) estimated from each rainfall station data, and Table 1-3-3 shows the constants of the rainfall intensity formula. Runoff analysis for each bridge basin uses the design rainfall waveform of this rainfall intensity formula.

Table 1-3-3 Constants for Rainfall Intensity Equations each Station

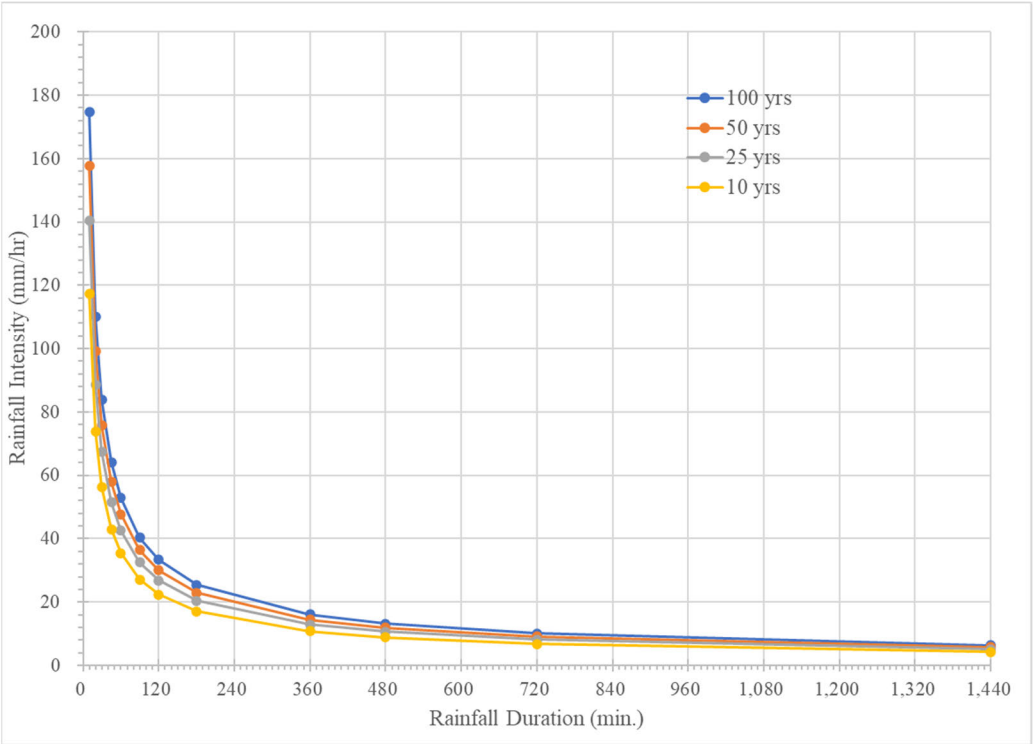
Return Period (Probability) (Year, %)		Rainfall Intensity Formulae, $I = a / t^{2/3}$ (Mononobe)						Remarks
		Autsho (for Namling)		Mongar (for Pakhadrang, Durdari)		Kanglung (for Revidrang, Rolling)		
		Value of coefficient 'a' when the unit of 't' in the formula is in the lower row						
		a for hrs.	a for min.	a for hrs.	a for min.	a for hrs.	a for min.	
1.1	90.9%	12.379	189.727	18.686	286.392	18.216	279.187	
2	50.0%	21.546	330.221	27.227	417.279	27.618	423.283	
3	33.3%	25.542	391.462	30.948	474.318	31.693	485.725	
5	20.0%	29.969	459.308	35.022	536.759	36.237	555.372	
10	10.0%	35.532	544.565	40.193	616.013	41.917	642.430	
20	5.0%	40.859	626.219	45.169	692.264	47.402	726.487	
25	4.0%	42.544	652.037	46.736	716.280	49.125	752.904	
30	3.33%	43.915	673.051	48.028	736.093	50.536	774.519	
50	2.0%	47.754	731.890	51.593	790.730	54.453	834.559	
80	1.25%	51.280	785.926	54.845	840.563	58.057	889.796	
100	1.0%	52.925	811.143	56.373	863.979	59.742	915.613	
150	0.667%	55.942	857.374	59.193	907.208	62.837	963.045	
200	0.5%	58.096	890.396	61.191	937.828	65.030	996.667	
300	0.33%	61.113	936.627	63.973	980.457	68.086	1043.499	
400	0.25%	63.228	969.049	65.971	1011.077	70.280	1077.121	
500	0.2%	64.874	994.266	67.498	1034.493	71.964	1102.939	

Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Table 1-3-4 Probable Rainfall each Rainfall Duration

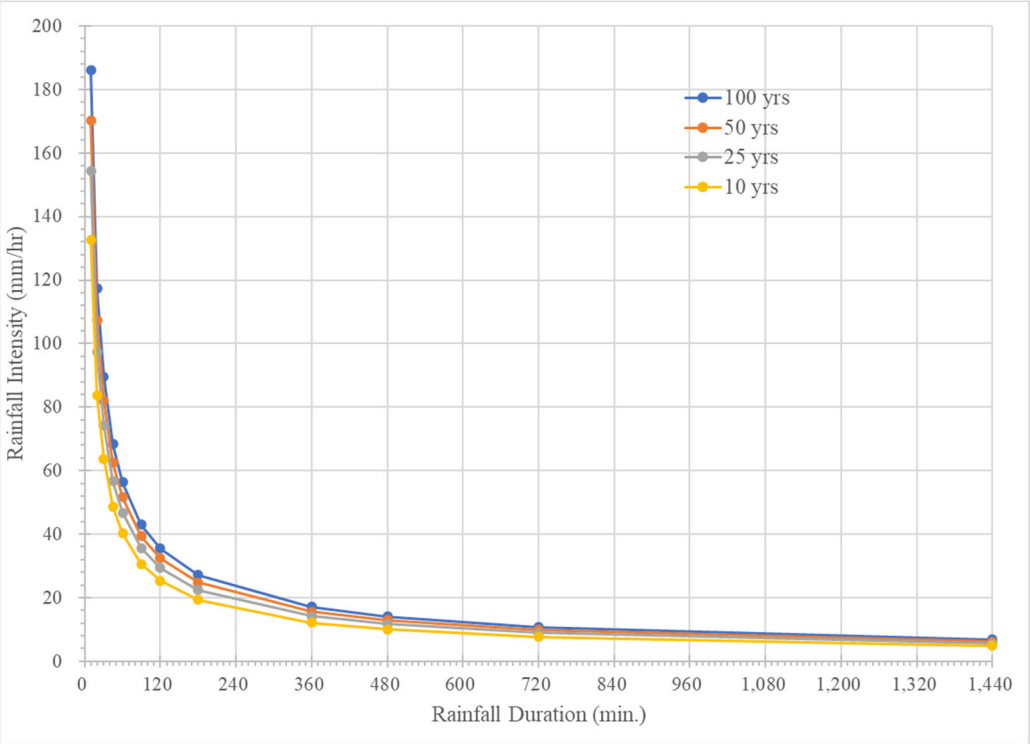
Observation Organization			NCHM			JAXA									Remarks
Station ID			17480046	16300046	16400046	GSMaP									
Station Name			Kanglung (Daily Rain)	Mongar (Daily Rain)	Autsho (Daily Rain)	Namling (24hr Rain)	Namling (6hr Rain)	Namling (1hr Rain)	Pakhadrang (24hr Rain)	Pakhadrang (6hr Rain)	Pakhadrang (1hr Rain)	Rolling (24hr Rain)	Rolling (6hr Rain)	Rolling (1hr Rain)	
River Name			Manas	Manas	Manas	Manas	Manas	Manas	Manas	Manas	Manas	Manas	Manas	Manas	
Long. (X)			91.5016	91.2357	91.17	91.1088				91.3748			91.4977		
Lat. (Y)			27.278	27.2793	27.44	27.3504				27.2732			27.3097		
Duration (min)			1,440	1,440	1,440	1,440	360	60	1,440	360	60	1,440	360	60	
Data No. of Extreme Value			27	27	18	23	23	23	23	23	23	23	23	23	
Probable Rainfall (mm)	(Year)	(%)													
	1.1	90.90%	46.5	47.7	31.6	19.9	17	5	19.8	13.6	-1.6	17.9	12	-1.8	
	2	50.00%	70.5	69.5	55	37.8	23.8	6.6	44.3	29.1	13.8	43	28.6	12.8	
	3	33.30%	80.9	79	65.2	45.6	26.7	7.3	54.8	35.8	20.4	53.9	35.8	19.1	
	5	20%	92.5	89.4	76.5	54.3	29.9	8.1	66.6	43.2	27.8	66	43.8	26.1	
	10	10%	107	102.6	90.7	65.1	34	9.1	81.4	52.5	37.1	81.2	53.8	34.9	
	20	5.00%	121	115.3	104.3	75.6	37.9	10.1	95.6	61.5	46	95.7	63.5	43.4	
	25	4%	125.4	119.3	108.6	78.9	39.2	10.4	100.1	64.4	48.8	100.4	66.5	46.1	
	30	3.33%	129	122.6	112.1	81.6	40.2	10.7	103.7	66.7	51.1	104.1	69	48.3	
	50	2%	139	131.7	121.9	89.1	43	11.3	113.9	73.1	57.5	114.6	75.9	54.4	
	80	1.25%	148.2	140	130.9	96	45.5	12	123.3	79	63.4	124.2	82.3	59.9	
	100	1%	152.5	143.9	135.1	99.2	46.8	12.3	127.7	81.8	66.2	128.8	85.3	62.6	
	150	0.67%	160.4	151.1	142.8	105.1	49	12.8	135.7	86.9	71.2	137	90.7	67.4	
	200	0.50%	166	156.2	148.3	109.3	50.5	13.2	141.4	90.5	74.8	142.8	94.6	70.8	
	300	0.33%	173.8	163.3	156	115.2	52.8	13.7	149.4	95.6	79.8	151.1	100	75.5	
	400	0.25%	179.4	168.4	161.4	119.3	54.3	14.1	155.1	99.2	83.4	156.9	103.9	78.9	
	500	0.20%	183.7	172.3	165.6	122.6	55.5	14.4	159.5	101.9	86.2	161.4	106.8	81.6	
X-COR(99%)			0.991	0.963	0.914	0.985	0.977	0.995	0.979	0.877	0.81	0.985	0.897	0.783	
P-COR(99%)			0.994	0.989	0.976	0.985	0.988	0.996	0.974	0.973	0.862	0.985	0.976	0.822	
SLSC(99%)			0.026	0.053	0.097	0.034	0.042	0.019	0.041	0.127	0.181	0.035	0.113	0.204	
Probabilistic Distributed model			Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	Gumbel	

Source: from Data of National Centre for Hydrology and Meteorology (NCHM) and Japan Aerospace Exploration Agency (JAXA, Global Satellite Mapping of Precipitation: GSMaP). However, the estimated value of GSMaP is not used as a reference value.



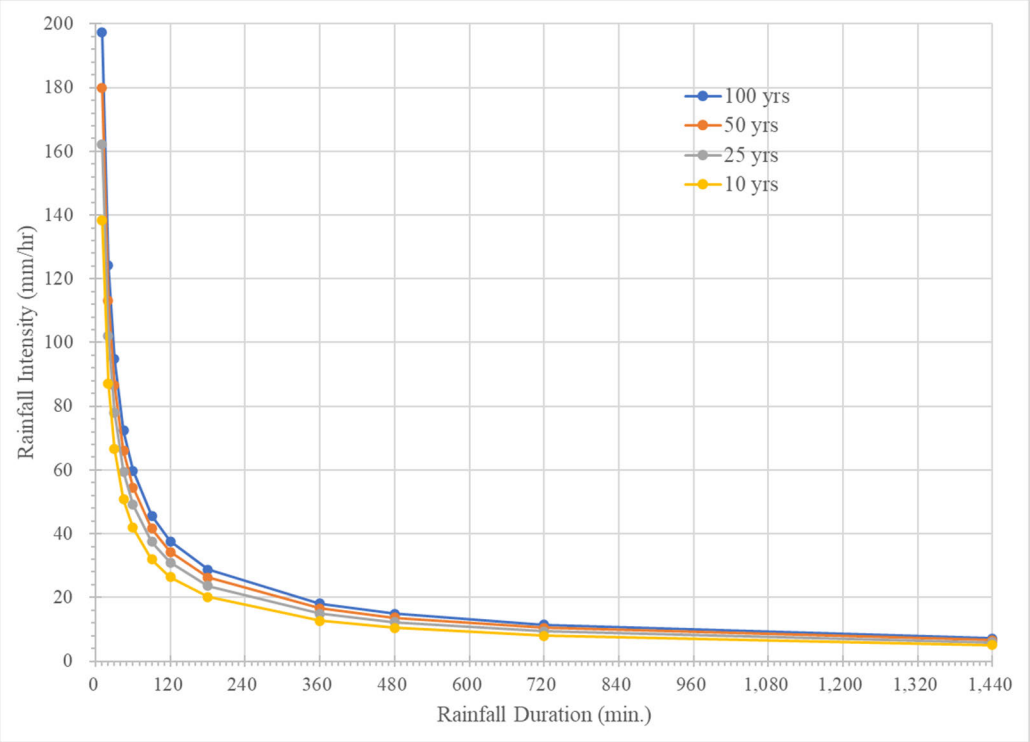
Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-10 IDF Curve at Autsho Station (for Namling Bridge)



Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-11 IDF Curve at Mongar Station (for Pakhadrang and Durdari Bridges)



Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-12 IDF Curve at Kanglung Station (for Revidrang and Rolling Bridges)

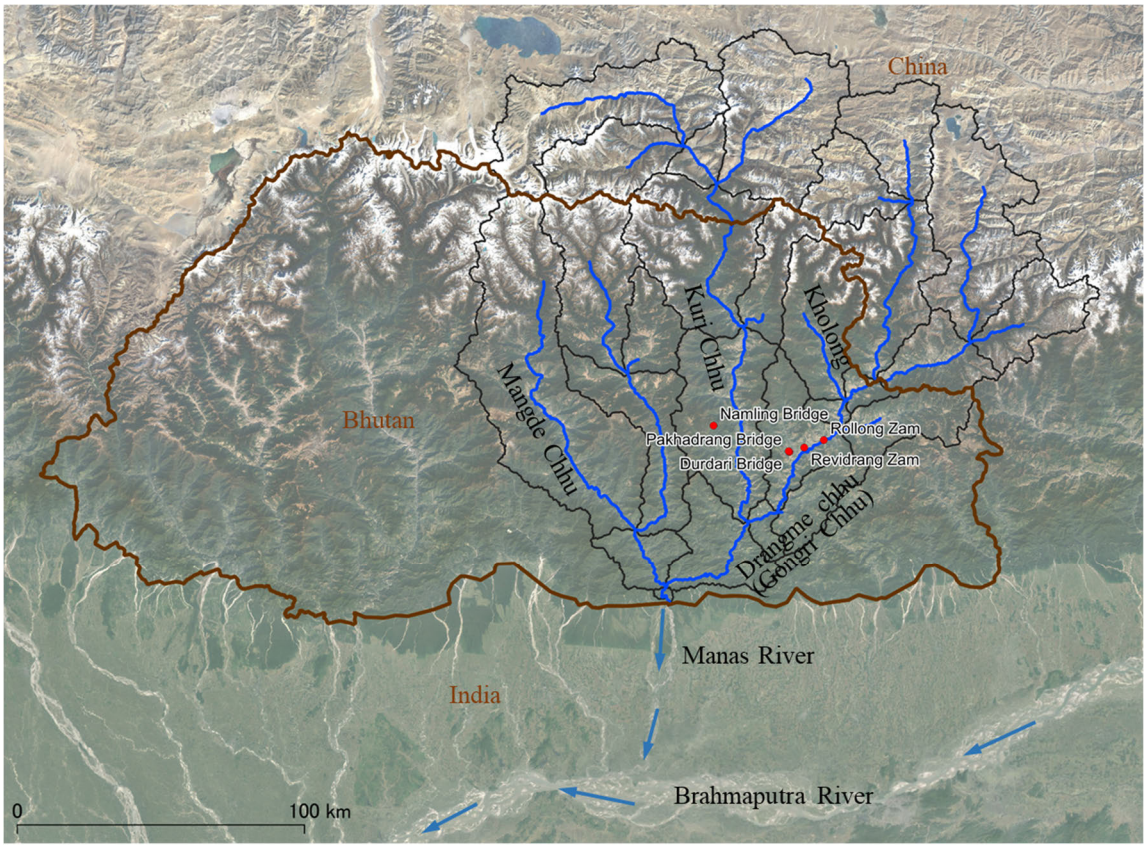
1-3-2 Hydraulics and Hydrology

As well as the meteorological data, hydrological data was also collected from the National Centre for Hydrology and Meteorology (NCHM). For the topographic data, FAB DEM (Forest And Buildings removed Copernicus DEM, University of Bristol, UK) with a resolution of 30 m is used for a wide area. And AW3D DEM (Remote Sensing Technology Center, Japan) with a resolution of 1 m is used near the target basins. Furthermore, actual river and plane-table surveys is conducted around the bridge, and hydrological and hydraulic analyses is conducted based on these results and field surveys.

(1) Overview of Target Basins

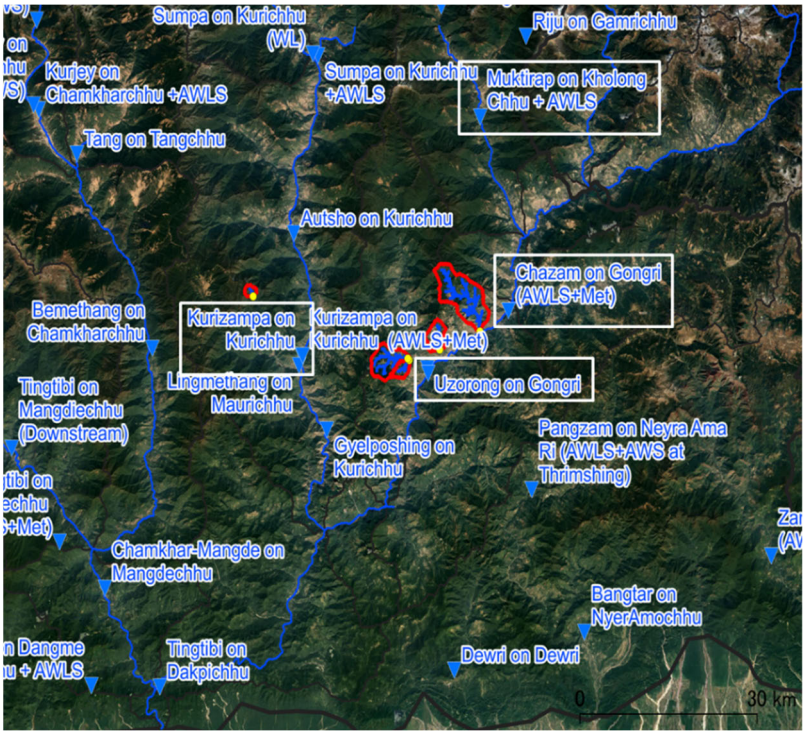
The basins where the target bridges are located is in the tributaries of the Manas River, an international river. The basin of the Namling Bridge is in a small tributary that flows into Kuri Chhu, a tributary of the Manas River, and the remaining four bridges are located in small tributaries that flow into Drangme Chhu (Gongri Chhu), a tributary of the Manas River. (See Figure 1-3-13.) Rolling Bridge is located near the confluence with Gongri Chhu and may be affected by backwater from Gongri Chhu.

Hydrological stations in Bhutan are not located in small river basins like the target bridges, but only in large rivers with a certain amount of basin. In this study, the hydrological data of 4 gaging stations near the target bridge's basins were collected, with the aim of calculating the specific discharge of the basin and obtaining a reference value, and estimating the discharge of Gongri Chhu at the confluence with the Rolling Bridge. The data items to be collected were only the daily water level and daily discharge from the results of interviews with NCHM. (See Figure 1-3-14.)



Source: from Watershed Boundary Analysis by HEC-HMS, Google Earth Image

Figure 1-3-13 Manas River Basin Diagram and Target Bridge Locations

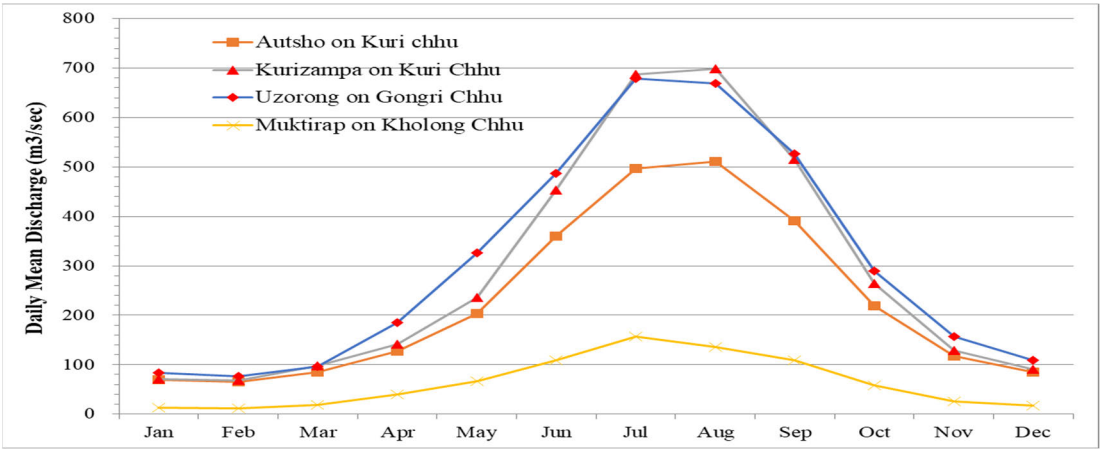


Source: National Centre for Hydrology and Meteorology (NCHM), Google Earth Image

Figure 1-3-14 Locations at Collected Hydrological Stations

1) Discharge at each Hydrological Station

The hydrological data collected from NCHM is the daily data of 32 years (1990-2022, missing in 2005) at Autsho Station in Kuri Chhu, 31 years (1992-2022) at Kurizampa Station in Kuri Chhu and Uzonrong Station in Gongri Chhu, and 22 years (2001-2022) at Muktirap Station in Kholong Chhu of a tributary of Gongri Chhu. Figure 1-3-15 shows the monthly average discharge collected at the 4 hydrological stations.



Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-15 Monthly Mean Discharge at 4 Stations (-2022)

The daily discharge at each gauging station is sorted the daily flow data for one year in descending order of discharge, creating a discharge-duration curve. And river flow conditions (river regime) values such as plentiful discharge, ordinary discharge, low discharge, and drought discharge, are calculated. The

ordinary discharge and low discharge of the 5 target bridges are calculated by multiplying each basin area by the flow regime values per catchment area in Table 1-3-5.

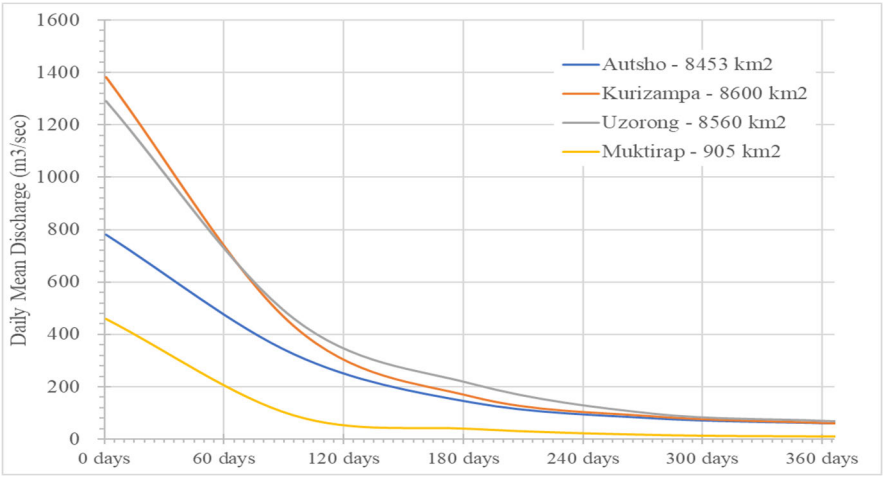
Table 1-3-5 Flow Regime at each Station and Flow Regime per Catchment Basin

Station (Area; km^2)	River	Item	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
			1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
Autsho (8453)	Kuri Chhu	Ave.	781.1	326.2	140.8	81.4	63.6	61.4	13.6	1990-2004,05-22
		Max.	1175.9	447.2	178.1	94.2	88.3	88.3	23.8	
		Min.	88.3	88.3	88.3	57.0	40.1	38.6	1.0	
Kurizampa (8600)		Ave.	1381.4	433.3	162.2	88.1	64.2	60.7	23.0	1992-2022
		Max.	3711.6	550.1	202.8	132.9	109.9	96.9	62.8	
		Min.	938.3	356.4	130.0	71.5	50.7	47.8	10.7	
Uzorong (8560)	Gongri Chhu	Ave.	1291.5	462.0	210.8	97.9	72.0	68.6	19.6	1992-2022
		Max.	3332.7	616.8	245.1	126.6	102.6	100.0	38.4	
		Min.	735.4	360.5	166.5	67.6	46.5	33.7	9.8	
Muktirap (905)	Kholong Chhu	Ave.	459.3	91.6	39.4	16.7	11.1	10.5	44.7	2001-2022
		Max.	958.4	119.1	51.3	22.2	15.3	14.4	99.9	
		Min.	193.4	74.4	31.3	13.4	8.9	8.3	19.5	

(Flow Regime Values per Catchment Area)

Station	River	Catch-ment Area (km^2)	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Remarks
			1-day	95-day	185-day	275-day	355-day	365-day	
Autsho	Kuri Chhu	8,453	0.0924	0.0386	0.0167	0.0096	0.0075	0.0073	
Kurizampa		8,600	0.1606	0.0504	0.0189	0.0102	0.0075	0.0071	For Namling
Uzorong	Gongri Chhu	8,560	0.1509	0.0540	0.0246	0.0114	0.0084	0.0080	Other 4 bridges
Uzorong	Kholong Chhu	905	0.5075	0.1012	0.0436	0.0185	0.0122	0.0116	

Source: JICA Survey Team



Source: from Data of National Centre for Hydrology and Meteorology (NCHM)

Figure 1-3-16 Discharge-Duration Curve at each Station (-2022)

2) Catchment Basins each Bridge and River Course Characteristics

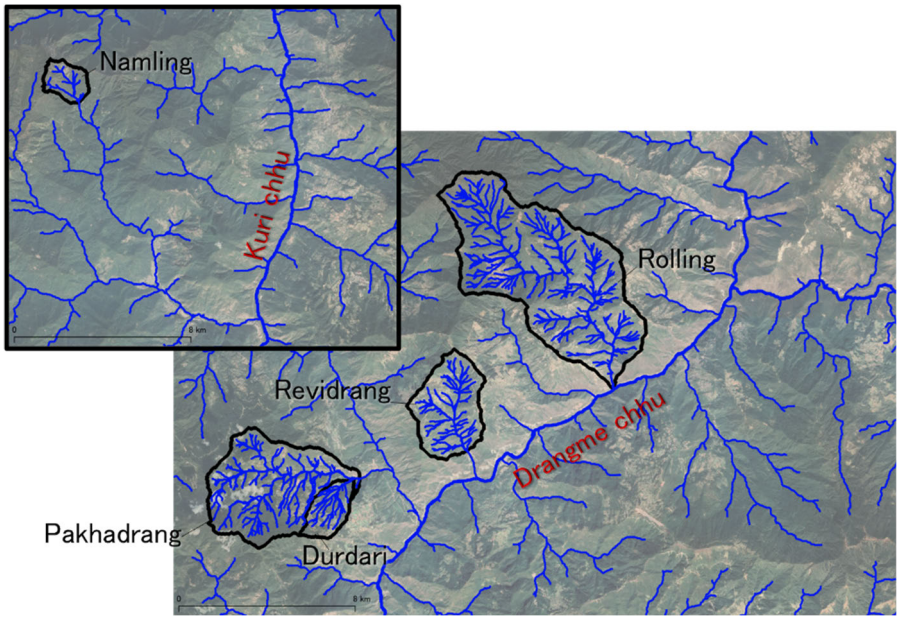
The target basins for the 5 bridges of this time is in the mountain river with a relatively small basin. (See Table 1-3-6, Figure 1-3-17.)

Figure 1-3-18 shows the river longitudinal profile from the vicinity of the bridge location to the farthest point in each basin, and the river bed profile is very steep gradient in the order of Namling, Durdari, Revidrang, Pakhadrang and Rolling Bridges basins. In such fast-flowing rivers, the concentration time (arrival time) of flood water is short, the flood waveform is sharp, and the energy of the flow is large. Therefore, the sediment is easy to be transported, and the risk of flooding with changes of the river channel due to erosion and scouring, becomes high. Also, it is also the river with a high risk of debris flows by the surrounding slopes collapse and the unstable river course. (The gradient distribution of each mountain stream bed and slope in the basin is described in 1-3-3.) In some parts of the basins, there are areas with relatively high altitudes, and snowmelt floods from residual snow in spring are concerned, but it is small compared to the amount of runoff during the rainy season. (However, slope failure is a concern as a spring snowmelt disaster.)

Table 1-3-6 Summary of Target Catchment Basins

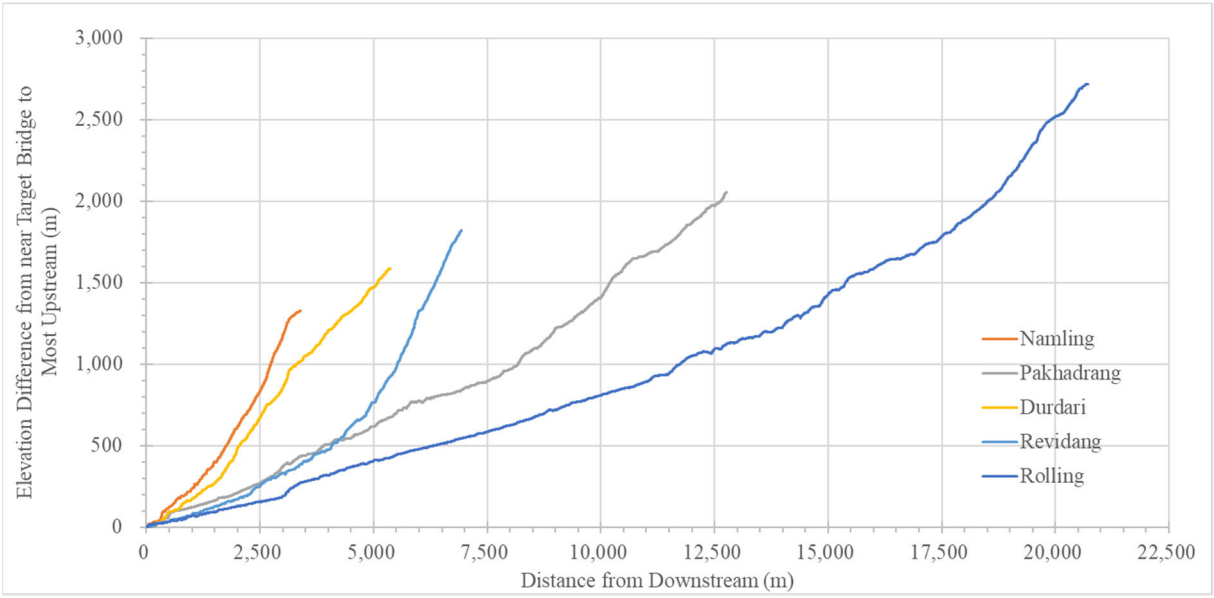
Bridge	Downstream River	Catchment Area (km^2)	Maximum Elevation (m)	Minimum Elevation (m)	Longest Flow Path (km)	Remarks
Namling	Kuri Chhu – Manas	2.50	3,424	2,160	2.589	
Pakhadrang	Drangme Chhu - Manas	21.33	2,919	982	10.467	
Durdari	Drangme Chhu - Manas	3.94	2,440	955	4.215	
Revidrang	Drangme Chhu - Manas	11.17	2,612	793	5.474	
Rolling	Drangme Chhu - Manas	45.73	3,378	635	18.364	

Source: JICA Survey Team



Source: JICA Survey Team, Google Earth

Figure 1-3-17 Target Catchment Basins Diagram



Source: from AW3D Data and Result of River Topographic Survey

Figure 1-3-18 River Longitudinal Profile from the Downstream Point of the River Topographic Survey Range for each Bridge to the Most Upstream Point

(2) Runoff Analysis

Runoff analysis is performed using the U.S. Army Corps of Engineers (USACE) software HEC-HMS (Hydrologic Engineering Center - Hydrologic Modeling System) by creating the 24-hour centralized hyetograph from the rainfall intensity curve in Table 1-3-3 for each target bridge basin. Since the basin of the Rolling Bridge joins the Manas River (Gongri Chhu) at downstream of the bridge, it is calculated by adding the discharg statistical analysis results at nearby streamflow gauging station for the Manas main river basin to the results of HEC-HMS for Rolling Bridge.

1) Design Return Period and Minimum Vertical Clearance with Girder Bottom (Freeboard)

The design scale (design return period) when determining the bottom height of a bridge girder is based on the 100-year return period flood by referring to Bhutan design standards (Indian standards), and the freeboard in Table 1-3-7 is ensured against the 100-years flood level (HFL). (And, for reference, the freeboard of the debris flow rate for 100-year flood are also checked.)

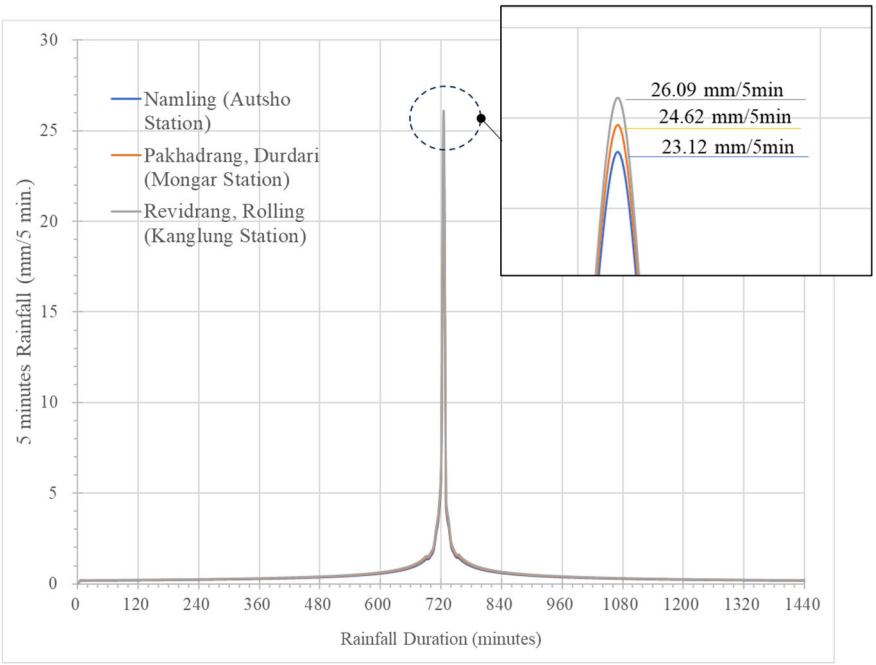
Table 1-3-7 Necessary Vertical Clearance with Girder Bottom

Discharge (m^3/s)	Minimum Vertical Clearance (mm)	Remarks
Q < 0.3	150	
0.3 ≤ Q < 3.0	450	
3.0 ≤ Q < 30.0	600	
30.0 ≤ Q < 300	900	Namling, Pakhadrang, Durdari, Revidrang
300 ≤ Q < 3000	1200	Rolling
Q ≥ 3000	1500	

Source: IRC-5 (Indian Roads Congress, Standard Specifications and Code of Practice for Road Bridges)

2) Design Hyetograph

The design hyetograph each rainfall station is shown in Figure 1-3-19. The design hyetograph also calculates hyetographs for 1.1, 5, 10, 25, and 50 years, in addition to the 100-years probable rainfall shown below.



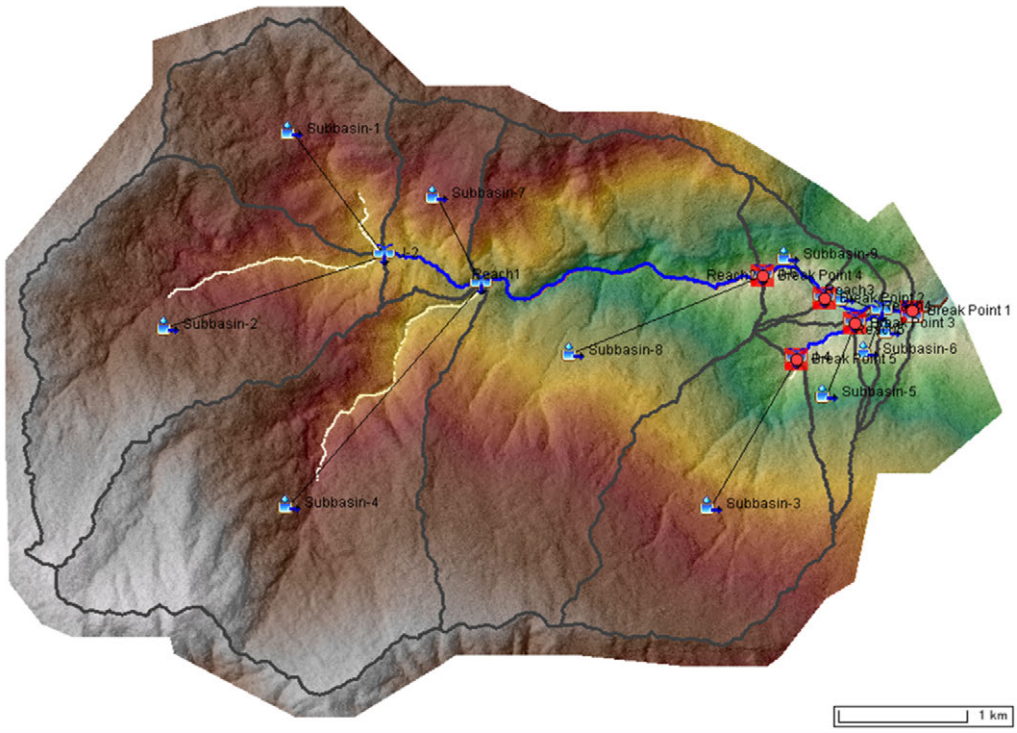
Source: JICA Survey Team

Figure 1-3-19 Design Hyetograph (100-years Flood, 3 Stations)

3) Runoff Analysis by HEC-HMS

Runoff analysis is performed using HEC-HMS. As for the runoff model, the SCS Unit Hydrograph method, which uses a rainfall runoff model based on the Soil Conservation Service - Curve Number method (SCS-CN method) devised by the U.S. Soil Conservation Service is widely used overseas as a practical model and is also used in this study. The basin is divided into small basins as shown in Figure 1-3-20, and the basin and river channels up to the location including each bridge location and topographic surveying area are modelled.

Table 1-3-8 shows the 1.1- to 100-year return period peak flood discharge obtained from the runoff analysis, and the ordinary and low flowrates obtained from Table 1-3-5. (In the resulting discharge hydro-graph, only the 100-year probability flood discharge at each bridge location is shown in Figure 1-3-21.) For reference, when considering the debris flow rate for the 100-years return period flood, it is calculated by referring to the Japanese standard and multiplying by the coefficient Kq shown in Table 1-3-9.



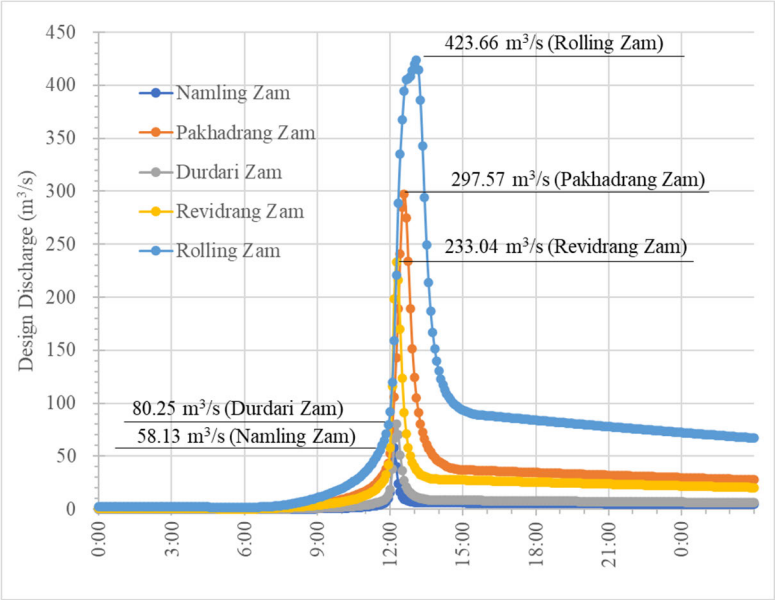
Source: JICA Survey Team

Figure 1-3-20 Runoff Model of HEC-HMS (Only Pakhadrang, Durdari Basins)

Table 1-3-8 Results for Floods by HEC-HMS Runoff Analysis and Ordinary / Low Flowrates

River / Bridge (Zam)	River Reach	River Station	Catchment Area (km^2)	Ordinary Q	Low Q	1.1yr Flood	5yrs Flood	10yrs Flood	25yrs Flood	50yrs Flood	100yrs Flood	100yrs Debris Flow	Remarks
Namling	Reach1	1133.93	1.62	0.04	0.02	0.17	12.25	17.92	25.65	31.70	37.88	99.92	
Namling Zam	Reach1	597.63	**2.50**	**0.06**	**0.03**	**0.26**	**18.71**	**27.42**	**39.31**	**48.61**	**58.13**	**153.33**	Bridge
	Reach1	502.50	2.87	0.07	0.03	0.29	20.27	29.80	42.80	52.97	63.40	167.22	
Durdari Zam	UpStream	1227.25	**3.94**	**0.10**	**0.05**	**5.83**	**33.76**	**44.37**	**58.49**	**69.35**	**80.25**	**211.64**	Bridge
	UpStream	590.06	4.05	0.10	0.05	5.79	33.00	43.43	57.32	68.00	78.74	207.65	
Pakhadrang Zam	UpStream	1568.47	**21.33**	**0.53**	**0.24**	**22.13**	**125.35**	**164.66**	**216.96**	**257.16**	**297.57**	**595.15**	Bridge
	UpStream	851.88	21.55	0.53	0.25	22.01	122.97	161.81	213.52	253.31	293.31	586.63	
	DownStream	285.17	25.87	0.64	0.30	24.66	135.07	177.40	233.71	277.01	320.53	641.06	
Revidrang Zam	Reach1	1488.08	**11.17**	**0.27**	**0.13**	**14.91**	**96.36**	**127.58**	**169.17**	**200.91**	**233.04**	**466.07**	Bridge
	Reach1	888.05	11.59	0.29	0.13	15.15	95.87	127.06	168.63	200.38	232.51	465.03	
Drangeme	DownStream	836.16	9058.61	223.1	103.6	908.9	1571.5	1781.8	2046.5	2242.4	2437.3	3284.6	
	UpStream	1032.39	9012.88	221.9	103.1	907.2	1568.6	1778.5	2042.7	2238.2	2432.8	2432.8	
Rolling Zam	Reach1	1504.73	**45.73**	**1.13**	**0.52**	**28.32**	**175.70**	**232.29**	**307.71**	**365.32**	**423.66**	**847.31**	Bridge

Source: JICA Survey Team



Source: JICA Survey Team (HEC-HMS Result)

Figure 1-3-21 Discharge Hydrograph of 100-years Flood at each Bridge Location

Table 1-3-9 Extra Coefficient to Debris Flow Rate for Flood Discharge; Kq

Target River / Bridge	Stones Density	Water Density	Internal Friction Angle	Slope of Stream Bed		Concentration of Debris Flow		Volume Concentration of Debris Flow	Unit Weight of Debris Flow	$C_*/(C_*-C_d)$
	Σ (t/m³)	P (t/m³)	Φ (deg.)	tan θ	θ (deg.)	C_d'	C_d	C_*	ρd (t/m³)	K_q' K_q
Namling Zam	2.60	1.2	35.0	0.2121	11.977	0.373	0.373	0.6	2.08	2.64 = 2.64
Pakhadrang Zam	2.60	1.2	35.0	0.0930	5.315	0.131	0.300	0.6	2.18	1.28 → 2.00
Durdari Zam	2.60	1.2	35.0	0.2121	11.976	0.372	0.372	0.6	2.08	2.64 = 2.64
Revidrang Zam	2.60	1.2	35.0	0.0696	3.983	0.095	0.300	0.6	2.18	1.19 → 2.00
Rolling Zam	2.60	1.2	35.0	0.0776	4.437	0.107	0.300	0.6	2.18	1.22 → 2.00

Source: Manual of Technical Standard for establishing Sabo master plan for debris flow and driftwood (National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, 2016)

(3) Hydraulic Analysis

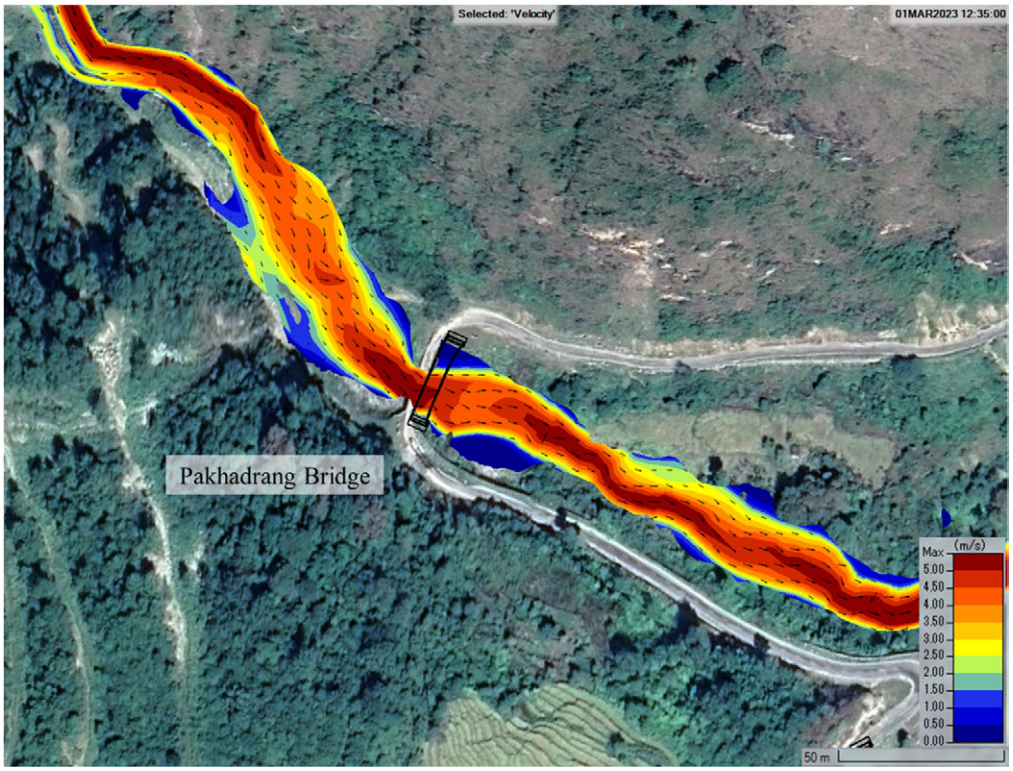
Similar to hydrological analysis, hydraulic analysis is performed using the USACE software HEC-RAS (Hydrologic Engineering Center - River Analysis System).

The analysis range is the river cross-sectional survey range, and the hydraulic analysis method is one-dimensional steady flow (fixed flow of peak value) and unsteady flow analysis (time-varying flow). And the discharge (peak value or hydrograph) calculated by HEC-HMS for each river channel is input.

The design water levels obtained from the hydraulic analysis are shown in Table 1-3-10. (Table 1-3-11 shows the secured clearance height below the girder, and the necessary clearance height has been secured against the 100-year return period flood level. For reference, although the values at the 100-year return period debris flow rate are also shown, only Pakhadrang Bridge cannot ensure the freeboard.) In addition, Figure 1-3-22 to Figure 1-3-26 show flow velocity distribution diagrams at the maximum water level. It has been shown that there are many torrential sections where the river bed gradient is very steep and the maximum flow velocity exceeds 5 m/s.

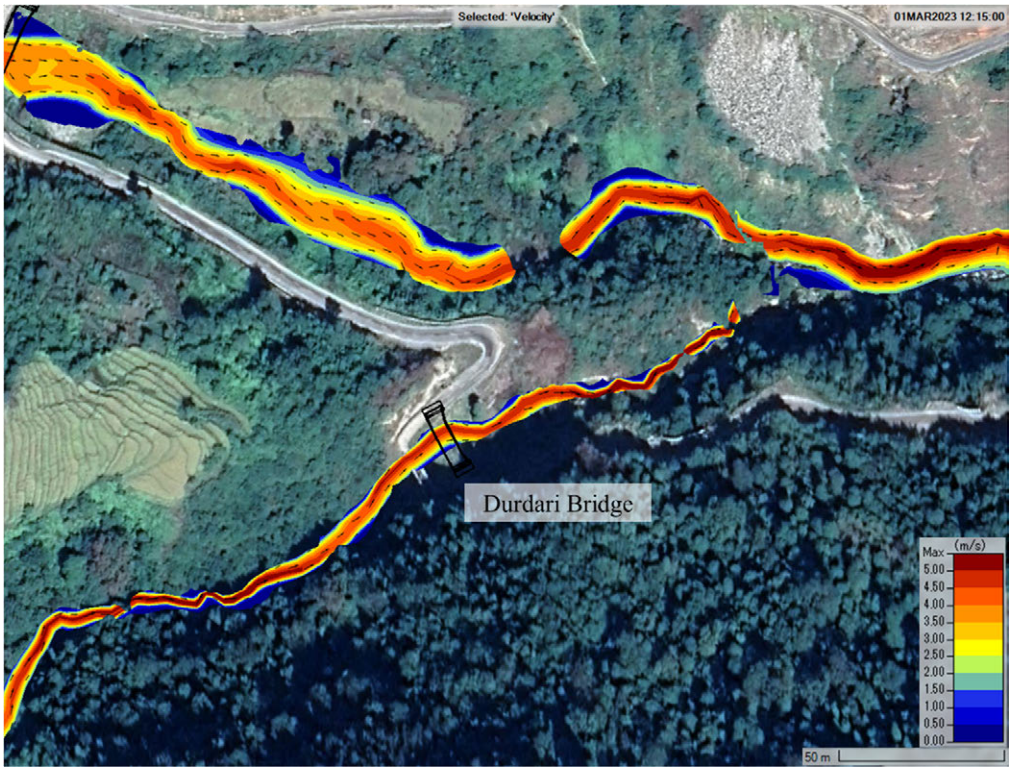
Source: JICA Survey Team (HEC-RAS Result), Google Earth Image

Figure 1-3-22 Velocity Distribution Diagram at Namlimg Bridge
(1-Dimensional Unsteady Flow Analysis, 100-years Flood)



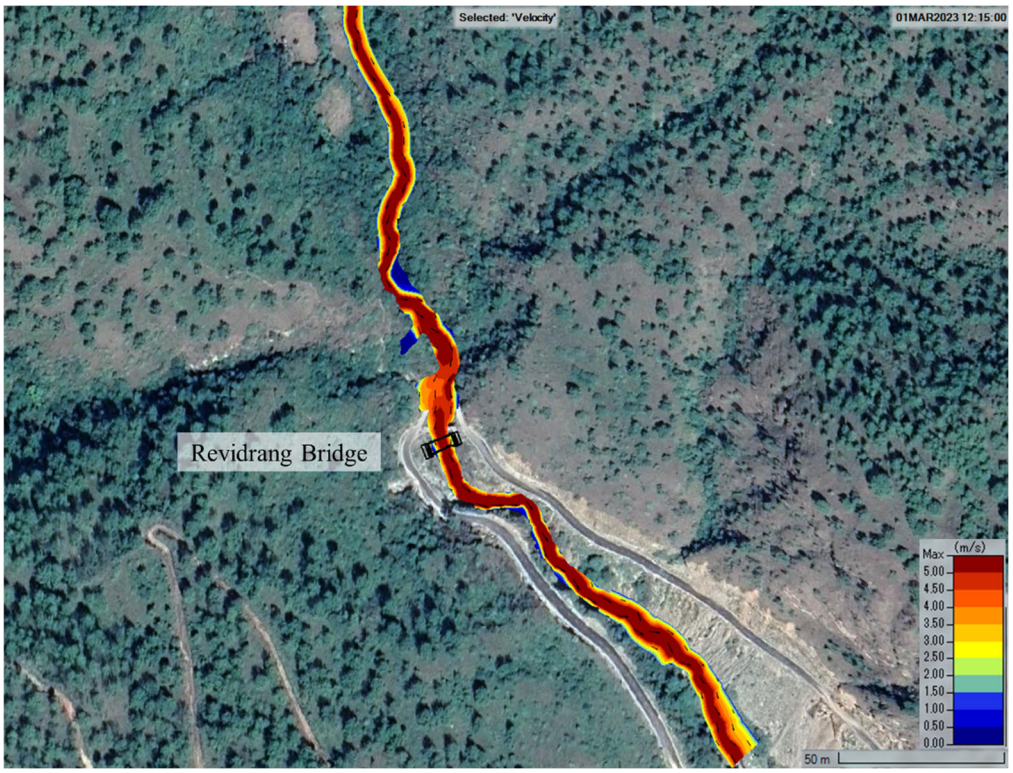
Source: JICA Survey Team (HEC-RAS Result), Google Earth Image

Figure 1-3-23 Velocity Distribution Diagram at Pakhadrang Bridge
(1-Dimensional Unsteady Flow Analysis, 100-years Flood)



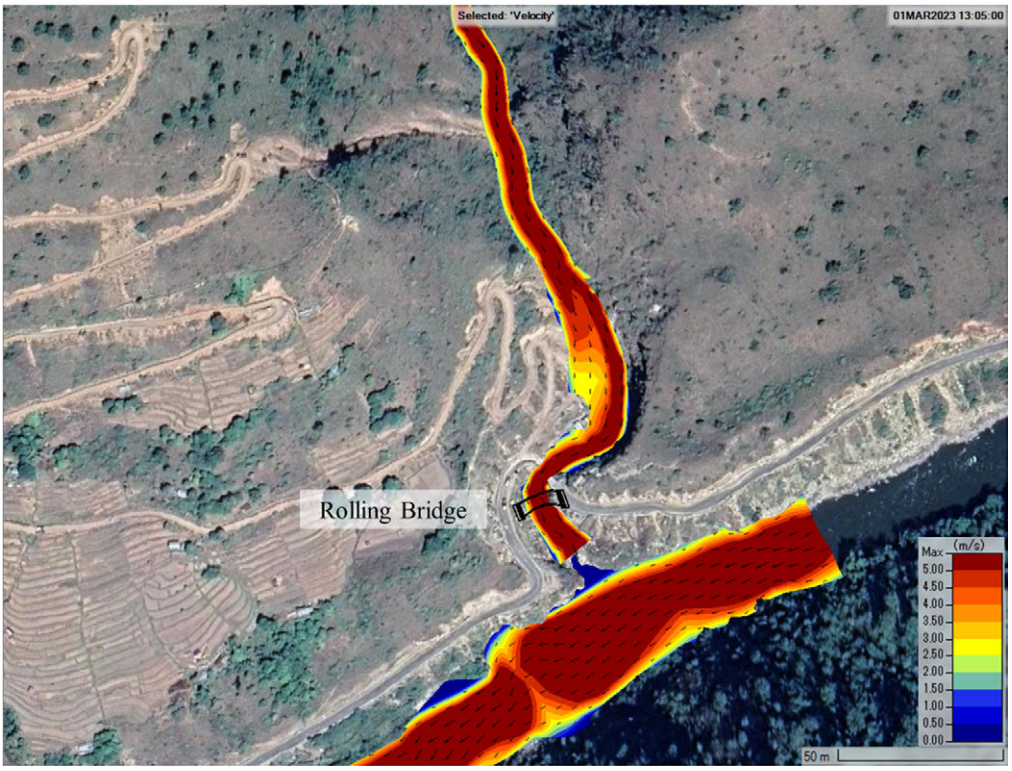
Source: JICA Survey Team (HEC-RAS Result), Google Earth Image

Figure 1-3-24 Velocity Distribution Diagram at Durdari Bridge
(1-Dimensional Unsteady Flow Analysis, 100-years Flood)



Source: JICA Survey Team (HEC-RAS Result), Google Earth Image

Figure 1-3-25 Velocity Distribution Diagram at Revidrang Bridge
(1-Dimensional Unsteady Flow Analysis, 100-years Flood)



Source: JICA Survey Team (HEC-RAS Result), Google Earth Image

Figure 1-3-26 Velocity Distribution D iagram at Rolling Bridge
(1-Dimensional Unsteady Flow Analysis, 100-years Flood)

Table 1-3-10 Design Water Levels at each Bridge Location

Bridge	Ordi-nary Q	Low Q (LWL)	1.1yrs Flood	5yrs Flood	10yrs Flood	25yrs Flood	50yrs Flood	100yrs Flood (HFL)	100yrs Debris Flow	Remarks
Namling	2170.55	2170.52	2170.63	2173.34	2173.57	2173.83	2174.01	2174.17	2175.34	
Pakhadrang	983.40	983.33	984.07	985.21	985.51	985.88	986.14	986.40	988.13	
Durdari	955.37	955.35	956.02	956.99	957.23	957.49	957.68	957.84	959.29	
Revidrang	794.74	794.68	795.94	797.80	798.22	798.71	799.04	799.34	801.06	
Rolling	636.43	636.33	637.44	639.42	639.90	640.46	640.85	641.22	643.39	

Source: JICA Survey Team (HEC-RAS Result)

Table 1-3-11 Vertical Clearance with Girder Bottom

Bridge	Minimum Soffit Level (Girder bottom) (m)	50yrs Flood	100yrs Flood (HFL)	100yrs Debris Flow	Remarks
Namling	2199.87	25.86	25.70 > Fb 0.90	24.53	
Pakhadrang	988.05	1.91	1.65 > Fb 0.90	-0.08	
Durdari	964.35	6.67	6.50 > Fb 0.90	5.05	
Revidrang	801.40	2.36	2.06 > Fb 0.90	0.34	
Rolling	644.27	3.42	3.05 > Fb 1.20	0.88	

Source: JICA Survey Team

(4) Examination of Materials for Revetment / Bed Protections

When constructing a bridge and improving a river near the bridge, it is necessary to select riverbank and riverbed protection materials, after taking into account the river characteristics and the ease with which materials can be procured locally.

