DEPARTMENT OF ROADS,
MINISTRY OF WORKS AND HUMAN SETTLEMENT,
BHUTAN

PREPARATORY SURVEY
ON
THE PROJECT
FOR
RECONSTRUCTION OF BRIDGES
ON
PRIMARY NATIONAL HIGHWAY NO.4
IN
BHUTAN

FINAL REPORT

NOVEMBER 2016

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
INGÉROSEC CORPORATION

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the Preparatory Survey on the Project for Reconstruction of Bridges on Primary National Highway No.4 in Bhutan, and entrust the survey to the consultant (consist of Oriental Consultants Global Co., Ltd. and INGÉROSEC Corporation).

The survey team held a series of discussions with the officials concerned of the Royal Government of Bhutan, and conducted field investigations. 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.

November, 2016

Akira NAKAMURA
Director General,
Infrastructure and Peacebuilding
Department
Japan International Cooperation Agency

SUMMARY

1. Overview of the Country

Bhutan is located at southern foot of Himalayas and is surrounded by India and China. The majority of the national land (A=38,394km^2) is mountainous and difference of elevation is large namely 100m in southern area and 7,561m in northern area. In respect of 4 bridges of the Project, Telegangchu Bridge is at approx. 2,100m, Beteni Bridge is at approx. 1,100m, Samkhara Bridge is at approx. 1,000m and Passang Bridge is at 300m. Bhutan also owns approx. 760,000 populations (2013).

Regarding climate condition, the national land is divided into 3 major climate zones namely Alpine-Tundra climate zone in northern Himalayas (above 3,000m), Monsoonal climate zone in central region (1,200 – 3,000m) and Subtropical climate zone in southern Tarai plains (below 1,200m). The annual season is classified to 2 major periods namely rainy season (May – September) and dry season (October – April) under effect of tropical monsoon. In respect of rainfall among the 4 bridges, the annual average rainfall at Telegangchu Bridge indicates approx. 1,200mm as well as other 3 bridges indicates approx. 3,700mm. Furthermore, regarding the average temperature, at the site of Telegangchu Bridge indicates 25 degree Celsius in summer and 5 degree Celsius (occasionally less than zero) in winter. On the other hand, other 3 bridges indicate over 25 degree Celsius in summer and approx. 10 degree Celsius in winter.

Regarding social and economic condition, approx. 70% of the population still reside in agricultural communities at present. They generally engage small scale labor based agricultural work in the local communities. The working population is approx. 334,000 which is equivalent to 67.4% of the total national population (2010). Furthermore, approx. 60% of them belong to agricultural sector. Unemployment rate is comparatively low (3.1%, 2011). However, the rate of young generation (15 – 29 years old) occupies 65.45% in the total unemployment population. It currently becomes one of the social issues in Bhutan.

The national economy indicated constant high growth rate of GDP as 9% in average since 2002 to 2008 (9th 5-year plan period). In particular, the rate shows 18% in 2007 due to inauguration of operation in Tara hydropower plant. After then, the rates still sustain high values as 5 – 12% annually. Total amount of GDP indicates 1.8 billion US dollar (GDP per capita = 2,400 US dollar) in 2013. The component of the GDP (2011) by the industry is 16.16% (construction), 15.72% (agriculture and forestry), 13.92% (electric power), 8.23% (manufacturing), 2.27% (mining) and 12.79% (social welfare & education) respectively. Regarding trade balance, amount of the export indicates approx. 527 million US dollar as well as the import indicates 815 million US dollar (288 million US dollar of deficit) in 2011.

2. Background, Circumstances, and Outlines of the Requested Project

In Bhutan, the majority of the national land is mountainous, therefore, road traffic is the most important means in transportation. The road in Bhutan has less number of highway as well as detour and alternative route and is inadequate in specification (width, alignment, pavement and slope protection etc.) because there is topographic constrains of steep mountainous area although the total length has been constantly expanding from about 4,000km in 2003 to about 10,600km in 2013.

Ministry of Works and Human Settlement (MoWHS) has established "Road Sector Master Plan (2007-2027)" in 2006 and plans to implement maintenance, repair and replacement of bridges, enhancement of feeder road and expansion of road network during next 20 years until 2027. In addition, the Royal Government of Bhutan (RGoB) indicates the plan such as maintenance of existing road (3,522km), replacement of bridges (24 bridges) and widening of Primary National Highway (PNH) No.1 administrated by DoR in "Eleventh Five Year Plan (2013-2018)".

Principal trunk roads are only PNH No.1 (PNH-1) which runs east to west of the country and four PNHs which run southward to Indian border (PNH-2 to 4& AH48) (Total length of PNH is 1,860km (in year 2013)). Among them, PNH-4 is one of the important roads in aspect of transportation of passenger and cargo which connecting between Trongsa (center in Central region) and Gelephu (center in Southern region) without an alternative route. Furthermore, PNH-4 is currently also playing a role for transportation route for Mangdechu Hydropower Plant Construction Project. However, almost of the existing bridges including the target 4 bridges had been constructed before 1980 and currently deterioration due to age has been in progress. Moreover, width and loading capacity of those bridges do not satisfy current design standard in Bhutan. Considering the above, risk of bridge collapse has been increasing day by day. In addition, those bridges are located in severe mountainous road section. Therefore, safe work execution with high quality will be required within a limited working space due to the terrain constraints.

Under such circumstances as above, the Royal Government of Bhutan (RGoB) requested reconstruction project of 5 bridges (Telegangchu, Chaplekhora, Beteni, Samkhara and Passang) by applying Grand Aid to the Government of Japan (GoJ) in July 2014.

3. Outline of Survey Results and Substance of the Project

In response to the request of the RGoB, the GoJ dispatched the survey team for implementation of the preparatory survey work and the discussion with the RGoB. The team examined adequacy of the initial request in aspect of technical difficulty during the survey work. As a result, modification of the request was made and consented between the both governments. Subsequently, signing of the Minutes of Discussions stating the above consent was made on 14th day of September, 2016. Modified content of the request is as shown below.

- ✧ Reconstruction of 4 bridges namely Telegangchu Bridge (25m), Beteni Bridge (25m), Samkhara Bridge (61m) and Passang Bridge (40m).
- ✧ Construction of approach roads of the new bridges.

Note Chaplekhora Bridge (17m) which included in the initial request was omitted due to the following reasons.

The existing bridge length is only 17m. The reconstruction will be capable by applying RC superstructure type under management of Bhutan side because they have a lot of work experiences for this structure type. Furthermore, the team confirmed the work requiring high technology such as slope protection work in the road section will not be necessary through the outline design work. Moreover, removal of the existing bridge will be comparatively easy because the existing bridge is made of RC structure.

On the other hand, other 4 bridges indicate the following technical difficulties during the construction work.

Design lengths of the bridges will be 30 – 50m and the superstructure will be erected without a pier (i.e. single span) due to terrain and river circumstances. Furthermore, the team examined the applicable superstructure type by multi-criteria comparison such as cost effectiveness, workability and maintenance difficulty etc. As a result, application of PC simple box girder type which Bhutan side does not own the work experience was decided. In addition, the slope protection work with installation of anchor bolt in the road sections (Telegangchu, Beteni and Samkhara) and the removal work of the existing bridge (steel) that requiring high and precise technology (Samkhara and Passang) will be implemented.

According to the above considerations, 4 bridges namely Telegangchu Bridge, Beteni Bridge, Samkhara Bridge and Passang Bridge were determined as the target bridges of the Project. Application of the Japanese contractor with high capacity in aspects of technology and management for the reconstruction of these bridges will be adequate.

Outlines of the design results for the bridges and the roads are summarized respectively in the following tables.

1) Bridge

Name of Bridge		Telegangchu	Beteni	Samkhara	Passang
Design Speed		20 km/h	20 km/h	20 km/h	60 km/h
Live Load		Single lane IRC 70R (wheeled) or Double lane IRC Class A			
Bridge Length		42.0m	30.0m	49.5m	41.5m
Road Width	Road width	13.7~11.4m	10.1~8.8m	9.1~11.6m	10.0m
	Carriageway	3.50×2=7.0m			
	Sidewalk	-	-	-	1.5m×2
Superstructure		PC simple box type girder			
Substructure		A1: Inverted T-Type Abutment A2: Gravity-Type Abutment	A1: Inverted T-Type Abutment A2: Inverted T-Type Abutment	A1: Gravity-Type Abutment A2: Inverted T-Type Abutment	A1: Inverted T-Type Abutment A2: Inverted T-Type Abutment
Foundation		A1: Cast in situ pile A2: Spread Foundation	A1: Cast in situ pile A2: Spread Foundation	A1: Spread Foundation A2: Cast in situ pile	A1: Cast in situ pile A2: Cast in situ pile
Revetment Work		A1: 41.5m A2: 0.0m	A1: 31.6m A2: 27.6m	A1: 0.0m A2: 18.6m	A1: 41.8m A2: 41.7m

2) Approach Road

Name of Bridge		Telegangchu	Beteni	Samkhara	Passang
Design Speed		20 km/h	20 km/h	20 km/h	60 km/h
Geometric dimension	Typical cross fall	2%			
	Max. cross fall	6%			
	Max. longitudinal gradient	7%			
	Min. curve radius	15m	26m	18m	160m
	Widening width	4.25m	2.75m	4.00m	0.25m
	Transition section length	17m	20m	17m	50m
Design length		53.5+95.9m	81.0+99.0m	59.0+84.0m	49.5+50.0m
Cross section	Total width	10.5m			
	Carriageway width	3.75 x 2 = 7.50m			
	Shoulder	1.0m (valley side)			
	Drainage width	1.0m (mountain side)			
	Tolerance width	1.0m (mountain side)			
Pavement	Wearing course	Asphalt concrete (5cm)			
	Binder course	Dense bituminous macadam (5cm)			
	Base course	Crushed stone (22.5cm)			
	Sub base course	Crushed stone (25cm)			
	Subgrade	Design CBR = 7%			

4. Project Implementation Period

The Project implementation period is composed of 3 principal stages namely the detailed design (6.0 month), tender procedure (3.0 month) and the construction work (40.0 month).

5. Project Assessment

(1) Relevance

PNH-4, connecting Trongsa (a major city in the Central region) and Gelephu (a major city in the Southern region) is one of the most important trunk roads in passenger and cargo transport. Also, a national scale project, Mangdechu Hydropower Plant Construction Project is currently under implementation along this road. This project is expected to accomplish further development of the national economy and PNH-4 is playing a vital role as a transportation route for goods and equipment essential to its success. This survey examined the relevance of the Project (i.e. reconstruction of the 4 requested bridges) in the following aspects:

- ✧ The RGoB developed "11th Five Year Plan (2013 – 2018)" indicating implementation of maintenance work of existing roads (3,522 km) and reconstruction of bridges under the jurisdiction of DoR. This plan also indicates road widening project on PNH-1 and improvement of accessibility to the hydropower plant construction sites. The Project components highly conform to the above plan; underlining the relevance of the Project implementation.
- ✧ PNH-4 being a trunk road (i.e. no diversion route) connecting Trongsa and Gelephu, plays an important role in the Mangdechu Hydropower Plant Construction Project. Given such importance, strengthening the connectivity on this road is very necessary.
- ✧ Most of the existing bridges on PNH-4 including the four target bridges, actually do not comply with the requirements in the current Bhutanese design standard. Implementation of the Project is considered highly relevant because the Project will contribute to traffic safety and connectivity on PNH-4 by improving the widths and loading capacities of the target bridges.
- ✧ Three of the four target bridges (Telegangchu, Beteni and Samkhara) are located in quite severe mountainous road sections. Therefore, construction work will be implemented with high technological difficulties (i.e. safe work implementation within a limited construction area, safe dismantling and removal of the existing bridges, slope protection work, etc.). The work of Passang Bridge also contains the same difficulties except terrain constraints. Therefore, the Project implementation by applying Japanese technology and methodology is reasonable.

In consequence, the Project is expected to be relevant.

(2) Effectiveness

[Quantitative effects]

Index		Standard value (measured in 2015)	Target value (2024) [In three years after completion of the project]
Average traveling speed* (km/h)	Telegangchu Bridge	13	20
	Beteni Bridge	12	20
	Samkhara Bridge	14	20
	Passang Bridge	19	60
Bridge loading capacity (total axle load) (t)	All bridges	55	100
Annual average daily traffic (vehicles/day)	Trongsa – Zhemgang	190	245
	Zhemgang – Gelephu	233	301
Annual average daily passengers (numbers/day)	Trongsa – Zhemgang	640	826
	Zhemgang – Gelephu	785	1,014
Annual average daily cargo (ton/day)	Trongsa – Zhemgang	382	493
	Zhemgang – Gelephu	469	606

[Qualitative effects]

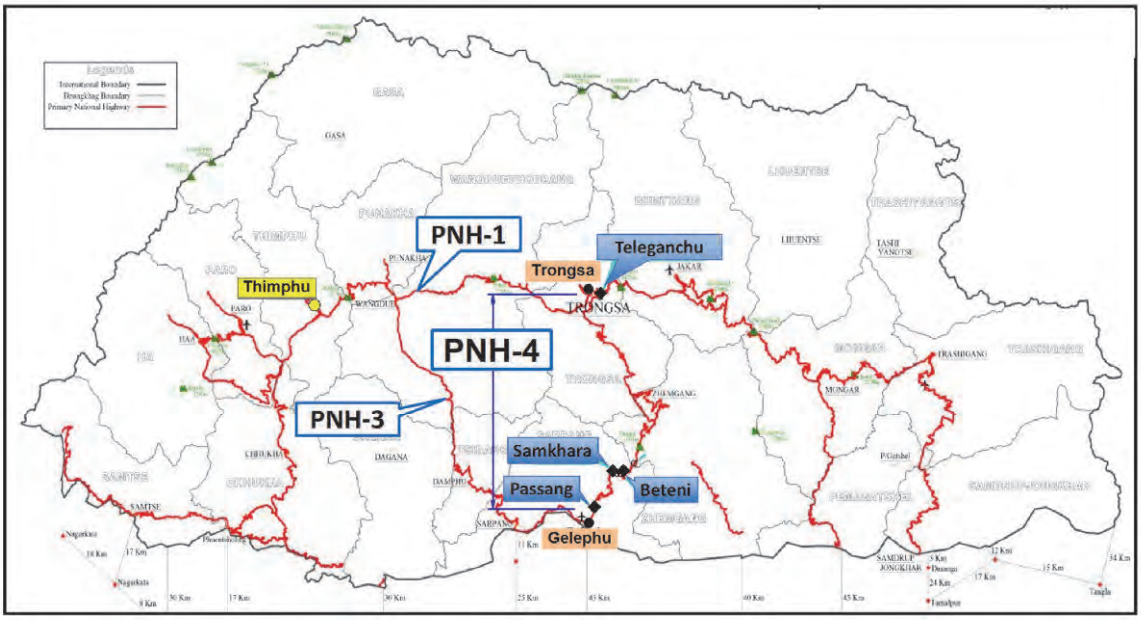
- ✧ Improving width and loading capacity of the bridges and strengthening of slope stability on the approach roads by the Project will promote traffic safety.
- ✧ PNH-4 is one of the most important trunk roads to Bhutanese economy. The Project will promote stable and smooth logistics by eliminating traffic bottlenecks. Subsequently, it will contribute to the development of local economy.
- ✧ There are local communities near Passang Bridge. Therefore, many pedestrians cross the bridge. Construction of sidewalks will ensure the safety of pedestrians (especially, vulnerable road users, such as women and children).

6. Recommendations

Implementation of routine and periodic maintenance is vital for keeping replaced bridges in a good condition. In addition, the traveling of large-heavy vehicles associated with hydropower plant construction has significant impact on bridge structure. Based on the above-mentioned viewpoints, the following recommendations are made;

- ✧ DoR will surely implement periodic inspection work to confirm current condition of the facilities. If any damages are observed, immediate repair work before enlarging of the damage is the most effective approach to ensure soundness of the facilities long-term in future.
- ✧ In order to ensure smooth traffic on PNH-4, not only 4 bridges for the Project but also widening of road and replacement and/or reinforcement of bridges in the other sections need to be conducted.

Location Map・Present Pictures



Telegangchu Bridge：
RC-T Girder Bridge
Length 25m, Width 4.5m
Construction: Year 1981

Beteni Bridge：
RC-T Girder Bridge
Length 25m, Width 4.2m
Construction: Year 1987

Samkhara Bridge：
Steel Truss Bridge
Length 61m, Width 4.3m
Construction: Year 2001

Passang Bridge：
Steel Truss Bridge
Length 40m, Width 7.5m
Construction: Year 1970

Perspective of the Project (Teleganchu Bridge)

Perspective of the Project (Beteni Bridge)

Perspective of the Project (Samkhara Bridge)

Perspective of the Project (Passang Bridge)

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Abbreviations

AC	Asphalt concrete
AH	Asian Highway
A/P	Authorization to Pay
B/A	Bank Arrangements
CA	Competent Authority
CBR	California Bearing Ratio
CDCL	The Construction Development Corporation Limited
DBM	Dense Bitumen Macadam
D/D	Detailed Design
DEC	Dzongkhag Environment Committee
DHMS	Department of Hydro-met Services
DLAAC	Dzongkhag Land Acquisition and Allotment Committee
DoFPS	Department of Forests and Park Service
DoR	Department of Roads, Ministry of Works and Human Settlement
EC	Environmental Clearance
EIA	Environmental Impact Assessment
EL	Elevation
EMoP	Environmental Monitoring of Plan
EMP	Environmental Management Plan
E/N	Exchange of Note
F/S	Feasibility Study
JPY	Japanese Yen
GoJ	Government of Japan
HWL	High Water Level
IEE	Initial Environmental Examination
IOL	Inventory of Loss
IRC	Indian Road Congress
JICA	Japan International Cooperation Agency
M/D	Minute of Discussion
MoF	Ministry of Finance
MoWHS	Ministry of Works and Human Settlement
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MWL	Medium Water Level
NEC	National Environmental Commission
NEXCO	Nippon Express Company
NLC	National Land Commission
NOC	No Objection Certificate
OD	Origin Destination
ODA	Official Development Assistance
PAP	Project Affected People
PAVA	Property Assessment and Valuation Agency
PC	Prestressed Concrete
PMR	Project Monitoring Report
PNH	Primary National Highway
P/Q	Pre-Qualification
RGoB	Royal Government of Bhutan
SPT	Standard Penetration Test
WB	World Bank

Chapter 1 Background of the Project

1.1 Background of the Project

1.1.1 Substance Requested

In Bhutan, the majority of the national land (Area is 38,394 km^2) is mountainous, therefore, road traffic is the most important sector in transportation. The road network in Bhutan has less number of principal highway as well as detour and alternative route and is inadequate in specification (width, alignment, pavement and slope protection etc.) because there is topographic constrains from steep mountainous area although the total length has been constantly expanding from about 4,000km in 2003 to about 10,600km in 2013.

Ministry of Works and Human Settlement (MoWHS) has established "Road Sector Master Plan (2007-2027)" in 2006 and plans to implement maintenance, repair and replacement of bridges, enhancement of feeder road and expansion of road network such as National Highway and Dzongkhag Road during next 20 years until 2027. So far, the Royal Government of Bhutan (RGoB) has been preferentially implementing improvement project of the principal national highways such as widening of project on Primary National Highway No.1 (PNH-1). Furthermore, "Eleventh Five Year Plan (2013-2018)" states some principal targets such as enhancement of national road network and improvement of accessibility to the hydropower plant construction site.

Primary National Highway No.4 (PNH-4: approximately 240km) connecting Trongsa (i.e. major city in Central region) and Gelephu (i.e. major city in Southern region) is one of the important trunk road in aspect of 2 transportation sectors namely passenger and cargo. Furthermore, national scale project known as Mangdechu Hydropower Plant Construction Project currently has been under implementation along this road. This project is expected to accomplish further development of the national economy and PNH-4 is playing quite important role for transportation route of goods and equipment for this project. However, current road condition shows quite inadequate performance due to narrow width and rough surface. Furthermore, deterioration due to age such as cracking on superstructure and substructure was observed on some of major bridges on PNH-4. It hinders structural safety of those bridges and becomes serious issue against securing stable connectivity.

Under such conditions, the RGoB requested reconstruction of five bridges on PNH-4 (Telegangchu, Chaplekhola, Beteni, Samkhara and Passang) by applying a grant aid cooperation to the Government of Japan (GoJ) in July 2014.

1.1.2 Agreement on the Substance Requested

During this survey period, the following agreements were made through discussions between the Japanese side and the Bhutanese side;

a) Reconstruction of four bridges on PNH-4 namely Telegangchu, Beteni, Samkhara and Passang

b) Construction of the approach roads for the above bridges

The Project contributes to ensure smooth and stable traffic through the reconstruction of 4 bridges on PNH-4 which requires high technology. Note reconstruction of Chaplekhola Bridge was excluded from the scope of the grant aid due to careful comparison with other 4 bridges in aspect of technical difficulty. The examination concluded the reconstruction work will be capable by the Bhutanese side.

With regard to the agreement on the substance requested, it was signed in the Minutes of Discussion on 14th September, 2015 in Thimphu.

1.2 Natural Conditions

1.2.1 Climate

(1) General

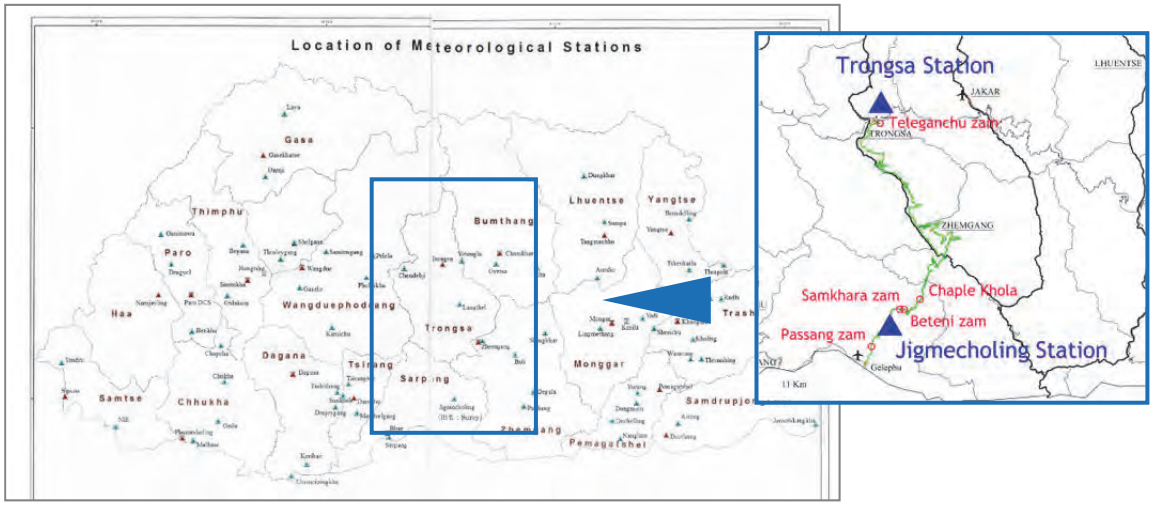
Bhutan is in the tropical monsoon climate zone, which can be divided into the rainy season (May to September), the dry season (November to March), and the transient time (April and October) between these seasons. Except for the southern lowland, the country is located mostly high above sea level, and the temperature and changes of the seasons are similar to those of the highland in Japan. The elevation at the surveyed bridge is approx. 2,100 m for Teleganchu Bridge, approx. 1,600m for Chaplekhola Bridge, approx. 1,100 m for Beteni Bridge, approx. 900 m for Samkhara Bridge, and approx. 300 m for Passang Bridge.

The meteorological observation records around the target areas of the study were made available to us from the Department of Hydro-met Services (hereinafter called “DHMS”). The table of available reference data and the location map of each observation Station are shown below. The Trongsa Station is close to Teleganchu Bridge while the Jigmecholing Station is close to other four bridges, so that observation results of these Stations will be used as a meteorological data for each of these bridges.

Table 1.2.1 Meteorological Study Items and Reference Data Obtained

Study items	Observation Station		Observation period	Source
Temperature (max/min)	Trongsa	Class A	1990.1～2013.12 (past 23 years) (※ No observation data for 2002)	DHMS
	Jigmecholing	Class C	1996.1～2014.12 (past 19 years)	DHMS
Humidity	Trongsa	Class A	1990.1～2013.12 (past 23 years) (※No observation data for 2002)	DHMS
	Jigmecholing	Class C	1996.1～2014.12 (past 19 years)	DHMS
Daily rainfall	Trongsa	Class A	1990.1～2013.12 (past 23 years) (※No observation data for 2002)	DHMS
	Jigmecholing	Class C	1996.1～2014.12 (past 19 years)	DHMS

Source: JICA Study Team

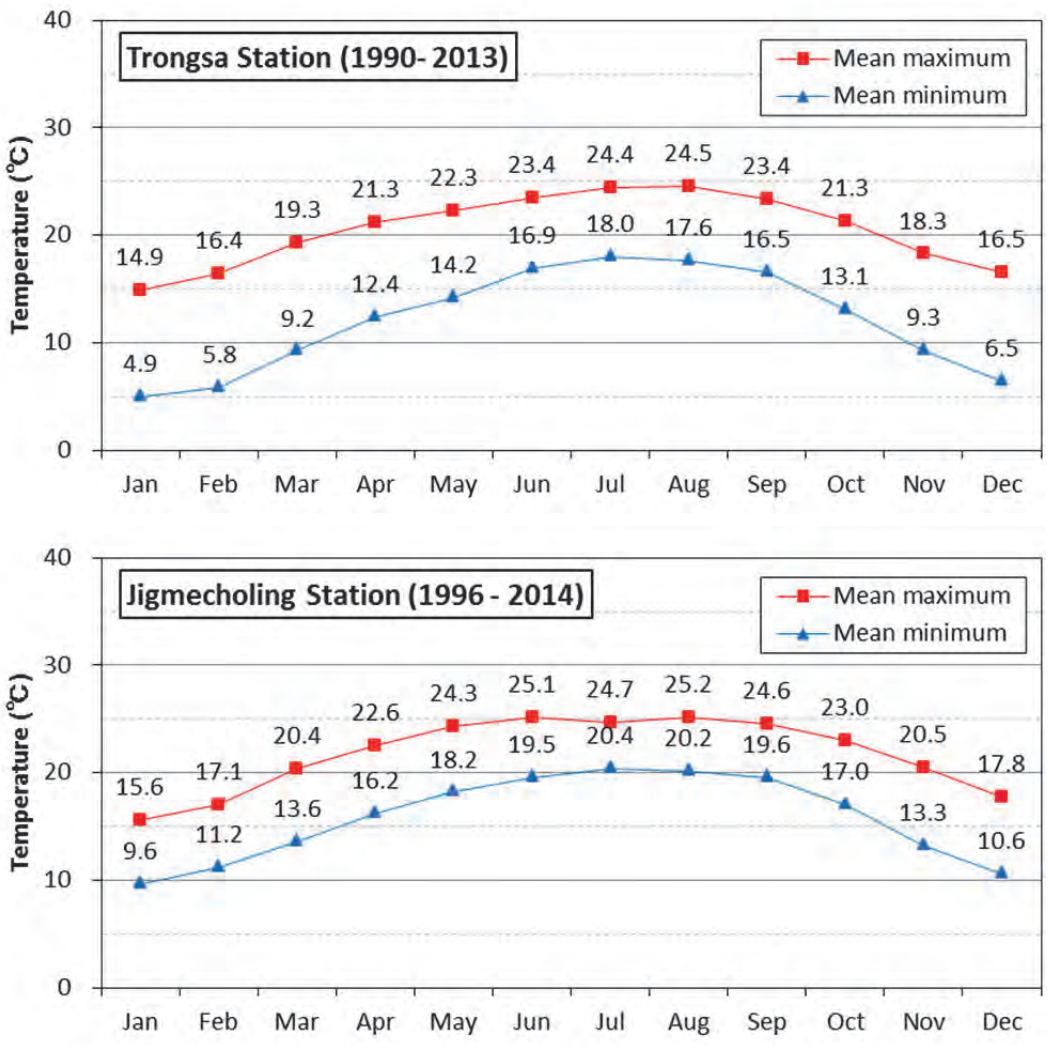


Source: Department of Hydro-met Services

Figure 1.2.1 Location Map of Meteorological Observation Stations

(2) Temperature

The monthly mean maximum temperature and the mean minimum temperature at the Trongsa Station and the Jigmecholing Station are shown in Figure 1.2.2. Around the Trongsa Station, the maximum temperature is about 25°C even in summer. In winter, the minimum temperature is about 5°C and may drop below freezing. Around the Jigmecholing Station, the climate is rather warmer than at the Trongsa Station; namely, the maximum temperature is 25°C or more in summer and the minimum temperature is about 10°C.The temperature difference between summer and winter is about 10°C for the Trongosa Station and about 7°C for the Jigmecholing Station.

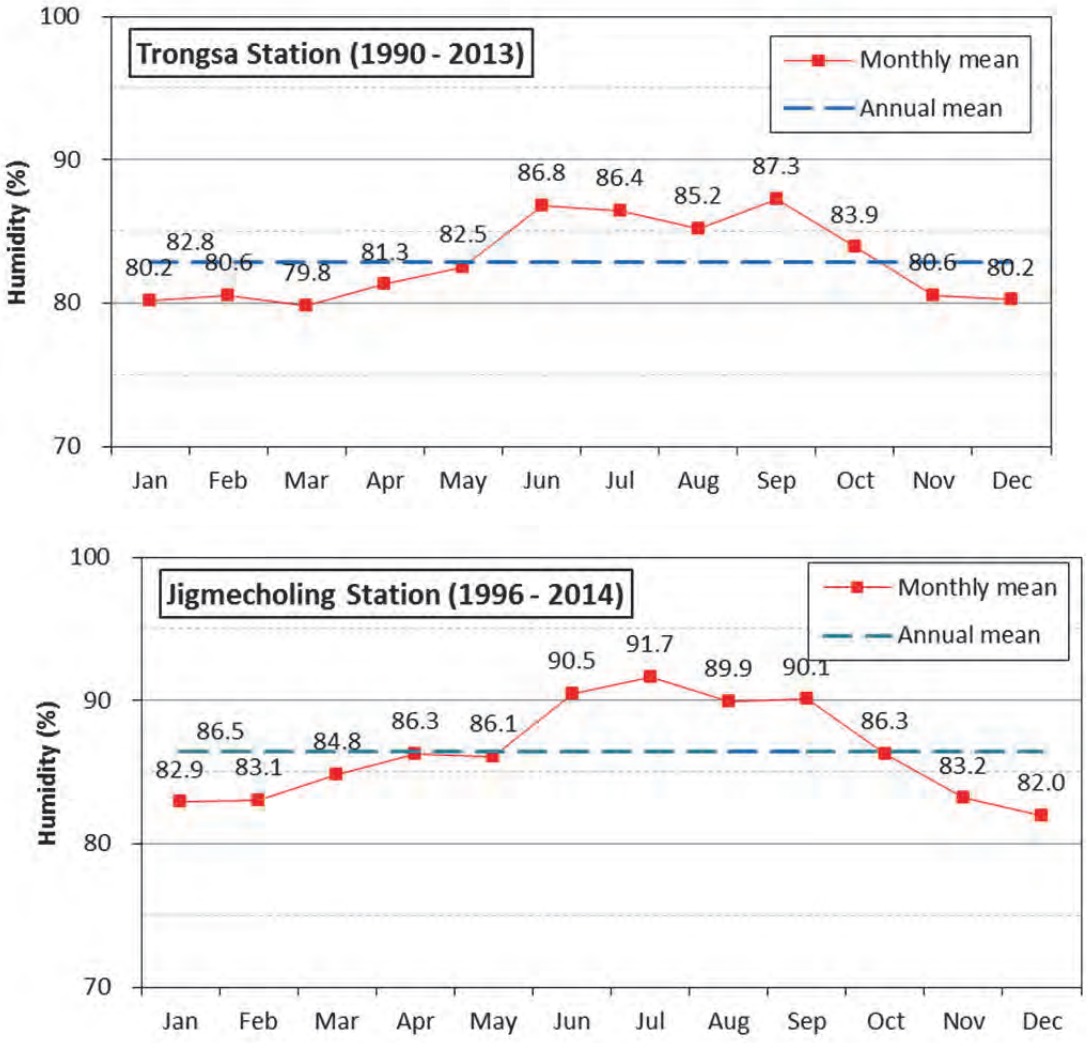


Source: Department of Hydro-met Services

Figure 1.2.2 Monthly Mean Maximum and Minimum Temperatures

(3) Humidity

The monthly mean humidity at the Trongsa Station and the Jigmecholing Station is shown in Figure 1.2.3. At both Stations, the annual mean humidity is about 80%～90%. Generally, the Jigmecholing Station tends to show higher humidity than the Trongsa Station and shows the annual highest humidity at 90% or more particularly in rainy season. At the Trongsa Station, the humidity is maximum 87% in rainy season, which drops to about 80% in dry season. The difference in monthly humidity is about 7% for the Trongsa Station and about 10% for the Jigmecholing Station.



Source: Department of Hydro-met Services

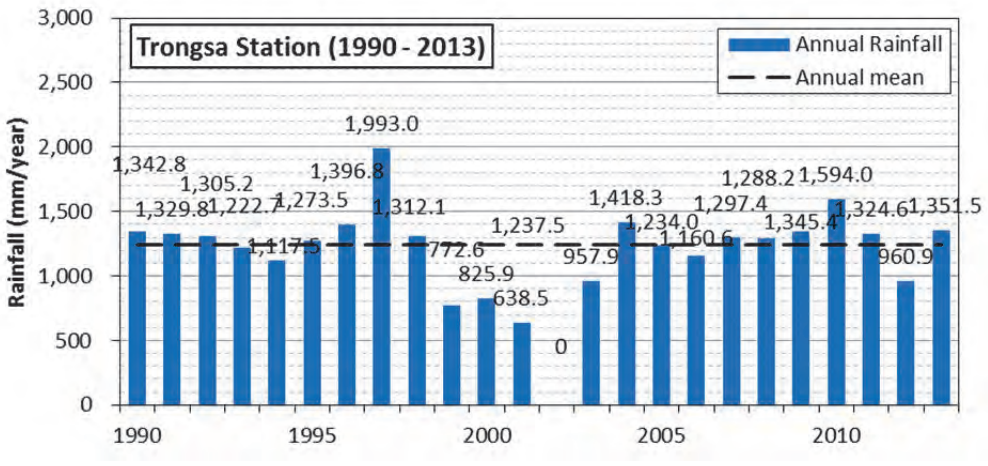
Figure 1.2.3 Monthly Mean Humidity

(4) Rainfall

1) Teleganchu Bridge basin (Trongsa Station)

➢ Annual rainfall

The annual rainfall for past 23 years (*no data for 2002) at the Trongsa Station is shown below. The mean rainfall is about 1,200mm. The rainfall here is 2,000 mm in years with high rainfall and about 600 mm in years with low rainfall. Anyway, the rainfall of the Station is lower than that of the Jigmecholin Station.

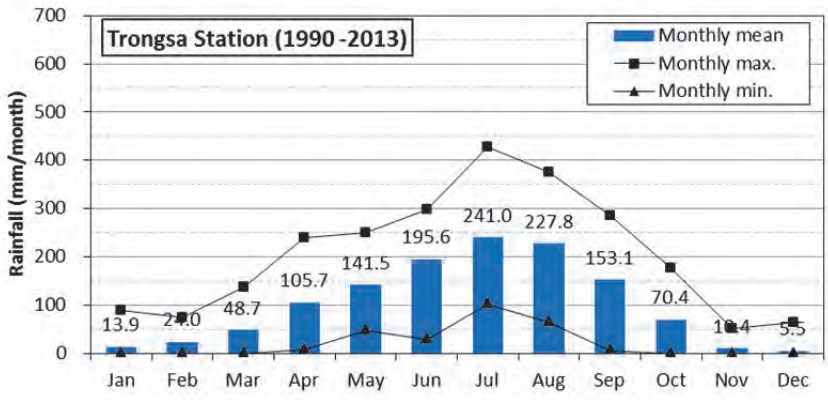


Source: Department of Hydro-met Services

Figure 1.2.4 Annual Rainfall (Trongsa Station)

➢ Monthly rainfall

The daily rainfalls at the Trongsa Station, which have been summarized by month, are shown below. The monthly rainfall is about 250 mm on an average even in July when the rainfall is the highest, and about 10 mm in dry season. This Station may be characterized by the overall low rainfall.

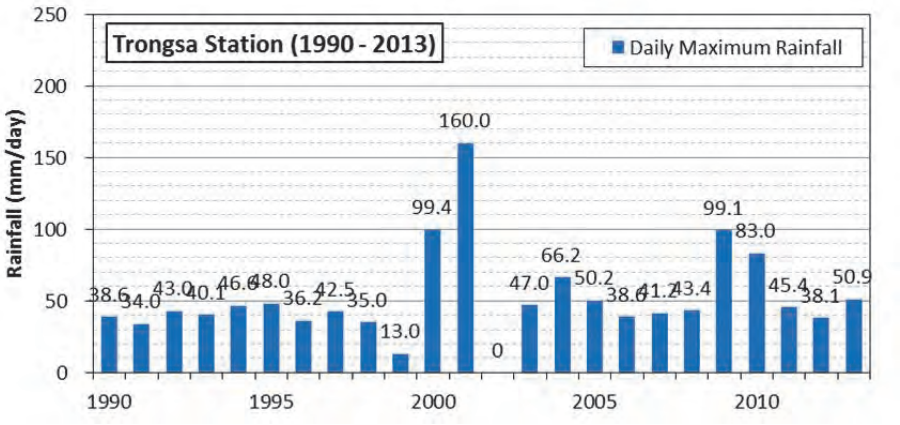


Source: Department of Hydro-met Services

Figure 1.2.5 Monthly Rainfall (Trongsa Station)

➢ Annual maximum daily rainfall

The annual maximum daily rainfall at the Trongsa Station is shown below, which is around 50 mm/day on an average. The rainfall here is not so high as a whole. However, there are several years in which the rainfall of around 100 mm/day was observed; for example, the maximum rainfall of 160 mm/day, the highest in the past 18 years, was recorded in 2001. There is no data for 2002.

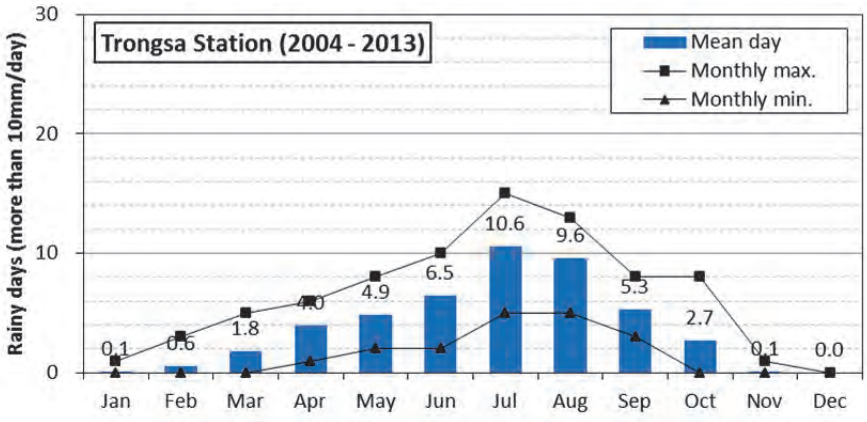


Source: Department of Hydro-met Services

Figure 1.2.6 Annual Maximum Daily Rainfall (Trongsa Station)

➢ Number of days with the daily rainfall of 10 mm or more by months

The number of days with the daily rainfall of 10 mm or more for the past decade at the Trongsa Station is shown below. The number of days when the daily rainfall of 10 mm or more is recorded is around 10 days even in July and August with the annual maximum monthly rainfall. The annual number of days with the daily rainfall of 10 mm or more is 45.7 days on an average, which is equivalent to about one month and a half in the year.



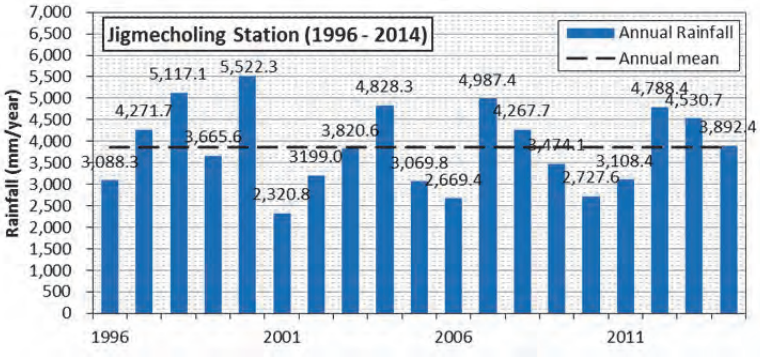
Source: Department of Hydro-met Services

Figure 1.2.7 Monthly Number of Days with the Daily Rainfall of 10 mm or More (Trongsa Station)

2) Basin of Chaplekhola, Beteni, Samkhara and Passang Bridges (Jigmecholing Station)

➢ Annual rainfall

The annual rainfall for the past 19 years at the Jigmecholing Station is shown below, which is about 3,700 mm on an average. This is a rainy region. Particularly the year 2000 was an extremely rainy year with the rainfall of 5,500 mm or more observed over the year. The rainfall was about annual 2,300 mm in low-rainfall years. The difference in the annual rainfall relative to that in high-rainfall years is 3,000 mm or more, which indicates substantial variation from year to year.

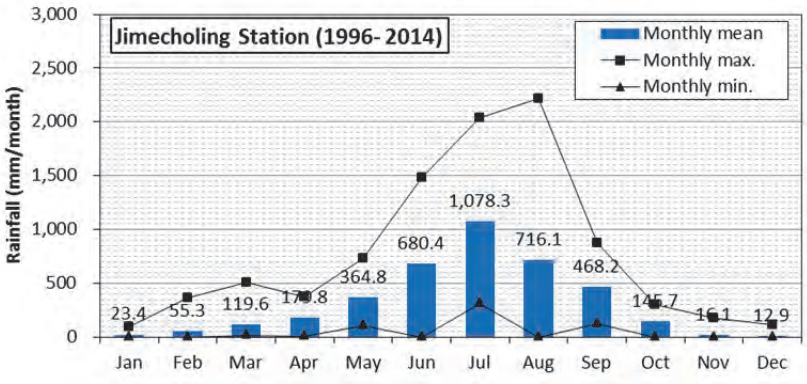


Source: Department of Hydro-met Services

Figure 1.2.8 Annual Rainfall (Jigmecholing Station)

➢ Monthly rainfall

The daily rainfalls at the Jigmecholing Station, which have been summarized by month, are shown below. July of the rainy season has the monthly rainfall of over 1,000 mm on an average and has exceeded 2,000 mm in certain years (2000 and 2007). The rainfall during dry season is as low as about 20 mm. The overall difference between dry and rainy seasons is extremely great.

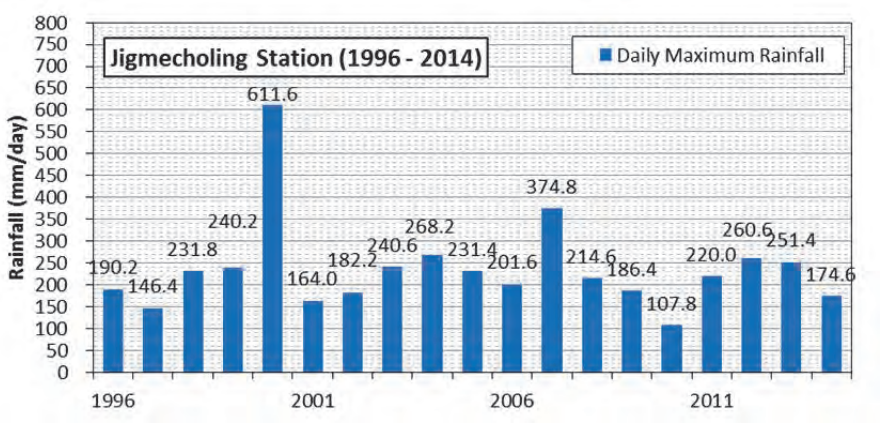


Source: Department of Hydro-met Services

Figure 1.2.9 Monthly Rainfall (Jigmecholing Station)

➢ Annual maximum daily rainfall

The annual maximum daily rainfall at the Jigmecholing Station is shown below, which is about 200 mm/day on an average. The daily rainfall of 611.6 mm/day observed in August 2000 was far higher than in other years. The Tokai Heavy Intensive Rain, which was designated the severe disaster, had the daily rainfall of about 500 mm, and the daily rainfall observed at Jigmecholing exceeds this level. According to the hearing with the Chief of branch office of DoR at Sarpang, the flood and other disasters of this rainfall are not recorded.

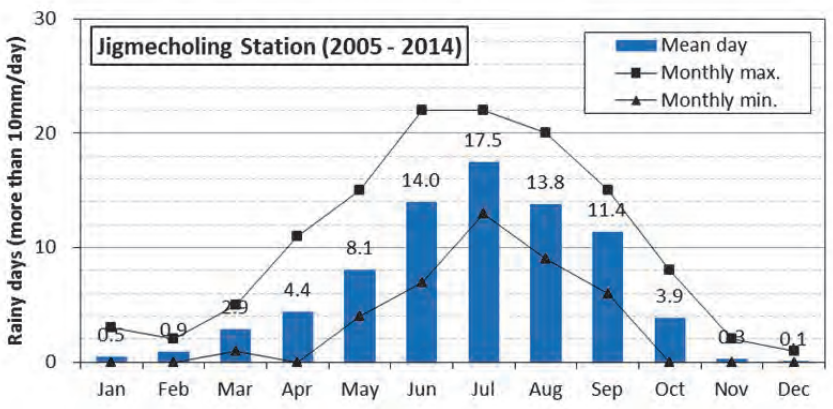


Source: Department of Hydro-met Services

Figure 1.2.10 Annual Maximum Daily Rainfall (Jigmecholing Station)

➢ Number of days with daily rainfall of 10 mm or more by months

The number of days with the daily rainfall of 10 mm or more for the past decade at the Jigmecholing Station is shown below. In June to August when the monthly rainfall is the highest in a year, the daily rainfall of 10 mm or more was recorded in about 15 days, which is equivalent to one half of the months. The annual number of days with the daily rainfall of 10 mm or more is 76.0 days on an average, which is equivalent to about 1/5 of the year.



Source: Department of Hydro-met Services

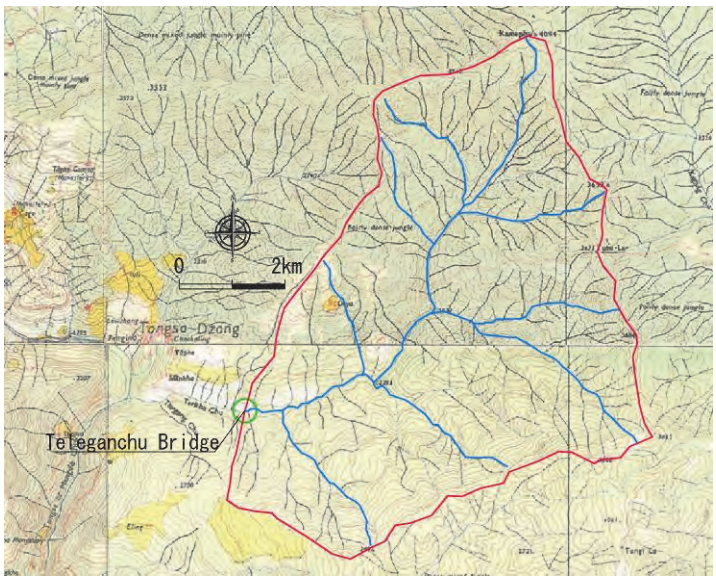
Figure 1.2.11 Number of Days with the Daily Rainfall of 10 mm or More by Months (Jigmecholing Station)

1.2.2 Hydrologic Survey

(1) Outline of the Basin

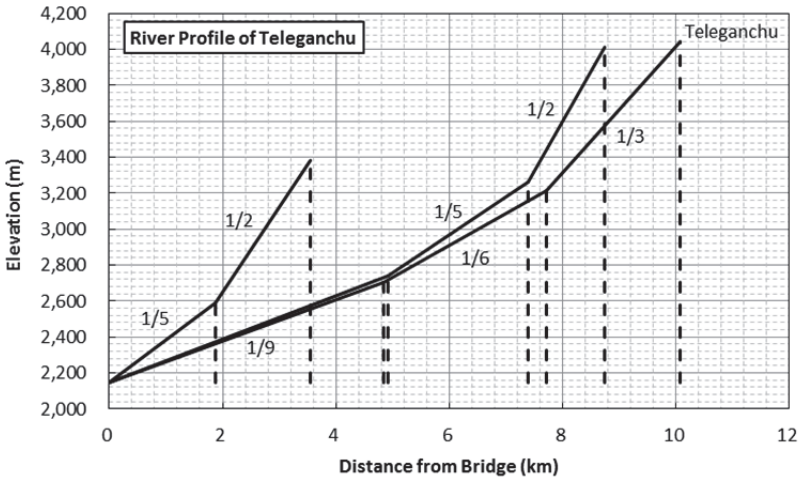
1) Telegan Chu River

Having its source in the mountains at elevations of 4,000 m, the Telegan Chu River flows down to south-west and into the MandeChu River. The basin is mostly covered with natural forests. Teleganchu Bridge intersecting with National Highway No. 4 has a basin extending about 10 km in the east-west direction and about 8 km in the south-north direction. The basin area is 46.5km^2. The riverbed slope is extremely steep with 1/6 or less on the upstream side and 1/9 on the medium and downstream sides.



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.12 Basin Map (Telegan Chu River)



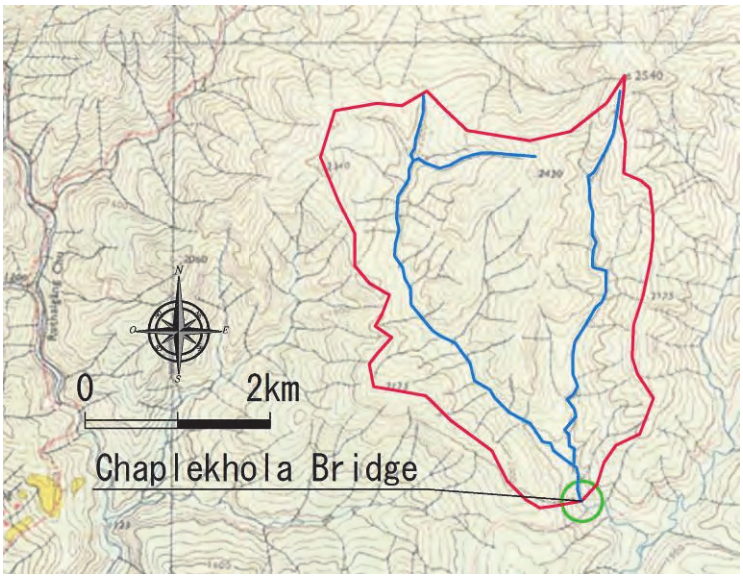
Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.13 River Profile (Telegan Chu River)

2) Chaple Chu River

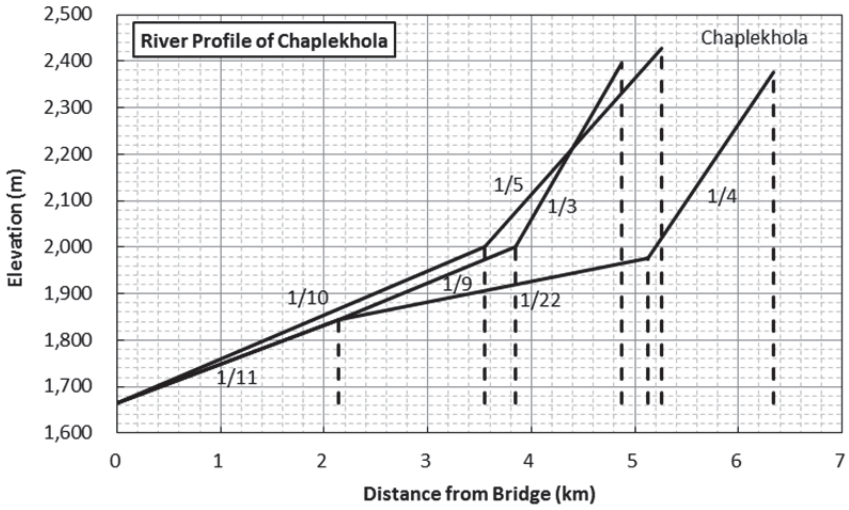
Having its source in the mountains at elevations of 2,500 m, the Chaple Chu River flows down to south, receiving two tributaries and flowing into the Samkhara Chu River, then merging onto Maokhola River. The basin is covered mostly with natural forests. Teleganchu Bridge intersecting with National Highway No. 4 has a basin extending about 3.5 km in the east-west direction and about 4.5 km in the south-north direction. The basin area is 11.0 km^2.