The rivers targeted of this time have steep riverbed slopes, are undergoing erosion, and there are many places where bedrock is exposed along the river channels. And there are also many huge stones on the riverbed due to past debris flow damage.

Therefore, it is desirable to avoid installing revetment and bed protection materials on exposed rocky areas of the river channel, and to repair only the areas where sediment has accumulated in the river channel. (When excavating an exposed rock area that will become a water impact area, it is desirable to backfill it with lean-mix concrete.)

In addition, it is desirable that protective materials for riverbanks and riverbeds be made of materials that will not be washed away by rapid currents and have individually a high ability to follow ground changes caused by river-channel scouring. Therefore, from the perspective of local procurement, it is considered that it is best to install bank protection and bed protection using stones (riprap and gabion works).

Table 1-3-12 shows the required riprap diameter for the riverbed protection material, determined from the hydraulic requirements (100-year return period) around the bridge.

Table 1-3-12 Necessary Bed Protection Materials near Target Bridges (Riprap Diameter)

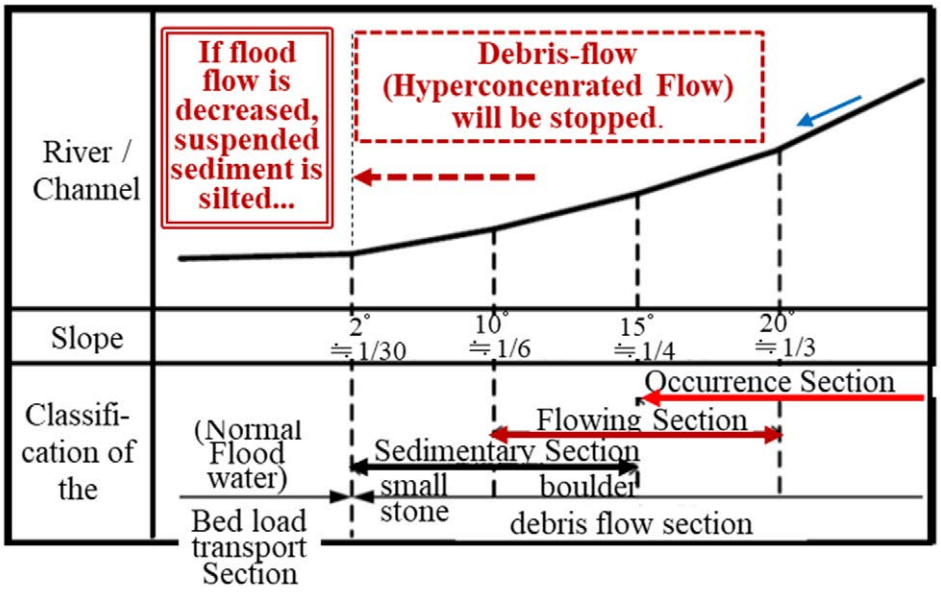
Items		Bridge	River Reach	1.1yrs Flood	5yrs Flood	10yrs Flood	25yrs Flood	50yrs Flood	100yrs Flood (HFL)	100yrs Debris Flow	Remarks
Riprap Size: D_{50} (m, $=D_{30}$ * 1.2)	1	Namling	451.76	0.027	0.184	0.228	0.272	0.311	0.343	0.628	No protection, because of a bedrock riverbed
	2	Pakhadrang	P 895.43	0.166	0.453	0.530	0.613	0.673	0.726	1.034	
	3	Durdari	D 590.06	0.134	0.289	0.326	0.368	0.398	0.426	0.688	D50= 0.6m
	4	Revidrang	844.83	0.239	0.526	0.592	0.667	0.715	0.762	1.062	
	5	Rolling	984.43	0.247	0.622	0.728	0.844	0.924	1.001	1.425	
Water Depth: y (m)	1	Namling	451.76	0.10	0.66	0.80	0.95	1.08	1.20	2.19	
	2	Pakhadrang	P 895.43	0.57	1.60	1.86	2.17	2.38	2.58	3.64	
	3	Durdari	D 590.06	0.47	1.03	1.16	1.31	1.41	1.51	2.36	
	4	Revidrang	844.83	0.84	1.87	2.10	2.36	2.53	2.69	3.50	
	5	Rolling	984.43	0.87	2.18	2.55	2.97	3.25	3.51	4.97	
Velocity: Vave (m/s)	1	Namling	451.76	0.98	2.54	2.82	3.08	3.29	3.46	4.68	
	2	Pakhadrang	P 895.43	2.40	3.98	4.30	4.63	4.85	5.04	6.01	
	3	Durdari	D 590.06	2.16	3.18	3.38	3.59	3.73	3.86	4.89	
	4	Revidrang	844.83	2.89	4.29	4.55	4.83	5.00	5.16	6.05	
	5	Rolling	984.43	2.94	4.66	5.04	5.43	5.68	5.91	7.05	

Note: Angle of repose of riprap (ϕ = 32 degrees), specific gravity of riprap (Sg=2.65 t/m^3). Calculation is based on the USACE 1994 (HEC-23) formula. D50 indicates the average particle size of riprap stone.
Source: JICA Survey Team

1-3-3 Risks for Debris Flow

In order to sort out the risk of debris flows, it needs to consider the slope-failure risk of the slope itself along the mountain stream in the basin, and the risk of collapsing the sand and gravel bodies dammed up into the mountain stream from the slope failure. And it needs to comprehensively grasp / examine the shape and amount of the mountain stream-bed materials that is unstably deposited in the mountain stream itself, etc, and large-scale field surveys and analysis are required. In this study, the terrain analysis is performed by purchasing an electronic elevation model (DTM, AW3D) with a resolution of 1m. The watershed boundary through analysis are extracted, and the gradient of the mountain slope within the catchment basin, the riverbed gradient of the mountain stream within the basin, etc. are examined, and finally perform debris flow risk assessment.

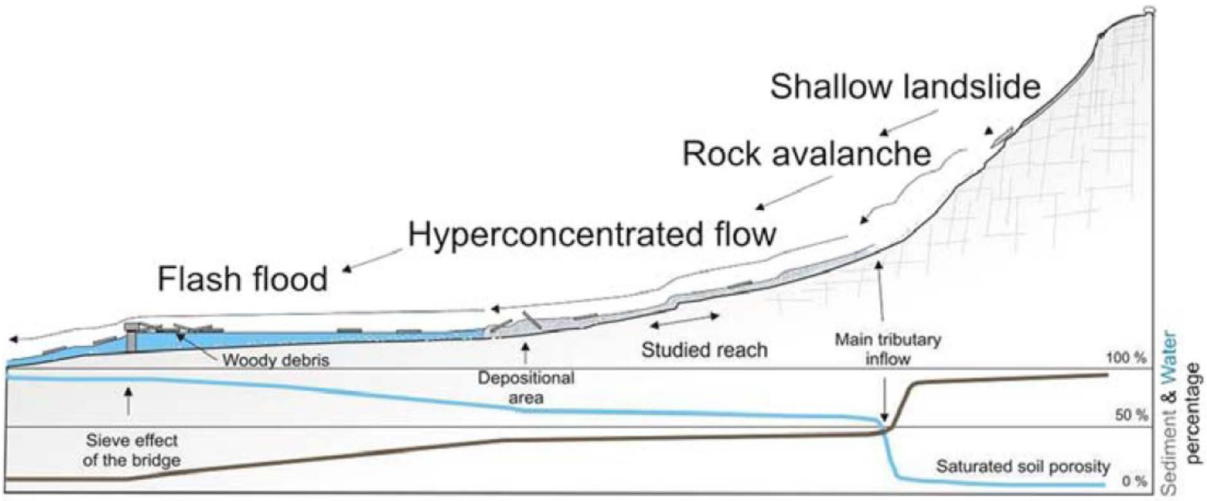
According to Japanese standards, it is described that "the debris flow occurs in areas where the slope of the stream bed is 15 degrees or more, and begin to accumulate at approximately 10 degrees, and in the case of stony debris flows, they stop by 3 degrees." (See Figure 1-3-27.) On the other hand, mountain slopes with a gradient of 30 degrees or more are designated as special hazard areas, it is considered that them of 45 degrees or more are at high risk and them of 60-70 degrees or more contains the considerable danger.



Source: Manual of Technical Standard for designing Sabo facilities against debris flow and driftwood (National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, 2016)

Figure 1-3-27 Standard of Sediment Transport Form based on Mountain Stream Bed Gradient

In Japan, the river section's flow to where the sand and gravel/stone in water flow will stop is uniformly defined as the debris flow. However, in other countries, it separately calls as the hyper-concentrated flow or the sediment flow of the flow at the sedimentary section with a stream-bed slope of 14 degrees or less. (i,e, The lower layer in flowing water is a concentrated sandy and stony flow, and the upper layer is a flow with a layer of water.) On the other hand, the debris flow with a stream-bed slope of 14 degrees or more is such flow that sand and gravel/stone are dispersed throughout the flow, and both definitions are divided.



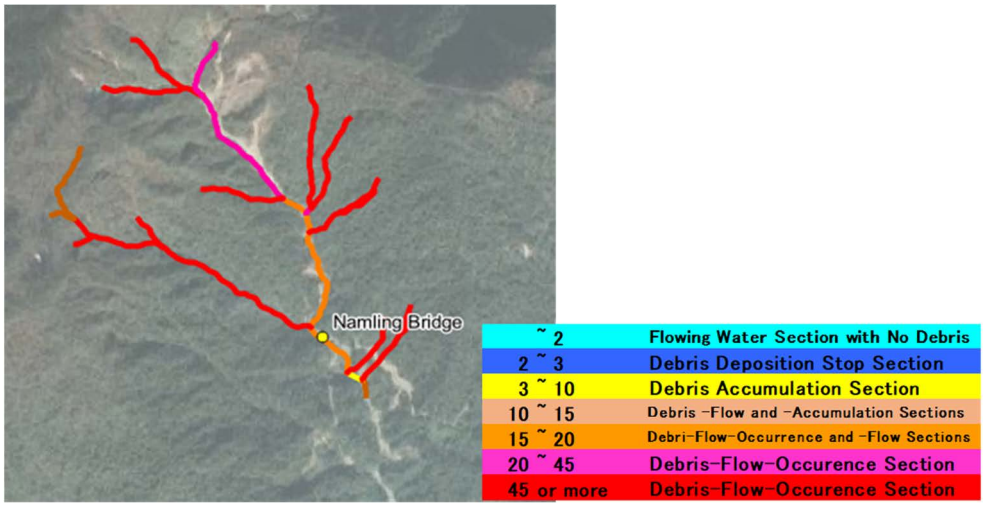
Source: Water Resources Research Vol.47 (American Geophysical Union, 2011)

Figure 1-3-28 Scheme showing Different Types of Sediment (Debris) Transport along Flow Path

(1) Primary Evaluation

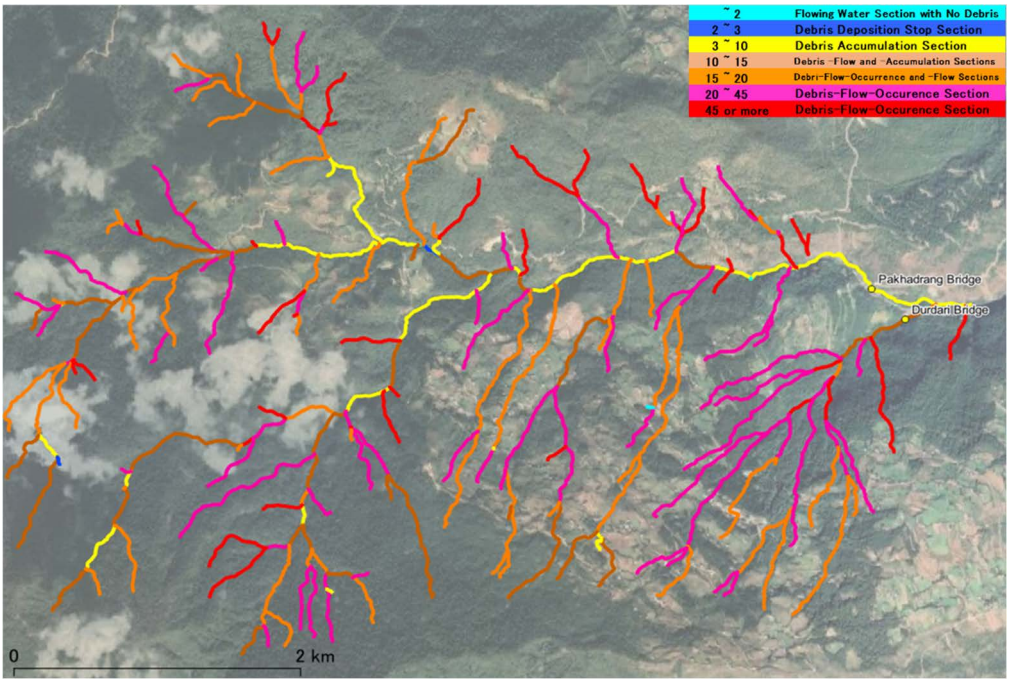
1) Stream Bed Gradient

From the terrain analysis by GIS, the basins and flow paths are extracted and the mountain streambed slopes of each river are calculated. (See Figure 1-3-29 to Figure 1-3-32.)



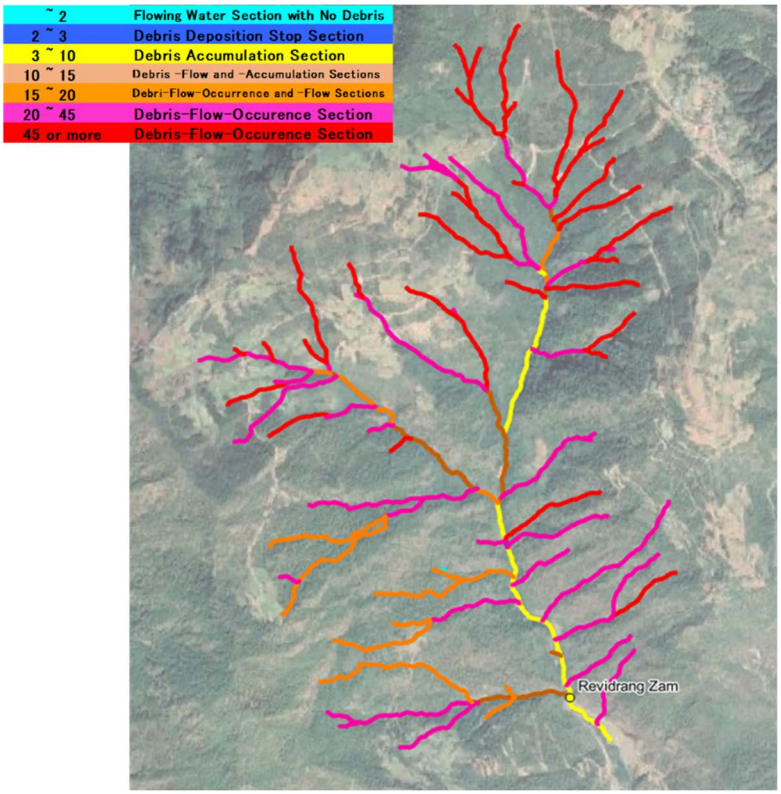
Source: JICA Survey Team

Figure 1-3-29 Risk Determination based on Stream Bed Gradient (Namling Basin)



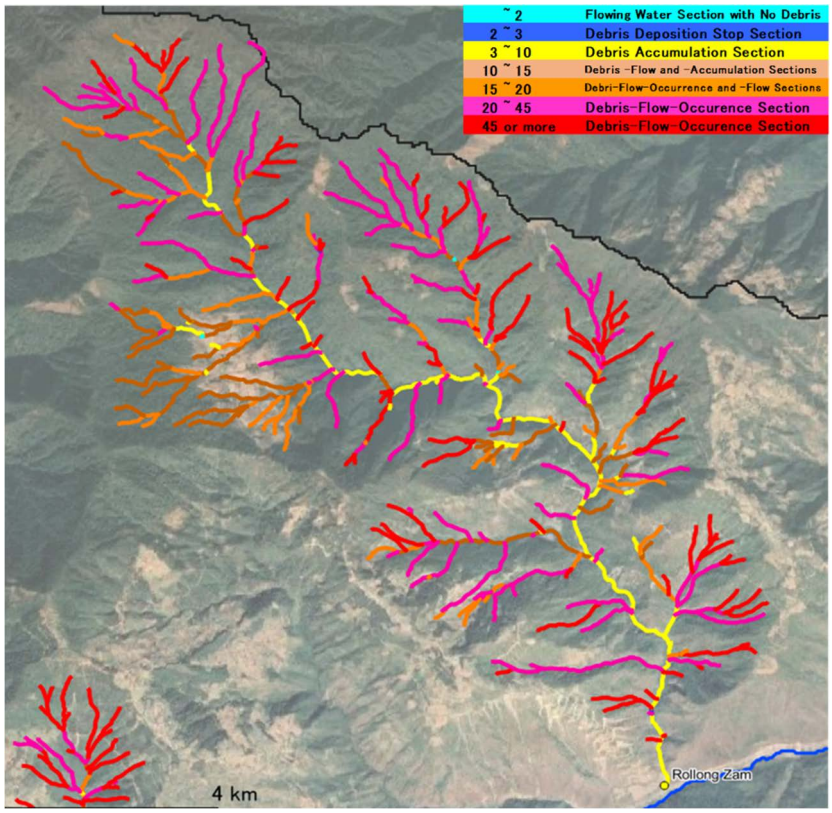
Source: JICA Survey Team

Figure 1-3-30 Risk Determination based on Stream Bed Gradient (Pakhadrang and Durdari Basins)



Source: JICA Survey Team

Figure 1-3-31 Risk Determination based on Stream Bed Gradient (Revidrang Basin)



Source: JICA Survey Team

Figure 1-3-32 Risk Determination based on Stream Bed Gradient (Rolling Basin)

Table 1-3-13 shows the sediment transport pattern of the debris flow near each bridge, that can be conceivable from the stream-bed slope shown in the above Figure. This time, the large-scale field surveys are not conducted to determine the risk of slope failure and the amount of sediment in mountain stream beds. However, even if considering facts of the accident that Namling Bridge and Durdari Bridge had washed away in the past, as well as the risk of mountain streams in the basin, and the upstream gradient, it can be judged that the risk of debris flow is high for these two streams. (The amount of debris flow for these two bridges takes into account the extra coefficient to normal flood, but the coefficient for these two rivers is high, risks are high.)

Table 1-3-13 Risk Determination for Debris Flow

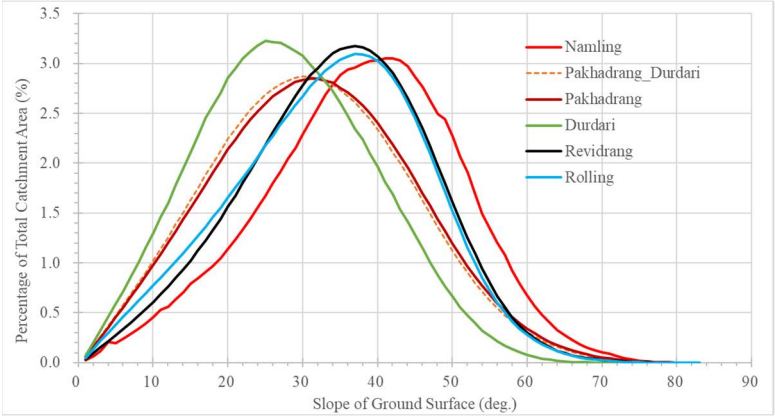
Bridge Name		Normal Flood Section	Debris-Flow Stopping Section	Debris-Flow Sedimentation Section	Debris-Flow Flowing/ Sedimen-tation Section	Debris-Flow Occurrence/ Flowing Section	Debris-Flow Occurence Section	Debris-Flow Occurence Section	Total Length (m, %) in the Basin	Risk for Instability of Stream Slope in the Basin		Stream Slope (degree) of upstream at bridge / Extra Coefficient to Normal Flood / Status	
		θ ≤ 2 deg.	2 < θ≤ 3 deg.	3 < θ≤ 10 deg.	10 < θ≤ 15 deg.	15 <θ≤ 20 deg.	20 < θ≤ 45 deg.	Θ > 45 deg.					
Namling	Length	0.0 m	0.0	80.8	659.4	1,115.0	6,524.5	0.0	8,379.7	0.936	**1**	11.977	**2.638**
	%	0.0	0.0	1.0	7.9	13.3	**77.9**	**0.0**	100.0			**1 (Flow. section)**	
Pakharang	Length	87.4 m	279.4	9,653.8	16,605.3	26,405.8	31,787.1	0.0	84,818.8	0.787	5	5.315	1.280
	%	0.1	0.3	11.4	19.6	31.1	**37.5**	**0.0**	100.0			**3** (Sedi. section)	
Durdari	Length	0.0 m	21.3	153.2	895.3	4,207.6	13,028.7	70.5	18,376.5	0.929	**2**	11.976	**2.637**
	%	0.0	0.1	0.8	4.9	22.9	**70.9**	**0.4**	100.0			**1 (Flow. section)**	
Revidrang	Length	26.0 m	61.5	2,990.9	2,730.7	7,163.3	30,544.6	0.0	43,516.9	0.899	3	3.983	1.187
	%	0.1	0.1	6.9	6.3	16.5	**70.2**	**0.0**	100.0			5 (Sedi. Section)	
Rolling	Length	196.1 m	233.8	17,809.0	29,506.2	25,196.5	93,197.8	0.0	166,139.4	0.832	4	4.437	1.217
	%	0.1	0.1	10.7	17.8	15.2	**56.1**	**0.0**	100.0			4 (Sedi. Section)	
Weighting coefficient		0.0	0.2	0.4	0.6	0.8	1.0	1.2	-	-		-	

Note. 1. Ranking of risk for Instability of stream slope in the basin was determined by considering the weighting factors by the study team.
2. Extra coefficient for debris-flow discharge to normal flood discharge was calculated according to Japanese standards.
3. Coloring in the table corresponds to the color of each Stream Bed Gradient in Figure 1-3-29 through Figure 1-3-32.

Source: JICA Survey Team

2) Slope Distribution within the Basin

From terrain analysis, the gradient distribution of slopes within the basin and the proportion of areas with high slope failure risk (≥30 or 45 degrees). The results are shown in Figure 1-3-33 and Table 1-3-14. The bridge with the highest risk of slope failure of 30 degrees (45 degrees) or more is the Namling Bridge.



Source: JICA Survey Team

Figure 1-3-33 Inclination Distribution Diagram of Slopes in each Basin (Area Ratio per degree, %)

Table 1-3-14 Inclination Distribution of Slope and Risk Assessment of Slope Failure in each Basin

Slope (deg.)	Namling	Pakhadrang	Durdari	Revidrang	Rolling	Remarks
0 ~29	25.6	44.3	56.7	33.7	36.0	
30 ~44	42.7	38.3	34.7	44.9	43.8	Slope ≥ 30 is special warning area in Japan.
45 ~59	27.9	15.4	8.4	20.0	18.9	High Risk
60 ~69	3.4	1.8	0.3	1.3	1.2	Highest Risk
70 ~	0.4	0.2	0.0	0.1	0.1	Highest Risk
Σ	100.0	100.0	100.0	100.0	100.0	
30 ~Max.	**74.4**	55.7	43.3	66.3	64.0	Percentage of Slope ≥ 30 degrees
45 ~Max	**31.7**	17.4	8.6	21.4	20.2	Percentage of Slope ≥ 45 degrees
Risk	**1**	4	5	2	3	

Note: Coloring in the table corresponds to the color of each Stream Bed Gradient in Figure 1-3-29 through Figure 1-3-32.

Source: JICA Survey Team

(2) Comprehensive Assessment

The risk of debris flow is determined from the sediment transport classifivcation of debris flow at the mountain stream directly upstream of the bridge location, the debris flow risk of the entire mountain stream within the basin, and the slope failure risk within the basin.

(The sediment transport classification of the debris flow directly upstream of the bridge location is the most important, and by doubling this ranking and the total score is by adding up the other ranks. The bridge rivers with lower scores are at higher risk.) According to Table 1-3-15, the bridges (river) with the highest risk of debris flow are Namling Bridge, Durdari Bridge and other 3 bridges, in that order, and the other three bridges are assessed to have a nearly same risk.

Table 1-3-15 Comprehensive Assessment for Risks of Debris Flow

Bridge Name	Stream Bed Gradient near the Bridge	Sediment Transport Classification of Debris Flow at Bridge Upstream ①		Danger Level of Debris Flows in Streams within the Basin ②		Danger Level of slopes within the basin ③		Comprehensive Judgement (Score=①*2+②+③)	Remarks
Nanling Bridge	0.2121	1	Debris-Flow-Occurrence and -Flow Sections	1	0.936	1	74.4%	1 (4)	Risk is the greatest. (Most dangerous streams within the Basin)
Pakhadrang Bridge	0.0931	3	Debris Accumulation Section	5	0.787	4	55.7%	3 (15)	
Durdari Bridge	0.2121	1	Debris-Flow-Occurrence and -Flow Sections	2	0.929	5	43.3%	2 (9)	This is a debris flow section, and there is a high risk.
Revidrang Bridge	0.0696	5	Debris Accumulation Section	3	0.899	2	66.3%	3 (15)	
Rolling Bridge	0.0661	4	Debris Accumulation Section	4	0.832	3	64.0%	3 (15)	\

Note: Coloring in the table corresponds to the color of each Stream Bed Gradient in Figure 1-3-29 through Figure 1-3-32.

Source: JICA Survey Team

1-3-4 Topographic Survey

(1) Overview of the project area

Bhutan is located on the eastern end of the Himalayan orogenic belt. The steep landforms were formed by fluvial erosion originating from active uplift movements that occurred during the Cenozoic Paleogene and Quaternary periods due to the Himalayan orogenic movement. The northern part is called the Greater Himalaya, which is a mountainous area with 7,541 m Gankerbunzum peak as the highest and formed a glaciated terrain. The central part is called the Lesser Himalaya. Although the region is a steep and gentle slope area and landslides occur due to heavy rains during the rainy season, people settle in valley plains. The southern part is called Siwalik Hills, a hilly region that connects to the Great Plains of India.

(2) Topographic Survey

A topographic survey was carried out for all target bridges from February to April 2023 and information required for bridge and road design and river analysis was collected.

(3) Result

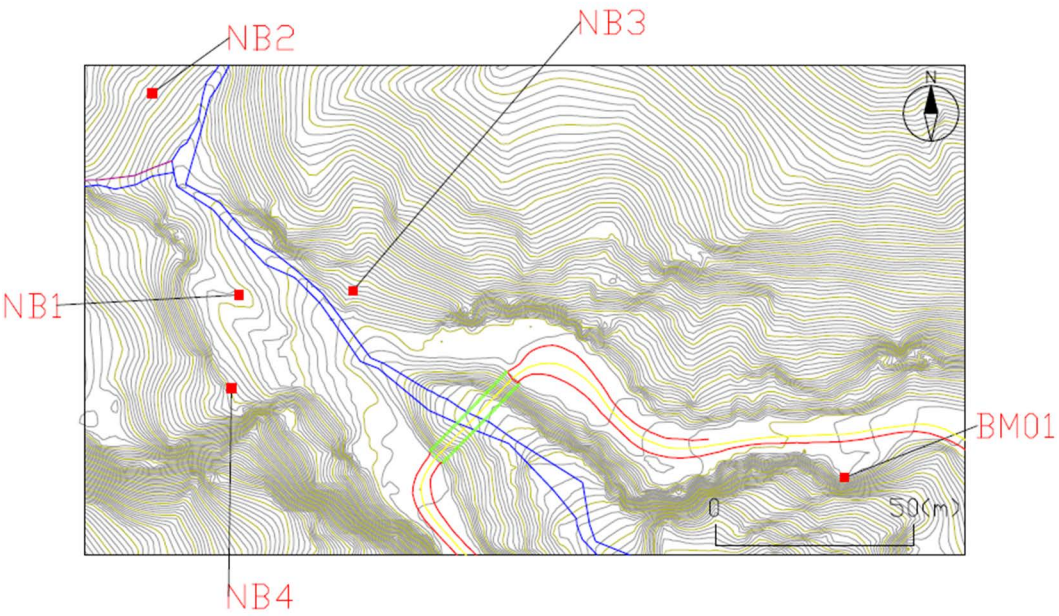
The Survey was conducted by using GPS and total station. The existing and new benchmarks of each bridge were shown in Table 1-3-16. World Geodetic System, WGS 84 / UTM zone 46N, was adopted on the Survey.

Table 1-3-16 Benchmark locations on each surveyed bridge

Bridge neme	ID	Easting	Northing	Elevation (MSL)	Remarks
Namling Bridge	NB1	312889.689	3026675.508	2215.769	New
	NB2	312867.889	3026726.152	2227.570	Ditto
	NB3	312918.427	3026676.674	2213.211	Ditto
	NB4	312887.796	3026652.088	2219.504	Ditto
	BM01	313041.845	3026629.617	2199.402	Existing
Pakhadrang Bridge	PB1	339153.914	3017802.625	1001.985	New
	PB2	339144.583	3017806.535	1002.752	Ditto
	PB3	339136.429	3017670.431	1008.454	Ditto
	PB4	339161.546	3017672.920	997.278	Ditto
	BM01	339160.945	3017766.530	990.390	Existing
	BM02	339124.406	3017724.969	990.433	Ditto
Durdari Bridge	DB1	339357.879	3017488.126	970.391	New
	DB2	339340.096	3017476.365	966.314	Ditto
	DB3	339376.116	3017563.199	987.123	Ditto
	DB4	339365.071	3017555.603	991.440	Ditto
	BM03	339438.042	3017590.143	978.161	Existing
	BM04	339494.043	3017531.809	959.402	Ditto
Revidrang Bridge	BR1	344491.286	3019000.250	823.613	New
	BR2	344501.585	3019012.362	817.558	Ditto
	BR3	344531.664	3019031.030	808.299	Ditto
	BR4	344532.067	3019045.129	809.981	Ditto
Rollong Bridge	RB1	351343.326	3021647.834	670.417	New
	RB2	351306.677	3021631.443	675.544	Ditto
	RB3	351395.890	3021625.890	665.193	Ditto
	RB4	351428.342	3021631.841	678.134	Ditto
	GONG5	351418.390	3021640.259	679.112	Existing

Source: JICA Survey Team

Location of Benchmarks (Namling Bridge)

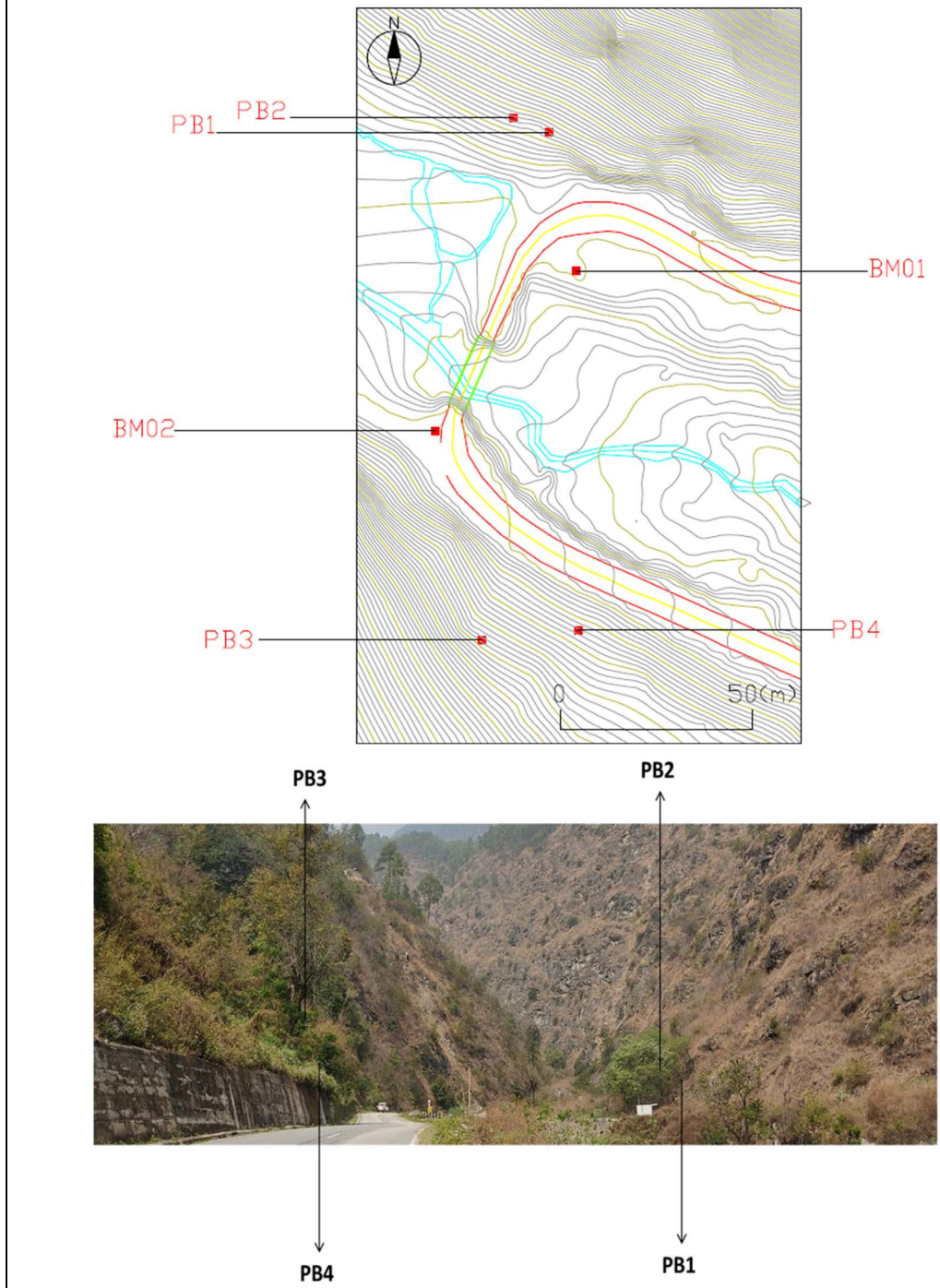


NB1	NB2	NB3	NB4	BM01
				

Source: JICA Survey Team

Figure 1-3-34 Benchmark location (Namling Bridge)

Location of Benchmarks (Pakhadrang Bridge)

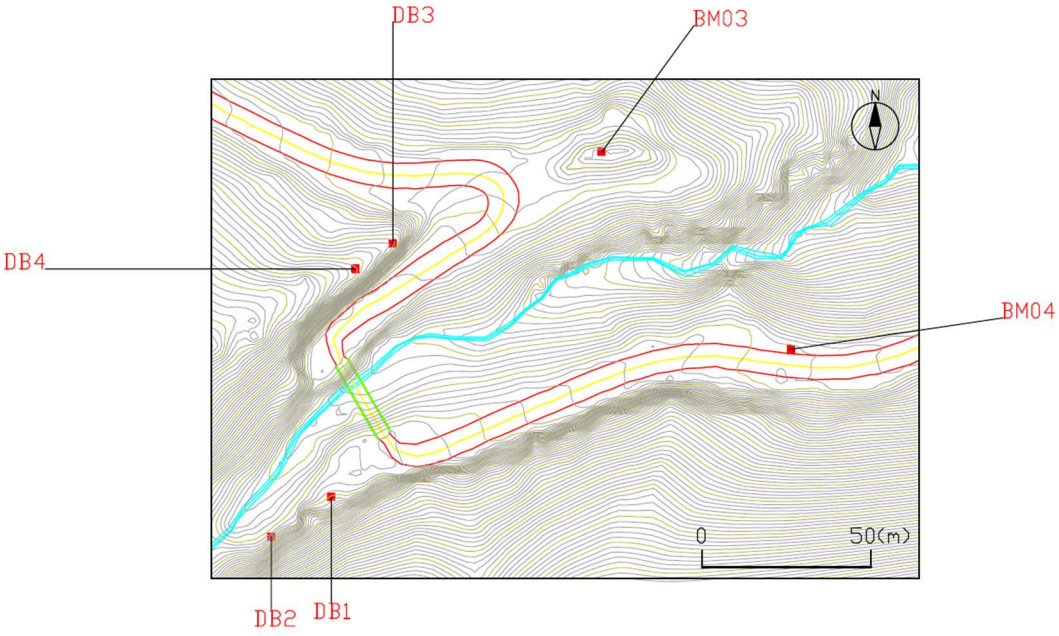


PB1	PB2	PB3	PB4
			

Source: JICA Survey Team

Figure 1-3-35 Benchmark location (Pakhadrang Bridge)

Location of Benchmarks (Durdari Bridge)

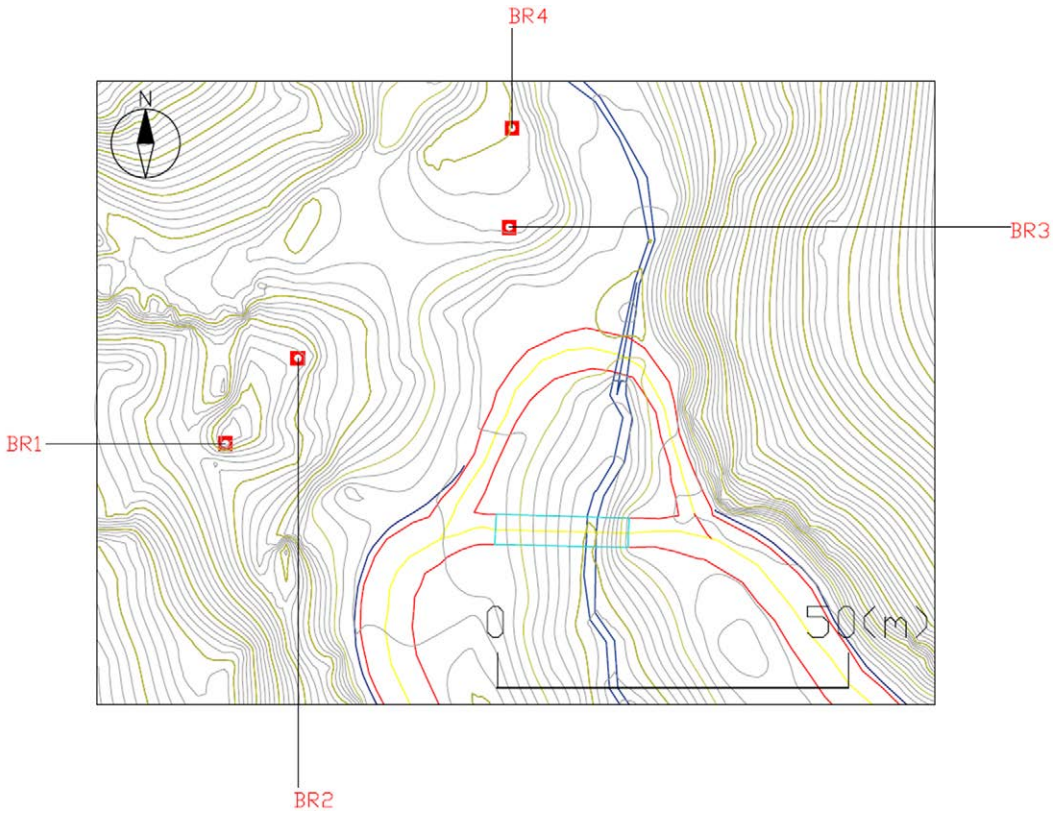


DB1	DB2	DB3	DB4
			

Source: JICA Survey Team

Figure 1-3-36 Benchmark location (Durdari Bridge)

Location of Benchmarks (Revidrang Bridge)

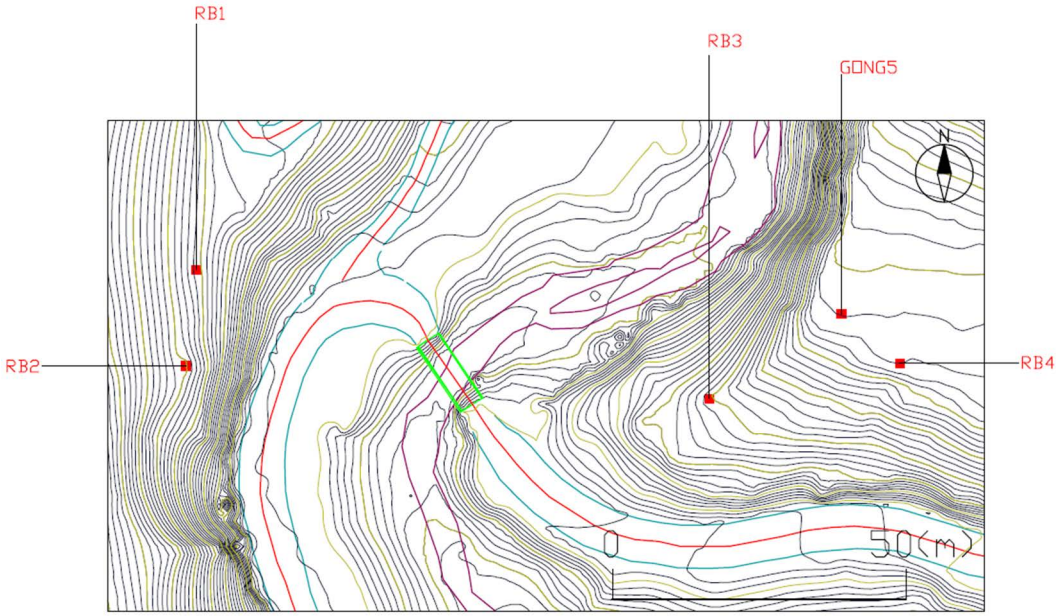


BR1	BR2	BR3	BR4
			

Source: JICA Survey Team

Figure 1-3-37 Benchmark location (Revidrang Bridge)

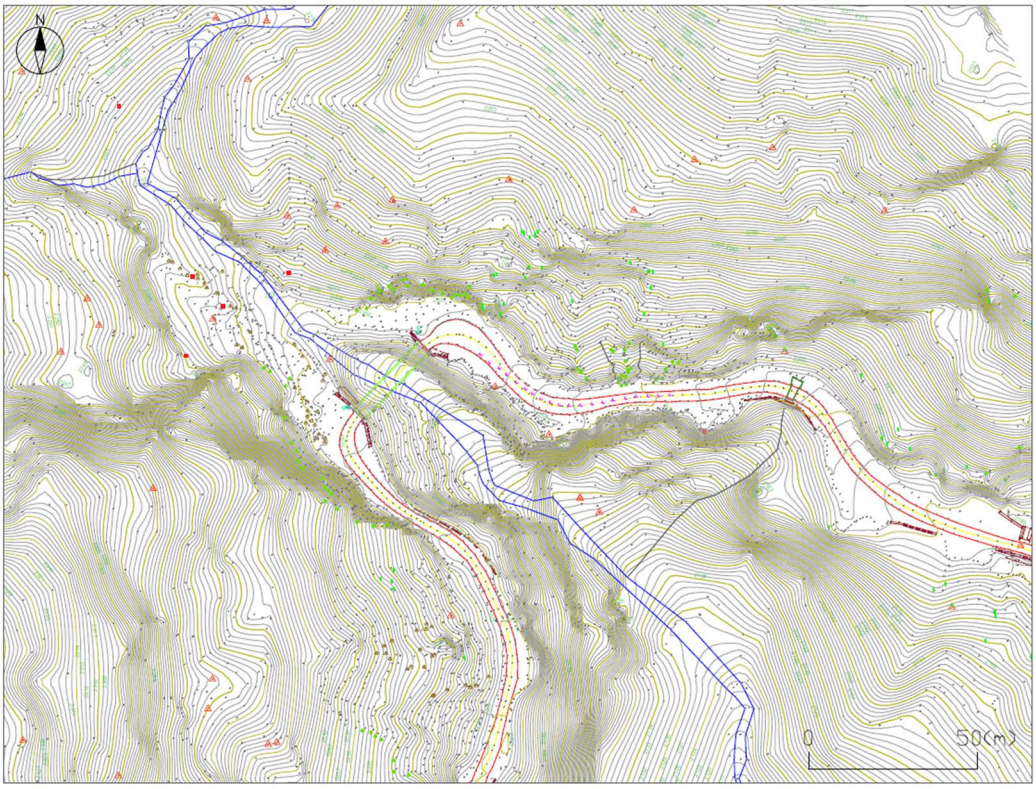
Location of Benchmarks (Rollong Bridge)



RB1	RB2	RB3	RB4	GONG5
				

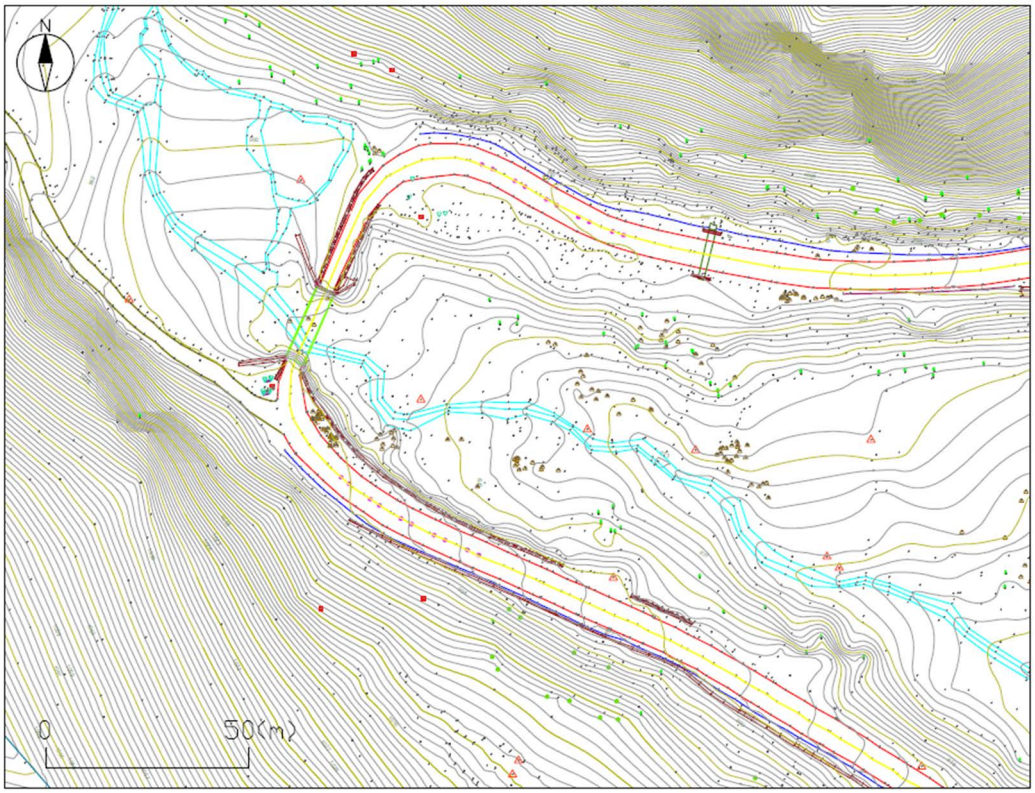
Source: JICA Survey Team

Figure 1-3-38 Benchmark location (Rollong Bridge)



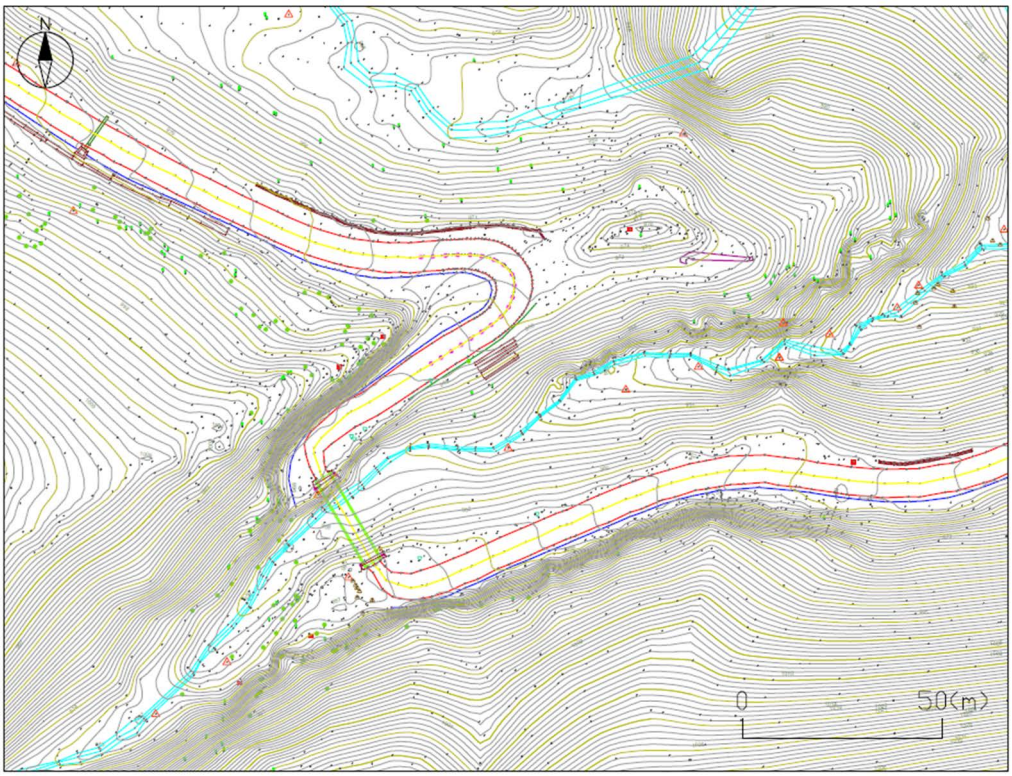
Source: JICA Survey Team

Figure 1-3-39 Output for Namling Bridge



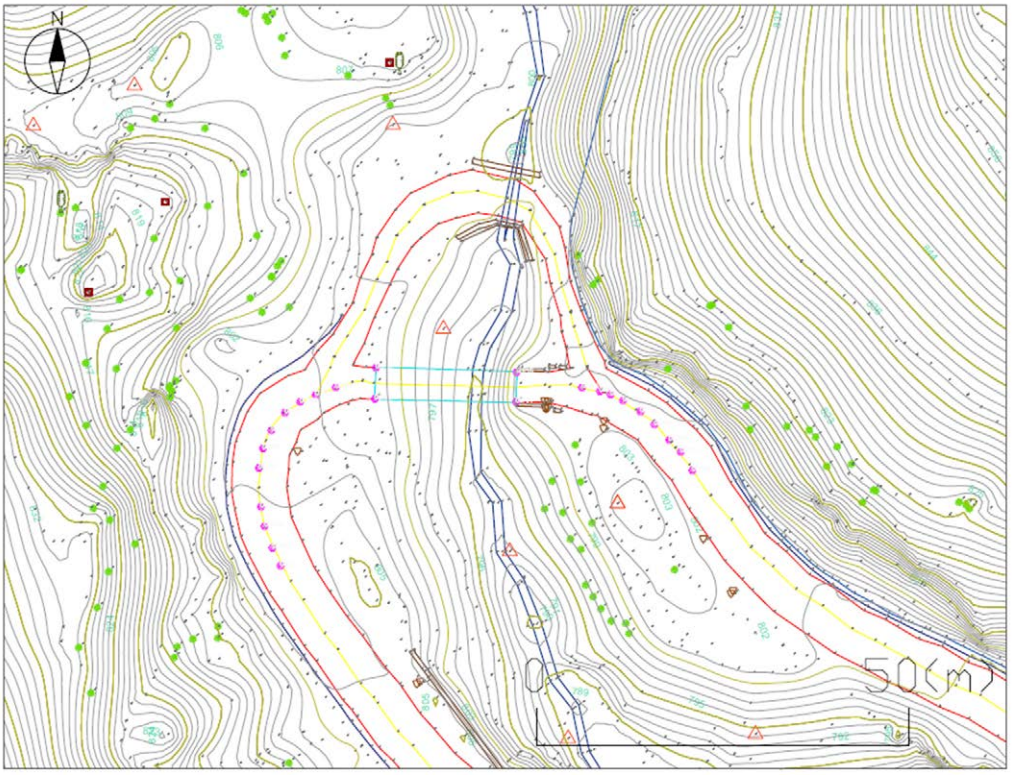
Source: JICA Survey Team

Figure 1-3-40 Output for Pakhadrang Bridge



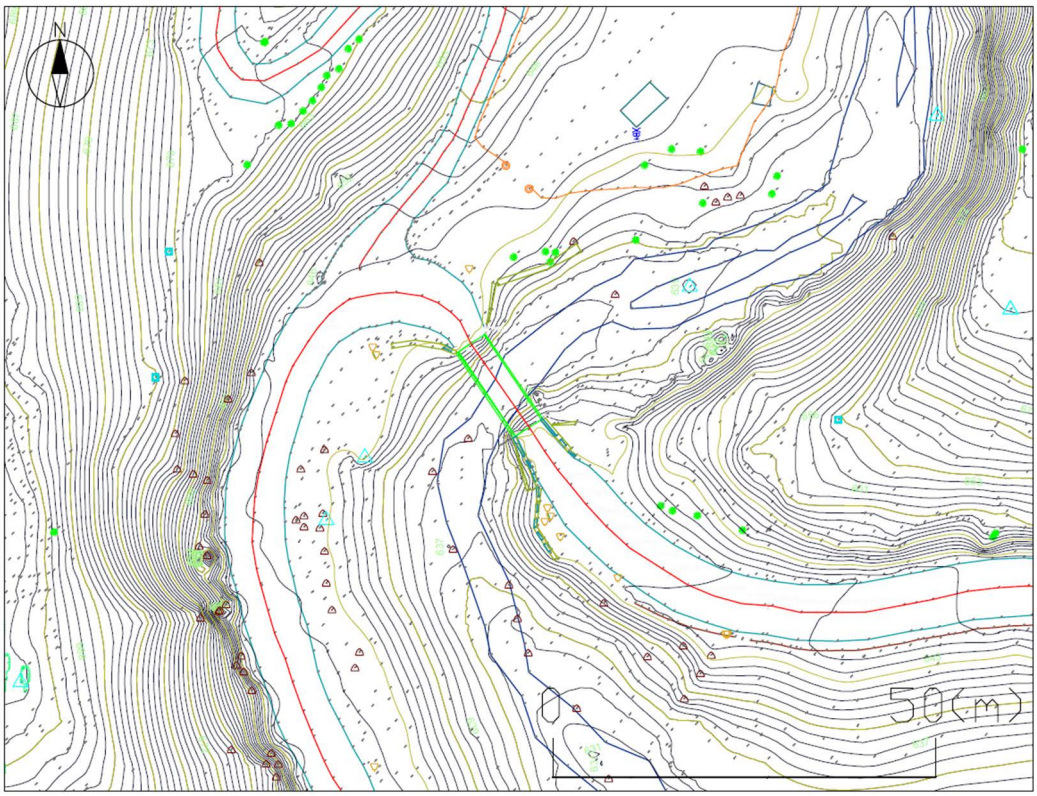
Source: JICA Survey Team

Figure 1-3-41 Output for Durdari Bridge



Source: JICA Survey Team

Figure 1-3-42 Output for Revidrang Bridge



Source: JICA Survey Team

Figure 1-3-43 Output for Rollong Bridge

1-3-5 Geological and Material Survey

Geotechnical and material survey were conducted on Namling Bridge and Durdari Bridge.

(1) Summary of Geology

1) Summary of Geology of Bhutan

The country of Bhutan is situated within the Himalayan orogeny formed by the collision between the Eurasian and Indian tectonic plates. Its southern region consists of a tropical area approximately 300 meters above sea level (around the Geref region), transitioning into the temperate zone ranging from 3,000 to 4,000 meters above sea level in the central part, and further into the higher elevated northern region. Due to the northward movement of the Indian Plate, ancient seabed sediments such as mudstone, shale, sandstone, and others were uplifted onto land through tectonic activities, including thrust faults (reverse faults) and folding, which involves metamorphic processes, restructuring the composition of the rocks thermodynamically. As a result, the geological composition of the surface rocks is in an extremely fragile state.

2) Geological Overview of the Survey area

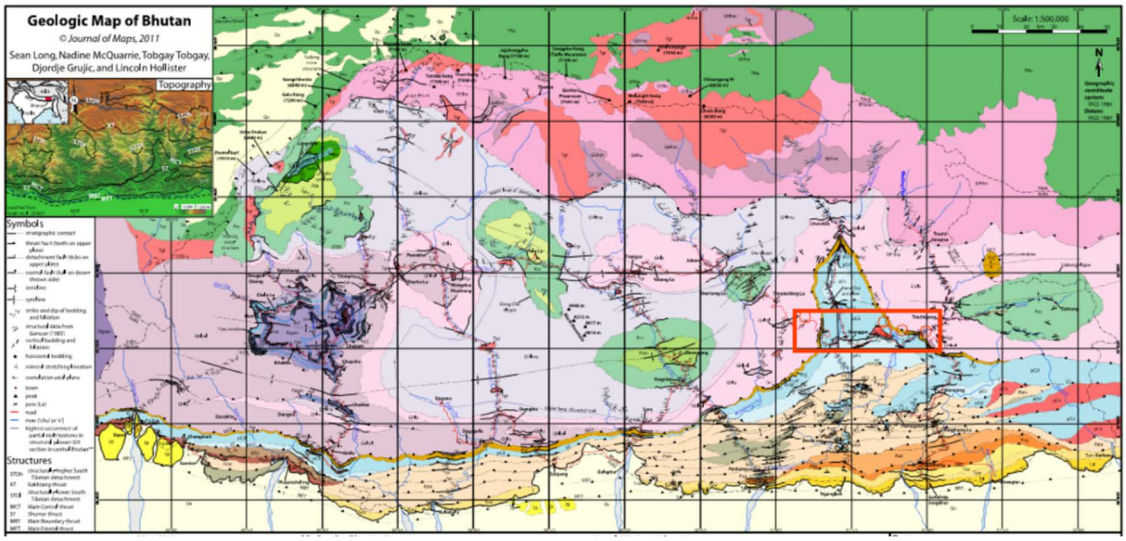
The geological structure of Bhutan is broadly divided into the southern foothills (Siwalik Hills), the Lesser Himalayas, and the Greater Himalayas. The two bridges (outlined in red in the geological map) are located near the boundary between the Lesser and Greater Himalayas. This boundary is marked by a major fault zone known as the Main Central Thrust. In the vicinity of this fault zone, there exist

fractured zones of weathered metamorphic rocks, primarily comprising slate and mudstone. The anticipated geological conditions based on the geological map are summarized in Table 1-3-17.

Table 1-3-17 Objective of the Survey

Target Bridge	Geological Period	Geological Group/Rock type
Namling Bridge	Pre-Cambrian～Ordovician	Gneiss of Paro Formation
Durdari Brdige	Early Paleozoic Era	Schist and Slate, Daling Formation, Schist of Lesser Himaraya zone, Schist and Siliceous Schist of Jaishidanda Formation

Source: JICA Survey Team



Source: Department of Geology in Bhutan, Journal of Maps 2011

Figure 1-3-44 Geological Map pf Bhutan

(2) Geological Survey and Material Survey

Eight (8) borehole drillings were carried out at the two bridges. Contents of survey and testing are shown in the following table.

Table 1-3-18 Summary of Survey Points

Location Name		Elevation	Drilling Length	Geological Survey	Location
Bridge Name	Bridge Name	[m]	[m]		
Namling Bridge	Right side /BH-No.1	2201.60	15	• Standard Penetration Test (N Value) • Installation of Monitoring Well and of Level logger for Groundwater	Approximately 15.0km Northwest of Mongar
	Right side /BH-No.2	2201.81	15		
	Left side/BH-No.3	2201.40	15		
	Left side/BH-No.4	2201.43	15		
Durdari Bridge	Right side /BH-No.1	962.10	15		Approximately 13.5km East of Mongar
	Right side /BH-No.2	966.07	15		
	Left side /BH-No.3	967.75	15		
	Left side /BH-No.4	967.93	15		
	Total		120		

Source: JICA Survey Team

1) Geological Summary of Namling Brdige

The Namling Bridge is located in a mountainous area approximately 15.0 kilometers northwest to Mongar.Around the bridge rocks are exposed on the surrounding slopes and beneath the road surface there are steep cliffs formed by deep valley topography.

On the right bank side, as shown in Figure 1-3-45, partial areas of the road slope showed signs of collapse. The current road alignment is a gentle curve, and the exposed rock surfaces along this road exhibit a loose joint pattern, forming a weak bedding structure.

Source: JICA Survey Team

Figure 1-3-45 Right side of Namling Bridge

The left bank side of the road slope, as shown in Figure 1-3-46, partial areas of collapsed terrain, and surface water was observed flowing down the slope due to rainfall or other factors. It is important to note that at the planned bridging position on the left bank side, the exposed rock surfaces along the current road exhibit a weaker bedding structure than the cut slope (approximately 50°), forming a gentle flow bedding structure.

Source: JICA Survey Team

Figure 1-3-46 Left side of Namling Bridge

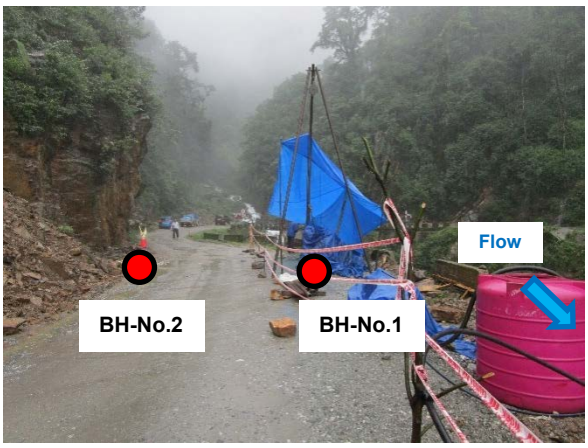
The results of the borehole investigation at the Namling Bridge are described below, with the survey locations shown in Figure 1-3-47.

At the bridge, borehole investigations were conducted at a total of four points: two on the right bank side (BH-No.1, BH-No.2) and two on the left bank side (BH-No.3, BH-No.4), with a depth of up to 15 meters each.

On the right bank side, the upper layer down to GL-0.5 to 1.0 meters consists of colluvial soil mainly composed of sandy soil with rock fragments, while deeper layers are dominated by thick layers of gneiss. The core recovery rate for rock samples is approximately 90%. The Rock Quality Designation (RQD) is roughly 20% to 70% down to GL-4.0 meters for BH-No.1, and approximately 10% to 30% down to GL-10.0 meters for BH-No.2, increasing to around 70% in deeper layers.

On the left bank side, there are extensive layers of gneiss from the surface. The core recovery rate for rock samples is approximately 95%. The RQD ranges from about 70% down to GL-13.0 meters for BH-No.3, decreasing to about 10% to 40% in deeper layers, and approximately 60% to 80% down to GL-15.0 meters for BH-No.4.

It is noted that post-drilling, water levels were observed within the boreholes on the following day. However, after the completion of drilling, water was discharged from rock fractures, indicating relatively dry conditions without significant groundwater. Consequently, it was determined that the installation of groundwater observation wells (PVC pipes) and self-recording water level gauges was not necessary at the borehole points (BH-No.1 to BH-No.4).

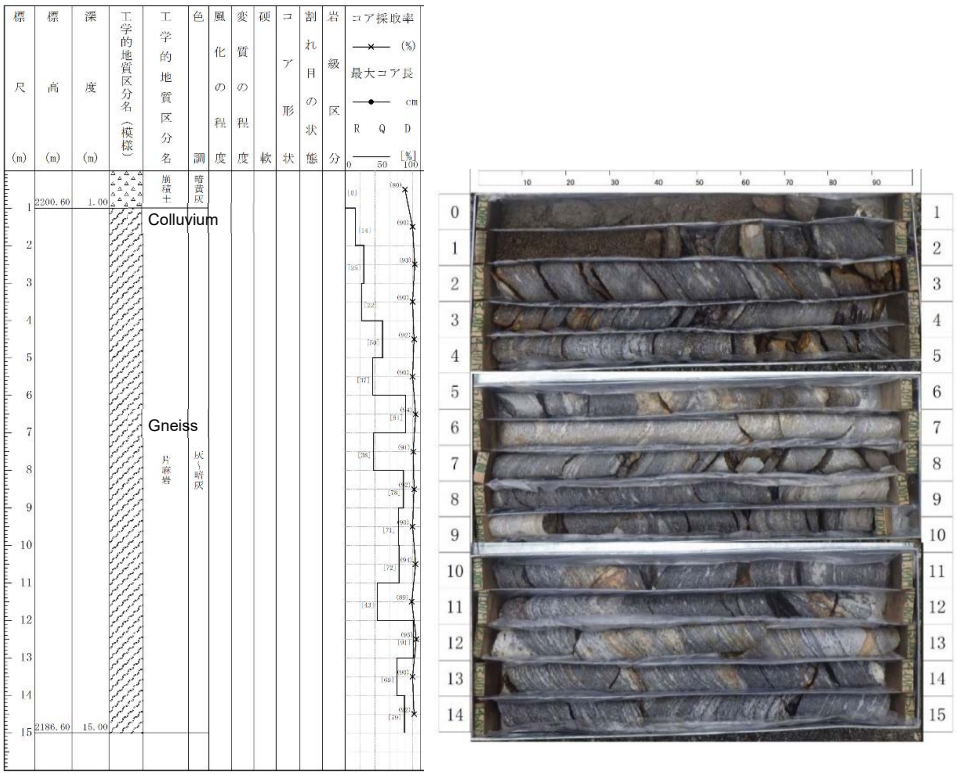


Namling Bridge Right side

Namling Bridge Left side

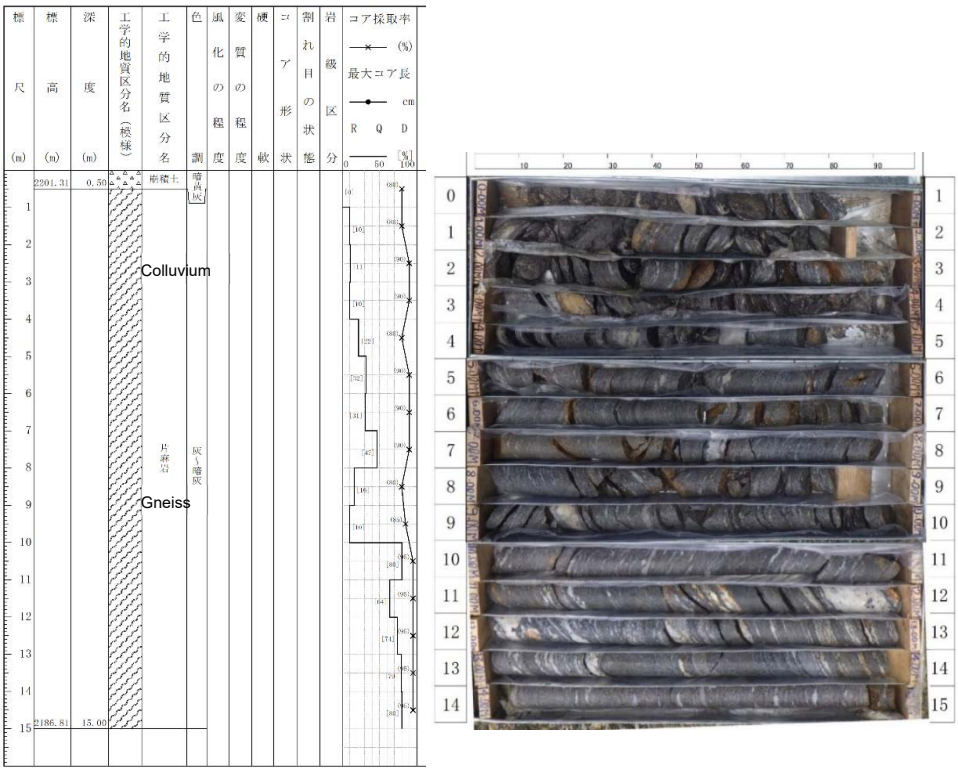
Source: JICA Survey Team

Figure 1-3-47 Borehole Location (Namling Bridge)



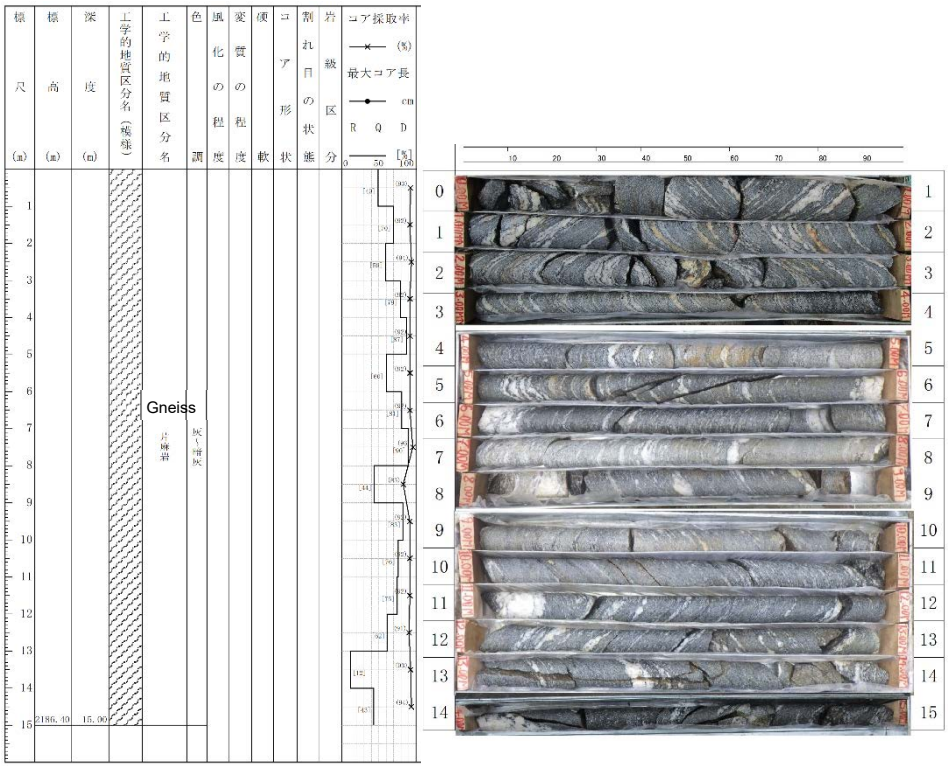
Source: JICA Survey Team

Figure 1-3-48 Borehole log (Namling Right side BH-No.1)



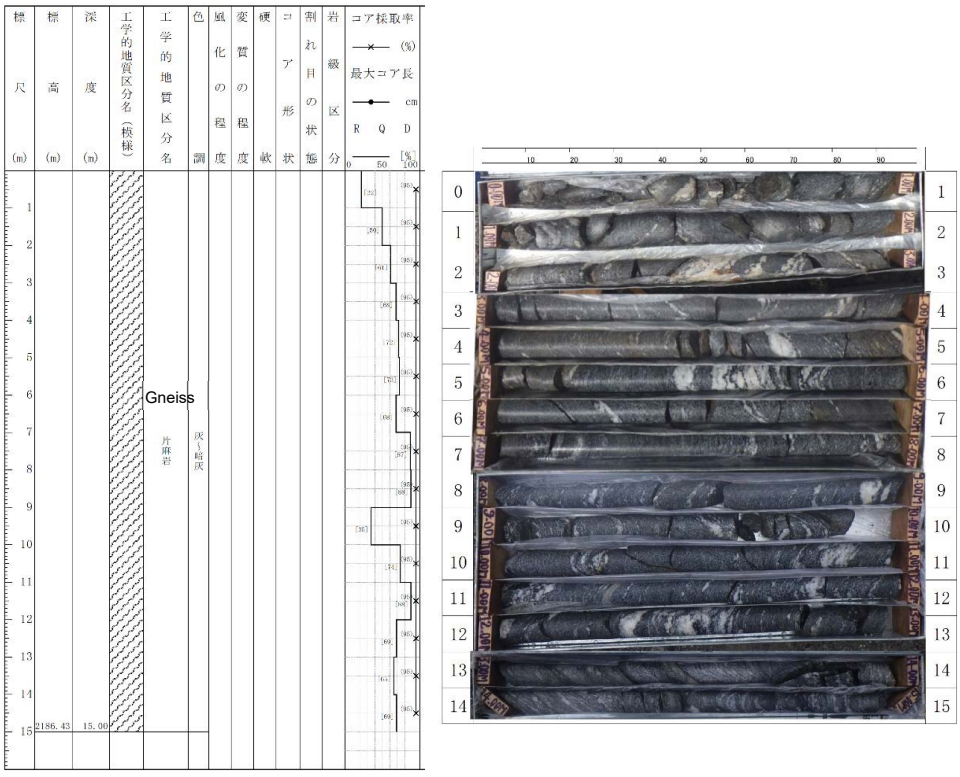
Source: JICA Survey Team

Figure 1-3-49 Borehole log (Namling Right side BH-No.2)



Source: JICA Survey Team

Figure 1-3-50 Borehole log (Namling Left side BH-No.3)



Source: JICA Survey Team

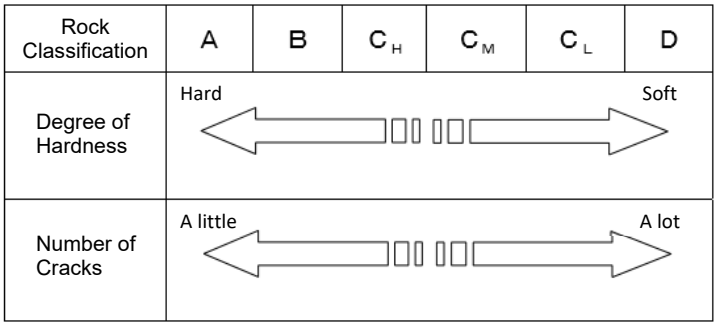
Figure 1-3-51 Borehole log (Namling Left side BH-No.3)

(a) Standard Penetration Test

The borehole investigation at the Namling Bridge revealed that bedrock (gneiss) was encountered near the surface. Consequently, the Standard Penetration Test was not conducted due to the situation where the hammer rebounded upon attempting to free-fall the weight during the test, indicating that penetration did not occur.

(b) Rock Classification

As a guideline for assessing the bedrock for bridge foundation, the classification of rock grades is determined based on the criteria in the table below. This serves as an indicator to evaluate the condition (hardness level) of the geological bedrock. It is utilized to gauge differences in hardness due to weathering and variations in rock fragment fragility based on the frequency of cracks.



Source: Design Guideline, Vol.1, Earthworks, July 2015, NEXCO

Figure 1-3-52 Idea of Rock Classification

Table 1-3-19 Criteria for rock grade classification

Class	Characteristics
A	It is extremely fresh, and the constituent minerals and particles have not undergone weathering or alteration. Cracks and joints are well-connected, and there are no signs of weathering along those surfaces. When tapped with a hammer, it produces a clear sound.
B	Its rock quality is hard, without any visible (even if only 1 mm) open cracks or joints, adhering well. However, some partial weathering or alteration can be observed in the constituent minerals and particles. When tapped with a hammer, it produces a clear sound.
CH	The rock constituents and particles, excluding quartz, have undergone weathering, but the rock quality is relatively hard. Generally, it is contaminated with minerals such as limonite, and the adhesion between joints or cracks is slightly reduced. Intense hammering can cause rock fragments to detach along the fissures, leaving a thin layer of clay-like material on the detachment surface. When tapped with a hammer, it produces a slightly muffled sound.
CM	The rock constituents and particles, excluding quartz, have undergone some degree of weathering, resulting in a slight softening. The rock quality has also become somewhat softer. The adhesion between joints or cracks has decreased slightly. With an average impact from a hammer, rock fragments may detach along the fissures, leaving a layer of clay-like material on the detachment surface. When tapped with a hammer, it produces a somewhat muffled sound.
CL	The rock constituents and particles have undergone weathering, resulting in softening, and the rock quality has become softer. The adhesion between joints or cracks has decreased. With a light strike from a hammer, rock fragments may detach along the fissures, leaving a residue of clay-like material on the detachment surface. When tapped with a hammer, it produces a muffled sound
D	The rock constituents and particles have significantly softened due to weathering, and the rock quality is notably soft. There is almost no adhesion between joints or cracks, causing the rock to easily crumble with just a slight strike from a hammer. Residue of clay-like material remains on the detachment surface. When tapped with a hammer, it produces a significantly muffled sound.

Source: Introduction of Geology for Civil Engineer (Sankaido)

The gneiss distributed in BH-No.1 to BH-No.4 is assessed to be categorized within the CM to CH grade based on the criteria outlined in Figure 1-3-52 for rock grade classification. (Refer Table 1-3-20)

Table 1-3-20 Rock Classification (Namling Bridge)

Right Bank(BH-No.1)		Right Bank(BH-No.2)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 1.00	colluvial deposit	0.00 - 0.50	colluvial deposit
1.00 - 6.00	CM	0.50 - 10.00	CM
6.00 - 15.00	CH	10.00 - 15.00	CH

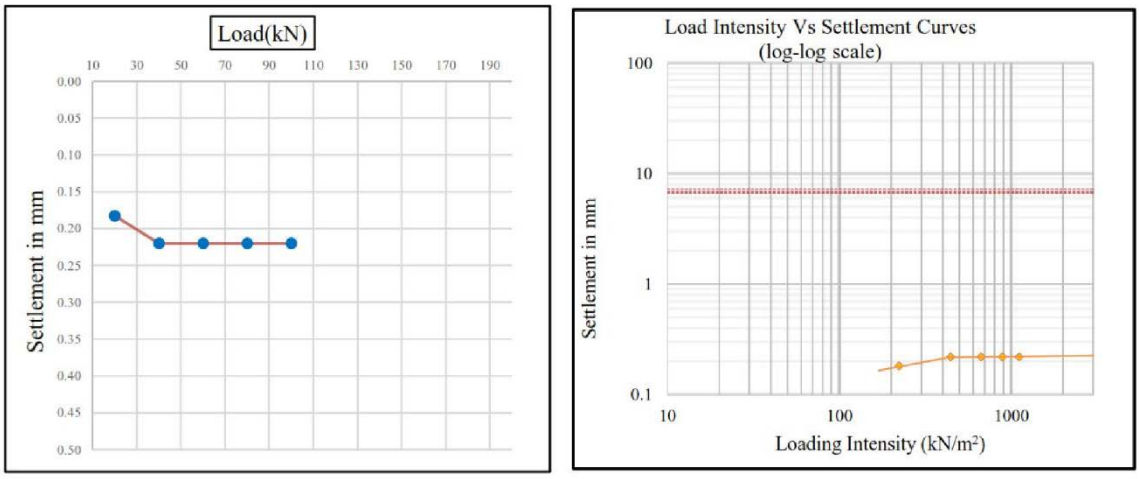
Left Bank(BH-No.3)		Left Bank(BH-No.4)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 1.00	CM	0.00 - 3.00	CM
1.00 - 13.00	CH	3.00 - 15.00	CH
13.00 - 15.00	CM		

Source: JICA Survey Team

(c) Plate Load Test

The plate load test was conducted in feasible locations (near the surface) on both banks of the Namling Bridge to verify the soil bearing capacity.

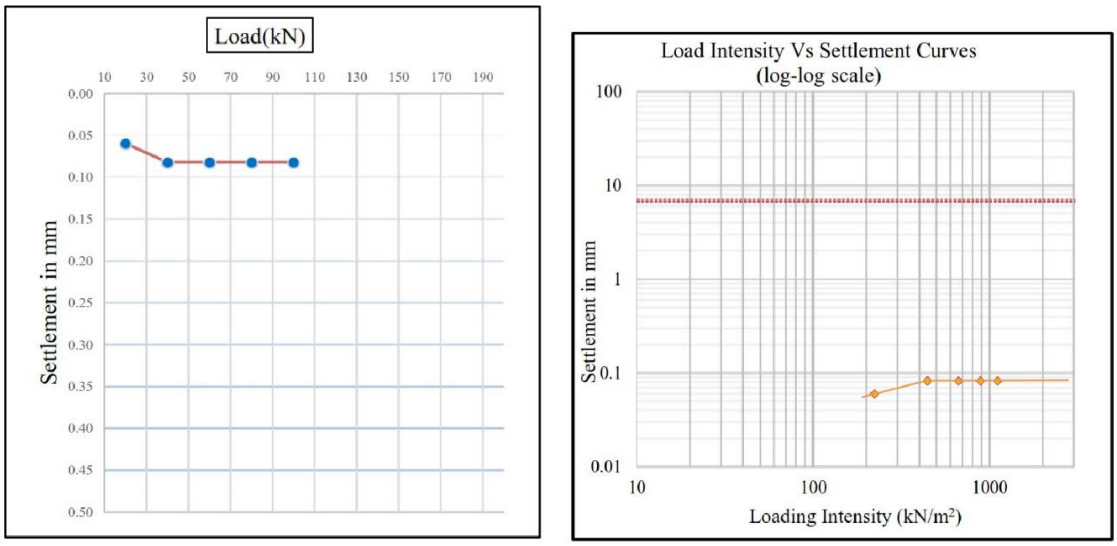
Below are the results of the plate load test on the right bank of the Namling Bridge. In the right bank area, bedrock emerged near the surface. Consequently, with a final load of P = 1,111 kN/m^2, the settlement was very small at S = 0.22mm. Within the range of the applied load for this test, it was determined that the ultimate bearing capacity limit (Pu) was not reached.



Source: JICA Survey Team

Figure 1-3-53 Relationship between Settlement S and Load Pressure P (Namling Right side)

Here are the results of the plate load test on the left bank of the Namling Bridge. In the left bank area, bedrock emerged near the surface. As a result, with a final load of P = 1,111 kN/m^2, the settlement was very minimal at S = 0.08mm. Within the range of the applied load for this test, it was determined that the ultimate bearing capacity limit (Pu) was not reached.



Source: JICA Survey Team

Figure 1-3-54 Relationship between Settlement S and Load Pressure P (Namling Left side)

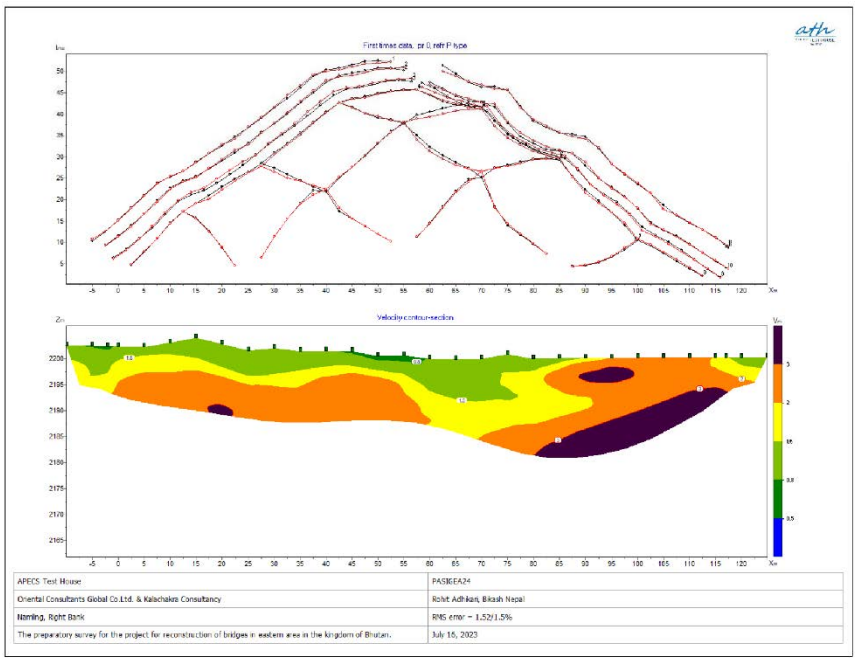
(d) Seismic Exploration

The slopes near the Namling Bridge are steep cliffs, and it was not feasible to install equipment in the transverse direction of the current road. Therefore, the seismic exploration was conducted by placing the equipment along the longitudinal direction of the current road.

Source: JICA Survey Team

Figure 1-3-55 Survey Location of Seismic Exploration (Namling Bridge Right side slope)

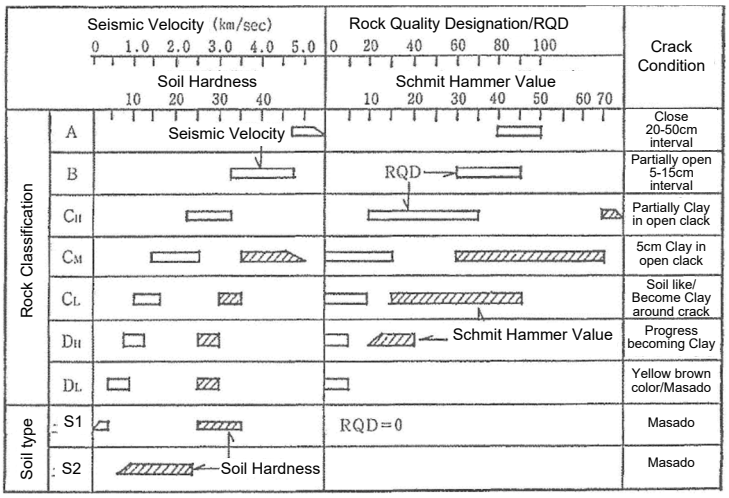
Below are the results of the seismic wave survey conducted on the right bank slope of the Namling Bridge. It generally shows Vp = 800-1,500m/s near the surface. Referring to the example in Figure 1-3-57, the rock types are classified with Vp = 500m/s or above. This result aligns with the emergence of bedrock layers at the borehole point (BH-No.2). Additionally, it is conceivable that the P-wave velocity increases significantly in the depth direction, gradually indicating a hardening of the rock formations.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	1.00	1.00	500～800
	2.30	3.30	800～1500
	2.70	6.00	1500～2000
	6.30	12.30	2000～3000
	6.60	18.90	>3000

Source: JICA Survey Team

Figure 1-3-56 P wave Speed Distribution (Namling Bridge Right hand slope)



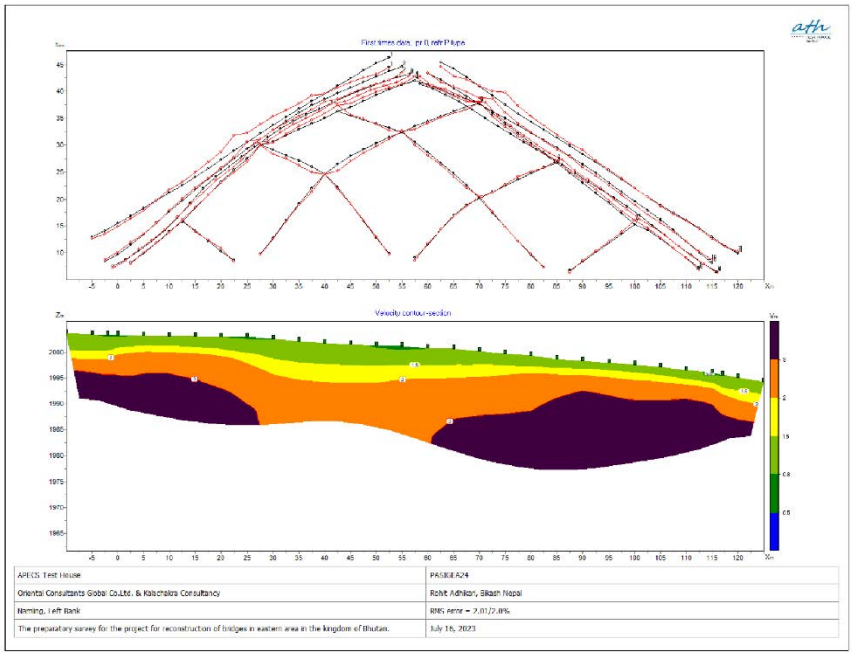
Source: Design and example of slope failure protection, Design guideline for steep slope failure protection, (Japan Water control and Sabo association)

Figure 1-3-57 Rock classification by Seismic velocity, RQD, Rock observation for granite

Source: JICA Survey Team

Figure 1-3-58 survey location of seismic exploration (Namling Bridge Left side slope)

The seismic wave survey results on the left bank slope of the Namling Bridge are presented below. Similar to the right bank side, it generally indicates Vp = 800-1,500m/s near the surface. Referring to the example in Figure 1-3-57, the rock types are classified with Vp = 500m/s or above. This aligns with the emergence of bedrock layers at the borehole point (BH-No.4). Additionally, it is conceivable that the P-wave velocity increases significantly in the depth direction, gradually indicating a hardening of the rock formations.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	0.50	0.50	500～800
	1.90	2.40	800～1500
	4.00	6.40	1500～2000
	7.30	13.70	2000～3000
	10.00	23.70	>3000

Source: JICA Survey Team

Figure 1-3-59 P wave Speed Distribution (Namling Bridge Left hand slope)

(e) Laboratory Testing

Laboratory testing of rock samples were conducted to identify the physical and mechanical characteristics using boring core samples.

The results are summarized in Table 1-3-21.

Table 1-3-21 Summary of Laboratory testing for rock samples (Namling Brdige)

bridge	BH No.	Sample Identity	Depth	Density test (g/cm3)		UCS (MN/m2)	
Namling	BH-No.1	BH-1-1	6.00 - 6.60	2.660		44.72	
				2.643	2.652	39.16	41.94
		BH-1-2	8.50 - 9.15	2.803		20.63	
				2.686		67.76	
				2.668	2.719	27.25	38.55
	BH-No.2	BH-2-1	5.50 - 6.20	2.778	2.778	25.69	25.69
		BH-2-2	7.70 - 8.25	2.794		20.47	
				2.724	2.759	10.02	15.25
	BH-No.3	BH-3-1	4.70 - 4.90	2.710	2.710	37.77	37.77
		BH-3-2	9.00 - 9.70	2.794		20.34	
				2.794	2.794	14.74	17.54
	BH-No.4	BH-4-1	4.00 - 4.45	2.731	2.731	16.84	16.84
		BH-4-2	7.20 - 7.70	2.753	2.753	33.31	33.31

Note 1) Since multiple core specimens were tested for BH-1-1, BH-1-2, BH-2-2, and BH-3-2, the average values are also shown.

Source: JICA Survey Team

2) Geological Summary of Durdari Brdige

Durdari Bridge is located in a mountainous area and approximately 13.5 kilometers east from Mongar. Around the bridge rocks are exposed on the surrounding slopes. The river flowing beneath the bridge forms a valley, but the elevation difference is moderate compared to the Namling Bridge.

On the right bank side, the road slope displays areas where schist is exposed, as shown in Figure 1-3-60, alongside sections with a mix of large boulders and gravel. The current road alignment predominantly forms nearly linear cut slopes, where the exposed rock parts reveal a structure with a bedding plane gentler than the cut slope (approximately 65 degrees).

Source: JICA Survey Team

Figure 1-3-60 Right side of Durdari Bridge

The left bank side of the road slope, as indicated in Figure 1-3-61, displayed partial areas of collapsed terrain, and surface water was observed flowing down the slope due to rainfall or other factors. It is important to note that at the planned bridging position on the left bank side, the exposed rock surfaces along the current road exhibit a weaker bedding structure than the cut slope (approximately 50°), forming a gentle flow bedding structure.

Source: JICA Survey Team

Figure 1-3-61 Left side of Namling Bridge

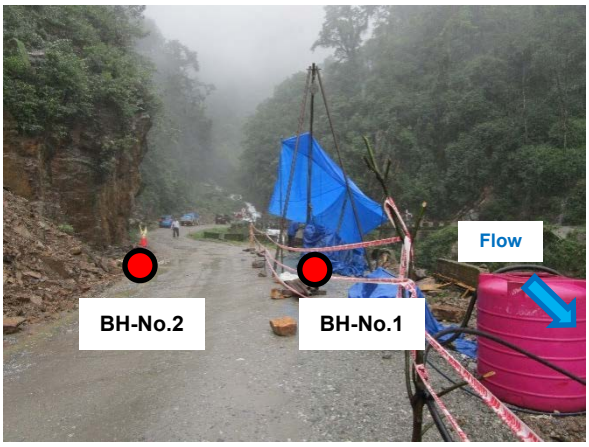
The results of the borehole investigation at the Namling Bridge are as follows, with the survey locations shown in Figure 1-3-62.

At the bridge, borehole investigations were conducted at a total of four points: two on the right bank side (BH-No.1, BH-No.2) and two on the left bank side (BH-No.3, BH-No.4), with a depth of up to 15 meters each.

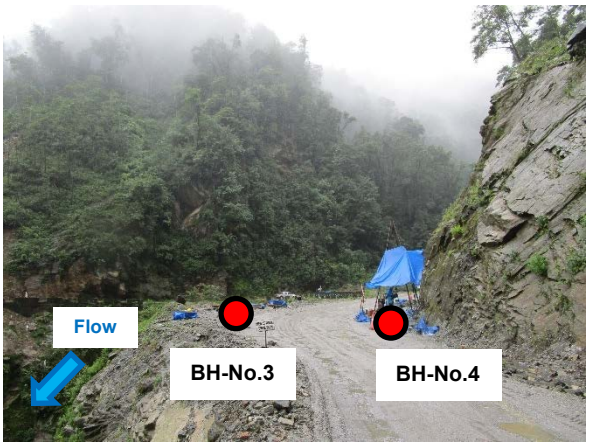
On the right bank side, the upper layer down to GL-0.5 to 1.0 meters consists of colluvial soil mainly composed of sandy soil with rock fragments, while deeper layers are dominated by thick layers of gneiss. The core recovery rate for rock samples is approximately 90%. The Rock Quality Designation (RQD) is roughly 20% to 70% down to GL-4.0 meters for BH-No.1, and approximately 10% to 30% down to GL-10.0 meters for BH-No.2, increasing to around 70% in deeper layers.

On the left bank side, there are extensive layers of gneiss from the surface. The core recovery rate for rock samples is approximately 95%. The RQD ranges from about 70% down to GL-13.0 meters for BH-No.3, decreasing to about 10% to 40% in deeper layers, and approximately 60% to 80% down to GL-15.0 meters for BH-No.4.

It is noted that post-drilling, water levels were observed within the boreholes on the following day. However, after the completion of drilling, water was discharged from rock fractures, indicating relatively dry conditions without significant groundwater. Consequently, it was determined that the installation of groundwater observation wells (PVC pipes) and self-recording water level gauges was not necessary at the borehole points (BH-No.1 to BH-No.4).



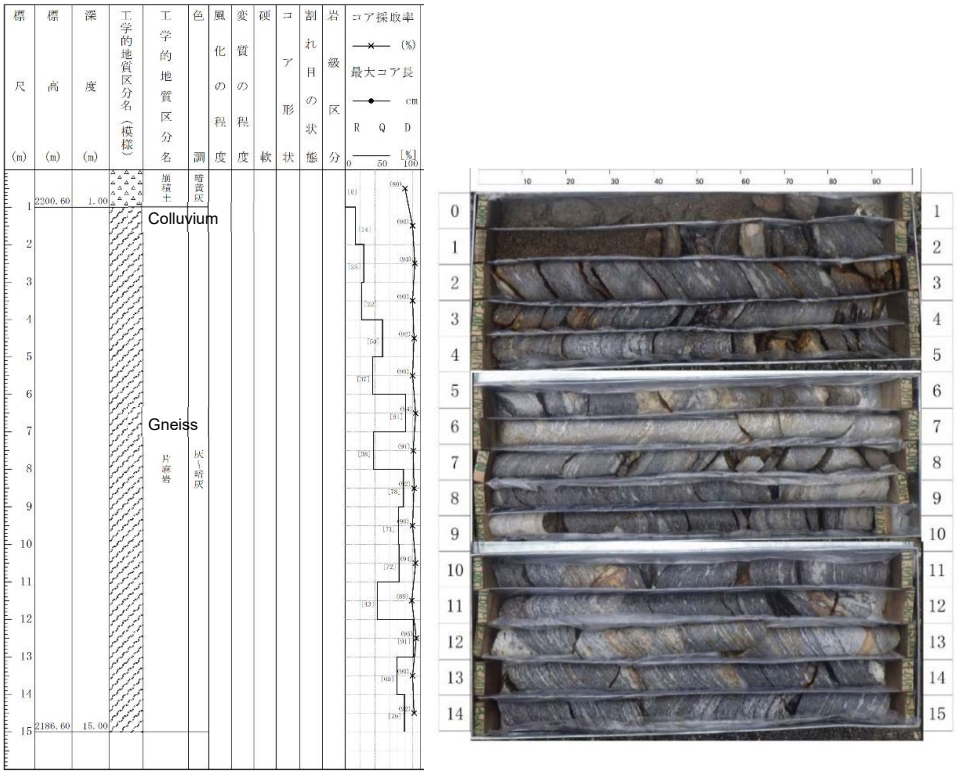
Namling Bridge Right side



Namling Bridge Left side

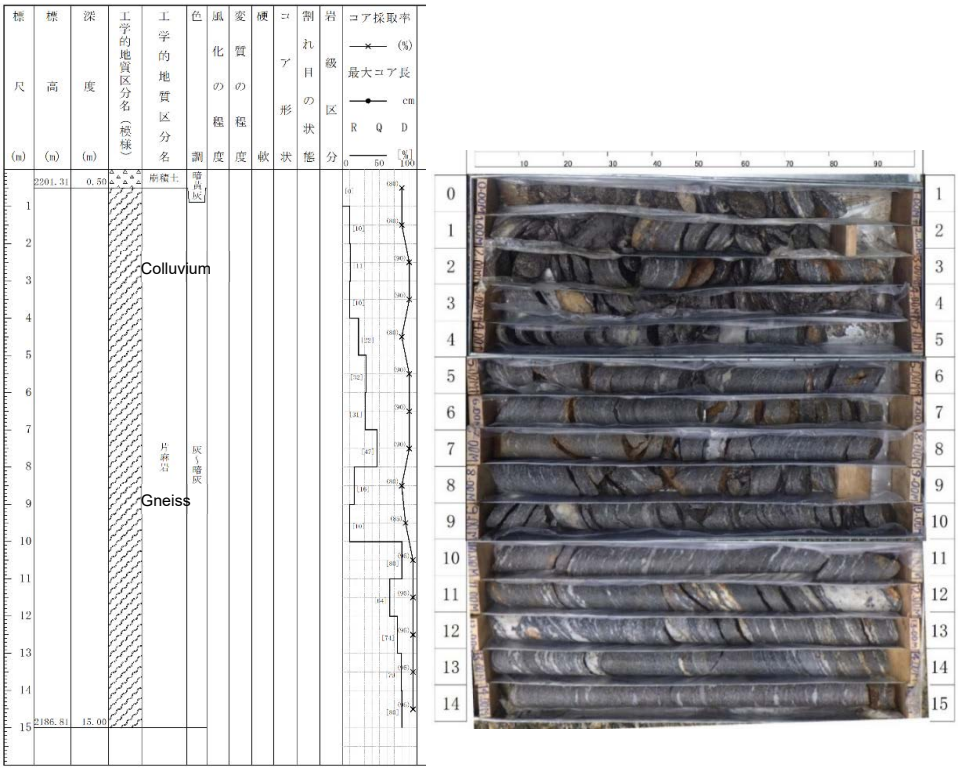
Source: JICA Survey Team

Figure 1-3-62 Borehole Location (Namling Bridge)



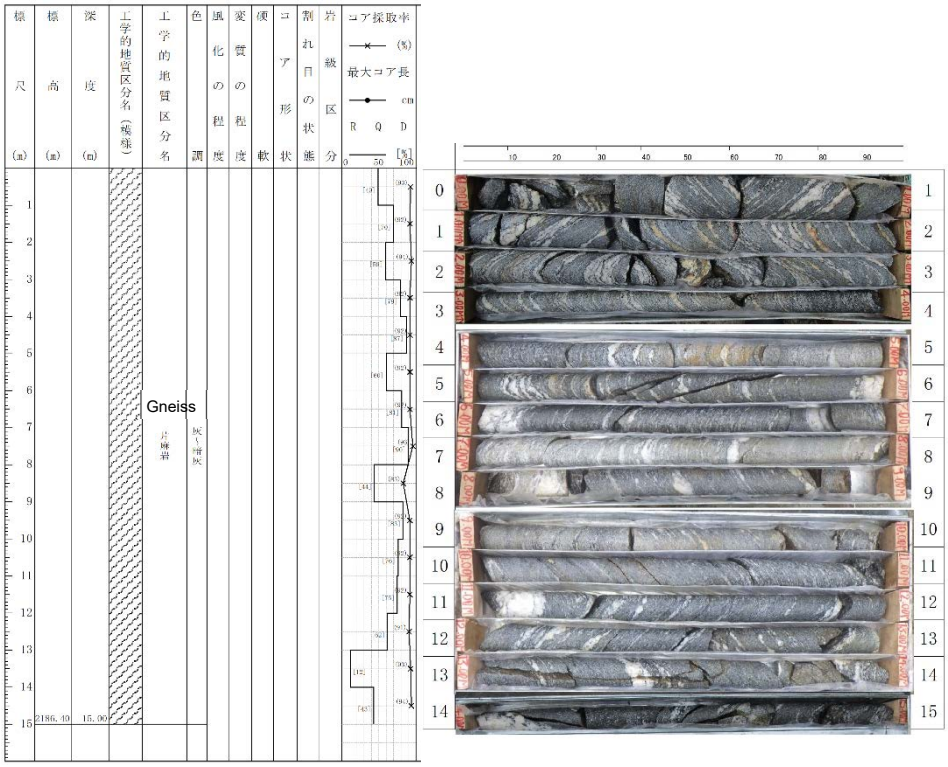
Source: JICA Survey Team

Figure 1-3-63 Borehole log (Namling Right side BH-No.1)



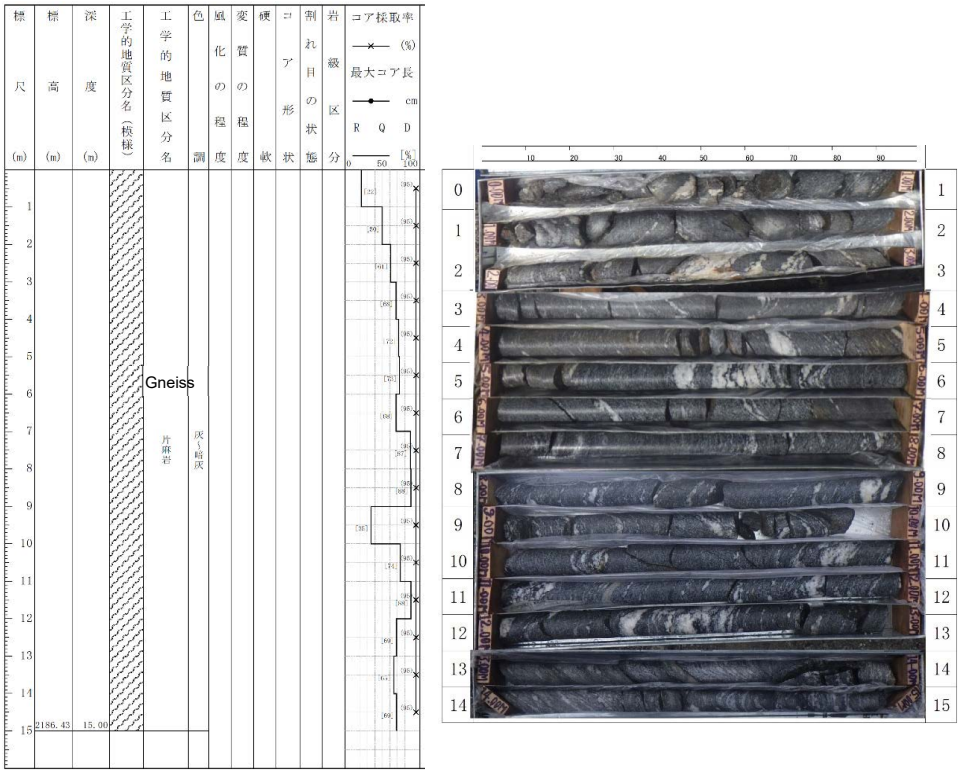
Source: JICA Survey Team

Figure 1-3-64 Borehole log (Namling Right side BH-No.2)



Source: JICA Survey Team

Figure 1-3-65 Borehole log (Namling Left side BH-No.3)



Source: JICA Survey Team

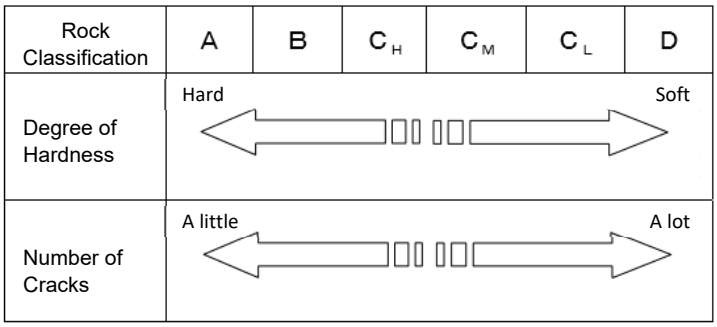
Figure 1-3-66 Borehole log (Namling Left side BH-No.3)

(a) Standard Penetration Test

The borehole investigation at the Namling Bridge revealed that bedrock (gneiss) was encountered near the surface. Consequently, the Standard Penetration Test was not conducted due to the situation where the hammer rebounded upon attempting to free-fall the weight during the test, indicating that penetration did not occur.

(b) Rock Classification

As a guideline for assessing the bedrock for bridge foundation, the classification of rock grades is determined based on the criteria in the table below. This serves as an indicator to evaluate the condition (hardness level) of the geological bedrock. It is utilized to gauge differences in hardness due to weathering and variations in rock fragment fragility based on the frequency of cracks.



Source: Design Guideline, Vol.1, Earthworks, July 2015, NEXCO

Figure 1-3-67 Idea of Rock Classification

Table 1-3-22 Criteria for rock grade classification

Class	Characteristics
A	It is extremely fresh, and the constituent minerals and particles have not undergone weathering or alteration. Cracks and joints are well-connected, and there are no signs of weathering along those surfaces. When tapped with a hammer, it produces a clear sound.
B	Its rock quality is hard, without any visible (even if only 1 mm) open cracks or joints, adhering well. However, some partial weathering or alteration can be observed in the constituent minerals and particles. When tapped with a hammer, it produces a clear sound.
CH	The rock constituents and particles, excluding quartz, have undergone weathering, but the rock quality is relatively hard. Generally, it is contaminated with minerals such as limonite, and the adhesion between joints or cracks is slightly reduced. Intense hammering can cause rock fragments to detach along the fissures, leaving a thin layer of clay-like material on the detachment surface. When tapped with a hammer, it produces a slightly muffled sound.
CM	The rock constituents and particles, excluding quartz, have undergone some degree of weathering, resulting in a slight softening. The rock quality has also become somewhat softer. The adhesion between joints or cracks has decreased slightly. With an average impact from a hammer, rock fragments may detach along the fissures, leaving a layer of clay-like material on the detachment surface. When tapped with a hammer, it produces a somewhat muffled sound.
CL	The rock constituents and particles have undergone weathering, resulting in softening, and the rock quality has become softer. The adhesion between joints or cracks has decreased. With a light strike from a hammer, rock fragments may detach along the fissures, leaving a residue of clay-like material on the detachment surface. When tapped with a hammer, it produces a muffled sound
D	The rock constituents and particles have significantly softened due to weathering, and the rock quality is notably soft. There is almost no adhesion between joints or cracks, causing the rock to easily crumble with just a slight strike from a hammer. Residue of clay-like material remains on the detachment surface. When tapped with a hammer, it produces a significantly muffled sound.

Source: Introduction of Geology for Civil Engineer（Sankaido）

The gneiss distributed in BH-No.1 to BH-No.4 is assessed to be categorized within the CM to CH grade based on the criteria outlined in Figure 1-3-67 for rock grade classification. (Refer Table 1-3-23)

Table 1-3-23 Rock Classification (Namling Bridge)

Right Bank(BH-No.1)		Right Bank(BH-No.2)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 1.00	colluvial deposit	0.00 - 0.50	colluvial deposit
1.00 - 6.00	CM	0.50 - 10.00	CM
6.00 - 15.00	CH	10.00 - 15.00	CH

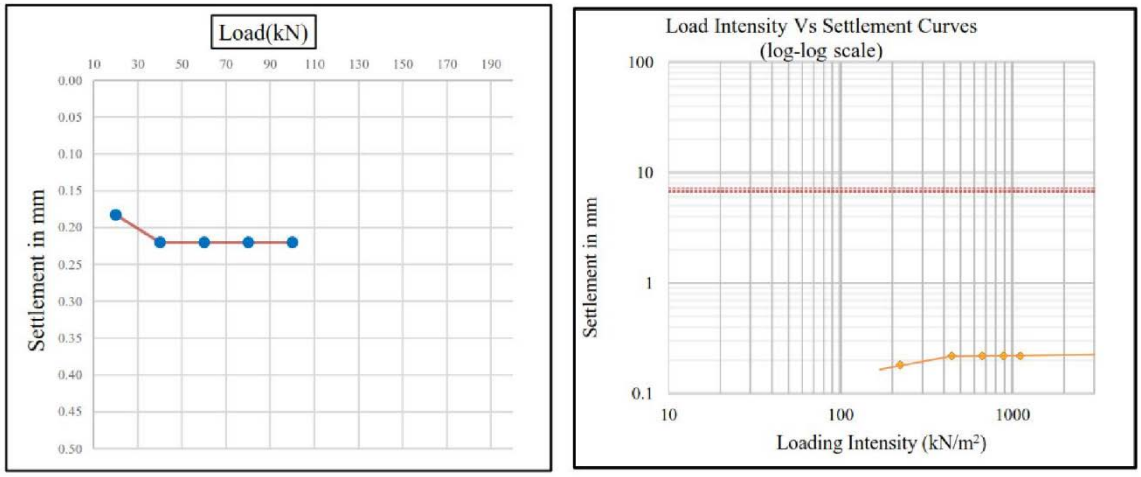
Left Bank(BH-No.3)		Left Bank(BH-No.4)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 1.00	CM	0.00 - 3.00	CM
1.00 - 13.00	CH	3.00 - 15.00	CH
13.00 - 15.00	CM		

Source: JICA Survey Team

(c) Plate Load Test

The plate load test was conducted in feasible locations (near the surface) on both banks of the Namling Bridge to verify the soil bearing capacity.

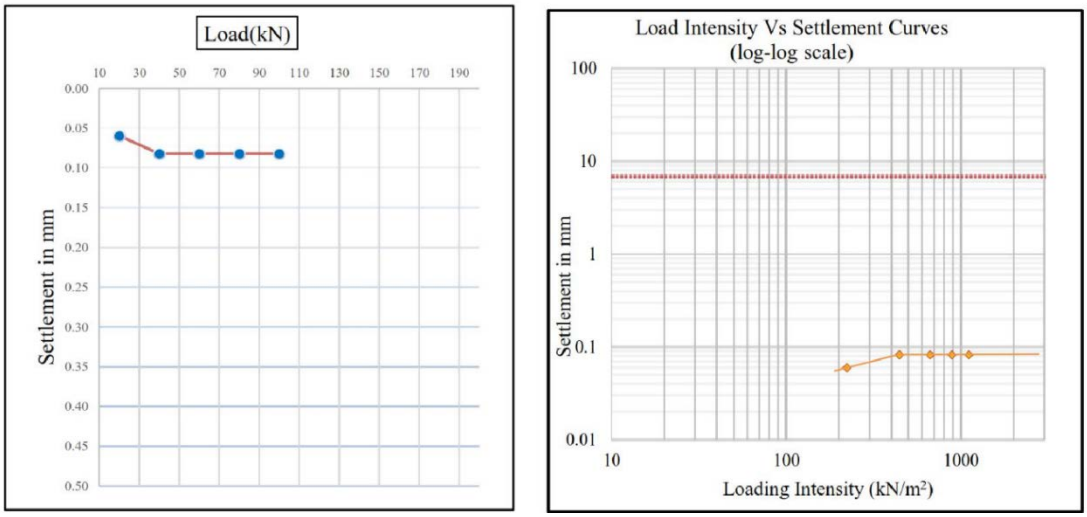
Below are the results of the plate load test on the right bank of the Namling Bridge. In the right bank area, bedrock emerged near the surface. Consequently, with a final load of P = 1,111 kN/m^2, the settlement was very small at S = 0.22mm. Within the range of the applied load for this test, it was determined that the ultimate bearing capacity limit (Pu) was not reached.