The riverbed slope is extremely steep with 1/4 or less on the upstream side, changing to the gentle slope of 1/22 in the middle reach and changing again to the steep slope.



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.14 Basin map (Chaple Chu River)

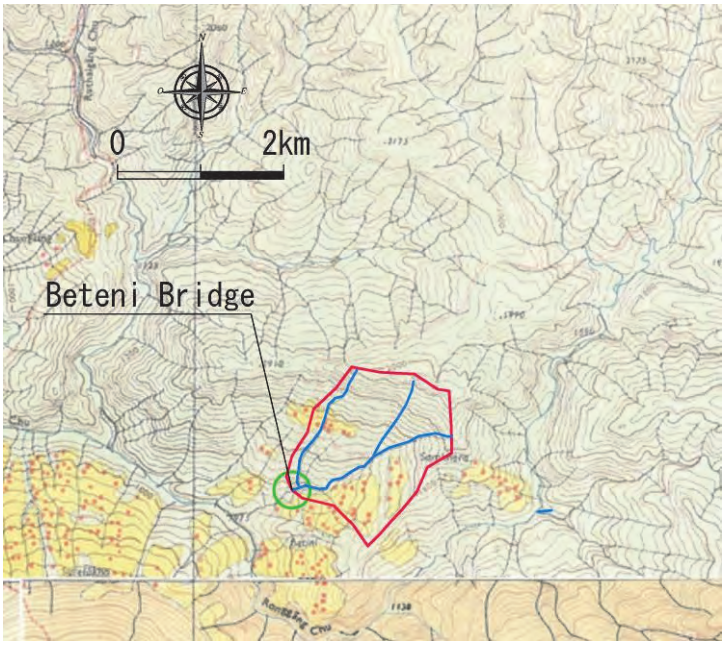


Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.15 River profile (Chaple Chu River)

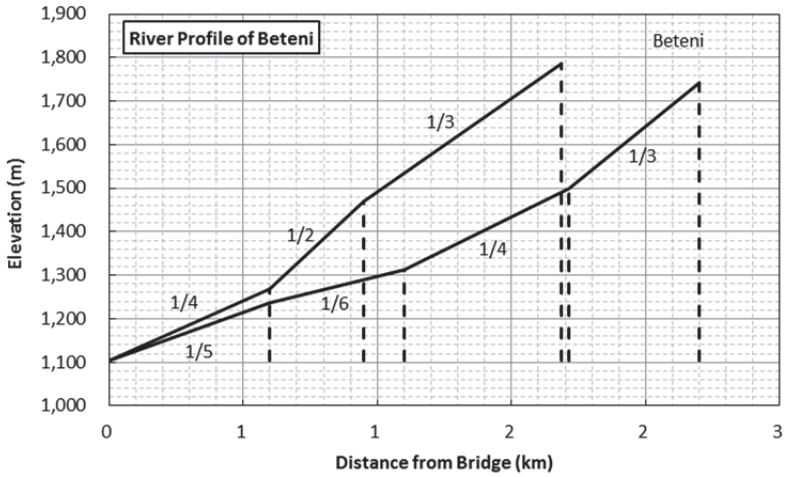
3) Beteni Chu River

The river over which Beteni Bridge crosses is relatively small and has no official name. For convenience, this section calls it the Beteni Chu River. Having its source in the mountains at elevations of 2,500 m, the Beteni Chu River flows down to south-west and flows into the Samkhara Chu River. The basin is covered mostly with natural forests. Beteni Bridge intersecting with National Highway No. 4 has a basin extending about 2 km in the east-west direction and about 2 km in the south-north direction. The basin area is extremely small at 2.8 km^2. The Beteni Chu River is extremely steep at 1/3 to 1/5 over the entire length because it is short and is located close to the source.



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.16 Basin Map (Beteni Chu River)



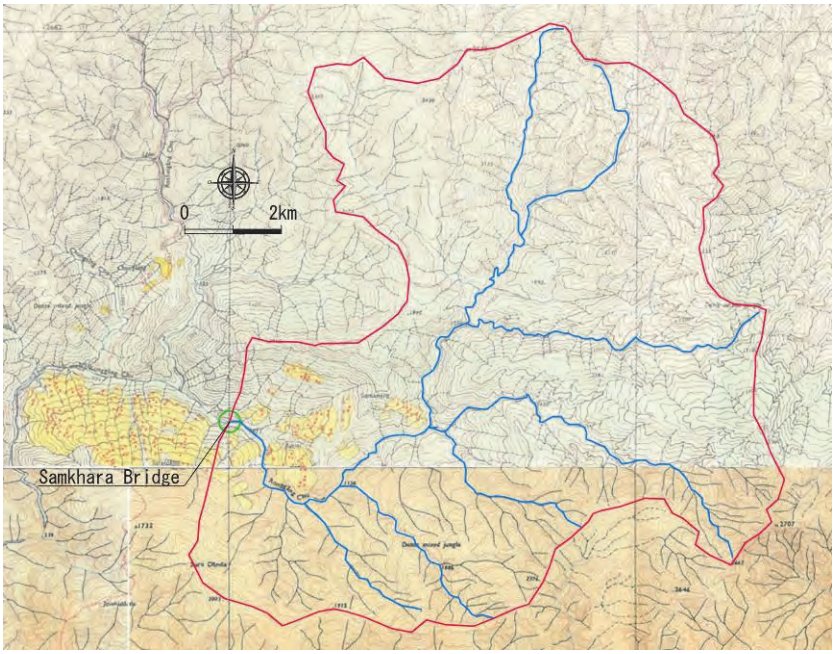
Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.17 River Profile (Beteni Chu River)

4) Samkhara Chu River

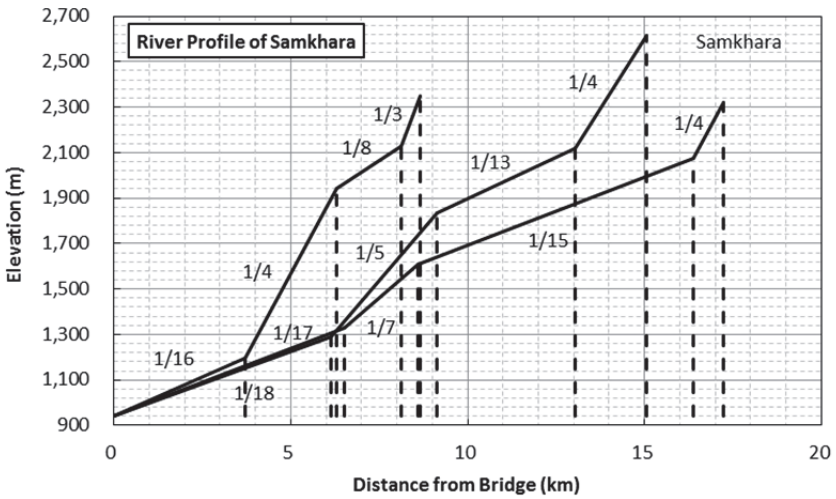
Having its source in the mountains at elevations of 2,500 m, the Samkhara Chu River flows down to south-west, receiving the Ratha Khola River from the west and flowing into the Maokhola River. The basin is covered mostly with natural forests. Samkhara Bridge intersecting with National Highway No. 4 has a basin extending about 11 km in the east-west direction and about 12 km in the south-north direction. The basin area is 98.7 km^2.

The riverbed slope is extremely steep at 1/4 on the upstream side, followed by slightly gentle slope and steep slope alternately, and the slope becomes gentle gradually.



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.18 Basin Map (Samkhara Chu River)



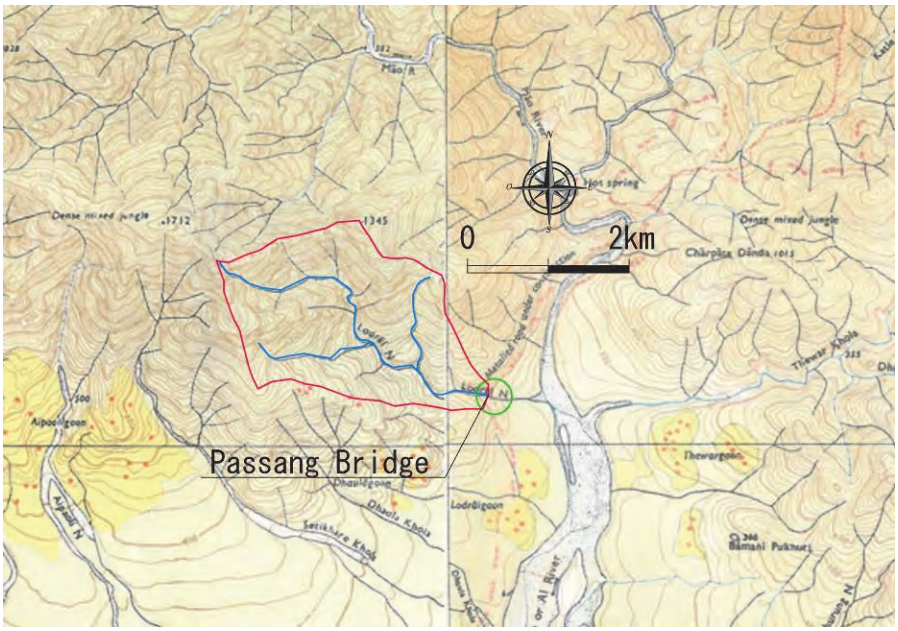
Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.19 River Profile (Samkhara Chu River)

5) Lodrai Chu River

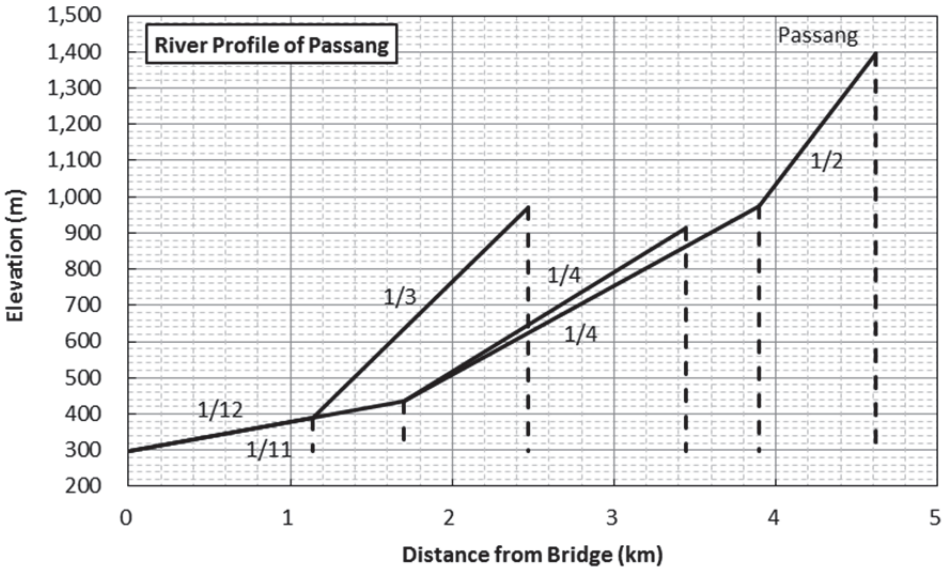
Having its source in the mountains at elevations of 1,500 m, the Lodrai Chu River flows down to east and flows into the Maokhola River. The basin is covered mostly with natural forests.

Passang Bridge intersecting with National Highway No. 4 has a basin extending about 3 km in the east-west direction and about 2 km in the south-north direction. The basin area is 5.2km^2. The riverbed slope is extremely steep at 1/2 or less on the upstream side and changes gently till the river flows into the Maokhola River.



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.20 Basin Map (Lodrai Chu River)



Source: Prepared by the study team from the 1:50,000 topographic map

Figure 1.2.21 River Profile (Lodrai Chu River)

(2) River Channel Characteristics at the Bridge Points

1) Teleganchu Bridge

Visual inspection showed the evidence of scour at the abutment on the right-bank side of the existing bridge (the depth of scour - about 1 m). The evidence of landslide could also be observed at the abutment on the left-bank side of the bridge. As there is a bend on the downstream side of the existing bridge, the bridge point is to be located further downstream from the bend to avoid effects of flowing water. As described in "2.2.2.1 Overall Plan", the downstream side is bridge point to avoid the landslide. This point has the right bank with exuberant vegetation and the vertical cliff on the left bank. According to the hearing with the DoR staff, the maximum high-water level is only about 1.0 m above the normal level.

a) Abutment on the right bank of existing bridge (scour)

b) Downstream side of the proposed bridge point

c) Left bank side of the proposed bridge point

Source: Photos taken by the study team

Figure 1.2.22 River Channel State around Teleganchu Bridge

2) Chaplekhola Bridge

The downstream side is recommended as bridge point to avoid the cut of land in case of the future construction work. This area around the bridge point is dotted with boulders, with precipitous cliff on the upstream side. Both banks on the downstream side are covered with exuberant vegetation, but no vegetation is observed partially on the downstream right bank. Since such lack of vegetation is limited to only a part of right bank, its cause is considered to be not the effect of flow water, but washing of part of road embankment by wind and rainfall. Visual inspection showed no evidence of bank erosion or scour. According to the hearing with the DoR staff, the existing highest water level is about 1.0 m above the normal level. The information made available to use shows the water level in dry season lowers only slightly from that in rainy season. There is not much fluctuation of water level between seasons.

		
a) Abutment on the right bank side of existing bridge	b) Viewing upstream from the existing bridge	c) Viewing downstream from the existing bridge

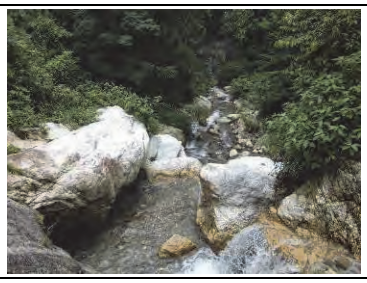
Source: Photos taken by the study team

Figure 1.2.23 River channel state around Chaplekhola Bridge

3) Beteni Bridge

As described in "2.2.2.1 Overall Plan", the slightly downstream side from existing bridge is the new bridge point to improve the alignment. This area around the bridge point is dotted with rolling stones. There is a alternative route on the upstream side, and sediments and gravel piled up on the further upstream side. It is assumed that these sediments and gravel are washed down from the upstream side during flood. Visual inspection showed no evidence of bank erosion or scour. According to the hearing with the chief of DoR Sarpang office, the existing highest water level is up to the point about 2 m under girder of the existing bridge. This is more than the flow rate expected initially.

* Setting of the flow rate is described later.

		
a) Checking the water level of the existing bridge	b) Viewing upstream from the existing bridge	c) Viewing downstream from the existing bridge

Source: Photos taken by the study team

Figure 1.2.24 River Channel State around Beteni Bridge

4) Samkhara Bridge

As described in "2.2.2.1 Overall Plan", the upstream side from existing bridge is the new bridge point because bridge length can be shorter. This area around the bridge point is dotted with rolling stones, with both banks covered with exuberant vegetation on both upstream and downstream sides. The upstream right-bank side was found to be precipitous cliff. Visual inspection showed no evidence of bank erosion or scour. According to the hearing with the chief of DoR Sarpang office, the existing highest water level is up to the point soaking the girder end of the existing bridge.

		
a) Checking the water level checking of existing bridge	b) Viewing upstream from on top of the bridge surface	c) Downstream state of the existing bridge

Source: Photos taken by the study team

Figure 1.2.25 River Channel State around Samkhara Bridge

5) Passang Bridge

As described in "2.2.2.1 Overall Plan", current bridge position is the new bridge point to avoid effects to military facilities and local residents, and from the view point of alignment. The area around the bridge point is dotted with rolling stones and boulders. Vegetation was observed on the upstream side, but they showed no evidence of collapse under effects of flow. Namely, it is assumed that the water level is below the vegetation level even during flood. Visual inspection showed no evidence of bank erosion or scour. According to the hearing with the DoR staff, the maximum high-water level is only about 1.0 m above the normal level. Once the alternative route was constructed on the upstream side, the flood flowed through the narrow width of the alternative route, resulting in further rising of the water level. According to the hearing, the water level rose to around 2 m under girder after provision of the alternative route. Hearing was also done with the DoR staff concerning the effect of backwater of the Maokhola River, which showed that no water level rising around Passang Bridge occurred though the water level of the Maokhola River rose. This is considered due to the following factors; namely, though this river merges with the Maokhola River, Passasng Bridge is distanced about 500 m from the confluence point. Besides the riverbed slopes are steep.

		
a) Checking the water level at the existing bridge	b) Viewing upstream from on top of the ridge surface	c) Downstream state of the existing bridge

Source: Photos taken by the study team

Figure 1.2.26 River Channel State around Passang Bridge

(3) Rainfall analysis

Rainfall analysis was done using the daily rainfall data of each station to calculate the daily rainfall by the return period. The results of rainfall analysis are shown below.

Table 1.2.2 Daily Rainfall by Return Period of Each Basin

Return Period	Daily Rainfall (mm/day)	
	Trongsa Station	Jigmecholing Station
2-year	47.5	207.9
5-year	71.8	282.8
10-year	90.2	347.1
20-year	109.7	423.0
50-year	137.3	546.9
100-year	159.9	663.3

Source: JICA Study Team

(4) Runoff analysis

1) Basic conditions

Hearing was done with neighborhood residents concerning the water level of each river. The results showed that, for bridges other than Beteni Bridge, the water level was close to or below the results obtained from the previous runoff analysis using the 100-year return period. Namely, the results of runoff analysis and the set conditions are valid for bridges other than Beteni Bridge.

For Beteni Bridge, on the other hand, the information was received, which confirmed the higher flow at the site than the results of previous runoff analysis. Disagreement of the runoff analysis results and the runoff at the site may be due to the following points. Namely, this analysis used the data of the Jigmecholing Station closest to Beteni Bridge, but actually there is a distance of about 8 km from the Jigmecholing Station to Beteni Bridge. In other words, local weather and rainfall do not always agree between Beteni Bridge located in the mountaineer area and the Station. The local hearing also provided information that the weather around Beteni Bridge varies greatly depending on the location.

Based on the above, the runoff is calculated for four bridges other than Beteni Bridge by using the rational formula because the basin area us 100 km^2 or less. At Beteni Bridge, the runoff calculation was performed by assuming the local hearing result of existing highest water level as the value based on the 100-year return period.

2) Results of runoff analysis

Since no observation of flow has been done for all rivers, the runoff at the bridge point was calculated using the rational formula. As described above, for Beteni Bridge, the runoff calculation is made from the water level known from the hearing results. The calculation result is shown in the table below.

Table 1.2.3 Runoff by Runoff Scale for Each Basin

Return Period	Discharge (m^3/s)					Remark
	Teleganchu Bridge	Chaplekhola Bridge	Beteni Bridge	Samkhara Bridge	Passang Bridge	
2-year	120	130	290	950	70	Road design
5-year	180	170	330	1,300	90	Road design
10-year	220	210	480	1,590	110	Road design
20-year	270	260	580	1,940	130	Road design
50-year	330	330	750	2,500	160	--
100-year	390	400	900	3,030	200	Bridge design

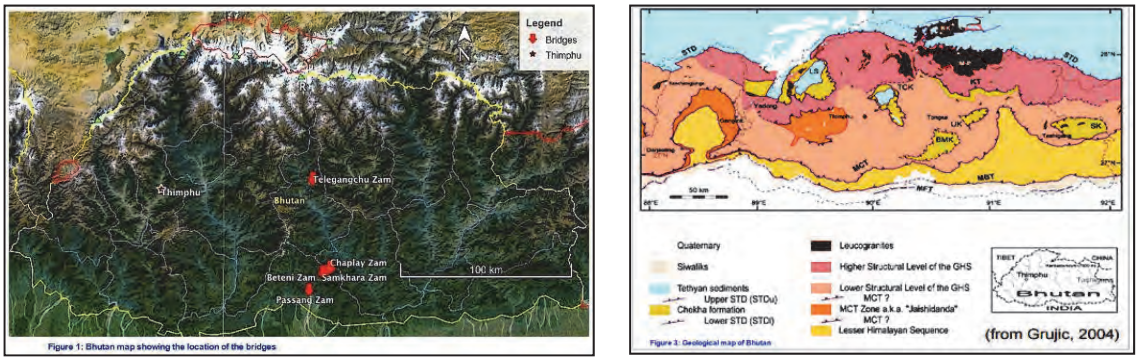
Source: JICA Study Team

1.2.3 Topographical and Geological Survey

(1) Outline of Topographical and Geological Condition

The topographical description is provided below. Bhutan is a country, 300km east and west by 130 km north and south, having the area of 40,000 km^2 nearly equivalent to that of Kyushu. The country is located at the eastern end of Himalayan orogenic belt, and the altitude decreases from the north with the 7,000 m class mountain range toward the lowland at 200 m or below. The Himalayan orogenic movement caused active upthrust during Tertiary and Quaternary periods, and river channel erosion formed precipitous terrain. The country is divided into the Himalayan area, the central area, and the southern area at the base of mountain in this order from the north. The central 4,000 m class mountainous area exists along the National Highway No.1, with precipitous gouges.

Geological features observed in Bhutan include remarkable development of planar structures like bedding, schistosity, and lamina. Apart from that, the outcrops show frequently fracture by folding and fault, and vulnerable portions disturbed by the tectonic movement. In particular, schist and phyllite of the Baxa Group found in the southern part of Bhutan, as shown in Figure 1.2.27, not only readily chip off because of the densely-developed planar structure, but also have fragile lithologic character.



Source: Grujic 2004

Figure 1.2.27 Topology and Geology of Bhutan

Briefly speaking, the area along the National Highway No.1 is observed to have massive to weathered rock bodies, which contribute to forming cliffs of leucocratic granite rocks to the east of

Thimphu. Also observed sporadically are the gneissic sites produced by predominant amphibolite. Heavily-weathered slopes of decomposed granite can also be observed. There are several precipitous cliffs in the west, with the road running through the bored linear wall.

Briefly speaking, the city of Gelephu, the staring city of the National Highway No.4, and its surroundings are situated at the hillside to the mouth of the valley. The area finds the fun deposit or talus deposit consisting mainly of the river deposit (sand and gravel). Severe surface failure can be found in the area where the topography transits from hill side through mountain side due to the affection of the fractured zone caused by the fault activity. The crops were observed ranging from the debris flow through talus deposit on top of pelitic/psammitic schist (shale, slate), luecogranite, gneiss etc. In geologically fractured zone such as Boxcut Landslide, the road has been blocked due to the rainfall and/or rock fall and/or slope failure. And in the river or valley, debris flow or talus deposit are found here and there on the slope adjacent to the shoulder of the road, that means the slope seemed to be very fragile. The figures include the observation found on the national high way. The photos were taken in the late August 2015.

Source: JICA Study Team

Figure 1.2.28 Observation on the Road
(From left, Sedimentation on the road, Debris flow, Fractured Zone (Boxcut Landslide))

Source: JICA Study Team

Figure 1.2.29 Environment around the Planned Bridge
(From left, Mountain Hill near the Gelephu, River near Gelephu, Outcrop (Gneiss))

(2) Topography

1) Result of Topographical Survey

The topographical survey was implemented from the mid-August through the mid October on the year 2015. The topographical survey included the below items. In the topographical survey, the GPS (Global Positioning System) survey instruments and the Total Station Survey (named as TS survey

hereafter) were employed so that the survey was conducted as accurate as possible even in the steep cliff area. The activity of the survey was done during the monsoon season (from June through September) so there was delay in activity behind the initial plan due to the thick vegetation, heavy rain and the rise of river water. The activity was completed in safe with the effort of surveyors.

The requirements, technical specification and working procedure of the survey works are listed below.

[Topographical Survey]

Items: Plane and Cross Section

- The results from GPS survey and TS survey were combined in the survey for plane mapping.

Scope 1 (Plane): The survey was implemented to the point where it extended 130m away from each edge of the each riverside.

Scope 2 (Plane): The survey was implemented to the point where it extended 150m upward and downward from the planned position of each bridge.

- Scope (Cross Section): The Cross Sectional Survey was conducted along centerline until 100m away from the each edge of bridges.
- Landmark objects, such as existing bridge, houses, walls, drainage facilities, boring site, natural objects (Boulders, Rock outcrop, failed slope etc.)

[River Survey]

- Longitudinal area over a distance of 300m (a total of upstream and downstream distances) from the new-bridge planning line. River crossing was done at interval of 20m.

The brief outline of the GPS (Global Positioning System) survey is described below. GPS survey is one of the survey methods where any two points on the ground will be identified by calculating the time difference generated from the signals traveling from the any GPS satellite. The signals from the GPS satellites include the positioning information (code signals) in the orbit where the GPS satellite circulates and the time information (code information) the GPS satellites emits the signals. The GPS survey has two receivers, the one is situated on the reference point (such as Bench Marking or Temporary Bench marking) and the other is situated on the unknown point. Then the position (the coordination from the reference point) of the unknown point will be sought by the calculation mentioned above. The below preconditions will be needed to be met when the calculation can be implemented. For example, the power of the signals from the GPS satellites is maintained over the level where GPS receiver will catch them. The signals from the GPS satellite travels from the reflector that are separated each other (Accurate results of calculation can be gained). The correction data which are installed in the processing unit (circuite) of the GPS receiver is kept updated (Correction process will be kept updated).



Source: JICA Study Team

Figure 1.2.30 GPS Survey Work on Site

The signal from the GPS satellite cannot reach the ground on the site condition where the vegetation is thick or the signal will be deflected on the steep cliff, which means that there is the risk of reduction of the accuracy. Toward this phenomenon we maintain the accuracy of the survey as a whole by complementing the Total Station Survey (abbreviated TS survey hereafter). Private company cannot possess the GPS survey instruments so the instruments and the technical staffs were dispatched from the National Land Commission (NLC).

TS survey is one of the methods of calculating the difference between the known point and the unknown point by measuring the time and angle of the light wave traveling between the above two points. The TS station will be put on one of the two points and the reflector will be put on the the other points. Calculation will give the coordination(X, Y, and Z) of the point where the Total Station will be stationed. The specifications of both survey is presented below.

Table 1.2.4 Specification of the Survey Instruments

	Name of Instrument	Geodetic System	Principle	Remarks
GPS survey	Trimble ® R6	UTM84	Signal from Satellite	Possessed by the National Land Commission
Total Station survey	Leica® R400	Bhutan Coordinate System (Druk No3)	Light Wave	Possessed by the private company

Source: JICA Study Team

The grid coordinates used for survey are outlined below.

Table 1.2.5 Information of Grid Coordination

NAME	DRUKREF 03
CODE	5264
CRS TYPE	geographic 2D
AREA OF USE	Bhutan
DATUM NAME	Bhutan National Geodetic Datum

Source: JICA Study Team

In the GPS survey the Real Kinematic Method is employed, the signals (carrier with its frequency 1.5GHz and C/A code) from the GPS satellites (flying over 20,000 meters above a head) are processed in one to two seconds instantly. So the accuracy will be influenced by how the correction data is precise and how the site condition was such as vegetation or weathering on site.

Source: JICA Study Team

Figure 1.2.31 Total Station Survey on Site

(a) Telegangchu Bridge (Trongsa)

In the Telegangchu Bridge site, two NLC points were used. They are located around 1 kilometer away from the bridge location. NLC points are 10452 and 10458. The 10452 is west of hydel about 200m and east of Kuenphen saw mill. The 10458 is located at Khongyul and is on the Zangmo's Land.

Table 1.2.6 NLC control points

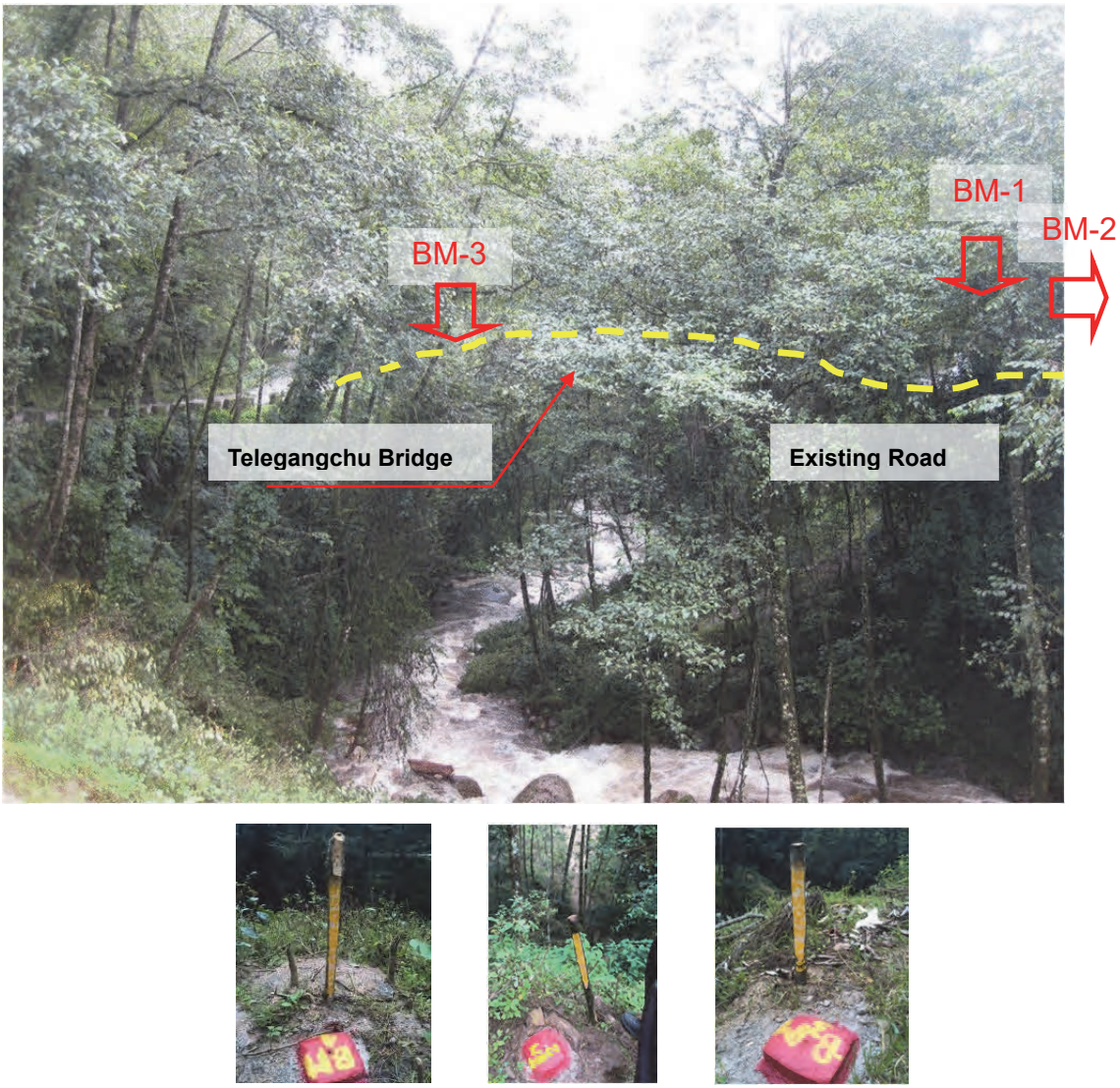
NLC DISC NO.	EASTING	NORTHING	ELEVATION
NLC 0010452	251583.7805	542654.1053	2340.6278
NLC 0025911	251136.9965	541893.262	2196.4873

Source: JICA Study Team

Table 1.2.7 Temporary Bench Marking

No.	E	N	Z	Location
BM-1	252363.274	541937.986	2106.055	Left Bank, 31m toward Zhemgang
BM-2	252308.765	541958.521	2100.639	Left bank, 44m at the boring BH-11
BM-3	252373.266	541989.232	2105.754	Right Bank, 27m toward Trongsa

Source: JICA Study Team



Source: JICA Study Team

Figure 1.2.32 Telegangchu Bridge and BM-1 BM-2 BM-3

(b) Chaplekhola Bridge (Zhemgang)

In the Chaplekhola Bridge site, two NLC points near the survey area were used as below. Three benchmarks were provided around the site.

Table 1.2.8 NLC control points

NLC DISC NO.	EASTING	NORTHING	ELEVATION
NLC 0026235	284684.187	488987.831	1537.598

Source: JICA Study Team

Table 1.2.9 Temporary Bench Mark

No.	E	N	Z	Location
BM-1	285792.455	491743.214	1621.285	Right Bank, On the Talus deposit downstream
BM-2	285758.808	491766.380	1619.164	Right Bank, 13m toward Geleph along road
BM-3	491779.790	491798.781	1618.954	Left Bank, 4.5m toward Zhemgan

Source: JICA Study Team

Source: JICA Study Team

Figure 1.2.33 Chaplekhola Bridge and BM-1 BM-2 BM-3

(c) Beteni Bridge (Sarpang)

In the Beteni Bridge site, two NLC points were used. One is in house above Beteni Bridge and the other is located above big boulder which is above the house. Temporary Bench Markings were established as below.

Table 1.2.10 NLC control points

NLC DISC NO.	EASTING	NORTHING	ELEVATION
NLC 0025986	282327.310	488878.623	1158.131
NLC 0025987	282145.477	488696.466	1131.082

Source: JICA Study Team

Table 1.2.11 Temporary Bench Marking

No.	E	N	Z	Location
BM-1	282113.410	488868.195	1087.911	Right Bank, On the gabion at the river side
BM-2	282128.304	488843.207	1087.939	Left Bank, On the gabion at the river side
BM-3	282118.993	488825.520	1088.041	Left Bank, Near the approaching road

Source: JICA Study Team

Source: JICA Study Team

Figure 1.2.34 Beteni Bridge and BM-1 BM-2 BM-3

(d) Samkhara Bridge (Sarpang)

In the Samkhara Bridge site, two points (25910 and 25911) were used as control points of NLC. They are located more than 700m away from the survey area so new bench mark were established.

Table 1.2.12 NLC control points

NLC DISC NO.	EASTING	NORTHING	ELEVATION
NLC 0025910	280469.590	488966.246	991.511
NLC 0025911	280170.469	489059.932	1013.244

Source: JICA Study Team

Table 1.2.13 Temporary Bench Mark

No.	E	N	Z	Location
BM-1	281182.359	488765.334	942.576	Left Bank, 6m toward Geleph
BM-2	281198.232	488833.815	941.241	Right Bank, 5m toward the Zhemgan
BM-3	281145.872	488859.840	946.527	Right Bank, Near retaining wall

Source: JICA Study Team

Source: JICA Study Team

Figure 1.2.35 Samkhara Bridge and BM-1,BM-2,BM-3

(e) Passang Bridge (Sarpang)

From data of Drukref, which is the Bhutan National Grid System, two control points of NLC were established. Three temporary benchmarks were provided near the target bridge. Information of each control point is as follow.

Table 1.2.14 NLC control points

NLC DISC NO.	EASTING	NORTHING	ELEVATION
NLC 0031697	273371.433	478936.331	300.512
NLC 0031698	273619.499	479145.689	287.543

Source: JICA Study Team

Table 1.2.15 Temporary Bench Marks

No.	E	N	Z	Location
BM-1	273385.986	478995.619	298.542	Right Bank, Hindu temple
BM-2	273466.882	479118.977	298.084	Left Ban, Margin of the road
BM-3	273426.420	479110.888	296.538	Left Bank, Pathway

Source: JICA Study Team

Source: JICA Study Team

Figure 1.2.36 Passang Bridge and BM-1, BM-2,BMN-3

(3) Geology

1) Boring survey and test Results

Boring survey was performed at a total of eleven sites for five bridges. The boring data of the position, elevation, etc. are shown in the table below. Details of the results of boring survey are shown in the boring log and core photos at the end of the document. Relating to the Samkhara Bridge, the additional boring (BH-5) was made for the purpose of confirming the depth of the top of bed rock in the left bank.

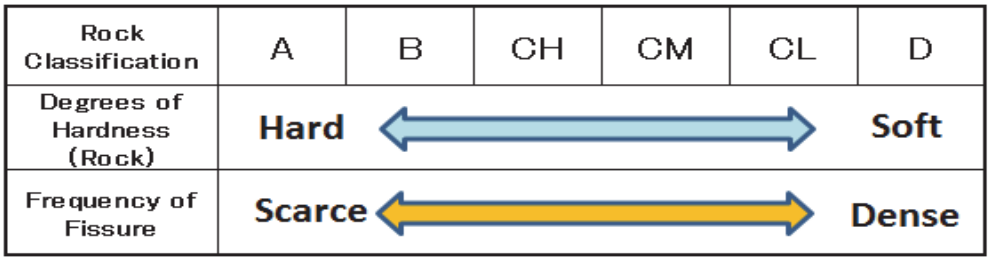
Table 1.2.16 List of Survey Sites

Site		Elevation [m]	Depth [m]	In situ test	Location
Name	Position				
Telegangchu	Right/BH-10	2095.42	17	S.P.T (N-value) CBR test Material Test (Aggregate)	3km south from Trongsa
	Left/BH-11	2100.614	15		
Chaplekhola	Right/BH-8	1619.663	15		50.6km north from Geleph
	River/BH-9	168.521	6		
Beteni	Right/BH-6	1086.870	15		36.6km north from Geleph
	Left/BH-7	1080.120	15		
Samkhara	Right/BH-3	943.000	15		34.4km north from Geleph
	Left/BH-4	940.763	17		
	Left/BH-5	941.210	14		
Passang	Right/BH-1	297.310	15		6km north from Geleph
	Left/BH-2	297.087	15		
	Sum		159		

Source: JICA Study Team

In the columnar chart of the boring, the observation were recorded in the detailed such as depth, diameter of the bore, geology, core recovery rate, RQD (Rock Quality Designation), and the S.P.T.. -N values.

The below table is used as a reference of rock classification when the strength of the bed rock will be examined as the foundation of the bridge footing. This table is reflected from the difference of its hardness affected by the grading of the weathering and/or fragility of the rocks due to the fissure or fluctuation.



Source: Technical guideline of design Earth Works (July 2015) NEXCO

Figure 1.2.37 Concept of Rock Classification

Table 1.2.17 Rock Classification

Grade	Features
A	Extremely fresh. Rock-forming minerals and particles are neither weathered nor altered. Cracks and joints are in tight coherence and no weathering mark is found along their surfaces. Hammering produces clear sound.
B	Standing ground without any open (even for small as 1 mm) crack or joint, indicating satisfactory coherence, except that rock-forming minerals and particles are more or less weathered and altered partially. Hammering produces clear sound.
CH	Rock-forming minerals and particles, other than quartz, are weathered, but the rock quality is relatively hard and firm. Generally, rocks are contaminated by limonite, with the cohesion between joints or cracks decreasing slightly. Smashing with hammer causes rock mass to come off along crack, and a thin film of clayey substance is left on the surface. Hammering produces slightly dull sound.
CM	Rock-forming minerals and particles, other than quartz, are weathered and more or less softened. The rock quality is also softened slightly. The cohesion between joints or cracks is slightly smaller. Normal impact of hammering is enough to allow rock mass to come off along the crack, with the bed of clayey substance remaining on the surface. Hammering produces slightly dull sound.
CL	Rock-forming minerals and particles are weathered and softened. The rock is also softened. The cohesion between joints or cracks decreases, and light impact with a hammer allows rock mass to come off along the crack, with the bed of clayey substance remaining on the surface. Hammering produces dull sound.
D	Rock-forming minerals and particles are heavily softened by weathering and the rock is extremely soft. No cohesion exists between joints or cracks, and the rock collapses easily under light impact with a hammer. Clayey substance remains on the surface. Hammering produces extremely dull sound.

Source: Technical guideline of design Earth Works (July 2015) NEXCO

(a) Telegangchu Bridge

i) Boring

The survey site is shown in the photo. The boring was done at a total of two points. The boring (BH-10) was located on the shoulder of the road on the right bank side and designated for the confirmation of the depth of the bed rock in the right bank. The boring (BH-9) was also situated at the edge of the shoulder of the road for the purpose of confirmation of the bed rock where the foundation would be planned to be located.

Source: JICA Study Team

Figure 1.2.38 Boring position at Telegangchu site

The S.P.T. N values obtained in the two boreholes at Telegangchu are shown below. The gneiss shows N value in excess of 50. However the N values are less than 50 where there is completely weathered schist.

Table 1.2.18 N values at each boring

Right Bank (BH-10)			Left Bank (BH-11)		
Depth (m)	N value	Geology	Depth (m)	N value	Geology
0.78	7	Embankment/ fill material	0.78	31	Embankment/fill material
1.78	14		1.78	45	Rock (Granite gneiss)
2.78	7		2.78	>50	
3.78	14		3.78	47	
4.78	21		4.78	>50	
5.78	50		5.78	>50	
6.78	45	Rock (Granite gneiss with inter-bed of weathered schist)	6.78	>50	
7.78	40		7.78	>50	
8.78	>50		8.78	>50	
9.78	45		9.78	>50	
10.78	>50		10.78	>50	
11.78	>50		11.78	>50	
12.78	>50		12.78	>50	
13.78	>50		13.78	>50	
14.78	37		14.78	>50	
15.78	30				
16.78	>50				

Source: JICA Study Team

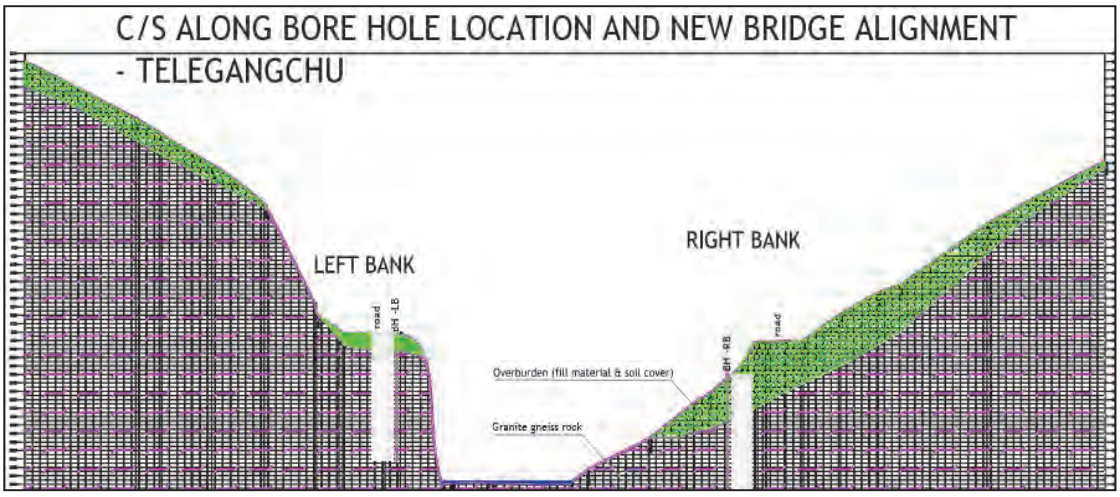
The rocks are relatively hard and firm. The hammering produces dull sound. These rocks are predominantly classified as CH to CM. However in the BH-10 on the right bank, the rocks are highly weathered below14m and these rocks are classified as D.

Table 1.2.19 Rock classification

Right Bank (BH-10)		Left Bank (BH-11)	
Depth	Rock Classification	Depth	Rock Classification
0.00m – 5.00m	Overburden	0.00m – 2.00m	Overburden
5.00m – 7.00m	CH	2.00m – 15.00m	CH
7.00m – 10.55m	CM		
10.55m – 14.00m	CH		
14.00m – 17.00m	D		

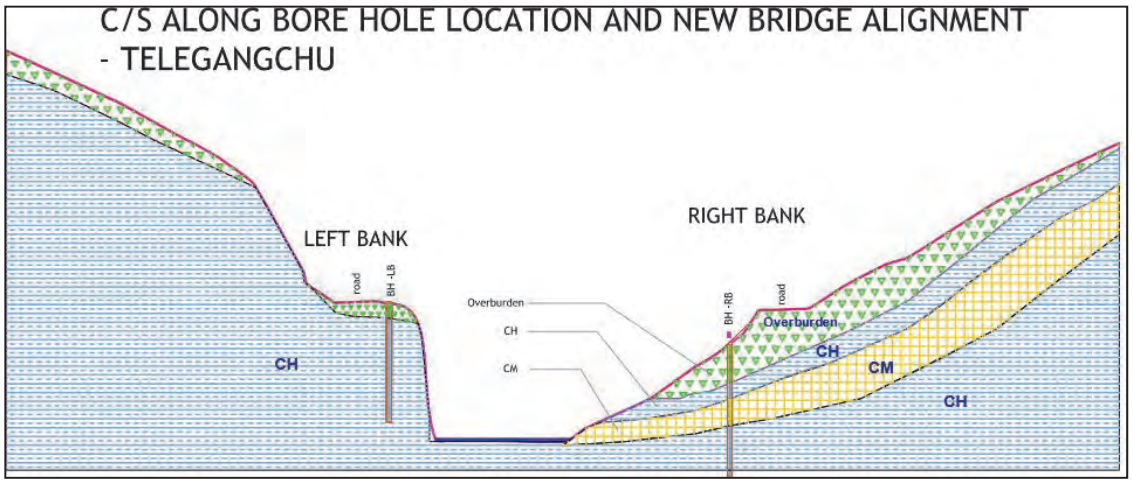
Source: JICA Study Team

The geological profile of Telegangchu is shown below. Unlike the other four bridge sites, this site is consisted of more competent geology of Higher Himalaya composing of granite gneiss overlain by overburden (Soil cover). The higher core recovery rate is indicating the better quality of geology.



Source: JICA Study Team

Figure 1.2.39 Geological Section



Source: JICA Study Team

Figure 1.2.40 Rock Classification

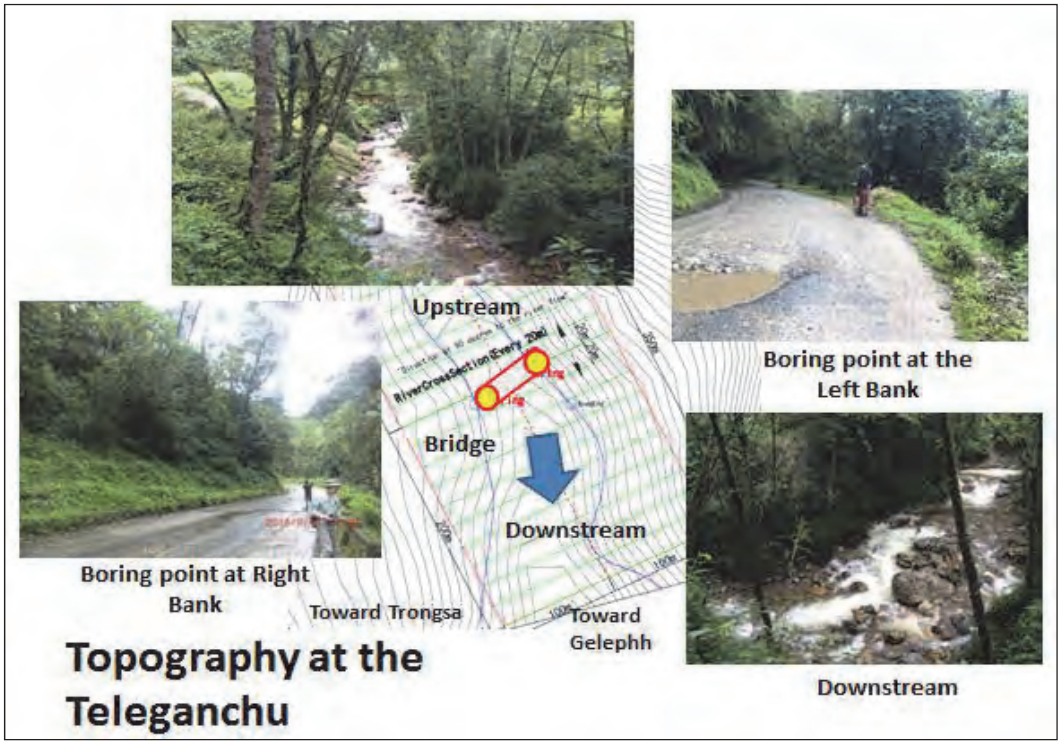
ii) Topography

<Right Bank: Trongsa side>

The inclination of the slope is gentle such as 30 degrees. This area is covered by the talus deposit as the outcrop of the rock cannot be seen in the surrounding and the rubble are scattering. Therefore slope protection might be needed in case that cutting slope is planned in the area.

<Left Bank: Gelephu side>

In the left bank where the rock is overhanging along the road as a cliff, the rock is slightly weathered in the outcrop and hard rock is outcropped overall in the cut slope. Therefore, slope protection might be needed in case that cutting slope is planned in the area.



Source: JICA Study Team

Figure 1.2.41 Topography of Telegangchu Site

(b) Chaplekhola Bridge

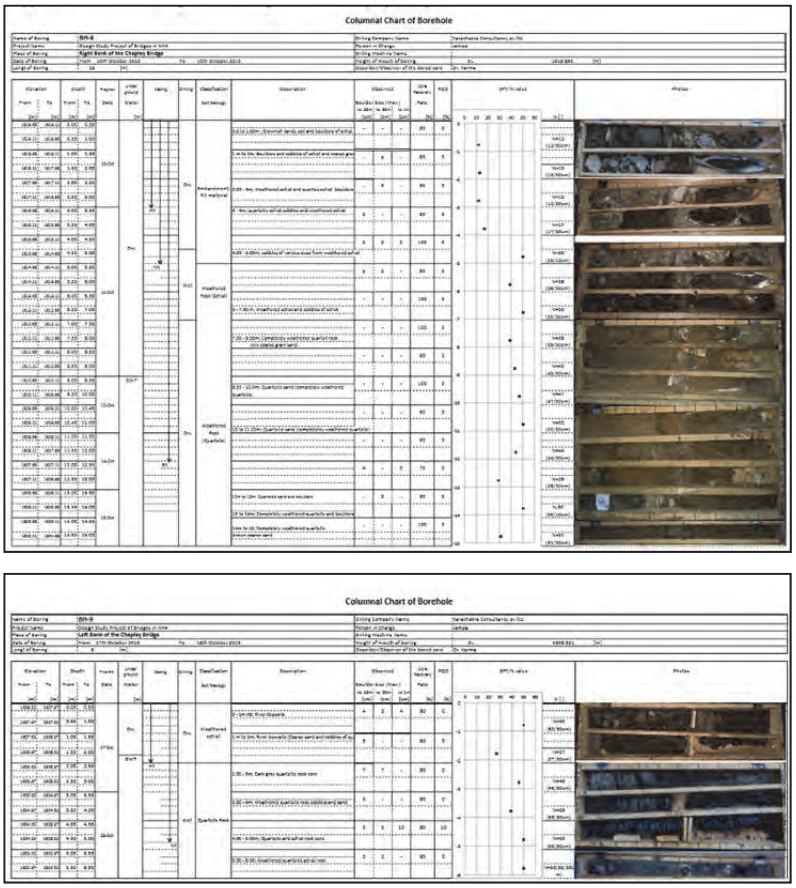
i) Boring

The survey site is shown in the photo. The boring was done at a total of two points. The boring (BH-8) was located on the embankment on the right bank side and designated for the confirmation of the depth of the bed rock in the right bank. The boring (BH-9) was situated on the river bed for the purpose of confirmation of the bed rock where the pier or the side wall of the culvert would be planned to be located.

Source: JICA Study Team

Figure 1.2.42 Boring position at Chapleykhora site

In the right bank material for the embankment were found from the surface to GL-5m. The weathered silisic schist (quartzite) was found at the depth of GL-5 or deeper. In the river bed, the river deposit is overlying the hard silisic schist at the depth of around 2m.



Source: JICA Study Team

Figure 1.2.43 Columnar chart (Above one is BH-8. Below one is BH-9)

The results of the S.P.T. show that the bed rock was found at the depth of 6m in the right bank. Also the results of the S.P.T. show that the bed rock was found at the shallower level of 2m because the boring (BH-7) was situated in the river bed. Overall the N values are recorded at 40 or more.

Table 1.2.20 N values at each boring

	Right Bank (BH-8)		Left Bank (BH-9)		
Depth (m)	N value	Geology	Depth (m)	N value	Geology
0.78	12	Embankment/ fill material	0.78	>50	Weathered rock (Schist)
1.78	13		1.78	27	
2.78	12		2.78	46	Rock (Quartzite)
3.78	17		3.78	39	
4.78	>50		4.78	>50	
5.78	39	Weathered rock (Schist)	5.78	>50	
6.78	>50				
7.78	39	Weathered rock (Quartzite)			
8.78	43				
9.78	47				
10.78	>50				
11.78	44				
12.78	29				
13.78	>50				
14.50	31				

Source: JICA Study Team

The rock classification of the site changes from low to high according to the depth.

Table 1.2.21 Rock classification

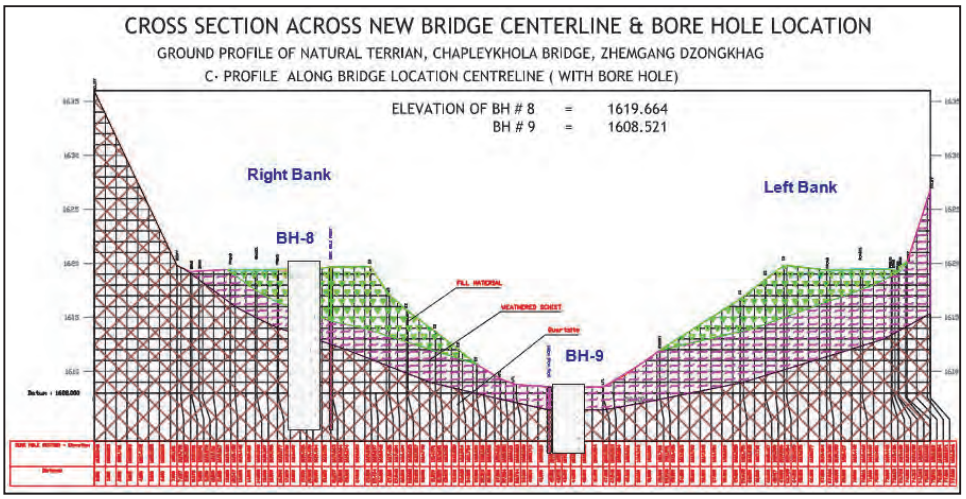
Right Bank (BH-8)		Left Bank (BH-9)	
Depth	Rock Classification	Depth	Rock Classification
0.00m – 5.00m	Overburden	0.00m – 2.00m	D
5.00m – 15.00m	D	2.00m – 6.00m	CL

Source: JICA Study Team

The geological section shows that the geological sequence from the surface is the embankment, weathered schist and weathered silisic schist. The rock classification is changed gradually fom the surface due to the affection from the weathering.

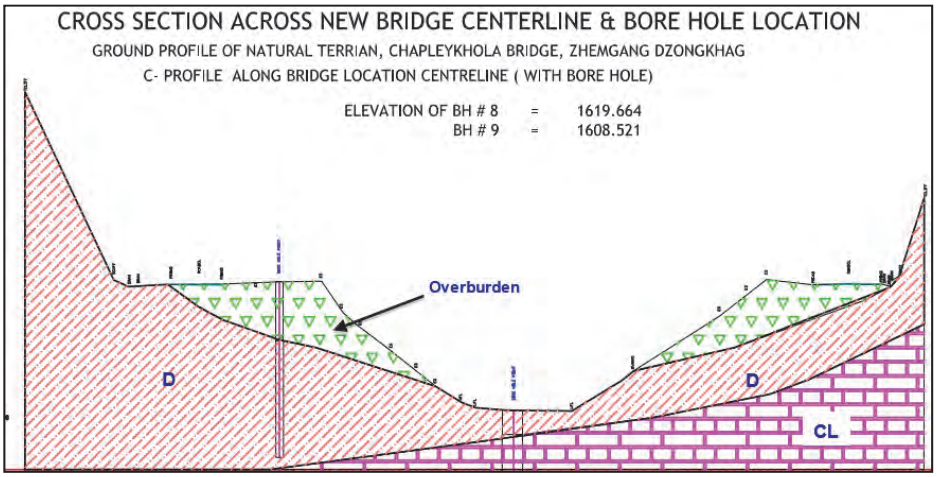
In BH-8 (right bank), the bedrock of schist was encountered at depth of 5m and below this was present weathered schist and quartzite. These rocks are highly weathered into soil with gravels and cobbles. They are classified as D.

In BH-9 (left bank), better quality rock of dark quartzite was found below a thin layer of weathered schists, which are classified as D. However, 50% of these rocks are also weathered. They are classified as CL. The details of the rock classification are given in above.



Source: JICA Study Team

Figure 1.2.44 Geological section



Source: JICA Study Team

Figure 1.2.45 Rock classification

ii) Topography

<Right Bank: Trongsa side>

The steep cliff is formed consisting of the metamorphic rocks (gneiss, pelitic schist) in the folding. The talus deposit (sedimentation deposit) is distributed from the current road to the riverbed. The weak bearing capacity is expected.

<Left Bank: Gelephu side>

The slope along the road is dotted with the outcrops consisting of the dip slope (cut slope). The rock in the outcrop is weathered slightly and is relatively hard.

Source: JICA Study Team

Figure 1.2.46 Topography of Chapleykhora site

(c) Beteni Bridge

i) Boring

The survey site is shown in the photo. The boring was done at a total of two points.

Source: JICA Study Team

Figure 1.2.47 Boring positions (Beteni)

In the right bank (BH-6), Gneiss/Pekitic schist was found overlain by the overburden below the level of GL-6m approximately. The core recovery rate is recorded at 80% or more. N values from the S.P.T. (Standard Penetration Test) are 50 or more at the depth deeper than GL-11m, although the core recovery rate is poor due to the difficulty of retrival of the bored core because the rock was fractured by the rotation of the boring. In the left bank (BH-7), the gneiss was retrieved at GL-2m or deeper.

The results of the S.P.T. show that the bed rock was found at the relative deep depth of 7m in the right bank because the boring (BH-6) was situated in the embankment of the road. Also the results of the S.P.T. show that the bed rock was found at the shallower level of 2m because the boring (BH-7) was situated near the river bed. The rock becomes fragile affected by the metamorphics (tectonic dynamics) although the N values were recorded high (the piece of rock is hard itself.). It is highly likely that the core recovery rate is poor due to the technical constraints of the boring works.

Table 1.2.22 N values at each boring

Right Bank (BH-6)			Left Bank (BH-7)		
Depth (m)	N value	Geology	Depth (m)	N value	Geology
0.78	45	Embankment/ fill material	0.78	43	Embankment/fill material
1.78	20		1.78	40	
2.78	>50		2.78	40	
3.78	49		3.78	41	
4.78	45		4.78	42	
5.78	44		5.78	42	
6.78	39	Rock (Gneiss & Schist)	6.78	40	Rock (Gneiss & Schist)
7.78	>50		7.78	>50	
8.78	>50		8.78	45	
9.78	35		9.78	48	
10.78	37		10.78	44	
11.78	>50		11.78	>50	
12.78	>50		12.78	>50	
13.78	>50		13.78	>50	
14.50	>50		14.78	39	

Source: JICA Study Team

The rock classification is arranged according as the degradation affected by the weathering from the surface layer.

Table 1.2.23 Rock classification

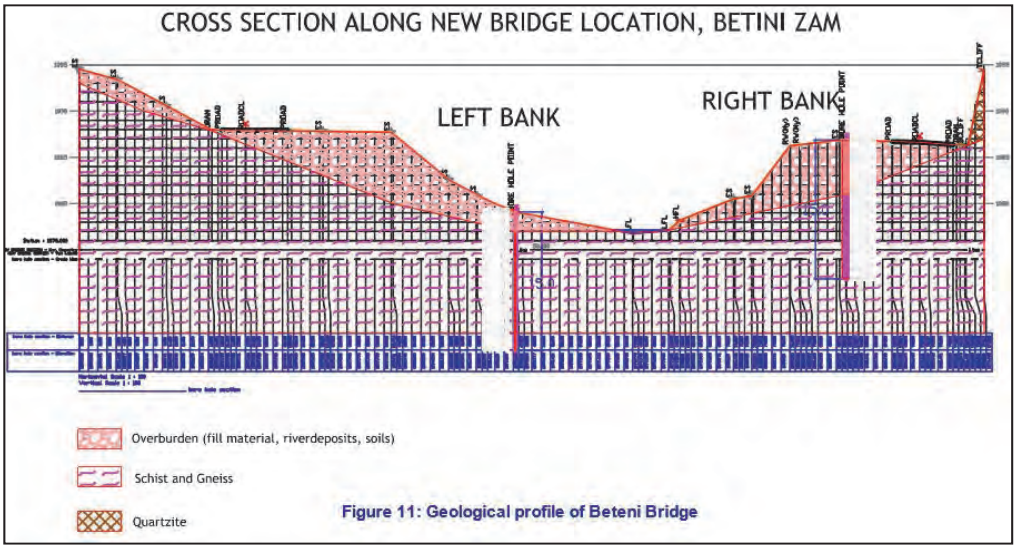
Right Bank (BH-6)		Left Bank (BH-7)	
Depth	Rock Classification	Depth	Rock Classification
0.00m – 6.00m	Overburden	0.00m – 2.00m	Overburden
6.00m – 11.00m	CL	2.00m – 11.00m	D
11.00m – 15.00m	D	11.00m – 14.00m	CH
		14.00m – 15.00m	D

Source: JICA Study Team

The geological section shows that gneiss is interposed in the bed rock consisting mainly of silisic schist (quartzite schist). The level of the rock classification is low overall due to the affection by the metamorphism.

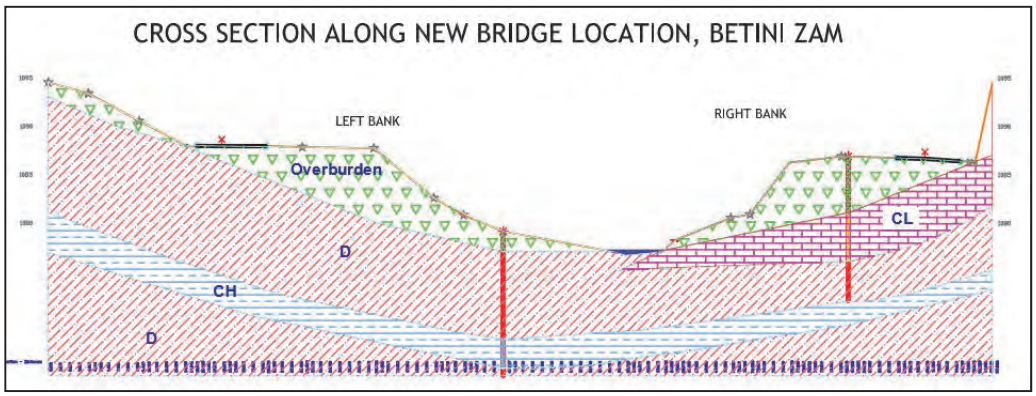
The borehole BH-6 (right bank) showed embankment/fill material from the surface to a depth of about 7m. Below this, there is bedrock composed of gneiss and schist, with schist rock completely weathered and crushed by drilling bits.

The borehole BH-7 (left bank) was drilled at the riverbed. Therefore, only about 2m of overburden layer was noted and below this, there is intermix of weathered gneiss and completely weathered schist. Of the two rocks, gneiss appears to be more competent.



Source: JICA Study Team

Figure 1.2.48 Geological Section



Source: JICA Study Team

Figure 1.2.49 Rock Classification

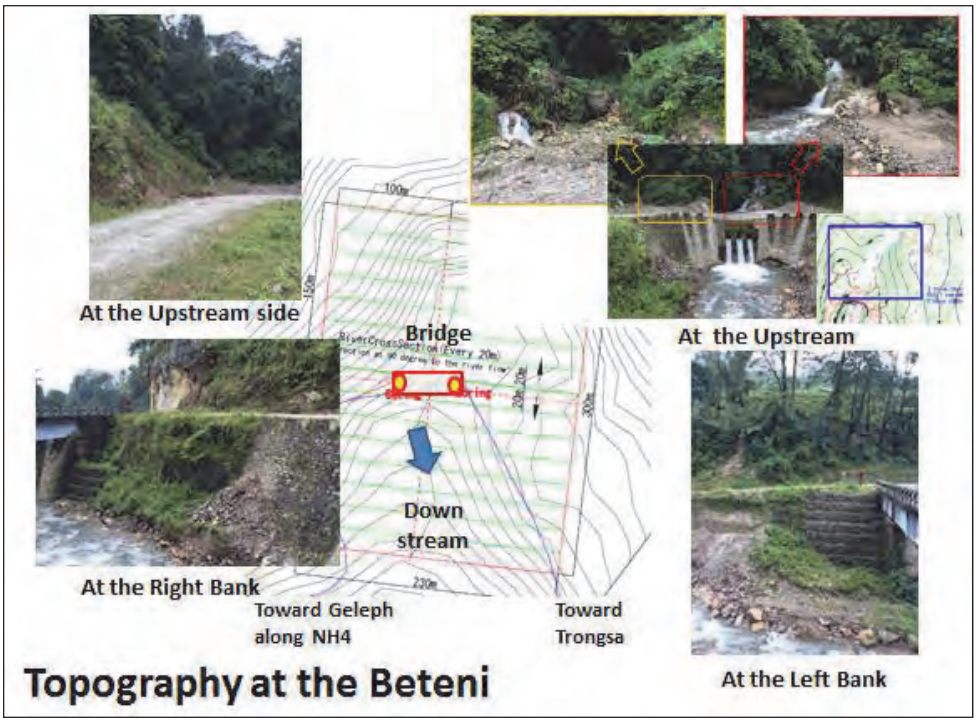
ii) Topography

<Right Bank: Gelephu side>

The outcropped rock (gneiss and schist) are found toward the upstream side. The possibility is high that the outcrop will be interfered with the construction space, where the rock is outcropped. So some consideration will be needed for the planning of the new bridge such as cutting slope and/or slope protection under these constrains. And the consideration for the blasting and ripping capacity also will be needed due to the schistosity.

<Left Bank: Trongsa side>

The relatively gentler slope is formed and terrace deposit is found in the left bank side. There is enough space between the road and river bank. Therefore, the space cannot be thought as to be the constraint of the construction.



Source: JICA Study Team

Figure 1.2.50 Topography of Beteni site

(d) Samkhara Bridge

i) Boring

The survey site is shown in the photo. The boring was done at a total of three points. The BH-5 was designated for the purpose of confirming the depth of the bed rock where the bridge foundation will be situated.

Source: JICA Study Team

Figure 1.2.51 Boring Position (Samkhara)

N values of S.P.T. varied as the sampler hit the round boulder in the river deposit. In the right bank the rock outcrop is approaching to the river side so the bed rock was found at the shallower level of 2m in the boring (BH-3) with its N value 50 or more. In the left bank boring BH-4 found the bedrock at deeper level of around 15m. The additional boring BH-5 found the bed rock (50 or more) at 5m or deeper.

Table 1.2.24 N values at Each Boring (Samkhara)

Right Bank (BH-3)			Left Bank (BH-4)			Left Bank (BH-5)		
Depth (m)	N value	Geology	Depth (m)	N value	Geology	Depth (m)	N value	Geology
0.78	46	Embankment/ fill material	0.78	33	Fill material	0.78	24	Fill material
1.78	>50	Rock (Schist)	1.78	21		1.78	39	
2.78	>50		2.78	41		2.78	>50	River deposits
3.78	>50		3.78	42		3.78	>50	
4.78	>50		4.78	39	River deposits	4.78	28	
5.78	>50		5.78	45		5.78	>50	
6.78	>50		6.78	31		6.78	>50	
7.23	>50		7.78	37		7.78	>50	
7.78	>50		8.78	47		8.78	>50	Bedrock (Quartzite)
8.78	>50		9.78	>50		9.78	>50	
9.23	>50		10.78			10.78	>50	
9.78	>50		11.78			11.78	>50	
			12.78			12.78	>50	
			13.78			13.78	>50	
			14.78					
			15.78	>50	Bedrock (Quartzite)			
			16.78	>50				

Source: JICA Study Team

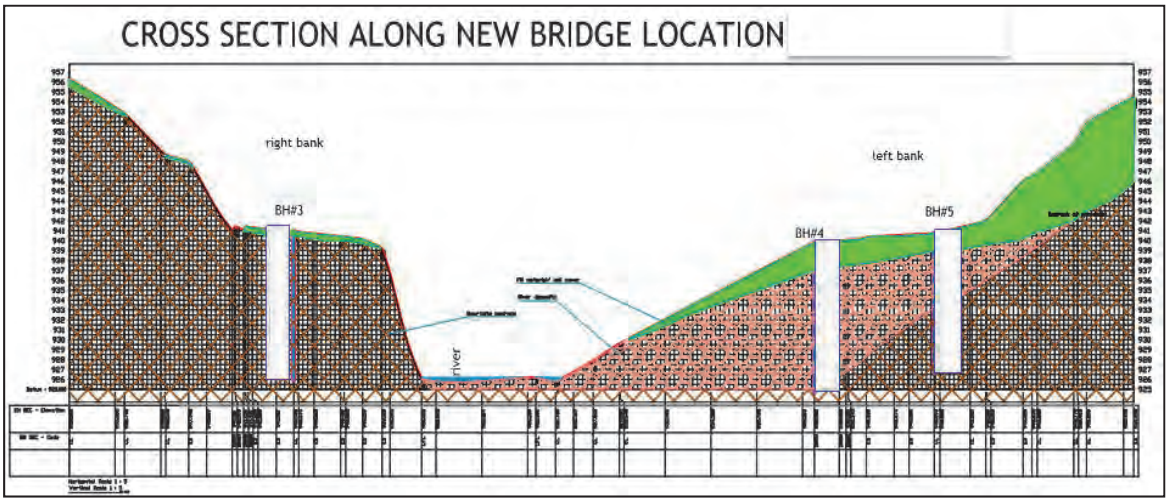
In the BH-3 schist with quartzite is classified as CL to CM. In the BH-4 and 5 found the bed rock with quartzite at the level of approximate 15m and 8m respectively.

Table 1.2.25 Rock classification (Samkhara)

Right Bank (BH-3)		Left Bank (BH-4)		Left Bank (BH-5)	
Depth	Rock Classification	Depth	Rock Classification	Depth	Rock Classification
0.00m – 0.55m	Overburden	0.00m – 3.55m	Overburden	0.00m – 2.00m	Overburden
0.55m – 9.00m	CM	3.55m – 15.00m	River deposits	2.00m – 8.00m	River deposits
9.00m – 15.00m	CL	15.00m – 17.00m	CH	8.00m – 14.00m	CH

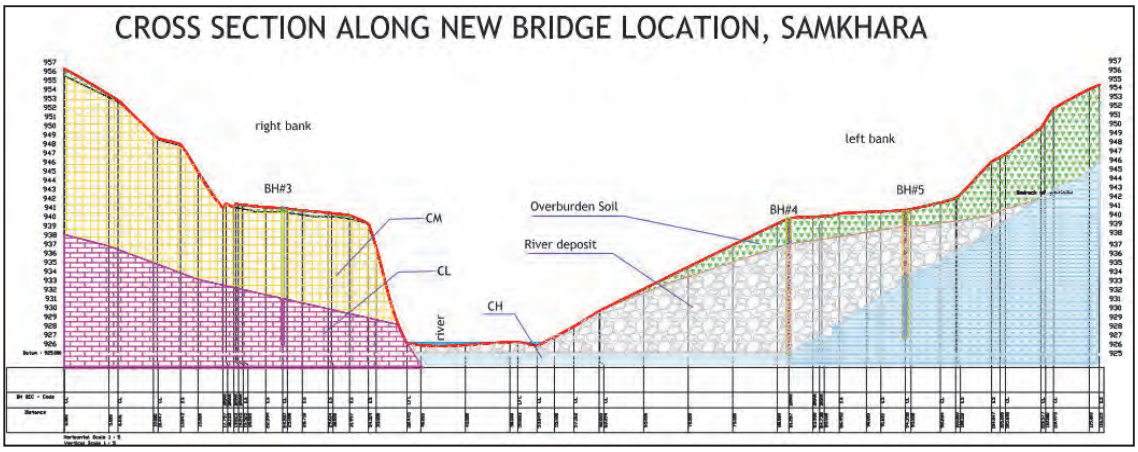
Source: JICA Study Team

In the geological cross section and rock classification, while schist with quartzite (CL through CM) is outcropped on the right bank, river deposit and overburden forms the terrace topography. This means that river has changed its course of the flow from left side to the current position over time. The geology on the right bank as indicated in BH-3 consists of bedrock of quartzite inter-bedded with schist. While quartzite is strong and competent rock, the schist is found either moderately or highly weathered. The left bank geology in borehole BH-4 consists of backfill or embankment material of 3.55m thick and below this layer was a 11m thick river deposit, which extends down to 15m depth. The quartzite bedrock was met only after 15 m depth. The river deposit was also noted in the Borehole BH-5, which was drilled farther away from the river channel. However, the deposit is much thinner and the bedrock was found at 8m from the surface, indicating the bedrock is inclined toward the river.



Source: JICA Study Team

Figure 1.2.52 Geological Section (Samkhara)



Source: JICA Study Team

Figure 1.2.53 Rock Classification

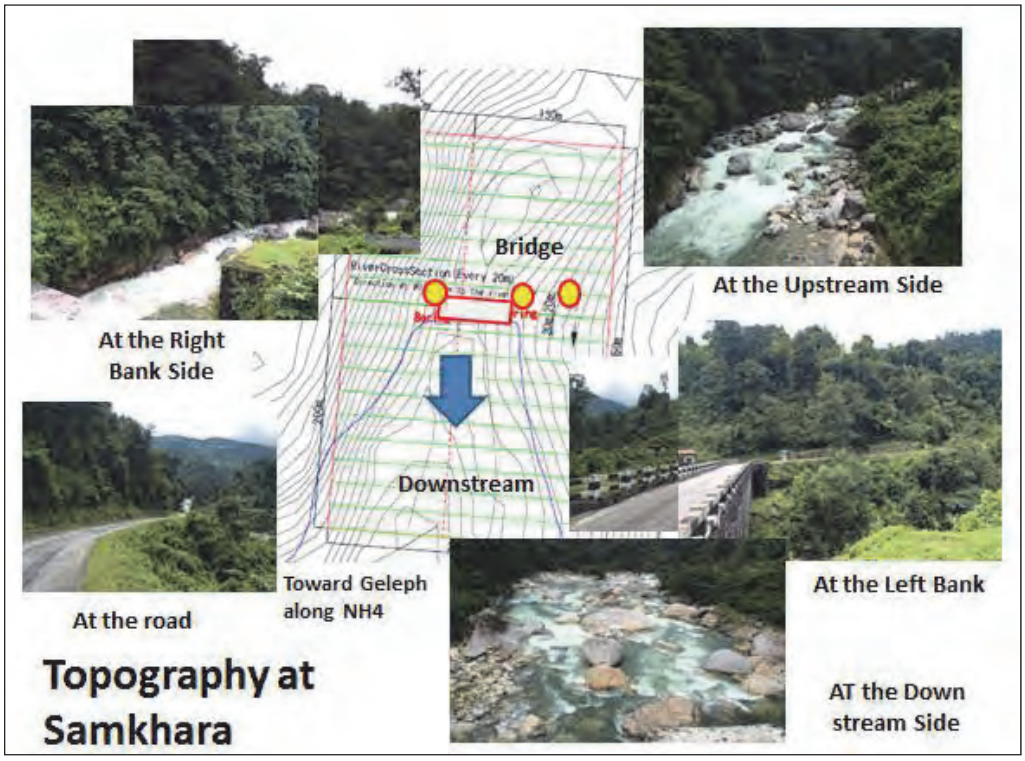
ii) Topography

<Right Bank: Trongsa side>

The flow of the river is biased toward the right bank. The face of the right bank is formed as the steep cliff as the river erosion undercut the slope of the right bank. The hard rock is outcropped in the right bank.

<Left Bank: Gelephu side>

The thick overburden is deposited on the right bank, which forms the terrace.The many talus deposits is found along the slope.



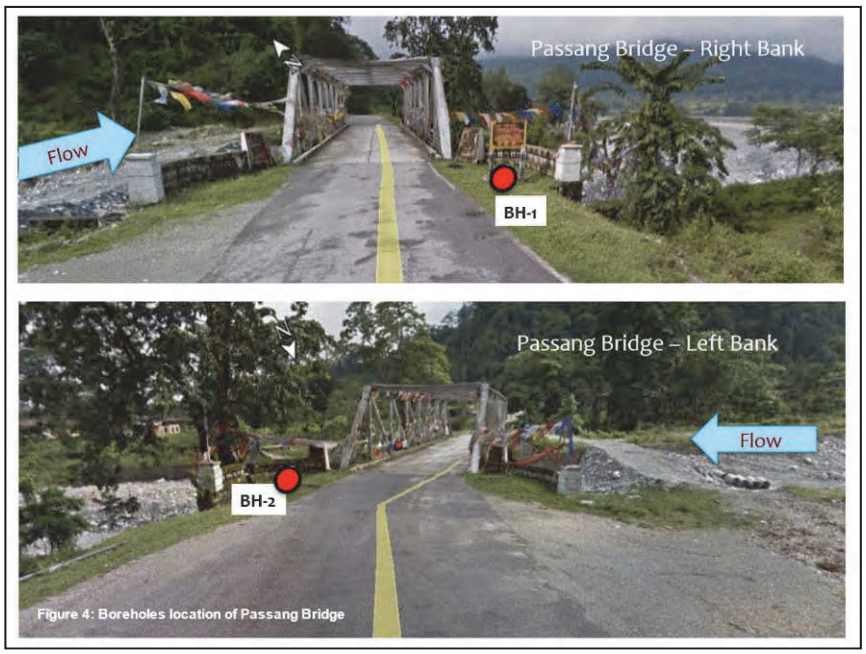
Source: JICA Study Team

Figure 1.2.54 Topography of Samkhara site

(e) Passang Bridge

i) Boring

The survey site is shown in the photo.



Source: JICA Study Team

Figure 1.2.55 Boring Position (Passang)

Borings were done at the two points (Right Bank and Left Bank) at the Passang Bridge Site situating about 6km from the Gelephu city. The depth of the boring was 15m at each right/left bank side. The columnar charts are shown as blow. In both borings, the embankment material with rubble was observed until GL-1.5m. From GL-1.5m to the bottom rounded gravel was observed with its core recovery rate at around 30%.

The S.P.T. test consisted of driving a standard thick-walled sampler into the geologic material (usually on in soil) at the bottom of a borehole, using repeated blows of a 63.5-kg hammer falling through 76 cm. The S.P.T. N value is the number of blows required to achieve a penetration of 30 cm, after an initial seating drive of 15 cm. The S.P.T. test was done at every 1 m throughout the entire length of the borehole and even in bedrock. The test has sufficient versatility that it can provide information on hard-to-sample soil and weak rocks.

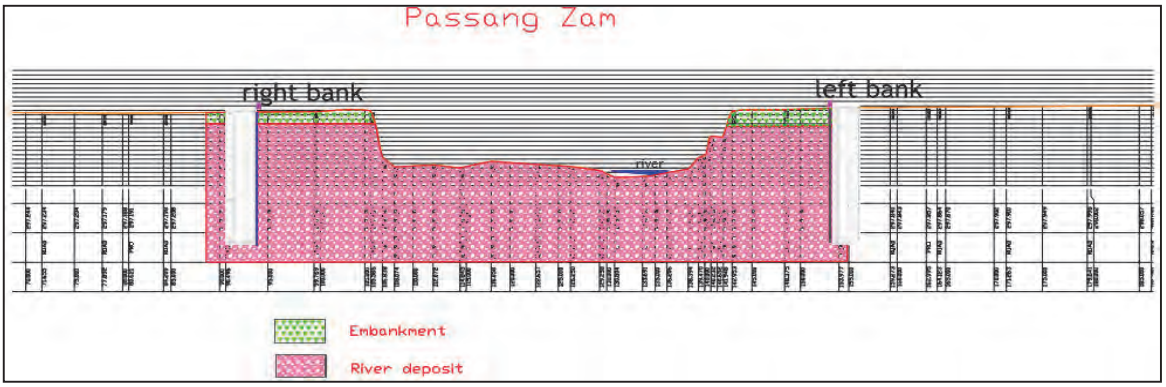
As the results of the Standard Penetration Test, N value has been recorded at 40 or more at the depth of GL-10m or more, which means as to be the hard layer in both BH-1 and BH-2.

Table 1.2.26 The results of the Standard Penetrating Test (Passang)

	Right Bank (BH-1)		Left Bank (BH-2)		
Depth (m)	N value	Geology	Depth (m)	N value	Geology
1.78	>50	Embankment/ fill material	1.23	>50	Embankment/fill material
3.23	>50	River deposits	2.23	21	River deposits
4.78	27		3.23	73	
6.23	38		4.78	22	
7.23	46		6.00	>50	
8.78	38		7.28	40	
9.23	45		8.00	>50	
11.23	46		9.00	40	
13.23	46		10.28	39	
14.78	49		10.95	40	
			11.50	42	
			12.78	45	
			13.73	48	
			14.73	>50	

Source: JICA Study Team

Geological Section shows that the road embankment (earth structure) is overlaying the river deposit including silt, sand, gravel and organic materials. On both the banks, the embankment material was found in the top few meters and the rest of the 15 m of drilling was mainly in the fluvial river deposits. Since the drilling was stopped at 15m depth, no bedrock was observed. The geological profile along the centerline of the proposed new bridge is shown in Figure1.2.56.



Source: JICA Study Team

Figure 1.2.56 Geological Section (Passang)

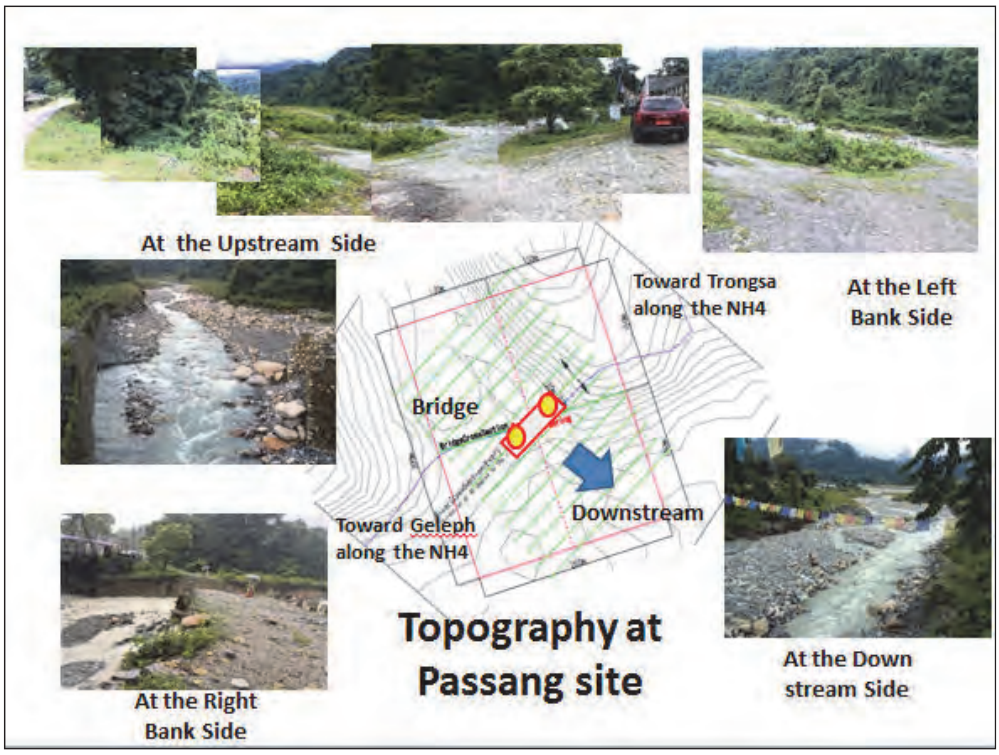
ii) Topography

<Right Bank: Gelephu side>

The bridge planned site is situated at the place where the mountainous topography opens out toward the plain area (mouth of the valley). The axis of the flow of the river is biased at the left bank, so the river deposit has accumulated in the right bank side.

<Left Bank: Trongsa side>

At the left bank the steep mountain side with its inclination at around 40 degree is facing close to the river side. In the steep cliff the boulders of slate and quartzite were found. But almost mountain side is covered by the weathered surface layer.



Source: JICA Study Team

Figure 1.2.57 Topography of the Passang site

2) Testings

The CBR test and material test were implemented as an on-site tests. The CBR test was purposed for desingning the thickness of the pavement of the planned road, and the material test was purposed for selecting the appropriate material for the planned road structures. Each result was described below.

(a) CBR test

The concept of the CBR test (California Bearing Ratio) is that evaluates the bearing capacity of the subgrade in the road structure. CBR test will divided into two methods, one is “Laboratory CBR” ,

and second one is named "in-situ CBR" test that introduces the experimental apparatus on site. The laboratory CBR test will be subdivided further into two kinds, that are the test (Design CBR Test) for evaluates whether the subgrade has the appropriate bearing capacity or not, and the test (Modified CBR Test) for evaluates the stiffness of the road materials at different condition of density & moisture.

In this study, design CBR test was implemented after the specimen had been sampled at the subgrade level on site. The number of the samples were 10 in total (5 sites, 2 sides (right and left bank)).

A set of dynamic penetrating test apparatus was utilized on site for in-situ CBR evaluation. The measured results from the dynamic penetrating apparatus were calculated through the statistical equation that estimates the equivalent CBR values. As for the evaluation method of the design CBR test disturbed sample was put in the mold after prepared for optimum water content, and then the characteristics was sought by comparing the relation between the penetration into the specimen and the force introduced on the sample. And finally the ratio was calculated from the characteristic relation of penetration and the induced load.

The table shows the purpose of the CBR test and its result in this study.

Table 1.2.27 Rsults of the CBR Tests

No.	item of the test	purpose	site	side	result value	result unit	remarks
1	Laboratory CBR	Designing the thickness of the Surface/Base/Subbase Course	Passang	right bank	13.47	%	The estimated range of the CBR were proposed as below.
				left bank	18.97	%	
			Samkhara	right bank	13.88	%	
				left bank	14.30	%	caly or silt: 3 or below
			Beteni	right bank	10.70	%	volcanic ash (high water content): 3 to 5
				left bank	8.91	%	laom (sandy volcanic ash): 7 to 15
			Chaplkhora	right bank	15.17	%	sandy soil: 7 to 15
				left bank	13.43	%	well graded sand: 7 to 15
			Teleganchu	right bank	13.62	%	Source: Soil Dynamics P197 (Morikita Books)
				left bank	7.55	%	
2	Dynamic Cone Penetrating	Alternative method of in-site CBR test Alternative method of in-site CBR test	Passang	right bank	13.0	%	The estimation is proposed by the statistical correration between DCP and CBR from army corps of engineering in US.
				left bank	20.0	%	
			Samkhara	right bank		%	
				left bank	8.0	%	
			Beteni	right bank	14.0	%	Estimation: CBR=292/DCP from the experimental redults using the same specimen.
				left bank	5.5	%	
			Chaplkhora	right bank		%	
				left bank	9.0	%	Estimation:$1/(0.017019*DCP)^2$
			Teleganchu	right bank	13.0	%	appicable to clay soil with lower watercontent ratio
				left bank	14.1	%	

Source: JICA Study Team

The point implemented were decided by taking the following points into consideration, such as position of the route of the planned road, the traffic situation on site, and soil property of the basement where the test will be trialed the results of the tests are summarized below. The detailed results will be carried in the Appendix. A

As for the interpretation of the results, the technical guide book of the soil property test (Japanese Geotechnical Society, P79) propose that the results below CBR=3 means that the specimen are not appropriate for the road material without any improvement. In this study, the minimum CBR was

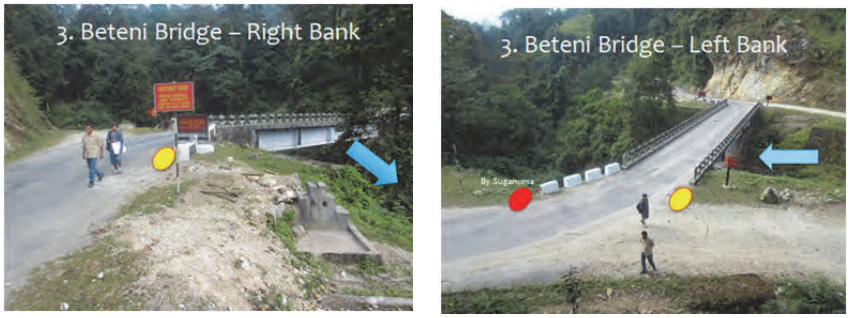
7.55%, therefore all materials sampled can be judged as to appropriate subgrade for the road structure.

Source: JICA Study Team

Figure 1.2.58 CBR Test Point on Passang Site
(Marked as yellow)

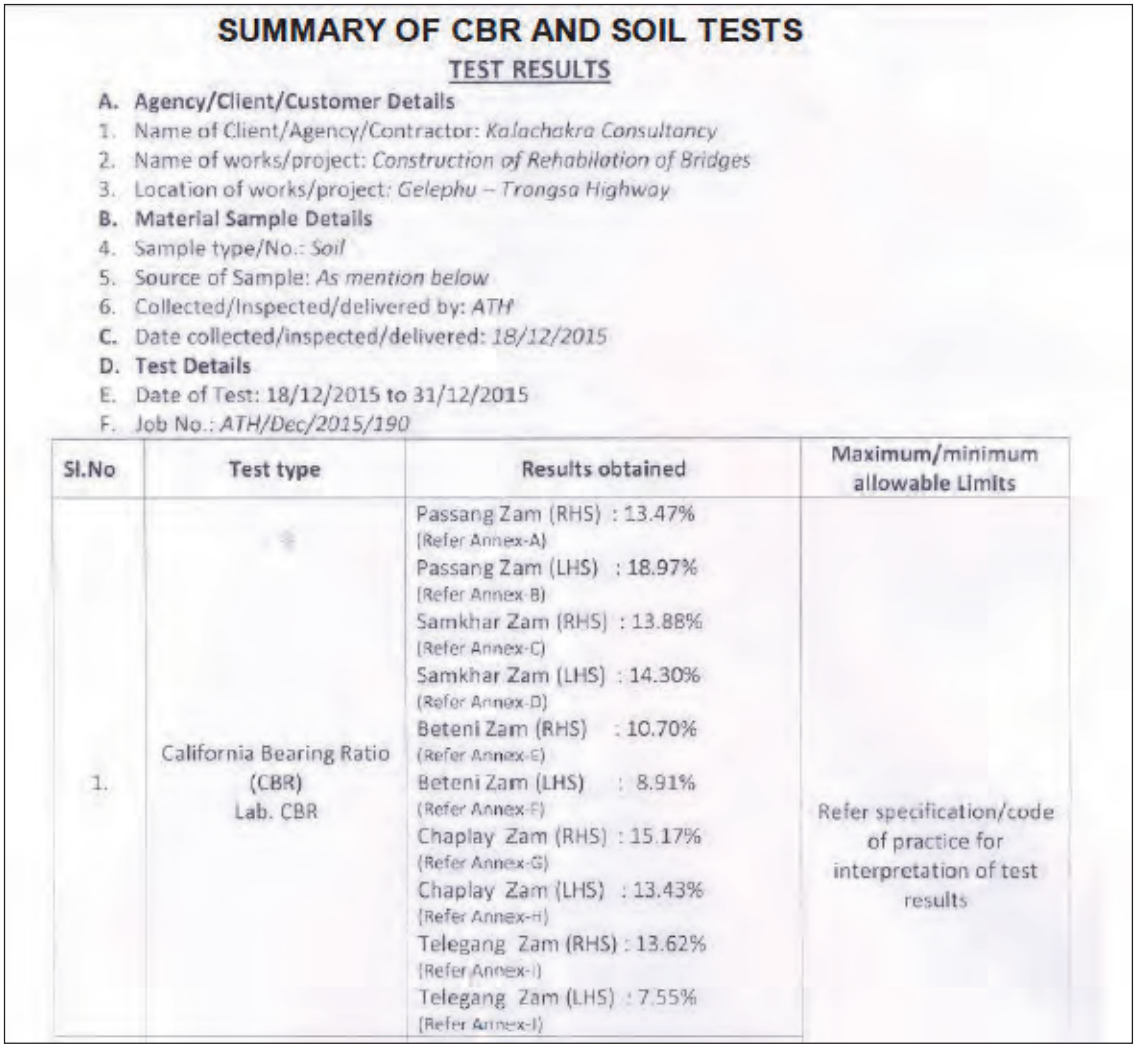
Source: JICA Study Team

Figure 1.2.59 CBR Test Point on Samkhala Site
(Marked as yellow)



Source: JICA Study Team

Figure 1.2.60 CBR Test Point on Beteni Site
(Marked as yellow at right bank and marked as red at the left bank)



SUMMARY OF CBR AND SOIL TESTS

TEST RESULTS

A. Agency/Client/Customer Details

1. Name of Client/Agency/Contractor: *Kalachakra Consultancy*
2. Name of works/project: *Construction of Rehabilation of Bridges*
3. Location of works/project: *Gelephu – Trongsa Highway*

B. Material Sample Details

4. Sample type/No.: *Soil*
5. Source of Sample: *As mention below*
6. Collected/Inspected/delivered by: *ATH*

C. Date collected/inspected/delivered: *18/12/2015*

D. Test Details

E. Date of Test: 18/12/2015 to 31/12/2015

F. Job No.: *ATH/Dec/2015/190*

Sl.No	Test type	Results obtained	Maximum/minimum allowable Limits
1.	California Bearing Ratio (CBR) Lab. CBR	Passang Zam (RHS) : 13.47% (Refer Annex-A) Passang Zam (LHS) : 18.97% (Refer Annex-B) Samkhar Zam (RHS) : 13.88% (Refer Annex-C) Samkhar Zam (LHS) : 14.30% (Refer Annex-D) Beteni Zam (RHS) : 10.70% (Refer Annex-E) Beteni Zam (LHS) : 8.91% (Refer Annex-F) Chaplay Zam (RHS) : 15.17% (Refer Annex-G) Chaplay Zam (LHS) : 13.43% (Refer Annex-H) Telegang Zam (RHS) : 13.62% (Refer Annex-I) Telegang Zam (LHS) : 7.55% (Refer Annex-J)	Refer specification/code of practice for interpretation of test results

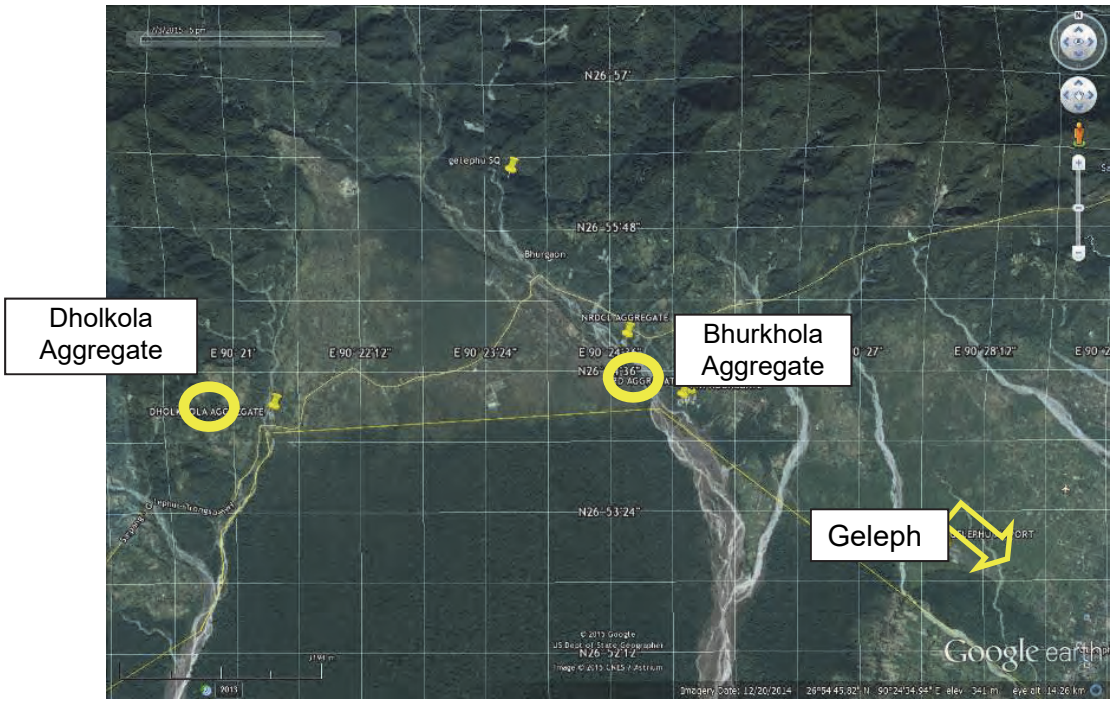
Source: JICA Study Team

Figure 1.2.61 The Summary in the laboratory CBR test

(b) Material Test

The quarry sites that can produce the materials for bridge construction were identified in the 2 sites shown below. Both site are situated along the Gelephu-Sarpang road and have easy access. In the material test for both quarry site, the below items were examined in the tests and it was found that the aggregate can be used, therefore these two quarry site are chosen as a proposed site.

- Dynamic cone penetrating test
- Direct shear test
- Water content ration
- Liquid Limit and Plastic limit tests
- Grain distribution test
- Alkali reaction test



Source: JICA Study Team

Figure 1.2.62 Selected Sites of the Quarry for Material

1.3 Environmental and Social Considerations

1.3.1 Environmental Impact Assessment

(1) Baseline of the Environmental and Social Condition

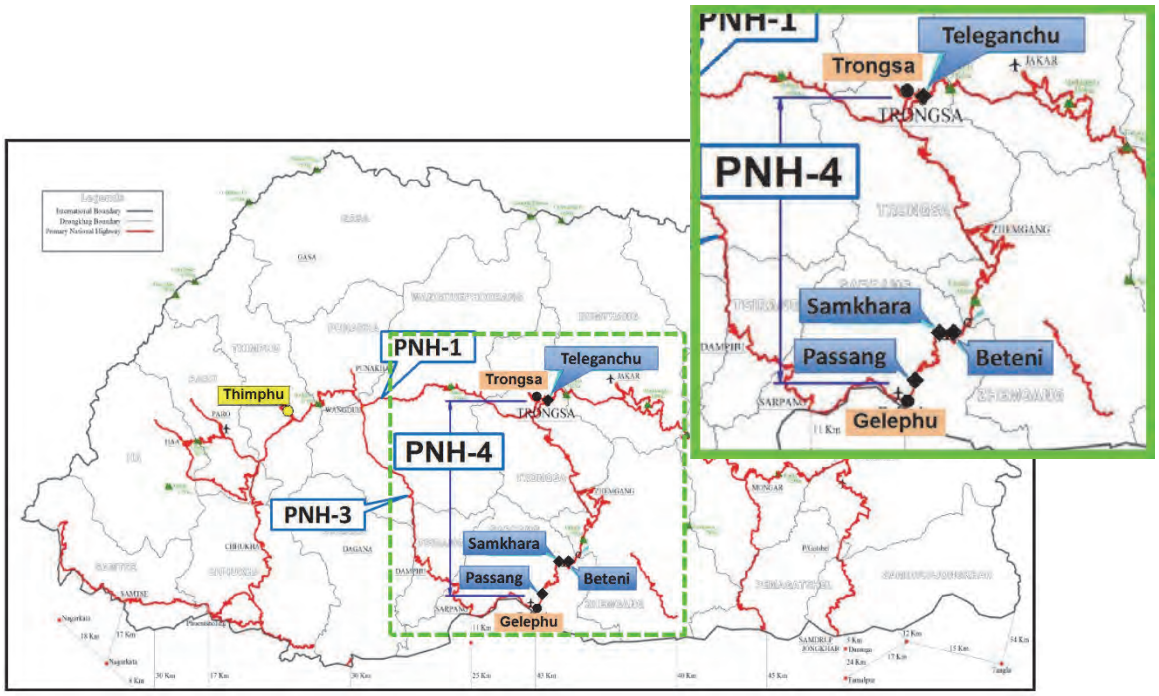
1) Outline of the target five bridges

The following is the outline and location map of the target four bridges of this study.

Table 1.3.1 Outline of the four existing bridges

Bridge(Dzongkhag・Gewog)	Outline
Telegangchu Bridge (Trongsa Dzongkhag・Nubi Gewog)	RC-T Girder Bridge, Length 25m, Width 4.5m, Built in 1981
Beteni Bridge (Sarpang PDzongkhag・Jimecholing Gewog)	RC-T Girder Bridge, Length 25m, Width 4.2m, Built in 1987
Samkhara Bridge (Sarpang Dzongkhag・Jimecholing Gewog)	Steel Truss Bridge, Length 61m, Width 4.3m, Built in 2001
Passang Bridge (Sarpang Dzongkhag・Gelephu Gewog)	Steel Truss Bridge, Length 40m, Width 7.5m, Built in 1970

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1.3.1 Outline of the target four bridges

2) River・Altitude

The following is the name of river and altitude of the target bridges.