Source: JICA Survey Team

Figure 1-3-68 Relationship between Settlement S and Load Pressure P (Namling Right side)

Here are the results of the plate load test on the left bank of the Namling Bridge. In the left bank area, bedrock emerged near the surface. As a result, with a final load of P = 1,111 kN/m^2, the settlement was very minimal at S = 0.08mm. Within the range of the applied load for this test, it was determined that the ultimate bearing capacity limit (Pu) was not reached.



Source: JICA Survey Team

Figure 1-3-69 Relationship between Settlement S and Load Pressure P (Namling Left side)

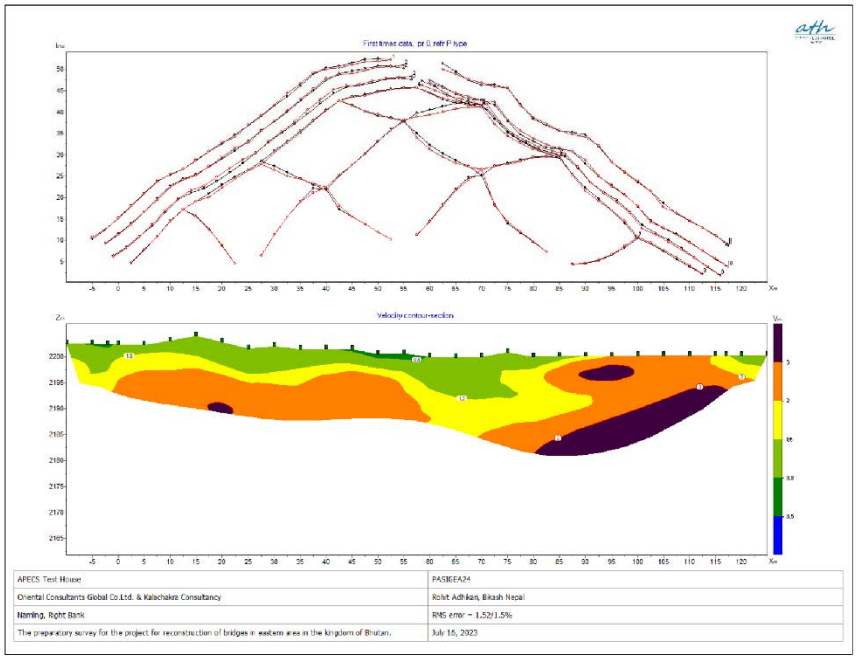
(d) Seismic Exploration

The slopes near the Namling Bridge are steep cliffs, and it was not feasible to install equipment in the transverse direction of the current road. Therefore, the seismic exploration was conducted by placing the equipment along the longitudinal direction of the current road.

Source: JICA Survey Team

Figure 1-3-70 Survey Location of Seismic Exploration (Namling Bridge Right side slope)

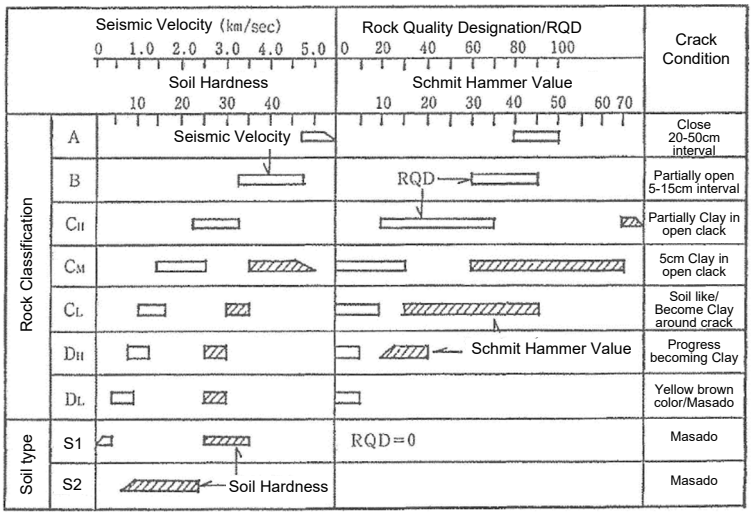
Below are the results of the seismic wave survey conducted on the right bank slope of the Namling Bridge. It generally shows Vp = 800-1,500m/s near the surface. Referring to the example in Figure 1-3-72, the rock types are classified with Vp = 500m/s or above. This result aligns with the emergence of bedrock layers at the borehole point (BH-No.2). Additionally, it is conceivable that the P-wave velocity increases significantly in the depth direction, gradually indicating a hardening of the rock formations.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	1.00	1.00	500～800
	2.30	3.30	800～1500
	2.70	6.00	1500～2000
	6.30	12.30	2000～3000
	6.60	18.90	>3000

Source: JICA Survey Team

Figure 1-3-71 P wave Speed Distribution (Namling Bridge Right hand slope)



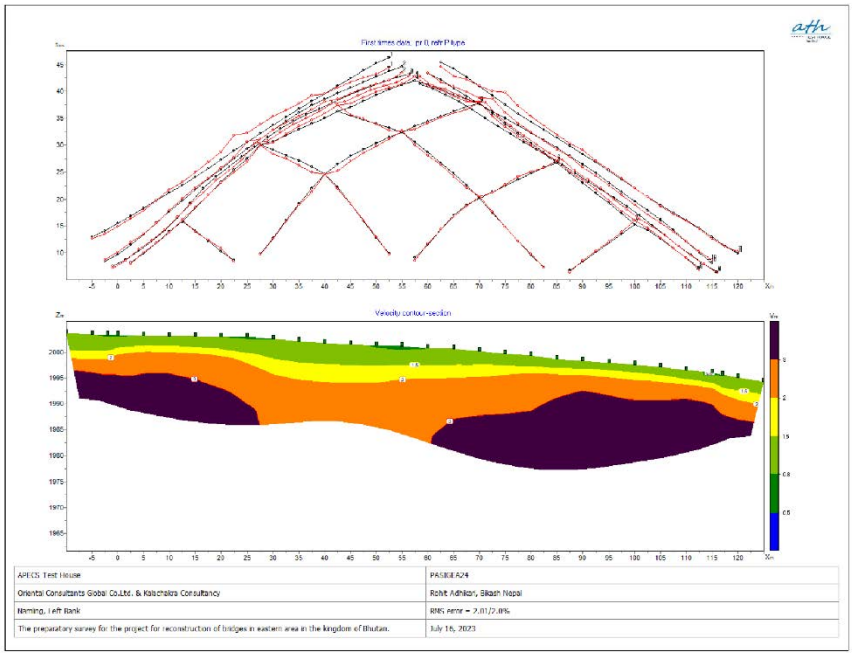
Source: Design and example of slope failure protection, Design guideline for steep slope failure protection, (Japan Water control and sabo association)

Figure 1-3-72 Rock classification by Seismic velocity, RQD, Rock observation for granite

Source: JICA Survey Team

Figure 1-3-73 Survey location of seismic exploration (Namling Bridge Left side slope)

The seismic wave survey results on the left bank slope of the Namling Bridge are presented below. Similar to the right bank side, it generally indicates Vp = 800-1,500m/s near the surface. Referring to the example in Figure 1-3-72, the rock types are classified with Vp = 500m/s or above. This aligns with the emergence of bedrock layers at the borehole point (BH-No.4). Additionally, it is conceivable that the P-wave velocity increases significantly in the depth direction, gradually indicating a hardening of the rock formations.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	0.50	0.50	500～800
	1.90	2.40	800～1500
	4.00	6.40	1500～2000
	7.30	13.70	2000～3000
	10.00	23.70	>3000

Source: JICA Survey Team

Figure 1-3-74 P wave Speed Distribution(Namling Bridge Left hand slope)

(e) Laboratory Testing

Laboratory testing of rock samples was conducted to identify the physical and mechanical characteristics using boring core samples.

The results are summarized in Table 1-3-24

Table 1-3-24 Summary of Laboratory testing for rock samples(Namling Brdige)

bridge	BH No.	Sample Identity	Depth	Density test (g/cm3)		UCS (MN/m2)	
Namling	BH-No.1	BH-1-1	6.00 - 6.60	2.660		44.72	
				2.643	2.652	39.16	41.94
		BH-1-2	8.50 - 9.15	2.803		20.63	
				2.686		67.76	
				2.668	2.719	27.25	38.55
	BH-No.2	BH-2-1	5.50 - 6.20	2.778	2.778	25.69	25.69
		BH-2-2	7.70 - 8.25	2.794		20.47	
				2.724	2.759	10.02	15.25
	BH-No.3	BH-3-1	4.70 - 4.90	2.710	2.710	37.77	37.77
		BH-3-2	9.00 - 9.70	2.794		20.34	
				2.794	2.794	14.74	17.54
	BH-No.4	BH-4-1	4.00 - 4.45	2.731	2.731	16.84	16.84
		BH-4-2	7.20 - 7.70	2.753	2.753	33.31	33.31

Note 1) Since multiple core specimens were tested for BH-1-1, BH-1-2, BH-2-2, and BH-3-2,the average values are also shown.

Source: JICA Survey Team

3) Geological Summary of Durdari Brdige

Durdari Bridge is situated approximately 13.5 kilometers east of Mongar in a mountainous area, where rocks are exposed on the surrounding slopes. The river flowing beneath the bridge forms a valley, but the elevation difference is not as pronounced as that of the Namling Bridge.

On the right bank side, the road slope displays areas where schist is exposed, as shown in Figure 1-3-75, alongside sections with a mix of large boulders and gravel. The current road alignment predominantly forms nearly linear cut slopes, where the exposed rock parts reveal a structure with a bedding plane gentler than the cut slope (approximately 65 degrees).

Source: JICA Survey Team

Figure 1-3-75 Right side of Durdari Bridge

The left bank road slope exhibits areas where rocks (schist) are exposed, as shown in Figure 1-3-76, similar to the right bank side, along with sections of conglomerates containing large boulders. Moreover,

at the planned bridge location on the left bank, the exposed rock surfaces along the current road alignment show a gentle bedding structure.

Source: JICA Survey Team

Figure 1-3-76 Left side of Durdari Bridge

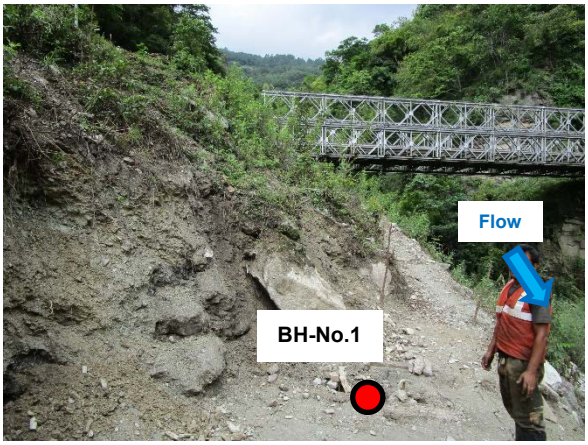
At Durdari Bridge, the results of the borehole investigation are as follows. The investigation was conducted at four locations—BH-No.1 and BH-No.2 on the right bank, and BH-No.3 and BH-No.4 on the left bank each reaching a depth of 15 meters, as shown in Figure 1-3-77.

At BH-No.1 on the right bank, a sandy soil layer mixed with rock fragments extends from the surface down to a depth of GL-5.75m, followed by a thick layer of muddy schist further below. Additionally, BH-No.2 reveals the presence of a schist layer (comprising siliceous schist and muddy schist) from the near-surface. The core recovery rate for BH-No.1 is approximately 20-30% down to GL-8.0m, increasing to about 70-90% in deeper sections. BH-No.2 exhibits a core recovery rate of approximately 20-30% down to GL-13.0m, increasing to roughly 60-90% in deeper segments. The Rock Quality Designation (RQD) for BH-No.1 ranges from 0-30% up to GL-11.0m, increasing to around 50% beyond this depth. For BH-No.2, RQD measures 0% up to GL-14.0m and increases to 10% in deeper layers.

Furthermore, the decrease in core recovery rates and Rock Quality Designation (RQD) can be influenced by the proficiency level of the drilling technicians. Moreover, due to the tendency of schist to fracture along bedding planes, it is possible that it might have been separated during drilling operations. This rock type often exhibits a tendency to break along sheet-like structures along its cleavage planes, impacting the drilling process.

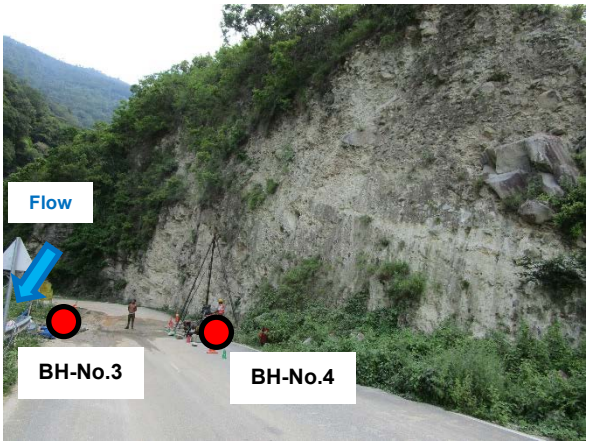
On the left bank, the area from GL-0.5 to 1.0 meters comprises an improved or loose topsoil layer, beyond which there is a distribution of schist (siliceous schist and muddy schist). The core recovery rate for the rock is generally about 50% to 90%, but it decreases to 0% to 50% beyond GL-12.0 meters for BH-No.3. The Rock Quality Designation (RQD) for BH-No.3 is roughly 20% to 30% until GL-9.0 meters, decreasing to about 0% to 10% further, and for BH-No.4, it is approximately 0% to 30% until GL-9.0 meters and then increases to about 20% to 40% deeper. The decrease in core recovery rates and RQD is likely due to similar reasons on the left bank, attributed to the same drilling technician and rock type, as observed on the right bank.

Moreover, during the drilling investigation of Durdari Bridge, the confirmation of groundwater levels after drilling was recorded. Consequently, groundwater observation boreholes (PVC pipes) and automatic water level recorders were installed at the drilling points (BH-No.1 to BH-No.4).



Durdari Bridge Right side

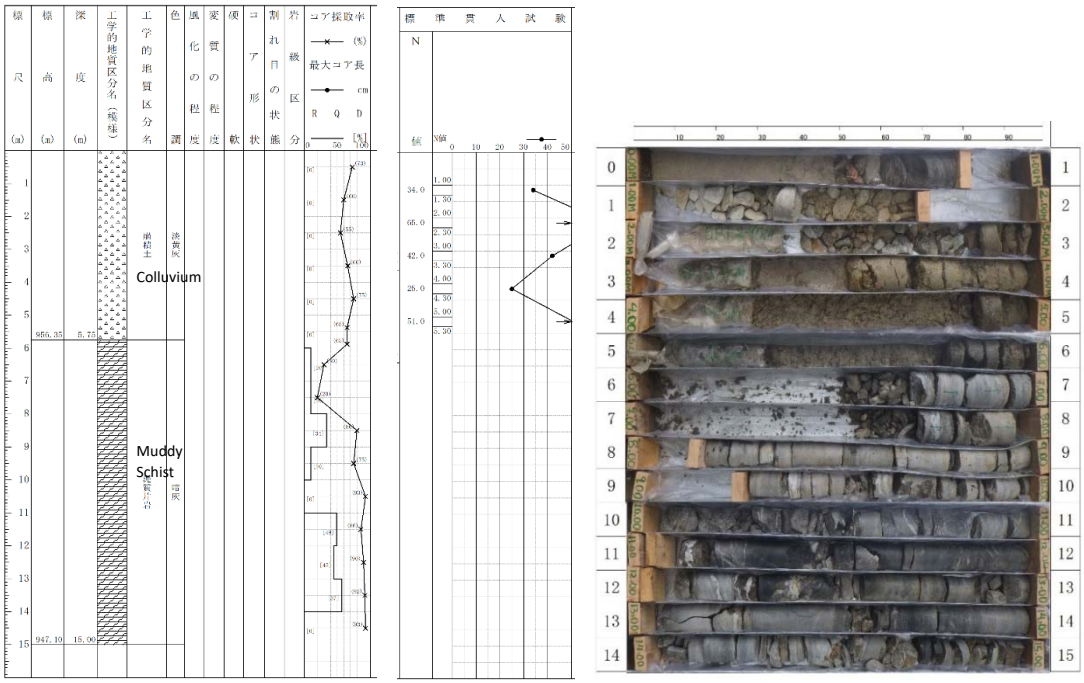
Durdari Bridge Right side



Durdari Bridge Left side

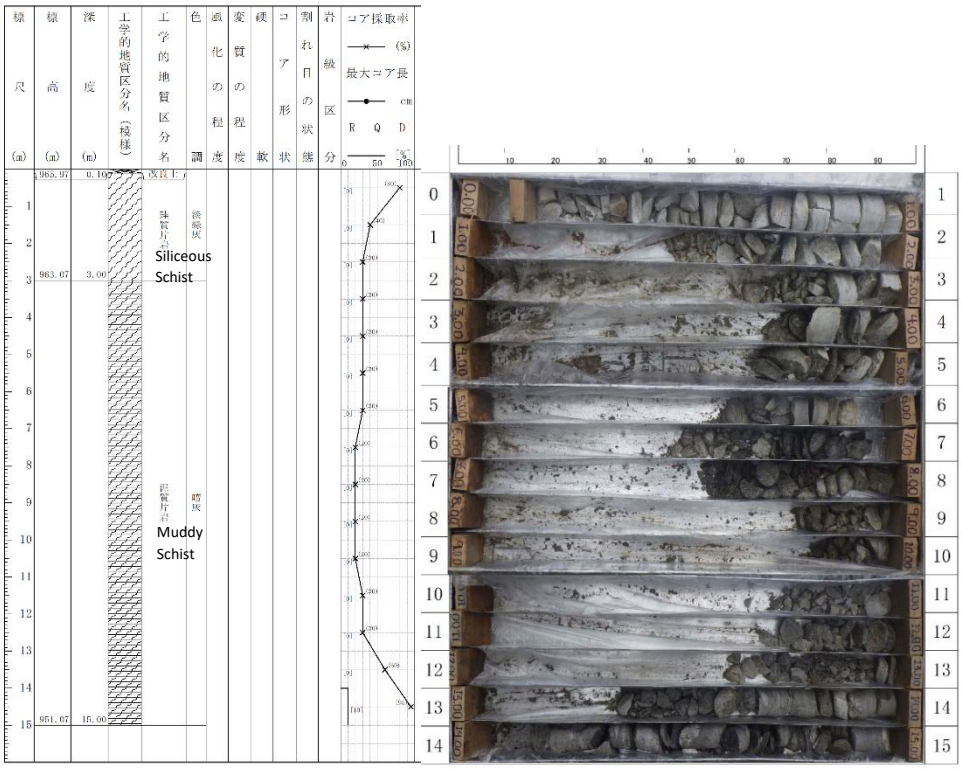
Source: JICA Survey Team

Figure 1-3-77 Borehole Location (Durdari Bridge)



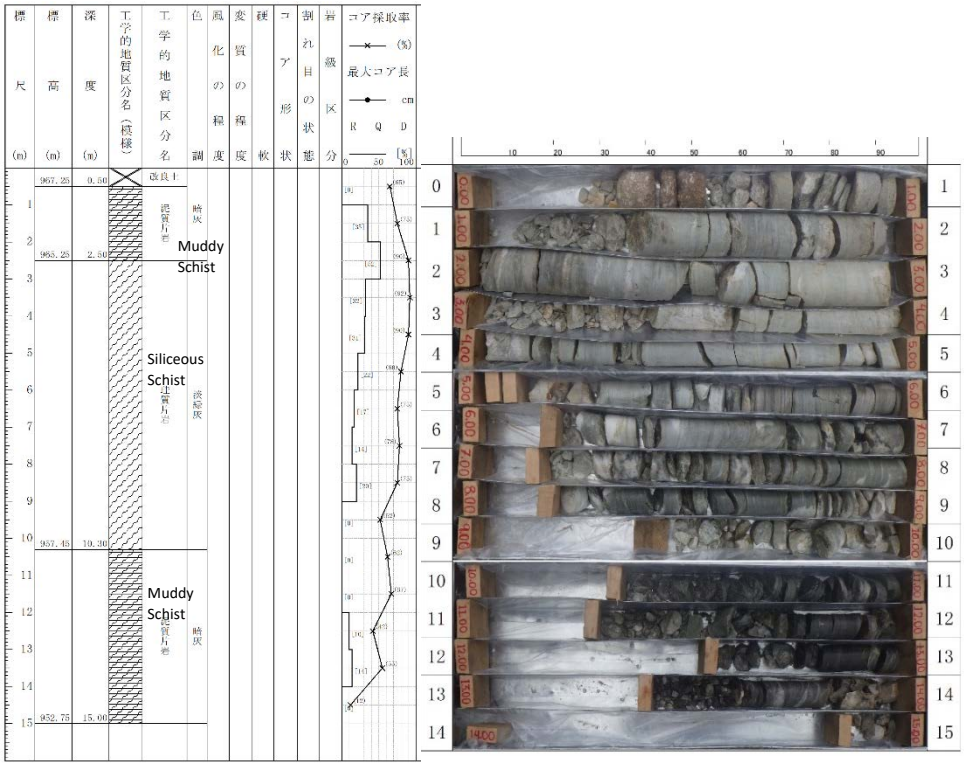
Source: JICA Survey Team

Figure 1-3-78 Borehole log (Durdari Right side BH-No.1)



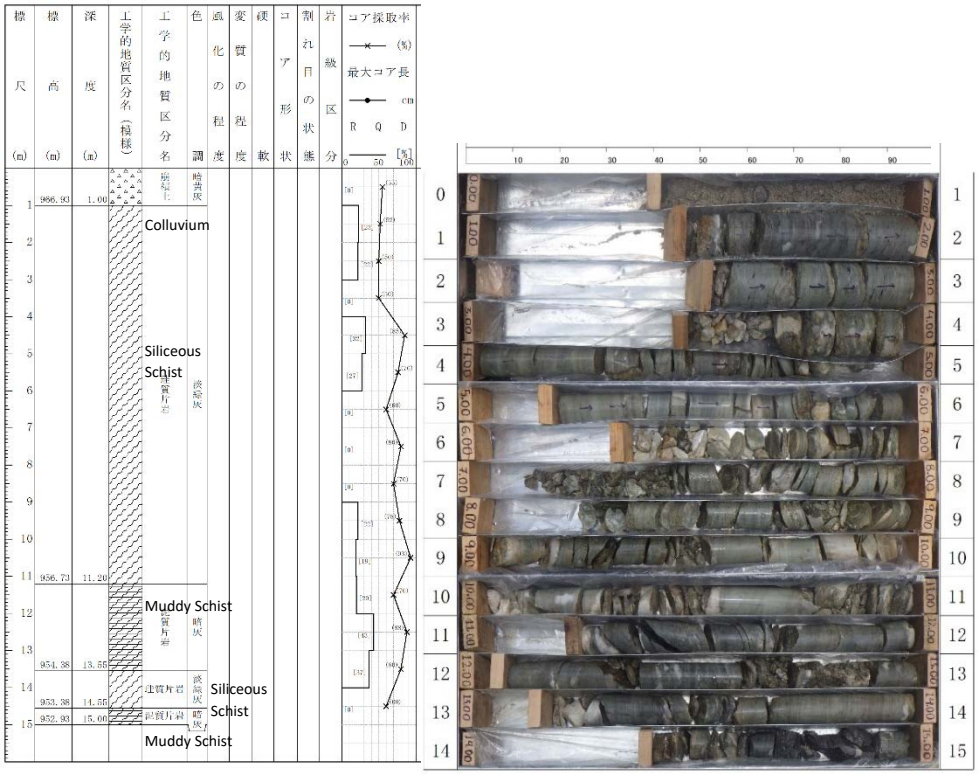
Source: JICA Survey Team

Figure 1-3-79 Borehole log (Durdari Right side BH-No.2)



Source: JICA Survey Team

Figure 1-3-80 Borehole log (Durdari Left side BH-No.3)



Source: JICA Survey Team

Figure 1-3-81 Borehole log (Durdari Left side BH-No.4)

(a) Standard Penetration Test

The results of the Standard Penetration Test for the Durdari Bridge are as follows: During the drilling investigation of the bridge, as the BH-No.1 location revealed the distribution of loose deposits down to GL-5.75 meters, the Standard Penetration Test was conducted. The outcomes showed N-values greater than 50 due to gravel and pebble inclusions until approximately GL-3 meters. However, beyond this point, the N-values varied from 25 to 42 due to a predominantly sandy soil structure. For the other locations (BH-No.2 to BH-No.4), the test could not be conducted as the surface near the boreholes exhibited the presence of bedrock (schist), resulting in a refusal condition when attempting the Standard Penetration Test by free-falling the hammer. Consequently, the Standard Penetration Test was not performed at these locations.

Table 1-3-25 Result of Standard Penetration (Durdari Bridge)

Right Bank（BH-No.1）		
Depth(m)	N value	Geology
1.00	34	colluvial deposit
2.00	>50	
3.00	42	
4.00	25	
5.00	>50	
6.00 or deeper	Refusal	Rock(Pelitic schist)

Source: JICA Survey Team

(b) Rock Classification

The schist (muddy shale or siliceous schist) distributed across BH-No.1 to BH-No.4 has been classified within the CL to CM class, according to the criteria outlined in Table 1-3-19. Please refer to Table 1-3-26 for details.

Table 1-3-26 Rock Classification (Durdari Bridge)

Right Bank(BH-No.1)		Right Bank(BH-No.2)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 5.75	colluvial deposit	0.00 - 0.10	improved soil
5.75 - 11.00	CL	0.10 - 15.00	CL
11.00 - 14.00	CM		
14.00 - 15.00	CL		

Left Bank(BH-No.3)		Left Bank(BH-No.4)	
Depth(m)	Rock Classification	Depth(m)	Rock Classification
0.00 - 0.50	improved soil	0.00 - 1.00	colluvial deposit
0.50 - 1.50	CL	1.00 - 15.00	CL
1.50 - 2.50	CM		
2.50 - 15.00	CL		

Source: JICA Survey Team

(c) Plate Load Test

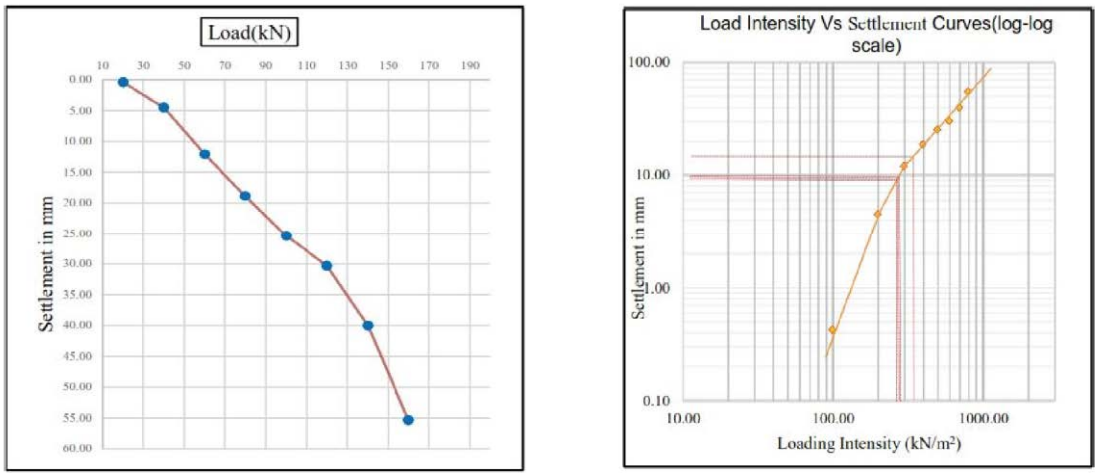
The results of the plate load test conducted on the right bank of the Durdari Bridge are described below. In this area, where it was assumed that fill material or soil was present near the surface, the final load (P =7 90.2kN/m^2) resulted in a significant settlement of S = 55.36mm.

The ultimate bearing capacity, Pu, is determined based on the P-S curve in Figure 1-3-82, where the load causes a sudden and nearly parallel increase in settlement. However, in cases where the ultimate bearing capacity cannot be clearly determined, the following criteria apply when the settlement is within 30mm:

1. The load where the settlement increases linearly in the P-S curve.
2. In cases where the load is not discernible within the 30mm settlement range: Consider the maximum test load as the ultimate bearing capacity.

Here, at the 7th load increment (P = 691.36kN/m^2), the settlement (S) measures S = 40mm, surpassing the specified settlement criterion of 30mm for test termination, indicating adequate settlement. Moreover, considering the increasing settlement from the 6th load increment in both graphs, a decision is made to determine the load of the 6th stage (Pu = 592.59kN/m^2) as the ultimate bearing capacity.

Generally, when plotting the relationship between load and settlement on a log-log graph (log P - log S curve), a distinct inflection point often appears, which corresponds to the yield load (Py). Here, based on the log P - log S curve shown in Figure 1-3-82, the yield load is determined as Py = 296.3kN/m^2 at the point of inflection.

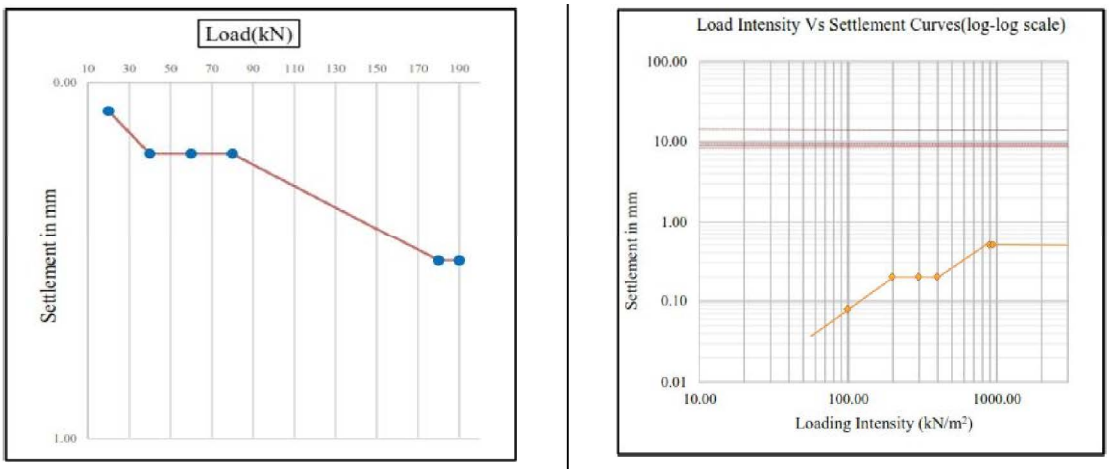


Source: JICA Survey Team

Figure 1-3-82 Relationship between Settlement S and Load Pressure P (Durdari Right side)

The result of the plate load test at Durdari Bridge's left bank are shown below. According to the tests, the final load was at P = 938.27kN/m^2, and the settlement observed was S = 0.50mm.

This settlement was minimal, indicating that within the applied range of load, the ultimate bearing capacity (Pu) had not been reached.



Source: JICA Survey Team

Figure 1-3-83 Relationship between Settlement S and Load Pressure P (Durdari Left side)

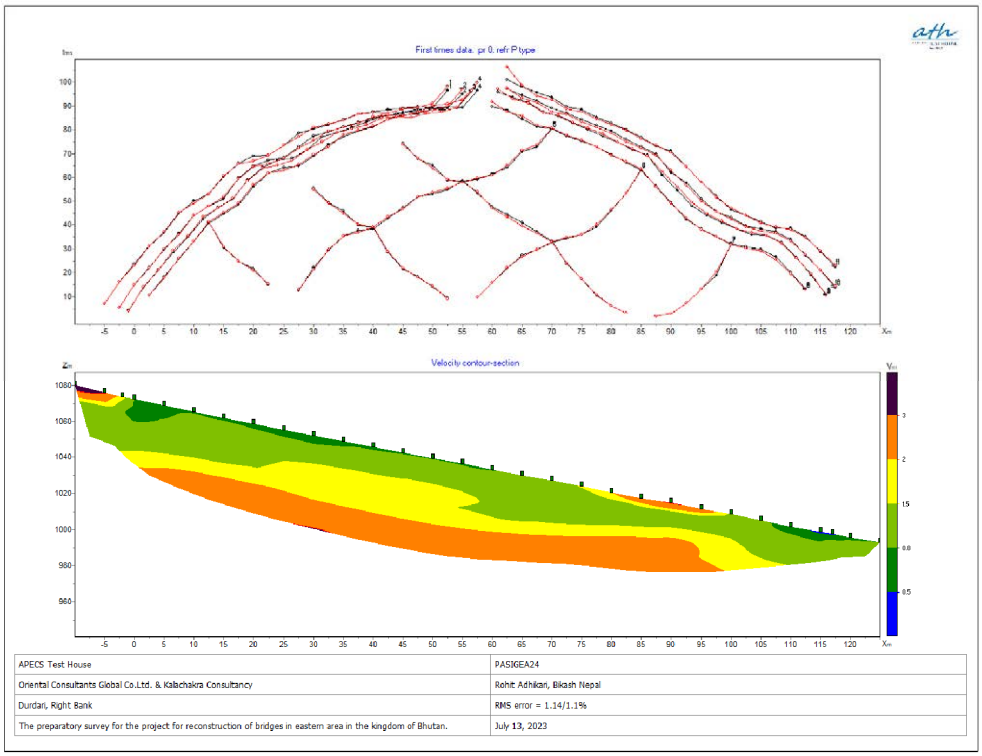
(d) Seismic Exploration

The seismic exploration for the Durdari Bridge was conducted by placing the equipment along the cross-sectional direction, from the steep cliff adjacent to the existing road, and projecting towards the rear side.

Source: JICA Survey Team

Figure 1-3-84 Survey Location of Seismic Exploration (Durdari Bridge Right side slope)

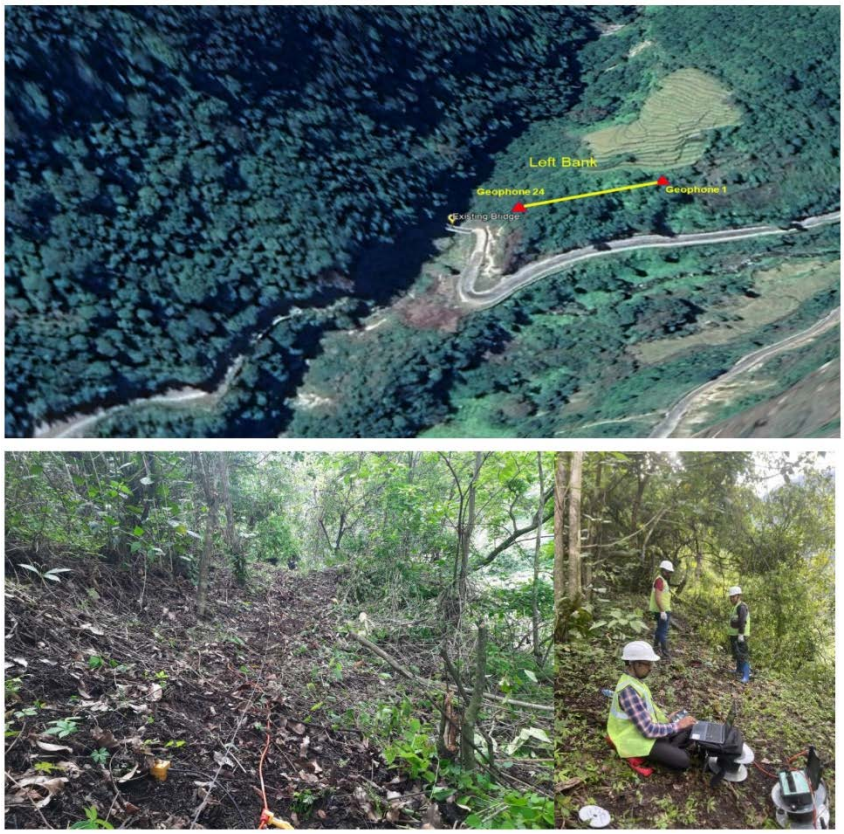
The results of the seismic exploration on the slope at the right bank of the Durdari Bridge are presented below. This exploration was carried out laterally across the slope from the steep cliff, and the detected P-wave velocities ranged approximately between 800 to 1500m/s near the surface. According to the example provided in Figure 1-3-57, the rock quality is categorized at Vp = 500m/s or more, coinciding with the emergence of a rock layer at the drilling point (BH-No.2) directly below the steep cliff. It indicates the presence of rock layers extending across the lateral direction of the slope. Moreover, there is an observed increase in the P-wave velocities with depth, suggesting a gradual hardening of the geological structure.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	4.10	4.10	500～800
	15.60	19.70	800～1500
	18.10	37.80	1500～2000
	15.30	53.10	2000～3000

Source: JICA Survey Team

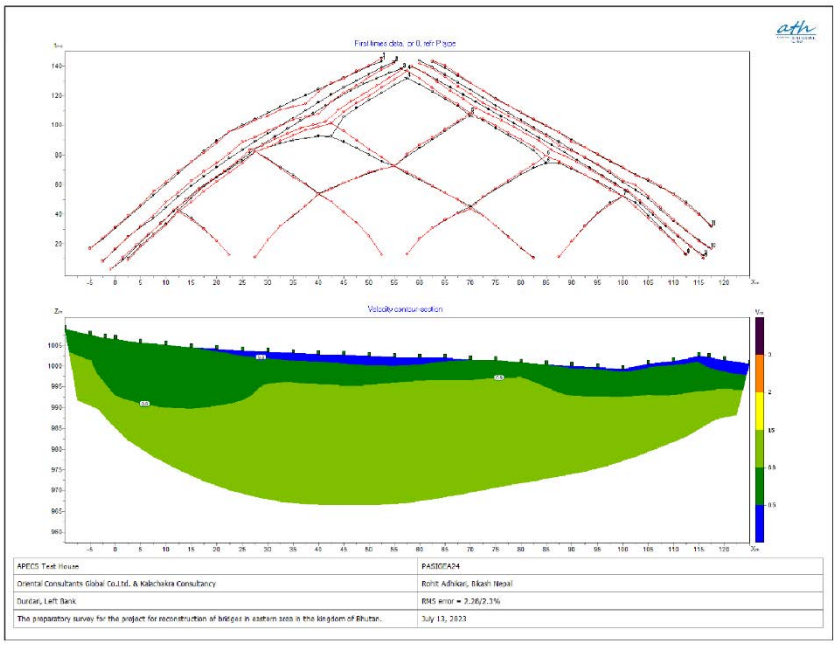
Figure 1-3-85 P wave Speed Distribution (Durdari Bridge Right hand slope)



Source: JICA Survey Team

Figure 1-3-86 Survey Location of Seismic Exploration (Durdari Bridge Left side slope)

The results of the seismic exploration on the slope at the left bank of the Durdari Bridge are presented below. The examination showed relatively lower values ranging approximately between 500 to 800m/s near the surface, suggesting the possibility of a thick deposit of either debris layers or heavily weathered rock strata. However, considering that the exploration was conducted on a gentle slope on the back face of the steep cliff, it is presumed that the rock layer confirmed at the drilling point directly beneath the cliff (BH-No.4) is not distributed near the surface.



Layer	Depth of Layer (m)	Cumulative Depth (GL-m)	Velocity (m/s)
	2.30	2.30	<500
	7.00	9.30	500～800
	28.90	38.20	800～1500

Source: JICA Survey Team

Figure 1-3-87 P wave Speed Distribution (Durdari Bridge Left hand slope)

(e) Laboratory Testing

Laboratory testing of soil and rock samples are conducted to identify the physical and mechanical characteristics using boring core samples and soil sample taken by SPT.

The results are summarized in Table 1-3-27 and Table 1-3-28.

Table 1-3-27 Summary of Laboratory testing for rock samples (Durdari Brdige)

bridge	BH No.	Sample Identity	Depth	Density test (g/cm3)		UCS (MN/m2)	
Durdari	BH-No.1	BH-1-1	6.80 - 6.90	–	–	–	–
		BH-1-2	8.40 - 8.64	2.615	2.615	55.50	55.50
		BH-1-3	11.20 - 11.90	2.738 2.725	2.732	33.13 41.48	37.31
	BH-No.2	BH-2-1	14.20 - 14.30	–	–	–	–
	BH-No.3	BH-3-1	6.40 - 6.70	2.675	2.675	33.58	33.58
		BH-3-2	7.80 - 8.00	2.672	2.672	47.59	47.59
	BH-No.4	BH-4-1	4.00 - 4.20	2.619 2.617	2.618	34.87 23.96	29.42
		BH-4-2	5.20 - 5.50	2.650	2.650	56.43	56.43
		BH-4-3	9.50 - 9.70	–	–	–	–

Note 1) Since multiple core specimens were tested for BH-1-3 and BH-4-1, the average values are also shown.
Note 2) " - " indicates that the test could not be conducted due to insufficient specimens obtained by core shaping.

Source: JICA Survey Team

Table 1-3-28 Summary of Laboratory Soil Testing (Durdari Bridge)

bridge	BH No.	Sample Identity	Depth	Soil Particle Density (g/cm3)	Moisture Content (%)	liquid Limit (%)	plastic Limit (%)
Durdari	BH-No.1	DBH-1	2.00 - 2.45	2.63	2.17	22.5	NP
		DBH-2	3.00 - 3.45	2.78	7.02	26.0	NP
		DBH-3	4.00 - 4.45	2.38	8.64	24.0	NP
		DBH-4	5.00 - 5.45	2.63	15.62	19.2	NP

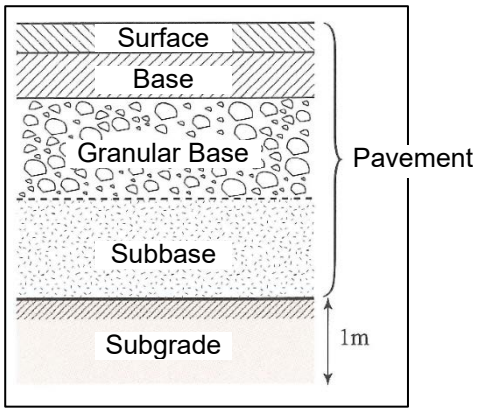
Source: JICA Survey Team

4) Material Survey

The material survey was conducted for eleven samples taken from two bridges and borrow pit.

(a) CBR Test

The road pavement is typically composed of three layers from the bottom, including the foundation or subgrade, the roadbed that exerts supporting strength, and the surface or base layers that bear the vehicle's weight through the tires.



Source: Soil Testing, Basic and guideline, Japanese Geotechnical Society

Figure 1-3-88 Structure of Asphalt Pavement

The concept of the California Bearing Ratio (CBR) test is an examination that evaluates the supportive strength of the subgrade in road pavement structures. It is divided into two main types: the "laboratory CBR test," performed indoors as a material test, and the "field CBR test," conducted directly on-site using testing apparatus.

The "laboratory CBR test" is implemented for determining the thickness of asphalt pavements and for evaluating whether the subgrade beneath the asphalt pavement has adequate supportive strength. It can be further classified into the "design CBR test" (conducted at the subgrade level to assess supportive strength) and the "modified CBR test" (evaluating material stiffness and resistance to breakage or deformation in the roadbed material).

This test involves the "laboratory CBR test," specifically the "design CBR test." Samples of soil materials (such as gravel, quarry stone, etc.) obtained from the subgrade level were brought indoors to conduct the "design CBR test." This test was performed at 11 locations (comprising 2 bridge sites with 4 locations on each side of the bridge and 3 borrow pit points)

The procedure for obtaining the test results in the "laboratory CBR test" involved placing field-collected samples adjusted to the optimum moisture content into a container (mold), compacting them using a piston, applying load to determine the load-deformation relationship, identifying the load at a specified penetration depth, and then comparing this load with a separate standard load. This comparison was used to assess the suitability of the collected samples on a material-specific basis, examining the relationship with different specified values.

The test items and results are shown in below table.

Table 1-3-29 Result of CBR Testing (Durdari Bridge)

Test Item	Objective	Location	Detail Location	Sample Name	Result
					Design CBR(%)
Laboratory CBR	Design of Pavement Thickness	Namling Bridge	RightBH-1	N-RB-1	18.0
			RightBH-2	N-RB-2	13.0
			LeftBH-3	N-LB-1	12.5
			LeftBH-4	N-LB-2	13.2
		Durdari Bridge	RightBH-1	D-RB-1	29.0
			RightBH-2	D-RB-2	26.0
			LeftBH-3	D-LB-1	35.0
			LeftBH-4	D-LB-2	37.0
		NRDCL Crusher quarry	Nearby Namling	NSQ-S	40.0
		Domdhe Stone quarry	Nearby Durdari	DSQ-S	7.4
		Borrow pit location	Nearby Durdari	BS-S	5.0

Source: JICA Survey Team

Regarding the interpretation of the test results, based on Table 1-3-30, if the CBR is less than 3%, the subgrade soil is considered unsuitable as pavement material. Each test value indicates CBR values ranging from 12.5 to 18.0 for the Namling Bridge samples and from 26.0 to 37.0 for the Durdari Bridge samples, suggesting that the soils are sandy with a good particle size distribution.

Table 1-3-30 Reference of CBR

Type of roadbed soil	On-site CBR(%)
Clay and silt-rich soil with high moisture content Volcanic ash cohesive soil with high moisture content	less than 3
Clay and silt-rich soil but relatively low moisture content	3～5
Clay soil mixed with sand	3～7
Sandy soil mixed with clay Clay soil mixed with sand with low moisture content	7～10
Sandy soil	7～15
Sand with good grain size distribution	10～30

Source: Method and Interpretation of material testing, Japanese Geotechnical Society

(b) Other material test

The results of other material testing are shown in Table 1-3-31.

Table 1-3-31 Result of Material Test

Sample location		Sample Identity	Soil Particle Density (g/cm3)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	LAA (%)	ACV (%)
Namling	Right side	N-RB-1	2.67	4.91	24.0	NP	–	–
		N-RB-2	2.69	4.81	24.5	NP	–	–
	Left side	N-LB-1	2.70	5.94	24.0	NP	–	–
		N-LB-2	2.69	4.13	23.5	NP	–	–
Durdari	Right side	D-RB-1	2.69	5.08	NP	NP	–	–
		D-RB-2	2.69	6.42	NP	NP	–	–
	Left side	D-LB-1	2.63	8.20	21.0	NP	–	–
		D-LB-2	2.64	4.51	23.2	NP	–	–
NRDCL Crusher quarry	Nearby Namling	NSQ-S	2.60	–	–	–	–	–
		NSQ-A	2.67	–	–	–	42.38	23.51
Domdhe Stone quarry	Nearby Durdari	DSQ-S	2.70	–	–	–	–	–
		DSQ-A	2.59	–	–	–	38.48	21.20
Borrow pit location	Neaby Durdari	BS-S	2.63	–	–	–	–	–

*LAA: Los Angeles Abrasion test, ACV: Aggregate Crushing Value test

Source: JICA Survey Team

1-4 Bridge situation Survey

1-4-1 Outline of Survey

Soundness of all target bridges were evaluated during the first field survey, 28th February to 5th March 2023. Inspection and Diagnosis manual developed in the "Technical Cooperation Project for Capacity Development in Construction and Maintenance of Bridges" was used for the evaluation of bridges. Evaluation criteria is shown in Figure 1-4-1 and Figure 1-4-2.

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found
	Others	Graffiti, bird damage, fire damage, etc.	Only record

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)
Super Structure	Deck Slab	Con	Crack	Appendix
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)
		Steel	Corrosion	Appendix
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more
			Fracture	a:Not found b:- c:- d:- e:Found
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust
	Main Girder	Con	Crack	Appendix
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)
		Steel	Corrosion	Appendix
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more
			Fracture	a:Not found b:- c:- d:- e:Found
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)
Sub Structure	Body	Con	Crack	Appendix
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found

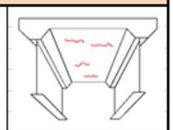
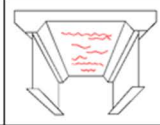
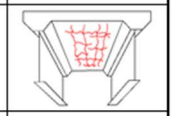
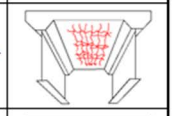
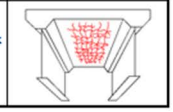
Note: Appendix is indicated as Figure 1-4-2

Source: Inspection and Diagnosis manual prepared by the technical cooperation project

Figure 1-4-1 Evaluation Criteria (1/2)

Appendix

【Crack on Deck Slab】

	Crack phenomenon	
a	【Crack spacing & crack characteristic】 Crack has occurred only on one direction and more than 1.0m as minimum crack spacing. 【Crack width】 Less than 0.05mm of maximum crack width. (such as hair crack)	
b	【Crack spacing & crack characteristic】 Crack has mainly occurred on one direction and crack spacing of between 1.0m~0.5m, but not square-block type. 【Crack width】 Mainly less than 0.1mm, but partly over 0.1mm.	
c	【Crack spacing & crack characteristic】 Crack has occurred on about 0.5m before square-block type. 【Crack width】 Mainly less than 0.2mm, but partly over 0.2mm.	
d	【Crack spacing & crack characteristic】 Crack has occurred on 0.5m~0.2m and also square-block type. 【Crack width】 Over 0.2mm and partly peeling off concrete.	
e	【Crack spacing & crack characteristic】 Crack has occurred on less than 0.2m and mainly square-block type. 【Crack width】 More than 0.2mm and continuously peeling off concrete.	

【Corrosion on Steel】

	Corrosion phenomenon
a	Nothing
b	Corrosion has occurred on steel surface, but impossible to see reduction of its thickness. Furthermore very minor area of corrosion damage.
c	Corrosion has occurred on steel surface, but impossible to see reduction of its thickness. And rust has occurred entirely on focusing parts or some spred area.
d	Corrosion has occurred on steel surface, also possible to see slightly reduction of its thickness. And rust has occurred entirely on focusing parts or many spred area.
e	Corrosion has apparently expanded on steel surface, also possible to see definitely reduction of its thickness. And rust has occurred entirely with many spred area.

【Crack on Concrete Structure】

	Crack phenomenon
a	Nothing
b	-
c	Small crack width (less than 0.2mm in case of RC structure)
d	Midium crack width (more than 0.2mm to less than 1.0mm in case of RC structure)
e	Large crack width (more than 1.0mm in case of RC structure)

Source: JICA Survey Team

Figure 1-4-2 Evaluation Criteria (2/2)

Inspection was basically conducted visually close to structure and confirmed situation and its hit sound. However, in case where close to a structure was difficult such as inaccessibility or safety reason, inspection was conducted with distance. Non-destructive test using a rebound hammer was also carried out to determine the concrete strength of existing bridges. Rebound hummer donated to the DoST on the technical cooperation project was used for the test. Concrete strength is shown in Table 1-4-1.

Concrete strength was obtained for each target bridge excepted Namling bridge as baily bridge and Rollong bridge as inaccessibility to the structure. Durdari bridge is baily bridge, but concrete strength of base concrete was obtained.

Table 1-4-1 Concrete strength of existing bridges

Bridge name	Compression Strenghth (N/mm^2)	Remarks
Namling bridge	-	Not measured due to Bailey Bridge
Pakhadrang Bridge	22	Side of main girder
Durdari bridge	32	Base concrete of baily bridge
Revidrang Bridge	36	Bottom of main girder
	32	Front of abutment
Rollong bridge	-	Not measured due to accessibility

Source: JICA Survey Team


Source: JICA Survey Team

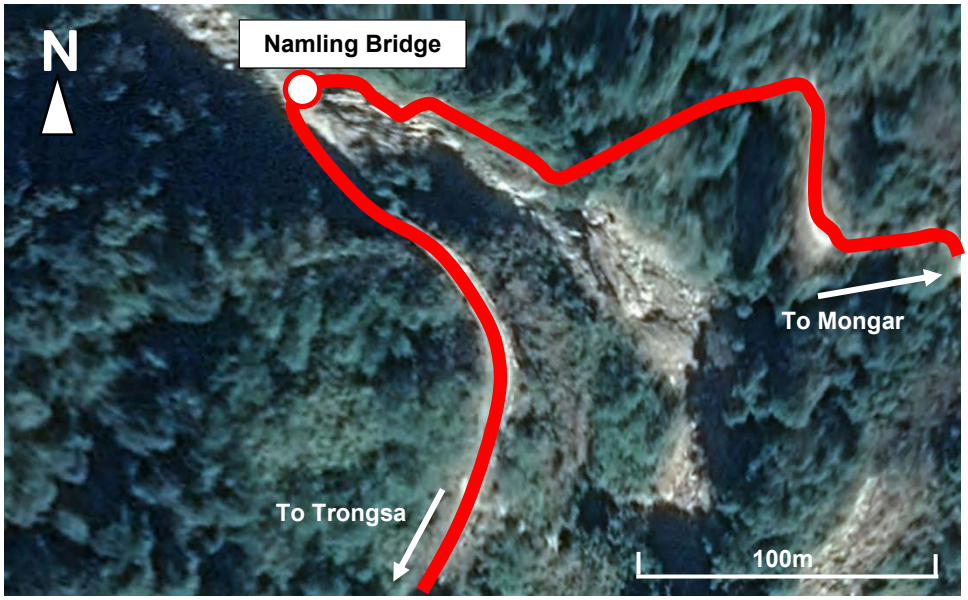
Figure 1-4-3 Situation of bridge inspection

1-4-2 Result of bridge inspection for Namling bridge

(1) Surrounding Road

The Namling Bridge is located in a mountainous area surrounded by 3,000 m high mountains. Therefore, the road near the bridge forms a curvy road aliment (see Figure 1-4-4). The speed of the vehicle is limited and the ride is uncomfortable because the road is unpaved and uneven. Road widening work is currently underway on PNH-1 to widen the road from one lane to two lanes. However, it is expected that the speed will still be limited due to the curvy road.

The surrounding road situation is shown in Figure 1-4-4. Bedrock appears on the right slope and minor rockfall was observed. On the other hand, the risk of rock fall is higher because the slope was composed of debris and bedrock on the left slope. Water leakage was observed from both side of the slope.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-4-4 Road alignment around Namling bridge site

Right slope (Trongsa side)

Left slope (Monger side)

Road situation

Traffic situation

Source: JICA Survey Team

Figure 1-4-5 The surrounding road situation of Namling bridge

(2) Bridge Body

1) Summary of bridge inspection

Following bridge inspection result was obtained:

- Overall: Sagging was observed (see inspection pic No. 1), foundation was exposed by scouring
- Superstructure: Temporary bridge (Baily bridge), steel corrosion was observed (see inspection pic No.4)
- Substructure: Foundation was exposed, but structure was not damaged
- Others: Pavement is damaged (see inspection pic No. 6)

2) Bridge inventory

Bridge Name	Namling Bridge	Road No.	PNH-1
Site situation	Photo No.1	From Trongsa side	Photo No.2	From Mongar side
		
	Photo No.3	From Trongsa downstream side	Photo No.4	From Mongar downstream side
		
	Photo No.5	From Trongsa upstream side	Photo No.6	From Mongar upstream side
		
	Photo No.7	On the bridge to downstream side	Photo No.8	On the bridge to upstream side
		

Source: JICA Survey Team

3) Inspection result+

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found	e
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found	a
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely	e
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found	e
	Others	Graffiti, bird damage, fire damage, etc.	Only record	–

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Super Structure	Deck Slab	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Steel	Corrosion	Appendix	c
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	a
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	a
			Fracture	a:Not found b:- c:- d:- e:Found	a
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	e
	Main Girder	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Steel	Corrosion	Appendix	c
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	a
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	a
			Fracture	a:Not found b:- c:- d:- e:Found	a
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	e

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Sub Structure	Body	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation	Not Exsist

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found	a
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found	a
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found	a
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely	a
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more	Not Exsist
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more	Not Exsist
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes	e
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm	a
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found	e
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing	Not Exsist
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more	Not Exsist
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	Not Exsist
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found	Not Exsist

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

4) Inspection photo

Photograph

Category	e	Type of Damage	Extraordinarydeflection	Pic.No.1

Category	e	Type of Damage	Scouring	Pic.No.2

Category	e	Type of Damage	Scouring	Pic.No.3

Category	c	Type of Damage	Corrosion	Pic.No.4

Category	e	Type of Damage	Deterioration of Painting	Pic.No.5

Category	e	Type of Damage	Abnormity	Pic.No.6

Category	e	Type of Damage	Sediment Deposition	Pic.No.7

Category		Type of Damage		Pic.No.8

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

(3) Surrounding Rever

The river is very steep from the existing bridge to downstream side and debris are found on the river. The upstream side are vegetated by grasses and trees and situation was visually unclear, but the angle was 15 to 20 degrees, which classified the occurrence or flow of debris flow area, according to the satellite photo data.