Table 1.3.2 Project location and the Surrounding Topography

Bridge	Location		River	Altitude
	Dzongkhag	Gewog		
Telegangchu Bridge	Trongsa	Nubi	Telegangchu chu	App. 2,100m
Beteni Bridge	Sarpang	Jimecholing	Beteni chu	App. 1,100m
Samkhara Bridge	Sarpang	Jimecholing	Samkhara chu	App. 900m
Passang Bridge	Sarpang	Gelephu	Lodrai chu	App. 300m

Source: JICA Survey Team

3) Protected area

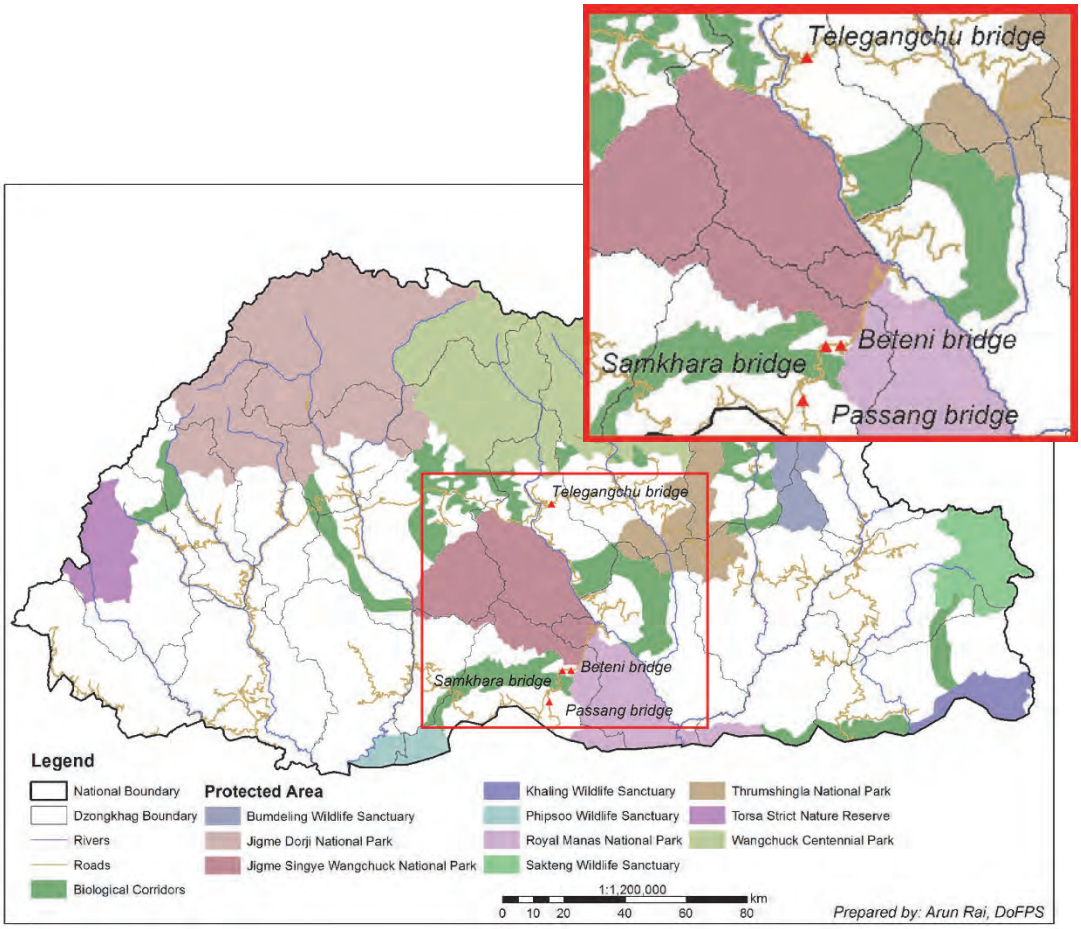
In Bhutan, about fifty percent of the national territory is designated as areas related to natural conservation, which are composed of five national parks, four wildlife sanctuaries, and one strict nature reserve. In addition, there are biological corridors which connect aforesaid protected area and it is also considered as protected area. These protected areas, including the biological corridors, were created under the Forest and Nature Conservation Act of Bhutan, 1995 and governed by DFPS, MoAF, which develops plans and policies for preservation of these areas and maintains, manages, and operates them. According to “Forest and nature Conservation Rules, 2006”, these protected areas are classified into three zones according to their locations and the ecological importance of the wildlife, as shown in the table below:

Table 1.3.3 Zoning within National Parks

Zone	Description
Core Zone	Areas where alteration or use of land is prohibited, giving top priority to wildlife conservation.
Buffer Zone	Areas that neighbor protection areas, where only specified action is permitted.
Multiple-use Zone	Areas including human habitats. Implementing a project requires an EIA.

Source: Forest and nature Conservation Rules, 2006

Protected areas in Bhutan and project target bridges are located as shown in Figure 1.3.2. Development activities inside of protected areas has regulation, however the target bridges are located outside of those protected areas.



Source: JICA Study Team

Figure 1.3.2 Protected areas near the project target area

4) Population

Population of the Dzongkhag and Gewog which each target bridges are located is shown in Table 1.3.4. There are several households in surrounding area of Beteni Bridge and Passang Bridge. However there is no village existing in surrounding area of other two bridges.

Table 1.3.4 Comparison of the population of target area (Dzongkhag and Gewog)

Bridge	Prefecture (Dzongkhag)	Population	Country (Gewog)	Population
Telegangchu Bridge	Trongsa	13,419	Nubi	2,451
Beteni Bridge	Sarpang	41,549	Jimecholing	3,414
Samkhara Bridge	Sarpang	41,549	Jimecholing	3,414
Passang Bridge	Sarpang	41,549	Gelephu	3,975

Source: National Statistics Bureau, Population & Housing Census of Bhutan 2005

5) Social condition

In Bhutan, population of the poverty (line is the person who lives in USD1.25/day or less) is decreasing. Especially it has decreased by half since 2007 (App. 24%) to 2012 (App.12%). The population of poverty in each Dzongkhag is follows:

Table 1.3.5 Poverty rate of target area (Dzongkhag)

Bridge	Prefecture (Dzongkhag)	Population of poverty	
		2007	2012
Telegangchu Bridge	Trongsa	3,231	1,995
Beteni Bridge	Sarpang	7,809	1,436
Passang Bridge			
Samkhara Bridge			

Source: Bhutan Poverty Assessment 2014

6) Water Area

The status of water use of crossing river of target bridges is checked and water pipes conducted from around 200m upper stream of Lodrai River is installed along Passang Bridge. The water is used for domestic use including drinking water for surrounding community such as houses, army compound, and temple. However, the use of the river water as drinking, agricultural water and other domestic uses are not observed in other bridges.

(2) Legislation and institution related to environmental clearance

1) Legislation and procedure related to environmental clearance

Environmental legislation and procedure related to environmental clearance in Bhutan as follows:

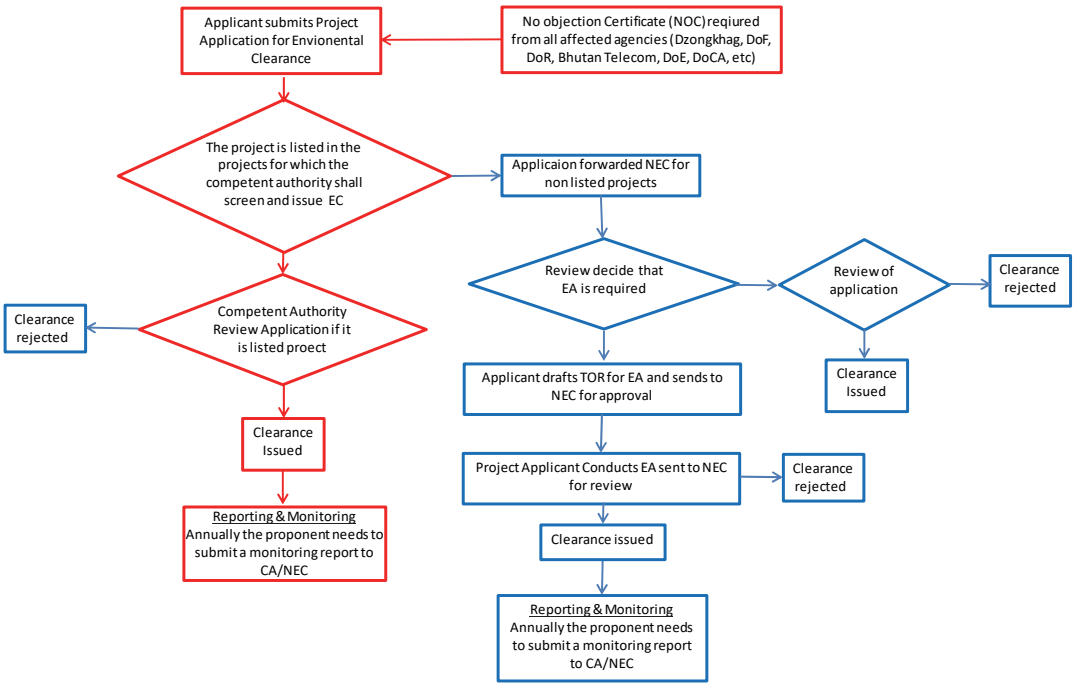
Table 1.3.6 Legislation and procedure related to environmental clearance in Bhutan

No.	Relevant Environmental Legislation	Year
1. Environmental Assessment, Environmental Clearance and Environmental Standards		
1-1	National Environment Protection Act	2007
1-2	Regulation for the Environmental Clearance of Projects	2002
1-3	Environmental Assessment Act, 2000	2000
1-4	Environmental Standards	2010
1-5	Notification of 42nd Session of NEC- Delegation and Exemption of Environment Clearance	2016
2. Natural Environment		
2-1	Biodiversity Act, 2003	2003
2-2	Forest and Nature Conservation Act of Bhutan, 1995	1995
2-3	Forest and Nature Conservation Rules, 2006	2006
3. Social Environment		
3-2	Land Act of Bhutan 2007	2007
3-3	Land Compensation Rates 2009	2009

Source: JICA Study Team

According to the regulations of "Environmental Assessment Act, 2000" above, all project which aim at development need to acquire "Environmental Clearance (EC)" from Competent Authority. The procedures and responsibilities for issuing EC are regulated by "Regulation for the Environmental Clearance of Projects 2002".As the law about national park and forest protected area, "Forest and Nature Conservation Rules, 2006" is established. In this law, the definition of protected area and limitation of activities inside protected area are regulated.

Procedure of the environmental clearance is shown as Figure 1.3.3. In the application of EC, project proponent need to obtain Forest Clearance: FC and Dzongkhag Clearance: DC and submit them with application. In addition, the developing entity must first get No Objection Certificate (NOC) from organization concerned if the project falls in a sensitive area such as close to human dwellings and hospital and inside of protected area. Application for Environmental Clearance will be submitted after those certificates were obtained as suggested by the guidelines. In this project, as the flow shown in red color in Figure 1.3.3, after obtains of NOC, application form and IEE will be submitted in expected process. According to the Environmental Assessment Act, 2000, IEE is suggested to be disclosed after obtaining EC. Accordingly, Survey team will offer to DoR and Local Government to disclose hard copy of IEE for a certain period.



Source: Application for Environmental Clearance Guideline for Highways and Roads

Figure 1.3.3 Flowchart of EIA procedure in Bhutan

2) Screening criteria of EIA and IEE

When the project is implemented, implementing agency needs to create either EIA report or Initial Environmental Examination (IEE) report. According to the interview with Environmental Unit of DoR and NEC, the case which requires EIA is only when the project falls protected areas. The bridges of this project is not located inside of protected area, therefore it requires IEE. Furthermore, based on the JICA Guidelines for environmental and social considerations (2010), this project is categorized as category B (impact is less adverse), therefore IEE report is required. In addition, IEE report is required based on Environmental Assessment Act, 2000 and the interview with NEC. Therefore, report in this project will be IEE.

3) Procedure of Environmental Clearance and roles of the relevant agencies

With regard to the procedure of acquisition of environmental clearance, the applicant is DoR in this project. According to Regulation for Environmental Clearance of Projects, competent authority(CA) depends on the type of the project, but the Notification of 42nd Session of NEC- Delegation and Exemption of Environment Clearance defines Dzongkhag Environment Committee (DEC) as the CA for bridge project. Accordingly, the application needs to be submitted to DEC in this project.

As described above, the procedure to acquire the Environmental Clearance for this project is under way according to the pertinent laws of Bhutan. The table below summarizes the environmental procedure (reference materials for permission, their destination and source) in the future.

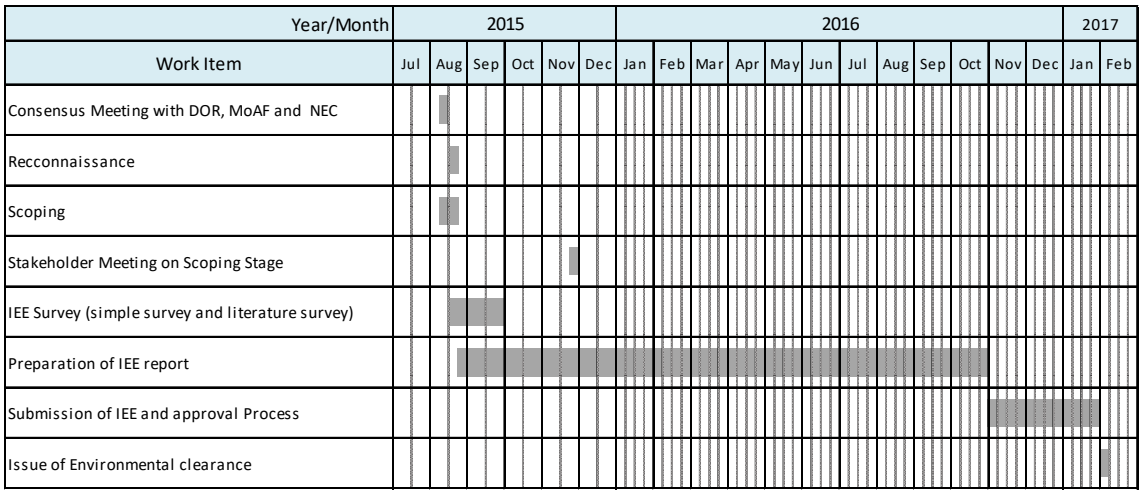
Table 1.3.7 Procedure of EC (Application destination/ issuing organization for each step)

	Telegangchu bridge	Beteni bridge	Samkhara bridge	Passang bridge
(i) Issue of FC	DoFPS Branch (Zhemgang Prefecture)	DoFPS Branch (Sarpang Prefecture)		
(ii) Issue of DC	Trongsa Prefecture	Sarpang Prefecture		
(iii) Application	DoR Prepares Application (Application Form: Report of EE level) for each bridge			
Acquisition of EC	Submit (i) (ii) (iii) to DEC→DEC issues of EC			

Source: JICA Study Team

4) Current status and future schedule of EIA

According to the aforementioned legislation the environmental clearance can be obtained in approximately 3 months and half after the submission of application. The same result was obtained in the interview with NEC. In addition, the schedule of acquisition of environmental clearance was confirmed with DoR by showing the schedule for EIA procedure shown below. Accordingly, it was confirmed that the conducting the procedure and the acquisition of clearance will be completed by project implementation.



Source: JICA Study Team

Figure 1.3.4 Work schedule of Environmental clearance

(3) Alternative Analysis

In this project, 4 options which are A. bridge construction at upstream side, B. construction at current location, C. construction at downstream side and D. no construction (zero-option) were analyzed for each bridge. The result of the analysis is shown in Chapter2, 2.2.2. As a result of analysis including the result of consultation with Bhutan government, the best options were selected.

(4) Scoping

In accordance with JICA Guideline, this project has been categorized B. Scoping has been carried out based on activities of this project at each stage and impact items. The result of scoping based on IEE (Matrix and degree of impact) is as follows.

Table 1.3.8 Scoping Matrix: Telegangchu Bridge

	No	Affected Activities / Impact Items (JICA)	Overall ranking	Pre/ During Construction Phase								Operation Phase		
				Land acquisition and Loss of properties Including demolition of existing bridge	Change of Land use plan, Control of various activities by regulations for the construction	Reclamation of Wetland, etc.	Deforestation	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	Increase of Through Traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment
Pollution	1	Air Pollution	**B-**				B-	B-	B-			B-		
	2	Water pollution	**B-**				B-				B-			
	3	Waste	**B-**				B-				B-			
	4	Soil contamination												
	5	Noise and Vibration	**B-**					B-	B-					
	6	Ground Subsidence												
	7	Odor												
	8	Sediment quality												
Natural Environment	9	Protected Area												
	10	Ecosystem	**B-**			B-								
	11	Hydrology												
	12	Topography and geology												
Social Environment	13	Involuntary resettlement												
	14	The poor												
	15	Indigenous and ethnic people												
	16	Local economy such as employment and livelihood	**B+**							B+			B+	
	17	Land use and utilization of local resources												
	18	Waste Usage												
	19	Existing social infrastructures and services	**B+**										B+	
	20	Social institutions such as local decision making institutions												
	21	Misdistribution of benefit and damage												
	22	Local conflict of interests												
	23	Cultural Heritage												
	24	Landscape												
	25	Gender												
	26	Right of Children												
	27	Infectious diseases such as HIV/AIDS												
	28	Labor environment (including work safety)												
Others	29	Accidents	**B-**					B-		B-				
	30	Cross Boundary impacts and climate change												

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.9 Scoping Result (Reasons of the Rating): Telegangchu Bridge

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation Phase	
Pollution		Air Pollution	B-	B-	**Construction phase:** Temporary negative impacts are expected on air quality due to construction machines and equipment. **Operation phase:** Negative impact is expected due to the increase in traffic number.
	2	Water pollution	B-		**Construction phase:** Turbid water may be generated by earth works and excavation. Additionally Organic polluted water may be discharged from base camp. **Operation phase:** No serious impacts are expected.
	3	Waste	B-		**Construction phase:** Construction waste such as waste soil and cutting trees are expected. Additionally night soil may be generated from construction base camp. **Operation phase:** No serious impact is expected.
	4	Soil contamination			**Construction and operation phase:** No adverse negative impact is expected.
	5	Noise and vibration	B-		**Construction phase:** Noise generation is expected due to works of construction machines and equipment. **Operation phase:** No serious impact is expected.
	6	Ground subsidence			**Construction and operation phase:** No adverse negative impact is expected since activities which cause ground subsidence not expected.
	7	Oder			**Construction and operation phase:** No adverse negative impact is expected since activities which cause odor are not expected.
	8	Sediment quality			**Construction and operation phase:** No adverse negative impact is expected.
Natural Environment	9	Protected area			**Construction and operation phase:** No protected area is observed in the project affected area and No adverse negative impact is expected.
	10	Ecosystem	B-		**Construction phase:** Deforestation of some trees may expect along the river and on slope. **Operation phase:** No adverse negative impact is expected.
	11	Hydrology			**Construction and operation phase:** No activities give negative impact to hydrological situation of the river.
	12	Topography and geology			**Construction and operation phase:** Cutting land is expected. However No adverse negative impact is expected. because of the land is limited
Social Environment	13	Involuntary resettlement and land acquisition			**Pre-construction phase:** No resettlement and land acquisition are expected and No adverse negative impact is expected. **Operation phase:** No adverse negative impact is expected.
	14	The poor			**Construction and operation phase:** No adverse negative impact is expected since there are not residential areas nearby project area.
	15	Indigenous and ethnic people			**Construction and operation phase:** No adverse negative impact is expected since there are not residential areas of indigenous and ethnic people nearby project area.
	16	Local economy such as employment and livelihood	B+	B+	**Construction and operation phase:** Increasing job opportunities during construction and revitalization of the economy due to increasing traffic volume is expected during operation.
	17	Land use and utilization of local resources			**Construction and operation phase:** No adverse negative impact is expected since the project site is government-own forest (copse).
	18	Water usage			**Construction and operation phase:** No impacts are expected since there are not any water usages in project area.
	19	Existing social infrastructures and services		B+	**Construction and operation phase:** Improving access to social infrastructure is expected.

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation Phase	
Social Environment	20	Social institutions such as local decision making institutions			**Construction and operation phase:** No adverse negative impact is expected since the project site is government-own forest (copse) and there are no changes of decision-making institution (Government of prefecture/ village).
	21	Misdistribution of benefit and damage			**Construction and operation phase:** Misdistribution of benefit and damage caused by the bridge rebuilding is not expected.
	22	Local conflict of interests			**Construction and operation phase:** No adverse negative impact is expected since this project is rebuilding of existing bridge.
	23	Cultural heritage			**Pre-construction and operation phase:** No adverse negative impact is expected since religious and cultural facility is not observed at the project area.
	24	Landscape			**Pre-Construction phase/ Construction and operation phase:** There are no law-based designated landscape areas around project areas.
	25	Gender			**Pre-Construction phase/ Construction and operation phase:** Negative impacts specified for women are not expected.
	26	Right of Children			**Pre-Construction phase/ Construction and operation phase:** .Negative impacts specified for children are not expected.
	27	Infectious diseases such as HIV/AIDS			**Construction and operation phase:** No adverse negative impact is expected since this project is for domestic road.
	28	Labor environment			**Construction phase:** No adverse negative impact is expected. for now. However construction work environment needs to be considered in accordance with relevant laws and regulations.
Others	29	Accident	B-		**Construction phase:** The number of construction car increase, thus number of traffic accident may increase. **Operation phase:** No adverse negative impact is expected.
	30	Cross boundary impacts and climate change			**Construction and operation phase:** Significant deforestation is not expected on this project, and number of construction machines is limited since No adverse negative impact is expected.

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.10 Scoping Result: Beteni Bridge

	No	Affected Activities / Impact Items (JICA)	Overall Rating	Pre-Construction phase／Construction phase								Operation phase		
				Land acquisition and Loss of properties Including demolition of existing bridge,	Change of Land use plan, Control of various activities by regulations for the construction	Deforestation	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	Increase of through traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Increasing influx of settlers
Pollution	1	Air Pollution	**B-**				B-	B-	B-			B-		
	2	Water Pollution	**B-**				B-				B-			
	3	Waste	**B-**				B-				B-			
	4	Soil contamination												
	5	Noise and Vibration	**B-**					B-	B-					
	6	Ground Subsidence												
	7	Odor												
	8	Sediment quality												
Natural Environment	9	Protected Area												
	10	Ecosystem	**B-**			B-								
	11	Hydrology												
	12	Topography and geology												
Social Environment	13	Involuntary resettlement	**C**	C										
	14	The poor												
	15	Indigenous and ethnic people												
	16	Local economy such as employment and livelihood	**B+**						B+			B+		
	17	Land use and utilization of local resources												
	18	Water Usage												
	19	Existing social infrastructures and services	**B+**									B+		
	20	Social institutions such as local decision making institutions												
	21	Misdistribution of benefit and damage												
	22	Local conflict of interests												
	23	Cultural Heritage												
	24	Landscape												
	25	Gender												
	26	Right of Children												
	27	INFECTIOUS DISEASES SUCH AS HIV/AIDS												
	28	Labor environment (including work safety)												
Others	29	Accidents	**B-**					B-		B-				
	30	Cross boundary impacts and climate change												

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.11 Scoping Matrix (Reasons of the Rating): Beteni Bridge

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Pollution	1	Air Pollution	B	B	**Construction phase:** Temporary negative impacts are expected on air quality due to construction machines and equipment. **Operation phase:** Negative impact is expected due to the increase in traffic number.
	2	Water Pollution	B		**Construction phase:** Turbid water may be generated by earth works and excavation. Additionally organic polluted water may be discharged from base camp. **Operation phase:** No adverse negative impact is expected.
	3	Waste	B		**Construction phase:** Construction waste such as waste soil and cutting trees are expected. Additionally night soil may be generated from base camp. **Operation phase:** No adverse negative impact is expected.
	4	Soil contamination			**Construction and operation phase:** No adverse negative impact is expected since soil pollutant is not discharged..
	5	Noise and Vibration	B		**Construction phase:** Noise generation is expected due to works of construction machines and equipment. **Operation phase:** No adverse negative impact is expected.
	6	Ground Subsidence			**Construction and operation phase:** No impacts are expected since activities which cause ground subsidence are not expected.
	7	Odor			**Construction and operation phase:** No adverse negative impact is expected since activities which cause odor are not expected.
	8	Sediment quality			**Construction and operation phase:** No adverse negative impact is expected since construction and operation do not influence sediment quality..
Natural Environment	9	Protected Area			**Construction and operation phase:** No protected area is observed in the project affected area and No adverse negative impact is expected..
	10	Ecosystem	B		**Construction phase:** Some trees have to be logged beside along the river and on slope. **Operation phase:** No adverse negative impact is expected.
	11	Hydrology			**Construction and operation phase:** Construction will not influence flow condition in river and riverbed..
	12	Topography and geology			**Construction and operation phase:** No adverse negative impact is expected.
Social Environment	13	Involuntary resettlement	C		**Pre-Construction phase:** Land acquisition of only one area may be caused. **Operation phase:** No adverse negative impact is expected.
	14	The poor			**Construction and operation phase:** No adverse negative impact is expected since around project area is not residential area.
	15	Indigenous and ethnic people			**Construction and operation phase:** Project site is not residential area for indigenous and ethnic people.
	16	Local economy such as employment and livelihood	B+	B+	**Construction and operation phase:** Increasing job opportunities during construction and revitalization of the economy due to increasing traffic volume is expected during operation.
	17	Land use and utilization of local resources			**Pre-Construction phase／Operation phase:** No negative impact is expected since around project area is government-owned forest (copse).
	18	Water Usage			**Construction and operation phase:** No adverse negative impact is expected since there is no water usage in project area.
	19	Existing social infrastructures and services		B+	**Construction and operation phase:** Improving access to social infrastructure is expected.
	20	Social institutions such as local decision making institutions			**Construction and operation phase:** No adverse negative impact is expected since the project site is government-own forest (copse) and there are no changes of decision-making institution (Government of prefecture/ village).

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Social Environment	21	Misdistribution of benefit and damage			**Construction and operation phase:** Misdistribution of benefit and damage caused by the bridge rebuilding is not expected.
	22	Local conflict of interests			**Construction and operation phase:** No adverse negative impact is expected since this project is rebuilding of existing bridge.
	23	Cultural Heritage			**Pre-Construction phase/ Construction and operation phase:** No adverse negative impact is expected since there are not religious facilities and cultural heritage in project area..
	24	Landscape			**Pre-Construction phase/ Construction and operation phase:** There are no law-based designated landscape areas around project area.
	25	Gender			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for woman are not expected.
	26	Right of Children			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for children are not expected.
	27	Infectious Diseases such as HIV/AIDS			**Construction phase/ Operation phase:** No adverse negative impact is expected since this project is for domestic road.
	28	Labor environment (including work safety)			**Construction phase:** Construction work environment needs to be considered in accordance with relevant laws and regulations. However No adverse negative impact is expected for now.
Others	29	Accidents	B-		**Construction phase:** The number of construction car increase, thus number of traffic accident may increase. **Operation phase:** No adverse negative impact is expected.
	30	Cross boundary impacts and climate change			**Construction and operation phase:** Significant deforestation is not expected. The number of construction machines is limited, thus no impacts are expected for climate change and influence of cross-border.

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.12 Scoping Matrix: Samkhara Bridge

	No	Affected Activities / Impact Items (JICA)	Overall Rating	Pre-Construction phase／Construction phase								Operation phase		
				Land acquisition and Loss of properties Including demolition of existing bridge,	Change of Land use plan, Control of various activities by regulations for the construction	Deforestation	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	Increase of through traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Increasing influx of settlers
Pollution	1	Air Pollution	**B-**				B-	B-	B-			B-		
	2	Water Pollution	**B-**				B-				B-			
	3	Waste	**B-**				B-				B-			
	4	Soil contamination												
	5	Noise and Vibration	**B-**					B-	B-					
	6	Ground Subsidence												
	7	Odor												
	8	Sediment quality												
Natural Environment	9	Protected Area												
	10	Ecosystem	**B-**			B-								
	11	Hydrology												
	12	Topography and geology												
Social Environment	13	Involuntary resettlement												
	14	The poor												
	15	Indigenous and ethnic people												
	16	Local economy such as employment and livelihood	**B+**						B+					
	17	Land use and utilization of local resources												
	18	Water Usage												
	19	Existing social infrastructures and services	**B+**									B+		
	20	Social institutions such as local decision making institutions												
	21	Misdistribution of benefit and damage												
	22	Local conflict of interests												
	23	Cultural Heritage												
	24	Landscape												
	25	Gender												
	26	Right of Children												
	27	Infectious Diseases such as HIV/AIDS												
	28	Labor environment (including work safety)												
Others	29	Accidents	**B-**					B-		B-				
	30	Cross boundary impacts and climate change												

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.13 Scoping Matrix (Reasons of the Rating): Samkhara Bridge

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Pollution	1	Air Pollution	B-	B-	**Construction phase:** Temporary negative impacts are expected on air quality due to construction machines and equipment.. **Operation phase:** Negative impact is expected due to the increase in traffic number..
	2	Water Pollution	B-		**Construction phase:** Turbid water may be generated by earth works and excavation. Additionally organic polluted water may be discharged from base camp. **Operation phase:** No adverse negative impact is expected.
	3	Waste	B-		**Construction phase:** Construction waste such as waste soil and cutting trees are expected. Additionally night soil may be generated from base camp.. **Operation phase:** No adverse negative impact is expected.
	4	Soil contamination			**Construction and operation phase:** No adverse negative impact is expected since soil pollutant is not discharged..
	5	Noise and Vibration	B-		**Construction phase:** Noise generation is expected due to works of construction machines and equipment.. **Operation phase:** No adverse negative impact is expected.
	6	Ground Subsidence			**Construction and operation phase:** No impacts are expected since activities which cause ground subsidence are not expected..
	7	Odor			**Construction and operation phase:** No adverse negative impact is expected since activities which cause odor are not expected..
	8	Sediment quality			**Construction and operation phase:** No adverse negative impact is expected since construction and operation do not influence sediment quality..
Natural Environment	9	Protected Area			**Construction and operation phase:** No protected area is observed in the project affected area and No adverse negative impact is expected..
	10	Ecosystem	B-		**Construction phase:** Some trees have to be logged beside along the river and on slope. **Operation phase:** No adverse negative impact is expected.
	11	Hydrology			**Construction and operation phase:** Construction will not influence flow condition in river and riverbed..
	12	Topography and geology			**Construction and operation phase:** Cutting land is limited since No adverse negative impact is expected.
Social Environment	13	Involuntary resettlement			**Pre-Construction phase:** No adverse negative impact is expected since lodges are government-owned (DoR) and no resettlement is expected.
	14	The poor			**Pre-Construction phase／Operation phase:** No adverse negative impact is expected since around project area is not residential area
	15	Indigenous and ethnic people			**Pre-Construction phase／Operation phase:** Project site is not residential area for indigenous and ethnic people.
	16	Local economy such as employment and livelihood	B+	B+	**Construction and operation phase:** Increasing job opportunities during construction and revitalization of the economy due to increasing traffic volume is expected during operation.
	17	Land use and utilization of local resources			**Pre-Construction phase:** No negative impact is expected since around project area is government-owned land (DoR). **Operation phase:** No negative impact is expected.
	18	Water Usage			**Construction and operation phase:** No adverse negative impact is expected since there is no water usage in project area.
	19	Existing social infrastructures and services		B+	**Construction and operation phase:** Improving access to social infrastructure is expected.
	20	Social institutions such as local decision making institutions			**Construction and operation phase:** No adverse negative impact is expected since the project site is government-own forest (copse) and there are no changes of decision-making institution (Government of prefecture/ village).

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Social Environment	21	Misdistribution of benefit and damage			**Construction and operation phase:** Misdistribution of benefit and damage caused by the bridge rebuilding is not expected.
	22	Local conflict of interests			**Construction and operation phase:** No adverse negative impact is expected since this project is rebuilding of existing bridge.
	23	Cultural Heritage			**Pre-Construction phase/ Construction and operation phase:** No adverse negative impact is expected since there are not religious facilities and cultural heritage in project area..
	24	Landscape			**Pre-Construction phase/ Construction and operation phase:** There are no law-based designated landscape areas around project area.
	25	Gender			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for woman are not expected.
	26	Right of Children			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for children are not expected.
	27	Infectious Diseases such as HIV/AIDS			**Construction and operation phase:** No adverse negative impact is expected since this project is for domestic road.
	28	Labor environment (including work safety)			**Construction phase:** No adverse negative impact is expected. for now. However construction work environment needs to be considered in accordance with relevant laws and regulations.
Others	29	Accidents	B-		**Construction phase:** The number of construction car increase, thus number of traffic accident may increase. **Operation phase:** No adverse negative impact is expected.
	30	Cross boundary impacts and climate change			**Construction and operation phase:** Significant deforestation is not expected. The number of construction machines is limited, thus no impacts are expected for climate change and influence of cross-border.

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.14 Scoping Matrix: Passang Bridge

	No	Affected Activities / Impact Items (JICA)	Overall Rating	Pre-Construction phase／Construction phase								Operation phase		
				Land acquisition and Loss of properties Including demolition of existing bridge,	Change of Land use plan, Control of various activities by regulations for the construction	Deforestation	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	Increase of through traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Increasing influx of settlers
Pollution	1	Air Pollution	**B-**				B-	B-				B-		
	2	Water Pollution	**B-**				B-				B-			
	3	Waste	**B-**				B-				B-			
	4	Soil contamination												
	5	Noise and Vibration	**B-**					B-	B-					
	6	Ground Subsidence												
	7	Odor												
	8	Sediment quality												
Natural Environment	9	Protected Area												
	10	Ecosystem	**B-**			B-								
	11	Hydrology												
	12	Topography and geology												
Social Environment	13	Involuntary resettlement	**C**	C										
	14	The poor												
	15	Indigenous and ethnic people												
	16	Local economy such as employment and livelihood												
	17	Land use and utilization of local resources												
	18	Water Usage												
	19	Existing social infrastructures and services	**B+**							B+				
	20	Social institutions such as local decision making institutions												
	21	Misdistribution of benefit and damage												
	22	Local conflict of interests												
	23	Cultural Heritage												
	24	Landscape												
	25	Gender												
	26	Right of Children												
	27	Infectious Diseases such as HIV/AIDS												
	28	Labor environment (including work safety)												
Others	29	Accidents	**B-**					B-		B-				
	30	Cross boundary impacts and climate change												

Note) Rating
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

Table 1.3.15 Scoping Matrix (Reasons of the Rating): Passang Bridge

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Pollution	1	Air Pollution	B-	B-	**Construction phase:** Temporary negative impact is expected on air quality due to construction machines and equipment. **Operation phase:** Negative impact is expected due to the increase in traffic number.
	2	Water Pollution	B-		**Construction phase:** Turbid water may be generated by earth works and excavation. Additionally organic polluted water may discharge from base camp. **Operation phase:** No adverse negative impact is expected.
	3	Waste	B-		**Construction phase:** Construction waste such as waste soil and cutting trees are expected. Additionally domestic waste and night soil may be generated from construction base camp. **Operation phase:** No adverse negative impact is expected.
	4	Soil contamination			**Construction and operation phase:** No adverse negative impact is expected since soil pollutant is not discharged..
	5	Noise and Vibration	B-		**Construction phase:** Noise generation is expected due to works of construction machines and equipment. **Operation phase:** No adverse negative impact is expected.
	6	Ground Subsidence			**Construction and operation phase:** No adverse negative impact is expected since activities which cause ground subsidence are not expected.
	7	Odor			**Construction and operation phase:** No adverse negative impact is expected since activities which cause odor are not expected.
	8	Sediment quality			**Construction and operation phase:** No adverse negative impact is expected since construction and operation do not influence sediment quality..
Natural Environment	9	Protected Area			**Construction and operation phase:** No protected area is observed in the project affected area and No adverse negative impact is expected..
	10	Ecosystem	B-		**Construction phase:** Some trees have to be logged beside along the river and on slope. **Operation phase:** No adverse negative impact is expected.
	11	Hydrology			**Construction and operation phase:** Construction will not influence flow condition in river and riverbed..
	12	Topography and geology			**Construction and operation phase:** Cutting land is limited since No adverse negative impact is expected..
Social Environment	13	Involuntary resettlement	C		**Pre-Construction phase:** Land acquisition of the one area may be caused. **Operation phase:** No adverse negative impact is expected.
	14	The poor			**Pre-Construction phase/ Operation phase:** No adverse negative impact is expected since around project area is not residential area.
	15	Indigenous and ethnic people			**Pre-Construction phase/ Operation phase:** Project site is not residential area for indigenous and ethnic people..
	16	Local economy such as employment and livelihood	B+	B+	**Construction and operation phase:** Increasing job opportunities during construction and revitalization of the economy due to increasing traffic volume is expected during operation.
	17	Land use and utilization of local resources			**Pre-Construction phase:** No negative impact is expected since around project area is government-owned forest (copse).. **Operation phase:** No adverse negative impact is expected.
	18	Water Usage			**Construction and operation phase:** No adverse negative impact is expected since there is no water usage in project area.
	19	Existing social infrastructures and services		B+	**Construction and operation phase:** Nearby project area, there are military facilities, office of the Geology and Mines and temples. Some temporary negative impact is expected but it will be improved access to these infrastructures during operation.

Category	No.	Impacted Item on JICA Guidelines	Rating		Reasons of the Rating
			Pre/ During Construction	Operation phase	
Social Environment	20	Social institutions such as local decision making institutions			**Construction and operation phase:** No adverse negative impact is expected since there are no changes for local decision making institute.
	21	Misdistribution of benefit and damage			**Construction and operation phase:** Misdistribution of benefit and damage caused by the bridge rebuilding is not expected.
	22	Local conflict of interests			**Construction and operation phase:** No adverse negative impact is expected since this project is rebuilding of existing bridge.
	23	Cultural Heritage			**Pre-Construction phase/ Construction and operation phase:** No adverse negative impact is expected since there are not religious facilities and cultural heritage in project area..
	24	Landscape			**Pre-Construction phase/ Construction and operation phase:** There are no law-based designated landscape areas around project area.
	25	Gender			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for woman are not expected.
	26	Right of Children			**Pre-Construction phase/ Construction and operation phase:** Negative Impacts specified for children are not expected.
	27	Infectious Diseases such as HIV/AIDS			**Construction and operation phase:** No adverse negative impact is expected since this project is for domestic road.
	28	Labor environment (including work safety)			**Construction phase:** Construction work environment needs to be considered in accordance with relevant laws and regulations. However No adverse negative impact is expected for now.
Others	29	Accidents	B-		**Construction phase:** The number of construction car increase, thus number of traffic accident may increase. **Operation phase:** No adverse negative impact is expected.
	30	Cross boundary impacts and climate change			**Construction and operation phase:** Significant deforestation is not expected. The number of construction machines is limited, thus no impacts are expected for climate change and influence of cross-border.

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

(5) Summary of Environmental and Social Impact

Impact forecast results in all 4 bridges are as follows;

Table 1.3.16 Results of Environmental Assessment (All 4 bridges)

Category	No	Impacted Item on JICA Guidelines	Rating at scoping stage		Rating based on survey result		Reasons of the Rating
			Pre/ During Construction	Operation Phase	Pre/ During Construction	Operation Phase	
Pollution	1	Air Pollution	B-	B-	B-	B-	**Construction phase:** Temporary negative impacts are expected on air quality due to construction machines and equipment. **Operation phase:** Negative impact is expected due to the increase in traffic number.
	2	Water Pollution	B-		B-		**Construction phase:** Turbid water may be generated by earth works and excavation.
	3	Waste	B-		B-		**Construction phase:** Construction waste such as waste soil, cutting trees, concrete and asphalt are expected. Domestic waste and waste water may be generated from construction base camp. Additionally, waste oil may be generated from construction machines.
	4	Soil contamination					No adverse negative impact is expected.
	5	Noise and Vibration	B-		B-		**Construction phase:** Temporary noise generation is expected due to works of construction machines and equipment.
	6	Ground Subsidence					No adverse negative impact is expected.
	7	Odor					No adverse negative impact is expected.
	8	Sediment quality					No adverse negative impact is expected.
Natural Environment	9	Protected Area					No adverse negative impact is expected..
	10	Ecosystem	B-		B-		**Construction phase:** Some trees have to be logged beside along the river and on slope. (Disappearance of vegetation)
	11	Hydrology					No adverse negative impact is expected.
	12	Topography and geology					No adverse negative impact is expected.
Social Environment	13	Involuntary resettlement	C				Land acquisition is not necessary around Beteni Bridge and Passang Bridge thus No adverse negative impact is expected.
	14	The poor					No adverse negative impact is expected.
	15	Indigenous and ethnic people					No adverse negative impact is expected.
	16	Local economy such as employment and livelihood	B+	B+	B+	B+	**Construction and operation phase**: Increasing job opportunities during construction and revitalization of the economy due to increasing traffic volume is expected during operation.
	17	Land use and utilization of local resources					No adverse negative impact is expected.
	18	Water Usage					No adverse negative impact is expected.
	19	Existing social infrastructures and services*	B±	B+	B±	B＋	**Construction phase:** Some temporary negative impact is expected at Passang bridge since nearby project area, there are military facilities, office of the geology and mines and temples. **Operation phase:** The access to the social infrastructure and services will be improved.

Category	No	Impacted Item on JICA Guidelines	Rating at scoping stage		Rating based on survey result		Reasons of the Rating
			Pre/ During Construction	Operation Phase	Pre/ During Construction	Operation Phase	
Social Environment	20	Social Capital/ Social organization					No adverse negative impact is expected.
	21	Misdistribution of benefit and damage					No adverse negative impact is expected.
	22	Local conflict of interests					No adverse negative impact is expected.
	23	Cultural Heritage					No adverse negative impact is expected.
	24	Landscape					No adverse negative impact is expected.
	25	Gender					No adverse negative impact is expected.
	26	Right of Children					No adverse negative impact is expected.
	27	Infectious Diseases such as HIV/AIDS					No adverse negative impact is expected.
	28	Labor environment					No adverse negative impact is expected.
Others	29	Accidents	B-		B-		**Construction phase:** There is concerned that traffic accident is increased due to increase the number of traffic and also traffic accident during construction phase
	30	Cross Boundary impacts and climate change					No adverse negative impact is expected.

* The reasons of rating of "No.7 Existing social infrastructures and services" is for Passang Bridge. There are No adverse negative impact is expected for other three bridges.

Note) Rating:
A+/-: Serious positive/negative impact is expected.
B+/-: Some positive/negative impact is expected.
C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done)
No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

(6) Mitigation measures (Draft)

Mitigation measures and Environmental Management Plan of 4 bridges are follows;

Table 1.3.17 Environmental Management Plan

Category	No.	Impacted Item on JICA Guidelines	Outline (Mitigation measures)	Implementation agency	Responsible agency	Cost
During Operation						
Pollution	1	Air Pollution	✓ Measure air quality regularly ✓ Use and maintain regularly low contamination construction equipment ✓ Avoid unnecessary idling ✓ Sprinkle water during the construction phase	Contractor	Project proponent (DoR)	Included in the construction cost
	2	Water Pollution	✓ Inspect water quality regularly ✓ Prevent oil leak of construction equipment ✓ Installation of sediment discharge prevention sheet ✓ Construction of drainage facilities and sedimentation pond	Contractor	Project proponent (DoR)	Included in the construction cost
	3	Waste	✓ Examine possibility of reuse ✓ Waste separation and collection/ disposal ✓ Transportation/ disposal of soil and specify the soil dumping area ✓ Appropriate treatment of waste oil ✓ Installation of wastewater treatment facility(septic tank) in base camp	Contractor	Project proponent (DoR)	Included in the construction cost
	4	Noise and Vibration	✓ Restriction of construction time (No construction during the night time) ✓ Use low-noise/ less-vibration type of construction equipment and maintain it regularly	Contractor	Project proponent (DoR)	Included in the construction cost
Natural Environment	5	Ecosystem	✓ Plant trees at roadside ✓ Avoid logging of fruit trees and useful trees as possible	Contractor	Project proponent (DoR)	Included in the construction cost
Social Environment	6	Existing social infrastructures and services	✓ Advance announcement about construction schedule and plan to road-user and local resident ✓ Secure the road traffic	Contractor	Project proponent (DoR)	Included in the construction cost
Others	7	Accidents	✓ Install sign to show construction schedule and night lighting ✓ Install fence to prevent resident from entering inside the construction area ✓ Secure the parking space for construction vehicle ✓ Post the traffic control staff	Contractor	Project proponent (DoR)	Included in the construction cost
During Operation						
PL	1	Air Pollution	✓ Measure air quality regularly	Contractor	Project proponent (DoR)	Included in the construction cost
Other	2	Accidents	✓ Installment of Indicator	Contractor	Project proponent (DoR)	Included in the construction cost

Source: JICA Study Team

(7) Monitoring Plan (Draft)

Monitoring plan of 4 bridges are follows;

Table 1.3.18 Monitoring Plan (4 bridges)

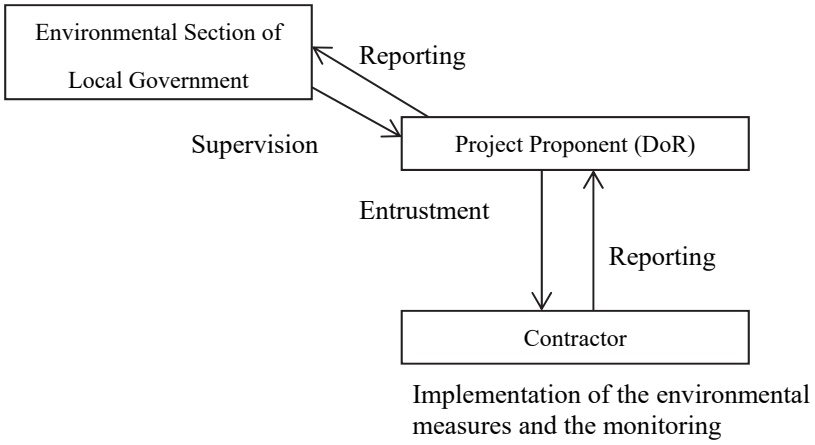
Category	Items	Location	Frequency	Implementation agency	Responsible agency
[Construction phase] (4 bridges)					
Air Pollution	TSP, PM_{10}, CO, NOx, SOx etc. of which measured in baseline data	Near construction site	4times/year	Contractor	Project proponent (DoR)
Noise	Noise generated by construction	Near construction site	4times/year	Contractor	Project proponent (DoR)
Water pollution	pH, SS,BOD, EC, T-Coli, etc. of which measured in baseline data	River at construction	Once/month	Contractor	Project proponent (DoR)
Waste	Type, Quantity and disposal sites of construction waste.	Construction site and waste disposal site	4times/year	Contractor	Project proponent (DoR)
Accidents	Number and details of accident	Construction site	4times/year	Contractor	Project proponent (DoR)
[Operation phase] (4 bridges)					
Air Pollution	TSP, PM_{10}, CO, NOx, SOx etc. of which measured in baseline data	Near construction site	twice/year	Contractor	Project proponent (DoR)
Accidents	Number and details of accident	Construction site	twice/year	Contractor	Project proponent (DoR)
[Construction phase] (Passang Bridge)					
Existing social infrastructures and services	Number of complaint and opinion	Near construction site	Suitably	Contractor	Project proponent (DoR)

Source: JICA Study Team

(8) Budget, Source of revenues, Implementation framework

Figure 1.3.5 shows frameworks of the environmental management during construction phase.

Environmental measures and monitoring survey based on the environmental management plan are implemented by the contractor under the supervision of construction supervision consultants and the responsibility of the project proponent.



Source: JICA Study Team

Figure 1.3.5 Implementation framework during construction

In the monthly report, the result of environmental mitigation measures and environmental monitoring are submitted to supervision consultants and reported to central government, environmental section of local government through DoR.

It should be noted that the cost of environmental mitigation measures and environmental monitoring will be included in the construction costs.

Grievance desk is prepared in the project proponent to hear the voice of local community related to the construction works. The project proponent instructs the consultant and the contractor if necessary. The contacts of the grievance desk (i.e. address and telephone number) are informed in advance to the local community by the contractor.

1.3.2 Land Acquisition and Resettlement

(1) Necessity of land acquisition and resettlement (Alternative analysis)

In this project, alignment is considered in the bridge design and road design, consequently the land acquisition is not occurred. In addition, it is confirmed that informal settlers are not existing in the project site.

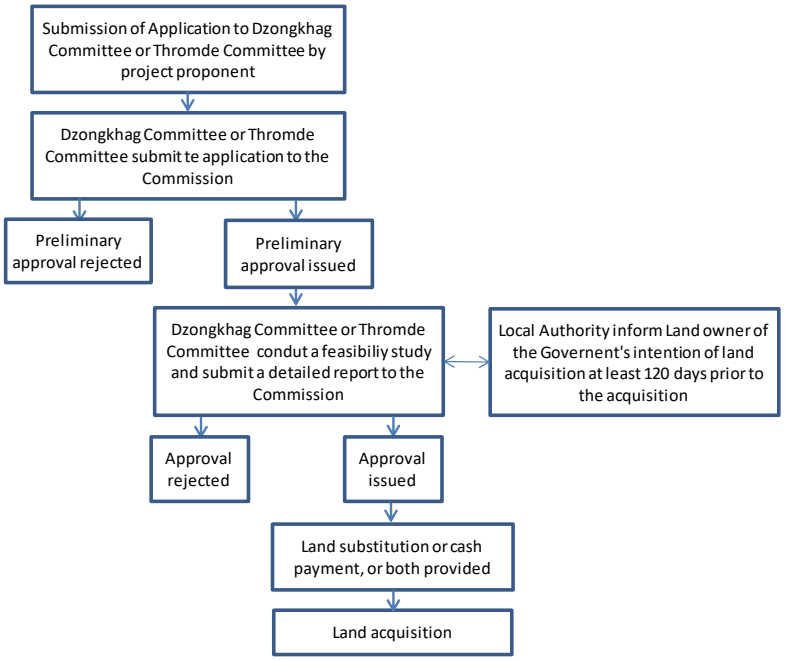
(2) Legal framework for land acquisition and resettlement

1) Legal framework related to land acquisition

In Bhutan, the core law regarding to land acquisition is “Land Act 2007”. According to “Land Act 2007”, the major responsible organization in land acquisition is implementation agency, local government which project is located and National Land Commission (NLC).

The procedure of land acquisition is shown in the Flowchart below. Firstly, implementation agency applies to Dzongkhag Land Acquisition and Allotment Committee (DLAAC). DLAAC files an application with NLC for preliminary permission of land acquisition. After getting the preliminary permission, DLAAC notifies the owners at least three months prior to the planned date of

expropriation, and conducts a detailed survey for scope of impact. The detailed survey includes such as calculation of land price and assessment of structures. DLAAC submits a report to NLC that summarizes where to relocate the inhabitants, amounts of compensation, necessary permission, etc. after the discussion and agreement with land owner. After getting the approval of NLC, the government can register substitute land and expropriated land, but the law prescribes that the government cannot carry out the land acquisition unless the owners are compensated with cash or substitute land, or both.



Source: JICA Study Team based on Land Act 2007 and the interview with NLC

Figure 1.3.6 Flowchart of land acquisition process

2) Compensation system

According to the above regulation, compensation is provided to a. Land, b. building, c. crops/plants d. other objects. Compensation form is by 1) cash, 2) substitute land or combination of 1) and 2).

The organ that examines and approves each case of land acquisition is NLC. The official compensation rate is fixed by PAVA, an agency under Ministry of Finance (MoF). Current official rate is "Land Compensation Rates 2009" issued in 2009. Final compensation price is assessed by assessment committee established in each Dzongkhag considering the factors such as local market price, accessibility to highways and others in addition to the official compensation rate.

3) Comparative analysis with International Practices on Involuntary Resettlement and proposed countermeasures to fill the Gaps

The comparative analysis between existing regulations in Bhutan and international practices including JICA on involuntary resettlement/Land acquisition was conducted to identify the gaps between them. Review of comparison between regulations in Bhutan and World Bank Operational Policy (OP) is shown in Table 1.3.19.