Upstream side of the existing bridg

Downstream side of the existing bridg

Source: JICA Survey Team

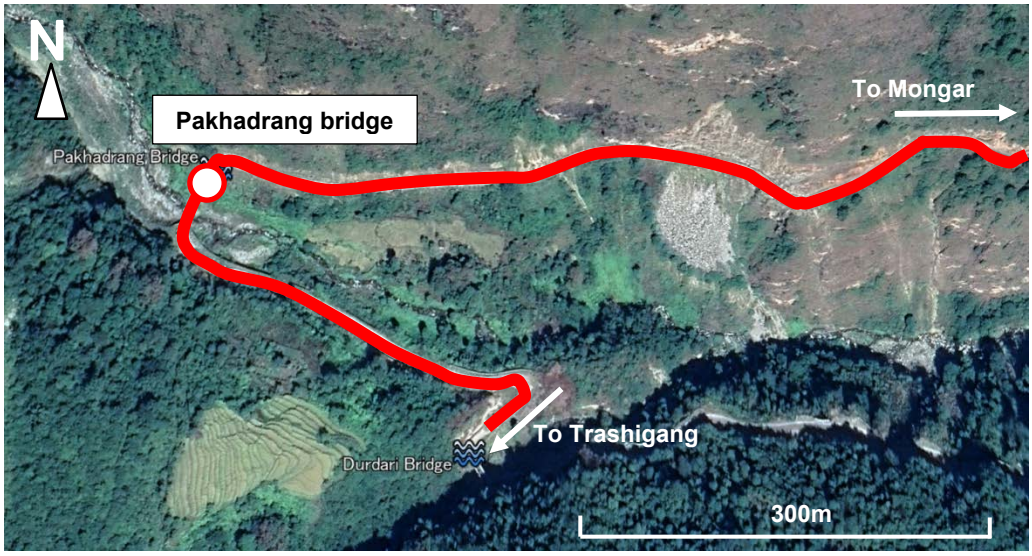
Figure 1-4-6 The surrounding river situation

1-4-3 Result of bridge inspection for Pakhadrang bridge

(1) Surrounding Road

Road widening and pavement work were completed around the area near to the Pakhadrang bridge. Although the curvy road exists around the area, radius of curve is relatively gentle (seeFigure 1-4-7).

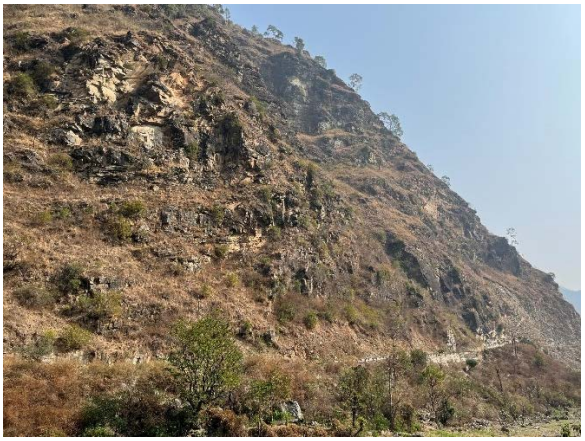
The surrounding road situation is shown in Figure 1-4-8. Right side slope is relatively gentle, and there is a local path for residents to access to the cultivated land at the top of the area. The slope is lower than left side slope and covered with grasses and trees. Therefore, the risk of rock fall is relatively low. On the other hand, left side slope is steep and observed a deposit of debris. Therefore, the risk of landside is considerable during the rainy season.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-4-7 Road alignment around Pakhadrang bridge site

Right slope(Trashigang side)



Left slope(Mongar side)

Road situation (Trashigang Side)

Road situation (Mongar Side)

Source: JICA Survey Team

Figure 1-4-8 The surrounding road situation of Pakhadrang bridge

(2) Bridge body

1) Summary of bridge inspection

Following bridge inspection result was obtained:

- Overall: Bridge life will be longer by proper repair or reinforcement for superstructure.
- Superstructure: Cover concrete at the deck bottom is pealed and rebar is exposed. Honeycomb caused by defect of concrete casting is observed (see inspection pic No. 2). Concrete strength was expected to reduce partially.
- Substructure: Partial loss on the abutment surface was repaired (see inspection pic No. 3).
- Others: Pavement and expansion joint were damaged (see inspection pic No. 4 and No. 6).

2) Bridge inventory

Bridge Name	Pakhadrang Bridge	Road No.	PNH-1
Site situation			
Photo No. 1	From Mongar side	Photo No. 2	From Trashigang side
			
Photo No. 3	From Mongar downstream side	Photo No. 4	From Trashigang downstream side
			
Photo No. 5	From Mongar upstream side	Photo No. 6	From Trashigang upstream side
			
Photo No. 7	On the bridge to downstream side	Photo No.8	On the bridge to upstream side
			

Source: JICA Survey Team

3) Inspection result

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found	a
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found	a
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely	a
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found	a
	Others	Graffiti, bird damage, fire damage, etc.	Only record	–

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Super Structure	Deck Slab	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	e
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	
	Main Girder	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	c
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Sub Structure	Body	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation	c

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found	a
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found	a
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found	a
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely	a
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more	a
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more	a
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes	e
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm	e
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found	a
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing	c
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more	e
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	a
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found	a

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

4) Inspection photo

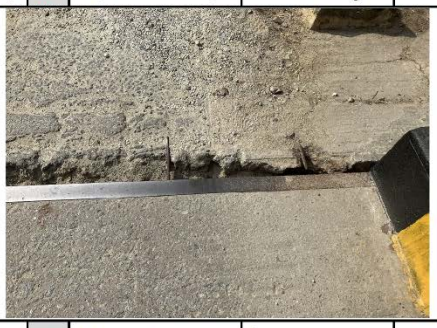
Photograph

Category	e	Type of Damage	Re-bar exposure	Pic.No.1

Category	e	Type of Damage	Honeycomb	Pic.No.2

Category	c	Type of Damage	Damage	Pic.No.3

Category	e	Type of Damage	Abnormity	Pic.No.4



Category	e	Type of Damage	Unevenness	Pic.No.5

Category	c	Type of Damage	Abnormity	Pic.No.6

Category	e	Type of Damage	Unevenness	Pic.No.7

Category		Type of Damage		Pic.No.8

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

(3) Surrounding Rever

Cobles were confirmed both upstream and downstream side of the bridge, and occurrence of debris flow was assumed. Rever water was not observed because our site survey was conducted in the dry season. River slope was visually gentle, but angle was 3 to 10 degrees, which classified debris deposit area, according to the satellite data.

Upstream side of the existing bridg

Downstream side of the existing bridg

Source: JICA Survey Team

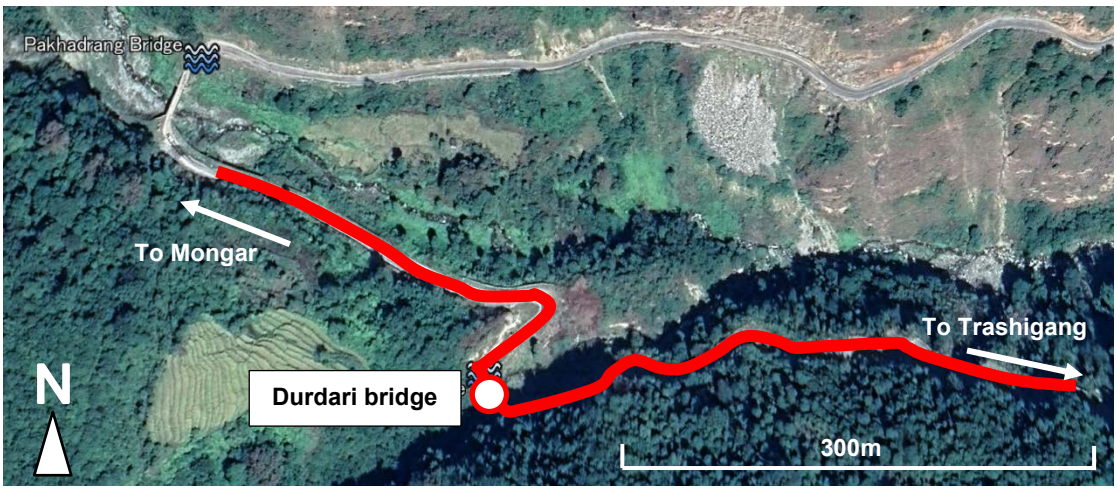
Figure 1-4-9 The surrounding river situation

1-4-4 Result of bridge inspection for Durdari bridge

(1) Surrounding Road

Road widening and pavement work were completed around the area near to the Durdari bridge. Although the curvy road exists around the area, radius of curve is relatively gentle (see Figure 1-4-10).

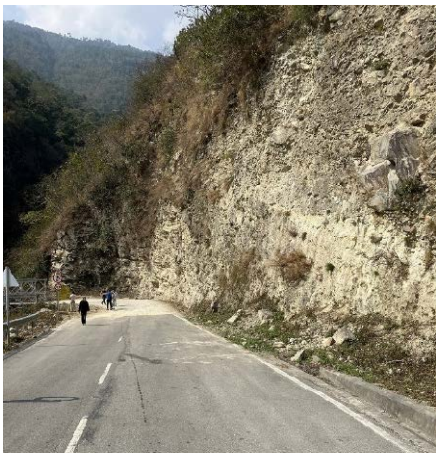
The surrounding road situation is shown in Figure 1-4-11. Both right side and left side slope is steep, and coble and rock are exposed on the slope. Therefore, the risk of debris flow is considerable during the rainy season.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-4-10 Road alignment around Durdari bridge site

Right slope (Trashigang side)



Left slope (Mongar side)

Source: JICA Survey Team

Figure 1-4-11 The surrounding road situation of Durdari bridge

(2) Bridge body

1) Summary of bridge inspection

Following bridge inspection result was obtained:

- Overall: Protection wall on right side is damaged and affection to substructure is considerable (see inspection pic No. 1).
- Superstructure: Temporary bridge (Baily bridge), steel corrosion was observed (see inspection pic No.2~6)
- Substructure: Protection wall is damaged, but structure was not damaged
- Others: Pavement is damaged (see inspection pic No.7)

2) Bridge inventory

Bridge Name	Durdari Bridge	Road No.	PNH-1
Site situation	Photo No. 1	From Mongar side	Photo No. 2	From Trashigang side
			
	Photo No. 3	From Mongar downstream side	Photo No. 4	From Trashigang downstream side
			
	Photo No. 5	From Mongar upstream side	Photo No. 6	From Trashigang upstream side
			
	Photo No. 7	On the bridge to downstream side	Photo No.8	On the bridge to upstream side
			

Source: JICA Survey Team

3) Inspection result

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found	a
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found	a
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely	e
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found	a
	Others	Graffiti, bird damage, fire damage, etc.	Only record	–

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Super Structure	Deck Slab	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Steel	Corrosion	Appendix	c
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	a
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	a
			Fracture	a:Not found b:- c:- d:- e:Found	a
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	e
	Main Girder	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Steel	Corrosion	Appendix	b
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	a
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	a
			Fracture	a:Not found b:- c:- d:- e:Found	e
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	d

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Sub Structure	Body	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation	

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found	a
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found	a
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found	a
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely	a
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more	Not Exsist
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more	Not Exsist
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes	e
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm	e
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found	a
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing	Not Exsist
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more	Not Exsist
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	Not Exsist
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found	Not Exsist

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

4) Inspection photo

Photograph

Category	e	Type of Damage	Scouring	Pic.No.1	Category	c	Type of Damage	Corrosion	Pic.No.2
									
Category	e	Type of Damage	Deterioration of Painting	Pic.No.3	Category	b	Type of Damage	Corrosion	Pic.No.4
									
Category	e	Type of Damage	Fracture	Pic.No.5	Category	d	Type of Damage	Deterioration of Painting	Pic.No.6
									
Category	e	Type of Damage	Abnormity	Pic.No.7	Category	e	Type of Damage	Unevenness	Pic.No.8
									

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

(3) Surrounding Rever

River situation both upstream and downstream side were visually unclear because the river is covered with grasses and trees. Rever water was not observed because our site survey was conducted in the dry season. the angle was 10 to 20 degrees, which classified the mudslide deposit area to the occurrence or flow of debris flow area, according to the satellite photo data.

Upstream side of the existing bridg

Downstream side of the existing bridg

Source: JICA Survey Team

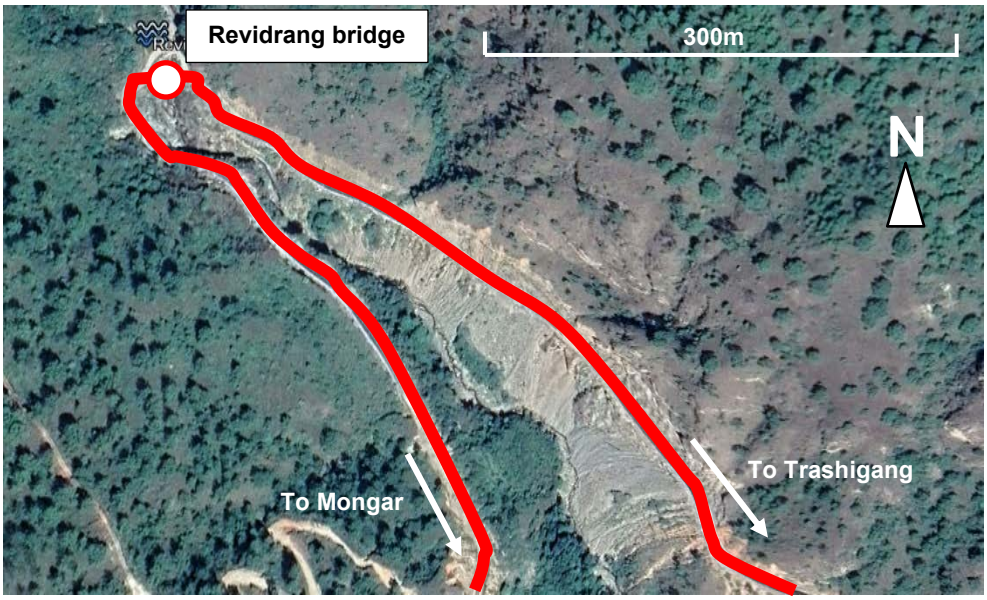
Figure 1-4-12 The surrounding river situation

1-4-5 Result of bridge inspection for Revidrang bridge

(1) Surrounding Road

Road widening and pavement work were completed around the area near to the Durdari bridge. Although the curvy road exists around the area, radius of curve is relatively gentle (see Figure 1-4-13).

The surrounding road situation is shown in Figure 1-4-14. Rock is exposed to right slope, on the other hand, debris is exposed to left slope. Both slopes are steep and have the risk of rock fall.



Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-4-13 Road alignment around Revidrang bridge site

Right slope (Mongar side)

Left slope (Trashigang side)

Road situation (Mongar side)

Road situation (Trashigang side)

Source: JICA Survey Team

Figure 1-4-14 The surrounding road situation of Revidrang bridge

(2) Bridge body

1) Summary of bridge inspection

Following bridge inspection result was obtained:

- Overall: Bridge is closed due to the damage to the bridge. Foundation is exposed due to scouring (see inspection pic No.1).
- Superstructure: Crack, maximum 0.5mm, is developed to transverse direction (see inspection pic No.2).
- Substructure: Crack is developed at right abutment and peeling of concrete with rebar exposure were observed (see inspection pic No.3 and 4).
- Others: Pavement and expansion joint are damaged (see inspection pic No.7 and 8).

2) Bridge inventory

Bridge Name	Revidrang Bridge	Road No.	PNH-1
Site situation			
Photo No. 1	From Mongar side	Photo No. 2	From Trashigang side

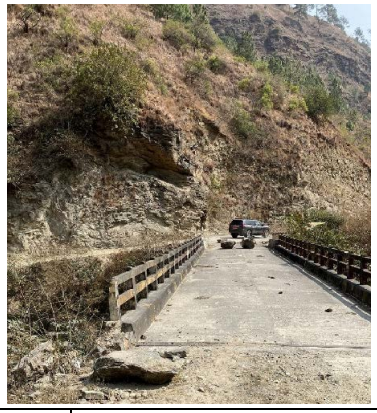
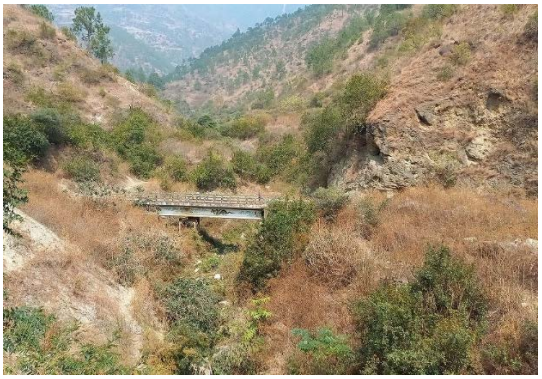



Photo No. 3	From Mongar downstream side	Photo No. 4	From Trashigang downstream side
			
Photo No. 5	From Mongar upstream side	Photo No. 6	From Trashigang upstream side
			
Photo No. 7	On the bridge to downstream side	Photo No.8	On the bridge to upstream side
			

Source: JICA Survey Team

3) Inspection result

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found	a
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found	a
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely	e
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found	a
	Others	Graffiti, bird damage, fire damage, etc.	Only record	–

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Super Structure	Deck Slab	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	
	Main Girder	Con	Crack	Appendix	d
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Sub Structure	Body	Con	Crack	Appendix	e
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	e
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	e
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation	c

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found	a
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found	a
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found	a
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely	a
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more	a
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more	a
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes	a
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm	a
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found	e
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing	c
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more	a
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	a
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found	a

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

4) Inspection photo

Photograph

Category	e	Type of Damage	Scouring	Pic.No.1

Category	d	Type of Damage	Crack	Pic.No.2

Category	e	Type of Damage	Crack	Pic.No.3

Category	e	Type of Damage	Rebar exposure	Pic.No.4

Category	e	Type of Damage	Honeycomb	Pic.No.5

Category	e	Type of Damage	Damage	Pic.No.6

Category	e	Type of Damage	Sediment Deposition	Pic.No.7

Category	c	Type of Damage	Abnormity	Pic.No.8

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

(3) Surrounding Rever

Cobles were confirmed near to the bridge. Rever water was not observed because our site survey was conducted in the dry season. Upstream side was visually unclear because the river is covered with grasses and trees, on the other side, the river slope to downstream side were relatively gentle. According to the satellite photo, the angle was 3 to 10 degrees, which classified debris deposit area.

Upstream side of the existing bridg

Downstream side of the existing bridg

Source: JICA Survey Team

Figure 1-4-15 The surrounding river situation

1-4-6 Result of bridge inspection for Rollong bridge

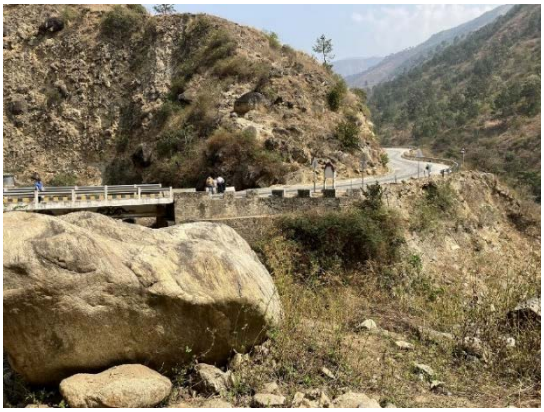
(1) Surrounding Road

Road widening and pavement work were completed around the area near to theRollong bridge. Although the curvy road exists around the area, radius of curve is relatively gentle (see Figure 1-4-16).

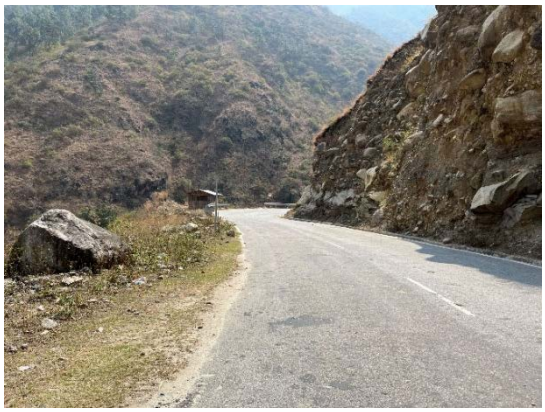
Source: Prepared by JICA Survey Team based on Google Earth

Figure 1-4-16 Road alignment around Rollong bridge site

Right slope (Mongar side)



Left slope (Trashigang side)



Road situation (Mongar side)

Road situation (Trashigang side)

Source: JICA Survey Team

Figure 1-4-17 The surrounding road situation of Rollong bridge

(2) Bridge body

1) Summary of bridge inspection

Following bridge inspection result was obtained:

- Overall: Foundation is exposed by scouring (see inspection pic No. 1), but bridge length is short. Therefore, counter measure required is not complicated.
- Superstructure: Cover concrete at the deck bottom is pealed and rebar is exposed (see inspection pic No. 2).
- Substructure: Partial loss was observed (see inspection pic No. 3).
- Others: Expansion joint is damaged (see inspection pic No. 4).

2) Bridge inventory

Bridge Name	Rollong Bridge	Road No.	PNH-1
Site situation	Photo No. 1	From Mongar side	Photo No. 2	From Trashigang side
				
	Photo No. 3	From Mongar downstream side	Photo No. 4	From Trashigang downstream side
				
	Photo No. 5	From Mongar upstream side	Photo No. 6	From Trashigang upstream side
				
	Photo No.7	On the bridge to downstream side	Photo No.8	On the bridge to upstream side
				

Source: JICA Survey Team

3) Inspection result

1.Overall Condition of Bridge

Structure	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Whole Bridge	Extraordinary deflection	Extraordinary sagging	a:Not found b:- c:- d:- e:Found	a
	Settlement Movement Inclination	Settlement, movement, inclination of foundation or bearing, etc	a:Not found b:- c:- d:- e:Found	a
	Scouring	Scouring of pier or foundation	a:Not found b:- c:Slightly d:- e:Severely	e
	Sediment Deposition	Dirt/litter deposited on Deck, Girder (Steel) or Abutment	a:Not found b:- c:- d:- e:Found	a
	Others	Graffiti, bird damage, fire damage, etc.	Only record	–

2.Condition of Damage(Super Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Super Structure	Deck Slab	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	d
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Partial loss of concrete	a:Not found b:- c:- d:- e:Found	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	
	Main Girder	Con	Crack	Appendix	a
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	a
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	a
		Steel	Corrosion	Appendix	
			Crack	a:Not found b:- c:Less than 3mm (length) d:- e:3mm or more (length)	
			Looseness/Omission	a:Not found b:- c:Less than 5% d:- e:5% or more	
			Fracture	a:Not found b:- c:- d:- e:Found	
			Deterioration of Painting	a:Not found b:- c:Partially d:Peelling e:Peelling and Rust	

3.Condition of Damage(Sub Structure)

Structure	Member	Material	Damage	Damage evaluation criterion (a～e)	Evaluation
Sub Structure	Body	Con	Crack	Appendix	
			Peeling/Rebar exposure	a:Not found b:- c:Peeling d:Rebar exposure (small) e:Rebar exposure (large)	
			Water leakage/Free lime	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	
			Honeycomb	a:Not found b:- c:Extensively d:Rebar exposure (small) e:Rebar exposure (large)	
		Con/masonry	Damage/Deformation	a:Not found b:- c:Partial Damage d:- e:Deformation	c

4.Presence of Damage

Structure	Member	Damage	Contents	Damage evaluation criterion(a～e)	Evaluation
Bearing	Bearing	Defect	Severe corrosion, defect / hardening / missing parts	a:Not found b:- c:- d:- e:Found	a
		Noise	Extraordinary noise during passing vehicle	a:Not found b:- c:- d:- e:Found	a
	Base Mortar (Bearing Sheet)	Sediment Deposition	Dirt/litter deposited on/around base mortar	a:Not found b:- c:- d:- e:Found	a
		Deformation/ Loss	Crack of mortar, partial defect	a:Not found b:- c:Partially d:- e:Severely	a
Ancillary Facilities	Railing	Deformation/ Damage	Deformation or broken part	a:Not found b:- c:Less than 50% d:- e:50% or more	a
			Dangerous parts for bridge users	a:Not found b:- c:Less than 50% d:- e:50% or more	a
Deck Surface	Pavement	Abnormity	Hole, big pothole, crack	a:Not found b:- c:Cracks d:- e:Pot Holes	a
		Unevenness	Dangerous parts for bridge users	a:Not found b:- c:Less than 2cm d:- e:More than 2cm	a
		Sediment Deposition	Dirt/litter deposited on pavement	a:Not found b:- c:- d:- e:Found	a
	Expansion joint	Abnormity	Broken	a:Not found b:- c:Minor d:- e:Separating or Squeezing	c
		Unevenness	Level difference	a:Not found b:- c:less than 2cm d:- e:2cm or more	e
Drainage Facilities		Clogging	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	a
		Water Leakage	Broken or drained water afftected to girder or other member	a:Not found b:- c:- d:- e:Found	a

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

4) Inspection photo

Photograph							
Category	e	Type of Damage	Scouring	Pic.No.1	Category	d	Type of Damage	Rebar exposure	Pic.No.2
									
Category	c	Type of Damage	Damage	Pic.No.3	Category	c	Type of Damage	Abnormity	Pic.No.4
									
Category	e	Type of Damage	Unevenness	Pic.No.5	Category		Type of Damage		Pic.No.6
									
Category		Type of Damage		Pic.No.7	Category		Type of Damage		Pic.No.8

Source: Prepared by JICA Survey Team based on inspection sheet developed by technical cooperation project

(3) Surrounding Rever

Cobles were confirmed upstream side of the bridge. River slope was visually gentle, but angle was 3 to 10 degrees, which classified mudslide deposit section, according to the satellite data.

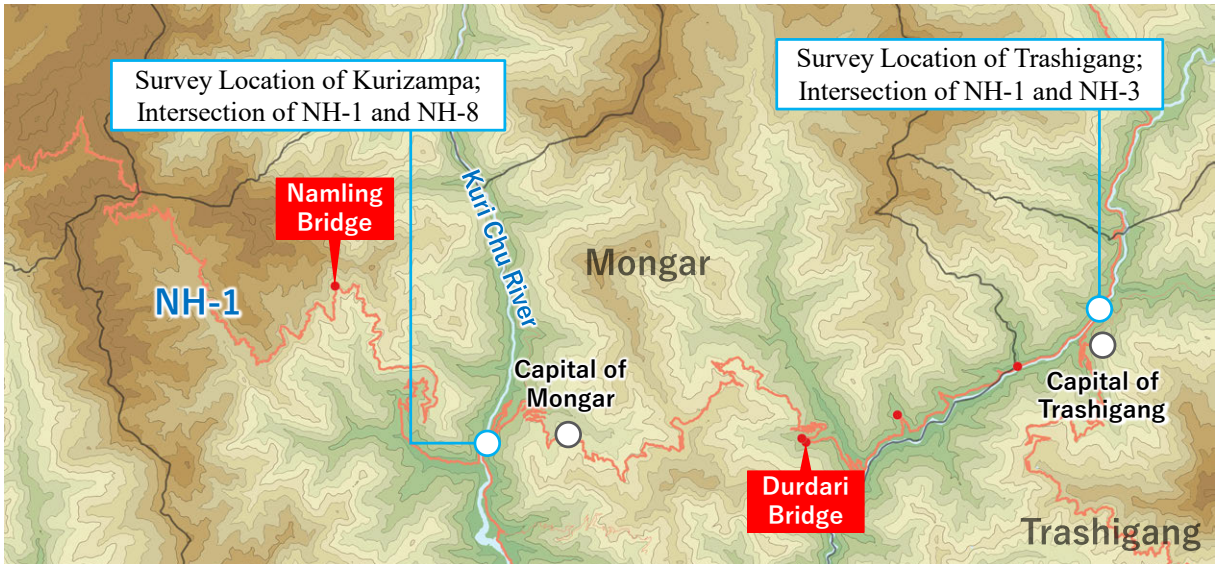
Upstream side of the existing bridg　　Downstream side of the existing bridg

Source: JICA Survey Team

Figure 1-4-18 The surrounding river situation

1-5 Traffic Survey and Traffic Demand Forecast

Traffic survey was conducted to obtain the traffic characteristics in the target areas. Data obtained from the survey was be used to calculate road design and future traffic demand forecasts, as well as the effects of project. Locations for the traffic survey are shown in Figure 1-5-1



Source: JICA Survey Team

Figure 1-5-1 Location of Traffic survey

1-5-1 Traffic Volume

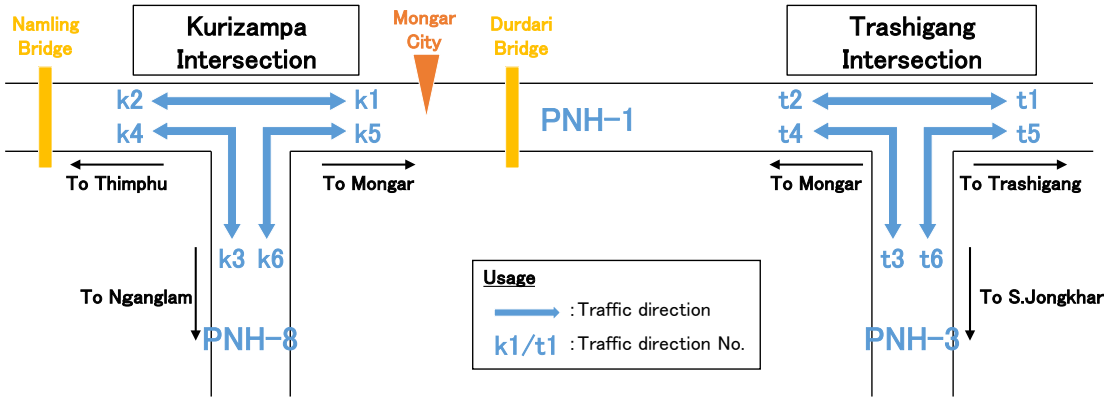
(1) Outline

Traffic volume survey was conducted to determine traffic volumes in the target areas. The work items are shown in Table 1-5-1.

Table 1-5-1 Detail of Traffic Volume Survey

Item	Detail
Method	Cross-sectional traffic (by type and direction) survey by surveyor • Direction: 6 directions (See Figure 1.7.2) • Type: car, van, mini bus, large bus, pickup track, track(2,3,4axles), pedestrian, others
Location	Kurizampa intersection (PNH-1 and PNH-8) and Trashigang intersection (PNH-1 and PNH-3)
Duration	The 1st Survey: • 26th Mar 2023 (Sun) and 28th (Tue), Total 2 days The 2nd Survey: • 11th July 2023(Tue) and 15th July (Sat), Total 2 days
Time	6AM to 6AM (Next day) 24 hours

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-5-2 Diagram of Traffic Survey

(2) Results

Traffic volumes by direction at each intersection were shown in Table 1-5-2.

Table 1-5-2 Traffic volume by direction at each intersection

Traffic	No.	Traffic direction	Traffic volume (cars /day)			
			26th March	28th March	11th July	15th July
Kurizampa	k1	Thimphu → Mongar	50	45	73	59
	k2	Mongar → Thimphu	57	44	70	63
	k3	Thimphu → Nganglam	32	31	89	70
	k4	Nganglam → Thimphu	36	25	95	65
	k5	Nganglam → Mongar	64	48	57	64
	k6	Mongar → Nganglam	70	45	83	73
Trashigang	t1	Mongar → Trashigang	44	53	107	64
	t2	Trashigang → Mongar	77	69	87	59
	t3	Mongar → S.jongkher	45	29	79	66
	t4	S.jongkher → Mongar	31	27	60	77
	t5	S.jongkher → Trashigang	49	43	73	59
	t6	Trashigang → S.jongkher	84	71	117	97

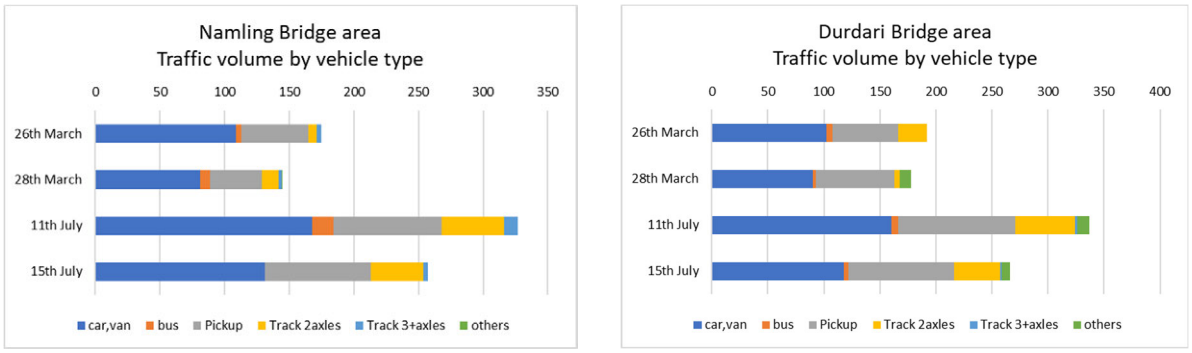
Source: JICA Survey Team

Traffic volume at each target Bridges is calculated as shown in Table 1-5-3 and its vehicle type observed are shown in Figure 1-5-3.

Table 1-5-3 Traffic Volume at each target Bridges

Bridge	26th March	28th March	11th July	15th Jult	Traffic direction
Namling	175	145	327	257	k1 + k2 + k3 + k4
Durdari	197	178	333	266	t1 + t2 + t3 + t4

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-5-3 Vehicle type passed at each target bridges

1-5-2 Origin-Destination (OD) Survey

(1) Outline

The OD survey and traffic volume survey were conducted. The details of the OD survey are shown in Table 1-5-4.

Table 1-5-4 Detail of OD Survey

Item	Detail
Method	Interview to passenger Contents of questionnaire are below: A. Personal: Type, Number of passengers, Purpose, Departure, Destination, Time for departure, estimated time for destination. B. Bus(20% of passenger was interviewed) Type, Number of passengers, Maximum capacity, Purpose for moving, Departure, Destination, Time for departure, estimated time for destination, Bus Route. C. Cargo: Type, Purpose for moving, Maximum Loading Capacity, Loading Capacity, Loading Items, Departure, Destination, Time for departure, estimated time for destination, Tax or Cost to be needed.
Location	Kurizampa intersection (PNH-1 and PNH-8) and Trashigang intersection (PNH-1 and PNH-3)
Duration	The 1st Survey: • 1day for weekday and weekend, Total 2 days • 26th Mar 2023 (Sun) and 28th (Tue) The 2nd Survey: • 1day for weekday and weekend, Total 2 days • 11th July 2023(Tue)and 15th July (Sat)
Time	6AM to 10PM (18 hours)

Source: JICA Survey Team

(2) Results

An OD matrix was prepared from the result of interview as shown in Table 1-5-5.

Table 1-5-5 OD Matrix

OD Matrix Kurizampa 26th March (weekend)

Origin \ Destination	Bumthang	Chukha	Lhuntse	Mongar	Pema-gatshel	Samdrup Jongkhar	Sarpang	Thimphu	Trashi-gang	Trashi-yangtse	Trongsa	Wangdue Phodrang	Zhemgang	**Total**
Bumthang			2	2					3	3				**10**
Chukha			1	1	1				3	1				**7**
Lhuntse		2		3				1	1		1			**8**
Mongar	3	3	5	186	4	1	1	9	3	2	1		3	**221**
Pemagatshel	1			5					3					**9**
Punakha										1				**1**
Samdrup Jongkhar			1	3										**4**
Sarpang				1						1				**2**
Thimphu			1	5					1	4				**11**
Trashigang	1			3	2			1				1		**8**
Trashiyangtse	1			1	1			2				1		**6**
Trongsa				2					1	1				**4**
Wangdue Phodrang				1										**1**
Total	**6**	**5**	**10**	**213**	**8**	**1**	**1**	**13**	**15**	**13**	**2**	**2**	**3**	**292**

OD Matrix Kurizampa 28th March (weekday)

Origin \ Destination	Bumthang	Chukha	Lhuntse	Mongar	Pema-gatshel	Samdrup Jongkhar	Thimphu	Trashi-gang	Trashi-yangtse	Wangdue Phodrang	Zhemgang	**Total**
Bumthang				2				2	1			**5**
Chukha								2	1			**3**
Lhuntse	2			2	1		3	1				**9**
Mongar	3	2	2	154	2	3	5	3	3	2		**179**
Pemagatshel				2								**2**
Punakha								1				**1**
Samdrup Jongkhar				2								**2**
Thimphu				4				1	4			**9**
Trashigang	2			4	1		1					**8**
Trashiyangtse					1		1				1	**3**
Trongsa			1	2					1			**4**
Total	**7**	**2**	**3**	**172**	**5**	**3**	**10**	**10**	**10**	**2**	**1**	**225**

OD Matrix Kurizampa 11th July (Weekday)

Origin \ Destination	Bumthang	Lhuntse	Mongar	Samdrup Jongkhar	Thimphu	Trashi-gang	Trashi-yangtse	Wangdue Phodrang	**Total**
Bumthang		1	4			3			**8**
Dagana			1						**1**
Lhuntse	1		6		1				**8**
Mongar	3		130	2	1	2	1		**139**
Pemagatshel			5						**5**
Punakha			1			1			**2**
Samdrup Jongkhar			4						**4**
Sarpang			1						**1**
Thimphu		3	6			3			**12**
Trashigang	2		1		5			1	**9**
Wangdue Phodrang						1			**1**
Total	**6**	**4**	**159**	**2**	**7**	**10**	**1**	**1**	**190**

OD Matrix Kurizampa15th July (weekend)

Origin \ Destination	Bumthang	Haa	Lhuntse	Mongar	Pema-gatshel	Thimphu	Trashi-gang	Trashi-yangtse	Wandue Phodrang	Zhemgang	Chukha	**Total**
Bumthang				5			1	1				**7**
Chukha				1				2				**3**
Lhuntse				2	1	3					1	**7**
Mongar	6	1	3	116	1	6	1	1	1	2		**138**
Pema gathsel				1								**1**
Punakha							1					**1**
Sarpang								1				**1**
Thimphu			3	3			3	1				**10**
Trashigang	1			2	2	1						**6**
Trashiyangtse				2	1	1						**4**
Trongsa								1				**1**
Wangdue Phodrang			1	3		1	1					**6**
Total	**7**	**1**	**7**	**135**	**5**	**12**	**7**	**7**	**1**	**2**	**1**	**185**

OD Matrix Trashigang 26th March (weekend)

Origin \ Destination	Chukha	Lhuntse	Mongar	Paro	Pema-gatshel	Punakha	Samdrup Jongkhar	Thiphu	Trashi-gang	Trashi-yangtse	Wangdue Phodrang	**Total**
Pemagatshel									1	1		**2**
Samdrup Jongkhar			1						5	2		**8**
Trashigang	1	2	15	1	2	1	9	2	127	50	1	**211**
Total	**1**	**2**	**16**	**1**	**2**	**1**	**9**	**2**	**133**	**53**	**1**	**221**

OD Matrix Trashigang 28th March (weekday)

Origin \ Destination	Bumthang	Mongar	Samdrup Jongkhar	Trashi-gang	Trashi-yangtse	**Total**
Pemagatshel		1			1	**2**
Samdrup jongkhar		3			3	**6**
Trashigang	1	13	8	115	62	**199**
Trashiyangtse				1		**1**
Total	**1**	**17**	**8**	**116**	**66**	**208**

OD Matrix Trashigang 11th July (weekday)

Origin \ Destination	Bumthang	Lhuntse	Mongar	Pema-gatshel	Samdrup Jongkhar	Thimphu	Trashi-gang	Trashi-yangtse	Trongsa	Wandue Phudrang	**Total**
Mongar								1			1
Samdrup Jongkhar		1	12				7				20
Trashigang	2	2	31	5	8	2	187	30	1	1	269
Trashiyangtse							4				4
Total	2	3	43	5	8	2	198	31	1	1	294

OD Matrix Trashigang 15th July weekend)

Origin \ Destination	Lhuntse	Mongar	Pema-gatshel	Samdrup Jongkhar	Thimphu	Trashi-gang	Trashi-yangtse	**Total**
Chukha		1						**1**
Samdrup Jongkhar	2	7				8	5	**22**
Trashigang	3	31	3	4	7	160	24	**232**
Total	**5**	**39**	**3**	**4**	**7**	**168**	**29**	**255**

Source: JICA Survey Team

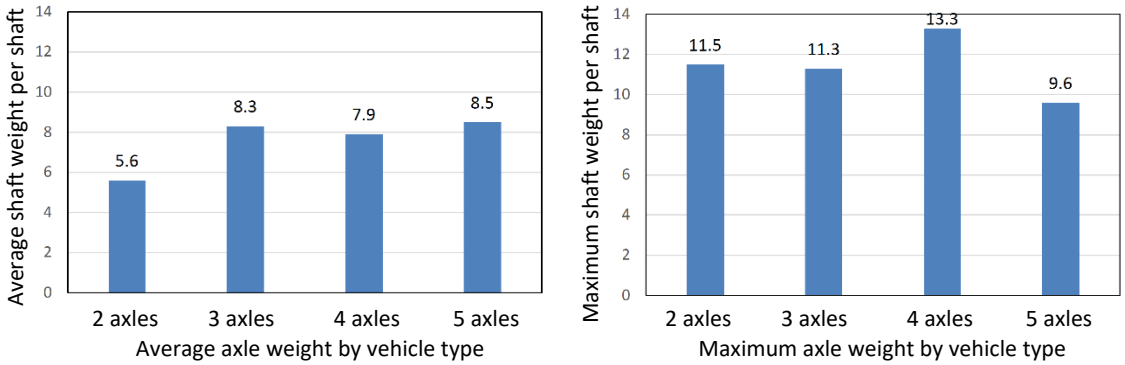
1-5-3 Data collection for Axial load

In order to grasp the loading capacity and overloading situations, data of Axial load survey conducted by a previous project, "Preparatory Survey on The Project for Reconstruction of Bridges On Primary National Highway No.1 in Bhutan", was used. Outline of the survey and result are shown in Table 1-5-6 and Figure 1-5-4.

Table 1-5-6 Outline of axial load test conducted by Previous project

Item	Detail
Method	Axial load test
Location	Chuka-Karbandi, Check post
Duration	8th Sep 2014 (Mon)
Time	9AM to 18PM
Sample Number	65:2 axial Vehicle: 23 3 axial Vehicle: 21 4 axial Vehicle: 16 5 axial Vehicle: 5

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-5-4 Axal-load test result (Previous Project)

1-5-4 Future traffic volume

Future traffic volume is calculated by using historical data on vehicle registrations and determining their growth rate. The growth rate was calculated by regression analysis using GDP and population as explanatory variables. Vehicle registrations in Bhutan is shown in Table 1-5-7 and GDP and population are shown in Table 1-5-8.

Table 1-5-7 Vehicle Registrations in Bhutan

year	Passenger Cars				Heavy Vehicles			
	Light Vehicle	Medium Vehicle	Taxi	**Total**	Heavy Vehicle	Bus	Earth Moving Equipment	**Total**
2011	37,538	1,126	no data	**38,664**	7,264	no data	1,463	**8,727**
2012	38,683	1,321	5,299	**45,303**	8,243	no data	1,842	**10,085**
2013	39,392	1,344	5,271	**46,007**	8,547	no data	1,953	**10,500**
2014	39,661	1,353	5,159	**46,173**	8,494	no data	1,981	**10,475**
2015	45,533	1,457	3,839	**50,829**	8,537	no data	2,059	**10,596**
2016	51,458	1,536	4,126	**57,120**	9,041	no data	2,411	**11,452**
2017	57,010	1,657	4,283	**62,950**	9,832	no data	2,834	**12,666**
2018	62,097	1,784	4,518	**68,399**	10,972	no data	3,199	**14,171**
2019	no data							
2020	72,040	1,935	5,513	**79,488**	8,603	606	3,662	**12,871**
2021	74,492	1,639	5,886	**82,017**	11,878	557	3,734	**16,169**
2022	80,666	1,789	6,162	**88,617**	12,032	586	4,059	**16,677**

Source: Prepared by JICA Survey Team referred to Road Safety and Transport Authority: Annual Report

Table 1-5-8 GDP and Population in Bhutan

year	GDP(USD)	Population	Remarks
2011	1,777,102,586	713,331	For historical values, World Bank Open Data values were used.
2012	1,781,280,170	721,145	
2013	1,756,214,304	728,889	
2014	1,907,090,362	736,357	
2015	2,003,596,824	743,274	
2016	2,158,971,718	749,761	
2017	2,450,366,108	756,121	
2018	2,446,867,582	762,096	
2019	2,535,655,609	767,459	
2020	2,325,185,521	772,506	
2021	2,539,551,327	777,486	
2022	3,216,265,314	782,455	
2023	3,486,206,390	821,289	Yellow cells in the left table are future estimates. ▶For GDP, an exponential approximation was made using 1980-2021 data. ▶For population, a linear approximation was made using 1960-2022 data.
2024	3,778,803,613	830,851	
2025	4,095,958,515	840,414	
2026	4,439,732,220	849,976	
2027	4,812,358,845	859,539	
2028	5,216,260,015	869,101	
2029	5,654,060,600	878,664	
2030	6,128,605,778	888,226	
2031	6,642,979,522	897,789	
2032	7,200,524,644	907,351	
2033	7,804,864,514	916,914	
2034	8,459,926,617	926,476	
2035	9,169,968,066	936,039	

Source: JICA Survey Team

Future growth of registration vehicle is calculated by regression analysis. It is expected that registration of passenger vehicle highly is affected by population growth and registration of cargo is affected by GDP. Therefore, Future traffic volume of both passenger vehicle and cargo were calculated by regression analysis that population and GDP was used as explanatory variables respectively. The result was shown in Table 1-5-9.

Table 1-5-9 Result of regression analysis

year	Regression analysis 1: Population x Passenger car registrations		Passenger Car Registrations Growth Rate Compared to 2023	Regression analysis 2: GDP x Heavy vehicles registrations		Heavy Vehicles Registrations Growth Rate Compared to 2023
	Explanatory variable: Population	Objective variable: Passenger car registrations		Explanatory variable: GDP (USD)	Objective Variable: Heavy vehicles registrations	
2011	713,331	38,664	-	1,777,102,586	8,727	-
2012	721,145	45,303	-	1,781,280,170	10,085	-
2013	728,889	46,007	-	1,756,214,304	10,500	-
2014	736,357	46,173	-	1,907,090,362	10,475	-
2015	743,274	50,829	-	2,003,596,824	10,596	-
2016	749,761	57,120	-	2,158,971,718	11,452	-
2017	756,121	62,950	-	2,450,366,108	12,666	-
2018	762,096	68,399	-	2,446,867,582	14,171	-
2019	767,459	-	-	2,535,655,609	-	-
2020	772,506	79,488	-	2,325,185,521	12,871	-
2021	777,486	82,017	-	2,539,551,327	16,169	-
2022	782,455	88,617	-	3,216,265,314	16,677	-
2023	821,289	112,221	100%	3,486,206,390	20,760	100%
2024	830,851	119,100	106%	3,778,803,613	22,677	109%
2025	840,414	125,979	112%	4,095,958,515	24,756	119%
2026	849,976	132,858	118%	4,439,732,220	27,009	130%
2027	859,539	139,738	125%	4,812,358,845	29,451	142%
2028	869,101	146,617	131%	5,216,260,015	32,098	155%
2029	878,664	153,496	137%	5,654,060,600	34,967	168%
2030	888,226	160,375	143%	6,128,605,778	38,077	183%
2031	897,789	167,254	149%	6,642,979,522	41,448	200%
2032	907,351	174,133	155%	7,200,524,644	45,102	217%
2033	916,914	181,012	161%	7,804,864,514	49,062	236%
2034	926,476	187,892	167%	8,459,926,617	53,355	257%
2035	936,039	194,771	174%	9,169,968,066	58,008	279%
Number of data	11 (2011-2018,2020-2022)			11 (2011-2018,2020-2022)		
Number of coefficients	0.719			5.37E-06		
Slices	-4.79E+05			3.18E+02		
Intentionally F	3.31E-07			2.00E-04		
Coefficient of determination	0.951			0.860		

Source: JICA Survey Team

Future traffic volume is obtained by multiplying growth ratio calculated above to OD survey result. Future traffic volume at both Namling and Durdali bridge were shown in Table 1-5-10.

Table 1-5-10 Future traffic volume (2023/2031)

Traffic volume (units/year)	Year 2023	Year 2031
Namling	15,435	25,180
Durdari	19,800	32,797

Source: JICA Survey Team

1-6 Social Survey

1-6-1 Outline of the Survey

Th five bridges are located in Mongar District (Dzongkhag). In terms of Gewog, the administrative divisions are: Namling Bridge is located in Saling, Pakhadrang and Durdari Bridge are in Chaskhar, Revidrang and Rollong Bridge are in Dramatse (Figure 1-6-1). Populated urban areas in the vicinity are Mongar located between Namling and Pakhadrang Bridge and Trashigang in Samkhar Gewog located east of Rollong Bridge, where long-distance bus terminals and hospitals are existing. The rest of the area along the national highway is a mountainous area with scattered farmlands and houses (Figure 1-6-2). In the area of Pakhadrang – Rollong Bridge, the settlements are located up the slope along the highway and cannot be seen from the highway. It was observed that residents were walking down to the highway and picked up by passing vehicles.

The objective of this social survey is to identify benefits of the Project to the residents. The survey was conducted by subcontractors in six Gewogs: Saling, Chaskhar and Drametse, where the five bridges are located as well as Mongar, Ngatshang and Samkhar, where urban areas and settlements are observed along the highway.

Source: JICA Survey Team

Figure 1-6-1 Locations of the Five Bridges with Administrative Borders

Saling

Ngatshang

Source: JICA Survey Team

Figure 1-6-2 Settlements Observed from the National Highway

Table 1-6-1 Outline of the Social Survey

Items	Methodology	Survey Locations (Gewog)
1. Location of medical and educational facilities	Secondary data, interview to key informants, field observation	Saling, Mongar, Ngatshang, Chaskhar, Dramatse, Samkhar
2. Socio-economic conditions of residents	Questionnaire survey to residents, interview to key informants	Ditto
3. Frequency and purpose of passing the bridges, alternative measures in case the bridges are closed	Questionnaire survey to residents, interview to key informants	Ditto
	Questionnaire survey to hospital users	Mongar, Samkhar
	Questionnaire survey to bus terminal users	Ditto

Source: JICA Survey Team

1-6-2 Location of Medical and Educational Facilities

Mongar, the capital of Mongar District, has a 150-bed Eastern Regional Referral Hospital, which also serves as the district hospital. Other health care facilities in the district include a 10-bed Grade I Basic Health Unit (BHU) in Gyelpozhing, 22 Grade II BHUs and five sub-posts at the Gewog level, and 59 outreach clinics at the village level. There are also four traditional medicine units, providing residents with a wide range of health care options. In the area where the Primary National Highway No.1 passes through, there is a BHU and several outreach clinics in each Gewog. However, it may be necessary to visit the well-equipped hospitals, the Regional Referral Hospital or the district hospital in Trashigang, depending on the medical conditions.

Mongar District has the second largest number of schools in the country following Trashigang District. It has 4 higher secondary schools (including a private school), 2 middle secondary schools, 7 lower secondary schools, 37 primary school, and 8 extended classrooms, providing education to ten thousand children. Primary schools are located in every Gewog in the areas along the national highway, and children walk to the schools. However, they need to travel across the Gewogs for commuting to middle secondary schools and above.

1-6-3 Socio-economic Conditions of Residents

The questionnaire survey was conducted to 696 households in May 2023 at five Gewogs (Saling, Mongar, Ngatshang, Chaskhar, and Drametse) in Mongar District and Samkhar Gewog in Trashigang District where the national highway passes through. The average number of household members (Table 1-6-2) was 3.9, almost similar to the national average household size (4 persons for urban and 3.8 persons for rural areas). The total population of the surveyed households was 2,746, which corresponds to 10.6% of the region's total population according to the census in 2017.

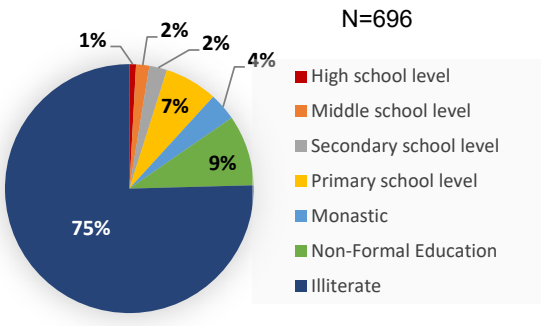
Table 1-6-2 Number of Household Members of the Socio-economic Questionnaire Survey

Bridge location	•Namling			•Pakhadrang •Durdari	•Revidrang •Rollong		
Gewog **Household members**	**Saling**	**Mongar**	**Ngatshang**	**Chaskhar**	**Drametse**	**Samkhar**	**Total**
Single member	5	2	4	9	4	4	28
Two members	29	14	25	23	36	9	136
Three members	27	22	47	32	33	4	165
Four members	32	8	33	30	27	5	135
Five members	11	18	19	19	24	7	98
Six members	13	9	12	20	15	1	70
Seven members	4	7	4	10	9		34
Eight members	3	7	1	2	2		15
Nine members	2	1	2	4			9
Ten members		1	1	2		1	5
Twelve members		1					1
Total surveyed household numbers	**126**	**90**	**148**	**151**	**150**	**31**	**696**
Total surveyed population	**475**	**408**	**558**	**628**	**572**	**105**	**2,746**
Gewog population by census in 2017	2,881	11,130	2,375	2,494	1,848	5,146	25,874
Ratio of surveyed population	16.5%	3.7%	23.5%	25.2%	31.0%	2.0%	10.6%

Source: JICA Survey Team

(1) Education

Figure 1-6-3 illustrates education levels of the household heads of the surveyed households. Illiterate household heads, who are uneducated and cannot read and write, accounted for 75% of the total. The second common were those enrolled in programs for elderlies who had no educational opportunities in their school age (Non-Formal Education) (9%) and the third were those finished elementary school level (7%).



Source: JICA Survey Team

Figure 1-6-3 Education Levels of the Surveyed Household Heads

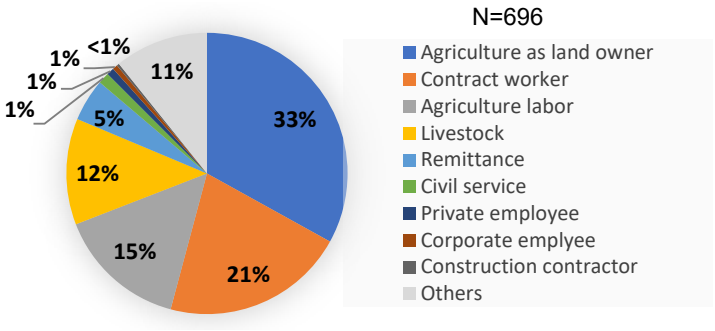
(2) Livelihood Means and Economic Conditions

Figure 1-6-4 shows the sources of income of the 696 households surveyed. Many of the households rely on agriculture, livestock production, and works as contract workers as their main sources of livelihood, while some of them replied that remittances from relatives were their main source of income.

The economy of Mongar District is dependent on agriculture. The products include such cereal crops as wheat, maize, rice, barley, buckwheat, and millet, as well as fruits such as orange, persimmon, banana, walnut, arecanut, plum, pear, peach, and apples. Vegetables such as ginger, garlic, onion, potato, chilli, cabbage, cauliflower, green leaves, radishes, cucumbers, pumpkin, legume, mustard, cardamom, and soybeans, as well as livestock products such as milk, butter, cheese, egg, beef, and pork also support livelihoods. In the industrial sector, there are no major industries except for a few sawmills and furniture makers.

As for farmers' self-help groups, there are a total of 38 registered farmers' groups, associations, and cooperatives in Mongar District. These groups are formed to promote the sale of agricultural and livestock products in the district and to export to other districts as well.