Table 1.3.19 Comparison Analysis on the Gaps between OP.4.12 and relevant Regulations of Bhutan

Issue	Operational Policy 4.12 of WB on Involuntary Resettlement	Regulation of Bhutan on Involuntary Resettlement and gaps with WB OP 4.12	Counter measures to fill gap
1) Preparation of Resettlement Action Plan(RAP)	A resettlement plan or abbreviated resettlement plan is required for all operations that entail involuntary resettlement unless otherwise specified. (OP.4.12 para 17(a))However, involuntary resettlement is not expected in this project.	Law of Bhutan (Land Act 2007) stipulates to submit an application for land acquisition including the nature of compensation. However, stipulation on the obligation for preparation of Resettlement Action Plan is not found.	Not necessary. (Resettlement is not expected in the project)
2) Minimization of Involuntary Resettlement	Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs (OP.4.12 para 2)	No stipulation for minimization of Involuntary resettlement is found.	The Survey Team made every effort to minimize the involuntary resettlement as much as possible in the basic design stage.
3) Impacts Covered	The compensation should cover not only physical aspects such as relocation or loss of shelter and loss of assets or access to assets etc. but also loss of income sources or means of livelihood.OP.4.12 para 3)	The compensation covers Land and immovable property which includes such as Buildings, Crops/Plants and Other objects attached to the land (Land Act 2007)	Not necessary. (Land acquisition and resettlement is not expected in the project)
4) Compensation for Squatters	Not applicable in this project	There is no squatters observed	Not necessary (There is no squatters affected by this project)
5) Estimation of compensation cost	To provide compensation at full replacement cost for losses of assets without depreciation of structures or assets For agricultural land; based on the market value of the pre-project land or pre-displacement, whichever is higher with the cost of preparing the land, plus the cost of any registration and transfer taxes. For land in urban areas; based on market value of the land with the cost of any registration and transfer taxes. For houses and other structures, based on the market cost of the materials to build a replacement structure or better than those of the affected structure with the cost of transporting building materials, any labor and contractors' fees and any registration and transfer taxes. (OP.4.12 para 6(a)(ii), O.P 4.12 footnote 11, O.P 4.12 Annex footnote 1)	Law of Bhutan stipulates that Property Assessment and Valuation Agency (PAVA) established under the Ministry of Finance to valuate and fix the value of land and any other collateral property that may be acquired. (Land Act 2007) Currently, the compensation rates 2009 issued by PAVA and market price is referred for compensation.	Not necessary. (Land acquisition and resettlement is not expected in the project)

Issue	Operational Policy 4.12 of WB on Involuntary Resettlement	Regulation of Bhutan on Involuntary Resettlement and gaps with WB OP 4.12	Counter measures to fill gap
6) Assistance for Restoration of Livelihood and Living Standard	Displaced persons should be supported after displacement for a transition period and provided with development assistance in addition to compensation measures such as land preparation, credit facilities, training, or job opportunities.(OP.4.12 para 6(c)	Resettlement is not expected. (No description on assistance for restoration of livelihood and living standard)	Not necessary. (Land acquisition and resettlement is not expected in the project)
7) Paying attention to vulnerable groups	Particular attention should be paid to the needs of vulnerable groups such as those below the poverty line, the landless, the elderly, women and children, indigenous peoples, ethnic minorities etc.(OP.4.12 para 8)	Vulnerable people are not identified in this project. (No description on consideration of vulnerable groups)	Not necessary. (Land acquisition and resettlement is not expected in the project)

Note) World Bank OP4.12, Law of Bhutan (Land Act 2007) and JICA Guidelines for Environmental and Social Consideration (2010) is referred on the comparative analysis. JICA Guidelines suggests to refer World Bank OP4.12 for preparation of resettlement action plan.

Source: JICA Study Team

1.3.3 Stakeholder Meetings

Based on the JICA guideline and the legislation in Bhutan, stakeholder meetings were held on 17th August and 30th November 2015. On 17th August 2015, meeting was held at Trongsa Dzongkhag for Telegangchu Bridge with DoR, Dzongdag and Environmental officer for Trongsa Dzongkhag. On 30th November 2015, the meetings for Beteni Bridge, Samkhara Bridge and Passang Bridge were held with DoR, concerned Dzongkhag Staff, Dzongdag, local residents.

In each meeting, speech from officials of local government, project outline, environmental impact and environmental study policy were presented. In accordance with this, question and answer session was held among the participants. Summary and major opinions raised during the meeting are shown in Table 1.3.20 and the state of meeting is shown in Figure 1.3.7.

Table 1.3.20 Summary of stakeholder meetings

Schedule	Location of the project concerned	Main participants and the number (Approximate)	Major opinions/questions and answers
1. 10:00-11:00 17th August, 2015	Telegangchu Bridge Trongsa Dzongkhag Office, Trongsa	Government: 3 JICA Study Team: 2 Total: 5[*1]	Q1: The question that from which countries contractor will be selected and if it is any chance the Bhutanese contractor being selected were raised. (Dzongdag) A1: It was answered that it will be Japanese contactor to be selected for this project. Bhutanese contractor may be subcontracted under Japanese contractor. (Confirmed by questioner)
2. 10:00-12:00 30th November, 2015	Passang Bridge Gelephu Gewog, Sarpang	Residents: 25 (Female 47%) Government: 13 JICA Study Team: 2 Total: 40	Q1: There are water pipes placed under the existing bridge. So, a question of possibility to access to the water during the time of construction was raised. In addition, the concern that the possibility of contamination of drinking water by construction activity was also raised. (Villager) A1: It was explained that alternative drinking water supply shall be provided during construction. In addition, it was confirmed that the water source for the current drinking water are 2km upstream from proposed new bridge location and negative impact is not expected. (Confirmed by questioner) Q2:There was a request that expansion of the range covers bank protection since flood tends to occur in the area corresponding to the explanation that the range for bank protection for current plan is 10m each for upstream and downstream.(Dzongdag) A2: The request would be considered. At least 20m for upstream and 10m for downstream shall be secured and other scope shall be discussed and considered by DoR. (Confirmed by questioner) Q3: The concern was raised that the bypass bridge (detour) may be damaged due to the flood during rainy season. (Dzongkhag officer) A3: It was agreed with DoR HQ that Bypass bridge (detour) shall be responsible in construction and maintenance. Therefore the correspondence by DoR shall be confirmed again. (Confirmed by questioner) [Other opinions] ✓ Dumping site was identified and it was confirmed that the site is government land. The use of the site was also confirmed by Forest Officer.

Schedule	Location of the project concerned	Main participants and the number (Approximate)	Major opinions/questions and answers
3. 14:30-16:00 30th November, 2015	Beteni Bridge and Samkhara Bridge Jigmicholing Gewog, Sarpang Trong Gewog, Zhemgang	Residents: 23 (Female 48%) Government: 8 JICA Study Team: 2 Total: 23	Q1: (Beteni Bridge) It was questioned if there is any impact to the shops which is recently built on the slop of Trongsa side. (Villager) A1: It was explained that impact such as land acquisition is not expected. (Confirmed by questioner) Q2: (Beteni Bridge) It was questioned that if the slope cut is expected. (Villager) A2: It was explained that cutting slope partly alongside of the approach road at Gelephu side is expected. (Confirmed by questioner) [Other opinions] ✓ (Samkhara Bridge/ Beteni Bridge) It was confirmed that demolish of the structure belongs to DoR which is no longer use is no problem. ✓ (Samkhara Bridge) It was confirmed that electric pole and wire can be removed (They are no longer use). It was also confirmed that acquisition of clearance is not required. ✓ (Samkhara Bridge/ Beteni Bridge) Dumping site was identified and it was confirmed that the site is government land. The use of the site was also accepted.

*1 There are no residence in the Telegangchu project site, therefore residents were not attended in the stakeholder meeting.

Source: JICA Study Team

Status of consultation meetings		
Passang Bridge	Beteni Bridge and Samkhara Bridge	
		

Source: JICA Study Team

Figure 1.3.7 Status of consultation meetings

1.3.4 Others

(1) Monitoring Form (draft)

Monitoring Form (draft) is shown below.

Table 1.3.21 Monitoring Form (draft)

- If environmental reviews indicate the need of monitoring by JICA, JICA undertakes monitoring for necessary items that are decided by environmental reviews. JICA undertakes monitoring based on regular reports including measured data submitted by the project proponent. When necessary, the project proponent should refer to the following monitoring form for submitting reports.
- When monitoring plans including monitoring items, frequencies and methods are decided, project phase or project life cycle (such as construction phase and operation phase) should be considered.

1. Pollution Countermeasures

- Air Quality (Traffic /Ambient Air Quality)[4 Bridges] (Construction phase and Operation phase)

Item	Unit	Measured Value (Mean) Along road/ Residential area	Measured Value (Max.)	Country's Standards	Referred International Standards (Japanese standard)	Remarks (Measurement Point, Frequency, Method, etc.)
TSP	$\mu g/m^3$			200 (24 Hour Average)	SPM ($0.1mg/m^3$)	– On the boundary of approach road and residence (1 point ×4 bridges) – 4 times a year during construction – Twice a year during operation – Air sampler High volume sampler
NO_2	$\mu g/m^3$			80 (24 Hour Average)	0.04-0.06 (ppm)	
SO_2	$\mu g/m^3$			80 (24 Hour Average)	0.04 (ppm)	
CO	$\mu g/m^3$			2000 (8 Hour Average)	10 (ppm)	
PM10	$\mu g/m^3$			100 (24 Hour Average)	SPM ($0.1mg/m^3$)	

- Water Quality (Water Quality in the river) [4 Bridges] (Construction phase)

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Country's Standards	Referred International Standards (Japanese Standards/ D category river)	Remarks (Measurement Point, Frequency, Method, etc.)
pH	-			6-9	6.5-8.5	– Downstream portions of affected water bodies (1 point ×4 bridges) – Once a month during construction – Grab sampling
DO	mg/l			-	2	
TSS	mg/l			-	SS 100	
BOD	mg/l			50	8	
Total Coliform	1,000 MPN/ 100ml			10,000	-	
EC	µS/cm			2,000	-	

- Noise / Vibration [4 Bridges] (Construction phase)

Item	Unit	Measured Value (Mean)	Measured Value (Max.)	Country's Standards	Referred International Standards (Japanese Standard)	Remarks (Measurement Point, Frequency, Method, etc.)
Noise level	dB(A)			For Industrial areas Day (0600-2200): 75 dB(A) Night (2200-0600) : 65 dB(A) * Value for industrial area is applied since the monitoring is planned only for temporary period of construction	Specified Construction noise 85 dB(A) (Maximum value of 90% range)	– On the boundary of construction yard and residence (1 point ×4 bridges) – 4 times a year during construction – Digital sound level meter

- Waste[4 Bridges] (Construction phase)

Monitoring Item	Monitoring Results during Report Period	Remarks (Measurement Point, Frequency, Method, etc.)
Type, quantity and disposal sites of construction waste		– On the construction site and waste disposal site – 4 times a year during construction

2. Social Environment and others

- Existing social infrastructures and services [Passang Bridge]

Monitoring Item	Monitoring Results during Report Period	Remarks (Measurement Point, Frequency, Method, etc.)
Number of opinions and complains		– Near the construction site – Suitably

- Accident [4 Bridges]

Monitoring Item	Monitoring Results during Report Period	Remarks (Measurement Point, Frequency, Method, etc.)
Number and details of accident		– Near the construction site – Suitably

Source: JICA Study Team

(2) Environmental Checklist

The result of environmental check on this project in accordance with JICA environmental checklist (12. Bridge) is shown below.

Table 1.3.22 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 (b) N (c) N (d) Y	(a) Application (which is same as IEE report) is under preparation and Environmental Clearanace is expected to be obtained in February, 2017. (b) ditto ↑ (c) The conditions are not expected as of September, 2016 (d) Forest Clearance(FC) and Dzongkhag Clearance (DC) are necesary and they have already been obtained as of September, 2016.
	(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) Local stakeholder meetings was held based on JICA Guidelines and Bhutan's EIA Procedure on August, November and December 2015. The project outline, tentative schedule was disclosed and exchange opinions with participants has been done. (b) The opinions and comments will be reflected to the engineering design and environmental management plan.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a) Several alternative plans were examined in this project including from the environmental and social considerations point of view.
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) The predicted air quality does not expected to exceed Bhutan's standard level considering traffic volume. (b) The predicted air quality does not expected to exceed Bhutan's standard level considering traffic volume.
	(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) Although turbid water is caused and discharged from the construction area, general and appropriate mitigation measures minimize the adverse impacts. These mitigation measures are planned on the environmental management plan. (b) There are no water sources affected by project.
	(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) Y (b) Y	(a) The predicted noise does not expected to exceed Bhutan's standard level because the expected traffic volume is around 300~400 a day. (b) There are no structure which cause low fequency sound.
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) N	(a) The project is not located in protected area and the impact to the protected area is not expected.
	(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 (d) N (e) N	(a) The project site is not applicable to ecologically valuble habitats. (b) The project site does not encompass the protected habitats of endangered species designated by the country's laws or international trieaies and conventions. (c) The project activities does not give significant impacts on the ecosystem. (d) The impact to wildlife and livestock is not expected therfore measures are not prepared. (e) Adverse impacts to the ecosystems are not expected since this project is replacement of exisiting 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) There are not any construction activitiy that cause hydroloogic change.
	(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) Y (b) N (c) N	(a) There are some area which may cause slope failures therefore the area is avoided in the route selection. In the cutting land section on the route, land protection measures are prepared. (b) Slope failures and land slides are not expected in the civil works. In the cutting land section on the route, land protection measures are prepared. (c) The mitigation measures for soil erosion and run off such as silt fence are planned in earth work section.

4 Social Environment	(1) Resettlement / Land acquisition	(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 (c) N (d) N (e) N (f) N (g) N (h) N (i) N (j) N	(a) Involuntary resettlement and land acquisition is not expected. (b) ditto↑ (c) ditto↑ (d) ditto↑ (e) ditto↑ (f) ditto↑ (g) ditto↑ (h)ditto↑ (i) ditto↑ (j) ditto↑
	(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 (b) N (c) N (d) Y (e) Y (f) N	(a) This project does not affect the existing means of transportation and the associated workers. (b) There are not possibility that the project will adversely affect the living conditions of inhabitants other than the target population. (c) There are no impacts expected in occurence of diseases, including communicable diseases, such as HIV will be introduced due to immigration of workers associated with the project. However, adequate mitigation measures such as health check and education will be conducted based on environmental management plan, if necessary. (d) The project may give adverse impact to existing connected road since traffic restriction is required, thus adequate mitigation measures will be prepared. Additionally traffic safety will be secured by the mitigation measures during construction. The driving speed after construction of the bypass will be controlled by local police and setting up sign boards along the road. (e) ditto ↑ (f) There are not any planned bridges cause adverse impact such as sun shading and radio interference.
4 Social Environment	(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) There are not any possibilities that the project will adversely affect the heritage.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) There are not any possibilities that the project will adversely affect the local landscape.
	(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 (b) N	(a) There are not any designated ethnic minorities and indigenous peoples in the rights-of-way. (b) ditto ↑
	(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) N (b) Y (c) Y (d) Y	(a) Construction will be carried out in compliance with labor law in Bhutan. (b) Adequate safety consideration will be taken. (c)(d) Based on Bhutan's labor law, safety education and educatin for consideration to residence willl be given to workers.
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) N (c) N	(a) Adequate measures considered to reduce impacts during construction will be prepared based on environmental management plan. (b) Adverse impacts on ecosystem are not predicted. (c) Adverse impacts on social environment is not expected.
	(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) The proponent will prepare monitoring program for the environmental items based on approved IEE and it will be implemented. (b) The monitoring items, methods and frequencies included in the monitoring program will be prepared based on JICA Guidelines and Bhutan's EIA procedures. (c) The proponent will establish an adequate monitoring framework based on JICA Guidelines and Bhutan's EIA procedures. (d) Regulatory requirements pertaining to the monitoring report system will be identified, such as the format and frequency of reports from the proponent to the regulatory authorities based on JICA Guidelines and Bhutan's EIA procedures.
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 (b) N	(a) Large scale deforestation is not expected. (b) There are not any construction plan for the Power Transmission and Distribution Lines.
	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) It is not likely to give impacts to transboundary or global issues.

1) Regarding the term "Country's Standards" mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental considerations are required to be made.
In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan's experience).
2) Environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which the project is located.

Source: JICA Study Team

Chapter 2 Contents of the Project

2.1 Basic Concept of the Project

2.1.1 Overall Goal and Target of the Project

(1) Overall Goal

Economic development plan of the Kingdom of Bhutan (hereinafter referred to as "Bhutan") was set as the 11th Five-Year Plan (2013-2018). Aim of this plan has targeted the national development plan which is "Self-reliant Social Economic Development: To be able to fulfill all of the domestic development needs planned in five years by the year 2020", "Comprehensive Social Economic Development: To reduce an inequality for making the social vulnerable persons improve in the standard of living and the quality of living" and "Environmental Consideration: To be mindful constantly of carbon-neutral development".

Furthermore, "Bhutan 2020" is the national developmental fundamental principles based on the sustainable planning and implementation planned in five years. The fundamental principles were drawn up as a vision to implement Bhutan's "Peace, Prosperity and Happiness" in 2000. The policy of the fundamental principles on the field of transport and traffic is further improvement of the network of Primary National Highway (hereinafter referred to as ""PNH") and construction of the southern east-west corridor as an alternative route of PNH No.1 (hereinafter referred to as "PNH-1"). Further improvement of these PNHs' network is the most important viewpoints for economic growth. On the other hand, an access to the historical, the cultural and the religious places is also very important. However there were no accesses and were not able to reach there so far. Therefore improvement of the access to reach easily for old people is important.

Based on these plans, Department of Roads (hereinafter referred to as "DoR") in Ministry of Works and Human Settlement (hereinafter referred to as "MoWHS") developed the Road Sector Master Plan (hereinafter referred to as "RSMP") on road improvement in 2006. During the twenty-year period up to 2027, RSMP has targeted to construct the road of municipality, the southern east-west corridor, connectivity between dzongkhaks, and to construct bypasses and to improve alignment of the existing roads, and to construct tunnels for connecting PNHs.

In 11th five year plan, the improvement of the network of PNH and access to the hydropower plant was listed as a priority items and maintenance of PNH No.4 (hereinafter referred to as "PNH-4") which connects north to south in the center of Bhutan is also considered as important. Specifically, replacement of bridges and widening of PNH maintained by DoR has been planning and the target 5 bridges of the project are also included in the list to be reconstructed.

(2) Target of the Project

The reconstruction of four bridges (Telegangchu Bridge, Bridge, Beteni Bridge, Samkhara Bridge and Passang Bridge) on PNH-4 (hereinafter referred to as "the Project") will improve performance and safety of the above bridges. Subsequently, stable traffic and logistics will be secured. Consequently, the Project will contribute for promotion of economy and improvement of living standard of the local communities in Trongsa and Gelephu.

2.1.2 Outline of the Project

The Project has been expected to improve the livelihood of the public road users and the inhabitants using the five bridges and living along PNH-4 as well as other PNH connecting to PNH-4 (PNH-1 and PNH-3 previously named as PHN-5) and advancement of safety and reliability of distribution transports on these routes.

In the policy of Bhutan government, the widening of PNH-4 has been considered to be carried out after the completion of widening of PNH-1 which currently being implemented. Under such circumstance, outline of the Project examined is shown in Table 2.1.1.

Table 2.1.1 Outline of the Project

Contents	
Construction Period	40 months
Telegangchu Bridge (PC Simple Box Girder)	Bridge Length: 42.0m
	Carriage Width: 3.5m*2
	Access Road: Bituminous Paving (63.14m+73.69m)
	Accessory Facilities: 1 set
Samkhara Bridge (PC Simple Box Girder)	Bridge Length: 30.0m
	Carriage Width: 3.5m*2
	Access Road: Bituminous Paving(81.00m+90.01m)
	Accessory Facilities: 1 set
Beteni Bridge (PC Simple Box Girder)	Bridge Length: 49.5m
	Carriage Width: 3.5m*2
	Access Road: Bituminous Paving(59.0m+83.92m)
	Accessory Facilities: 1 set
Passang Bridge (PC Simple Box Girder)	Bridge Length: 41.5m
	Carriage Width: 3.5m*2+Sidewalk (1.5m*2)
	Access Road: Bituminous Paving(93.5m+50.0m)
	Accessory Facilities: 1 set

Source: JICA Study Team

2.2 Outline Design of the Japanese Assistance

2.2.1 Design Policy

2.2.1.1 Basic Policy

In Bhutan, the majority of the national land (Area is 38,394 km^2) is mountainous, therefore, road traffic is the only transportation, namely the most important means in transportation. The road network in Bhutan has less number of highway as well as detour and alternative route and is inadequate in specification (width, alignment and slope protection etc.) because there is topographic constrains from steep mountainous area although the total length has been constantly expanding from about 4,000km in 2003 to about 10,600km in 2013 and 11,200km in 2015. In addition, many of the bridges on primary national highway has passed more than 30 years after construction and they are not satisfied with the current design criteria of width and load capacity. Therefore, it has the challenge to secure stable traffic.

(1) Development Policy of Bhutan

MoWHS has established Road Sector Master Plan in 2006 and plans to implement maintenance, repair and replacement of bridges, enhancement of feeder road and expansion of road network such as National Highway and Dzongkhag Roads during next 20 years until 2027. In addition, the Royal Government of Bhutan indicates the plan such as maintenance of existing roads/bridges and replacement of bridges by DoR in “The 11th Five Years Plan (2013-2018)”. From the above background, in July 2014, the Royal Government of Bhutan requests the grant aid to Japan for replacement of five bridges (Telegangchu Bridge, Chaplekhola Bridge, Samkhara Bridge, Beteni Bridge and Passang Bridge) on PNH-4.

(2) Design Criteria in Bhutan

According to the current design criteria in Bhutan, PNH-4 is classified as "Primary National Highway". The bridges require to meet the criteria of securing the 7.0m of effective width and IRC Criteria (Design standard in India) which are IRC70R (100t, single lane) or IRC Class A (double lane) for load capacity criteria. However, the most of the bridges on PNH-4 do not meet the above mentioned width and load criteria.

(3) Future Plan and Priority for Bridge Reconstruction

There are total 22 existing bridges on PNH-4 (Trongsa – Gelephu) as shown in Table 2.2.1. Of these, 8 bridges including initially requested 5 bridges are classified as high priority and listed to be reconstructed on the 11th Five Year Plan by Bhutan government. Among 8 bridges, the Bhutan government plans for reconstruction of 4 bridges except for the target bridges of the Project (i.e. Teleganchu, Beteni, Samkhara and Passang) by applying the own budget and/or other donor’s financial assistance.

Considering the above, the validity of the Project namely reconstruction the target bridges those does not secure the certain budget yet is deemed "High".

Table 2.2.1 List of Existing Bridges on PNH-4

Dzongkhag	Field Division	Road Name	Location (Km)	Bridge Name	Type	Span (ft)	Span (mtr)	Width (mtr)	Load Class	Yr of Const	Criticality Rating	Target for reconstruction in 11th FYP	Reconstruction/repair plan
Route Name: Gelephu - Trongsa													
Sarpang	Sarpang	Gelephu - Trongsa	1.00	Gelephu zam	RC Slab		9.20	7.40	40	2007			
Sarpang	Sarpang		0.85	No Name	RC T-Beam		8.00	4.50	40	1965			RGoB budget or assistance from donnor (GOI or ADB)
Sarpang	Sarpang		3.35	No Name	RC T-Beam		8.00	4.50	40	1965			
Sarpang	Sarpang		3.39	No Name	Composite		12.00	4.50	30	1965			
Sarpang	**Sarpang**		**7.50**	**Passang zam**	**Steel Hemilton**		**40.00**	**7.50**	**40**	**1970**	High	Listed	**JICA Grant aid**
Sarpang	Sarpang		10.58	Geleg zam	Steel girder		120.00	4.30	40	2001	High	Listed	
Sarpang	Sarpang		20.02	Katley 1	Composite		11.00	4.50	40	1964			RGoB budget or assistance from donnor (GOI or ADB)
Sarpang	Sarpang		22.86	Katley 2	Steel Hemilton		11.00	4.50	40	1964			
Sarpang	Sarpang		24.95	Katley 3	RC T-Beam		25.00	4.50	40	1981			
Sarpang	**Sarpang**		**36.66**	**Samkhara zam**	**Steel Truss**		**61.00**	**4.30**	**40**	**2001**	High	Listed	**JICA Grant aid**
Sarpang	**Sarpang**		**38.85**	**Beteni zam**	**RC T-Beam**		**25.00**	**4.20**	**40**	**1987**	High	Listed	**JICA Grant aid**
Zhemgang	**Zhemgang**		**53.25**	**Chaplekhola**	**RC T-Beam**		**20.00**	**4.50**	**40**	**1969**	High	Listed	**JICA Grant aid**
Trongsa	Zhemgang		62.27	Golipong zam	RC T-Beam		12.00	4.50	40	1967			RGoB budget or assistance from donnor (GOI or ADB)
Trongsa	Zhemgang		98.00	Mangdechu zam	Langar Arch		95.25	5.50	40	2003			Reconstructed already under JICA GA Ph-1
Trongsa	Zhemgang		108.30	Lower Phushing zam	Composite		12.00	4.50	30	1973			
Trongsa	Zhemgang		155.60	Wangdigang zam	Steel Truss		43.20	5.50	40	2010	High	Listed	
Trongsa	Zhemgang		169.00	Panjurmani zam	RC-T Girder (PT)		28.00	6.70	40	2008	High	Listed	
Trongsa	Zhemgang		188.75	Dungdung zam	RC T-Beam		25.00	4.50	40	1983			RGoB budget or assistance from donnor (GOI or ADB)
Trongsa	Zhemgang		198.65	Yoormu zam	BB	140.0		3.27	40	2013			
Trongsa	Trongsa		224.65	Yeshey zam	Steel Truss		33.60	5.50	40	2010			
Trongsa	Trongsa		233.43	Dzongkhaluma zam	BB, DSR	80.0		3.27	40	2013			
Trongsa	**Trongsa**		**241.36**	**Telegangchu zam**	**RC T-Beam**		**25.00**	**4.50**	**40**	**1981**	High	Listed	**JICA Grant aid**
	Total	**22**				**220.0**	**624.25**						

Source: DoR

(4) Technical Difficulty

There are several bridges which are deteriorated after the construction before 1980s and do not meet current width and load criteria in bridges on PNH-4. Three bridges of four target bridges of the Project were constructed before 1980s and it has difficulty in reinforcement and replacement due to the bridge length, height of under bridge girder and surrounding topographical condition. Thus, taking advantage of Japanese technology considered being relevant since the reinforcement and replacement of the target bridges with local technology is difficult.

(5) Survey on the Degree of Damage to Bridges

Since deterioration of four target bridges has been in progress as stated above, the soundness survey was conducted based on the damage evaluation criteria of Ministry of Land, Infrastructure, Transport and Tourism, Japan. The result indicates that four bridges were suffering from damage due to degrading, which led to the determination that they are currently in the state "requiring repair and other measures." The damage of each bridge is shown below. The detail result of the soundness survey is attached in Appendix-6.

- Telegangchu: There is the spalling/ rebar exposure at the slab and slope failure area around right side of the existing bridge.
- Beteni: There is a heavy crack on the wall of the abutment.
- Samkhara: There are many corrosions in the girder and many damages of the slab.

– Passang: There are many corrosions in the girder and many damages of the slab and the abutment.

All of them are not necessarily facing immediate collapse, so that partial repair, instead of reconstruction, may be considered as countermeasure. Considering that the capacity of the existing bridges was as small as 40R (55t) even at the time of construction, however, the allowable load of 70R (100t) would be difficult to establish simply by repair. Consequently, it would be advisable to undertake reconstruction, not repair.

(6) Relevance with the National Project

Construction projects of hydropower plants are extremely vital for economic development of Bhutan. Ten hydropower plant construction projects are planned in the 11th five-year plan. At present, the Mangdechu hydropower plant is being constructed in Trongsa, and PNH-4 proved the importance of its role for transport of dam construction materials. The main route for transportation of dam construction materials is going through the PNH-1 from Thimphu to the construction site currently, however in the future, it is expected that opportunity of going through PNH-4 from Gelephu will be increased. In this context, reconstruction of five target bridges in PNH-4 is considered relevant.

As described so far, “reconstruction” of four target bridges is considered appropriate. The design policy concerning reconstruction is described below.

2.2.1.2 Policy concerning Natural Conditions

(1) Geological Conditions

1) Telegangchu Bridge

The N values are recorded at 40 or more at the depth of 8.4m or deeper in the right bank and at the depth of 2m or deeper in the left bank. Especially the talus deposit is situated close to approach part of the current road, so the consideration for the slope cutting and/or slope stability will be needed. The hard slope is overhanging above the current road, so the consideration for the excavation will be needed.

2) Beteni Bridge

For construction of the foundation for new bridge, soft rock observed at depth of 6.5m or deeper at right bank(BH-6) and at depth of 9.4m or deeper at left bank (BH-7) needs to be considered.

As for the situation of the rock outcrop, steep cliff with north dip (N30W40N for example) continues and schistosity has developed. This steep cliff is consisting of alteration of gneiss and pelitic schist with pegmatite intermixed, so the consideration for the planning of slope cutting will be needed.

3) Samkhara Bridge

Selection of a new bridge foundation type requires consideration of the N values when the level of the bottom of the foundation will be examined to be set. While N values distributes 50 or more from around the mouth of the boring in the right bank, material for the embankment for old bridge situated itself at the planned point of the bridge foundation as the observation of the BH-4 show. So the consideration will be needed for setting the position of the foundation.

The steep cliff is consisted of the medium to hard rock classified as CM in the background area, so the consideration will be needed for the elaborate plan of the slope cutting.

The river deposit accumulated deeply in the left bank, so planning of the slope cutting and treatment for the soil generated by construction will be needed.

4) Passang Bridge

Selection of a new bridge foundation type requires consideration of the river deposit situated deeply around the river. Especially in both boring BH-1 and 2, it is recognized that the N values vary widely in shallower level. It is advisable to designate the bottom level of the foundation at the level where the N values recorded at least 30 in the stable condition.

The level which is correspondents to above level is 9.0m or deeper in the right bank (BH-1) and is 10m or deeper in the left bank (BH-2).

Topography has the wide open topography in the left bank. The pelitic schist is outcropped and the steep slope with its inclination 50 degree or more is formed along the road, so the consideration for the cutting and the stability measure will be needed.

The river deposit is accumulated deeply on the right bank, so the consideration for the river bed will be needed when the level of bottom of the foundation will be examined to be set.

(2) River Planning

1) Telegangchu Bridge

(a) Planning Scale

This river (Telegan Chu) belongs to the Mandechu river. Mandechu river is a particularly long river that flows through from north to south while passing through the important cities such as Trongsa and Zhemgang. In the middle basin, there is planned hydroelectric power plant. Therefore, this river is very important. Mandechu river is considered to be equivalent to the primary rivers that managed by government, then this branch is also included in the primary river. However, around the new bridge position, there are few residents because that is located in the mountainous region. Therefore, currently, there is no specific object to be preserved around the position.

On the other hand, for the planning scale, not only the importance of the river, but also securing the route when the flood happens is important. Although NH4 is important, that has no alternative route. If the bridge is damaged by the flood, that disrupts logistics, transportation and traffic movement. For this reason, it is not desirable to excessively low planning scale.

From the above "importance of the river" and, "securing route", B-class (100 years return period) was chosen for the planning scale.

Table 2.2.2 Importance of the River and Planning Scale

Importance of the river	Planning scale	Application
A class	More than 200	Primary rivers of the main section (especially important)
B class	100 ~ 200	Primary rivers of the main section
C class	50 ~ 100	Primary or secondary rivers of municipal rivers
D class	10 ~ 50	Primary or secondary rivers of general section
E class	Less than 10	Primary or secondary rivers of general section

Source: Technical Criteria for River Works: Practical Guide for Planning

(b) River Gauge Section

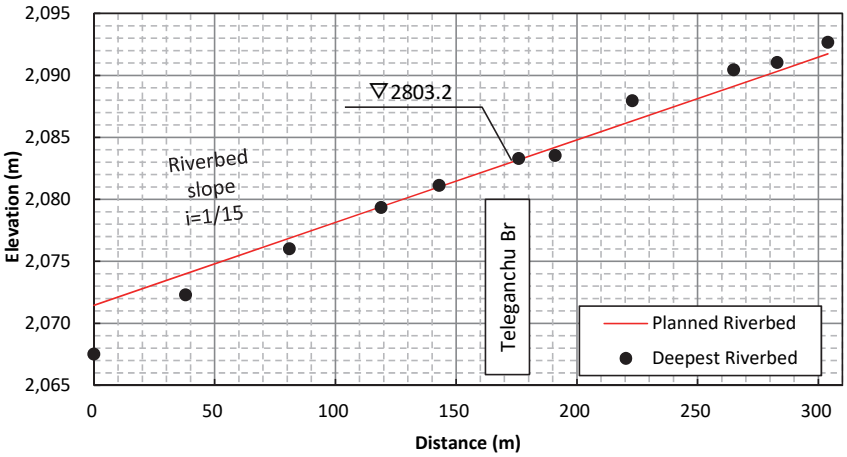
The river gauge section is established on the basis of the following basic conditions:

- Gauge section must be set to ensure an adequate capacity of flow while taking care not to cause excessive change in the existing river channel.
- Design bed width must be approximately similar to the existing one, and the revetment slope gradient must be established with reference made to the existing one.
- For revetment, the footing depth of 1m must be secured.
- Basically, direct height of revetment must be 5m or less. If the bridge length increases excessively or the site configuration is changed substantially because the revetment is of two stages with a berm provided, the elevation of revetment must be 5m or more without providing the berm.
- Allowance height and crest width of revetment must be established in accordance with the Government Ordinance for Structural Standards for River Administration Facilities.

(c) Planned Riverbed Elevation

River surveying at the bridge point over the time has not been done. The riverbed is considered to be stabilizing because factors causing degradation of riverbed, such as gravel extraction, are not confirmed and the riverbed materials consist mainly of bedrock. Visual inspection at the site also confirmed no evidence of scour or bank erosion around the bridge point. Accordingly, the planned riverbed elevation is to be the elevation of the deepest riverbed of the existing river channel. Since the elevation of the deepest riverbed as well as its location varies depending on scour or back filling during flood, however, it is not appropriate to use the elevation of the deepest riverbed at the bridge

point of the survey result as it is. In this context, the planned riverbed slope was set from the deepest riverbed elevation profile so that it envelopes the latest riverbed excluding part of localized deep points. This resulted in the planned riverbed elevation EL.2083.2 at the bridge point. As the riverbed materials consist mainly of bedrock, no further degradation may occur even at the localized deepest riverbed points.



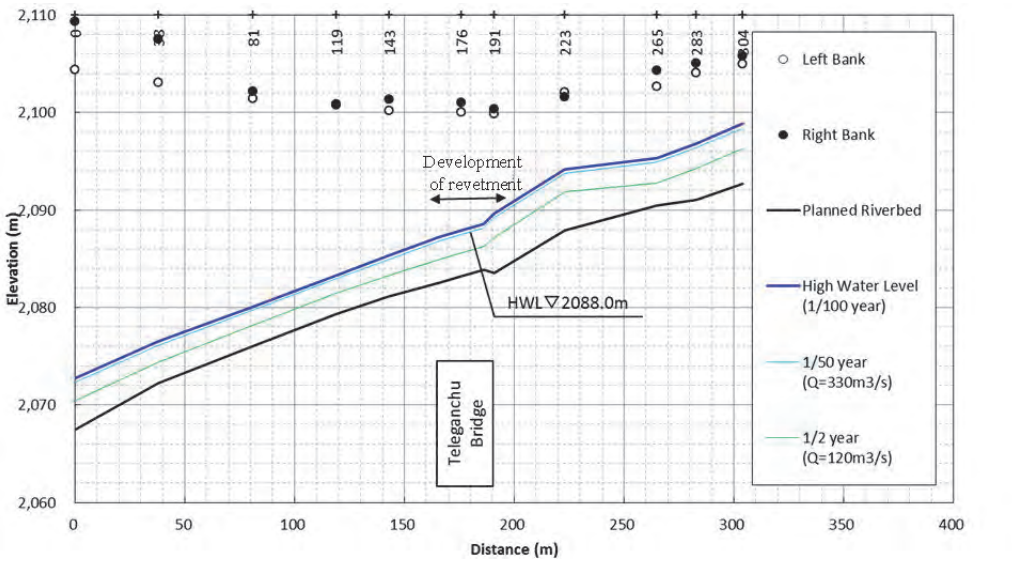
Source: Prepared by the study team

Figure 2.2.1 Location Map of Meteorological Observation Stations

(d) Planned High-water Level

Calculation on non-uniform flow was performed for the river channel after development of revetment. At the planned flow of 390m^3/s, the calculated water level at the bridge point is EL.2088.0, which is taken as the planned high-water level. The clearance under girder of the existing bridge is EL.2103.3m (the bridge deck elevation EL.2105.5m – clearance 2.2m), which is higher by about 15m than the planned high-water level. This means that retaining the existing bridge exerts only the limited effects in terms of flood control. The flow capacity at the bridge point is approximately 1800m^3/s. For the existing flow capacity, the lowest right or left bank was selected in the upstream and downstream sections at the bridge point

Note that the design flow velocity is 5.4m/s.



Source: Prepared by the study team

Figure 2.2.2 Water Level Profile after Development of Revetment (Telegangchu Bridge)

(e) Run Off during Construction

According to the "Cofferdam Construction Standard (draft), Ministry of Land, Infrastructure, Transport and Tourism," the target design water level of cofferdam construction is either the highest water level in the past five years or the second highest water level in the past decade if the water level concerned is judged to be the unusual flood in the past five years. In this study, the runoff during the period scheduled for works in the river, such as detouring of river, etc., was calculated for the past decade. Since any observation on the water level and flow had not been performed around the bridge point, however, the runoff was calculated and converted to the water level by using the observed daily rainfall of the Trongsa Station.

The maximum daily rainfall by months in the past decade at the Station is shown below. For the works in the river, the period from November to March is planned and the maximum daily rainfall of 28.6mm/day (February, 2013) during this period was employed. The runoff is 70m^3/s, which is below the flow based on the two-year return period.

Table 2.2.3 Maximum Daily Rainfall by Months in the Past Decade (Trongsa Station)

(mm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.
2004	15.4	4.1	10.2	32.3	21.1	36.4	51.1	58.3	24.2	66.2	4.5	1.2	66.2
2005	0.0	8.0	14.4	15.8	19.1	20.2	50.2	38.0	17.0	41.6	3.4	0.0	50.2
2006	0.0	0.0	24.4	21.8	17.6	17.2	31.2	38.6	25.8	6.2	14.5	3.4	38.6
2007	3.0	13.2	10.0	20.8	25.4	37.0	24.9	41.2	25.2	19.3	0.0	0.0	41.2
2008	4.4	0.0	10.3	36.1	18.4	37.2	37.4	36.4	16.0	43.4	2.4	7.0	43.4
2009	2.0	0.0	13.3	28.3	99.1	18.4	32.0	38.4	52.8	77.2	2.4	4.0	99.1
2010	0.0	0.0	16.4	83.0	25.4	47.4	46.0	28.4	26.8	30.0	2.8	0.0	83.0
2011	1.8	16.2	20.6	13.4	31.2	30.2	45.4	27.6	37.3	8.2	9.0	0.0	45.4
2012	0.0	9.2	8.0	26.5	16.2	38.1	21.8	35.4	26.4	3.5	0.0	6.0	38.1
2013	1.0	28.6	13.6	30.2	50.9	20.4	15.5	23.3	33.8	34.4	3.5	0.7	50.9

: rainy season (Apr and Oct are transient month)

River Work (Nov - Mar)

Source: Prepared by the study team

2) Beteni Bridge

(a) Planning Scale

This river (Beteni Chu) belongs to the Maokhola River. Maokhola river flows through the Gelephu, and the width of the river around Gelephu is about 750m. According to the " DATA COLLECTION SURVEY ON ROAD CONNECTIVITY IN THE KINGDOM OF BHUTAN (2014 ORIENTAL CONSULTANTS CO., LTD. INGÉROSEC CORPORATION)", DoE (Department of Engineering Service) has been built revetment partially for the purpose of flood management of Maokhola river. Therefore, this river is very important. Maokhola river is considered to be equivalent to the primary rivers that managed by government, then this branch is also included in the primary river. However, around the new bridge position, there are few residents because that is located in the mountainous region. Therefore, currently, there is no specific object to be preserved around the position.

On the other hand, for the planning scale, not only the importance of the river, but also securing the route when the flood happens is important. Although NH4 is important, that has no alternative route. If the bridge is damaged by the flood, that disrupts logistics, transportation and traffic movement. For this reason, it is not desirable to excessively low planning scale.

From the above "importance of the river" and, "securing route", B-class (100 years return period) was chosen for the planning scale in accordance with Table 2.2.2.

(b) River Gauge Section

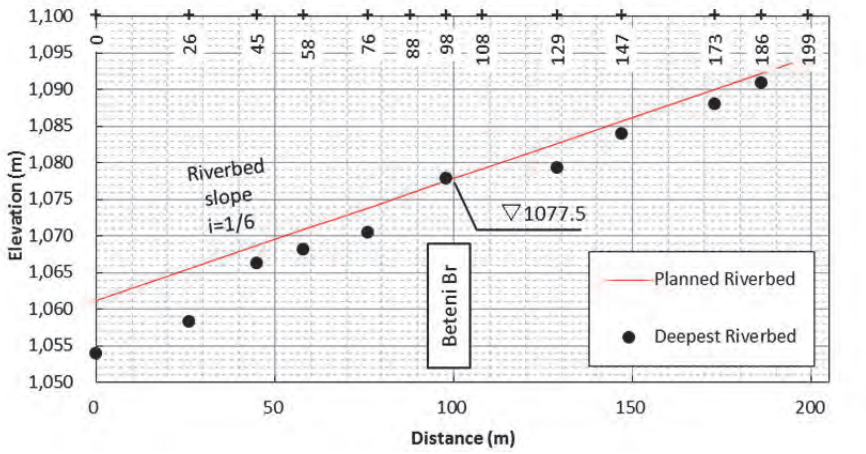
The river gauge section is established on the basis of the following basic conditions:

- Gauge section must be set to ensure an adequate capacity of flow while taking care not to cause excessive change in the existing river channel.
- Design bed width must be approximately similar to the existing one, and the revetment slope gradient must be established with reference made to the existing one.
- For revetment, the footing depth of 1m must be secured.
- Basically, direct height of revetment must be 5m or less. If the bridge length increases excessively or the site configuration is changed substantially because the revetment is of two stages with a berm provided, the elevation of revetment must be 5m or more without providing the berm.
- Allowance height and crest width of revetment must be established in accordance with the Government ordinance for Structural Standards for River Administration Facilities.

(c) Planned Riverbed Elevation

No river surveying with age has been performed at the bridge point. The riverbed is considered to be stabilizing because factors causing degradation of riverbed, such as gravel extraction, are not confirmed. Visual inspection on site also confirmed no evidence of scour or bank erosion around the

bridge point. Accordingly, the planned riverbed elevation is to be the elevation of the deepest riverbed of the existing river channel. Since the elevation of the deepest riverbed as well as its location varies depending on scour or back filling during flood, however, it is not appropriate to use the elevation of the deepest riverbed at the bridge point of the survey result as it is. Particularly in the case of Beteni Bridge, the vertical grade is steep at 1/6, with the elevation varying substantially, which requires large-scale excavation of around 5m around the bridge point when the profile is to be set vertically to envelope the deepest riverbed. In this context, the plan to envelope the deepest riverbeds difficult, and the riverbed slope was set on the basis of profiles before and after the bridge. Consequently the planned riverbed elevation at the bridge point is EL.1077.5.

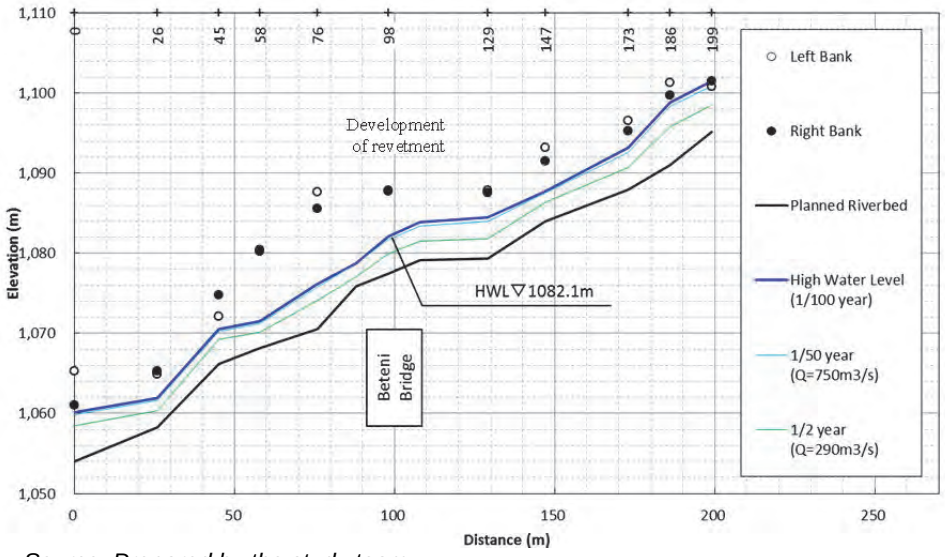


Source: Prepared by the study team

Figure 2.2.3 Planned Riverbed Profile (Beteni Bridge)

(d) Planned High Water Level

Calculation on non-uniform flow was performed for the river channel after development of revetment. At the planned flow of 900m^3/s, the calculated water level at the bridge point is EL.1082.1, which is taken as the planned high-water level. The clearance under girder of the existing bridge is EL.1084.2m (the bridge deck elevation EL.1087.7m － clearance 3.5m), which is higher by about 210cm than the planned high-water level. This means that retaining the existing bridge exerts only the limited effects in terms of flood control. The flow capacity of river channel at the bridge point is approximately 1,200m^3/s. For the existing flow capacity, the lowest right or left bank was selected in the upstream and downstream sections at the bridge point.



Source: Prepared by the study team

Figure 2.2.4 Water Level Profile after Development of Revetment (Beteni Bridge)

(e) Run Off During Construction

According to the "Cofferdam Bank Construction Standard (draft), Ministry of Land, Infrastructure, Transport and Tourism," the target design water level of cofferdam construction is either the highest water level in the past five years or the second highest water level in the past decade if the water level concerned is judged to be the unusual flood in the past five years. In this study, the runoff during the period scheduled for works in the river, such as detouring of river, etc., was calculated for the past decade. Since any observation on the water level and flow had not been performed around the bridge point, however, the runoff was calculated and converted to the water level by using the observed daily rainfall of the Jigmecholing Station.

The maximum daily rainfall by months in the past decade at the Station is shown below. For the works in the river, the period of November to March is planned and the maximum daily rainfall of 44.2mm/day (March, 2007) during this period was employed. The runoff is 60m^3/s, which is below the flow based on the two-year return period.

Table 2.2.4 Maximum Daily Rainfall by Months in the Past Decade (Jigmecholing Station)

(mm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.
2005	33.6	7.0	22.8	14.0	51.8	61.4	119.4	160.0	231.4	78.4	3.8	0.0	231.4
2006	0.0	25.8	26.4	37.6	201.6	72.8	79.4	43.4	197.2	16.6	21.0	19.6	201.6
2007	0.0	27.4	44.2	27.4	38.6	103.6	374.8	89.8	197.8	47.4	0.0	0.0	374.8
2008	21.6	19.4	42.4	48.2	121.4	140.0	214.6	192.8	76.4	38.8	0.0	0.0	214.6
2009	2.2	19.4	13.2	122.4	156.4	147.6	174.8	63.4	186.4	159.0	2.2	1.8	186.4
2010	0.0	1.8	10.4	45.6	53.4	57.6	88.8	101.4	107.8	19.4	2.4	0.0	107.8
2011	0.0	0.0	39.8	113.6	23.4	93.6	220.0	72.8	159.4	1.4	5.2	0.0	220.0
2012	11.2	6.2	34.8	52.4	26.8	122.4	231.6	260.6	113.8	52.4	0.0	2.6	260.6
2013	0.0	33.4	17.8	86.6	104.8	251.4	217.4	101.6	128.4	67.4	11.4	0.0	251.4
2014	3.4	1.8	40.8	4.8	135.4	88.4	126.8	174.6	119.8	57.6	3.8	0.0	174.6

: rainy season (Apr and Oct are transient month)

River Work (Nov - Mar)

Source: Prepared by the study team

3) Samkhara Bridge

(a) Planning Scale

This river (Samkhara Chu) belongs to the Maokhola River. Maokhola river flows through the Gelephu, and the width of the river around Gelephu is about 750m. According to the " DATA COLLECTION SURVEY ON ROAD CONNECTIVITY IN THE KINGDOM OF BHUTAN (2014 ORIENTAL CONSULTANTS CO., LTD. INGÉROSEC CORPORATION)", DoE (Department of Engineering Service) has been built revetment partially for the purpose of flood management of Maokhola river. Therefore, this river is very important. Maokhola river is considered to be equivalent to the primary rivers that managed by government, then this branch is also included in the primary river. However, around the new bridge position, there are few residents because that is located in the mountainous region. Therefore, currently, there is no specific object to be preserved around the position.

On the other hand, for the planning scale, not only the importance of the river, but also securing the route when the flood happens is important. Although NH4 is important, that has no alternative route. If the bridge is damaged by the flood, that disrupts logistics, transportation and traffic movement. For this reason, it is not desirable to excessively low planning scale.

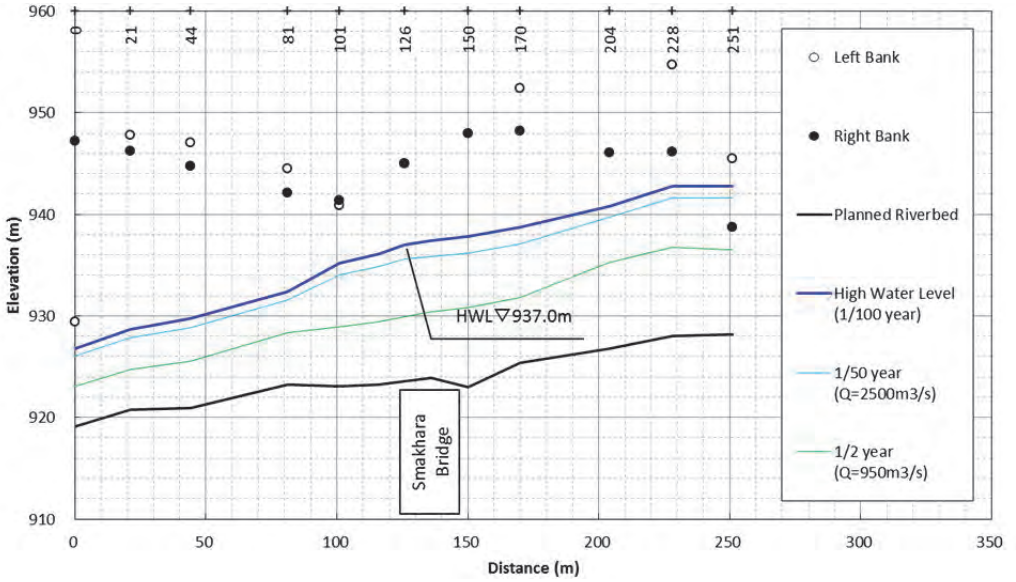
From the above "importance of the river" and, "securing route", B-class (100 years return period) was chosen for the planning scale in accordance with Table 2.2.2.

(b) River Gauge Section

For Samkhara Bridge, the valley is deep and the normal water level is much lower from the abutment. Since this is the case as stipulated in Article 61 “the narrow portion in which hindrance to flood control is not recognized” of the Government Ordinance for Structural Standards for River Administration Facilities, the abutment position is planned while referring to the “actual state” of the surrounding geography and rivers (Article 2, Interpretation 3-(4), the same Government ordinance above), instead of setting the river gauge section and planned flow velocity.

(c) Planned High Water Level

Calculation on non-uniform flow was performed for the river channel after development of revetment. At the planned flow of 3,030m^3/s, the calculated water level at the bridge point is EL.937.0, which is taken as the planned high-water level. The clearance under girder of the existing bridge is EL.935.5m (the bridge deck elevation EL.941.0m － clearance 5.5m), which is lower by about 150cm than the planned high-water level. This means that retaining the existing bridge may cause river blockage due to drift woods caught during flood. The flow capacity at the bridge point is approximately 3,600m^3/s. For the existing flow capacity, the lowest right or left bank was selected in the upstream and downstream sections at the bridge point



Source: Prepared by the study team

Figure 2.2.5 Water Level Profile after Development of Revetment (Samkhara Bridge)

(d) Run Off During Construction

According to the "Cofferdam Bank Construction Standard (draft), Ministry of Land, Infrastructure, Transport and Tourism," the target design water level of cofferdam construction is either the highest water level in the past five years or the second highest water level in the past decade if the water level concerned is judged to be the unusual flood in the past five years. In this study, the runoff during the period scheduled for works in the river, such as detouring of river, etc., was calculated for the past decade. Since any observation on the water level and flow had not been performed around the bridge point, however, the runoff was calculated and converted to the water level by using the observed daily rainfall of the Jigmecholing Station.

The maximum daily rainfall by months in the past decade at the Station is shown below. For the works in the river, the period from November to April is planned and the maximum daily rainfall of 122.4mm/day (April, 2009) during this period was employed. The runoff is 560m^3/s, which is below the flow based on the two-year return period.

Table 2.2.5 Maximum Daily Rainfall by Months in the Past Decade (Jigmecholing Station)

(mm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.
2005	33.6	7.0	22.8	14.0	51.8	61.4	119.4	160.0	231.4	78.4	3.8	0.0	231.4
2006	0.0	25.8	26.4	37.6	201.6	72.8	79.4	43.4	197.2	16.6	21.0	19.6	201.6
2007	0.0	27.4	44.2	27.4	38.6	103.6	374.8	89.8	197.8	47.4	0.0	0.0	374.8
2008	21.6	19.4	42.4	48.2	121.4	140.0	214.6	192.8	76.4	38.8	0.0	0.0	214.6
2009	2.2	19.4	13.2	122.4	156.4	147.6	174.8	63.4	186.4	159.0	2.2	1.8	186.4
2010	0.0	1.8	10.4	45.6	53.4	57.6	88.8	101.4	107.8	19.4	2.4	0.0	107.8
2011	0.0	0.0	39.8	113.6	23.4	93.6	220.0	72.8	159.4	1.4	5.2	0.0	220.0
2012	11.2	6.2	34.8	52.4	26.8	122.4	231.6	260.6	113.8	52.4	0.0	2.6	260.6
2013	0.0	33.4	17.8	86.6	104.8	251.4	217.4	101.6	128.4	67.4	11.4	0.0	251.4
2014	3.4	1.8	40.8	4.8	135.4	88.4	126.8	174.6	119.8	57.6	3.8	0.0	174.6

: rainy season (Apr and Oct are transient month)

River Work (Nov - Apr)

Source: Prepared by the study team

4) Passang Bridge

(a) Planning Scale

This river (Lodrai Chu) belongs to the Maokhola River. Maokhola river flows through the Gelephu, and the width of the river around Gelephu is about 750m. According to the " DATA COLLECTION SURVEY ON ROAD CONNECTIVITY IN THE KINGDOM OF BHUTAN (2014 ORIENTAL CONSULTANTS CO., LTD. INGÉROSEC CORPORATION)", DoE (Department of Engineering Service) has been built revetment partially for the purpose of flood management of Maokhola river. Therefore, this river is very important. Maokhola river is considered to be equivalent to the primary rivers that managed by government, then this branch is also included in the primary river. Furthermore, the bridge is located at plain area unlike other 3 bridges. There are local settlement, military facility and the government facility beside the bridge.

On the other hand, for the planning scale, not only the importance of the river, but also securing the route when the flood happens is important. Although NH4 is important, that has no alternative route. If the bridge is damaged by the flood, that disrupts logistics, transportation and traffic movement. For this reason, it is not desirable to excessively low planning scale.

From the above "importance of the river" and, "securing route", B-class (100 years return period) was chosen for the planning scale in accordance with Table 2.2.2.

(b) River Gauge Section

The river gauge section is established on the basis of the following basic conditions:

- Gauge section must be set to ensure an adequate capacity of flow while taking care not to cause excessive change in the existing river channel.
- Design bed width must be approximately similar to the existing one, and the revetment slope gradient must be established with reference made to the existing one.

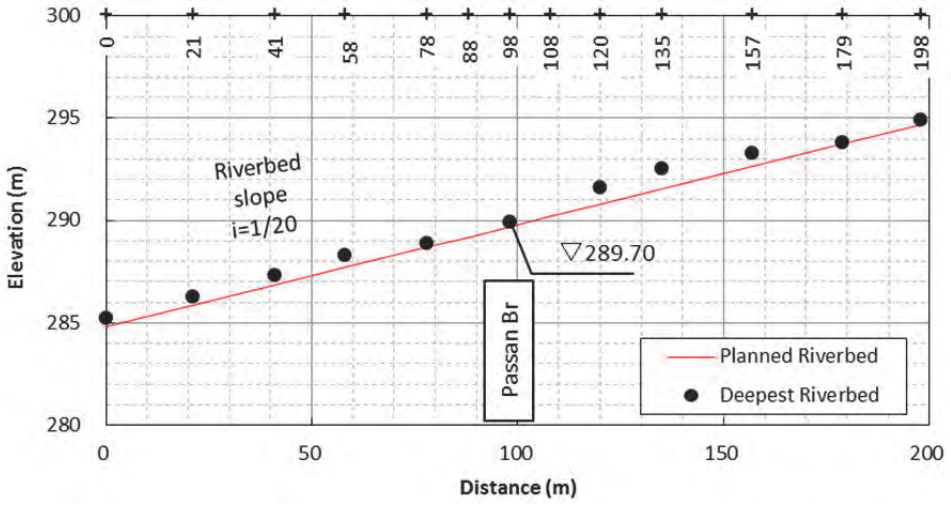
For revetment, the footing depth of 1m must be secured.

- Basically, the direct height of revetment must be 5m or less. If the bridge length increases excessively or the site configuration is changed substantially because the revetment is of two stages with a berm provided, the elevation of revetment must be 5m or more without providing the berm.
- Allowance height and crest width of revetment must be established in accordance with the Government Ordinance Structural Standards for River Administration Facilities.

(c) Planned Riverbed Elevation

River surveying at the bridge point over the time has not been done. The riverbed is considered to be stabilizing because factors causing degradation of riverbed, such as gravel extraction, are not confirmed. Visual inspection on site also confirmed no evidence of scour or bank erosion around the

bridge point. Accordingly, the planned riverbed elevation is to be the elevation of the deepest riverbed of the existing river channel. Since the elevation of the deepest riverbed as well as its location varies depending on scour or back filling during flood, however, it is not appropriate to use the elevation of the deepest riverbed at the bridge point of the survey result as it is. In this context, the planned riverbed slope was set from the deepest riverbed elevation profile so that it envelopes the latest riverbed excluding part of localized deep points. This resulted in the planned riverbed elevation EL.289.7 at the bridge point.



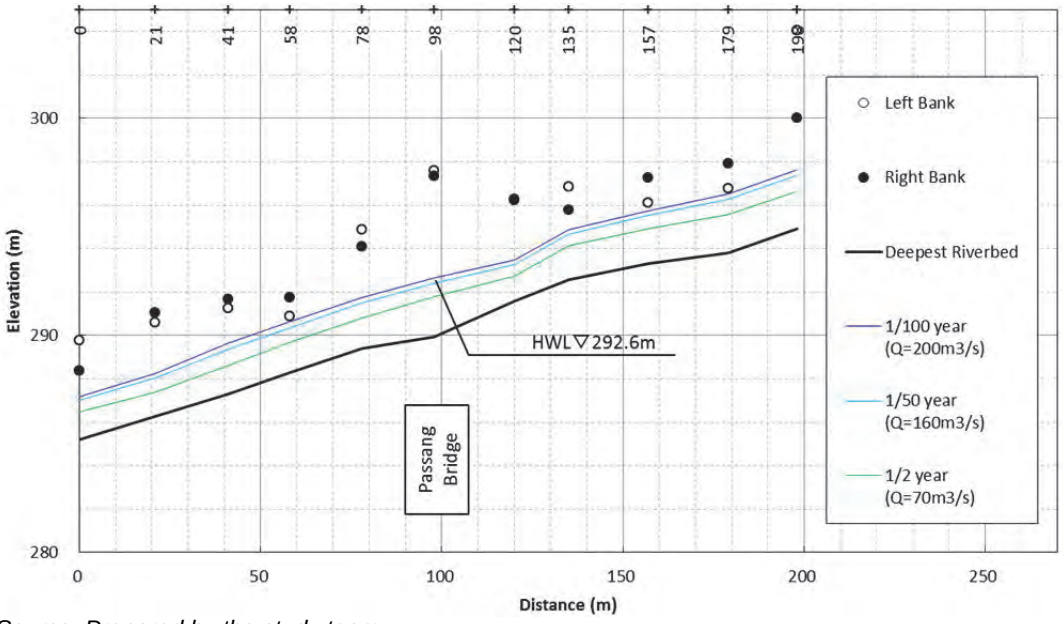
Source: Prepared by the study team

Figure 2.2.6 Planned Riverbed Profile (Passang Bridge)

(d) Planned High Water Level

As there are lots of sediments around Passang Bridge, it is possible that river sediments may accumulate even after development of revetment. Calculation on non-uniform flow was performed for the river channel. At the planned flow of 200m^3/s, the calculated water level at the bridge point is EL.292.6, which is taken as the planned high-water level. The clearance under girder of the existing bridge is EL.296.2m (the bridge deck elevation EL.297.4m － clearance 1.2m), which is higher by about 360cm than the planned high-water level. This means that retaining the existing bridge exerts only the limited effects in terms of flood control. The flow capacity of river channel at the bridge point is approximately 240m^3/s. For the existing flow capacity, the lowest right or left bank was selected in the upstream and downstream sections at the bridge point.

Note that the planned flow velocity is 4.1 m/s.



Source: Prepared by the study team

Figure 2.2.7 Water Level Profile after Development of Revetment (Passang Bridge)

(e) Run Off during Construction

According to the "Cofferdam Construction Standard (draft), Ministry of Land, Infrastructure, Transport and Tourism," the target design water level of cofferdam construction is either the highest water level in the past five years or the second highest water level in the past decade if the water level concerned is judged to be the unusual flood in the past five years. In this study, the runoff during the period scheduled for works in the river, such as detouring of river, etc., was calculated for the past decade. Since any observation on the water level and flow had not been performed around the bridge point, however, the runoff was calculated and converted to the water level by using the observed daily rainfall of the Jigmecholing Station.

The maximum daily rainfall by months in the past decade at the Station is shown below. For the works in the river, the period from November to March is planned and the maximum daily rainfall of 44.2mm/day (March, 2007) during this period was employed. The runoff is 20m^3/s, which is below the flow based on the two-year return period.

Table 2.2.6 Maximum Daily Rainfall by Months in the Past Decade (Jigmecholing Station)

(mm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max.
2005	33.6	7.0	22.8	14.0	51.8	61.4	119.4	160.0	231.4	78.4	3.8	0.0	231.4
2006	0.0	25.8	26.4	37.6	201.6	72.8	79.4	43.4	197.2	16.6	21.0	19.6	201.6
2007	0.0	27.4	44.2	27.4	38.6	103.6	374.8	89.8	197.8	47.4	0.0	0.0	374.8
2008	21.6	19.4	42.4	48.2	121.4	140.0	214.6	192.8	76.4	38.8	0.0	0.0	214.6
2009	2.2	19.4	13.2	122.4	156.4	147.6	174.8	63.4	186.4	159.0	2.2	1.8	186.4
2010	0.0	1.8	10.4	45.6	53.4	57.6	88.8	101.4	107.8	19.4	2.4	0.0	107.8
2011	0.0	0.0	39.8	113.6	23.4	93.6	220.0	72.8	159.4	1.4	5.2	0.0	220.0
2012	11.2	6.2	34.8	52.4	26.8	122.4	231.6	260.6	113.8	52.4	0.0	2.6	260.6
2013	0.0	33.4	17.8	86.6	104.8	251.4	217.4	101.6	128.4	67.4	11.4	0.0	251.4
2014	3.4	1.8	40.8	4.8	135.4	88.4	126.8	174.6	119.8	57.6	3.8	0.0	174.6

: rainy season (Apr and Oct are transient month)

River Work (Nov - Mar)

Source: Prepared by the study team

2.2.1.3 Policy concerning Social and Economic Conditions

(1) Consideration to Economic Activity

Target bridges of the project are on PNH-4 which is one of the 5 major primary highways in Bhutan and play important role in supporting economic activity. Since there is no detour in concerned Dzongkhag, approach road and bridges are planned in order not to inhibit current traffic. In addition, Mandechu Hydropower plant project, which is national project, is currently under construction and it is considered to contribute to economic growth of Bhutan. In the construction stage, the increase of the traffic of heavy vehicle is expected, therefore the design is considered not to affect the traffic condition in order to promote the smooth construction of power plant.

(2) Consideration to Roadside Community

Near the Passang Bridge, there are residences and government-related facilities are located and pedestrian are often observed around the bridge. Therefore, design is considered by placing sidewalk in order to ensure the safety of pedestrians.

2.2.1.4 Policy concerning Circumstances of Construction

The construction work in Bhutan is increasing annually, and the number of construction workers has been increasing because of dam constriction and widening of PNH-1. Since the well-experienced civil engineers to be in charge of their management are insufficient, the field-work management and safety control are not satisfactory, leading to qualitative degradation or delay of the work.

The design policy taking the local construction circumstances into account is as follows:

- The basic policy for equipment and materials are to source from local
- Materials will be selected with a view to utilizing local materials and products and in consideration of cost, ease of execution, quality, and procurement reliability.
- Concerning equipment and materials that cannot be procured locally, procure from Japan or third countries. Concerning procurement sources, make final decisions upon considering price, quality, delivery time and other relevant issues.
- For selection of the bridge superstructure, the prestressed concrete bridge is considered for the benefit of utilization of local materials and technology upgrade.
- The large-scale box culvert is being considered because of the benefit of technology transfer to Bhutan and utilization of local materials.
- When the heavy machinery/vehicles are to be used, the construction plan must take into account restriction of traffic on the road.

2.2.1.5 Policy regarding the Utilization of Local Contractor

With a view to creating employment opportunities, promoting technology transfer and vitalizing the local economy, local engineers and laborers will be utilized to the fullest extent; however, for jobs that are beyond the local technical level, skilled workers will be dispatched from Japan or third countries.

The design policy taking the local construction circumstances into account is as follows:

- The basic policy for subcontractor is to procure from local under appropriate management of Japanese engineers.
- The bridge construction are being considered because of the benefit of technology transfer to Bhutan.

2.2.1.6 Policy concerning Operation and Maintenance

Regarding the operation and maintenance for 5 bridges, the DoR Reginal Offices (RO) are in charged. There are about 20 engineers in each RO, Trongsa RO and Sarpang RO. DoR has a lot of experience of the execution of Japan's grant aid projects. And also in each RO for operation and maintenance, the certain technicians have employed and work on their duties. In this circumstance, they are operating the cycle operation and maintenance. In addition, they are getting the technical support from the DoR headquarters and outsourcing system. But the damages of the bridges are left so it can be said that there is a problem for the systematic maintenance by the bridge maintenance cycle. This problem is supported by technical project of JICA. In these views, their capability of proceeding the operation and maintenance is sufficient.

2.2.1.7 Policy concerning the Setting of Construction Grade

PNH-4 is a very important route for economic development of Bhutan. This project has goal of obtaining a quantitative and qualitative effects of the following.

(1) Quantitative Effects

1) Increase in bridge load bearing capacity

The existing bridges were designed to bear load of 40R (55t). The new bridges will be able to withstand loads of 70R (100t). This is possible also to cope with the heaviest transformers of transport in the dam construction equipment transportation of Mangdechu Hydropower plant project at Trongsa Dzongkhag.

2) Increase in Average Driving Speed

The average speed of each bridge is as follows;

- Telegangchu Bridge: 13.1km / h
- Beteni Bridge 11.7km / h

- Samkhara Bridge 14.1km / h
- Passang Bridge 18.8km / h

The new bridges will be possible to pass through each bridges, 20km/h at Telegangchu Bridge, 20km/h at Beteni Bridge, 20km/h at Samkhara Bridge and 60km/h at Passang Bridge.

3) Average Daily Traffic Volume

The actual daily traffic volume in the field survey was 233units/day between Trongsa and Gelephu. Daily traffic volume after the completion of the project three years will be about 1.2times, i.e. 275units/day between Trongsa and Gelephu.

4) Average Daily Numbers of Passengers

The actual daily numbers of passengers in the field survey was 785nos/day between Trongsa and Gelephu. Daily numbers after the completion of the project three years will be about 1.3times, i.e. 1,014nos/day between Trongsa and Gelephu.

5) Average Daily Cargo Weight

The actual daily cargo weight in the field survey was 469tons/day between Trongsa and Gelephu. Daily weight after the completion of the project three years will be about 1.3times, i.e. 606tons/day between Trongsa and Gelephu.

(2) Qualitative Effects

1) Improvement in Bridge Performance and Safety

With the new construction of bridges, the load bearing capacity will increase and by the road alignment, there will be less chance of vehicles crashing into the bridges. Thus, safety will be improved.

2) Improvement of the Safety for the Road Environment

One side of connection road of Telegangchu Bridge and Beteni Bridge have risk of falling rocks and land slide, because of the overhang geographical features. After reconstruction of bridges, that location is cut for improvement of road alignments. It is planned that the cut surface is protected and secured the stable gradient.

3) Improvement of River Environment

Existing Samkhara Bridge is in a situation that bridge girder may be contacted with water at the flood. After reconstruction of bridges, girder clearance is secured. Then river environment is improved, because the risk of girder damage by flood and driftwood is reduced. In addition, river gauge section at the flood is secured for all of bridges.

4) Promotion for Smooth Logistics

With the new construction of bridges, vehicles will immediately pass over the bridge and this will contribute to the promotion of logistics on PNH-4.

5) Ensuring Safety of Pedestrians

There is no sidewalk on the existing bridges. However, because sidewalks will be included on CPassang Bridge, the safety of pedestrians will be secured.

(3) Grade of the Project

The target facilities will be upgraded as shown in Table 2.2.7 and Table 2.2.8 to accomplish the Project goal by considering economy, workability, durability, procurement of construction material, transportation, maintenance work and so on.

Table 2.2.7 Grade of New Bridges

Name of Bridge		Telegangchu	Beteni	Samkhara	Passang
Design Speed		20 km/h	20 km/h	20 km/h	60 km/h
Live Load		Single lane IRC 70R (wheeled) or Double lane IRC Class A			
Bridge Length		42.0m	30.0m	49.5m	41.5m
Road Width	Road width	13.7~11.4m	10.1~8.8m	9.1~11.6m	10.0m
	Carriageway	3.50×2=7.0m			
	Sidewalk	-	-	-	1.5m×2
Superstructure		PC Box-Shaped Girder	PC Box-Shaped Girder	PC Box-Shaped Girder	PC Box-Shaped Girder
Substructure		A1: Inverted T-Type Abutment A2: Gravity-Type Abutment	A1: Inverted T-Type Abutment A2: Inverted T-Type Abutment	A1: Gravity-Type Abutment A2: Inverted T-Type Abutment	A1: Inverted T-Type Abutment A2: Inverted T-Type Abutment
Foundation		A1: Cast in situ pile A2: Spread Foundation	A1: Cast in situ pile A2: Spread Foundation	A1: Spread Foundation A2: Cast in situ pile	A1: Cast in situ pile A2: Cast in situ pile
Revetment Work		A1: 41.5m A2: 0.0m	A1: 31.6m A2: 27.6m	A1: 0.0m A2: 18.6m	A1: 41.8m A2: 41.7m

Source: Prepared by the study team

Table 2.2.8 Geometric Dimension of Approach Roads

Items	Unit	Applied value	Remarks
Design speed	km/hr	20 60 (Passang Bridge)	Japanese Standards Bhutanese Standards
Carriageway width	m	7.5m	Bhutanese Standards
Width of shoulder	m	1.0	Bhutanese Standards
Standard cross fall	%	2	Bhutanese Standards
Maximum superelevation at curve section	%	6	Japanese Standards
Maximum vertical grade	%	7	Bhutanese Standards
Minimum radius	m	20km/hr: 15 60km/hr: 115	Japanese Standards Bhutanese Standards
Widening	m	90 ≦ Radius < 160 ⇒ 0.25 60 ≦ Radius < 90 ⇒ 0.50 45 ≦ Radius < 60 ⇒ 0.75 32 ≦ Radius < 45 ⇒ 1.00 26 ≦ Radius < 32 ⇒ 1.25 21 ≦ Radius < 26 ⇒ 1.50 19 ≦ Radius < 21 ⇒ 1.75 16 ≦ Radius < 19 ⇒ 2.00	Japanese Standards

Items	Unit	Applied value	Remarks
		15 ≦ Radius < 16 ⇒ 2.25	
Length of transition	m	20km/hr: 17* 60km/hr: 50	Japanese Standards
Pavement	mm	Wearing course: 50 (Asphalt concrete (AC)) Binder course: 75 (dense-graded asphalt concrete DBM)) Base course: 225 Subbase course: 250	Bhutanese Standards

* It adopts a length obtained from the steering time at design speed 20 km / hr.

Source: Prepared by the study team

2.2.1.8 Policy concerning Construction Methods and Construction Schedule

(1) Construction methods

[Foundation works] Pile and spread foundation

[Substructure work] Telegangchu and Samkhara: Reversed T type abutment, Gravity type abutment
Beteni and Passang : Reversed T type abutment

[Superstructure work] PC simple box girder type

(2) Construction Schedule

The climate in Bhutan is divided into the rainy (May to September) and dry (October to April) seasons under the influence of the monsoonal climate. Most of the national land except for the southern lowland is located at high altitude, so that the atmospheric temperature and changes of the seasons are similar to those of Japanese plateau areas. At Telegangchu Bridge, Beteni Bridge and Passang Bridge, the river water level during rainy season is high. Then during rainy season, it affects the construction. However, at Samkhara Bridge, during rainy season, it does not affect the construction. Thus Samkhara Bridge can be constructed all season.

2.2.1.9 Policy concerning Environmental and Social Considerations

In order to minimize the effects on natural and social environments, the following factors must be taken into account and reflected in the design.

- Minimization of the amount of cutting
- Minimization of deforestation
- Minimization of the impact to flora and fauna
- Minimization of resettlement and land acquisition

2.2.2 Basic Plan

2.2.2.1 Overall plan

(1) Comparison of Proposed Routes and Selection of Bridge Location

In regard with the selection of the route and bridge location, 4 points of cost effectiveness, environmental aspect, engineering aspect and DoR's priority were considered comprehensively. The reason that 4 points are chosen were as follows.

- Cost effectiveness: The bridges locate in mountainous area and the change of terrain is great, therefore the cost differs largely depending on the selection of bridge location and construction method.
- Environmental aspect (Impact to the environment and resettlement): For the bridges which locate near the private land, land acquisition and resettlement might be required.
- Engineering aspect (Road and Bridge engineering view): The construction of the bridges in the narrow valley is expected therefore it is necessary to assess the construction method carefully.
- DoR's priority: It is important to consider the request from DoR which in charge of maintenance work of target bridges.

1) Telegangchu Bridge

As shown in Figure 2.2.8, comparison was made among the four proposed routes.

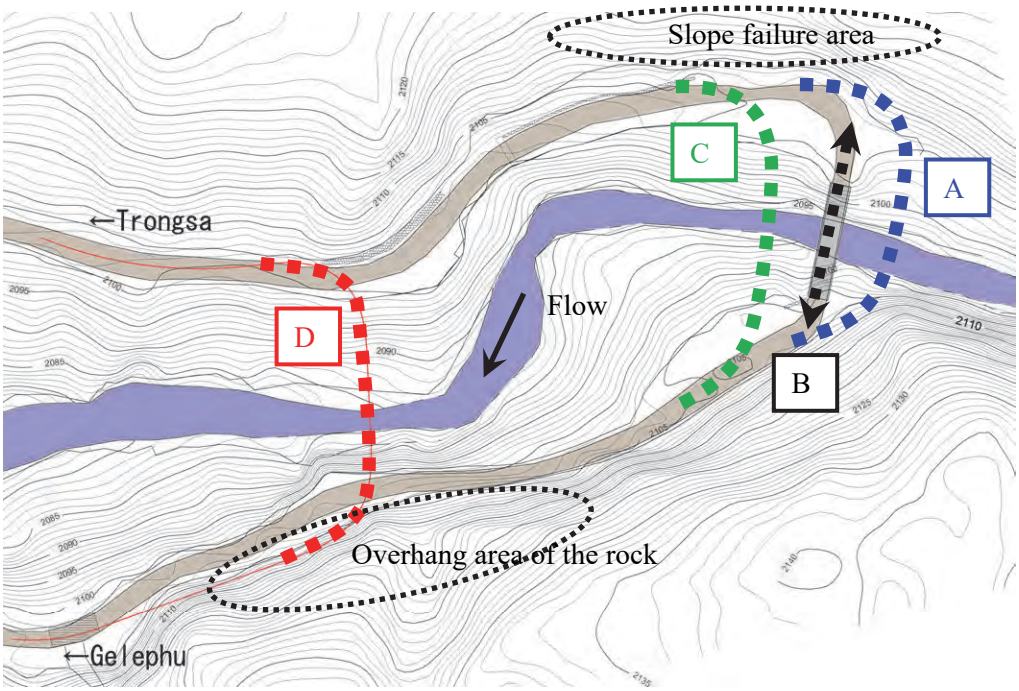
Route A: The bridge is constructed on the upstream side of the existing bridge and the temporary bridge for vehicle is not necessary.

Route B: The bridge is constructed on the location of the existing bridge.

Route C: The bridge is constructed on the downstream side of the existing bridge and the temporary bridge for vehicle is not necessary.

Route D: The bridge is constructed on the downstream side of the existing bridge more.

Route D was determined to be the best route. Because this route is able to avoid the slope failure area in the right bank side of the existing bridge. And the road alignment is improved. And the overhang area of the rock which is dangerous for the vehicle is cut to become safety.



Alternative Route	Cost effectiveness	Environmental Aspect	Engineering Aspect	DoR's Priority	Total
A (Upstream)	The cost for the slope failure is necessary every year.	No resettlement is expected.	The space of constructing the bridge is nothing due to the narrow around the existing bridge.	DoR does not expect this route.	The slope failure area and road alignment is not improved.
	4th	1st	3rd	2nd	3rd
B (Location of existing bridge)	The cost for the slope failure is necessary every year. And temporary bridge for vehicles is also.	No resettlement is expected.	The slope failure area is not improved.	DoR does not expect this route.	The slope failure area and road alignment is not improved.
	4th	1st	3rd	2nd	3rd
C (Downstream)	The cost for the slope failure is not necessary every year. And temporary bridge for vehicles is also.	No resettlement is expected.	The overhang area of the rock which is dangerous for the vehicle is not improved.	DoR does not expect this route.	The overhang area of the rock which is dangerous for the vehicle is not improved.
	1st	1st	2nd	2nd	2nd
D (Downstream more)	The cutting rock is necessary for vehicles under construction. →And the overhang area of the rock which is dangerous for the vehicle is cut to become safety.	No resettlement is expected.	The overhang area of the rock which is dangerous for the vehicle is improved to become safety.	DoR's preferable route.	The road alignment is improved.
	3rd	1st	1st	1st	1st
No replacement	No cost is required.	No resettlement and influence is expected.	In case of using existing bridge, width of bridge is narrow and loading capacity will be lacking.	DoR is expecting replacement of old bridge.	Replacement of bridge is necessary due to lack of width and loading capacity.
	1st	1st	5th	5th	3rd

Source: JICA Survey Team

Figure 2.2.8 Comparison of Proposed Routes (Telegangchu Bridge)

2) Beteni Bridge

As shown in Figure 2.2.9, comparison was made among the four proposed routes.

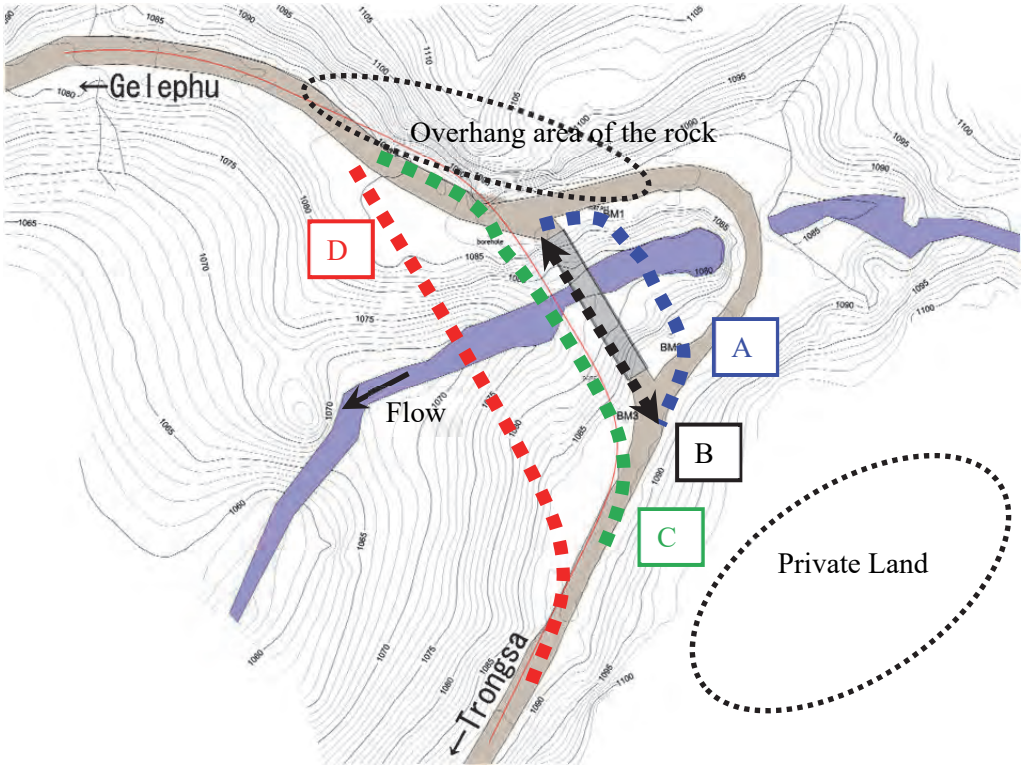
Route A: The bridge is constructed on the upstream side of the existing bridge.

Route B: The bridge is constructed on the location of the existing bridge.

Route C: The bridge is constructed on the downstream side of the existing bridge.

Route D: The bridge is constructed on the downstream side of the existing bridge more.

Route C was determined to be the best route. The road alignment is improved and the overhang area of the rock which is dangerous for the vehicle is cut to become safety.



Alternative Route	Cost effectiveness	Environmental Aspect	Engineering Aspect	DoR's Priority	Total
A (Upstream)	The cost of temporary bridge for vehicles is necessary. Because heavy vehicles are not able to pass the existing bridge due to the limit.	The private land of the left bank side has environmental impact by cutting soil for the temporary bridge.	The space of constructing the bridge is nothing due to the narrow around the existing bridge.	DoR does not expect this route.	This route is not preferable route due to the cost and environments.
	5th	4th	3rd	2nd	4th
B (Location of existing bridge)	The cost of temporary bridge for vehicles is necessary. Because heavy vehicles are not able to pass the existing bridge due to the limit.	The private land of the left bank side has environmental impact by cutting soil for the temporary bridge.	The space of constructing the bridge is nothing due to the narrow around the existing bridge.	DoR does not expect this route.	This route is not preferable route due to the cost and environments.
	2nd	4th	3rd	2nd	3rd
C (Downstream)	The cost for the cutting rock is necessary.	The private land of the left bank side does not have environmental impact.	The overhang area of the rock which is dangerous for the vehicle is improved.	DoR's preferable route.	The road alignment is improved.
	2nd	1st	1st	1st	1st
D (Downstream more)	The cost of the long span bridge is very high.	The private land of the left bank side does not have environmental impact.	The span of the bridge is so long because the river width is large.	DoR dose not expect this route.	This route is not preferable route due to the cost.
	2nd	1st	2nd	2nd	2nd
No replacement	No cost is required.	No resettlement and influence is expected.	In case of using existing bridge, width of bridge is narrow and loading capacity will be lacking.	DoR is expecting replacement of old bridge.	Replacement of bridge is necessary due to lack of width and loading capacity.
	1st	1st	5th	5th	4th

Source: JICA Survey Team

Figure 2.2.9 Comparison of Proposed Routes (Beteni Bridge)

3) Samkhara Bridge

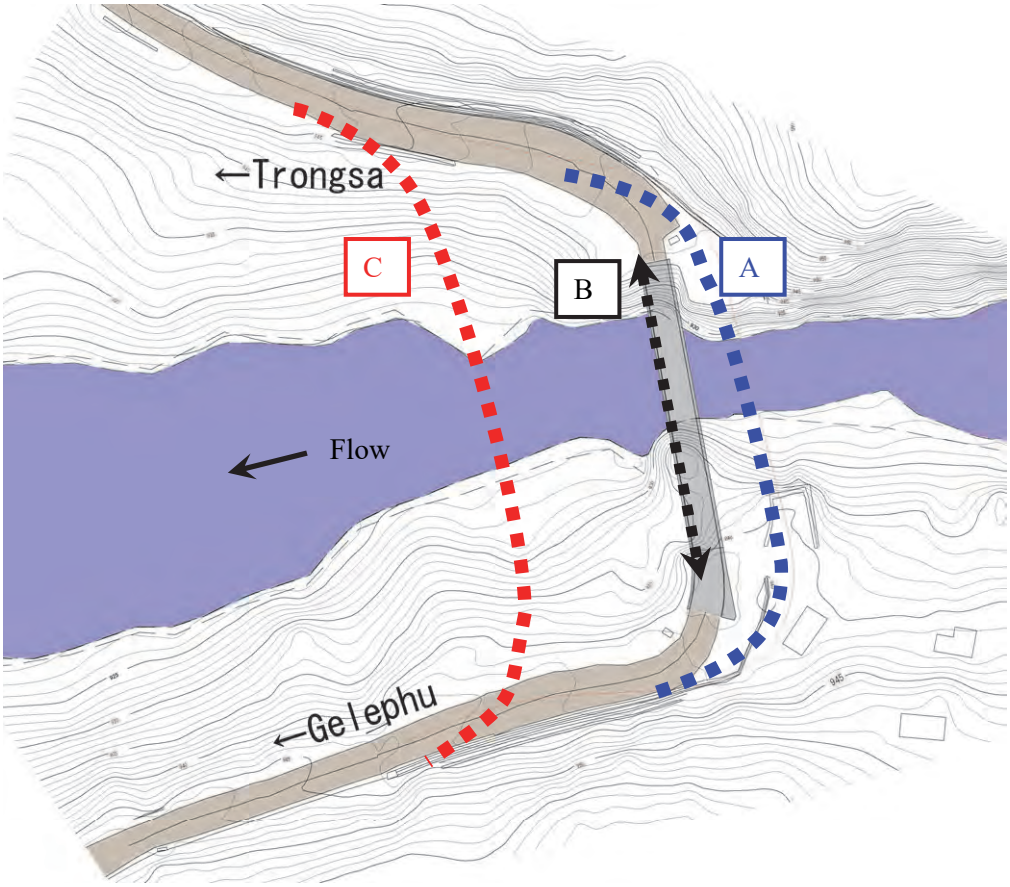
As shown in Figure 2.2.10, comparison was made among the three proposed routes.

Route A: The bridge is constructed on the upstream side of the existing bridge and the temporary bridge for vehicle is not necessary.

Route B: The bridge is constructed on the location of the existing bridge.

Route C: The bridge is constructed on the downstream side of the existing bridge and the temporary bridge for vehicle is not necessary.

Route A was determined to be the best route because of the bridge cost. And in case of this route, the vehicle is able to pass the river under construction without the temporary bridge which cost is very high due the big river.



Alternative Route	Cost effectiveness	Environmental Aspect	Engineering Aspect	DoR's Priority	Total
A (Upstream)	The cost of the new bridge is not high because the bridge span is short.	No resettlement is expected.	The construction is possible.	DoR's preferable route.	This route is preferable route.
	1st	1st	1st	1st	1st
B (Location of existing bridge)	The cost of temporary bridge for vehicles is necessary.	No resettlement is expected.	The temporary bridge for vehicles is necessary.	DoR does not expect this route.	This route is not preferable route due to the cost.
	3rd	1st	2nd	2nd	2nd
C (Downstream)	The cost of the new bridge is high because the bridge span is long.	No resettlement is expected.	The construction Is very hard due to the long bridge and the construction area which is a steep.	DoR does not expect this route.	This route is not preferable route due to the cost.
	3rd	1st	2nd	2nd	2nd
No replacement	No cost is required.	No resettlement and influence is expected.	In case of using existing bridge, width of bridge is narrow and loading capacity will be lacking.	DoR is expecting replacement of old bridge.	Replacement of bridge is necessary due to lack of width and loading capacity.
	1st	1st	4th	4th	4th

Source: JICA Survey Team

Figure 2.2.10 Comparison of proposed routes (Samkhara Bridge)

4) Passang Bridge

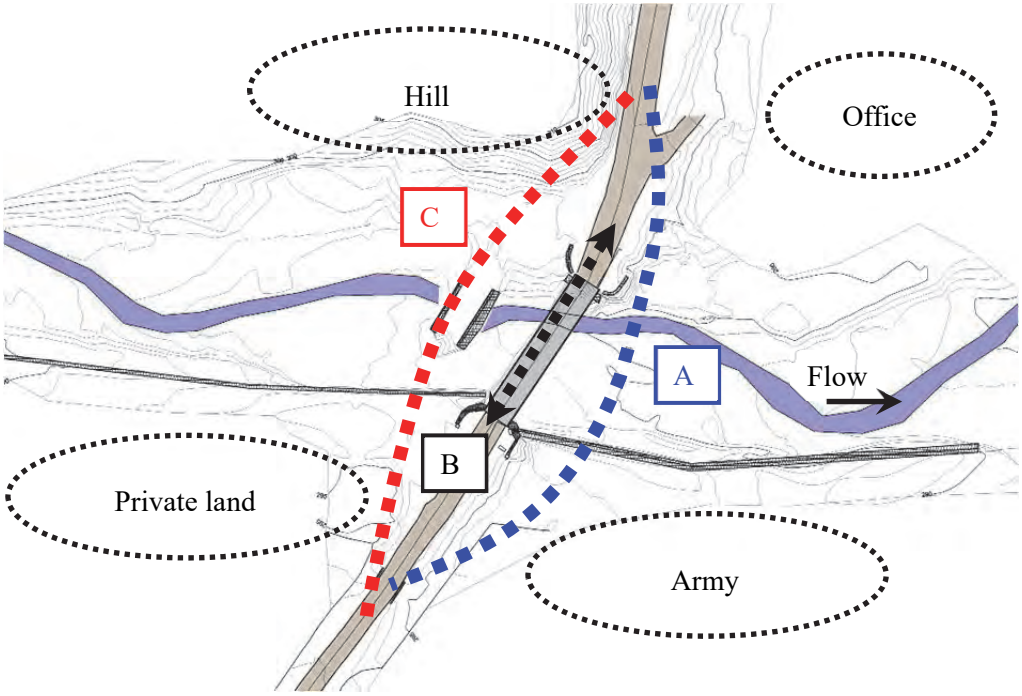
As shown in Figure 2.2.11, comparison was made among the three proposed routes.

Route A: The bridge is constructed on the downstream side of the existing bridge and the temporary bridge for vehicle is not necessary.

Route B: The bridge is constructed on the location of the existing bridge.

Route C: The bridge is constructed on the upstream side of the existing bridge and the temporary bridge for vehicle is not necessary

Route B was determined to be the best route. The existing bridge is very old and necessary to remove soon. And there are the office, hill, private houses around the bridge so it is hard to construct new bridge in the upstream side and downstream side.



Alternative Route	Cost effectiveness	Environmental Aspect	Engineering Aspect	DoR's Priority	Total
A (Downstream)	The cost is high because the road length is long.	The army area has environmental impact.	The leased land is necessary for the construction.	DoR does not expect this route.	This route is not preferable route due to the army.
	3rd	4th	2nd	3rd	3rd
B (Location of existing bridge)	The cost of temporary bridge for vehicles is not necessary.	No resettlement is expected.	The road alignment is smooth	DoR's preferable route.	This route is preferable route.
	2nd	1st	1st	1st	1st
C (Upstream)	The cost of cutting soil in the left bank side is necessary.	The private land in the right bank side has environmental impact.	The leased land is necessary for the construction.	DoR does not expect this route.	This route is not preferable route due to the cost.
	3rd	3rd	2nd	2nd	2nd
No replacement	No cost is required.	No resettlement and influence is expected.	In case of using existing bridge, width of bridge is narrow and loading capacity will be lacking.	DoR is expecting replacement of old bridge.	Replacement of bridge is necessary due to lack of width and loading capacity.
	1st	1st	4th	3rd	3rd

Source: JICA Survey Team

Figure 2.2.11 Comparison of Proposed Routes (Passang Bridge)

(2) Contents of the plan

The specification for the major facilities namely the bridges and approach roads are shown in Table 2.2.7 and Table 2.2.9 respectively.

Table 2.2.9 Specification of the Approach Roads

Name of Bridge		Telegangchu	Beteni	Samkhara	Passang
Design Speed		20 km/h	20 km/h	20 km/h	60 km/h
Geometric dimension	Typical cross fall	2%			
	Max. cross fall	6%			
	Max. longitudinal gradient	7%			
	Min. curve radius	15m	26m	18m	160m
	Widening width	4.25m	2.75m	4.00m	0.25m
	Transition section length	17m	20m	17m	50m
Design length		53.5+95.9m	81.0+99.0m	59.0+84.0m	49.5+50.0m
Cross section	Total width	10.5m			
	Carriageway width	3.75 x 2 = 7.50m			
	Shoulder	1.0m (valley side)			
	Drainage width	1.0m (mountain side)			
	Tolerance width	1.0m (mountain side)			
Pavement	Wearing course	Asphalt concrete (5cm)			
	Binder course	Dense bituminous macadam (5cm)			
	Base course	Crushed stone (22.5cm)			
	Sub base course	Crushed stone (25cm)			
	Subgrade	Design CBR = 7%			

Source: JICA Survey Team

2.2.2.2 Road Plan

(1) Contents of the Traffic Survey

The traffic survey was made on various traffic volumes as follows so as to identify the existing traffic characteristics of the target region.

1) Collection of the Existing Traffic Data

The existing result of traffic survey at the project site was made available to us from the DoR Maintenance Department. Attempt was made to obtain the existing data at three locations (the start point side, the intermediate point (Zhemgang), and the end point side of the Trogsa – Gelephu section). However, the DoR's data control state is unsatisfactory, and continuous availability of past data could not be ensured. Data availability at each location is shown below:

Trongsa: 2005-2007, 2014 (Data for one weekday for all years)

Zhemgang: 2005-2009, 2013 (Data for one weekday for all year)

Gelephu: 2013 (Data for one weekday for the year)

The existing data amount is not sufficient, and it is difficult to project the future traffic volume by using the existing data plus the traffic counts obtained in this study. Therefore the future traffic is to be estimated by using the demand forecast for Primary National Highway No.4 described in the "Information Collection and Confirmation Study Report (2014) related to the Domestic Traffic Network" of Bhutan and the traffic counting results of this study.

2) Roadside OD Survey

The roadside OD survey was conducted as follows at three points between Trongsa and Gelephu (Teleganchu Bridge (Trongsa), Beteni Bridge (north of Gelephu), and Passang Bridge (south of Gelephu). Note that this survey was recommissioned locally.

Table 2.2.10 Details of Roadside OD Survey

Item	Description
Survey method	Method is interview by investigator. Interview items are following Type of vehicle, Number of axles, Point of departure, Final destination, Number of passengers, Departure time, Expected arrival time, Trip purpose, Loading item and weight, The maximum loading weight
Location	Trongsa side (Tereganchu Bridge), the middle point (Beteni Bridge), Gerefu side (Passan Bridge) each one place, places a total of three (the same point as the traffic survey)
Survey period	Weekday and Holiday one day total of 2 days Weekdays 9/2 (Wednesday), holiday 9/4 (Sat)
Survey time	6 am to 6 pm 12-hour survey

Source: JICA Survey Team

3) Owner Interview Survey

In order to identify the distribution route, load contents, and carrying capacity of particularly heavy trucks, the interview was held with the dam constructors as follows. Note that the owner interview was recommissioned locally.

Table 2.2.11 Details of Owner Interview Survey

Item	Description
Survey method	Method is interview by investigator. Interview items are following Type of vehicle, Number of axles, Point of departure, Final destination, Number of passengers, Departure time, Expected arrival time, Trip purpose, Loading item and weight, The maximum loading weight
Location	Interview with Mondachu Hydroric Power Project

Source: JICA Survey Team

4) Traffic Count Survey

In order to determine the current traffic volume on the project site, the traffic survey was conducted as follows. Note that the traffic survey was recommissioned locally.

Table 2.2.12 Details of Traffic Count Survey

Item	Description
Survey method	Road cross-section traffic volume Survey (by vehicle type, direction)
Location	Trongsa side (Teleganchu Bridge), the middle point (Beteni Bridge), Gelephu side (Passang Bridge) each one place, places a total of three (the same point as the traffic survey)
Survey period	Weekday and Holiday one day total of 2 days Weekdays 9/2 (Wednesday), holiday 9/4 (Sat)
Survey time	6 am to 6 pm 12-hour survey

Source: JICA Survey Team

5) Survey on Traveling Speed of the Vehicles

In order to determine the traveling speed of current passing vehicles on the project site, the survey on the traveling speed of passing vehicles was conducted as follows. Note that the survey on the traveling speed of passing vehicles was conducted under our direct control.

Table 2.2.13 Details of Survey on Traveling Speed of the Vehicles

Item	Description
Survey method	Survey in which the surveyor measured, using stopwatches, the vehicle passing speed over the section including the approach road section (20 m) before and after the bridge point
Location	Total of 5 points, each point at each of Teleganchu Bridge, Chaplekhola Bridge, Beteni Bridge, Samkhara Bridge, Passang Bridge
Survey period	August 6 (Monday), August 7 (Friday) August 9 (Sunday)
Survey time	About 15 – 30 minutes at each bridge

Source: JICA Survey Team

(2) Survey Results

1) Summary of the Collected Data

To summarize the traffic survey results in this study, the target section (Trongsa – Gelephu) of the project is divided into three areas including the major city. Among the target bridges, Teleganchu Bridge belongs to Trongsa section, Beteni Bridge and Samkhara Bridge belong to Zhemgang section, and Passang Bridge belogs to Gelephu section respectively.

The traffic volume was as follows:

- Trongsa section : 190 vehicles/day on 03/Sep (weekday)
  164 vehicles/day on 05/Sep (holiday)
- Zhemgang section : 48 vehicles/day on 03/Sep (weekday)
  47 vehicles/day on 05/Sep (holiday)
- Gelephu : 233 vehicles/day on 03/Sep (weekday)
  197 vehicles/day on 05/Sep (holiday)

The survey was performed on both weekday and holiday. As there is no significant difference, the survey results on weekday with large number of vehicles are to be used.

The large-vehicle mixing ratio is high for all sections; 15% for the Trongsa section, 31% for the Zhemgang section, and 21% for the Gelephu section. This is considered due greatly to construction vehicles for the Mangdechu hydropower plant currently under construction.

2) Summary of the Result of OD Survey and Owner Interview Survey

The roadside OD survey was conducted according to the procedure described above. The results are summarized below. This survey covers mainly vehicles departing from/arriving at Trongsa and Gelephu to/from two cities and the cities along Primary National Highway No.4. It can be confirmed that National Highway No.4, the target area of this project, plays a vital role. The past project survey also confirmed that transport of equipment and materials to Trongsa and Gelephu was done along the route starting from Phuentsholing and via Primary National Highway Nos. 1 and 5.

Teleganchu Bridge (Weekday survey: 2015.9.3)

From \ To	P/PING	TRONGSA	ZHEMGANG	BUMTHANG	THIMPHU	TASHIGANG	Total
TRONGSA	8	4	1	0	1	0	14
P/PING	0	3	0	0	0	0	3
GELEPHU	0	2	0	2	0	0	4
MONGAR	0	0	0	0	0	0	0
Langthel	0	1	0	0	0	0	1
THIMPHU	0	2	0	0	0	0	2
Total	8	12	1	2	1	0	24

Teleganchu Bridge (Holiday survey: 2015.9.5)

From \ To	P/PING	TRONGSA	ZHEMGANG	BUMTHANG	THIMPHU	TASHIGANG	Total
TRONGSA	2	12	1	0	0	0	15
P/PING	0	7	0	0	0	0	7
GELEPHU	0	1	0	1	0	0	2
MONGAR	0	0	0	0	0	0	0
S Jhonkhar	0	0	0	0	0	2	2
THIMPHU	0	0	0	0	0	1	1
Total	2	20	1	1	0	3	27

Beteni Bridge (Weekday survey: 2015.9.3)

From \ To	TRONGSA	ZHEMGANG	BUMTHANG	GELEPHU	Total
TRONGSA	0	0	0	0	0
ZHEMGANG	0	0	0	6	6
BUMTHANG	0	0	0	4	4
GELEPHU	1	3	1	0	5
Total	1	3	1	10	15

Beteni Bridge (Holiday survey: 2015.9.5)

From \ To	TRONGSA	ZHEMGANG	BUMTHANG	GELEPHU	Total
TRONGSA	0	0	0	3	3
ZHEMGANG	0	0	0	1	1
BUMTHANG	0	0	0	0	0
GELEPHU	15	4	1	0	20
Total	15	4	1	4	24

Passang Bridge (Weekday survey: 2015.9.3)

From \ To	TRONGSA	ZHEMGANG	BUMTHANG	GELEPHU	Total
TRONGSA	0	0	0	8	8
ZHEMGANG	0	0	0	5	5
BUMTHANG	0	0	0	0	0
GELEPHU	6	3	1	2	12
Total	6	3	1	15	25

Passang Bridge (Holiday survey: 2015.9.13)

From \ To	TRONGSA	ZHEMGANG	BUMTHANG	GELEPHU	Total
TRONGSA	0	0	0	4	4
ZHEMGANG	0	0	0	3	3
BUMTHANG	0	0	0	0	0
GELEPHU	25	5	1	1	32
Total	25	5	1	8	39

Source: JICA Survey Team

Figure 2.2.12 OD Survey Results

(3) Forecasting the Future Traffic Volume

1) Forecasting Method

For this survey, the number of existing data is not enough. It is difficult to predict the future traffic volume by using the existing data and the traffic counting results in this study. Therefore the future traffic is to be estimated by using the demand forecast for Primary National Highway No.4 described in the "Information Collection and Confirmation Study Report (2014) related to the Domestic Traffic Network" of Bhutan and the traffic counting results of this study. This Report

estimates the traffic demand using the population data from future forecast while using the regression analysis for the traffic demand forecast formula.

National Highway No.4

Data used

Traffic volume by section	Population	Year	City using the highway
Y	X		
93	41,549	2005	Sarpng
107	37,916	2006	Sarpng
92	38,740	2007	Sarpng
118	39,581	2008	Sarpng
196	41,300	2010	Sarpng
240	44,504	2014	Sarpng

Regression analysis results (PNH4)

Objective variable Traffic volume
Explanatory variable Population
No. of data 6
Traffic volume = 0.0207* Population -697.6247

Contribution ratio 0.6292
(Weighted) coefficient of correlation 0.7932

Source: "Information Collection and Confirmation Study Report (2014) related to the Domestic Traffic Network"

Figure 2.2.13 Regression Analysis Results on PNH-4

Using the above regression formula, demand forecast is as follows.

Traffic volume = 0.0207 × Population – 697.6247

2015 year Traffic volume 253 vehicles Population 757,042 persons

2020 year Traffic volume 253 vehicles Population 757,042 persons

2025 year Traffic volume 253 vehicles Population 757,042 persons

2) Forecast Results

Demand forecast is performed from the traffic volume survey results in this study while using the above regression formula. This formula is valid because the result (253 vehicles) calculated through regression in 2015 does not differ much from the survey result (233 vehicles) in this study. Consequently, this forecast result is considered valid.