Table 1-6-3 shows the average income and expenditure of the surveyed households. The average income ranges from 3,537 to 6,644 Nu/month in each Gewog in Mongar and 9,148 Nu/month in Trashigang, while the average expenditure ranges from 1,530 to 4,127 Nu/month in Mongar and 3,919 Nu/month in Trashigang. Expenditures are mainly for rice, flour, clothing, and other necessities. The national poverty line is an income of 2,195.95 Nu/month (Poverty Analysis Report 2017, the National Statistical Bureau), and of the 696 households, three in Saling Gewog, one in Ngatshang Gewog and one in Ngatshang Gewog are identified as those below the poverty line. On the other hand, a total of 7 high-income households (Saling 3, Ngatshang 2, Chaskhar 1, and Drametse 1) are identified as those with income above Nu 100,000/month.



Source: JICA Survey Team

Figure 1-6-4 Income Source of the Surveyed Households

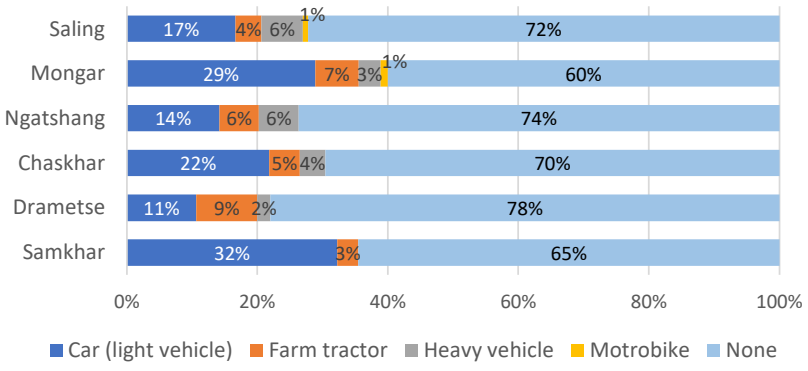
Table 1-6-3 Average Income and Expenditure of the Surveyed Households

Dzongkhag (District)	Mongar					Trashigang
Gewog	Saling	Mongar	Ngatshang	Chaskhar	Drametse	Samkhar
Average income (Nu/month)	6,644	4,478	3,875	4,517	3,537	9,148
Average expenditure (Nu/month)	4,127	3,706	1,615	2,159	1,530	3,919
Number of households below the poverty line (income below 2,195.95Nu/month) out of the surveyed 696	3	0	1	0	0	0
Number of households with income above 100,000Nu/month out of the surveyed 696	3	0	2	1	1	0

Source: JICA Survey Team

(3) Means of Mobilization

Figure 1-6-5 shows the ownership rates by vehicle type of the 696 households surveyed. In all Gewog, 60-78% of households do not own any vehicles. The most common type of vehicle is a light vehicle such as a private car, and households that own a vehicle are more prevalent in Mongar and Samkhar. The means of long-distance travel for those who do not own a vehicle is bus, taxi, or getting a ride in someone else's vehicle.



Source: JICA Survey Team

Figure 1-6-5 Types of Vehicles Owned by the Surveyed Households

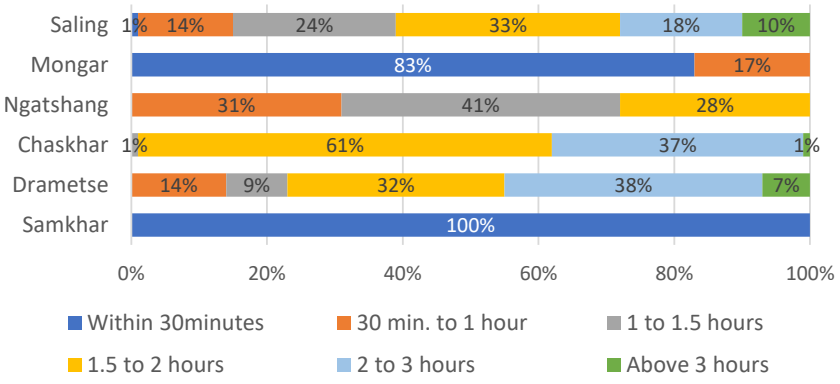
(4) Accessibility to Educational and Medical Services

As shown in Section 1.8.2, each Gewog has a primary school as an educational facility and a Basic Health Unit (BHU) and Outreach Clinic (ORC) as medical facilities. Table 1-6-4 shows the average walking time to each facility based on the questionnaire survey. On the other hand, people need to go to the Eastern Regional Referral Hospital or the district hospital if the conditions cannot be handled at the BHUs and ORC. Average access time by car to those hospitals are shown in Figure 1-6-6. In Mongar where the Eastern Regional Referral Hospital is located and in Trashigang where the Trashigang District hospital is located, the travel to the hospital usually takes less than 30 minutes, while in Saling and Drametse, which are far from the hospitals, the travel takes up to 3 hours or more.

Table 1-6-4 Average Walking Time (Minutes) to Educational and Medical Facilities in Gewogs

Dzongkhag (District)	Mongar					Trashigang
Gewog	Saling	Mongar	Ngatshang	Chaskhar	Drametse	Samkhar
Primary school	42	41	51	70	46	20
BHU	79	98	48	45	66	60
ORC	38	31	14	40	56	30

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-6-6 Average Access Time by Car to Hospitals in Mongar and Trashigang

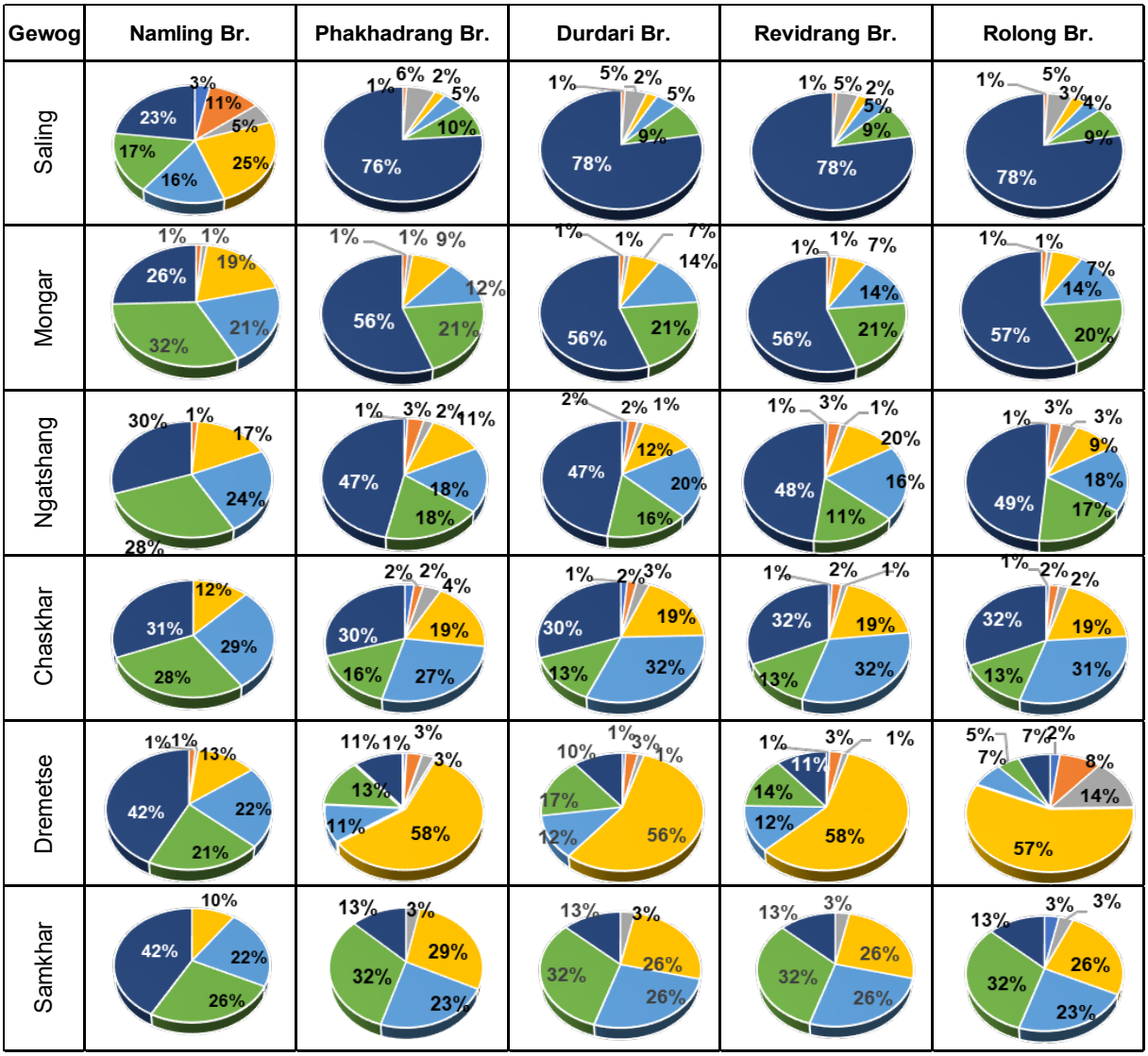
1-6-4 Frequency of Passing the Bridges

(1) Frequency of Passing the Bridges by Gewog

Figure 1-6-7 shows the questionnaire survey results on frequency of passing each of the five bridges of the six Gewog residents (696 households). Namling Bridge is relatively well used by residents in Saling Gewog, where the bridge is located, with 60% of households using the bridge at least once a year. In the other five Gewogs, the further away from Namling Bridge, the less frequently the bridge was used, but even in Samkhar in Trashigang District, the furthest away, about 30% of households replied they used the bridge at least once a year. It indicates that Namling Bridge is used by residents in a wide area. The other four bridges were used relatively frequently by residents in the east, while the use rate was low in Saling and Mongar which are located west of the bridges. Especially in Drametse, where Revidrang and Rollong Bridge are located, over 60% of households replied that they used all four bridges several times a year or more. Although the purpose of travel through the five bridges varied, 17% of households

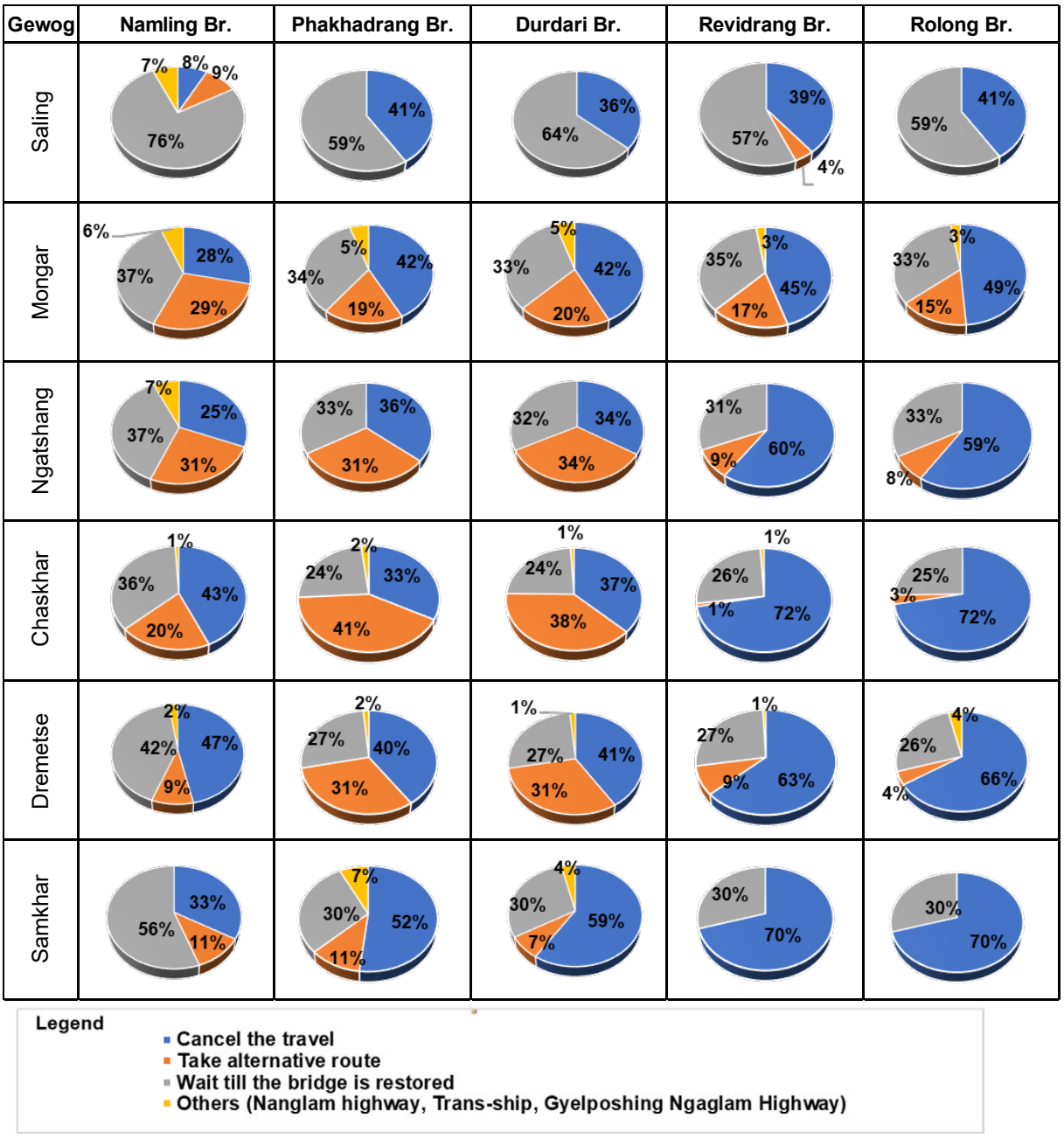
mentioned medical purposes. The other common purposes of travel were visiting friends/relatives and pilgrimage sites (35%), as well as working, shopping, commuting to school, and selling agricultural products, indicating that the five bridges are used for daily purposes.

Figure 1-6-8 shows the answers on alternatives if the bridges are closed. The majority of respondents in Saling Gewog answered they would wait until the bridges were recovered while the proportions of respondents who chose to cancel their travel or take alternative routes (farm roads) were also large in the other Gewogs. For Revidrang and Rollong Bridge, many respondents answered they would cancel their travel if those bridges were closed.



Source: JICA Survey Team

Figure 1-6-7 Frequency of Passing the Bridges by Gewog



Note: Pakhadrang and Durdari when blocked people used the Chaskhar farm road

Source: JICA Survey Team

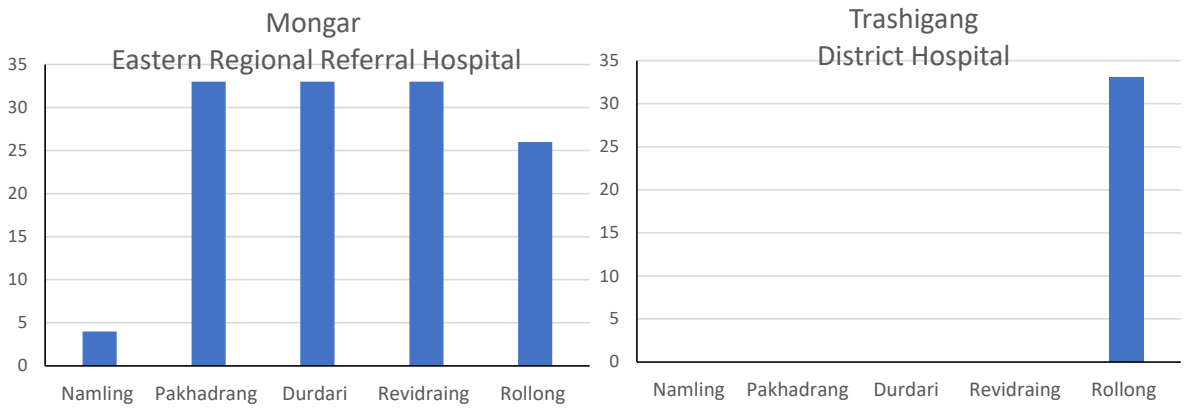
Figure 1-6-8 Alternatives of Gewog Residents If the Bridges Are Closed

(2) Frequency of Passing the Bridges by Hospital Users

A questionnaire survey was conducted to investigate the bridge usage of hospital users at two locations: Eastern Regional Referral Hospital in Mongar and Trashigang District Hospital in Trashigang. The number of hospital users surveyed was 73 in total, comprising of 40 at the Eastern Regional Referral Hospital and 33 at Trashigang District Hospital. Figure 1-6-9 summarizes the frequency of bridge usage that respondents likely passed on their way to the hospital based on their place of residence. Out of the users of Reginal Referral Hospital, many of them passed the four bridges at the east of Mongar (Pakhadrang to Rollong Bridge) as they were from Trashigang District in the east and Tashiyangtse District in the north of Trashigang District in addition to those from Mongar District. Users of

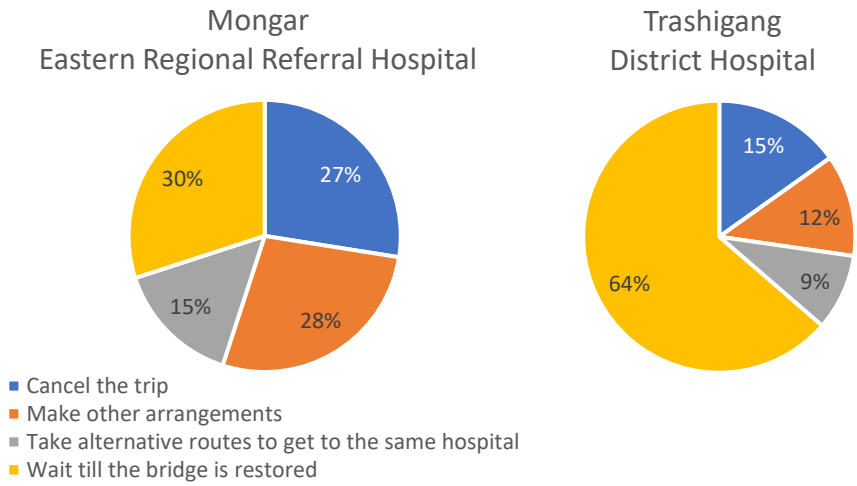
Trashigang District Hospital were residents of Trashigang and Mongar Districts and they passed only Rollong Bridge out of the five, which was the closest to the hospital. Regarding the frequency of respondents' visits to hospitals, 47% of Regional Referral Hospital users and 88% of Trashigang District Hospital users answered they visited several times a year or more.

As for the alternatives if the bridges are closed (Figure 1-6-10), most users of both hospitals responded that they would either wait until the bridge be restored or cancel their visit.



Source: JICA Survey Team

Figure 1-6-9 Frequency of Passing the Bridges by Hospital Users



Source: JICA Survey Team

Figure 1-6-10 Alternatives of Hospital Users If the Bridges Are Closed

(3) Frequency of Passing the Bridges by Bus Terminal Users

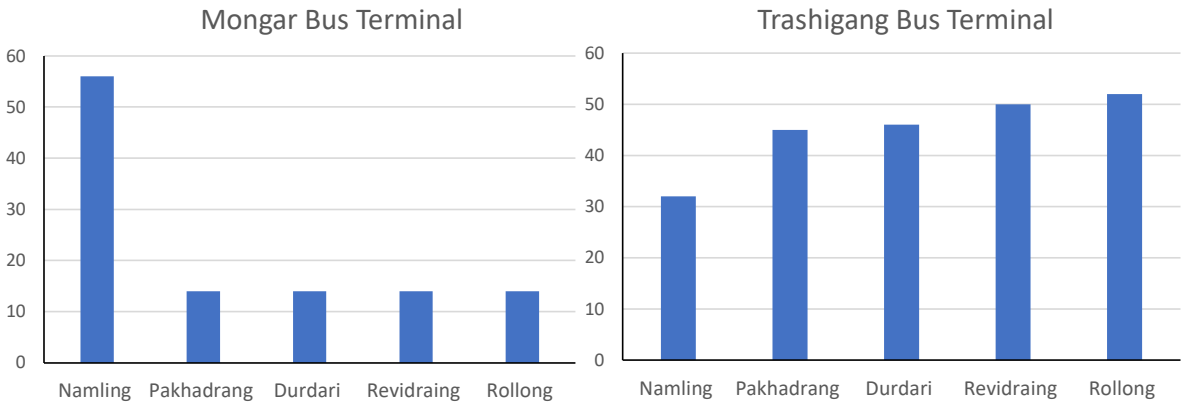
The questionnaire survey was conducted at bus terminals in Mongar and Trashigang to investigate the use of bridges by travellers. A total of 123 travellers were surveyed consisting of 71 in Mongar and 52 in Trashigang, of which 14 travellers in Mongar were heading toward Trashigang (east) and 57 toward Thimphu (west), and all in Trashigang were heading toward Mongar and Thimphu (west).

The frequency of passing through the bridges by travellers is shown in Figure 1-6-11. At Mongar bus terminal, Namling Bridge had a high frequency due to the large number of travellers heading west. At

Trashigang bus terminal, the bridges farther west from the departure had lower frequencies; however, even Namling Bridge located at the farthest west had more than half of the entire number of travellers.

Many respondents cited working and medical care as the purpose of their travel (Figure 1-6-12). As for frequency of travel, more than half of the travellers at both terminals reported they travelled several times a year or more, and 10% at Mongar and 4% at Trashigang were identified as frequent travellers who travelled several times a week or more.

In terms of alternatives if the bridge is closed (Figure 1-6-13), 52% of travellers at Mongar and 73% at Trashigang indicated that they would cancel their trips.

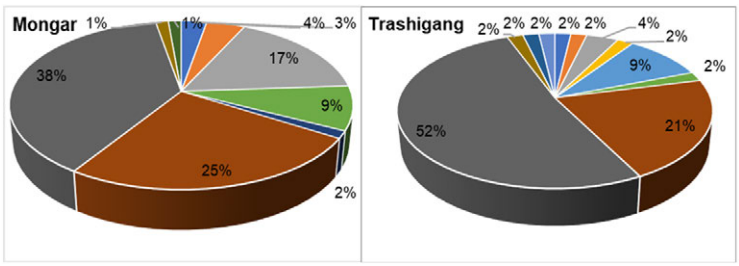


N=71

N=52

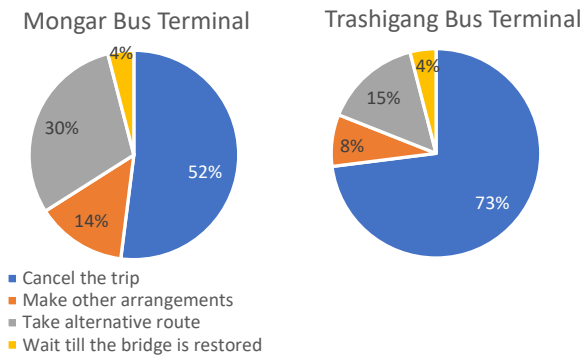
Source: JICA Survey Team

Figure 1-6-11 Frequency of Passing the Bridges by Bus Terminal Users



Source: JICA Survey Team

Figure 1-6-12 Travel Purpose of Bus Terminal Users



Source: JICA Survey Team

Figure 1-6-13 Alternatives of Bus Terminal Users If the Bridges Are Closed

1-6-5 Needs of Rehabilitation of the Bridges and the Benefits

The five bridges are located on the Primary National Highway No.1, which passes through Mongar and Trashigang, the major towns in eastern Bhutan. In order to examine benefits of the bridge rehabilitation, the use of the bridges was investigated in six Gewogs in the vicinity of the bridges. The results showed that although residents of the six Gewogs do not necessarily use the five bridges frequently, Namling Bridge is relatively well used by local residents of Saling Gewog, and about 30% of households in Samkhar, Trashigang District, use the bridge at least once a year, indicating that Namling Bridge is used by residents in a wide area. This may reflect the fact that Namling Bridge is located on the way from Trashigang and Mongar toward Thimphu, the capital of the country, and is in an important position to connect the eastern part of the country with the capital city. The other four bridges were relatively well used by residents east of Mongar and were considered to play an important role in regional mobility.

The purpose of bridge passage varied, but many respondents cited medical care as the purpose; the fact was confirmed by the survey conducted at hospitals. In particular, Eastern Regional Referral Hospital in Mongar was found to be visited by residents not only from within Mongar District but also from outside such as from Trashigang District, suggesting that the four bridges located on the way to the hospital from the east are important for the traffic.

A common result in the surveys of Gewog residents, hospital users, and bus terminal users was that many respondents answered that they would cancel their travel or wait until the bridges be restored if the bridges become impassable. Some respondents indicated that they would take an alternate route, but this would mean a significant detour, such as via more time-consuming farm roads or India, which may not be practical. Without a safe and realistic detour route, residents will have no choice but to wait for restoration, which will not only disrupt economic activities and livelihoods, but may also be life-threatening in some cases due to limited access to medical care. The Primary National Route No.1 and its bridges are the only route practically available to local residents, and it is imperative to eliminate the risk of any of the five bridges becoming impassable due to bridge collapse, etc. It is possible to conclude that the benefits of reconstruction and rehabilitation are very high.

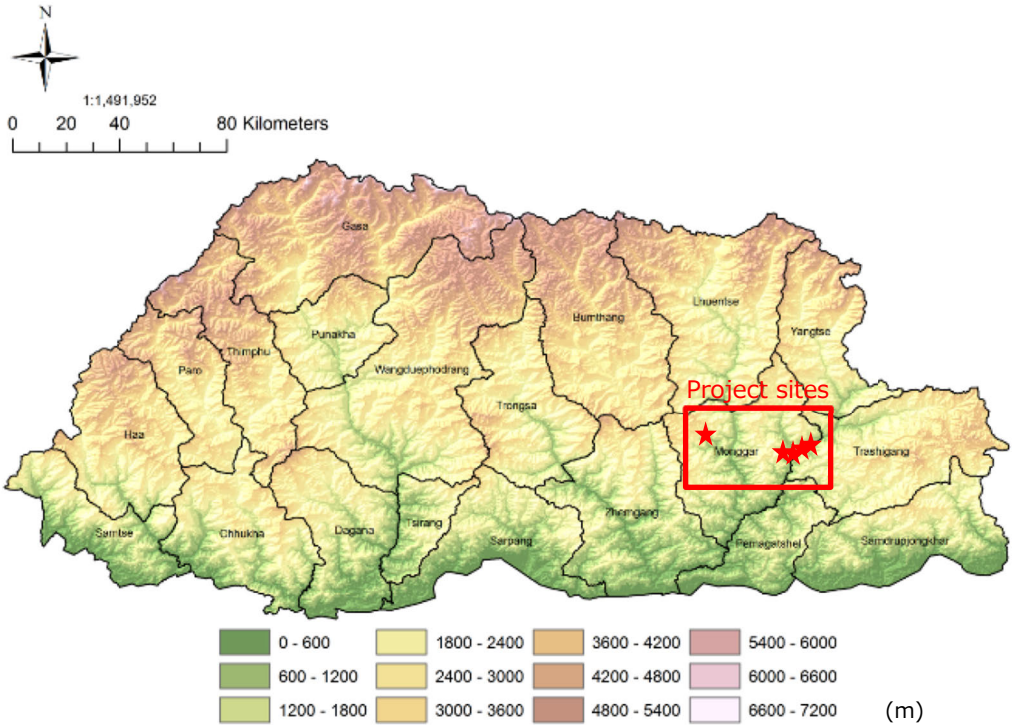
1-7 Environmental and Social Considerations

(1) Baseline of the Environmental and Social Conditions

1) Topography and Geology

Mongar District, where the five bridges are located, is situated in the eastern Himalayan Mountains, which are characterized by diverse and rugged terrain. The elevation in the district varies considerably from about 200 m to more than 4,000 m, and the mountain ranges, deep valleys, and steep slopes are forming a scenic mountain landscape.

The geology of the area where Mongar District is located consists mainly of alluvium; rounded boulders can be seen exposed on the slopes. These alluvial deposits produce moderately coarse soils and form fine or very fine sandy loam.



Source: Bhutan State of the Environment Report 2022, National Environment Commission

Figure 1-7-1 Elevation in the Country and the Location of Project Sites

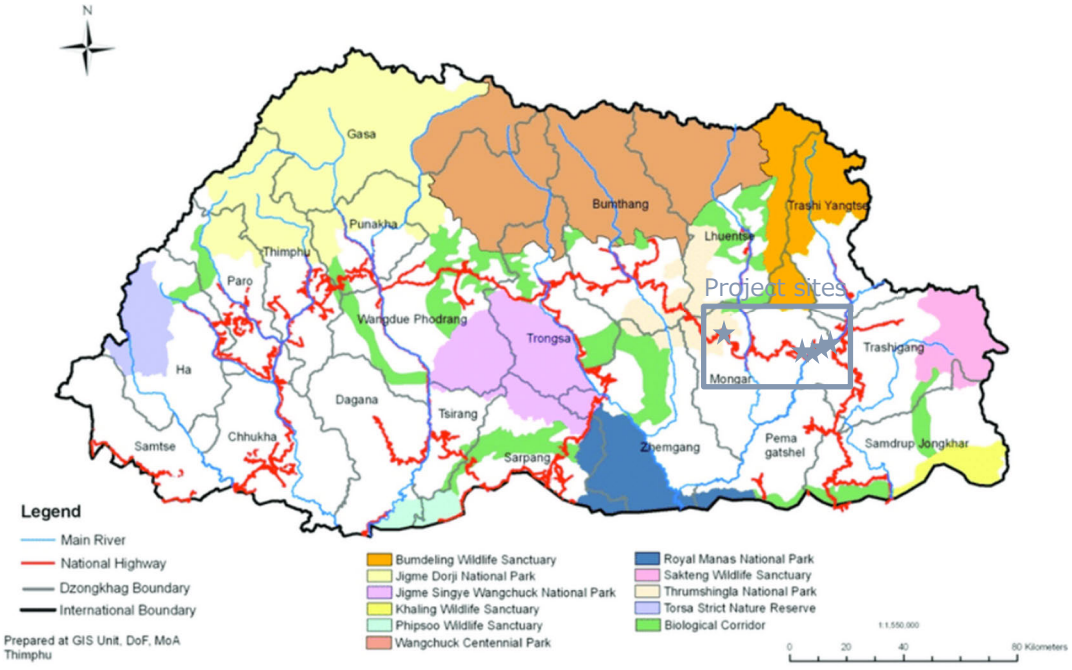
2) Protected Areas

The government of Bhutan has designated protected areas based on Forest and Nature Conservation Act (2023) to be managed by the Department of Forests and Park Services of the Ministry of Energy and Natural Resources. According to Forest and Nature Conservation Rules and Regulations (2017) under the Act, protected areas are designated when (1) the area is of biological significance to the country, or the world at large; (2) the specific habitat area is under threat, and its protection is of national interest; or (3) the area is necessary for protection or conservation for hydrological or watershed reasons; and (4) the area is of cultural or natural heritage significance. " Currently, 10 areas are designated as protected areas, connected by biological corridors (Figure 1-7-2). Many of these protected areas are also

designated as Key Biodiversity Areas (KBA) and Important Bird and Biodiversity Areas (IBA) by international organizations such as BirdLife International (Figure 1-7-3).

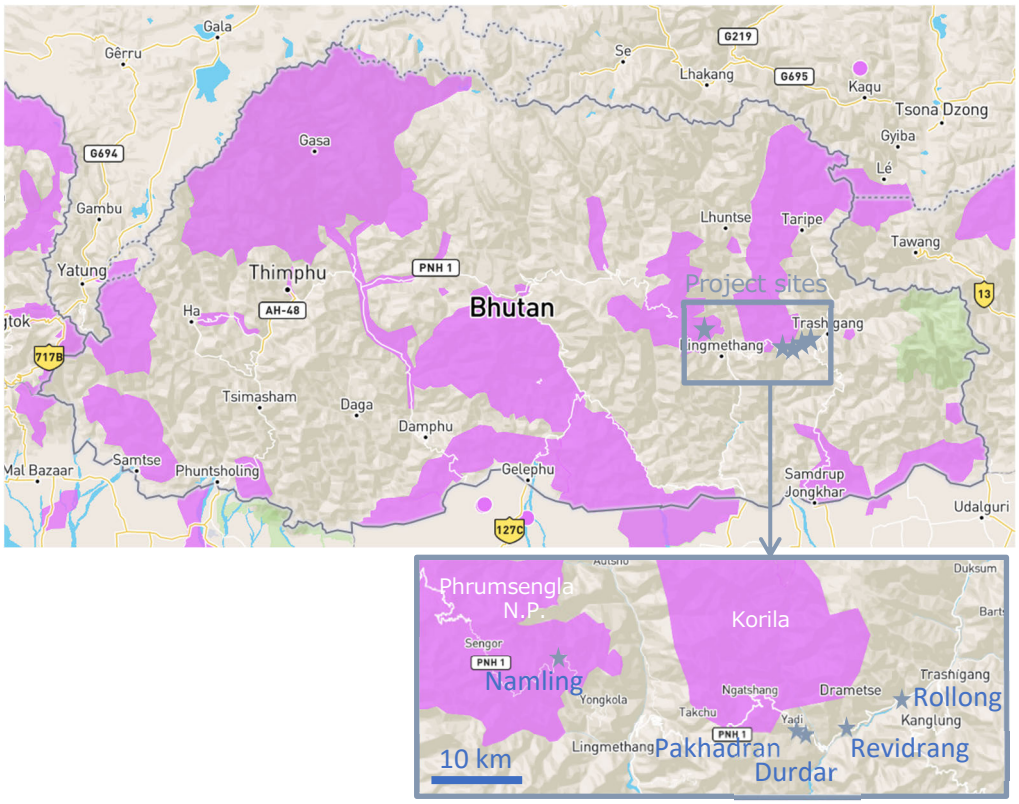
Namling Bridge is located in Phrumsengla National Park, a protected area established to protect temperate ecosystems. The responsible agency for the park management is Phrumsengla National Park Office of Department of Forests and Park Services, and it is working on preparing the park management plan and its operation. The area of the national park has been divided into four zones, core zone, transition zone, buffer zone, and multiple use zone based on Forest and Nature Conservation Act (2023) and the zonation guidelines of the department. The levels of the protection is the highest in core zone, and the degree of acceptance of human activity increases in the order of transition zone, buffer zone, and multiple use zone (Table 1-7-1). According to the latest zonation map issued in 2023 (Figure 1-7-4) and the confirmation with the park office, the Right of Way (ROW) of the National Highway, 100 feet (approximately 30 m) wide, falls in a multiple use zone, and 150 m on each side of the ROW is a buffer zone. It shows that the existing Namling bridge is in the multiple use zone, and the proposed site for the replacement (50 m downstream of the existing bridge) is in the multiple use zone for the abutment within the ROW and in the buffer zone for the structure outside the ROW. It means that a part of the superstructure and a part of the slope protection of Namling Bridge is recognized to fall into the buffer zone (Figure 1-7-5). The slope protection works will include cutting slope with a backhoe and blasting in combination. Blasting will be performed in a period of about 1.5 months with several small-scale blasting operations to excavate up to 4 m of the ground surface. Figure 1-7-6 shows examples of the slope protection.

According to the zonation guidelines, infrastructure development is available as far as necessary clearances are obtained. The necessary clearances for the Project are Forestry Clearance and Environmental Clearance. These clearances can be issued even if blasting works are applied. Blasting works has already been implemented for road expansion at the national highway near Namling bridge.



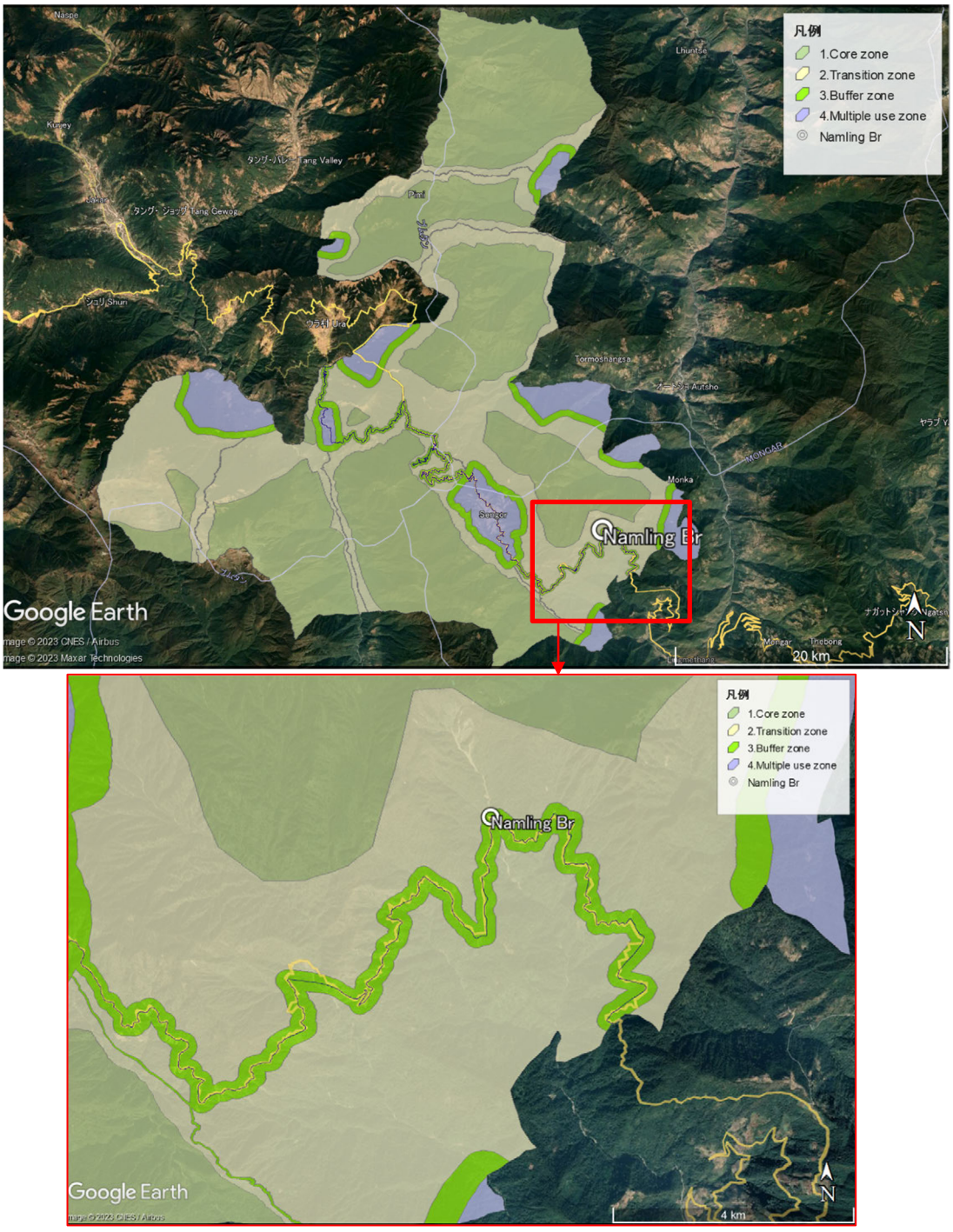
Source: Department of Forests & Park Services

Figure 1-7-2 Locations of Protected Areas and the Project Sites



Source: Integrated Biodiversity Assessment Tool

Figure 1-7-3 Locations of KBA/IBA and the Project Sites



Source: Phrumsengla National Park Office

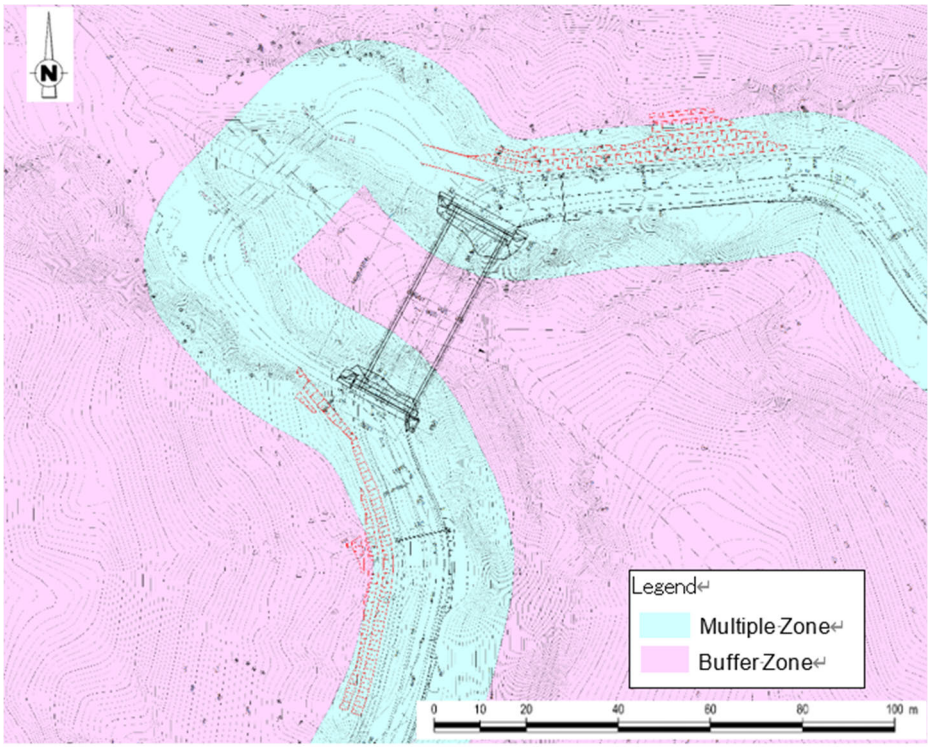
Figure 1-7-4 The Zoning Map of Phrumsengla National Park and the Location of Namling Bridge

Table 1-7-1 Definition of Zones and the Protection Levels

Name of Zones	Definitions and Protected Levels
1. Core zone	Core zones are areas with high conservation values that seem to provide critical services for the persistence of flora and fauna of international, regional, national or local importance including resident or migratory fauna. This is a non-negotiable zone except in cases used for regulated research and monitoring programs.
2. Transition zone	Transition zones are areas of interdependence between wildlife and communities wherein traditional and legal rights for sustainable use of natural resources is permitted for a certain period of time (e.g., cordyceps collection areas and pasture lands). The protection status of this zone is equivalent to that of the core zone except during the traditional/legal use-right season or for a fixed time use.
3. Buffer zone	Buffer zones are classified mainly to provide cushioning function to the core or transition zone when these zones are located in the immediate vicinity of anthropogenic disturbances both from within and outside of the protected aeras. The trails that pass through the transition zone will also become part of the buffer zone after assigning a minimum buffer width on either side. The buffer zone may be regarded as an area in which human interventions is less intensive than what might be found in the multiple-use zone and may accommodate activities for environmental education, tourism, traditional resource use and recreation facilities. The following activities shall be prohibited in the buffer zone except after obtaining all necessary clearances from the concerned agencies: - Infrastructure development - Timber extraction - Non-wood forest produce collection
4. Multipule use zone	Multiple use zone may include settlements, built-up areas, private registered lands and resource allocation areas for the residents of the protected area. This zone is also termed as 'zone of cooperation' underscoring the role of cooperation between the park management and its residents. The area shall be classified based on the resource mapping exercise and resource need assessment of local communities inside the park. The area includes resource allocation such as collection of fuelwoods, ecotourism, construction of infrastructure such as transmission lines and roads, agricultural farmlands, grazing, visitor centres, campsites, etc. The following activity shall be restricted in the multiple use zones except with a written permission from Department of Forests and Park Services, and only following a determination that the activity is necessary to accomplish the objectives of nature conservation and the zone designation of the protected area. - Timber extraction - Quarrying for rural used by the local inhabitants - Developmental activity

Source: Department of Forests and Park Services, Forest and Nature Conservation Code of Best Management Practices of Bhutan, Vol IV: Protected Area Management

Nature Conservation Division, Department of Forests and Park Services, Ministry of Agriculture and Forests, Protected Area Zonation Guidelines of Bhutan, 2020.



Source: JICA survey team

Figure 1-7-5 Zones around the Reconstruction Site of Namling Bridge

Slope protection (Teleganchu Bridge)

Guard fence

Source: Left; JICA survey team, Right; https://www.proteng.co.jp/product_detail.php?Srch=y&keyno=10

Figure 1-7-6 Examples of Slope Protection and Guard Fence

3) Endangered Species

Table 1-7-2 presents a list of wildlife species in Phrumsengla National Park. The list includes species classified as endangered on IUCN Red list, such as red panda, dhole, tiger, and alpine musk deer, as well as species regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Table 1-7-2 Wildlife Species in Phrumsengla National Park

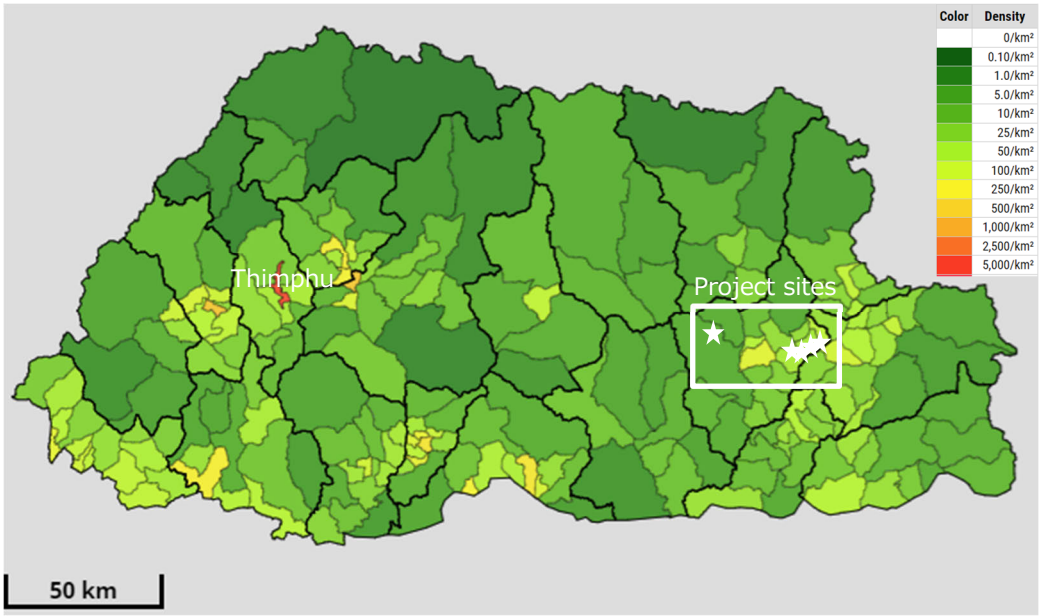
	Order	Family	Common Name	Scientific Name	Protected status		
					IUCN	National legislation	CITES
1	Primates	Cercopithecidae	Assam Macaque	*Macaca assamensis*	NT		
2			Black Capped Langur	*Trachypithecus pileatus*	VU		I
3	Carnivora	Ailuridae	Red Panda	*Ailurus fulgens*	EN	FNCA & FNCRR	I
4		Canidae	Dhole	*Cuon alpinus*	EN		II
5			Asian Red Fox	*Vulpes vulpes*	LC		
6		Felidae	Asian Golden Cat	*Catopuma temminckii*	NT		II
7			Asian Leopard Cat	*Prionailurus bengalensis*	LC	FNCA & FNCRR	II
8			Clouded Leopard	*Neofelis nebulosa*	VU	FNCA & FNCRR	I
9			Leopard	*Panthera pardus*	VU	FNCA & FNCRR	I
10			Tiger	*Panthera tigris*	EN	FNCA & FNCRR	I
11			Marbled Cat	*Pardofelis marmorata*	NT		I
12		Mustelidae	Asian Small-clawed Otter	*Anonyx cinereus*	VU		
13			Himalayan Yellow Throated Martin	*Martes flavigula*	LC		
14		Ursidae	Himalayan Black Bear	*Ursus (Selenarctos) thibetanus*	VU	FNCA & FNCRR	I
15	Cetartiodactyla	Bovidae	Hymalayan Goral	*Naemorhedus goral*	NT		I
16			Barking Deer/ Muntjac	*Muntiacus muntjak*	LC		
17			Mainland Serow	*Capricornis sumatraensis*	VU		
18			Takin (Bhutan Takin)	*Budorcas taxicolor whitei*	VU	FNCA & FNCRR	II
19		Cervidae	Sambar Deer	*Rusa unicolor*	VU	FNCRR	
20		Moschidae	Alpine musk deer	*Moschus chrysogaster*	EN		I
21		Suidae	Himalayan Wild Pig	*Sus scrofa*	LC		
22	Lagomorpha	Ochotonidae	Royle's Pika	*Ochotona roylei*	LC		
23	Insectivora	Soricidae	Himalayan Water Shrew	*Chimarrogale himalayica*	LC		
24	Rodentia	Rodentia	Malayan Porcupine	*Hystrix brachyura*	LC		
25		Sciuridae	Orange-bellied Himalayan Squirrel	*Dremomys lokriah*	LC		
26			Three-Striped Himalayan Squirrel	*Funambulus palmarum*	LC		
27			Parti-coloured Flying Squirrel	*Hylopetes alboniger*	LC		
28			Black Giant Squirrel	*Ratufa bicolor*	NT		

Notes) IUCN categories/EN:Endangered, VU:Vulnerable, NT:Near Threatened, LC:Least Concern
National legislation/FNCA: Protected by Forest and Nature Conservation Act 1995
FNCRR: Protected by Forest and Nature Conservation Rules and Regulation 2017
CITES(Convention on International Trade in Endangered Species of Wild Fauna and Flora)/ I:threatened with extinction,
II:trade must be controlled,

Source: Wangchuk, R. & Namgyel, U. 2016. Faunal Diversity of Phrumsengla National Park. Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan. Ura: Bumthang.

4) Population

The distribution of population density in the country is shown in Figure 1-7-7. According to the 2017 population census, the population of the country is 727,145, of which 114,551 are concentrated in Thimphu, the capital city. The population of Mongar District, where the project sites are located, is 37,150, of which 4,452 are in Mongar Town, the capital of the district; 1,929 in Saling, where Namling Bridge is located; 2,494 in Chaskhar, where Pakhadrang and Durdari Bridges are located; Drametse, where Revidrang and Rollong Bridges are located, has 1,848 people.

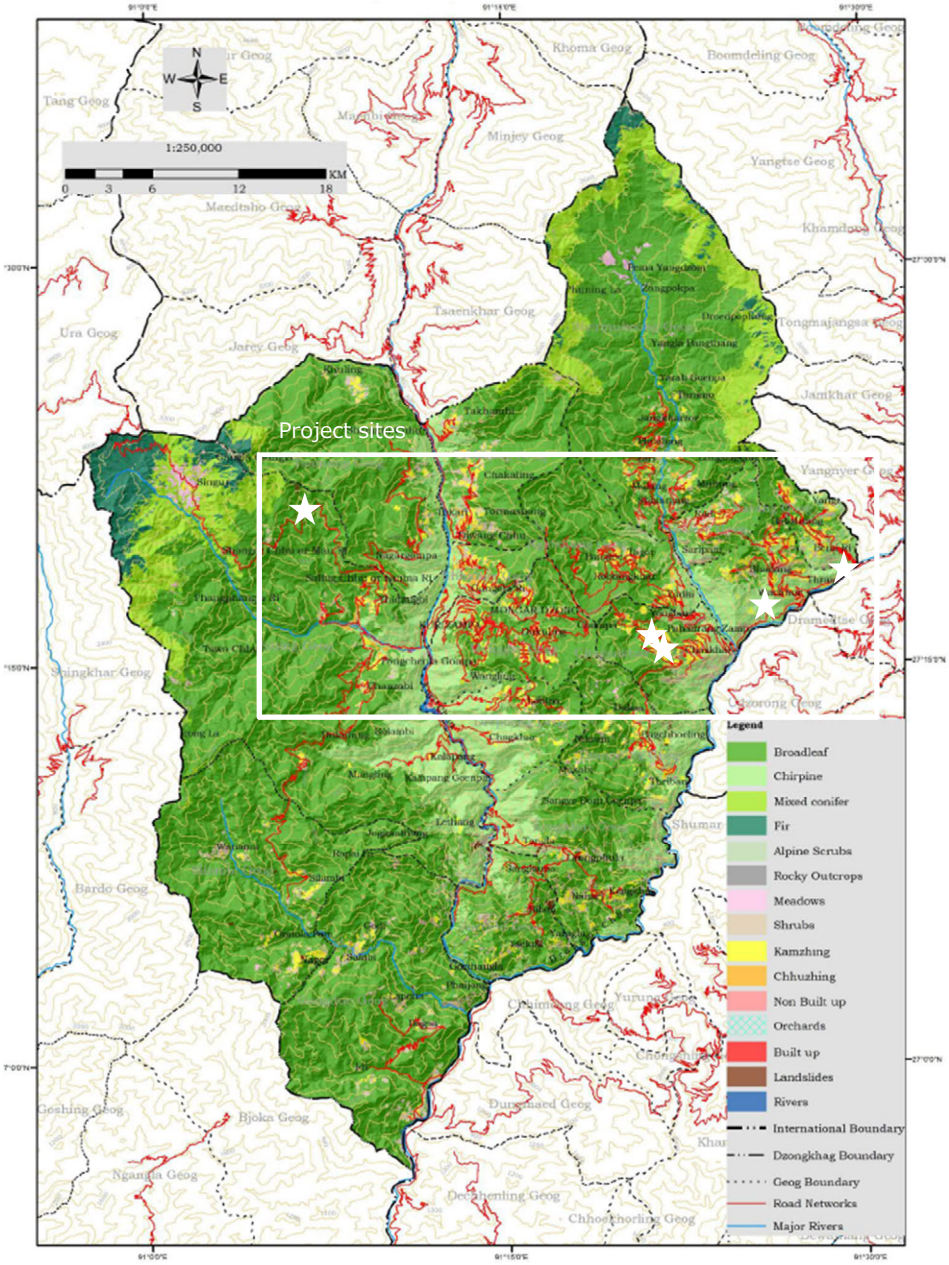


Source: CITYPOPULATION

Figure 1-7-7 Distribution of Population Density in the Country (2017 Census)

5) Land Cover

Figure 1-7-8 presents the land cover in Mongar District. More than 90% of the area of Mongar District is covered by forests consisting of broadleaf and chirpine, with rice, corn, wheat, potatoes, and vegetables cultivated among the forests. The cultivated land types are both Kamzhing (dry land use) and Chhuzhing (wet land use). There are a few urban areas in the center of Mongar Town; the area is limited to less than 1% of the total area.



Source: Land Use and Land Cover of Bhutan 2016, Forest Resources Management Division

Figure 1-7-8 Land Cover Map of Mongar District

(2) Legislation of Environmental and Social Consideration in Bhutan

1) Lows, Regulations, Standards, etc. for Environmental Considerations

Environmental laws, regulations, and standards of the country are listed in Table 1-7-3. The Environmental Assessment Act (2000) which regulates environmental assessments in Bhutan stipulates that an Environmental Clearance (EC) is required for implementing projects. According to the guidelines (A Guide to Environmental Clearance Application Procedure, May 2022) of the National Environment Commission (NEC), the requirements and process of obtaining an EC are decided depending on the project types, with Green projects not requiring an EC, Blue projects requiring an EC which can be obtained through an Initial Environmental Examination (IEE), and Red projects requiring an Environmental Impact Assessment (EIA).

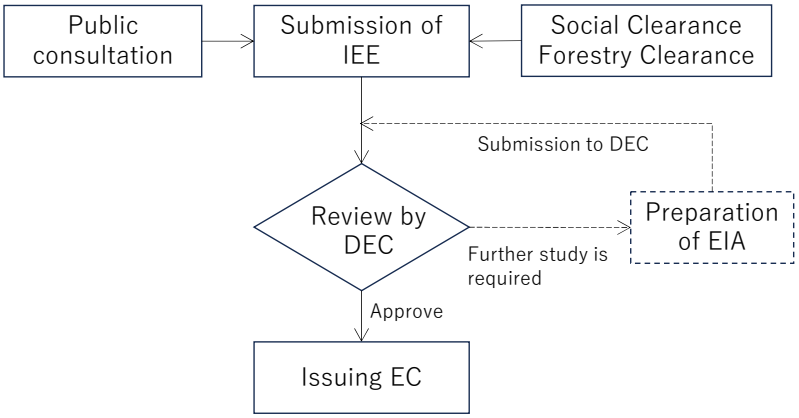
In the case of bridge construction, the project is classified as Blue under the above guidelines and is required to obtain an EC based on IEE; the application needs to be submitted to Dzongkhag (District) Environment Commission (DEC). The process for obtaining EC is illustrated in Figure 1-7-9. Since the targets bridges of this Project are located in Mongar District, the application should be submitted to DEC of Mongar District.

The guidelines also stipulate the form of IEE. Project proponents are required to fill the form with project description, scale, etc. and submit it to DEC together with the environmental management plan and the record of public consultation. After the submission, DEC will review the IEE and issue an EC but may require an EIA if the result of the review shows that further investigation is necessary. According to the environmental officer of Mongar District, the EIA is not required for this Project because the Project is replacements of existing bridges. To obtain an EC, the project proponent needs to obtain a letter of consent (Social Clearance) from the local government, as well as a Forestry Clearance in accordance with Forest and Nature Conservation Rules and Regulations, 2017. The Forestry Clearance is equivalent to a land use permit and is issued by Department of Forests and Park Services through an online application by the proponent. According to the district and Department of Forestry and Park Services, durations for issuing the clearances are about 10 days for the Forestry Clearance and one week for EC from the submission of IEE.