Table 2.2.14 Demand Forecast Result

表	Teleganchu Bridge	Beteni Bridge	Passang Bridge	Increase
2015	198	48	233	
2016	210	51	248	1.063
2017	222	54	262	1.057
2018	234	57	275	1.052
2019	245	59	288	1.047
2020	255	62	301	1.042
2021	265	64	312	1.038
2022	274	67	323	1.035
2023	283	69	334	1.033
2024	292	71	344	1.031
2025	300	73	354	1.029
2026	308	75	363	1.026
2027	316	77	372	1.025
2028	324	78	381	1.024
2029	331	80	390	1.023
2030	338	82	398	1.022
2031	346	84	407	1.021

Source: JICA Survey Team

(4) Applicable Design Standards

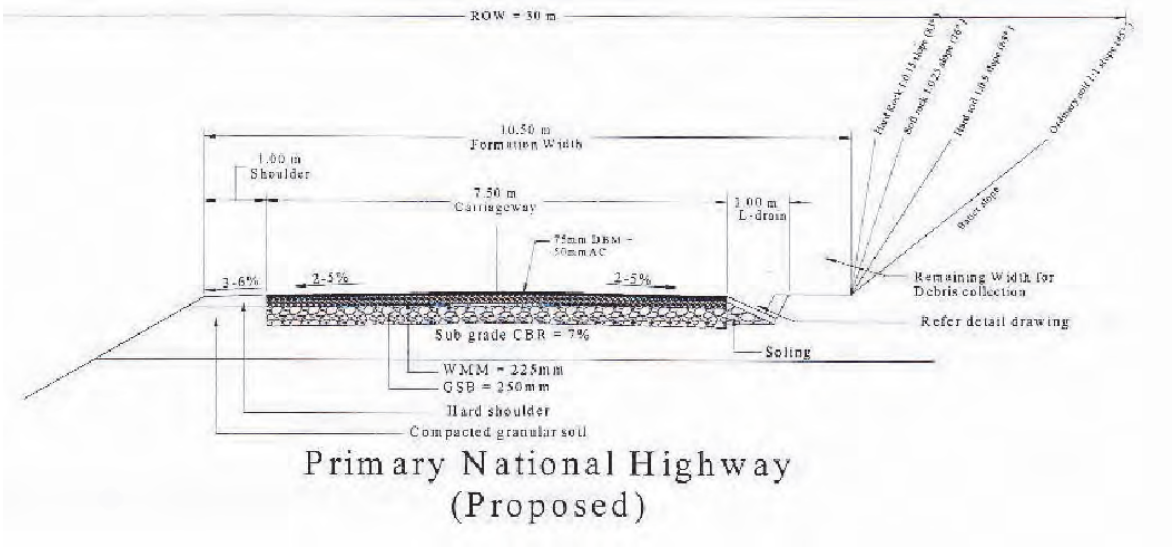
Applicable to the road design are the Bhutanese design standard, "Road Survey & Design Manual (First Edition June 2005), Royal Government of Bhutan, Ministry of Works & Human Settlement, Department of Roads, Thimphu" and "Guidelines on use of Standard Work Items for Common Road Works, Royal Government of Bhutan, Ministry of Works & Human Settlement, Department of Roads, Survey and Design Division." For matters not clearly stipulated in these standards, the Japanese design standard "Explanation and Operation of the Road Structure Ordinance, February, 1983, the Japan Road Association" is applied.

(5) Road Criteria

DoR is proceeding with the work to turn the Primary National Highway into the double-lane road. Accordingly, the section concerned will be developed with double lanes.

- Road section: Primary National Highway (Class A , Double Lane)
- Design speed: 60km/hr

The road width is shown in Figure 2.2.14. The 7.5m carriageway width and 1.0m shoulder are secured according to the "Guidelines on use of Standard Work Items for Common Road Works: Royal Government of Bhutan Ministry of Works & Human Settlement Department of Roads" and on the basis of the letter (Ref.no. DOR/DD/2015-2016/01/1018) issued on October 12, 2015.



Source: Guidelines on use of Standard Work Items for Common Road Works (Ref.no DOR/DD/2015-2016/01/1018)

Figure 2.2.14 Road Width Composition

(6) Design Speed

Design speed for each bridge is as follows;

- Telegangchu Bridge : 20km/hr
- Beteni Bridge : 20km/hr
- Samkhara Bridge : 20km/hr
- Passang Bridge : 60km/hr

(7) Reference Values of Geometric Dimension

The reference values of geometric dimension are summarized below according to the above design speed. The traffic survey in the site confirmed that the semi-trailer (the one with maximum five axles confirmed) for transport of materials and equipment into the hydropower plant construction project site entered from India to Bhutan. Accordingly, the widening of the curved portion is determined by taking into account the vehicular swept path of semi-trailer (L=16.5m, W=2.5m).

Table 2.2.15 Reference Values of Geometric Dimension

Items	Unit	Applied value	Remarks
Design speed	km/hr	20 (Approach road)	Japanese Standards Bhutanese Standards
Carriageway width	m	7.5m	Bhutanese Standards
Width of shoulder	m	1.0	Bhutanese Standards
Standard cross fall	%	2	Bhutanese Standards
Maximum superelevation at curve section	%	6	Japanese Standards
Maximum vertical grade	%	7	Bhutanese Standards
Minimum radius	m	20km/hr:15	Japanese Standards Bhutanese Standards
Widening	m	90 ≦ Radius < 160 ⇒ 0.25 60 ≦ Radius < 90 ⇒ 0.50 45 ≦ Radius < 60 ⇒ 0.75 32 ≦ Radius < 45 ⇒ 1.00 26 ≦ Radius < 32 ⇒ 1.25 21 ≦ Radius < 26 ⇒ 1.50 19 ≦ Radius < 21 ⇒ 1.75 16 ≦ Radius < 19 ⇒ 2.00 15 ≦ Radius < 16 ⇒ 2.25	Japanese Standards
Length of transition	m	20km/hr:17m	Japanese Standards

Source: JICA Study Team

Source: JICA Study Team

Figure 2.2.15 Semi-Trailer Truck in Bhutan

(8) Pavement Composition

The approach road will be paved with asphalt. As shown in the Road Width Composition describe above, INITIAL PROJECT DOCUMENT (IPD) specifies the highway pavement composition as follows:

- Surface course: 50mm (Asphalt concrete (AC))
- Binder course: 75mm (dense-graded asphalt concrete DBM))
- Base course: 225mm
- Subbase course: 250mm
- Total: 600mm
- Subgrade: Design CBR=7%

Verification checks of the above pavement composition were performed on the traffic volume in accordance with the Japanese Pavement Design Manual (TA method), which showed that the pavement has a sufficient required thickness. This verification is outlined below.

[Design conditions]

Design conditions are summarized below:

Wheel load	Calculated from project on PNH-1, the results of survey on the axle load of this study (Two-axle vehicles: 27.44kN, three-axle vehicles: 40.67kN, four-axle vehicles: 38.71kN)
Traffic growth rate	Calculated from the rate of increase from 2020 to 2030 (Growth rate: 1.05%/year)
Design period	2020 – 2030
Design CBR	7%
Reliability	90%

[Number of wheels required for fatigue failure]

The number of wheels required for fatigue failure (accumulated number of wheels as converted to 49 kN) is determined as follows:

$$N_{49} = \sum_{j=1}^{m} \left[\left(\frac{P_j}{49} \right)^4 \times N_j \right]$$

$$N = \sum_{i=1}^{n} (N_{49} \times 365 \times a_j)$$

Wherein;

- N_{49}: Number of wheels, as converted to 49kN, per day per direction
- P_j: Representative value of wheel load classified to the magnitude of the j-th wheel load
- m: Classification of the magnitude of wheel load (j=1 – m)
- N_j: Number of passages of P_j
- N: Cumulative number of wheels as converted to 49 kN during the design period
- n: Design period (years)
- a_j: Rate of increase relative to N_{49} in "i" years (i=1 – n)

The number of wheels required for fatigue failure is determined as follows from the above equation and design conditions:

$$N = 206,277$$

[Target TA and verification]

The total thickness of asphalt concrete (TA) is calculated as follows;

$$TA = 3.84N^{0.16} / CBR^{0.3} = 15.2$$

Wherein:

TA: Total thickness of asphalt concrete

CBR: Design CBR of the subgrade

The calculated value is compared with the TA value of pavement thickness determined by DoR, with the result as shown in Table 2.2.16. In this way, the required pavement thickness of this project is considered to be sufficient.

Table 2.2.16 Verification of Pavement Thickness

Items	Material	Scale factor	Thickness	TA Value	
Surface course	Asphalt concrete (AC)	1	5	5	
Binder course	Dense Bituminous Macadam (DBM)	1	7.5	7.5	
Base course		0.35	22.5	7.9	
Sub base course		0.25	25.0	6.3	
				26.6	≧15.2

Source: JICA Study Team

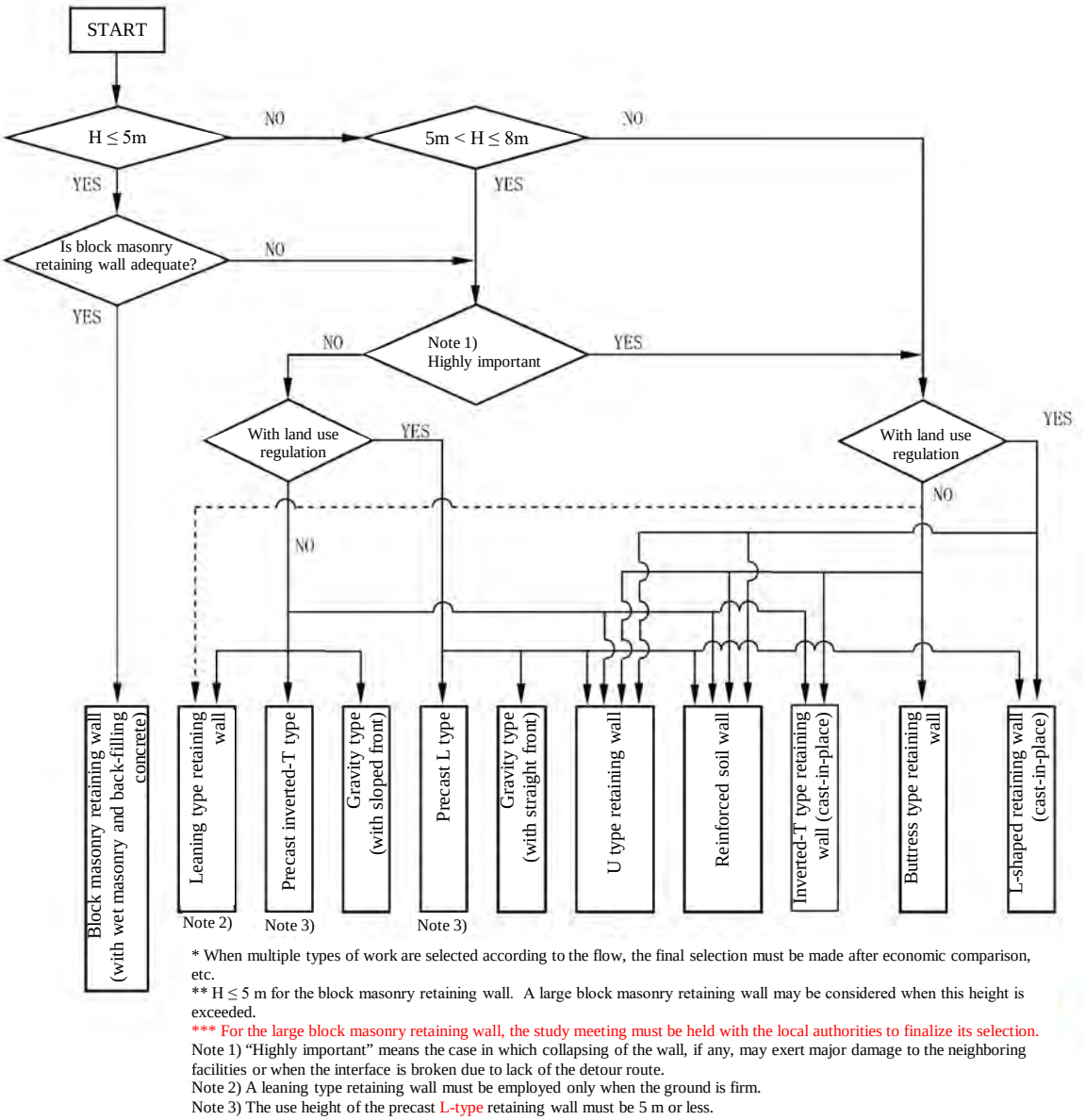
For the bridge section, the waterproof sheet will be put between the slab and asphalt pavement, and asphalt pavement is applied (t=60mm). The cement concrete pavement commonly applied in Bhutan could not be provided with the water-proof course. There is a possibility, therefore, that water may enter slabs through crack in pavement concrete, leading to the possibility of deteriorating the slab durability.

Note that the sidewalk also will be paved with asphalt concrete (t = 30mm).

(9) Retaining Wall

The retaining wall type is selected via the flow shown below according to the structural height of the retaining wall.

As a result of planning, in principle, the gravity type retaining wall is selected for the structural height of 5 m or less and the L-shaped retaining wall for the above height exceeding 5 m. Note however that, even if the height is 5m or less, the L-shaped retaining wall is employed in case of land use regulation or when the wall is a part of extension of planned L-shaped retaining wall.



* When multiple types of work are selected according to the flow, the final selection must be made after economic comparison, etc.
** H ≤ 5 m for the block masonry retaining wall. A large block masonry retaining wall may be considered when this height is exceeded.
*** For the large block masonry retaining wall, the study meeting must be held with the local authorities to finalize its selection.
Note 1) "Highly important" means the case in which collapsing of the wall, if any, may exert major damage to the neighboring facilities or when the interface is broken due to lack of the detour route.
Note 2) A leaning type retaining wall must be employed only when the ground is firm.
Note 3) The use height of the precast L-type retaining wall must be 5 m or less.

Source: Road retaining wall work guidelines, JAPAN

Figure 2.2.16 Retaining Wall Structural Type Selection Flow

(10) Slope Cut

To cut the slope, the cutting gradient must be determined on the basis of geological state of the ground while referring to the values in Table 2.2.17. The gradients of 1:0.3, 1:0.5 and 1:1.2 are applied to the hard rock, soft rock and soil respectively. The standard maximum cut height is 7.0m (according to the design procedure of MLIT) by taking into account the expected weathering to a certain degree for the purpose of cutting the existing cut surface. The width of berm provided every 7.0m of the cut height is 1.5m. In order to prevent weathering of bedrock and to prevent erosion and failure due to infiltration of stormwater, shotcrete for prevention of weathering and erosion is provided for hard rocks. For the thick weathered rock portion, crib work with ground anchors is provided according to cut of height.

Table 2.2.17 Standard Slope Gradient for Cut

Ground geological features		Cut height	Gradient
Hard rocks			1:0.3-1:0.8
Soft rocks			1:0.5-1:1.2
Sand	Soil not compact and with poor grain distribution		1:1.5 or more
Sandy soil	Compact	5m or less	1:0.8-1:1.0
		5-10m	1:1.0-1:1.2
	Not compact	5m or less	1:1.0-1:1.2
		5-10m	1:1.2-1:1.5
Sandy soil mixed with gravel or rock mass	Soil compact or with good grain distribution	10m or less	1:0.8-1:1.0
		10-15m	1:1.0-1:1.2
	Soil not compact and with poor gradin distribution	10m or less	1:1.0-1:1.2
		10-15m	1:1.2-1:1.5
Clayey soil		10m or less	1:0.8-1:1.2
Clayey soil mixed with rock mass or boulder		5m or less	1:1.0-1:1.2
		5-10m	1:1.2-1:1.5

Source: Guidelines for road earthwork cutting and slope stabilization work, JAPAN

(11) Drainage Facilities

In order to handle stormwater flowing on the road surface or slope properly, drainage facilities, including gutters or conduits, are provided. The type to be employed should be the one commonly employed locally as far as practicable by taking into account the locally-available manpower and material procurement.

(12) Traffic Safety Facilities

The on-site survey results show occurrence of vehicle falling outside the road in the sections with sharp curve. The following safety facilities are provided:

Vehicle falling preventive facilities : Guardrail

Lane marking : Centre line

2.2.2.3 Bridge Plan

(1) Design Conditions

1) Basic Policy

The basic policy of the bridge plan is, basically, to comply with the standards of Bhutan and with the Japanese standards (“Explanation and Operation of the Road Structure Ordinance, February, 1983, Japan Road Association”) where no description is provided.

2) Basic Road Conditions of the Bridge Section

(a) Vertical and Horizontal Alignment

The road vertical alignment is planned while referring to the current road height before and after the bridge section.

Telegangchu Bridge is a bridge which comes down with the longitudinal gradient of about 2.5% from the starting point to this bridge and comes up about 1.0～1.45% from this bridge to the end point. The horizontal alignment of this bridge is a clothoid curve with A(abbreviation) = 16 and R(Radius) = 15 in the starting side and A(abbreviation) = 18 and R(Radius) = 18 in the end side.

Beteni Bridge is a bridge which comes down with the longitudinal gradient of about 5.6% from the starting point to this bridge and comes down about 0.45～8.5% from this bridge to the end point. The horizontal alignment of this bridge is a clothoid curve with A(abbreviation) = 26 and R(Radius) = 23 in the starting side and A(abbreviation) = 45 and R(Radius) = 30 in the end side.

Samkhara Bridge is a bridge which comes down with the longitudinal gradient of about 8.0% from the starting point to this bridge and comes up about 1.8～5.7% from this bridge to the end point. The horizontal alignment of this bridge is a clothoid curve with A(abbreviation) = 17.5 and R(Radius) = 18 in the starting side and A(abbreviation) = 17.5 and R(Radius) = 18 in the end side.

Passang Bridge is a bridge which comes down with the longitudinal gradient of about 4.8% from the starting point to this bridge and comes up about 1.5% from this bridge to the end point. The horizontal alignment of this bridge is a clothoid curve with A(abbreviation) = 90 and R(Radius) = 160 on this bridge.

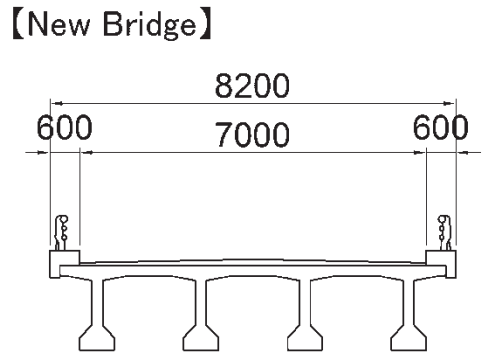
(b) Basic Width Composition of the Bridge Section

The basic width of the bridge section is as follows in compliance with the Bhutan standard. The amount of widening appropriate to the radius of curve in the road alignment is added to the basic width; the 1.5m sidewalk width is added in the case of Passang Bridge. The curb size is based on the Japanese standards (Specifications for Highway Bridges); the 600 mm wide curb is provided to the roadway and the 400mm wide curb is provided to the sidewalk. For the guard fence, the vehicle guard fence for both sidewalk and roadway is to be provided. Details are shown in the bridge general drawing attached to the report.

Standard Specification for permanent bridges/culverts on various roads

Sl. No	Road Classification	Carriage Width (m)	Loading Capacity	Footpath
1	Asian Highway (AH-48)	7.50	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Optional
2	Primary National Highway (PNH)	7.00	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Optional
3	Secondary National Highway (SNH)	5.50	IRC Class A (double lane)	Optional
4	Dzongkhag Road	3.50	IRC Class A (single lane)	Optional
5	Farm road	3.50	IRC Class A (single lane)	
6	Thromde road	Varies from 7.50 to 15.00	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Both side 1.50m wide

Note: Bridges shall be designed for IRC class 70R (wheeled) loading and at least 5.5m carriage width irrespective of the load classification, if the road has potential of catering traffic to planned or Hydro Power Plants or Projects.
However, the width of the temporary bridges (bailey bridges) for single lane is 3.22m wide with 24R loading commonly used in farm roads and double lane bailey bridge of 7.30m wide can be used in the PNH and SNH for temporary measures.



Source: Bhutan Standards (left), Standards prepared by the study team (right)

Figure 2.2.17 Basic Width Composition of the Bridge Section

(c) Sidewalk Width

For the existing Passang Bridge, there are private houses, army office and frequent traffic of the people in the surrounding area. The new bridges are to be the reconstructed ones and offer the traveling performance satisfactory for vehicles through improvement of the road alignment. On the other hand, the road with satisfactory traveling performance for vehicles can be a risk (dangerous road) for pedestrians in the road environment without sidewalks. Considering such possibly dangerous situation, Bhutan requested to plan the sidewalk on the bridge so as to ensure the safety of pedestrians for Passang Bridge.

Considering the position of private houses relative to the new bridges, the sidewalk is to be provided to the downstream side and the upstream side relative to the roadway for Passang Bridge. Regarding the sidewalk width, Bhutan requested 1.5m as shown below. As the comparison with the Japanese standards shows, the requested width is considered applicable here as the safe width allowing two pedestrians to pass by safely (1.5m = 0.75m x 2) and allowing bicycles and wheeled chairs to pass (1.0m or more).

Department of Roads

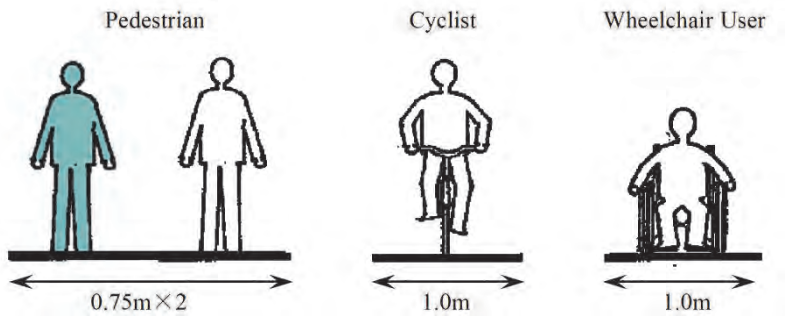
Subject: Request for planning footpath/ side walk at Passang zam on Gelephu-Trongsa Highway

Dear Sir,

With reference to **"Technical Notes for Reconstruction of Bridges on PNH No. 4"** which was signed between DoR and JICA Preparatory Survey Team (hereinafter referred to as "the Team") on 10th August 2015, DoR would like to request the Team to plan footpath / side walk (width 1.5 mtr on both sides) at Passang zam on Gelephu-Trongsa Highway. Since the bridge is located in an urban area footpath / side walk on both sides is necessary for smooth flow of pedestrian traffic including cyclists.

Source: Prepared by the Bhutanese counterpart

Figure 2.2.18 Bhutan's Request concerning Construction of the Sidewalk



Source: Explanation and operation of the Road Structure Ordinance, JAPAN

Figure 2.2.19 Width Occupied by the Road Users

3) River Conditions

(a) Setting the Clearance under Girder

The value (freeboard) to be added to the design high-water level according to the design high-water discharge of the target river is extracted from the table below. The extracted value is added to HWL. The clearance under girder is to be the "freeboard + HWL" or more and planned to prevent blockage of the space under the girder with driftwoods.

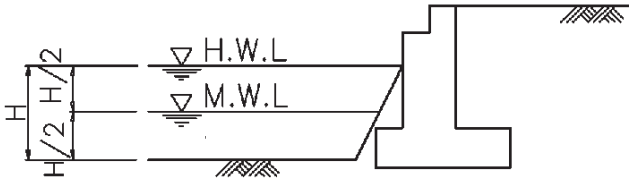
Table 2.2.18 Freeboard Appropriate for the Water Flow

Item	1	2	3	4	5	6
Design high-water discharge (t/s)	Less than 200	200 or more Less than 500	500 or more Less than 2000	2000 or more Less than 5000	5000 or more Less than 10000	10000 or more
Value to be added to the design high-water level (m)	0.6	0.8	1	1.2	1.5	2

Source: Government Ordinance for Structural Standards for River Administration Facilities, JAPAN

(b) Design Water Level

The design water level used for designing of the substructure is to comply with the Japanese standards (Specifications for Highway Bridges); normally HWL, but MWL (HWL – design bed height) x 1/2) in the case of earthquake. The water level during construction is to comply with the Japanese standards (Planning Manual, MLIT) and set by calculating the 10-year river flow during the draught period (November to April in principle).



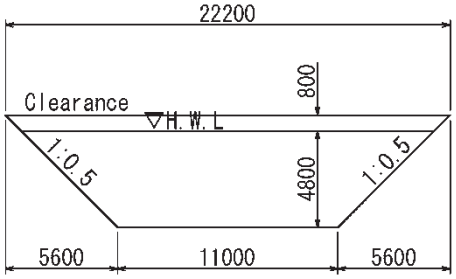
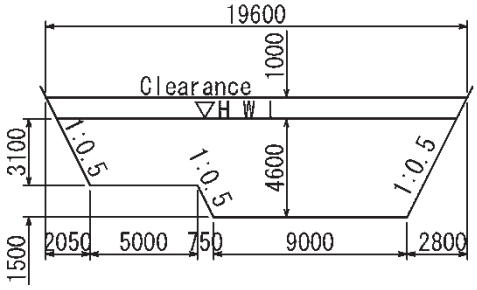
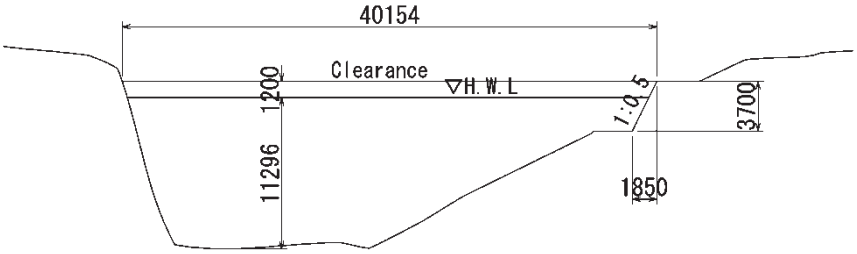
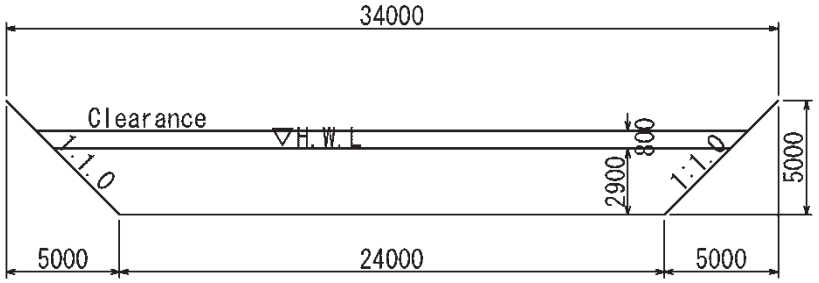
Source: Planning manual, MLIT, JAPAN

Figure 2.2.20 Design Water Level

(c) River Gauge Section

After setting the river gauge section on the basis of the flow of the target rivers determined in this survey, the bridge length, substructure planning position, revetment plan are to be determined in accordance with the Japanese standards (Government Ordinance for Structural Standards for River Administration Facilities). The river gauge section of each bridge as determined from the above description is shown in the table below.

Table 2.2.19 River Conditions of Each Bridge

Bridge	River gauge section
Telegangchu Design high-water discharge: 390(m^3/s) Flow during construction: 70(m^3/s)	
Beteni Design high-water discharge: 900(m^3/s) Flow during construction: 60(m^3/s)	
Samkhara Design high-water discharge: 3030(m^3/s) Flow during construction: 560(m^3/s)	
Passang Design high-water discharge: 200(m^3/s) Flow during construction: 20(m^3/s)	

Source: Prepared by the study team

4) Ground Conditions

(a) Foundation Ground Reaction upper limit and Coefficient of Friction

When the bearing stratum is rocks, the bearing force of ground is examined by referring to the upper limit of the foundation ground reaction shown in the table below. When the bearing stratum is gravels, the bearing force of ground is examined by the extreme support power degree calculated from gravel condition. The coefficient of friction tanφB to be used in the examination of slide is 0.6. In case of the pile foundation plan, the bearing force of ground is examined by referring the specifications for Highway Bridges of Japan.

Table 2.2.20 Upper Limit (kN/m^2) of Maximum Degree of Foundation Ground Reaction (above) & Rock Classification (below)

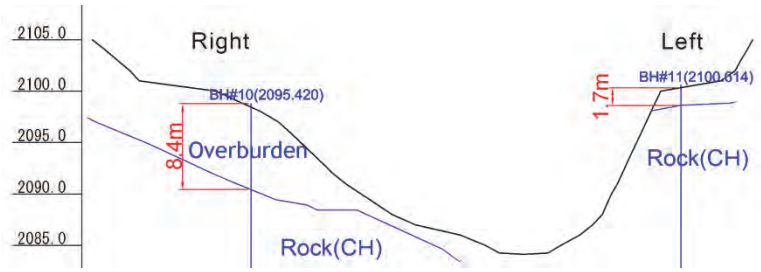
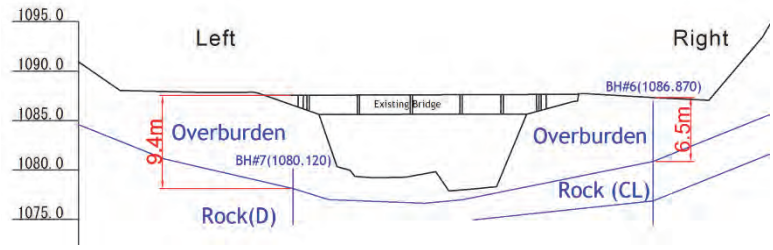
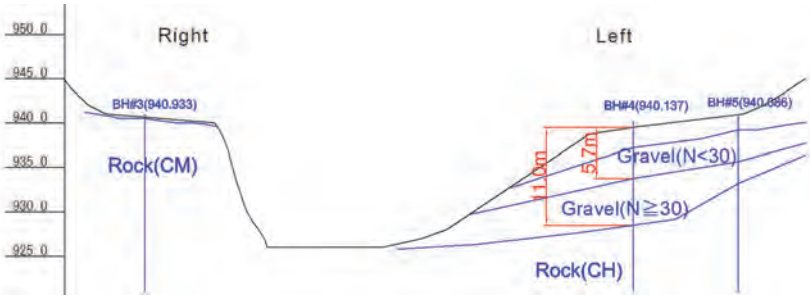
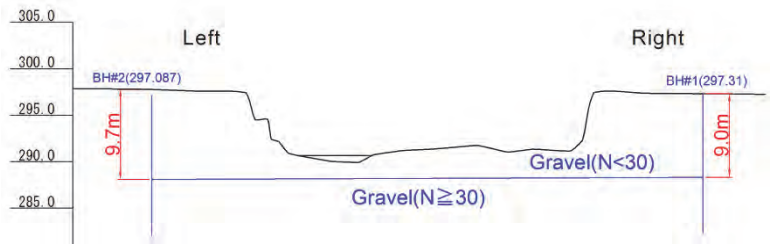
Ground type		Max degree of subgrade reaction
Hard rock	Few cracks	2,500
	Many cracks	1,000
Soft rock, mud stone		600
Gravel ground		700
Sand ground		400
Clayey ground		200

Rock Classification		Slate				Granite		
		c (kN/m^2)		φ(°)		c (kN/m^2)		φ(°)
		Coverage	Ave.	Coverage	Ave.	Coverage	Representative value	Representative value
Hard rock	B	2,250-2,750	2,500	40-50	45	1,500-2,500	1,500	45
	CH	1,750-2,250	2,000	35-45	40	1,000-2,000	1,000	40
	CM	750-1,750	1,250	35-45	40	500-1,000	500	40
Soft rock	CL	250-750	500	30-40	35	100-1,000	100	37
	D	Less than 100	0	20-30	25	0-500	0	30-35

Source: Specifications for Highway Bridges (above), NEXCO Design Procedure (below), JAPAN

(b) Ground Condition of Each Bridge

Table 2.2.21 Ground Condition of Each Bridge

	Cross-sectional view	Condition
Telegangchu		On the right bank, the rock layer exists at the depth of 9 m below the design road surface. On the left bank, the rock layer exists at the depth of 2 m below the design road surface.
Beteni		On the left bank, the rock layer exists at the depth of 10 m below the design road surface. On the right bank, the rock layer exists at the depth of 7 m below the design road surface.
Samkhara		On the right bank, the rock layer exists at the surface. On the left bank, the gravel layer exists at the depth of 6 m below the surface. And the rock layer exists at the depth of 5m below the end of the gravel layer.
Passang		On the right bank, the gravel layer exists at the depth of 9 m below the design road surface. On the left bank, the gravel layer exists at the depth of 10 m below the design road surface.

Source: Prepared by the study team

5) Seismic Condition

For the design horizontal seismic coefficient (the coefficient for calculation of seismic force) used in the design, 0.36 of "Zone V" in the seismic zone map of IRC Codes is used. The value determined from this by using the equation of the above Codes, that is, 0.22, is adopted.

$Kh = (Z/2) \times (Sa/g) / (R/I) \times \alpha = 0.216$

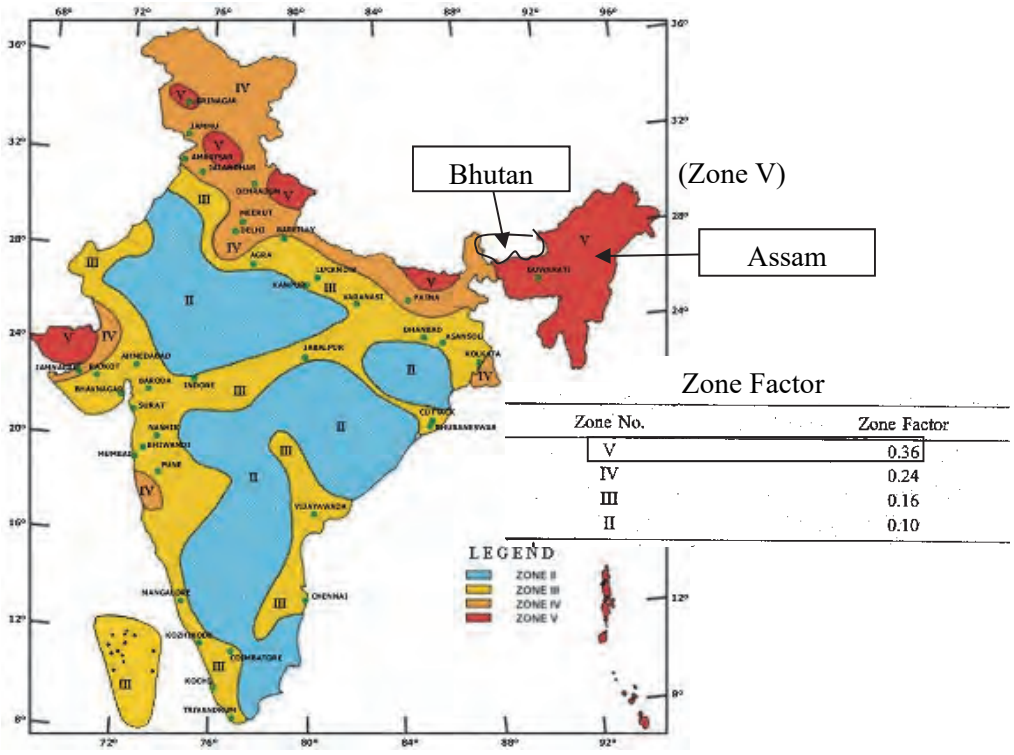
Wherein: Z: Zone factor (V) = 0.36

Sa/g: 2.5 (T＜0.5sec : h=0.05)

R: Response reduction factor (=2.5)

I: Importance factor (=1.2 from DoR)

A: Compensating rate due to difference in damping constant (=1.0)



Source: IRC Codes

Figure 2.2.21 Zone Factor for Earthquakes in the Assam District

6) Constants used in the Design

(a) Design Load

The design load to be used is the load that is selected as critical from the single lane 70R and the double lane Class A live load. They have been determined from the Bhutan design standard based on the IRC Codes.

Table 2.2.22 Design Live-Load

SL No	Road Classification	Carriage Width (m)	Loading Capacity	Footpath
1	Asian Highway (AH-48)	7.50	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Optional
2	Primary National Highway (PNH)	7.00	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Optional
3	Secondary National Highway (SNH)	5.50	IRC Class A (double lane)	Optional
4	Dzongkhag Road	3.50	IRC Class A (single lane)	Optional
5	Farm road	3.50	IRC Class A (single lane)	
6	Thromde road	Varies from 7.50 to 15.00	Single lane IRC 70R (wheeled) or Double lane IRC class A (whichever is critical)	Both side 1.50m wide

Source: Bhutan Standards

(b) Material to be Used

The standard and specified design strength of materials used are as shown below. For the concrete, the minimum specified strength value of plain concrete, reinforced concrete, and pre-stressed concrete is used. Regarding the reinforcement, the reinforcement manufacturing plant of Bhutan is inspected and the Japanese reinforcement specifications appropriate to the material strength data obtained in the plant are assumed and adopted.

Table 2.2.23 Concrete Specified Strength

Use classification	Specified design strength (N/mm^2)
Plain concrete	18
Reinforced concrete	21
Pre-stressed concrete	30

Source: Specifications for Highway Bridges, JAPAN

Table 2.2.24 Specifications of Reinforcement

Name of reinforcement product of Bhutan	Japanese specifications
IR500 (Yield point =500, tensile strength =545)	SD345 (Yield point=345～440, tensile strength =490 or more)

Source: Specifications for Highway Bridges, JAPAN

(c) Unit Weight

The unit weights used in the design calculation is summarized below.

Table 2.2.25 Unit Weight (kN/m^3)

Use classification	Unit weight
Plain concrete	23.0
Reinforced concrete	24.5
Prestressed concrete	24.5
Pavement	22.5

Ground	Soil	Loose	Tight
Natural ground	Sand and gravel	18	20
	Sandy	17	19
	Clayey	14	18
Embankment	Sand and gravel	20	
	Sandy	19	
	Clayey	18	

Source: Specifications for Highway Bridges, JAPAN

(d) Allowable Values

The allowable values used in the design calculation are summarized below.

Table 2.2.26 Allowable Compressive Stress for Reinforced Concrete (N/mm^2)

Type of stress \ Specified design concrete strength	18	21	24	27	30
1) Bending compressive stress	6.0	7.0	8.0	9.0	10.0
2) Axial compressive stress	4.5	5.5	6.5	7.5	8.5

Source: Specifications for Highway Bridges, JAPAN

Table 2.2.27 Allowable Compressive Stress for Pre-stressed Concrete (N/mm^2)

Type of stress \ Specified design concrete strength			30	40	50	60
Immediately after prestressing	Bending compressive stress	1) For rectangular section	15.0	19.0	21.0	23.0
		2) For T-shaped and box-shaped section	14.0	18.0	20.0	22.0
	3) Axial compressive stress		11.0	14.5	16.0	17.0
Others	Bending compressive stress	4) For rectangular section	12.0	15.0	17.0	19.0
		5) For T-shaped and box-shaped section	11.0	14.0	16.0	18.0
	6) Axial compressive stress		8.5	11.0	13.5	15.0

Source: Specifications for Highway Bridges, JAPAN

Table 2.2.28 Allowable Stress of Reinforcing Bar (N/mm^2)

Stress, type of members \ Type of reinforcing bar			SD345
Tensile stress	1) Principal load other than live load and impact		100
	2) Basic value of allowable stress when the load combination does not take the effect of collision load or earthquake into account	General members	180
		Slab and slab bridge with the span length of 10 m or less	140
	3) Basic value of allowable stress when the load combination takes into account the effect of collision load or earthquake	Consideration in the axial direction of girder	200
		Others	200
	4) Basic value of allowable stress when the length of reinforcement lapped joint or development is calculated		200
5) Compressive stress			200

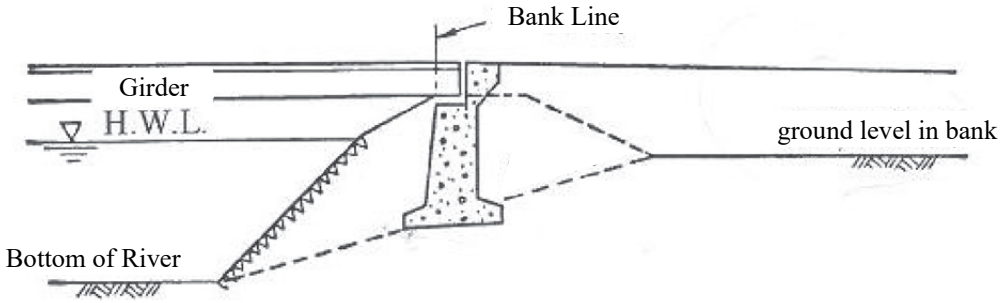
Source: Specifications for Highway Bridges, JAPAN

(2) Bridge Basic Plan

1) Setting the Abutment Position (Bridge Length)

(a) Plan according to the Government Ordinance for Structural Standards for River Administration Facilities, JAPAN

For bridges which is planned to construct the abutment near the river side, the abutment position (bridge length) is set on the basis of Government Ordinance for Structural Standards for River Administration Facilities. As the river width is 50 m or less, the plan is not to provide the front surface of abutment vertical wall closer to the river from the top of slope of bank.

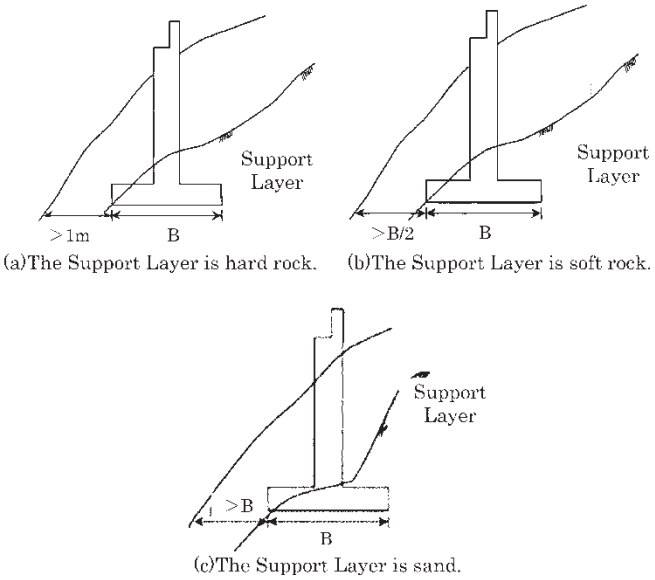


Source: Government Ordinance for Structural Standards for River Administration Facilities, JAPAN

Figure 2.2.22 Abutment Position Relative to the River

(b) Plan to set the Abutment on the Slope

For bridges which is planned to construct the abutment on the slope. The abutment position (bridge length) is set by securing separation from the slope on the basis of the state of bearing stratum. The figure below shows the separation.



Source: Planning Manual, MLIT, JAPAN

Figure 2.2.23 Abutment Position Relative to the Slope

(c) Considerations concerning the Skew Angle of Abutment

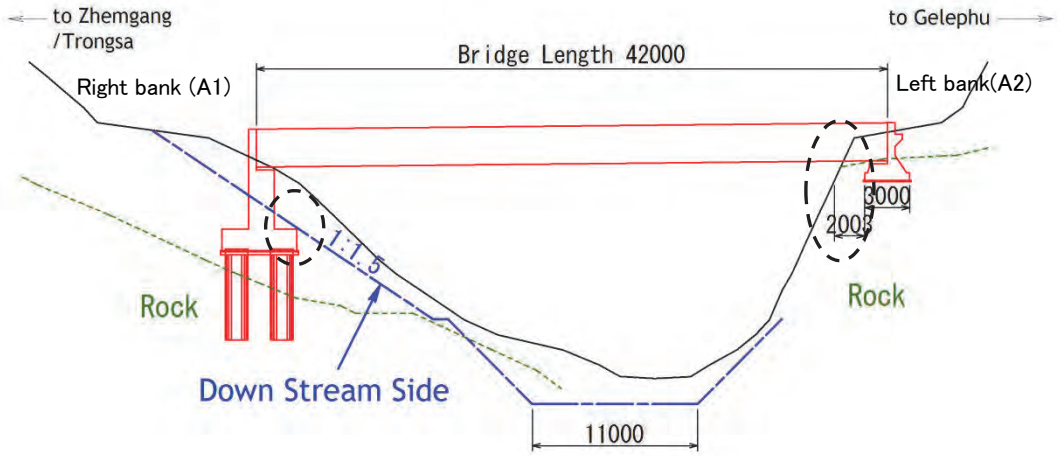
Passang Bridge will have the skew angle because of the road horizontal alignment, river alignment, and topographical condition. When the oblique angle is small (generally, less than 60°), the earth pressure direction acting on the abutment from its rear side will differ greatly from the direction of inertia force of the superstructure under seismic effect. Actually, the Specifications for Highway Bridges describe that such phenomenon contains too many unknown elements for exact solution. If the slab is configured to a plain with an oblique angle of smaller than 75° relative to the earth-pressure acting direction, instability due to rotation of the abutment may possibly occur because the center-of-gravity position is greatly deviated from the center of the resultant force of effects of the earth pressure. Consequently, the oblique angle of the bridge (the oblique angle of vertical wall) must be set to 60° or more relative to the superstructure while that of slab must be 75° or more relative to the vertical wall.

2) Setting the Length of Each Bridge

(a) Telegangchu Bridge

We planned the abutment (A1) of the right bank side of the Telegangchu Bridge is set under the river side slope. In case of this bridge, if this abutment is planned near the mountain side, amount of the cutting soil under the construction become larger, and the width of this abutment becomes larger because of road alignment. If this abutment is planned near the river side, the size of this abutment becomes larger because the height of this abutment becomes higher and soil pressure become larger. Finally we planned the position of this abutment with piles by our comparison and study. The abutment (A2) of the left side needs the separation from slop to the abutment because this abutment is planned on the slope. This separation is to comply with the Japanese standards, and finally we

planned this separation is 2m because of considering weathered rock from our study. From the above the length of this bridge is 42m.



Source: Prepared by the study team

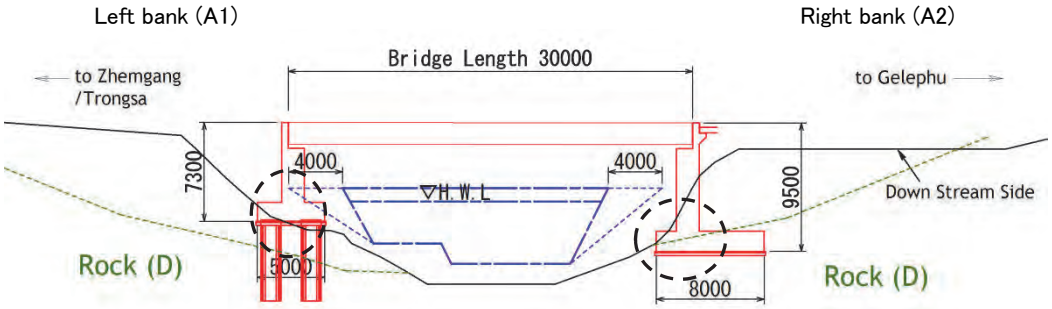
Figure 2.2.24 Abutment Position of Telegangchu Bridge

(b) Beteni Bridge

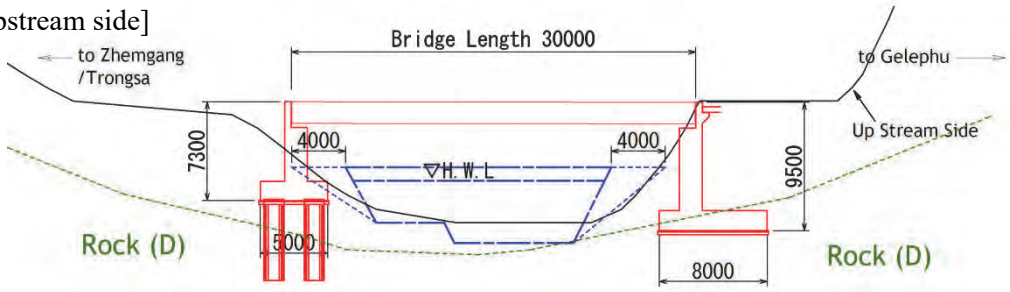
In Beteni Bridge, the topography of upstream side is different from the topography of the downstream side. We must consider the difference about planning the abutments.

The abutment (A1) of the left bank side has the constraint condition which is near the existing road and private land on the hill. Finally we planned the position of this abutment with piles by our comparison and study. For this plan and near river side, the abutment position is set on the basis of Government Ordinance for Structural Standards for River Administration Facilities. Then we planned about the abutment (A2) of the right bank side, the foundation type is spread foundation because the ground level of the downstream side is near the support layer. This situation is difficult to plan the pile foundation. From the above the length of this bridge is 30m.

[Downstream side]



[Upstream side]



Source: Prepared by the study team

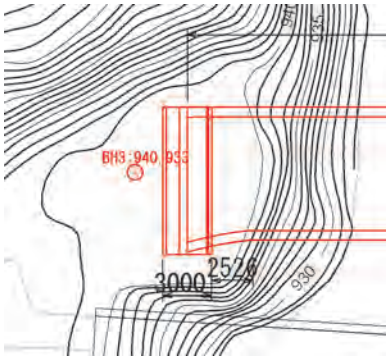
Figure 2.2.25 Abutment Position of Beteni Bridge

(c) Samkhara Bridge

In Samkhara Bridge, we planned the abutment in consideration of the topography situation and near existing bridge.

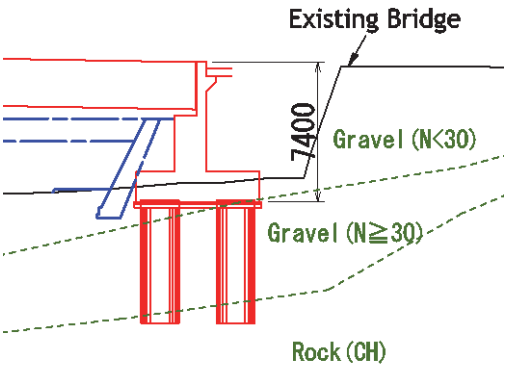
The abutment (A1) of the right side needs the separation from slop to the abutment because this abutment is planned on the slope. This separation is to comply with the Japanese standards, and finally we planned this separation is 2.5m because of considering weathered rock from our study and putting this abutment at the center of flat ground (it is shown below picture). In the abutment (A2) of the left side, there is the former abutment. This former abutment with filling road is standing out against a ground. We planned the bottom of abutment is set under this ground level and the position of the abutment is planned by river condition. From the above the length of this bridge is 49.5m.

Right bank (A1)

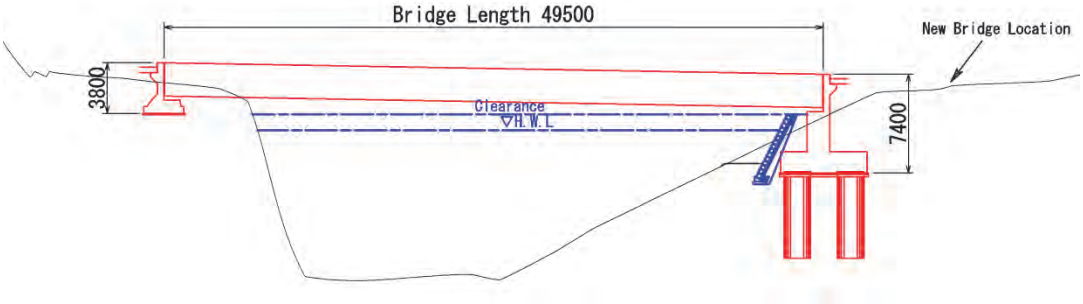


* A1 is set at the center of flat ground

Left bank (A2)



* The bottom of A2 is under the ground level (black line).