Table 1-7-3 Laws, Regulations, Standards, etc. for Environmental Considerations

Classification		Name	Overview
General for Environmental Considerations		National Environment Protection Act, 2007	A basic low for protecting environment
Environmental Impact Assessment	Laws and Regulations	Environmental Assessment Act, 2000	Process of environmental assessment
		Regulation for Environmental Clearance of Projects, 2016	Detailes of the process above
	Guidelines	Environmental Assessment Guideline - May 2012	Technical guidelines of EIA
		A Guide to Environmental Clearance Application Procedure - May 2022	Details of application of EC and the form, etc.
Environmental Standards		Environmental Standards, 2020	Ambient and emission standards
Forest and Biodiversity Conservation		Forest and Nature Conservation Act, 1995	Conservation and sustainable use of forest, wildlife, and natural resources
		Forest and Nature Conservation Rules and Regulations, 2017	Implementation rules of forest management and use
		Biodiversity Act, 2022	Conservation and use of biological genetic resources
Waste Management		Waste Prevention and Management Act, 2009	Principle of waste management
		Waste Prevention and Management Regulation, 2012	Implementation rules of waste management
		Waste Prevention and Management Regulation, 2016	ditto
Land Acquisition and Resettlement		Land Act, 2007	Land ownership, registration, acquisition, transaction, lease, rights related to lands, etc.
		Land Rules and Regulations, 2007	Details of the act above
		Land Compensation Rate, 2019	Compensation rate of land and structure
Labor		Labour and Employment Act, 2007	Working condition, wadge, duties of employer on health and safety management, etc.

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-7-9 The Process of Environmental Clarance for Bridge Construction Projects

2) Gaps with JICA Guidelines for Environmental and Social Considerations

A gap analysis was made for filling the disparities between JICA Guidelines for Environmental and Social Considerations and the legislation in Bhutan. The results are summarized in Table 1-7-4.

Table 1-7-4 A Gap Analysis between JICA Guidelines and Legislation in Bhutan

Items	JICA Guidelines for Environmental and Social Considerations	Legislation in Bhutan	Measures to Fill the Gaps in this Project
Underlying principles	- Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan. (JICA Guidelines, Appendix 1.1)	An environmental impact assessment is required to obtain a development permit in accordance with the law. (Environmental Assessment Act, 2000).	None
Information disclosure	- EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them. - EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted. (JICA Guidelines, Appendix 2)	There are no provisions regarding the language of EIA reports. EIA reports are publicly available, and copies are permitted to be obtained. (Regulation for Environmental Clearance of Projects, 2016)	EIA reports are not required for the Project. A draft environmental management and monitoring plan based on IEE was prepared in Dzongkha and distributed to the local residents during the consultation meetings.
Public consultation	- In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared. - Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared. (JICA Guidelines, Appendix 2)	Public consultation is required for applying for an environmental clearance to be reflected in the projects. (Regulation for Environmental Clearance of Projects, 2016) There are no provisions regarding frequency or timing.	Consultation meetings were held twice, once when the environmental impact assessment items were selected and once when the draft report was prepared.
Impact Assessment Items	- The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social	Various aspects are listed as impacts to be assessed, including relocation and livelihood impacts, land use change, habitat impacts and fragmentation, air pollution, noise, water pollution, waste, worker influx, risk of accidents, health hazards, traffic congestion, etc. It is also noted that indirect and cumulative impacts should not be omitted. (Environmental Assessment Guideline,2012)	The survey items were selected based on JICA Guidelines.

Items	JICA Guidelines for Environmental and Social Considerations	Legislation in Bhutan	Measures to Fill the Gaps in this Project
	infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety. - In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project. (JICA Guidelines, Appendix 1.3)	No provisions focusing on socially vulnerable groups, equality of benefits and losses, gender, children's rights, and conflicts of interest are found.	
Monitoring, complaint handling, etc.	- Project proponents etc. should make efforts to make the results of the monitoring process available to local project stakeholders. - When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders' participation in relevant projects. Project proponents etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems. (JICA Guidelines, Appendix 1.9)	Although there are no regulations specific to monitoring results, public disclosure of environmental information is recommended. (National Environment Protection Act, 2007) Complaints after issuance of an environmental clearance are examined by the relevant agency and, if necessary, mitigation measures, compensation, or a review of the conditions of the environmental clearance are made. If there is an appeal against the decision, an appeal may be filed with the National Environmental Commission or a court of law. (Regulation for Environmental Clearance of Projects, 2016)	The results of monitoring will be provided by the DoST to residents and others as requested.
Ecosystem and biota	- Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. (JICA Guidelines, Appendix 1.6)	The forest is protected by the Forest and Nature Conservation Act, 1995 and requires a permit for use.	None
Indigenous peoples	- Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses. (JICA Guidelines, Appendix 1.8)	Laws regarding protection of indigenous peoples are not found.	No indigenous peoples to be protected are identified.

Source: JICA Survey Team

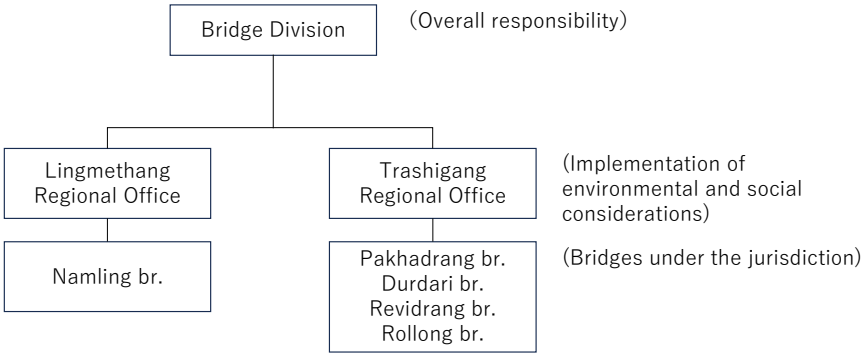
3) Roles of Related Organizations

For implementing the Project, it is necessary to obtain an Environmental Clearance (EC) through IEE based on the legislation of Bhutan. The applicant for the EC is the project executing agency, DoST, and the EC will be issued by DEC (Dzongkhag Environment Commission) of Mongar District. Table 1-7-5 lists applicants and permit issuers of the EC and the other related permits. The applications will be submitted separately by bridge: Namling Bridge is by Lingmethang Regional Office and Durdari Bridge is by Trashigang Regional Office of DoST, respectively.

Table 1-7-5 Applicants and Issuers of Environment-Related Permits

Name of Permit	Applicant	Issuer	Status (as of November 2023)
Environmental Permits (EC)	DoST (Regional Office)	Dzongkhag Environmental Commission (DEC)	Under preparation (will be issued by March 2024)
Forestry Clearance	DoST（Regional Office）	Department of Forests and Park Services	Already issued in October for Durdari br. and November for Namling br.2023
Social Clearance	DoST（Regional Office）	Local government of the project site (Gewog)	Already issued in October 2023

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-7-10 Implementation Structure of Environmental and Social Considerations of DoST

(3) Scoping

Table 1-7-6 presents scoping results for reconstruction of Namling and Durdari Bridges selected for the Project. Table 1-7-7shows a TOR of the environmental and social survey to be conducted in this preparatory survey.

Table 1-7-6 Scoping Results

Category	No.	Impacts	Evaluation		Reasons for Evaluation
			Pre/ During construction	Operation phase	
Pollution	1	Air pollution	✓		**Construction phase:** A temporary increase of dust and exhaust emissions is expected due to the operation of construction vehicles and heavy equipment.
					Operation phase: Passing vehicles will emit air pollutants; however, additional air pollution is not expected with the new bridge because the new bridge is to maintain existing traffic.

Category	No.	Impacts	Evaluation		Reasons for Evaluation
			Pre/ During construction	Operation phase	
	2	Water pollution	✓		**During construction:** Earthworks and riprap works may cause turbidity in the river. Domestic wastewater will be generated from construction workers' camps. **Operation phase:** No water pollution is expected with the new bridge in service.
	3	Waste	✓		**Construction phase:** Construction waste such as surplus soil and hazardous waste such as used oil may be generated. Construction workers' camps generate domestic wastes. **Operation phase:** No waste will be generated by the bridge in service.
	4	Soil contamination	✓		**Construction phase:** Oil and other substances may leak from construction equipment and vehicles. **Operation phase:** No soil contamination is expected by the bridge in service.
	5	Noise and vibration	✓		**Construction phase:** Noise and vibration are expected due to operation of construction machinery and vehicles. **Operation phase:** Noise and vibration will be generated by passing vehicles; however, additional noise or vibration is not expected with the new bridge because the new bridge is to maintain existing traffic.
	6	Ground subsidence			Activities that would cause land subsidence (use of large volumes of groundwater) are not anticipated.
	7	Odor			Activities that would cause odor are not anticipated.
	8	Sediment quality			Activities that would cause deterioration of sediment qualities are not anticipated.
Natural environment	9	Protected area	✓	✓	Namling Bridge is located in a national park. Durdari Bridge is outside of protected areas.
	10	Ecosystem	✓	✓	**Construction phase:** Habitats of flora and fauna in/around the construction site may be disturbed by the activities. **Operation phase:** Wildlife could be involved in traffic accidents on the bridge.
	11	Hydrology			Activities that would alter the river flow are not anticipated.
	12	Topography and geology	✓		**Construction phase:** The topography will change due to cutting slopes. **Operation phase:** No topographic or geological impacts are expected due to the bridge in service.

Category	No.	Impacts	Evaluation		Reasons for Evaluation
			Pre/ During construction	Operation phase	
Social environment	13	Involuntary resettlement	✓		**Pre-construction phase:** Although no buildings such as houses or land use such as agricultural land are identified within the proposed construction area (both legal and illegal), land ownership needs to be clarified. **Operation phase:** No land acquisition or resettlement is anticipated for the bridge in service.
	14	The poor	✓	✓	Impacts are to be assessed after examining economic conditions of local residents living near the project sites.
	15	Indigenous and ethnic minorities	✓	✓	Although no ethnic minorities or indigenous peoples are identified in the vicinity of the project sites, it should be confirmed.
	16	Local economy such as employment and livelihood	✓	✓	**Construction phase:** Employment opportunities are expected due to construction activities. **Operation phase:** The bridge reconstruction is expected to stabilize the local economy by reducing the risk of bridge falls, etc.
	17	Land use and utilization of local resources			**Pre-construction phase:** The proposed construction area is limited and will not affect land use, etc. **Operation phase:** No land use changes are expected with the bridge in service.
	18	Water usage	✓		**Construction phase:** Although the construction work will not use a large amount of water, it is necessary to confirm the water use in the river since the construction work will take place in the vicinity of the river. **Operation phase:** No impact on water use is expected with the bridge in service.
	19	Existing social infrastructure and services	✓	✓	**Pre-construction phase:** It is necessary to consider the construction work not to hinder existing traffic on the national highway. **Operation phase:** The bridge reconstruction is expected to stabilize access to social services such as hospitals, etc., as it will reduce the risk of bridge falls, etc.
	20	Social capital and local organizations for decision making etc.			Since the Project is a national project aims to secure benefits and safety of the national highway, no impact is anticipated on local decision-making functions.
	21	Misdistribution of benefit and damage	✓	✓	Although no factors have been identified to cause misdistribution of benefit and damage, it should be assessed after collecting information of the surrounding social conditions.
	22	Local conflicts of interests	✓	✓	Although no factors have been identified to cause local conflicts of interests, it should be assessed after collecting information of the surrounding social conditions.
	23	Cultural heritage	✓	✓	Need to identify surrounding cultural heritage, etc.
	24	Landscape	✓	✓	Need to identify the need for landscape considerations.
	25	Gender	✓	✓	To be assessed based on the characteristics of the community.
	26	Right of children	✓		**Construction phase:** Need to assess the possibility of child labor in construction. **Operation phase:** No impact on children's rights is anticipated by the bridge in service.

Category	No.	Impacts	Evaluation		Reasons for Evaluation
			Pre/ During construction	Operation phase	
	27	Infectious diseases such as HIV/AIDS	✓		**Construction phase:** Influx of construction workers may spread infectious diseases such as HIV and Covid-19. **Operation phase:** No outbreak of infectious diseases is expected by the bridge in service.
	28	Working environment (including occupational safety)	✓		**Construction phase:** Occupational safety needs to be considered for construction workers. **Operation phase:** No worker will be involved in the service of the bridge.
Others	29	Accidents	✓	✓	**Construction phase:** Consideration is required on construction accidents and traffic accidents caused by construction vehicles. **Operation phase:** Consideration is required on traffic accidents at the new bridge.
	30	Transboundary impacts and climate change			**Construction phase:** No transboundary impacts or climate change impacts are anticipated due to the limited scale and duration of the construction works. **Operation phase:** No additional greenhouse gases is expected with the new bridge because the new bridge is to maintain existing traffic.

Source: JICA survey team

Table 1-7-7 TOR of the Survey

Category	Items	Survey items	Survey method
Pollution	Air pollution	- Existing condition of air quality (CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$, TSP) (dry season, rainy season) - Environmental standards in Bhutan - Existence of residences, schools, hospitals, etc. in the vicinity of the construction sites	- Field survey (1 site at each bridge, rainy and dry seasons) - Review of laws and regulations, etc. - Comparison of the survey results with the national environmental standards
	Water pollution	- Existing condition of river water quality (BOD, pH, TSS, water temperature, coliform) (dry season, rainy season) - Environmental standards in Bhutan - Domestic use of river water	- Field survey (1 site at each bridge, rainy and dry seasons) - Review of laws and regulations, etc. - Comparison of the survey results with the national environmental standards
	Waste	- Types of construction waste (surplus soil, scraps, hazardous waste, domestic waste from workers' camps) and disposal methods	- Field survey (Conditions of disposal sites, etc.) - Interviews with relevant organizations, etc.
	Soil contamination	- Possibility of oil leaks during construction and prevention measures	- Confirmation of construction details, methods, and equipment
	Noise and vibration	- Existing condition of noise - Environmental standards in Bhutan - Existence of residences, schools, hospitals, etc. in the vicinity of the construction sites	- Field survey (1 site at each bridge, rainy and dry seasons) - Review of laws and regulations - Comparison of the survey results with the national environmental standards

Category	Items	Survey items	Survey method
Natural environment	Protected area (Namling Bridge)	- Confirmation of relevant laws and management plans	- Review of laws and regulations - Interview with the national park manager
	Ecosystem	- Flora and fauna in the vicinity	- Field survey (In the vicinity of each bridge, dry and rainy seasons) - Collecting secondary data if there are, or interviews with local residents
	Topography and geology	- Location of cutting slope and the amount of soil	- Confirmation of construction details
Social environment	Involuntary resettlement	- Land ownership of the construction area	- Interviews with relevant organizations, collecting existing data if there is
	The poor	- Economic condition of residents nearby the sites	- Questionnaire survey (696 households along the national highway)
	Indigenous and ethnic minorities	- Minority and indigenous people	- Questionnaire survey (696 households along the national highway)
	Local economy such as employment and livelihood	- Means of livelihood of residents nearby the sites - Bridge usage by residents and contribution of bridge reconstruction to the local economy	- Questionnaire survey (696 households along the national highway)
	Water usage	- River water usage	- Interviews with residents nearby the sites
	Existing social infrastructure and services	- Bridge usage by residents and contribution to residents' lives by reconstructing bridges	- Questionnaire survey (696 households along the national highway)
	Misdistribution of benefit and damage	- Residents' opinions on bridge reconstruction	- Public consultation
	Local conflicts of interests	- Residents' opinions on bridge reconstruction	- Public consultation
	Cultural heritage	- Existence and location of cultural heritage	- Field survey - Interviews with residents nearby the sites
	Landscape	- Tourist attractions, landscapes requiring consideration	- Field survey - Interviews with residents nearby the sites
	Gender	- Women's right to make decisions at home, etc.	- Questionnaire survey
	Right of children	- Possibility of child labor	- Interviews with local residents and local government
	Infectious disease	- HIV/AIDS and other sexually transmitted infections (STIs)	- Interviews with local government
	Working environment (including occupational safety)	- Working environment for construction workers	- Interviews with local government
Others	Accidents	- Traffic accidents in surrounding area	- Interviews with local government

Source: JICA Survey Team

(4) Prediction of Impacts

The results of the environmental and social considerations survey for reconstruction of Namling and Durdari Bridge are presented below.

1) Pollution

(a) Air pollution

Table 1-7-8 presents air quality observed near the bridges. The air pollutant levels were well below the national environmental standard in both the dry and rainy seasons. Although the Project is expected to temporarily generate dust and exhaust gases during the construction works, little impact on the natural and living environment is expected as far as appropriate measures are taken because the present levels of air pollutants are sufficiently low and no residences, schools, hospitals, and other sensitive facilities are existing around Namling and Durdari Bridge.

Table 1-7-8 Survey Results of Air Quality

Survey date: 25-27 March 2023 (Dry season)

Parameter		Measured results		National standards		International standards (reference)	Measured results (reference)		
		Namling	Durdari	Mixed area	Sensitive area		Pakhadrang	Revidang	Rollong
CO	(ppm)	BDL	BDL	2,000	1,000	-	BDL	BDL	BDL
NO_2	($\mu g/m^3$)	0.088	0.051	80*	30*	40 (1 year)	0.116	0.042	0.101
SO_2	($\mu g/m^3$)	BDL	BDL	80	30	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)	BDL	BDL	BDL
PM10	($\mu g/m^3$)	25.89	35.73	100	75	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)	24.41	35.44	25.55
PM2.5	($\mu g/m^3$)	23.24	17.73	60	60	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)	19.65	23.76	15.87
TSPM	($\mu g/m^3$)	34.93	36.44	200	100	-	33.15	46.62	27.70
Air temperature	(°C)	12.64	20.26			-	26.20	25.97	31.90
Wind Speed	(m/sec)	1.31	0.83	-	-	-	1.47	1.17	1.07
Wind direction		South-east	South-east	-	-	-	South-east	South-east	South-east
Relative Humidity	(%)	75.49	56.27	-	-	-	57.60	51.94	54.12

Survey date: 12-14 July 2023 (Rainy season)

Parameter		Measured results		National standards		International standards (reference)	Measured results (reference)		
		Namling	Durdari	Mixed area	Sensitive area		Pakhadrang	Revidang	Rollong
CO	(ppm)	BDL	BDL	2,000	1,000	-	BDL	BDL	BDL
NO_2	($\mu g/m^3$)	0.116	0.103	80*	30*	40 (1 year)	0.106	0.109	0.116
SO_2	($\mu g/m^3$)	BDL	BDL	80	30	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)	BDL	BDL	BDL
PM10	($\mu g/m^3$)	13.52	22.41	100	75	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)	20.77	12.87	14.78
PM2.5	($\mu g/m^3$)	11.06	12.66	60	60	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)	17.81	9.42	10.01
TSPM	($\mu g/m^3$)	15.69	30.05	200	100	-	30.27	14.89	17.63
Air temperature	(°C)	17.41	23.64			-	29.36	25.86	29.14
Wind Speed	(m/sec)	0.79	0.94	-	-	-	1.29	0.81	1.26
Wind direction		South-east	South-east	-	-	-	South-east	South-east	South-east
Relative Humidity	(%)	89.35	65.13	-	-	-	69.26	68.02	63.92

1. BDL: Below Detectable Limit
2. National standards: Environmental Standards, 2020, National Environment Commission of Bhutan
3. Mixed area means area where residential, commercial or both activities take place
4. Sensitive area means area where sensitive targets are in place like hospitals, schools, sensitive ecosystems
5. Standards with * shows those for Nox
6. International standards: International Finance Corporation, General Environmental, Health, and Safety (EHS) Guidelines, 2007
Interim targets are provided in recognition of the need for a staged approach toachieving the recommended guidelines.

Source: JICA Survey Team

(b) Water pollution

Table 1-7-9 shows the water quality of the river at each bridge site. The water quality was in good condition comparing with the national standards in both the dry and rainy seasons. The total suspended solid (TSS) in the rainy season was several tens of times higher than in the dry season, indicating that turbidity occurs as flow volume increases due to rainfall. According to interviews with neighbouring

villages, river water is not used in the vicinity of any of the bridges, but 50-60 households in a village (Thridangbi Chiwog) located about 10 km downstream of Namling Bridge use the water for irrigation.

There is a possibility that the Project will generate turbidity due to earthworks planned for both bridges and riprap works for Durdari Bridge as well as pollution due to domestic wastewater discharge from workers' camps. However, the turbidity is expected to have little impact because the amount will be limited since no excavation has been planned in the river channel and even if some turbidity is generated, it is expected to be within the range of natural fluctuation. For the domestic wastewater, the impact is not anticipated since it is not used as drinking water; however, appropriate treatment is necessary for securing sanitary conditions.

Table 1-7-9 Survey Results of River Water Quality

Survey date: 25-28 March 2023 (Dry season)

Parameter		Measured results		National standards			Japan Std. (reference)	Measured results (reference)		
		Namling	Durdari	A	B	C		Pakhadrang	Revidang	Rollong
BOD	(mg/L)	1.07	1.22	2	5	50	10	1.26	2.87	1.54
pH		7.34	7.61	6.5-8.5	6.0-9.0	6.0-9.0	6.5-8.5	7.55	7.84	7.23
TSS	(mg/L)	2.34	2.19	25	100	-	-	2.12	2.64	1.86
Water temperature	(°C)	15.6	22.1	-	-	-	-	22.4	22.5	22.1
Fecal Coliform	(MPN/100mL)	4	6	50*	5000*	10000*	-	4	5	3
Total Coliform	(MPN/100mL)	7	9	20*	2000*	5000*	-	8	8	5

Survey date: 12-20 July 2023 (Rainy season)

Parameter		Measured results		National standards			Japan Std. (reference)	Measured results (reference)		
		Namling	Durdari	A	B	C		Pakhadrang	Revidang	Rollong
BOD	(mg/L)	3.62	2.12	2	5	50	10	2.74	3.19	1.86
pH		7.46	7.51	6.5-8.5	6.0-9.0	6.0-9.0	6.5-8.5	7.28	7.74	7.31
TSS	(mg/L)	128.96	67.21	25	100	-	-	78.74	84.92	96.99
Water temperature	(°C)	15.9	22.8	-	-	-	-	23.4	23.1	22.5
Fecal Coliform	(MPN/100mL)	9	13	50*	5000*	10000*	-	11	7	6
Total Coliform	(MPN/100mL)	13	14	20*	2000*	5000*	-	14	12	9

1. Standards: Environmental Standards, 2020, National Environment Commission of Bhutan
2. A: (Very good) Drinking water source without conventional treatment, but after disinfection whenever necessary
3. B: (Good) Drinking water source with conventional treatment
4. C: (Moderate) Used for irrigation, industrial cooling, etc.
5. Japan Std. : Environmental Quality Standards for Conservation of the Living Environment (River; Industry water class 3 and conservation of environment)

Source: JICA Survey Team

(c) Waste

Table 1-7-10 shows the types of waste that could be generated by the construction of this Project and the anticipated disposal measures. The surplus soil generated by cutting slopes will be transported and disposed of at nearby sites approved by DoST. Other construction and solid domestic wastes will be transported and disposed of at existing disposal sites. Disposal sites are identified in Gyelposhing, Mongar District and Satshalo, Tashigang District. Hazardous wastes including used oil from construction equipment are expected to be accepted at these disposal sites. Organic wastes, such as food residues, are to be disposed of considering sanitary conditions, such as by composting. No licences are required related to the waste for the Project.

Table 1-7-10 Types of Wastes Likely Generated by the Construction of this Project and the Expected Disposal Measures

Type of Waste	Disposal Measures
Surplus soil produced by cutting slopes etc.	Transport and disposal to nearby sites with DoST approval
Non-hazardous construction waste (concrete pieces, bitumen, cut trees, etc.)	Transport and disposal at existing disposal sites
Hazardous waste (used oil, etc.)	Transport and disposal at existing disposal sites
Domestic waste	Solid wastes such as plastics are transported and disposed of at existing disposal sites. Organic materials such as food residues are disposed of by composting.

Source: JICA Survey Team

(d) Soil Contamination

Soil contamination is not anticipated because the quantities of hazardous substances to be used for the construction in this Project are limited, such as oil from construction machinery.

(e) Noise and Vibration

Table 1-7-11 presents the results of noise measurements near each bridge. It shows that the noise level is 50-65 Db during both day and night due to its location on the road. As Namling Bridge is located in the National Park, the noise level was compared to the standard of sensitive area. It was almost equal to the standard (55 Db) during the day and above the standard (45 Db) during the night. Durdari Bridge also met the standard (65 dB) during the daytime but exceeded it (55 dB) during the nighttime when compared to the mixed area standard. During the construction, the noise level will increase especially during the daytime when construction is underway due to the addition of construction noise, and the standard may be exceeded not only during the nighttime but also during the daytime. However, since there are no sensitive receptors such as residences, schools, and hospitals nearby both bridges, the impact on the living environment is considered to be negligible. Although Namling Bridge requires consideration for the ecosystem, it will be acceptable because it is within a multiple use zone and a buffer zone and the impact will be temporary.

As for construction vibration, since there are no residences nearby, it is not expected to have a significant impact even if it occurs temporarily during earth-cutting operations, etc.

Table 1-7-11 Survey Results of Noise

Survey date: 25-27 March 2023 (Dry season)

	Measured results		National standards			International standards (reference)	Measured results (reference)		
	Namling	Durdari	Industrial area	Mixed area	Sensitive area		Pakhadrang	Revidang	Rollong
Day time [6 am-10 pm] (Db)	54.65	56.92	75	65	55	55	58.50	54.95	63.33
Night time [10 pm-6 am] (Db)	51.63	59.68	65	55	45	45	52.60	52.39	65.09

Survey date: 12-14 July 2023 (Rainy season)

	Measured results		National standards			International standards (reference)	Measured results (reference)		
	Namling	Durdari	Industrial area	Mixed area	Sensitive area		Pakhadrang	Revidang	Rollong
Day time [6 am-10 pm] (Db)	56.20	58.03	75	65	55	55	54.94	60.07	55.40
Night time [10 pm-6 am] (Db)	56.33	57.79	65	55	45	45	54.60	59.38	53.78

1. Standards: Environmental Standards, 2020, National Environment Commission of Bhutan
2. Mixed area means area where residential, commercial or both activities take place
3. Sensitive area means area where sensitive targets are in place like hospitals, schools, sensitive ecosystems
4. International standards: Guidelines for Community Noise, World Health Organization (WHO), 1999

Source: JICA Survey Team

2) Natural Environment

(a) Protected Area (Namling Bridge)

Phrumsengla National Park, a protected area where Namling Bridge is located, has been designated by the government of Bhutan for nature conservation by law; however, it has been confirmed that this Project can be implemented legally because the Project is a reconstruction of an existing bridge. On the other hand, JICA Guidelines state that, in principle, projects must be implemented outside of protected areas and that all five conditions in the FAQs of the guidelines must be met in order to implement projects exceptionally. Table 1-7-12 shows the conformity of this Project to these five conditions. As shown in the table, the Project was considered feasible under the JICA Guidelines because it fulfilled all five conditions.

Table 1-7-12 Conformity to the JICA's Five Conditions for Implementing Projects in Protected Areas

Five Conditions for Implementing Projects in Protected Areas	Conformity of Namling Bridge Reconstruction Project	
(1) No feasible alternative plans shall be available in areas other than the area designated as such by the country and/or local governments by laws and/or ordinances to protect nature and cultural heritage ("the Designated Area" hereinafter):	✓	No alternative plans are available because Namling Bridge is located in the protected area and reconstruction of Namling Bridge means implementation in the area. If road traffic is to be maintained by another project outside the protected area other than the reconstruction of Namling Bridge, it is necessary to construct a new detour road with a distance of several tens of kilometres or more, which is not realistic.
(2) development in the Designated Area shall be legally acceptable by the host country's domestic laws:	✓	The location of Namling Bridge is positioned in a multiple use zone and a buffer zone within the protected area. The Project is legally acceptable by obtaining clearances from competent agencies.
(3) Project proponents, shall comply with the laws, ordinance concerning the Designated Area and management plan of the protected zones:	✓	In line with the management plan of Phrumsengla National Park*, the following programs have been formulated and implemented by the Park Office under relevant laws and regulations with the aim of co-existence between people and biodiversity. 1) Enhanced understanding of landscape, species composition and abundance in the park, 2) Wildlife habitat enrichment and species resilience in multiple use and buffer zones 3) Empowering local communities to ensure sustainable management and utilization of natural resources 4) Reduce Human-Wildlife Conflict and enhance communities' livelihoods 5) Diversification and promotion of sustainable ecotourism and recreation avenues 6) Strengthening institutional capacity 7) Enhancing proper waste management and environmental education. In this project, the executing agency (DoST) will manage the construction and related activities and be responsible for ensuring that the above program do not interfere with the intended results. Particular attention will be paid to illegal collection of plants and animals by workers and waste management.
(4) Project proponents, shall form a consensus about project implementation with stakeholders including organizations responsible for managing the Designated Area, local communities through consultations:	✓	Consensus from Phrumsengla National Park Office, Department of Forests and Park Services, has been obtained and a Forestry Clearance has been issued from the department in November 2023. The project has been endorsed by the surrounding communities through community consultations held in May and October 2023 in Saling Gewog where Namling Bridge is located.
(5) Project proponents, shall perform additional programmes, where necessary, to ensure that the Designated Area is effectively managed for its conservation.	✓	At this stage, there is no particular need for additional programmes, but if it becomes necessary after the monitoring, etc., DoST will promptly develop and implement programmes in consultation with the park office.

* Phrumsengla National Park. (2019). Phrumsengla National Park: Management Plan (2019– 2029). Department of Forests and Park Services, Ministry of Agriculture and Forest. Royal Government of Bhutan. Ura: Bumthang.

Source: JICA Survey Team

(b) Ecosystem

Table 1-7-13 and Table 1-7-14 shows fauna and flora identified near each bridge (within about 100m distance from the bridges) during the field survey. No valuable species were identified at any of the sites. No fish or other aquatic animals were observed in the river below each bridge.

On the other hand, as shown in Table 1-7-2, Phrumsengla National Park where the Namling Bridge is located is reported to be inhabited by wildlife classified as Endangered (EN), Vulnerable (VU), and Near Threatened (NT) on the IUCN Red List. In addition, supplemental interview results which were conducted with residents in the vicinity of each bridge to ask about wildlife inhabiting the area (Table

1-7-15) indicated the potential of wildlife species to live including species classified as EN, VU, and NT, not only in the national park, but also in the areas surrounding the four bridges outside the park.

JICA Guidelines state that "projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests," and that if a project is to be implemented, it must confirm that there are no feasible alternatives in areas other than "critical natural habitat," and then satisfy all three conditions as indicated in the FAQs of the guidelines. Since the Project is reconstructions of existing bridges, there are no alternatives in another area. As shown in Table 1-7-16, the areas around Namling and Durdari Bridge are possible to be recognized as critical natural habitats based on the conditions defined for “critical natural habitats” referring to the world banks’ environmental and social policies, etc. We therefore discussed the Project's compliance with the three conditions for implementing the Project in critical natural habitat and summarized in Table 1-7-17 and Table 1-7-18. Since the Project meets all three conditions for both the Namling and Durdari Bridge, the Project is considered to be feasible.

The conformity of the project areas to JICA’s five conditions of critical natural habitats.

Table 1-7-13 Fauna Identified by Field Survey

Survey date: 25 March - 7 April 2023 (Dry season)

No.	Class	Family	Common name	Scientific name	Location					Protected status*
					Namling	Pakhadang	Revidang	Durdari	Rollong	
1	Mammalia	Cervidae	Barking deer	*Muntiacus muntjac*					✓	LC
2	Gastropoda	Achatinidae	Giant African land snail	*Lissachatina fulica*		✓	✓	✓		-
3	Insecta	Acrididae	Autumnal grasshopper	*Aiolopus strepens*			✓			-
4		Tettigoniidae	Bush cricket	*Stilpnochlora couloniana*	✓		✓			-
5		Chlorocyphidae	Black emperor	*Aristocypha quadrimaculata*		✓		✓		LC
6	Amphibia	Ranidae	Sucker frogs	*Amolops* sp.				✓		-

*IUCN Redlist/ LC: Least Concern

No.1 Barking deer

No.2 Giant African land snail

No.3 Autumnal Grasshopper

No.4 Bush cricket

No.5 Black Emperor

No.6 Sucker frogs

Survey date: 12-17 July (Rainy season)

No.	Class	Family	Common name	Scientific name	Location					Protected status*
					Namling	Pakhadang	Revidang	Durdari	Rollong	
1	Gastropoda	Achatinidae	Giant African snail	*Lissachatina fulica*	✓					-
2		Helicidae	White garden snail	*Theba pisana*	✓		✓	✓		-
3	Insecta	Nymphalidae	Chocolate pansy	*Junonia iphita*		✓	✓	✓	✓	-
4		Tetrigidae	Mexican pygmy grasshopper	*Paratettix mexicanus*		✓		✓	✓	-
5		Geometridae	Winter moth caterpillar	*Operophtera* sp.				✓		-
6		Strphidae	Hover fly insect	*Allograpta obliqua*	✓	✓	✓			-

*IUCN Redlist

No.1 Giant African snail

No.2 White garden snail

No.3 Chocolate pansy

No.4 Mexican pygmy grasshopper

No.5 Winter moth caterpillar

No.6 Hover fly insect

Source: JICA Survey Team

Table 1-7-14 Flora Identified by Field Survey

Survey date: 25 March - 7 April 2023（Dry season）

No.	Order	Family	Common name	Scientific name	Location					Protected status*
					Namling	Pakhadang	Revidang	Durdari	Rollong	
1	Asterales	Asteraceae	Siam weed	*Chromolaena odorata*	✓	✓				-
2			Common mugwort	*Artemisia vulgaris*		✓		✓		-
3			Mexican devil	*Ageratina adenophora*		✓				-
4			Hairy fleabane	*Conyza bonariensis*					✓	-
5			Falconer's thistle	*Cirsum falconeri*	✓					-
6			Crofton weed	*Ageratina Adenophora*	✓		✓		✓	-
7	Rosales	Cannabaceae	Marijuana	*Cannabis sativa*		✓			✓	-
8		Urticaceae	Nettle	*Urtica ardens*				✓		-
9	Saxifragales	Crassulaceae	Chirstmas kalanchoe	*Kalanchoe pinnata*					✓	-
10	Malpighiales	Euphorbiaceae	Castor bean	*Ricinus communis*			✓			-
11	Lamiales	Lamiaceae	Hill glory bower	*Clerodendrum infortunatum*			✓			-
12	Caryophyllales	Polygonaceae	Vietnamese coriander	*Persicaria odorata*					✓	-
13			Thrumbula	*Aconogonon molle*	✓					-
14	Ericales	Primulaceae	Wrinkled leaf wild berry	*Maesa rugosa*	✓					-
15		Symplocaceae	Saphire berry	*Symplocos ramosissima*	✓					LC
(Trees in surrownding areas)										
1	Sapindales	Meliaceae	Chinaberry	*Melia azedarach*		✓				LC
2	Myrtales	Lythraceae	Lampatey	*Duabanga grandiflora*			✓			LC
3	Pinales	Pinaceae	Chirpine	*Pinus roxburghii*				✓		LC

*IUCN Redlist/ LC: Least Concern

Survey date: 12-17 July（Rainy season）

No.	Order	Family	Common name	Scientific name	Location					Protected status*
					Namling	Pakhadang	Revidang	Durdari	Rollong	
1	Agaricales	Omphalotaceae	Spindleshank	*Gymnopus sp*	✓					-
2	Alismatales	Araceae	Taro	*Colocasia esculenta*		✓		✓		-
3	Asterales	Asteraceae	Crofton weed	*Ageratina adenophora*	✓		✓		✓	-
4			Firweed	*Crassocephalum crepidioides*		✓		✓		-
5			Santa Maria	*Parthenium hysterophorus*				✓	✓	-
6			Artemisia myriantha	*Artemisia myriantha*			✓	✓		-
7	Boraginales	Boraginaceae	Gorget ne not	*Cynoglossum furcatum*	✓					-
8	Caryophyllales	Polygonaceae	Knot weed	*Aconogonon molle*				✓		-
9	Cornales	Hydrangeacae	Dichora	*Hydrangea febrifuga*	✓		✓			-
10	Fabales	Fabaceae	Tick clover	*Desmodium* sp.		✓		✓	✓	-
11	Lamiales	Lamiaceae	Hill glory	*Clerodendron infortunatum*	✓		✓			-
12			Hat Plant	*Holmskioldia sanguinea*			✓	✓		-
13	Malpighiales	Euphorbiaceae	Royle	*Sapium insigne*		✓		✓		-
14			Physic nut	*Jatropha curcas*			✓			LC
15			Croton	*Croton bonplandianus*	✓		✓			-
16			Astor	*Ricinus communis*					✓	-
17	Myrtales	Lythraceae	Colombian weed	*Cuphea carthagenensis*		✓	✓			-
18	Ophioglossales	Ophioglossaceae	Fern Pteridophyte	*Ophioglossum*				✓		-
19	Polypodiales	Dryopteridaceae	Male fern	*Dryopteris filix-mas*				✓		-
20	Poales	Poaceae	Lemon grass	*Cymbopogon flexuosus*		✓			✓	-
21		Cyperaceae	Carex	*Carex* sp.	✓		✓			-
22	Rosales	Moraceae	Fig	*Ficus semicordata*				✓		LC
23		Urticaceae	Clearweed	*Pilea scripta*	✓		✓			-

*IUCN Redlist/ LC: Least Concern

Source: JICA Survey Team

Table 1-7-15 Wildlife Possibly Lives in Surrounding Areas Based on Interviews with Residents

No.	Class	Family	Common name	Scientific name	Name of Bridge					Protected status*
					Namling	Pakhadang	Revidang	Durdari	Rollong	
1	Primates	Cercopithecidae	Assamese Macaque	*Macaca assamensis*	✓	✓	✓	✓	✓	NT
2			Capped Langur	*Trachypithecus pileatus*		✓	✓	✓		VU
3	Carnivora	Canidae	Dhole	*Cuon alpinus*	✓	✓	✓	✓	✓	EN
4		Felidae	Leopard Cat	*Prionailurus bengalensis*		✓	✓		✓	LC
5			Common Leopard	*Panthera pardus*	✓	✓		✓	✓	VU
6		Mustelidae	Yellow-throated Martin	*Martes flavigula*	✓		✓	✓	✓	LC
7			Yellow-bellied Weasel	Mustela kathiah		✓		✓	✓	
8		Ursidae	Himalayan Black Bear	*Ursus (Selenarctos) thibetanus*	✓		✓			VU
9	Cetartiodactyla	Bovidae	Himalayan Goral	*Naemorhedus goral*		✓	✓	✓	✓	NT
10			Barking Deer	*Muntiacus muntjak*		✓			✓	LC
11		Cervidae	Sambar Deer	*Rusa unicolor*			✓	✓	✓	VU
12		Suidae	Wild Boar	*Sus scrofa*	✓	✓	✓	✓	✓	LC
13	Rodentia	Rodentia	Porcupine	*Hystrix brachyura*	✓		✓		✓	LC
14		Sciuridae	Orange-bellied Himalayan Squirrel	*Dremomys lokriah*	✓			✓	✓	LC
15			Black Giant Squirrel	*Ratufa bicolor*	✓		✓		✓	NT

*IUCN Redlist/ LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered

Source: JICA Survey Team

Table 1-7-16 Conformity of the Project Areas to JICA's Five Conditions of Critical Natural Habitats

Five Conditions of Critical Natural Habitats	Conformity of the Project Areas			
	Area vicinity of Namling br.		Area vicinity of Durdari br.	
(1) Habitat of significant importance to Critically Endangered (CR), Endangered (EN), Vulnerable (VU), or Near Threatened (NT) species, as listed in the IUCN (International Union for Conservation of Nature) Red List of threatened species or equivalent national approaches;	✓	Phrumsengla national park is possible to be a critical natural habitat because EN, VU, NT species inhabit.	✓	The results of interview to residents showed that EN, VU, NT species may inhabit. Therefore, the area is possible to be a critical natural habitat.
(2) Habitat of significant importance to endemic or restricted-range species;	✓	Bhutan takin as endemic species inhabits in Phrumsengla national park. The habitat is possible to be significant important.	-	Endemic and restricted-range species are not identified.
(3) Habitat supporting globally or nationally significant concentrations of migratory or congregatory species;	-	No information to meet the condition.	-	No information to meet the condition.
(4) Highly threatened or unique ecosystems;	-	No information to meet the condition.	-	No information to meet the condition.
(5) Areas associated with important evolutionary processes	-	No information to meet the condition.	-	No information to meet the condition.

✓: possible to meet the condition, -: not meet the condition

Source: JICA Survey Team

Table 1-7-17 Conformity to the JICA's Three Conditions for Implementing Projects in Critical Natural Habitats (Namling Bridge)

Three Conditions for Implementing Projects in Critical Natural Habitats	Conformity of the Project	
(1) Projects shall not exert significant adverse impacts on biodiversity values existing in "critical natural habitats" and key functions of the ecosystems:	✓	As Namling Bridge is located within the national park where endangered species inhabit, the surrounding area is possible to be a critical natural habitat for these species. However, the Project is not expected to have a significant negative impact on the value or function of critical natural habitat, as the construction site is limited to the area along the existing road where vehicles are passing.
(2) Over a reasonable period of time, projects shall not cause net reduction in endangered species population listed below: Species classified into "Critically Endangered (CR)" and "Endangered (EN）" out of "Threatened" species listed on the IUCN Red List of Threatened Species, , or those that fall under such classifications in accordance with the host country's rules and regulations:	✓	As mentioned above, the Project is implemented in a limited area around the existing road, and no endangered species have been identified in the vicinity. In addition, according to the national park office, no roadkill of wildlife including endangered species has occurred, and it is considered rare for animals to come out to the national highway. Therefore, even if endangered species are present in the vicinity, it is unlikely that endangered species will approach the new bridge during construction and after the completion and encounter accidents. It indicates the Project will not affect their populations.
(3) Long-term and effective mitigation measures and monitoring shall be put in place be performed with regard to (1) and (2) above.	✓	Information on encountered wildlife and the roadkill is recorded during and after the construction. If any concerns about impacts are raised, necessary measures are taken place.

Source: JICA Survey Team

Table 1-7-18 Conformity to the JICA's Three Conditions for Implementing Projects in Critical Natural Habitats (Durdari Bridge)

Three Conditions for Implementing Projects in Critical Natural Habitats	Conformity of the Project	
(1) Projects shall not exert significant adverse impacts on biodiversity values existing in "critical natural habitats" and key functions of the ecosystems:	✓	As Durdari Bridge is located in a forest area with some farmlands and settlements, there is a possibility that the area is a critical natural habitat for endangered species. However, the Project is not expected to have a significant negative impact on the value or function of critical natural habitat, as the construction site is limited to the area along the existing road where vehicles are passing.
(2) Over a reasonable period of time, projects shall not cause net reduction in endangered species population listed below: Species classified into "Critically Endangered (CR)" and "Endangered (EN）" out of "Threatened" species listed on the IUCN Red List of Threatened Species, , or those that fall under such classifications in accordance with the host country's rules and regulations:	✓	As mentioned above, the Project is implemented in a limited area around the existing road, and no endangered species have been identified in the vicinity. In addition, the area seems to have human interactions due to farmland activities, and according to residents, no wildlife has been sighted in the vicinity of the bridge. Therefore, even if endangered species are present in the vicinity, it is unlikely that endangered species will approach the new bridge during construction and after the completion and encounter accidents. It indicates the Project will not affect their populations.
(3) Long-term and effective mitigation measures and monitoring shall be put in place be performed with regard to (1) and (2) above.	✓	Information on encountered wildlife and the roadkill is recorded during and after the construction. If any concerns about impacts are raised, necessary measures are taken place.

Source: JICA Survey Team

(c) Topography and Geology

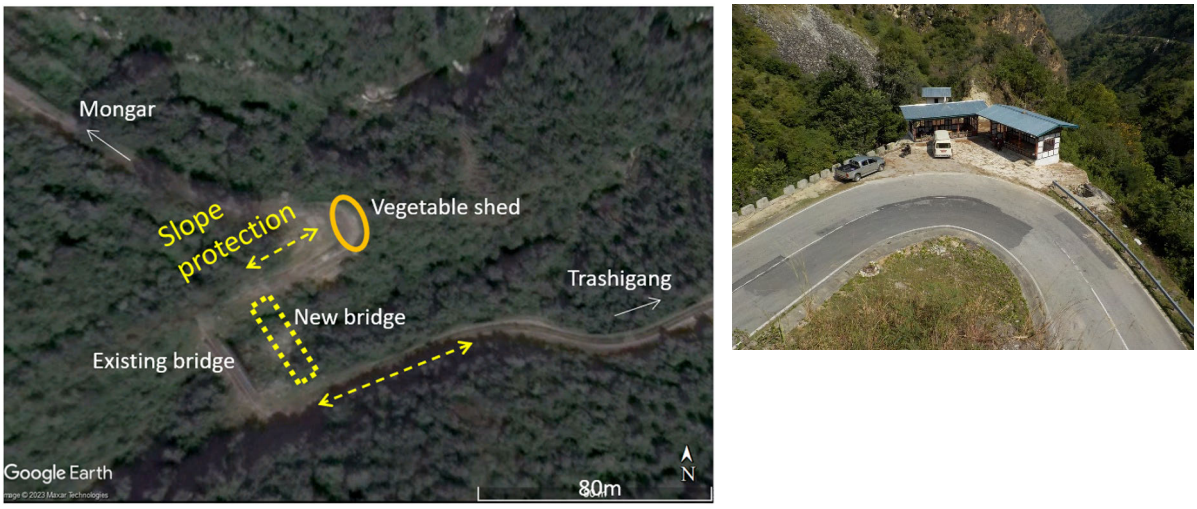
The topography of slopes facing to the bridges will be modified due to excavation for adjusting the road alignments to connect to the new bridges. However, the extent of the modification is limited to the area along the road, and the bridge locations were decided to minimize the amount of excavation as much as possible; therefore, the impact on the topography is limited. In addition, since the slopes will be protected after the excavation, no slope collapse or soil runoff is expected to occur after the construction.

3) Social Environment

(a) Involuntary Resettlement

No involuntary resettlement is required for the Project because there are no residences or other structures as well as land use such as farmland within the construction sites of both Namling and Durdari Bridges. In addition, 50 feet (about 15 m) to the left and right of the center line of the road is defined as the right of way (ROW), and the Project is implemented within the area; therefore, there will be no need of land acquisition for the Project.

Meanwhile, a shed for selling vegetables and fruits was constructed by the local government (Gewog) in the ROW, a few tens of meters away from Durdari Bridge, between June and October 2023 during this survey period (Figure 1-7-11). Although the shed seemed not being used as of October 2023, sufficient coordination with the users is required during the construction since it faces the construction area for the slope protection. As the vegetable shed is outside the construction site, relocation of the facility is not necessary.



Source: JICA Survey Team

Figure 1-7-11 Vegetable Shed Constructed Near Durdari Bridge

(b) The Poor

According to the questionnaire survey conducted among 696 households in 5 Gewogs (Saling, Mongar, Ngatshang, Chaskhar, and Drametse) in Mongar District and Samkhar in Trashigang District through which the national highway passes (see section 1-8.3), three households in Saling Gewog and one in Ngatshang Gewog were identified as below the national poverty line. However, the average monthly income by Gewog was above the poverty line. Since the Project does not affect any particular household, special consideration due to poverty is not considered necessary.

(c) Ethnic Minorities and Indigenous Peoples

According to the above questionnaire survey, the ethnic majority of the surrounding residents are Sharschop. In addition, Bumthap, Kurtoep, and the other ethnicity are also mixed to form communities in Saling Gewog (Table 1-7-19). Since no ethnic groups were identified as minorities, special consideration for particular ethnic groups is not considered necessary. Regarding religion, all respondents indicated they were Buddhist.

Table 1-7-19 Ethnic Composition of the Surrounding Population

Dzongkhag	Mongar					Trashigang	Total
Gewog	Saling	Mongar	Ngatshang	Chaskhar	Dremitse	Samkhar	
Ethnicity							
Bumthap	28 (22.22%)			1 (0.66%)			29 (4.17%)
Khengpa	13 (10.32%)	1 (1.11%)					14 (2.01%)
Kurtoep	28 (22.22%)	1 (1.11%)	1 (0.68%)				30 (4.31%)
Sharschop	44 (34.92%)	87 (96.67%)	147 (99.32%)	149 (98.68%)	150 (100.00%)	31 (100.00%)	608 (87.36%)
Others	13 (10.32%)	1 (1.11%)		1 (0.66%)			15 (2.16%)
Total	126 (100.00%)	90 (100.00%)	148 (100.00%)	151 (100.00%)	150 (100.00%)	31 (100.00%)	696 (100.00%)

Source: JICA Survey Team

(d) Local Economy such as Employment and Livelihood

Many households in the vicinity are earning their livelihood from agriculture and livestock farming based on the questionnaire survey as described in Section 1-8.3. According to residents of Saling Gewog in the vicinity of Namling Bridge, their activities in agriculture were affected by the traffic block when Namling Bridge was washed away by a flood earlier. In Chaskhar Gewog, where Durdari Bridge is located, residents also reported that they faced difficulties such as having to detour on farm roads when the bridge was in a dangerous condition. Considering those local situations, it is expected that stabilizing road traffic by reconstructing the bridge will have a positive effect on livelihoods and the local economy. As for the impacts during the construction period, business and employment opportunities are expected to arise from the procurement of construction-related materials and the stay of workers.

(e) Water Usage

Through interviews with local residents, no use of river water was identified in the vicinity of both Namling and Durdari Bridge. In a village (Thridangbi Chiwog) located about 10 km downstream of Namling Bridge, 50 to 60 households use river water for irrigation; however, the Project will not affect the water use since it will not cause a decrease in flow volume.

(f) Existing Social Infrastructure and Services

Since the Primary National Highway No.1, where the bridges are located, is the only major route connecting the east and the west areas in the country, eliminating the risk of bridge falls by reconstruction of the bridges will greatly contribute to the stabilization of road traffic. On the other hand, even if it is temporary, any closure or restriction of the traffic may affect the traffic in country wide. The construction works of the Project will have to temporarily close the road due to blasting for slope protection works, etc. Therefore, it is necessary to shorten the time of the road closure as much as possible and thoroughly inform related organizations and residents before the closure.

(g) Misdistribution of Benefit and Damage, and Local Conflicts of Interests

In the public consultation meetings held in Gewogs the bridges are located, the participants uniformly welcomed the stabilization of road traffic brought by reconstruction of the bridges, and no factors that could cause uneven distribution of damage and benefits or local conflicts of interest were identified for the Project.

(h) Cultural Heritage

No cultural heritage or religious sites were identified within 1 km of either Namling or Durdari Bridge. However, it is believed that a deity called Gokpula (Kayla/Tsen) lives in the mountains about 3 km west of Namling Bridge, and the community showed concern that the construction would violate it. It is necessary to respect the local religious sentiments for implementing the construction works at Namling Bridge.

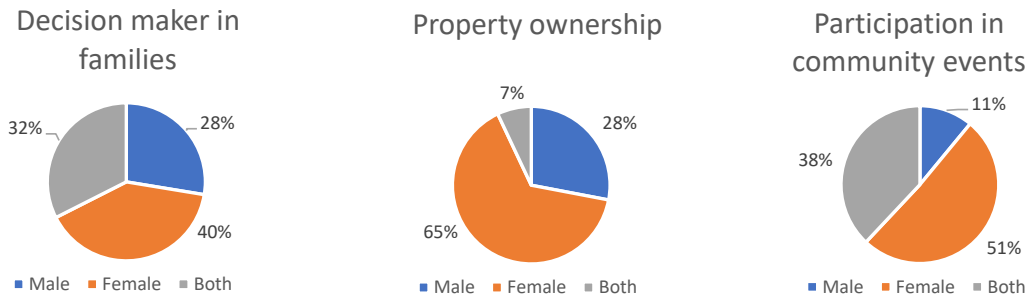
(i) Landscape

Namling and Durdari Bridge are bridges over valleys in the mountains, and the landscape will not be significantly changed by the reconstruction.

(j) Gender

Figure 1-7-12 presents the male/female ratio in household decision making, asset ownership, and participation in community events based on the questionnaire survey. It showed the proportion of female was higher in all three topics. The fact seems indicating that women's voice has been secured in households and communities.

On the other hand, in economic activities such as political participation and employment, women are generally underrepresented in the country, and the government recommends the empowerment of women to achieve gender equality (National Gender Equality Policy 2020). Although the Project will not cause impacts specifically on women, it is recommended to consider women's rights in such manner as actively employing women in construction employment in light of the above policy and JICA's gender considerations policy.



Source: JICA Survey Team

Figure 1-7-12 Male/Female Ratios on Roles in Families and Communities

(k) Right of Children

The information obtained in each Gewog regarding the rights of children was summarized in Table 1-7-20. It explains that Gewog administrations are addressing to being aware of and takeing initiatives to ensure that children's rights are secured. For child labor, the Project will also comply with the Labour

and Employment Act 2007 which prohibits children from working in risky mechanical works or hard work, and in a working environment where they are exposed to hazardous substances, temperature, noise, and vibration.

Table 1-7-20 Local Awareness of and Response to Children's Rights

Gewog.	Description
Saling	Gewog's administration is closely watching children's right to education, child labor, domestic violence, and possible child abuse, and recognizes the need to monitor such cases and provide necessary awareness and support.
Chaskhar	According to the head of Gewog, people have become aware of children's rights through television and radio as development has progressed. School teachers also explain to parents the importance of caring for their children and disciplining them without using violence.
Drametse	A workshop was held by UNODC (United Nations Office on Drugs and Crime) in Mongar focusing on issues such as crimes against children, child trafficking, and child drug abuse, where knowledge on child rights was shared with Gewog.

Source: JICA Survey Team

(l) Infectious Disease

Table 1-7-21 shows the information of infectious diseases and health care in each Gewog. For HIV/AIDS, the country has a low new infection rate of 0.10 per 1,000 population (HIV Country Profile 2022, WHO), and awareness-raising activities are regularly conducted by medical institutions and health staff. Regarding the COVID-19, strict measures were taken in the early stage by the government to prevent the spread of infection, and there was no information of particular concern about the infection in each Gewog.

Table 1-7-21 Local Situation on Infectious Diseases and Health Care

Gewog.	Description
Saling	The most prevalent health issues are common colds, digestive related problems, skin infections, eye infections, and work-related injuries. There are 3 ORC (Outreach Clinic) and 2 PHC (Primary Health Centre) as health care institutions. Health care coverage reaches all Chiwogs.
Chaskhar.	The most prevalent health issues are common colds and coughs, skin infections, eye infections, and work-related injuries. There are 4 ORC and 1 BHU (Basic Health Unit) as health care institutions. Health care coverage reaches all Chiwogs.
Drametse	The most prevalent health issues are common colds and coughs, disorder of skins and subcutaneous tissues, acute pharyngitis, tonsillitis, digestive disorders, nervous including peripheral disorders, musculoskeletal disorders, skin infections, and peptic ulcer syndrome. There are 3 ORC and 1 BHU as health care institutions. Health care coverage reaches all Chiwogs.

Source: JICA Survey Team

(m) Working Environment

The working environment in Bhutan is governed under Labour and Employment Act 2007 and is monitored by district supervisors. The Act includes provisions for equal pay for equal work, restrictions on the employment of children in construction work and other employment regulations, break time for lactating mothers, leave and weekend breaks for workers, appropriate working hours, overtime, and other provisions related to employment and protection of workers. In the construction of the Project, the contractor will be required to comply with these regulations under the supervision of district supervisor.

4) Others

(a) Accidents

In 2023, Mongar traffic police recorded 15 motor vehicle accidents on the stretch from Sengor to Rollong by May, according to Mongar District Road Safety and Traffic Department. The causes of the accidents are reported to be drunk driving, unlicensed driving, overloading, excessive speed, wrong lane, overtaking, road conditions (slipping due to gravel), fog, and vehicle malfunction. Although the new bridges will not be a new cause of traffic accidents, it is necessary to ensure safe driving and vehicle maintenance when construction vehicles are passing by to transport construction materials and soils.

Since the construction of the Project includes working at heights and blasting on slopes, it is necessary to install safety equipment to prevent falls and to properly manage explosives and hazardous materials.

(5) Impact Assessment and Comparison of Alternatives

The following is the assessment results of the impacts and alternatives for Namling and Durdari Bridge reconstruction projects, respectively.

(a) Namling Bridge

Table 1-7-22 summarizes the results of the impact assessment of Namling Bridge reconstruction project. Since there is no alternative plan to be compared as the Project is reconstruction of an existing bridge, and the site of reconstruction was selected at a location where the excavation of surrounding slopes is small with sufficient clearance under the girder, in addition to that the length of bridge is minimized as much as possible, the comparison with alternatives was made by analysing with or without implementation of the Project. The results of the comparison are shown in Table 1-7-23. It indicates that the implementation of the Project would contribute to the improvement of social conditions through the stabilization of road traffic in the area while it is necessary to properly manage the pollution and the temporary road closures associated with the construction.

Table 1-7-22 Impact Assessment Results (Namling Bridge)

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
Pollution	1	Air pollution	✓	-	B-	N/A	**Construction phase:** Although there will be a temporary increase of dust and exhaust emissions due to the operation of construction vehicles and heavy equipment, the standard values will be met, and there are no residences, schools, or hospitals in the vicinity of the construction site that require special consideration.
							Operation phase: Passing vehicles will emit air pollutants; however, additional air pollution is not expected with the new bridge because the new bridge is to maintain existing traffic.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	2	Water pollution	✓	-	B-	N/A	**Construction phase:** There is no water use in the vicinity and the possibility of construction turbidity affecting the living and natural environment is low because turbidity increases even under natural conditions when flow volume increases. Appropriate treatment of domestic wastewater from construction workers' camps is necessary for sanitary conditions.
							Operation phase: No water pollution is expected with the new bridge in service.
	3	Waste	✓	-	B-	N/A	**Construction phase:** Surplus soil generated by excavation of surrounding slopes will be transported to and disposed of at a nearby site approved by the DoST. Construction waste such as concrete pieces, used oil from construction equipment, and domestic waste from construction workers may be generated and must be disposed of properly.
							Operation phase: No waste will be generated by the bridge in service.
	4	Soil contamination	✓	-	D	N/A	**Construction phase:** No oil or hazardous substances are used in large quantities, which cause soil contamination.
							Operation phase: No soil contamination is expected by the bridge in service.
	5	Noise and vibration	✓	-	B-	N/A	**Construction phase:** The current noise level is the same level with the standard for sensitive area during the daytime while exceeds the standard during the nighttime. With the addition of the construction noise, the daytime noise level will increase and may exceed the standard value both day and night. However, there will be little impact on the living environment because there is no residence in the vicinity.
							Operation phase: Noise and vibration will be generated by passing vehicles; however, additional noise or vibration is not expected with the new bridge because the new bridge is to maintain existing traffic.
	6	Ground subsidence	-	-	N/A	N/A	Activities that would cause land subsidence (use of large volumes of groundwater) are not anticipated.
	7	Odor	-	-	N/A	N/A	Activities that would cause odor are not anticipated.
	8	Sediment quality	-	-	N/A	N/A	Activities that would cause deterioration of sediment qualities are not anticipated.
Natural environment	9	Protected area	✓	✓	B-	D	**Construction phase:** Although located in a national park, the reconstruction of the existing bridge is legally feasible. It also meets the five conditions for implementing projects exceptionally in protected areas under JICA Guidelines.
							Operation phase: Existence of new bridge will not cause any impacts on designation of the national park and the management.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	10	Ecosystem	✓	✓	B-	B-	**Construction phase:** No valuable flora or fauna was identified at the reconstruction site, but species classified as EN, VU, and NT have been reported in the national park. Although the park is possible to be a critical natural habitat for these species, it meets the three conditions for implementing projects in critical natural habitats under JICA Guidelines. The ecological impact is considered acceptable because it is within the multiple use zone and buffer zone and the impact will be temporary. **Operation phase:** Although it will be rare, wildlife could be involved in traffic accidents on the bridge.
	11	Hydrology	-	-	N/A	N/A	Activities that would alter the river flow are not anticipated.
	12	Topography and geology	✓	-	D	N/A	**Construction phase:** The impact is limited because of the limited excavation. **Operation phase:** No topographic or geological impacts are expected due to the bridge in service.
Social environment	13	Involuntary resettlement	✓	-	D	N/A	**Pre-construction:** Resettlement and land acquisition are not required. **Operation phase:** No land acquisition or resettlement is anticipated for the bridge in service.
	14	The poor	✓	✓	D	D	Since the average monthly income in Saling Gewog, where the bridge is located, is above the national poverty line and the Project does not affect any particular household, no special consideration is required.
	15	Indigenous and ethnic minorities	✓	✓	D	D	There are no ethnic minorities or indigenous peoples in the vicinity of the project site.
	16	Local economy such as employment and livelihood	✓	✓	B+	B+	**Construction phase:** Business and employment opportunities related to construction may arise. **Operation phase:** Stabilization of road traffic brought by reconstruction of the bridge will have positive impacts on livelihoods and the local economy.
	17	Land use and utilization of local resources	-	-	N/A	N/A	**Pre-construction phase:** The proposed construction area is limited and will not affect land use, etc. **Operation phase:** No land use changes are expected with the bridge in service.
	18	Water usage	✓	-	D	N/A	**Construction phase:** No river water use is identified in the vicinity, and the downstream irrigation use is not affected. **Operation phase:** No impact on water use is expected with the bridge in service.
	19	Existing social infrastructure and social services	✓	✓	B-	B+	**Pre-construction:** Closures and restrictions on national highways due to construction will affect the traffic in the region and the country. **Operation phase:** Eliminating the risk of bridge failures brought by reconstruction of the bridge will stabilize the road traffic in the region and the country.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	20	Social capital and local organizations for decision making etc.	-	-	N/A	N/A	Since the Project is a national project aims to secure benefits and safety of the national highway, no impact is anticipated on local decision-making functions.
	21	Misdistribution of benefit and damage	✓	✓	D	D	Factors that could cause uneven distribution of damage and benefits are not identified.
	22	Local conflicts of interests	✓	✓	D	D	Factors that could cause regional conflicts of interest are not identified.
	23	Cultural heritage	✓	✓	B-	D	**Construction phase:** Although there are no cultural heritage sites or religious facilities affected by the Project, local religious sentiments must be taken into consideration because mountains about 3 km from the bridge is believed to be inhabited by a god and there are concerns that it may be violated by the construction. **Operation phase:** Bridge operation will not cause any impacts on cultural heritage and religious sentiments.
	24	Landscape	✓	✓	D	D	The landscape will not be significantly changed by the reconstruction.
	25	Gender	✓	✓	D	D	The Project does not cause women-specific impacts.
	26	Right of children	✓	-	D	N/A	**Construction phase:** Child labor in construction is regulated by law and children's rights are secured by community's monitoring. **Operation phase:** No impact on children's rights is anticipated by the bridge in service.
	27	Infectious diseases such as HIV/AIDS	✓	-	D	N/A	**Construction phase:** The possibility of outbreak of HIV/AIDS and Covid-19 infection through the construction is low because of the low infection rates of HIV/AIDS and Covid-19 and the measures being taken in the region and the country. **Operation phase:** No outbreak of infectious diseases is expected by the bridge in service.
	28	Working environment (including occupational safety)	✓	-	D	N/A	**Construction phase:** Occupational safety considerations for construction workers will be made in accordance with the Labour and Employment Act 2007. **Operation phase:** No worker will be involved in the service of the bridge.
Other	29	Accidents	✓	✓	B-	D	**Construction phase:** To prevent traffic accidents caused by construction vehicles, safe driving and thorough vehicle maintenance are necessary. Installation of safety equipment and proper control of explosives and hazardous materials are necessary to prevent accidents during construction. **Operation phase:** The new bridge will not be a new cause of traffic accidents.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc -tion	Opera -tion phase	Pre/ During construc -tion	Opera -tion phase	
	30	Transboundary impacts and climate change	-	-	N/A	N/A	**Construction phase:** No transboundary impacts or climate change impacts are anticipated due to the limited scale and duration of the construction works.
							Operation phase: No additional greenhouse gases is expected with the new bridge because the new bridge is to maintain existing traffic.

A+/-: significant positive/negative impact, B+/-: some positive/negative impact, C: unknown impact (needs investigation), D: no impact

Source: JICA Survey Team

Table 1-7-23 Comparison with Alternative (Without Project Case) (Namling Bridge)

Item	With Project	Without Project
Pollution	The reconstruction work will generate dust, exhaust emissions, and noise due to the operation of vehicles and heavy equipment. Surplus soil will be generated from excavation of slopes. Used oil as hazardous waste and construction workers' domestic waste will be generated.	No pollutants listed on the left are generated.
Natural environment	Since the reconstruction site is located in a national park where valuable wildlife inhabits, there is a risk of roadkill of wildlife due to construction activities and traffic passing over the completed bridge.	Even if the new bridge is not constructed, there is a risk of roadkill of valuable wildlife by passing vehicles on the existing road and the bridge.
Social environment	Although the construction work will require temporary closure of the national highway at the construction site, the impact of traffic block can be minimized by shortening the period and by notification in advance.	If the bridge were to fall without reconstruction, traffic would be divided over an extended period of time, which would have a significant impact on the lives of local residents and the economy.

Source: JICA Survey Team

(b) Durdari Bridge

Table 1-7-24 summarizes the results of the impact assessment of Durdari Bridge reconstruction project. As for the alternatives, there is no alternative plan to be compared as well as Namling Bridge because the location was selected to secure the clearance under the girder and minimize the length of the bridge as much as possible; therefore, the comparison with alternatives was made by analysing with or without implementation of the Project. The results of the comparison are shown in Table 1-7-25. It indicates that the implementation of the Project would contribute to the improvement of social conditions through the stabilization of road traffic in the area, while it is necessary to properly manage the pollution and the temporary road closures as well as to minimize excavation and removal of vegetation during the construction.

Table 1-7-24 Impact Assessment Results (Durdari Bridge)

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
Pollution	1	Air pollution	✓	-	B-	N/A	**Construction phase:** Although there will be a temporary increase of dust and exhaust emissions due to the operation of construction vehicles and heavy equipment, the standard values will be met, and there are no residences, schools, or hospitals in the vicinity of the construction site that require special consideration. **Operation phase:** Passing vehicles will emit air pollutants; however, additional air pollution is not expected with the new bridge because the new bridge is to maintain existing traffic.
	2	Water pollution	✓	-	B-	N/A	**Construction phase:** There is no water use in the vicinity and the possibility of construction turbidity affecting the living and natural environment is low because turbidity increases even under natural conditions when flow volume increases. Appropriate treatment of domestic wastewater from construction workers' camps is necessary for sanitary conditions. **Operation phase:** No water pollution is expected with the new bridge in service.
	3	Waste	✓	-	B-	N/A	**Construction phase:** Surplus soil generated by excavation of surrounding slopes will be transported to and disposed of at a nearby site approved by the DoST. Construction waste such as concrete pieces, used oil from construction equipment, and domestic waste from construction workers may be generated and must be disposed of properly. **Operation phase:** No waste will be generated by the bridge in service.
	4	Soil contamination	✓	-	D	N/A	**Construction phase:** No oil or hazardous substances are used in large quantities, which cause soil contamination. **Operation phase:** No soil contamination is expected by the bridge in service.
	5	Noise and vibration	✓	-	B-	N/A	**Construction phase:** The current noise level meets the standard during the daytime while exceeds during the nighttime. With the addition of the construction noise, the daytime noise level will increase and may exceed the standard value both day and night. However, there will be little impact on the living environment because there is no residence in the vicinity. **Operation phase:** Noise and vibration will be generated by passing vehicles; however, additional noise or vibration is not expected with the new bridge because the new bridge is to maintain existing traffic.
	6	Ground subsidence	-	-	N/A	N/A	Activities that would cause land subsidence (use of large volumes of groundwater) are not anticipated.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	7	Odor	-	-	N/A	N/A	Activities that would cause odor are not anticipated.
	8	Sediment quality	-	-	N/A	N/A	Activities that would cause deterioration of sediment qualities are not anticipated.
Natural environment	9	Protected area	-	-	N/A	N/A	Durdari bridge is outside of protected areas.
	10	Ecosystem	✓	✓	B-	B-	**Construction phase:** No valuable flora or fauna was identified at the reconstruction site, but there is a possibility that species classified as EN, VU, and NT inhabit in the surrounding area. Although the area may be considered as a critical natural habitat for these species, the Project meets the three conditions for implementing projects in critical natural habitats under JICA Guidelines. **Operation phase:** Although it will be rare, wildlife could be involved in traffic accidents on the bridge.
	11	Hydrology	-	-	N/A	N/A	Activities that would alter the river flow are not anticipated.
	12	Topography and geology	✓	-	D	N/A	**Construction phase:** The impact is limited because of the limited excavation. **Operation phase:** No topographic or geological impacts are expected due to the bridge in service.
Social environment	13	Involuntary resettlement	✓	-	D	N/A	**Pre-construction:** Resettlement and land acquisition are not required. **Operation phase:** No land acquisition or resettlement is anticipated for the bridge in service.
	14	The poor	✓	✓	D	D	Since the average monthly income in Chaskhar Gewog, where the bridge is located, is above the national poverty line and the Project does not affect any particular household, no special consideration is required.
	15	Indigenous and ethnic minorities	✓	✓	D	D	There are no ethnic minorities or indigenous peoples in the vicinity of the project site.
	16	Local economy such as employment and livelihood	✓	✓	B+	B+	**Construction phase:** Business and employment opportunities related to construction may arise. **Operation phase:** Stabilization of road traffic brought by reconstruction of the bridge will have positive impacts on livelihoods and the local economy.
	17	Land use and utilization of local resources	-	-	N/A	N/A	**Pre-construction phase:** The proposed construction area is limited and will not affect land use, etc. **Operation phase:** No land use changes are expected with the bridge in service.
	18	Water usage	✓	-	D	N/A	**Construction phase:** No river water use is identified in the vicinity. **Operation phase:** No impact on water use is expected with the bridge in service.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	19	Existing social infrastructure and social services	✓	✓	B-	B+	**Pre-construction:** Closures and restrictions on national highways due to construction will affect the traffic in the region and the country. **Operation phase:** Eliminating the risk of bridge failures brought by reconstruction of the bridge will stabilize the road traffic in the region and the country.
	20	Social capital and local organizations for decision making etc.	-	-	N/A	N/A	Since the Project is a national project aims to secure benefits and safety of the national highway, no impact is anticipated on local decision-making functions.
	21	Misdistribution of benefit and damage	✓	✓	D	D	Factors that could cause uneven distribution of damage and benefits are not identified.
	22	Local conflicts of interests	✓	✓	D	D	Factors that could cause regional conflicts of interest are not identified.
	23	Cultural heritage	✓	✓	D	D	There are no cultural heritage sites or religious facilities to be affected.
	24	Landscape	✓	✓	D	D	The landscape will not be significantly changed by the reconstruction.
	25	Gender	✓	✓	D	D	The Project does not cause women-specific impacts.
	26	Right of children	✓	-	D	N/A	**Construction phase:** Child labor in construction is regulated by law and children's rights are secured by community's monitoring. **Operation phase:** No impact on children's rights is anticipated by the bridge in service.
	27	Infectious diseases such as HIV/AIDS	✓	-	D	N/A	**Construction phase:** The possibility of outbreak of HIV/AIDS and Covid-19 infection through the construction is low because of the low infection rates of HIV/AIDS and Covid-19 and the measures being taken in the region and the country. **Operation phase:** No outbreak of infectious diseases is expected by the bridge in service.
	28	Working environment (including occupational safety)	✓	-	D	N/A	**Construction phase:** Occupational safety considerations for construction workers will be made in accordance with the Labour and Employment Act 2007. **Operation phase:** No worker will be involved in the service of the bridge.
Other	29	Accidents	✓	✓	B-	D	**Construction phase:** To prevent traffic accidents caused by construction vehicles, safe driving and thorough vehicle maintenance are necessary. Installation of safety equipment and proper control of explosives and hazardous materials are necessary to prevent accidents during construction. **Operation phase:** The new bridge will not be a new cause of traffic accidents.

Category	No.	Impacts	Evaluation in Scoping		Assessment Results		Reasons for Assessment Results
			Pre/ During construc-tion	Opera-tion phase	Pre/ During construc-tion	Opera-tion phase	
	30	Transboundary impacts and climate change	-	-	N/A	N/A	**Construction phase:** No transboundary impacts or climate change impacts are anticipated due to the limited scale and duration of the construction works.
							Operation phase: No additional greenhouse gases is expected with the new bridge because the new bridge is to maintain existing traffic.

A+/-: significant positive/negative impact, B+/-: some positive/negative impact, C: unknown impact (needs investigation), D: no impact

Source: JICA Survey Team

Table 1-7-25 Comparison with Alternative (Without Project Case) (Namling Bridge)

Item	With Project	Without Project
Pollution	The reconstruction work will generate dust, exhaust emissions, and noise due to the operation of vehicles and heavy equipment. Surplus soil will be generated from excavation of slopes. Used oil as hazardous waste and construction workers' domestic waste will be generated.	No pollutants listed on the left are generated.
Natural environment	Although limited in scale, vegetation will be removed as a result of the excavation.	No vegetation removal will occur.
Social environment	Although the construction work will require temporary closure of the national highway at the construction site, the impact of traffic block can be minimized by shortening the period and by notification in advance.	If the bridge were to fall without reconstruction, traffic would be divided over an extended period of time, which would have a significant impact on the lives of local residents and the economy.

Source: JICA Survey Team

(6) Mitigation Measures and Monitoring Plan

Mitigation measures for Namling Bridge and Durdari Bridge are listed in

Table 1-7-26 and Table 1-7-27, respectively. The monitoring plan which is common to both bridges is presented in Table 1-7-28.

Table 1-7-26 Mitigation Measures (Namling Bridge)

Category	Mitigation Measures	Implementing agency	Responsible agency	Budget
[Construction phase]				
Pollution				
Air pollution	- Reduce emissions by maintaining equipment in good conditions, - Avoid unnecessary idling, - Prevent scattering of soil in such way as covering with sheet after loading vehicles, - Dust prevention by sprinkling water.	Contractor	DoST	Included in construction cost
Water pollution	- Installation, proper use, and maintenance of domestic wastewater treatment facilities (wastewater treatment pits, etc.) at workers' camp.	Contractor	DoST	Included in construction cost
Waste	- Transportation and disposal of surplus soil to neighbouring sites, - Review and comply with waste management policies in the national park, - Transport and disposal of solid waste, used oil and other hazardous waste from construction equipment to disposal sites, - Disposal of workers' food residues and other organic waste by composting.	Contractor	DoST	Included in construction cost
Noise	- Restrict nighttime construction works.	Contractor	DoST	Included in construction cost
Natural environment				
Protected area	- Comply with the management plan of the national park (prohibit collection of animals and plants, waste management, etc.), - Coordinate and cooperate with the national park office.	Contractor	DoST	Included in construction cost
Ecosystem	- Prohibit workers from collecting wild animals and plants in the national park, - Educate workers for conservation of the ecosystem (prohibition of dumping garbage, restriction of access to forests, etc.), - Minimize tree felling.	Contractor	DoST	Included in construction cost
Social environment				
Existing social infrastructure and services	- Advance notice of traffic restrictions and road closures - Minimize the period of road closure	Contractor	DoST	Included in construction cost
Cultural heritage	- Respect Kayla/Tsen beliefs of local residents (having rituals before the construction, etc.)	Contractor	DoST	Included in construction cost
Others				
Accidents	- Safety training for construction vehicle drivers and workers, - Maintenance of construction vehicles, - Installation of signs and flagmen, - Installation of safety equipment, - Management of explosives and hazardous substances.	Contractor	DoST	Included in construction cost
[Operation phase]				
Natural environment				
Ecosystem	Measures based on monitoring results (If unforeseen problems are identified, for example, the new bridge accelerate wildlife's roadkill, etc., specialized studies and countermeasures will be conducted.)	DoST	DoST	-

Source: JICA Survey Team

Table 1-7-27 Mitigation Measures (Durdari Bridge)

Category	Mitigation Measures	Implementing agency	Responsible agency	Budget
[Construction phase]				
Pollution				
Air pollution	- Reduce emissions by maintaining equipment in good conditions, - Avoid unnecessary idling, - Prevent scattering of soil in such way as covering with sheet after loading vehicles, - Dust prevention by sprinkling water.	Contractor	DoST	Included in construction cost
Water pollution	- Installation, proper use, and maintenance of domestic wastewater treatment facilities (wastewater treatment pits, etc.) at workers' camp.	Contractor	DoST	Included in construction cost
Waste	- Transportation and disposal of surplus soil to neighbouring sites, - Transport and disposal of solid waste, used oil and other hazardous waste from construction equipment to disposal sites, - Disposal of workers' food residues and other organic waste by composting.	Contractor	DoST	Included in construction cost
Noise	- Restrict nighttime construction works.	Contractor	DoST	Included in construction cost
Natural environment				
Ecosystem	- Minimize tree felling.	Contractor	DoST	Included in construction cost
Social environment				
Existing social infrastructure and services	- Advance notice of traffic restrictions and road closures - Minimize the period of road closure	Contractor	DoST	Included in construction cost
Others				
Accidents	- Safety training for construction vehicle drivers and workers, - Maintenance of construction vehicles, - Installation of signs and flagmen, - Installation of safety equipment, - Management of explosives and hazardous substances.	Contractor	DoST	Included in construction cost
[Operation phase]				
Natural environment				
Ecosystem	Measures based on monitoring results (If unforeseen problems are identified, for example, the new bridge accelerate wildlife's roadkill, etc., specialized studies and countermeasures will be conducted.)	DoST	DoST	-

Source: JICA Survey Team

Table 1-7-28 Monitoring Plan (Namling and Durdari Bridge)

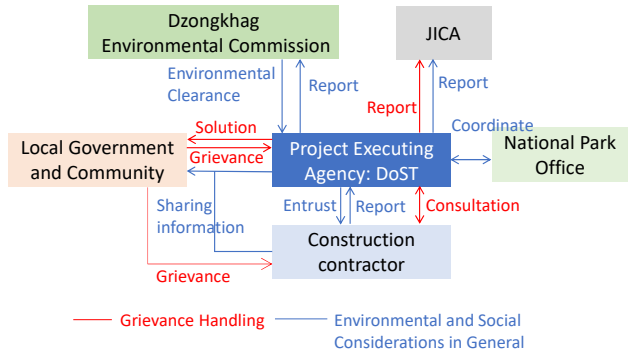
Category	Items	Locations	Frequency	Implementing agency	Responsible agency	Budget
[Constructionphase]						
Pollution						
Air pollution	CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$, TSPM	1 location around the construction site	2 times/year (dry season, rainy season)	DoST	DoST	DoST
Water pollution	BOD, pH, TSS, water temperature, fecal coliforms, total coliforms	1 location around the construction site	2 times/year (dry season, rainy season)	DoST	DoST	DoST
Waste	Volume of waste generated by type and method of disposal	Construction sites, workers' camps	at any time	Contractor	DoST	Included in construction cost
Noise	Noise	1 location around the construction site	2 times/year (dry season, rainy season)	DoST	DoST	DoST
Natural environment						
Ecosystem	Wildlife and roadkill sighted by workers and others	Around the construction site	at any time	Contractor, DoST, the park office* (*Namling Bridge)	DoST	Included in construction cost
Social environment						
Existing social infrastructure and services	Complaints and opinions from residents etc. and the response	Around the construction site	at any time	Contractor, DoST	DoST	Included in construction cost
Cultural heritage (Namling Bridge)	Respect Kayla/Tsen beliefs of local residents (having rituals before the construction, etc.)	To be decided after consulting with local residents	To be decided after consulting with local residents	Contractor, DoST	DoST	Included in construction cost
Others						
Accident	Accidents related to construction, and the causes	Around the construction site and vehicle traffic routes	at any time	Contractor	DoST	Included in construction cost
[Operation phase]						
Natural environment						
Ecosystem	Wildlife and roadkill etc.	Around the construction site	at any time	DoST, the park office* (*Namling Bridge)	DoST	DoST (as needed)

Source: JICA Survey Team

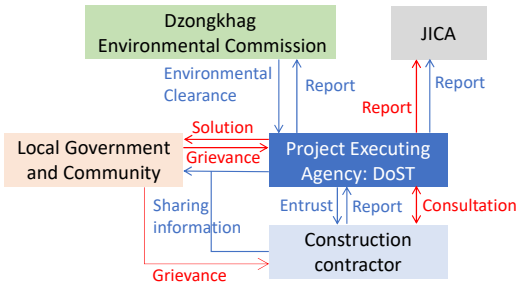
(7) Implementation Structure

Figure 1-7-13 and Figure 1-7-14 show the implementation structure of environmental and social considerations for reconstruction of Namling and Durdari Bridges. DoST, as the project proponent, is responsible for reporting the results of the environmental management and monitoring to JICA, as well as to Environmental Commission of Mongar District during the construction in accordance with the requirements that will be stated in the environmental clearance. DoST and the contractor will provide necessary information to the local government (Gewog) and communities as needed and will cooperate and collaborate with the national park office for the Namling Bridge project. Grievances from the local government, community, residents, etc. will be received in either way of verbal or written. They are recorded and addressed by DoST and reported to JICA along with other monitoring results. As for the structure in DoST, Lingmethang regional office and Trashigang regional office will handle the local operation at sites for Namling and Durdari Bridges, respectively. For grievance handling, the regional offices will receive, record, and respond to complaints, but will also coordinate responses with other departments within DoST and with other agencies, depending on the nature of the complaint. The results of the grievance response will be made public after consultation with the complainants.

<Namling Bridge>



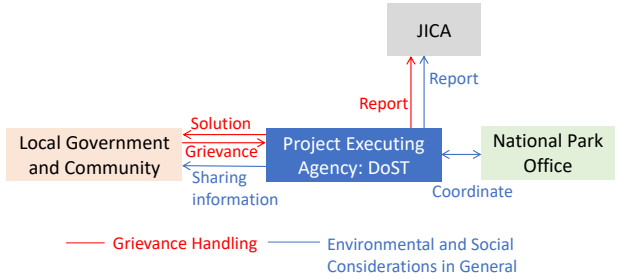
<Durdari Bridge>



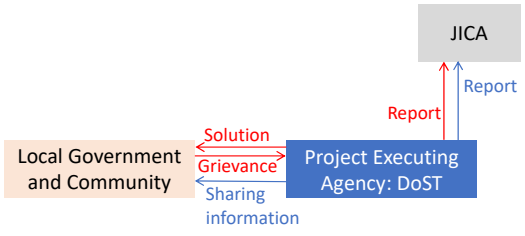
Source: JICA Survey Team

Figure 1-7-13 Implementation Structure of Environmental and Social Considerations (Construction Phase)

<Namling Bridge>



<Durdari Bridge>



Source: JICA Survey Team

Figure 1-7-14 Implementation Structure of Environmental and Social Considerations (Operation Phase)

(8) Stakeholder Meetings

In conformity with JICA Guidelines, local stakeholder meetings were held twice at the scoping stage and the report drafting stage. The results of the meetings are summarized below.

(a) The First Meetings

In May 2023, stakeholder meetings in the scoping stage were held in three Gewogs: Saling, where the Namling Bridge is located; Chaskhar, where the Pakhadrang and Durdari Bridges are located; and Drametse, where Revidrang and Rollong Bridges are located inviting Gewog representatives and residents in general (Figure 1-7-15). The meeting schedule was announced by heads of the Gewogs to each Chiwog, and each Chiwog head disseminated to households using SNS and phone calls. During the meetings, the local consultant provided the project information and the survey schedule, and participants were asked to state their opinions on the environmental and social impacts of the Project. Table 1-7-29 shows a summary of each meeting. The information provided during the meetings are expected to be shared with residents including socially vulnerable people such as elders by the representatives of Gewog and Chiwog who attended the meetings.

Saling Gewog

Chaskhar Gewog

Drametse Gewog

Source: JICA Survey Team

Figure 1-7-15 Photo of the First Stakeholder Meetings

Table 1-7-29 Summary of the First Stakeholder Meetings

Saling Gewog (Namling Bridge)

Items	Description
Date & Time	Tuesday, May 16, 2023, 2-3 p.m.
Location	Gewog meeting hall
Date of Announcement	Wednesday, May 10, 2023 and reconfirmed on Monday, May 15, 2023.
Participant	Saling Gewog residents and businesses 7 males, 8 females

[Summary of Participant Statements]

Speaker's Affiliation	Gender	Comments/Question	Response (Consultant)
Gewog head	Male	What is the purpose of the survey?	To get understanding of socio-economic status of people residing along national east-west highway. Also, to understand their experience about plying along the highway and bridges as well as any possible impacts of the Project (positive and negative).
Resident of Lingmethang	Female	When will construction begin?	After the survey, priorities will be discussed.
Resident of Masangdaza	Male	Japanese-funded bridges are of good quality and beautiful. We thank JICA for their support.	We hope that the bridge reconstruction will benefit the eastern districts.
Resident of Lingmethang	Female	Namling Bridge connects our land in Lingmethang. We depend on rice and maize cultivation as our main source of income. In the past, when Namling Bridge was washed away by a flash flood, we could not do paddy cultivation and also faced delayed administrative work in our Gewog centre based in Lingmethang.	The construction of the Namlin Bridge will benefit not only Sengor Chiwog, but also the many people traveling east and west.
Gewog head	Male	Namling bridge is the lifeline structure that connects the east, central, and western parts of Bhutan. There is no alternate bypass road connectivity except for Gyelposhing-Ngaglam Highway. There have been occasions in the past that Namling Bridge was damaged by monsoon rain and movement of vehicles and people both from the east and the west were disrupted. The new construction will immensely benefit public not only of Saling Gewog by selling their agricultural products and fruits for income generation but also people of other localities in further east. The business community like Lingmethang will also benefits with more commuters plying through the east-west highway. On the other hand, there is a concern that the Kayla/Tsen (local deity), which alters seasonal pattern like timely rainfall, will be disturbed. There would be an increase of sickness among infants and children. With corrective measures like commencing the construction on a very auspicious day and laying down of Sachur Bumther (religious article) may lessen aforementioned concerns. JICA, DoST, and Gewog administration should facilitate and coordinate with the local people as well as the religious persons accordingly.	Respect the religious sentiments of the community and communicate the concerns to the DoST.

Chaskhar Gewog (Durdari and Pakhadrang Bridge)

Items	Description
Date & Time	Friday, May 26, 2023, 11-12 a.m.
Location	Gewog meeting hall
Date of Announcement	Wednesday, May 17, 2023
Participant	Chaskhar Gewog residents, Gewog council members 7 males, 8 females

[Summary of Participant Statements]

Speaker's Affiliation	Gender	Comments/Question	Response (Consultant)
Gewog head	Male	What is the purpose of the survey?	To get understanding of socio-economic status of people residing along national east west highway. Also, to understand their experience about plying along the highway and bridges as well as any possible impacts of the Project (positive and negative).
Resident of Borphai	Female	When will construction begin?	After the survey, priorities will be discussed.
Resident of Kheshingra	Female	Japanese-funded bridges are of good quality and beautiful. We thank JICA for their support.	We hope that the bridge reconstruction will benefit the eastern districts.
Agriculture sector	Male	Previously, we had planned to build a marketing shed near Pakhadrang, but the plan never materialized due to land acquisition problems. Hope to solve the problems if new Pakhadrang Bridge is constructed which will also provide avenue for selling agricultural and livestock products.	We really hope that the land acquisition will not hinder the construction of Pakhadrang Bridge. Gewog administration should facilitate the land acquisition. I understand only one household will be affected.
-	-	If one of the bridges (either Pakhadrang or Durdari) is at risk for the commuters to cross, then the commuters have to use the farm road which goes through Chaskhar Gewog and Dungsingma Pam village. It has happened in the past when Pakhadrang Bridge was damaged. Using the farm road, the commuters have to cross 3 bailey bridges which are temporary in nature. The concern was if the project has any possibility of resolving this issue by upgrading the bailey bridges along the farm/Gewog Road.	Once the two bridges on the national highway are permanently rehabilitated, there will be no future need to use the farm road.

Drametse Gewog (Revidrang and Rollong Bridge)

Items	Description
Date & Time	Tuesday, May 30, 2023, 10-11 a.m.
Location	Gewog meeting hall
Date of Announcement	Sunday, May 21, 2023
Participant	Drametse Gewog residents, Gewog council members 6 males, 11 females

[Summary of Participant Statements]

Speaker's Affiliation	Gender	Comments/Question	Response (Consultant)
Gewog head	Male	We welcome the survey team and assure of all support in the field to carry out the household survey successfully.	The team thanked the Gewog administration for their timely support and help and thanked all the participants for attending the meeting to share their thoughts and opinion.
Gewog administrative officer	Male	Is the bridge construction through JICA's grant or a state loan?	The bridge construction is a complete grant package. JICA has been important and key development partner for the country.
Resident of Nangkhar	Female	We have seen JICA-funded bridges in Trongsa and Wandue and there is no doubt about their quality. We hope that bridges of the same quality will be built in Revidrang and Rollong. Furthermore, two-way lane is favourable.	JICA is one of the development partners that has prioritized quality over quantity and timely implementation of projects.
Gewog administrative officer	Male	The new bridge construction will enormously benefit general public of six eastern districts. All patients of eastern districts are referred to Mongar referral hospital and the current Rollong Bridge is old and poses risk to commuters especially during rainy season. Revidrang Bridge is currently closed and bypass road is temporarily constructed. With the upcoming monsoon seasons, Revidrang will be unable to ply over especially small cars with influx of heavy rainfall. Even otherwise during such rainy season it becomes difficult for people to cross over. For both the bridges, will only boost the movement of people and vehicles. Some inconvenience may be caused for stoppages at the bridge sites at the time of construction which they said is tolerable as it will ultimately benefit all commuters after the bridges are completed. The land holdings within 1000m near Revidrang Bridge are as follows. 1.Baging chiwog (16 HHs) – wetland (6-7 acres), dryland (3-4 acres) 2.Zangkhar Chiwog (4 HHs) – wetland (1.5 acres) Note: Approximate land holding according to participants.	We appreciate the input and will include the information in the report.

Source: JICA Survey Team

(b) The Second Meetings

After it was decided that Namling and Durdari Bridges would be the target bridges of the Project, a second stakeholder meetings were held in October 2023 in two Gewogs, Saling, where Namling Bridge is located, and Chaskhar, where Durdari Bridge is located (Figure 1-7-16). The method of announcement, invitees, and considerations for vulnerable people are the same with the first meeting. During the consultations, the local consultant provided an overview of the results of the environmental and social considerations study (environmental and social impacts and the mitigation measures) as well as the project plan, and exchanged opinions. Table 1-7-30 shows a summary of each meeting.

Saling Gewog

Chaskhar Gewog

Source: JICA Survey Team

Figure 1-7-16 Photo of the Second Stakeholder Meetings

Table 1-7-30 Summary of the Second Stakeholder Meetings

Saling Gewog (Namling Bridge)

Items	Description
Date & Time	Tuesday, October 17, 2023, 10:00 a.m. - 12:00 p.m.
Location	Gewog meeting hall
Date of Announcement	Wednesday, October 4, 2023
Participant	Residents and businesses in Saling Gewog (5 males and 8 females) 2 from Phrumsengla National Park Office, Forest and Park Service, and 1 from DoST

[Summary of Participant Statements]

Speaker's Affiliation	Gender	Comments/Questions	Response (DoST/Consultant)
National Park Office	Male	The current loading capacity of Namling bridge is 40t. In this regard, he inquired about the loading capacity of new bridge.	The consultant informed that the loading capacity of new bridge is 70t.
Council member	Male	The bridge constructed under JICA funding is of good quality. What will new bridge look like?	The current bridge type is bailey bridge. The new bridge will be steel truss bridge similar to that of Kurizampa bridge on the way to Mongar.
National Park Office	Male	There are 7 rock bee (giant honey bee) hives below the bridge which is exactly where the new bridge construction is planned. An endangered bird named honeyguides (NT) feeds on the hive larvae and wax. The construction may disturb the present coexisted ecosystem. The construction team should be careful not to disturb honeyguides while honeyguides are expected to find alternative hives for their survival during the construction phase. CAUTION: There is a risk for the construction worker that the bee may pose treat to the workers.	Will do best not to disturb their living environment expecting honeyguide would come back after the construction.
National Park Office	Male	Namling area fall under Phrumsengla Park and waste management is a concern during bridge construction period. We hope that the contractor will monitor waste disposal and manage it as per the waste management guidelines of Park, which follows the national waste management guidelines.	The project does acknowledge the waste issues and will strictly comply with waste management guidelines. The project has plan to segregate waste and transport to proper identified sites.
Business	Male	Will there be road closure information shared with local government and business entities?	The project will inform the general public about the road closure timing through BBS TV and DoST will also inform traffic police and Road Safety and Transport Authority (RSTA) for further ease of traffic control.
Business	Female	Children born in Lingmethang area are associated with Namling deity (locally called Gokpula) and for this reason it is important that the Namling catchment areas be free from human activities contamination like smoking, open defecation and burning of meats.	Bridge construction project will adhere to the social cultural belief and minimize the contamination as concerned shared. Also, Project will make awareness program at the camp site during implementation phase.
Deputy head of Gewog	Male	Our country strongly believes in auspiciousness timing prior to any undertaking important work. We hope that that project will consult Local Government for such auspicious day for the commencement of work. In addition, if possible, it will be good if "Sang-Sur" offering arrangement are made occasionally for the benefits of local deity and all sentient beings.	Will discuss with Contractor for such arrangement during the project implementation phase.

Chaskhar Gewog (Durdari Bridge)

Items	Description
Date & Time	Wednesday, October 18, 2023, 10:00 a.m. - 12:00 p.m.
Location	Gewog meeting hall
Date of Announcement	Saturday, October 14, 2023
Participant	Residents of Chaskhar Gewog (12 males and 2 females) DoST 3 persons

[Summary of Participant Statements]

Speaker's Affiliation	Gender	Comments/Questions	Response (DoST/Consultant)
DoST	Male	Dudari bridge loading capacity was initially 40t at the time of bridge construction completion period in the year 2004. At present, with aging period of the bridge, the loading capacity is 24t. The Gewog administration is also requested to share the information to relevant stakeholders.	Noted and will correct the information.
Gewog head	Male	Will be good if the project spray water occasionally to minimize the dust and air pollution during the bridge construction phase.	Will discuss with Contractor and ensure that such pollution mitigation mechanism are put in place.
Village elder	Male	Water pollution is not a concern as there are no settlement downstream the bridge and no drinking water are tapped for commercial and household use.	Good to know that. Besides, project will install wastewater treatment pit at campsite and also monitor water quality periodically at construction site.
DoST	Male	For the interest and information to the meeting participants, bridge construction under JICA funding is undoubtedly of good quality. JICA is ensuring all documentations and necessary clearance are followed up with relevant stakeholders. DoST will follow up with social and forest clearance with Gewog for processing the environment clearance.	Consultant thanked DoST for being proactive partners for the bridge construction project and for providing all necessary support.
Gewog head	Male	Gewog will facilitate the identification of waste disposal site for domestic waste from the camp site. The current waste disposal site at Yongbari near Yadi town is far away from construction site.	Waste problems will be minimal at construction site. Nonetheless, project will ensure waste management a priority and monitor proper waste disposal. Gewog administration in providing necessary support is welcomed.
Gewog Forest Division	Male	Providing forest clearance for identification of waste disposal place within the construction site is not a problem. However, the sustainability and future management of the disposal site after the completion of bridge construction need to be discussed and agreed upon within the relevant stakeholders.	Gewog administration will further discuss with Forestry Division and identify proper disposal site with operation and management plan thereafter.
Gewog head	Male	The newly constructed vegetable shed near the Dudari bridge will boost the economy of nearby farmers. It will also serve fresh local vegetables to the campsite workers and highway commuters. The Gewog administration request project to develop parking areas in front of the shed along with the bridge construction.	Will inform and discuss with Contactors for the proposed request.

Source: JICA Survey Team

(9) Environmental Checklists, Monitoring Forms, and Environmental Management Plans under the Legislation

Environmental checklist (12. Bridges) and monitoring forms based on JICA Guidelines are presented in Table 1-7-31 andTable 1-7-32. In addition, the environmental management plan required to apply for the Environmental Clarance is shown in Table 1-7-33.

Table 1-7-31 JICA Environmental Checklist

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) N/A (b) N (c) N/A (d) N	(a) EIA is not required for the Project. Application for environmental clearance will be submitted with IEE. (b) IEE form will be submitted to Mongar Dzongkhag Environmental Commission for environmental clearance. (at the latest by March 2024) (c) The conditions will be confirmed when environmental clearance is issued. (d) Prior to above, social clearance from local government and forestry clearance from Department of Forests and Park Services need to be obtained. They were already obtained for both two bridges in October to November in 2023.
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comment from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) Y	(a) Stakeholder meetings were held near the project sites to explain the project contents and the potential impacts as well as the environmental management plan. Understanding has been obtained from the local stakeholders. (b) The comments from the stakeholders have been reflected in the environmental management plan to be submitted to the Mongar Environmental Commission when applying for the environmental clearance.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) N/A	(a) Since the Project is to reconstruct existing bridges, there are no alternative plans to be discussed. Without project options were examined to compare with the Project option in terms of environmental and social considerations.
2 Pollution Control	(1) Air Quality	(a) Is there a possibility that air pollutants emitted from the project related sources, such as vehicles traffic will affect ambient air quality? Does ambient air quality comply with the country's air quality standards? Are any mitigating measures taken? (b) If air quality already exceed country's standards near the route, is there a possibility that the project will make air pollution worse?	(a) N (b) N/A	(a) The Project will not affect ambient air quality. (b) The current air pollutants at the project sites are far below the country's standards.
	(2) Water Quality	(a) Is there a possibility that soil runoff from the bare lands resulting from earthmoving activities, such as cutting and filling will cause water quality degradation in downstream water areas? (b) Is there a possibility that the project will contaminate water sources, such as well water?	(a) N (b) N	(a) Water quality degradation caused by soil runoff is not expected because slope protection measures will be taken to the bare lands after cutting. (b) There are no water sources around the project sites.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(3) Noise and Vibration	(a) Do noise and vibrations from the vehicle and train traffic comply with the country's standards? (b) Do low frequency sound from the vehicle and train traffic comply with the country's standards?	(a) N (b) N/A	(a) Present noise level at the project site has already exceed country's standards for sensitive area and mixed area during nighttime while it meets those for industrial area. The noise level will not be changed by the Project because it is to reconstruct existing bridges. (b) There are no country's standards for low frequency sound. The noise level will not be changed by the Project because it is to reconstruct existing bridges.
3 Natural Environment	(1) Protected Areas	(a) Is the project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	(a) Y, N	(a)The project site (Namling Bridge) is located in Phrumsengla National Park designated by the country's law. The Project will not affect the protected area because the Project is to reconstruct the existing bridge and the area for the construction work is limited to the existing road and the surrounding area.
	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Are adequate protection measures taken to prevent impacts, such as disruption of migration routes, habitat fragmentation, and traffic accident of wildlife and livestock? (e) Is there a possibility that installation of bridges and access roads will cause impacts, such as destruction of forest, poaching, desertification, reduction in wetland areas, and disturbance of ecosystems due to introduction of exotic (non-native invasive) species and pests? Are adequate measures for preventing such impacts considered?	(a) N (b) N (c) N/A (d) N/A (e) N	(a)The project sites are located on and in the vicinity of the existing highway and does not encompass coral reefs, mangroves, or tidal flats. (b)The project sites do not encompass habitats of endangered species although they seem to be inhabiting around the site. (c) Significant ecological impacts are not anticipated. (d) Protection measures are not necessary because traffic accidents of wildlife have rarely occurred according to the national park office. (e) Installation of bridges will not cause such impacts because it is reconstruction of the existing bridges.
	(3) Hydrology	(a) Is there a possibility that hydrologic changes due to the installation of structures will adversely affect surface water and groundwater flows?	(a) N	(a) Structures will not be installed in water flows.
	(4) Topography and Geology	(a) Is there any soft ground on the route that may cause slope failures or landslides? Are adequate measures considered to prevent slope failures or landslides, where needed? (b) Is there a possibility that civil works, such as cutting and filling will cause slope failures or landslides? Are adequate measures considered to prevent slope failures or landslides? (c) Is there a possibility that soil runoff will result from cut and fill areas, waste soil disposal sites, and borrow sites? Are adequate measures taken to prevent soil runoff?	(a) N (b) Y (c) N	(a) There is no soft ground is identified. Slope protection measures will be taken on the slopes along the existing road on both sides of the bridges. (b) Cutting and filling works will be conducted in the dry season to prevent slope failures. (c) Soil runoff is not expected because slope protection measures will be taken. Because slope protection works are avoided during the rainy season, soil runoff will not be expected.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlment assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Is the compensations going to be paid prior to the resettlement? (e) Is the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?	(a) N (b) N/A (c) N/A (d) N/A (e) N/A (f) N/A (g) N/A (h) N/A (i) N/A (j) N/A	(a) Involuntary resettlement is not caused. (b) N/A (c) N/A (d) N/A (e) N/A (f) N/A (g) N/A (h) N/A (i) N/A (j) N/A
	(2) Living and Livelihood	(a) Where bridges and access roads are newly installed, is there a possibility that the project will affect the existing means of transportation and the associated workers? Is there a possibility that the project will cause significant impacts, such as extensive alteration of existing land uses, changes in sources of livelihood, or unemployment? Are adequate measures considered for preventing these impacts? (b) Is there any possibility that the project will adversely affect the living conditions of the inhabitants other than the target population? Are adequate measures considered to reduce the impacts, if necessary? (c) Is there any possibility that diseases, including infectious diseases, such as HIV will be brought due to immigration of workers associated with the project? Are adequate considerations given to public health, if necessary? (d) Is there any possibility that the project will adversely affect road traffic in the surrounding areas (e.g., increase of traffic congestion and traffic accidents)? (e) Is there any possibility that project will impede the movement of inhabitants? (f) Is there any possibility that bridges will cause a sun shading and radio interference?	(a) N/A (b) N (c) N (d) N (e) N (f) N	(a) The bridges are not newly installed. (b) Since the road traffic will be stabilized by the reconstruction of bridges, no adverse impacts but positive impacts on the livelihood and regional economy are expected. During the construction, business and employment opportunities related to the construction may arise. (c) Possibility of outbreak of HIV/AIDS and Covid-19 caused by immigration of infected workers is low because infection rates are low in the country and managed by the government. (d) The Project will positively affect the road traffic by reducing the risk of collapse of the bridges. During the construction, it is expected that the national highway will be temporarily closed to traffic; however, consideration will be given to shortening the time of the road closure as much as possible and thoroughly informing related organizations and residents in the surrounding area in advance. (e) The Project will secure the movement of inhabitants through the national highway. Temporary closure of the national highway during construction will affect the movement of inhabitants; however, will be taken into consideration as described above. (f) Sun shading and radio interference are not expected because there are no houses etc. around the site.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(3) Heritage	(a) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a) N	(a) Although there are no cultural heritage sites or religious facilities affected, local religious feelings must be taken into consideration because a mountain of about 3 km from Namling Bridge is believed to be inhabited by a god, and there are concerns that this may be disturbed by the construction work.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) Adverse impacts on the local landscape are not expected.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N/A (b) N/A	(a) Ethnic minorities and indigenous people are not identified around the project sites. (b) N/A
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that security guards involved in the project not to violate safety of other individuals involved, or local residents?	(a) Y (b) Y (c) Y (d) Y	(a) DoST and the contractor will comply with Labour and Employment Act 2007. (b) Safety equipment and hazardous material management will be secured by the contractor for the construction works with the responsibility of DoST. (c) Safety and health program and safety training will be implemented by the contractor for the construction works with the responsibility of DoST. (d) Security guards will be educated not to violate other individuals and local residents with the responsibility of DoST.
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts?	(a) Y (b) Y (c) Y	(a) Mitigation measures (restriction of nighttime works, dust prevention by sprinkling water, reduction of emission by maintenance of equipment, proper waste disposal, etc.) are stated in the environmental management plan to be submitted to Mongar environmental commission for approval. (b) No significant impacts are expected as the construction area is limited along the existing road. As mitigation measures, tree cutting is minimized. Educating workers for ecological conservation is implemented for Namling bridge which is located in the national park. (c) Closure of the national highway is expected due to the construction works; however, it will be temporary. Minimizing the closing period and advance notice will be provided as mitigation measures.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(2) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d) Y	(a) During both construction and operation, monitoring program will be planned and implemented by DoST. (b) During construction, on-site measurement of air, water quality, and noise will be made twice a year. The amount of waste generated and disposal methods, wildlife sightings and roadkill, grievances from inhabitants and the responses, and construction-related accidents will be recorded at any time. During operation, wildlife sightings and roadkill will be recorded. (c) During construction, the monitoring of the environmental management will be implemented by the contractor. The budget for on-site measurements will be secured by DoST. During operation, DoST will implement it as a part of their regular work or acquire the budget if necessary. (d) It will be decided when the environmental clearance is issued.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Roads, Railways and Forestry Projects checklist should also be checked (e.g., projects including large areas of deforestation). (b) Where necessary, pertinent items described in the Power Transmission and Distribution Lines checklist should also be checked (e.g., projects including installation of power transmission lines and/or electric distribution facilities).	(a) N/A (b) N/A	(a) The Project does not include large scale deforestation. (b) The Project does not install power transmission lines or electric distribution facilities.
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a) N/A	(a) The Project does not include factors related to transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming.

Source: JICA Survey Team

Table 1-7-32 Monitoring Form

[Construction phase]

1. Pollution

1.1 Air quality

Survey date	Baseline				**Monitoring results**		Standards	
	Dry season `March 2023		Rainy season July 2023		**dd/mm/yy**			
Parameter	Namling	Durdari	Namling	Durdari	**Namling**	**Durdari**	Mixed area	Sensitive area
CO (ppm)	BDL	BDL	BDL	BDL			2,000	1,000
NO_2 ($\mu g/m^3$)	0.088	0.051	0.116	0.103			80*	30*
SO_2 ($\mu g/m^3$)	BDL	BDL	BDL	BDL			80	30
PM10 ($\mu g/m^3$)	25.89	35.73	13.52	22.41			100	75
PM2.5 ($\mu g/m^3$)	23.24	17.73	11.06	12.66			60	60
TSPM ($\mu g/m^3$)	34.93	36.44	15.69	30.05			200	100

1. BDL: Below Detectable Limit
2. Standards: Environmental Standards, 2020, National Environment Commission of Bhutan
3. Mixed area means area where residential, commercial or both activities take place
4. Sensitive area means area where sensitive targets are in place like hospitals, schools, sensitive ecosystems
5. Standards with * shows those for Nox

Comments on the monitoring results (Causes of exceeding standards, etc.):

1.2 Water quality

Survey date	Baseline				**Monitoring results**		Standards		
	Dry season `March 2023		Rainy season July 2023		**dd/mm/yy**				
Parameter	Namling	Durdari	Namling	Durdari	**Namling**	**Durdari**	A	B	C
BOD (mg/L)	1.07	1.22	3.62	2.12			2	5	50
pH	7.34	7.61	7.46	7.51			6.5-8.5	6.0-9.0	6.0-9.0
TSS (mg/L)	2.34	2.19	128.96	67.21			25	100	-
Water temperature (°C)	15.6	22.1	15.9	22.8			-	-	-
Fecal Coliform (MPN/100mL)	4	6	9	13			50*	5000*	10000*
Total Coliform (MPN/100mL)	7	9	13	14			20*	2000*	5000*

1. Standards: Environmental Standards, 2020, National Environment Commission of Bhutan
2. A: (Very good) Drinking water source without conventional treatment, but after disinfection whenever necessary
3. B: (Good) Drinking water source with conventional treatment
4. C: (Moderate) Used for irrigation, industrial cooling, etc.

Comments on the monitoring results (Causes of exceeding standards, etc.):

1.3 Noise

Survey date	Baseline				**Monitoring results**		Standards		
	Dry season `March 2023		Rainy season July 2023		**dd/mm/yy**				
	Namling	Durdari	Namling	Durdari	**Namling**	**Durdari**	Industrial area	Mixed area	Sensitive area
Day time [6 am-10 pm] (Db)	54.65	56.92	56.20	58.03			75	65	55
Night time [10 pm-6 am] (Db)	51.63	59.68	56.33	57.79			65	55	45

1. Standards: Environmental Standards, 2020, National Environment Commission of Bhutan
2. Mixed area means area where residential, commercial or both activities take place
3. Sensitive area means area where sensitive targets are in place like hospitals, schools, sensitive ecosystems

Comments on the monitoring results (Causes of exceeding standards, etc.):

1.4 Waste

Reporting period: from (dd/mm/yy) to (dd/mm/yy)

Source of waste	Type of waste *	Method of disposal	Volume/Weight
Construction site (Bridge:)			
Workers' camp			

*Surplus soil/Removed vegetation/Hazardous waste (oil, etc.)/
Organic waste (food residue, etc.) /Non-organic solid waste

2. Natural Environment

Record of encountered wildlife including roadkill

Date	Location	Species	Details of encountering

3. Social Environment

Complaint handling record

Complaint reception		Status for solution	
Date		Date	
Complainant		Responsible agency	
Details of complaint		Action taken	

4. Others

Record of project related accidents including construction and traffic accidents

Date	Location	Details of accidents including causes

[Operation phase]

1. Natural Environment

Record of encountered wildlife including roadkill

Date	Location	Species	Details of encountering

2. Social Environment

Complaint handling record

Complaint reception		Status for solution	
Date		Date	
Complainant		Responsible agency	
Details of complaint		Action taken	

Source: JICA Survey Team

Table 1-7-33 Environmental Management Plan (To Be Submitted for Environmental Clearance)

Activity	Potential Negative Environmental Impacts	Mitigation Measures	Public Participation and Coordination	Socio-Economic and Cultural Considerations	Budgeting	Supervision	Monitoring /Evaluation
1. Purchase aggregates/sand from commercial aggregate pits.	• NA	• NA	• NA	• NA	• NA	• NA	• DoST
2. Transportation of materials and equipment	• Dust and emission from vehicles	• Maintenance of vehicles, • Avoidance of unnecessary idling, • Prevention of scattering of soil in such way as covering with sheet after loading vehicles.	• NA	• NA	• Include in project cost	• Bridge division, DoST	• DoST
3. Spoil Disposal (including temporary stockpiling of material)	• Slides of piled materials • Damage to vegetation	• Deposit materials in suitable location designated by DoST, • Place materials in proper shape, • Minimize cutting trees in the deposit site.	• NA	• Protect adjoining properties	• Include in project cost	• Bridge division, DoST	• DoST
4. Bridge installation	• Emission from equipment • Construction noise • Accidents while working at heights	• Maintenance of vehicles, • Restrict nighttime works, • Equip safety tools.	• NA	• NA	• Include in project cost	• Bridge division, DoST	• DoST
5. Slope protection work on both sides of bridge	• Slope failure • Hinder the highway traffic	• Avoid slope works during rainy season, • Notify local government and communities prior to blocking the traffic, • Minimize the blocking period.	• NA	• Coordinate with traffic agency	• Include in project cost	• Bridge division, DoST	• DoST
6. Work Camp Location, Operation & Closure, restrictions on workers (sanitation, fuelwood collection, poaching)	• Conflict with locals • Garbage, oil & grease pollution • Domestic wastewater discharge • Damage to Vegetation and wildlife	• Proper siting, • Prohibit collecting wild animals and plants by workers, • Provide sanitary facilities including wastewater treatment pit, • Segregate solid waste and transport to proposed disposal site, • Compost disposal of organic waste, • Minimize cutting trees.	• Dzongkhag administration and local people • Awareness of labors	• Consider local, • Culture, use state land, • Comply with national waste management guidelines,	• Include in project cost	• Bridge division, DoST	• DoST

Activity	Potential Negative Environmental Impacts	Mitigation Measures	Public Participation and Coordination	Socio-Economic and Cultural Considerations	Budgeting	Supervision	Monitoring /Evaluation
7. Explosives & Toxic Waste Management	• Fire & explosion hazard • Ground & surface water pollution	• Do not store near surface waters, • Use plastic sheeting under hazardous materials, • Use Magazine to store explosive materials, • Collect wastes properly and dispose safely.	• Contact Ministry of Home Affairs in case of hazard or needing material annihilation. • Contact Ministry of Home Affairs for explosive materials	• NA	• Include in project cost	• Bridge division, DoST	• Dost
8. Air and noise management	• Dust generation by earth work • Excessive noise disrupting livestock and wildlife	• Spraying water in the project area, • Conduct blasting during day times, • Restricting nighttime works.	• NA	• NA	• Include in project cost	• Bridge division, DoST	• DoST
9. Safety operation	• Loss of human life • Loss of property	• Safety training for drivers and workers, • Maintenance of vehicles and equipment, • Traffic sign and flagman.	• NA	• NA	• Include in project cost	• Bridge division, DoST	• DoST

Source: JICA Survey Team