Source: Prepared by the study team

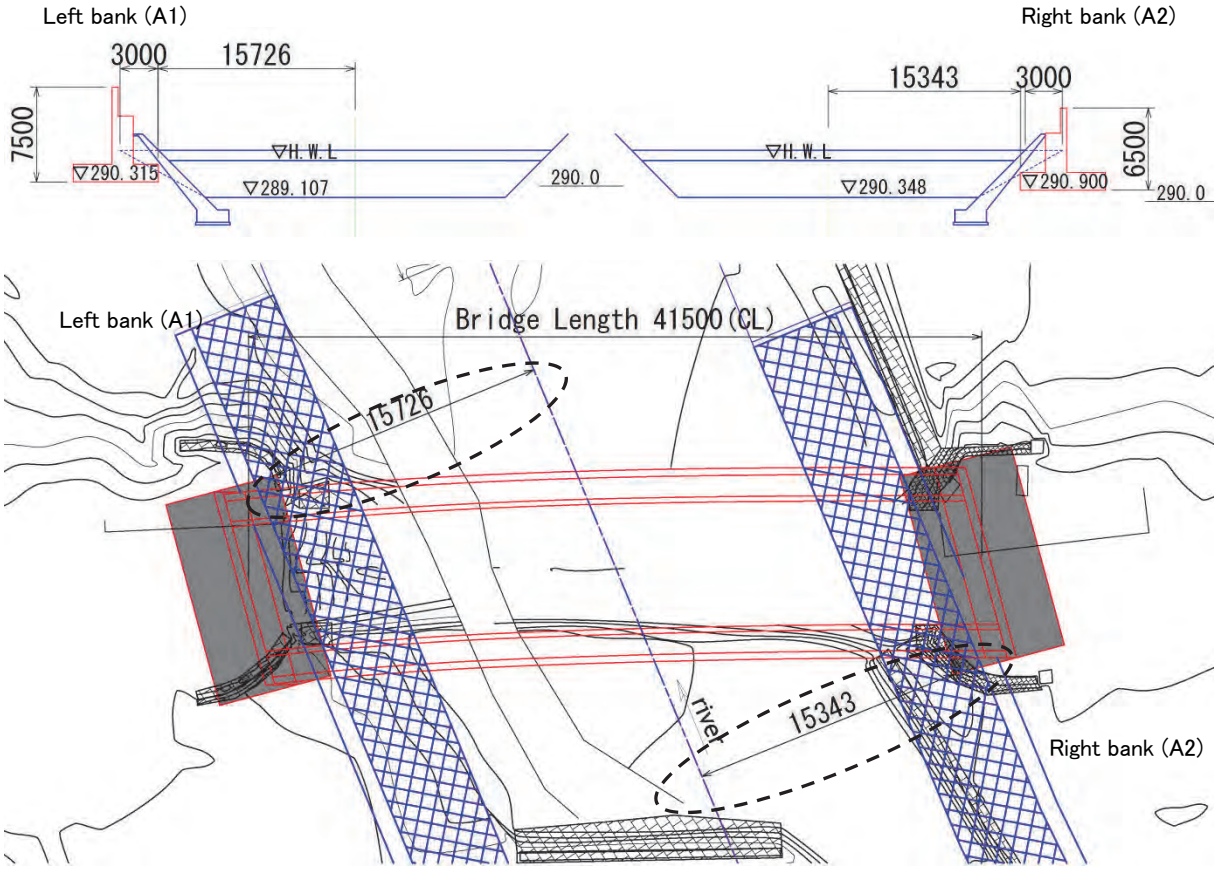
Figure 2.2.26 Abutment position of Samkhara bridge

(d) Passang Bridge

In Passang Bridge, we planned the abutment in consideration of the river condition and near existing bridge.

The abutment (A1) of the left side is planned by considering the separation from abutment to revetment in left downstream side. The abutment (A2) of the right side is planned by considering the separation from abutment to revetment in right upstream side. And the bottom of abutment is set on the basis of Government Ordinance for Structural Standards for River Administration Facilities.

From the above the length of this bridge is 41.5m.



Source: Prepared by the study team

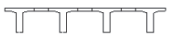
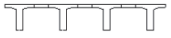
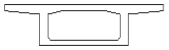
Figure 2.2.27 Abutment position of Passang bridge

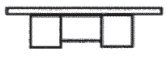
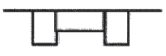
3) Selection of the Superstructure Type

(a) Initial Selection

The bridge length is 42.0 m for Telegangchu Bridge, 30.0 m for Beteni Bridge, 49.5 m for Samkhara Bridge, and 41.5 m for Passang Bridge. According to the table below, the post-tensioned T-girder bridge, slab bridge (only Beteni Bridge) and the box-girder bridge can be extracted for the pre-stressed concrete bridge. For the steel bridge, the plate-girder (I-girder) bridge and steel box-girder bridge can be chosen.

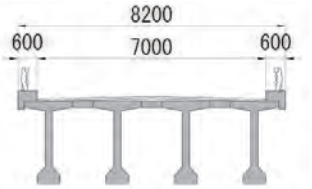
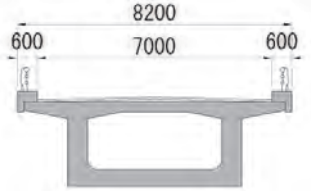
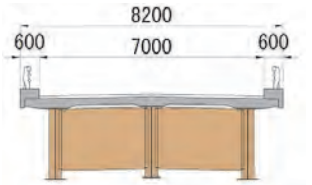
Table 2.2.29 Standard Applicable Span Length by Type
(Upper: Pre-stressed concrete bridge, Under: Steel bridge)

Applicable span length by bridge type					
Type			Shape	Construction method	Span (m)
Prestressed concrete bridge	Factory products	slab		crane truck	5～24
		T-girder		crane truck	18～24
	Site products	T-girder		crane truck or erection beam	20～45
		slab		stationary falsework	20～30
		Box -girder		stationary falsework	30～60

Applicable span length by bridge type					
Type			Shape	Construction method	Span (m)
Steel bridge	Girder bridge	I-girder		crane truck	30～60
		Box-girder (RC slab)		crane truck	40～80
		Box-girder (Steel plate)		crane truck	40～150
	Truss bridge			Tower crane	60～120
	Arch bridge			Tower crane	60～200

Source: Planning manual, MLIT

Table 2.2.30 Features of Each Bridge Type

Item	Prestressed-concrete T-girder bridge	Prestressed-concrete box-girder bridge	Steel plate-girder bridge (including the box-girder bridge)
Superstructure section			
Material availability	Many materials, such aggregate, etc. are procurable domestically. **Namely, procurement at low price is possible.**	Many materials, such aggregate, etc. are procurable domestically. **Namely, procurement at low price is possible.**	Materials have to be imported from other countries because there is no production plant in Bhutan. **Expensive when compared with concrete materials.**
Construction method	The gantry crane installed at the abutment is used to transport the girders manufactured on the backside of abutment for erection (erection of erection girders). If crane erection is to be used, two 200t cranes are necessary and the construction work in the narrow portion is difficult. **Since the work within the river is not included, the construction work can be done even in the rainy season.**	Erection is made by providing the falsework within the river and by means of cast-in-place placement. **The construction work during rainy season is difficult.**	Bent is installed within the river for erection by means of crane or launching method. A 100-ton class crane is necessary and the construction work in the narrow section is difficult. And the transportation of the steel is general to use a trailer. This transportation is difficult in case of a road with a lot of curved lines and small road width. **The number of days for erection in the site is less than those for the concrete bridge (cast-in-place pile).**
Maintenance	In principle, **maintenance is not necessary.**	In principle, **maintenance is not necessary**	If the weather-resistant steels are employed, there is no need of maintenance by re-coating of paint.

Source: Prepared by the study team

(b) Secondary Selection

The type of bridge is determined by this secondary selection. The secondary selection has some bridge type from primary selection. The determination of bridge type in this secondary selection depends on the construction cost, the experience of construction in Bhutan, the transportation method and the materials acquisition, etc. The plan of bridge type is shown below table.

Table 2.2.31 The Plan of Bridge Type in Secondary Selection

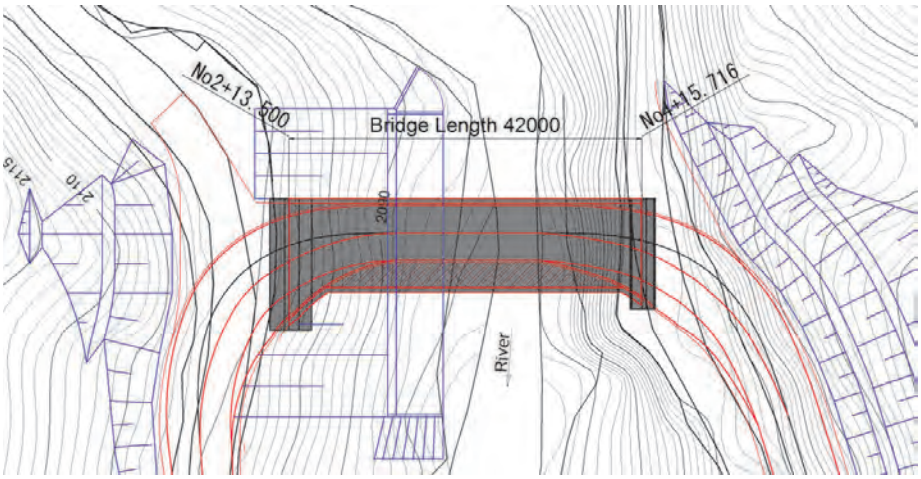
Bridge	Plan	Reason of plan
Telegangchu	• PC-Box girder • Steel-I girder	The bridge length is 42m. The construction yard is very narrow because of surrounding by the mountains so it is difficult to construct by using the large crane. And the large crane is noting in Bhutan and the transportation of the large crane from other country is very difficult because the road to this area is very narrow. For this condition, the construction of girder by using the large crane is difficult, but the girder type by cast-in-place like PC-Box girder is possible to construct. And Steel-I girder is not easy to construct. The possibility depends on the cost and the size of steel member.
Beteni	• PC-Slab bridge • PC-Box girder • Steel-I girder	The bridge length is 30m. The construction yard is very narrow because of surrounding by the mountains so it is difficult to construct by using the large crane. And the large crane is noting in Bhutan and the transportation of the large crane from other country is very difficult because the road to this area is very narrow. For this condition, the construction of girder by using the large crane is difficult, but the girder type by cast-in-place like slab bridge and PC-Box girder is possible to construct. And Steel-I girder is not easy to construct. The possibility depends on the cost and the size of steel member.
Samkhara	• PC-Box girder • Steel-I girder	The bridge length is 50m. The construction yard is very narrow because of surrounding by the mountains so it is difficult to construct by using the large crane. And the large crane is noting in Bhutan and the transportation of the large crane from other country is very difficult because the road to this area is very narrow. For this condition, the construction of girder by using the large crane is difficult, but the girder type by cast-in-place like PC-Box girder is possible to construct. And Steel-I girder is not easy to construct. The possibility depends on the cost and the size of steel member.
Passang	• PC-Box girder • Steel-I girder	The bridge length is 41.5m. The construction yard is near the private area and army office so it is not free to use the area for construction and difficult to construct by using the large crane. And the large crane is noting in Bhutan and the transportation of the large crane from other country is very difficult because the road to this area is very narrow. For this condition, the construction of girder by using the large crane is difficult, but the girder type by cast-in-place like PC-Box girder is possible to construct. And Steel-I girder is not easy to construct. The possibility depends on the cost and the size of steel member.

Source: Prepared by the study team

(c) Determination of the Adopted Plan

i) Telegangchu Bridge

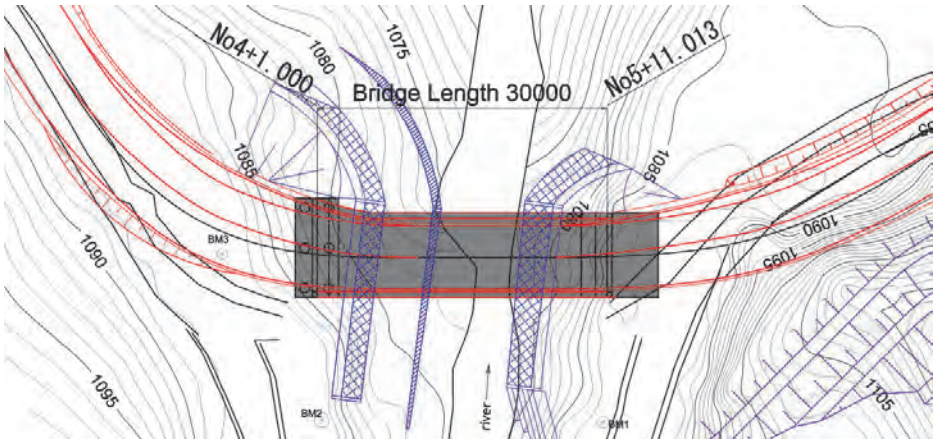
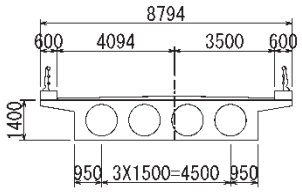
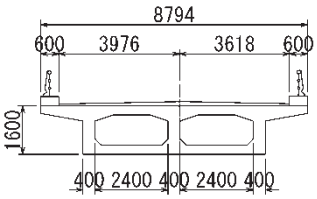
Table 2.2.32 Telegangchu Bridge Comparison of Secondary Selection

Plan view		
Plans proposed	Plan 1: Prestressed-concrete box-girder bridge	Plan 2: Steel box-girder bridge
Example		
Outline of the bridge	The girders are prestressed-concrete members while the slabs are reinforced-concrete members. The sectional shape of girders is box and constructed according to the timbering construction method. Bhutan has the experience of constructing this type of bridge.	The girders are steel members while the slabs are reinforced-concrete members. The girders are manufactured in the plant, divided into components, and transported to the site. In the site, divided parts are assembled into girders, which are erected with a crane.
Site applicability	Erection is done by constructing the timbering within the river. Erection is possible when the construction is based on the river flow during non-flood season. (OK)	The girder manufacturing plant does not exist in Bhutan, so that girders are to be manufactured outside Bhutan and transported to the site, Since the site is narrow, installation of large crane is difficult. (NG)
Maintenance	It is possible to inspect the girder for the maintenance from the inspection hole. (OK)	The maintenance for girder is needless by adopting the atmospheric corrosion resisting steel for the girder. (OK)
Economy (ratio)	1.000	1.087
Evaluation	1st This type is adopted by the cost.	2nd

Source: Prepared by the study team

ii) Beteni Bridge

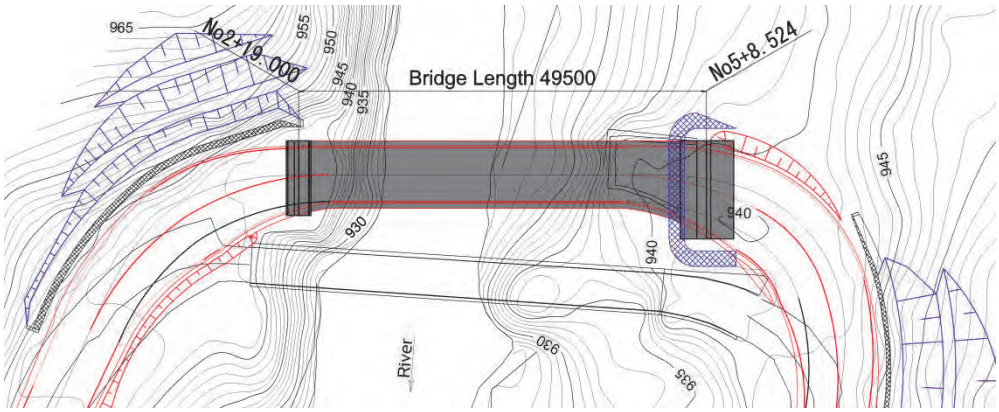
Table 2.2.33 Beteni Bridge Comparison of Secondary Selection

Plan view			
Plans proposed	Plan 2: Prestressed-concrete slab bridge	Plan 2: Prestressed-concrete box-girder bridge	Plan 3: Steel box-girder bridge
Example			
Outline of the bridge	This type is prestressed-concrete slab bridge. The shape of the girder is like a plate. The height of the structure is small so the appearance of this bridge is superior. Bhutan has the experience of this bridge type constructed by other country.	The girders are prestressed-concrete members while the slabs are reinforced-concrete members. The sectional shape of girders is box and constructed according to the timbering construction method. Bhutan has the experience of constructing this type of bridge.	The girders are steel members while the slabs are reinforced-concrete members. The girders are manufactured in the plant, divided into components, and transported to the site. In the site, divided parts are assembled into girders, which are erected with a crane.
Site applicability	Erection is done by constructing the timbering within the river. Erection is possible when the construction is based on the river flow during non-flood season. It is reported in Japan that assembling the reinforcement and casting the concrete is not easy because the section is small. (Moderate)	Erection is done by constructing the timbering within the river. Erection is possible when the construction is based on the river flow during non-flood season. (OK)	The girder manufacturing plant does not exist in Bhutan, so that girders are to be manufactured outside Bhutan and transported to the site, Since the site is narrow, installation of large crane is difficult. (NG)
Maintenance	After service, it is impossible to inspect the inside of the girder for the maintenance because of .closing. (NG)	It is possible to inspect the girder for the maintenance from the inspection hole. (OK)	The maintenance for girder is needless by adopting the atmospheric corrosion resisting steel for the girder. (OK)
Economy (ratio)	1.000	1.016	1.168
Evaluation	2nd	1st Light construction and maintenance.	3rd

Source: Prepared by the study team

iii) Samkhara Bridge

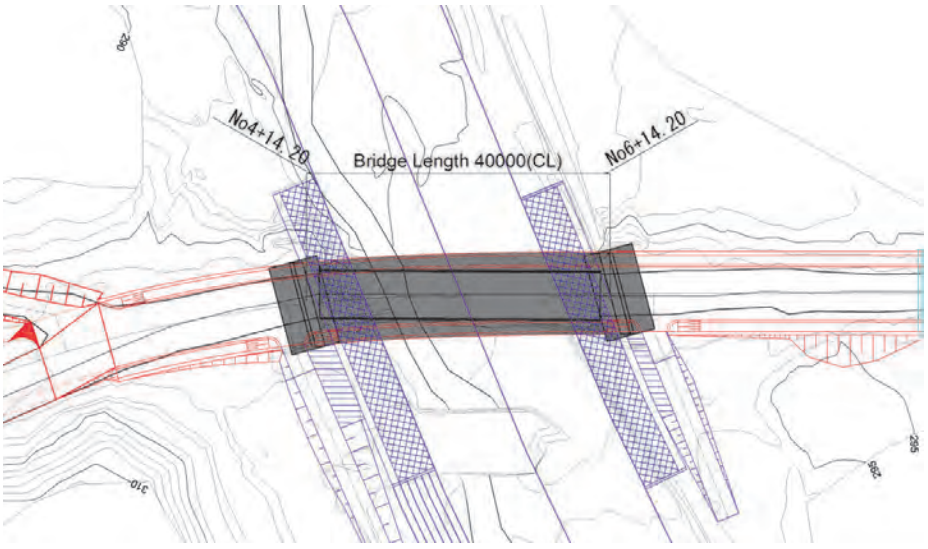
Table 2.2.34 Samkhara Bridge Comparison of Secondary Selection

Plan view		
Plans proposed	Plan 1: Prestressed-concrete box-girder bridge	Plan 2: Steel box-girder bridge
Example		
Outline of the bridge	The girders are prestressed-concrete members while the slabs are reinforced-concrete members. The sectional shape of girders is box and constructed according to the timbering construction method. Bhutan has the experience of constructing this type of bridge.	The girders are steel members while the slabs are reinforced-concrete members. The girders are manufactured in the plant, divided into components, and transported to the site. In the site, divided parts are assembled into girders, which are erected with a crane.
Site applicability	Erection is done by constructing the timbering within the river. Erection is possible when the construction is based on the river flow during non-flood season. (OK)	The girder manufacturing plant does not exist in Bhutan, so that girders are to be manufactured outside Bhutan and transported to the site, Since the site is narrow, installation of large crane is difficult. (NG)
Maintenance	It is possible to inspect the girder for the maintenance from the inspection hole. (OK)	The maintenance for girder is needless by adopting the atmospheric corrosion resisting steel for the girder. (OK)
Economy (ratio)	1.000	1.021
Evaluation	1st This type is adopted by the cost.	2nd

Source: Prepared by the study team

iv) Passang Bridge

Table 2.2.35 Passang Bridge Comparison of secondary selection

Plan view		
Plans proposed	Plan 1: Prestressed-concrete box-girder bridge	Plan 2: Steel box-girder bridge
Example		
Outline of the bridge	The girders are prestressed-concrete members while the slabs are reinforced-concrete members. The sectional shape of girders is box and constructed according to the timbering construction method. Bhutan has the experience of constructing this type of bridge.	The girders are steel members while the slabs are reinforced-concrete members. The girders are manufactured in the plant, divided into components, and transported to the site. In the site, divided parts are assembled into girders, which are erected with a crane.
Site applicability	Erection is done by constructing the timbering within the river. Erection is possible when the construction is based on the river flow during non-flood season. (OK)	The girder manufacturing plant does not exist in Bhutan, so that girders are to be manufactured outside Bhutan and transported to the site, Since the site is narrow, installation of large crane is difficult. (NG)
Maintenance	It is possible to inspect the girder for the maintenance from the inspection hole. (OK)	The maintenance for girder is needless by adopting the atmospheric corrosion resisting steel for the girder. (OK)
Economy (ratio)	1.000	1.086
Evaluation	1st This type is adopted by the cost.	2nd

Source: Prepared by the study team

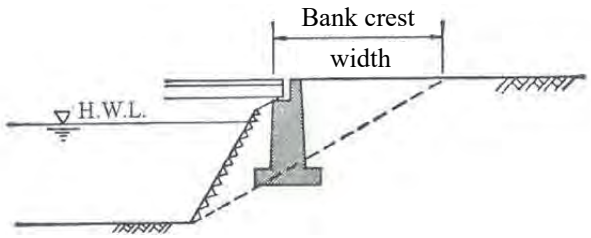
4) Selection of Substructure Type

(a) Substructure Height Determined on the Relationship between the Bearing Stratum Position and the Height of Road Surface

On the basis of the relationship between the new road and the bearing stratum position, the structural height of substructure of each bridge is as shown below:

- Telegangchu Bridge → Right bank=10 - 12m, Left bank=5m or less
- Beteni Bridge → Right ban=10 - 12m, Left bank =10 - 12m
- Samkhara Bridge → Right ban=5m or less, Left bank =10 - 12m
- Passang Bridge → Right ban=10 - 12m, Left bank =10 - 12m

Being bridges over the artificially-excavated river bed, A1 abutment of Telegangchu Bridge, A1 abutment of Beteni Bridge and both abutments of Passang Bridge must have the abutment bottom slabs established below the line connecting the bank crest width to the toe of slope (see the figure below) or below the bearing stratum. As the bearing layer is below the river bed, the slab position is also below the river bed, namely below the line connecting to the toe of slope. Accordingly, the plan meets this specification.



Source: Government Ordinance for Structural Standards for River Administration Facilities, JAPAN

Figure 2.2.28 Abutment Bottom-slab Position

(b) Determination of the Adopted Plan

The adopted plan is selected from the table below according to the structural height of substructure.

- Telegangchu Bridge → Inverted-T abutment on the right bank and gravity-type abutment on the left bank
- Beteni Bridge → Inverted-T abutment on both banks
- Samkhara Bridge → gravity-type abutment on the right bank and Inverted-T abutment on the left bank
- Passang Bridge → Inverted-T abutment on both banks

Table 2.2.36 Guideline for Selection of Abutment Type

Type	Height (m) 10 20 30	Image
Gravity	3 5	
Reverse-T	5 15	
Counterfort	12 15	
Rigid	15	
Box	12	
Buried	5 7 10	

Source: Planning Manual, MLIT, JAPAN

5) Selection of Foundation Type

(a) Outline of Comparing the Foundation

The type of foundation in each bridge is determined by comparison including the cost and soil condition. The plan of foundation type is shown below table.

Table 2.2.37 The Plan of Foundation Type

Bridge	Plan	Reason of plan
Telegangchu	[Right bank] pile or spread foundation	In case of the plan of the spread foundation type, the size of abutment becomes larger because of depth of support layer. So the plan of the pile is added to the comparison.
	[Left bank] spread foundation	**Adopted**
Beteni	[Right bank] spread foundation	**Adopted** In case of the plan of the pile foundation type, pile will be located above the existing land. In this case, the abutment will be set inside of embankment and it has a lot of issues to adopt in terms of quality management and maintenance of material of embankment. Thus it shall not be adopted.
	[Left bank] pile or spread foundation	In case of the plan of the spread foundation type, the size of abutment becomes larger because of depth of support layer. And the private area near the abutment is influenced by the yard of construction. So the plan of the pile is added to the comparison.
Samkhara	[Right bank] spread foundation	**Adopted**
	[Left bank] pile or spread foundation	In case of the plan of the spread foundation type, the size of abutment becomes larger because of depth of support layer. So the plan of the pile is added to the comparison.
Passang	[both bank] pile or spread foundation	In case of the plan of the spread foundation type, the size of abutment becomes larger because support layer is gravel. So the plan of the pile is added to the comparison.

Source: Prepared by the study team

(b) Selection of Pile Type

There is the gravel in the middle layer from the result of geological survey. And the size of gravel is more than 100mm. And the yard of constructing piles is narrow in the all bridges.

From the above the concrete pile casted in place is chosen by below table.

Table 2.2.38 Adaptability of Pile Type

Adaptability				Pile foundation												
				Driving pile			Pile installation by inner excavation						Steel with soil pile	Concrete pile in site			
				PHC・SC	Steel-Pile		PHC-pile・SC-pile			Steel-Pile				All-casing	Reverse	Drill	Cast in place
				PHC・SC	Driving	Vibratory hammer	Last blow	Spout stirring	Concrete-cast	Last blow	Spout stirring	Concrete-cast	Steel with soil pile	All-casing	Reverse	Drill	Cast in place
Soil condition	From ground to support layer	There is an extremely soft layer in the near ground or middle		○	○	○	○	○	○	○	○	○	○	×	○	○	×
		There is an extremely hard layer in the middle layer.		△	△	△	○	○	○	○	○	○	○	△	○	×	○
		Gravel in the middle layer	Size 50mm less than	△	○	○	○	○	○	○	○	○	○	○	○	○	○
			Size 50～100mm	△	△	△	△	△	△	△	△	△	○	△	×	○	○
			Size 100～500mm	×	×	×	×	×	×	×	×	×	×	△	×	×	○
	Support layer	depth	5m less than	×	×	×	×	×	×	×	×	×	×	×	×	×	○
			5～15m	○	○	○	○	○	○	○	○	○	○	○	△	○	○
			15～25m	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			25～40m	○	○	○	○	○	○	○	○	○	○	○	○	△	△
			40～60m	△	○	○	△	△	△	○	○	○	○	△	×	○	×
			60m more than	×	△	△	×	×	×	×	×	×	△	×	△	×	×
		soil type	Sand, Gravel (30≦N)	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			Cohesive soil (20≦N)	○	○	○	○	△	×	○	△	×	△	○	○	○	○
			Rock	×	○	△	○	△	×	○	△	×	△	○	○	○	△
			Hard rock	×	×	×	×	×	×	×	×	×	×	△	△	△	○
		The slope of support layer is steep.		△	△	△	△	△	△	△	△	△	△	○	○	○	○
	ground water	The water level is near ground.		○	○	○	○	○	○	○	○	○	○	△	△	△	△
		The amount of water is much.		○	○	○	○	○	○	○	○	○	△	△	△	△	×
		The height of water is more than 2m from the ground.		○	○	○	×	×	×	×	×	×	×	×	×	×	×
		The velocity of water is more than 3m/min.		○	○	○	○	×	×	○	×	×	×	×	×	×	×
Support type		Support pile		○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Friction pile		○	○	○	×	×	×	×	×	×	○	○	○	○	
Site condition	water	The depth of water is less than		○	○	○	△	△	△	△	△	△	×	×	×	×	
		The depth of water is more than		△	○	○	△	△	△	△	△	△	×	×	×	×	
	The construction yard is narrow.			△	△	△	△	△	△	△	△	△	△	△	△	△	○
	Batter pile			○	○	○	×	×	×	×	×	×	×	×	×	×	×
	Poisonous gas			○	○	○	○	○	○	○	○	○	○	○	○	○	×
	area	Vibration and Noise		×	×	△	△	○	○	△	○	○	○	○	○	○	○
		The influence of the near		×	△	△	△	○	○	△	○	○	○	○	○	○	△

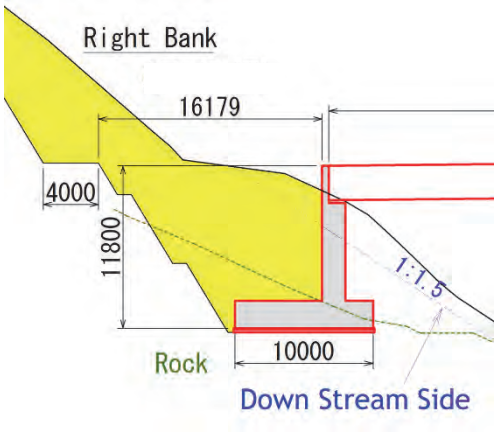
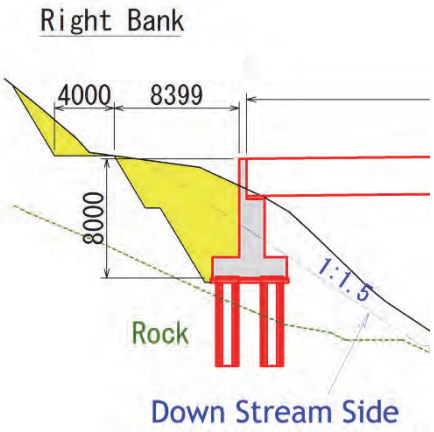
Adaptability → ○ : Good △ : not bad × : Bad

Source: Specifications for Highway Bridges, JAPAN

(c) Determination of the Foundation Type

i) Telegangchu Bridge: A1 Abutment

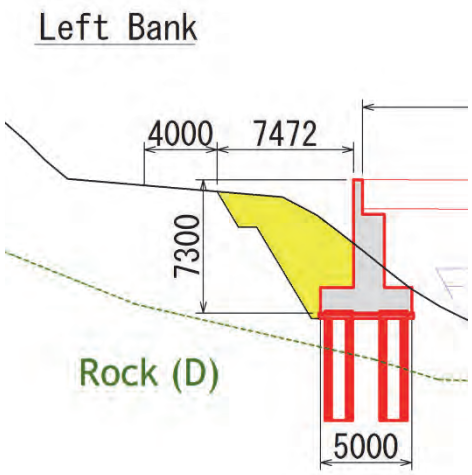
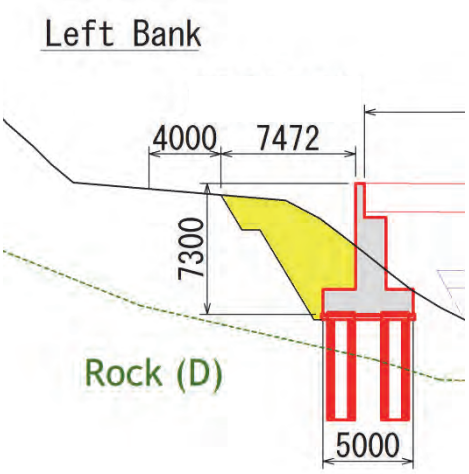
Table 2.2.39 Telegangchu Bridge Comparison of Foundation Type

Plans proposed	Plan 1: Spread foundation	Plan 2: Pile (φ1,500,n=10,L=6.0m)
Example		
Outline of the bridge	This plan is the spread foundation in the support layer which is rock. The height of the abutment is high, and the soil pressure is large too. The enough length of the front toe of the abutment is necessary for against the large soil pressure. It is impossible to shorten the bridge length because of the length of the front toe.	The diameter of the pile is 1500mm. The temporary retaining wall is used in the gravel layer while constricting the pile. In the area of the temporary retaining wall, the surface friction of pile is nothing. The bearing capacity of pile is gotten from the rock layer only. The length of the pile depends on the bearing capacity
Site applicability	The temporary road under construction for the vehicles by slope cutting is necessary. When the abutment is large, cutting area is large.	Because the size of abutment is smaller than Plan1, cutting area is small.
Economy (ratio)	1.385	1.000
Evaluation	2nd	1st This type is adopted by the cost.

Source: Prepared by the study team

ii) Beteni Bridge: A1 Abutment

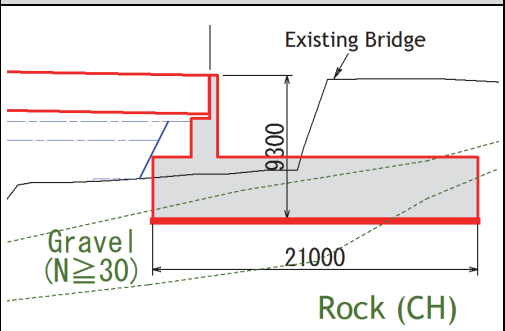
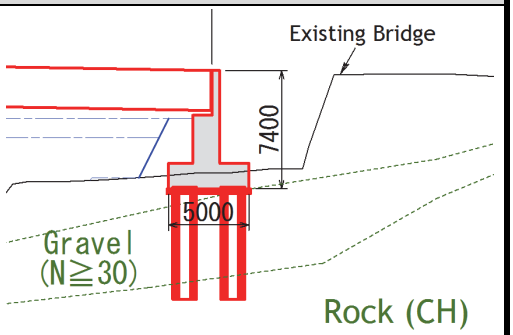
Table 2.2.40 Beteni Bridge Comparison of Foundation Type

Plans proposed	Plan 1: Spread foundation	Plan 2: Pile (φ1,500,n=6,L=6.0m)
Example		
Outline of the bridge	This plan is the spread foundation in the support layer which is rock. The height of the abutment is high, and the soil pressure is large too. The enough length of the front toe of the abutment is necessary for against the large soil pressure. It is impossible to shorten the bridge length because of the length of the front toe.	The diameter of the pile is 1500mm. The temporary retaining wall is used in the gravel layer while constricting the pile. In the area of the temporary retaining wall, the surface friction of pile is nothing. The bearing capacity of pile is gotten from the rock layer only. The length of the pile depends on the bearing capacity
Site applicability	The temporary road under construction for the vehicles by slope cutting is necessary. But it is impossible to cut the slope because of private land. For the private land the temporary retaining wall is necessary then the cost becomes expensive.	Because the size of abutment is smaller than Plan1, cutting area is small.
Economy (ratio)	1.246	1.000
Evaluation	2nd	1st This type is adopted by the cost.

Source: Prepared by the study team

iii) Samkhara Bridge: A2 Abutment

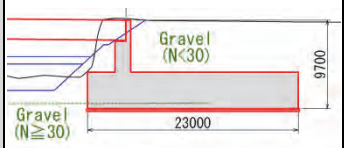
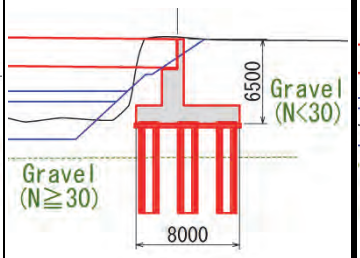
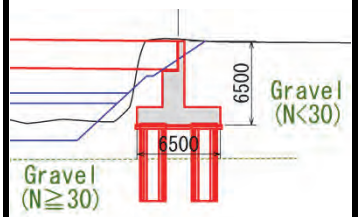
Table 2.2.41 Samkhara Bridge Comparison of Foundation Type

Plans proposed	Plan 1: Spread foundation	Plan 2: Pile (φ1,500)
Example		
Outline of the bridge	The support layer is gravel. In this case, ultimate bearing capacity is necessary for the design of abutment and the size of abutment tends to become large.	The diameter of the pile is 1500mm. The temporary retaining wall is used in the gravel layer while constricting the pile. In the area of the temporary retaining wall, the surface friction of pile is nothing. The bearing capacity of pile is gotten from the rock layer only. The length of the pile depends on the bearing capacity
Applicability to the site	The construction of abutment is not easier than Plan2 and 3 because the size of abutment is large.	Because the size of abutment is smaller than Plan1, cutting area is small.
Economy (ratio)	2.435	1.000
Evaluation	2nd	1st This type is adopted by the cost.

Source: Prepared by the study team

iv) Passang Bridge: Both Abutments

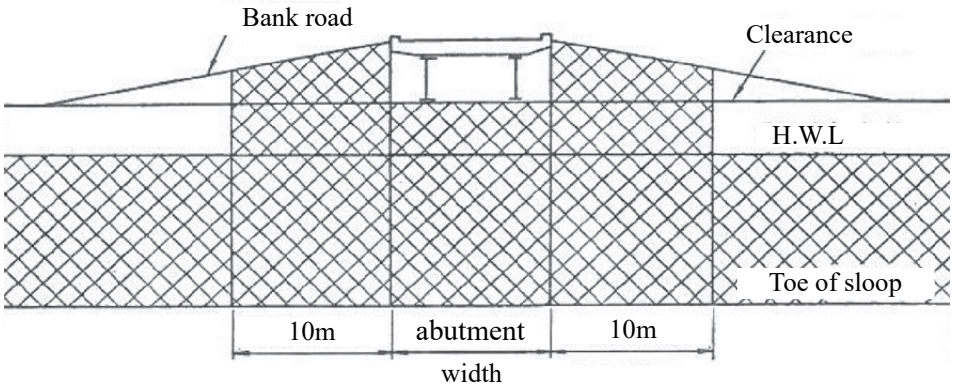
Table 2.2.42 Passang Bridge Comparison of Foundation Type

Plans proposed	Plan 1: Spread foundation	Plan 2: Pile (φ1,500)	Plan 3: Pile (φ2,000)
Example			
Outline of the bridge	The support layer is gravel. In this case, ultimate bearing capacity is necessary for the design of abutment and the size of abutment tends to become large.	The diameter of the pile is 1,500mm. The temporary retaining wall is used in the gravel layer while constricting the pile. In the area of the temporary retaining wall, the surface friction of pile is nothing. The bearing capacity of pile is gotten from the tip area of pile. The number of the pile is more than Plan3.	The diameter of the pile is 2,000mm. The temporary retaining wall is used in the gravel layer while constricting the pile. In the area of the temporary retaining wall, the surface friction of pile is nothing. The bearing capacity of pile is gotten from the tip area of pile. The number of the pile is less than Plan2.
Site applicability	The construction of abutment is not easier than Plan2 and 3 because the size of abutment is large.	The construction of abutment is easier than Plan1 because the size of abutment is small. But the construction of pile is not easier than Plan3 because the number of pile is many.	The construction of abutment is easier than Plan1 because the size of abutment is small. And the construction of pile is easier than Plan2 because the number of pile is few.
Economy (ratio)	2.134	1.079	1.000
Evaluation	3rd	2nd	1st This type is adopted by the cost.

Source: Prepared by the study team

6) Other accessories

Guard fence	Vehicle guard fence for both sidewalk and roadway (Type B or equivalent)
Public utilities	Water pipe (φ 9cm) in Passag bridge only
Approach slab	Provided (t=400mm, L=5.0m)
Drainage	Installed according to the drainage work guideline by taking into account the longitudinal gradient and crossfall of road
Revetment construction range	Constructed according to the Government Ordinance for Structural Standards for River Administration Facilities within the range (maximum 10 m on both upstream and downstream from the abutment) as shown below



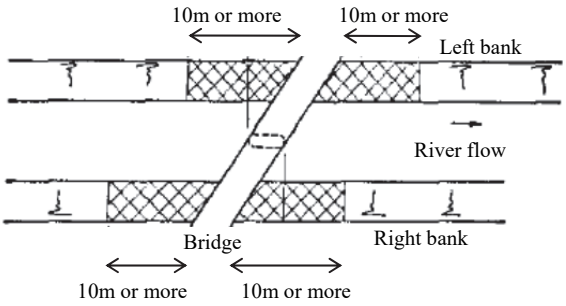
Source: Government Ordinance for Structural Standards for River Administration Facilities

Figure 2.2.29 Revetment construction range

2.2.3 Revetment Work Plan

(1) Construction Range of the Revetment Works

The revetment work is provided to protect the surrounding banks from the effects of installing abutments. The range of construction of the revetment work is for a distance of 10 m or more on upstream and downstream sides from both ends of abutment according to the Government Ordinance for Structural Standards for River Administration Facilities. However, for Passang Bridge, locally low revetment has been found on the upstream side of the existing bridge. DoR has a plan to build revetment in the future, but that area is at more than 20m upstream from the new bridge position. Therefore, the above-mentioned range is not included. In the stakeholders meeting, there was a request to build revetment by Japanese aid. Thus, the range is to be for a distance of 20m (downstream 10m) on the upstream side only to develop the locally low revetment, and continue with the revetment installed



Source: Prepared by the study team

Figure 2.2.30 Required Revetment Length on the Bridge Site

by DoR. Note that the revetment work will not be provided in the case of Samkhara and Teleganchu Bridges because the A1 abutment of the former bridge and the A2 abutment of the latter bridge will be constructed in the location not affected by flood.

(2) Revetment Structure

1) Type of Revetment

The revetment is to be structured in such a manner as to prevent erosion of the bank caused by change in the water flow while taking into account harmonization with the surrounding landscape and preservation of the river environment. Moreover, the structure must be based on the consideration of the availability of materials and maintainability in the future in Bhutan. For selection of the revetment work method, the revetment height is determined in connection with HWL and local topography. If the revetment height exceeds 5 m, a leaning type revetment which is applicable even at the height of more than 5m, is chosen. If the revetment height is 5m or less, masonry revetment is chosen.

Table 3-2-1 (m)

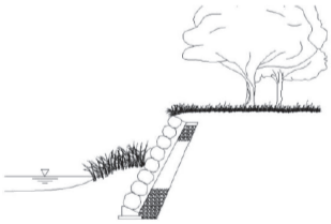
Type \ Height (H)	2.0	4.0	6.0	8.0	10.
Block masonry (masonry)	----	----	----		
Leaning type		----	----	----	----
Small gravity type	----				
Gravity type	----	----	----		
Inverted-T type		----	----	----	
L type		----	----		
Retaining wall type				----	----
Grill type		----	----	----	----

Note: Values in ---- were calculated values.

Source: Ministry of Land, Infrastructure, Transport and Tourism; Revetment works plan manual

Figure 2.2.31 Retaining Wall Type and Applicable Height

Table 2.2.43 Features of the Selected Revetment Works

Revetment method	Stone masonry (mortar) (Revetment height 5 m or less)	Leaning type (Revetment height 5m or more)
Outline view		
Features of the method	The structure for mutual integration of stones with filling concrete while increasing the shear resistance by allowing stones to interlock each other. The works conform readily to the surrounding landscape.	Revetment works using concrete, in which steep slope is retained by its own weight. This is applicable to the height exceeding 5 m.

Source: Prepared by the study team

Table 2.2.44 Correspondence between the Revetment works and the Design Flow Velocity (for the Revetment Height of 5 m or less)

Segment			Typical rehabilitation method				Design flow velocity	
River channel in mountainous area	Valley bottom plain River channel in the alluvial fan	Natural levee Delta	Material	Structure		Method	(m/s) 2 3 4 5 6 7 8 –	
			Stone	Natural stones (mortar)	1	Cyclopean masonry (mortar)	4-8	
					2	Quarry stone masonry (mortar)	4-8	
					3	Kenchi-ishi masonry (mortar)	4-8	
				Natural stones (dry masonry)	4	Cyclopean masonry (dry masonry)	5	
					5	Quarry stone masonry (dry masonry)	5	
					6	Kenchi-ishi masonry (dry masonry)	5	
					7	Coupled field stone (dry masonry)	4-8	
			Concrete	Concrete block pitching	8	Concrete block pitching	4-8	
					9	Porous concrete block pitching	4-8	
					10	Crib works	4-8	
				Articulated concrete mattress	11	Articulated blocks	5	
					12	Large articulated blocks	5	
					13	Porous articulated blocks	5	
			Cage	Gabion	14	Vegetation gabion	5	
				Cage (Carvel-built)	15	Wire basket type carvel-built	5	
				Bags	16	Articulated bag masonry (gravel)	5	
			Wood	Log grating	17	Log grating (single grating crib works included)	4	
				Fascine crib works	18	Fascine crib works	4	
					19	Fascine pile-hurdle works	4	
					20	Wood grating works	4	
				Pile-hurdle works	21	Pile-hurdle works	4	
					22	Plate-hurdle works	4	
			Sheet	Geo-textiles	23	Geo-textiles	3	
					24	Vegetation mat	3	
				Block mats	25	Block mat	4	
					26	Vegetation stone net	4	
			Vegetation	Sodding	27	Sodding	2	

* The scope of application shown in the table above are for reference. Any reasonable method appropriate to the design flow velocity may be positively employed.
* The method must be selected while taking into account the considerations of the rehabilitation method.
* Crib works: This method causes change in the design flow velocity depending on the internal material: 8 m/s for concrete and 5 m/s for natural stone (dry).)

Source: Basic Policy for Disaster Rehabilitation to Protect Beautiful Mountains and Rivers: MLIT

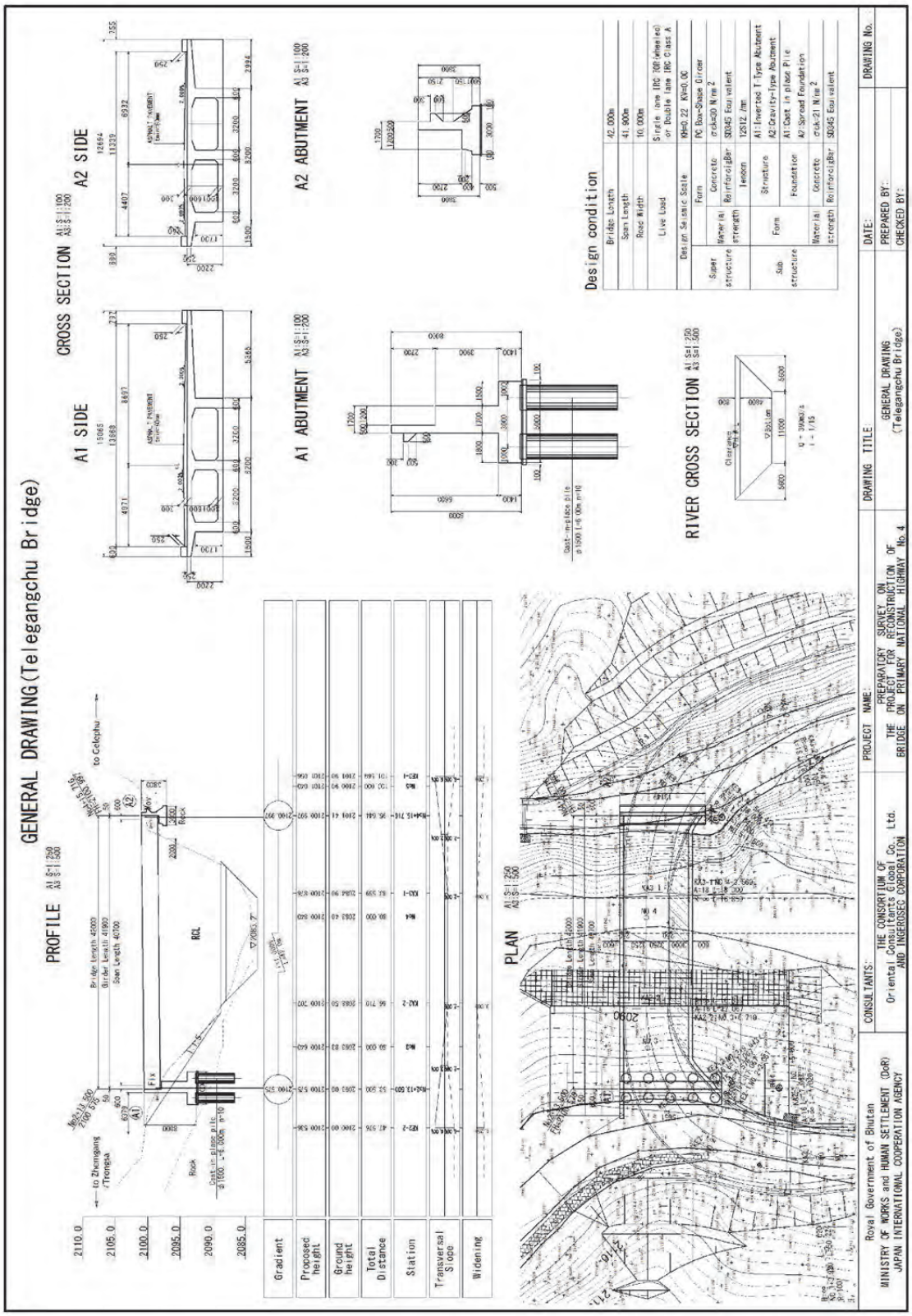
(3) Footing depth of revetment and the bed protection works

As a result of on-site visual inspection, the footing length longer by 1 m or more than the planned riverbed elevation is determined without foot protection with blocks because the possibility of bank erosion and riverbed scour is limited.

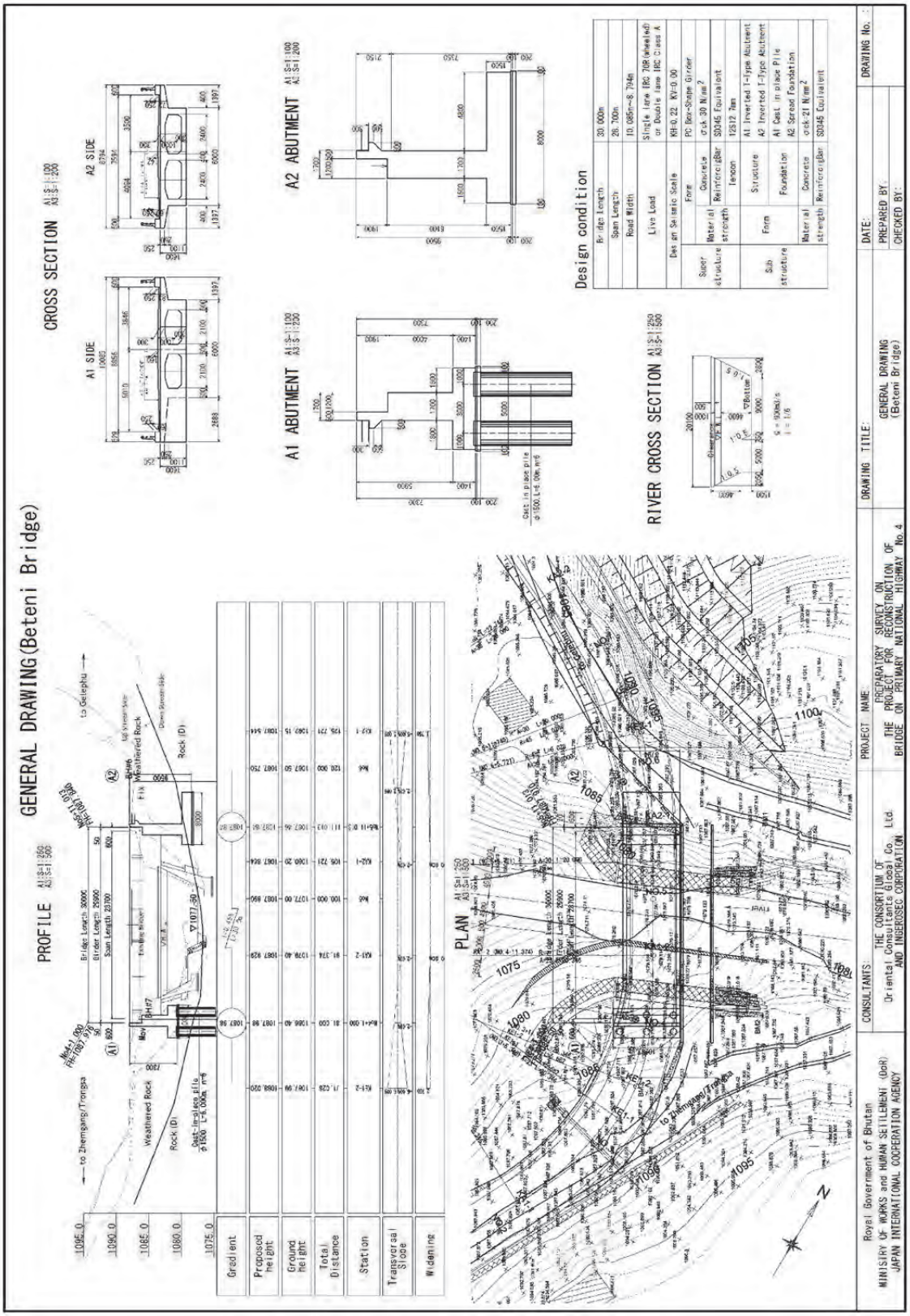
2.2.4 Outline Design Drawings

General drawings of the bridges are illustrated below.

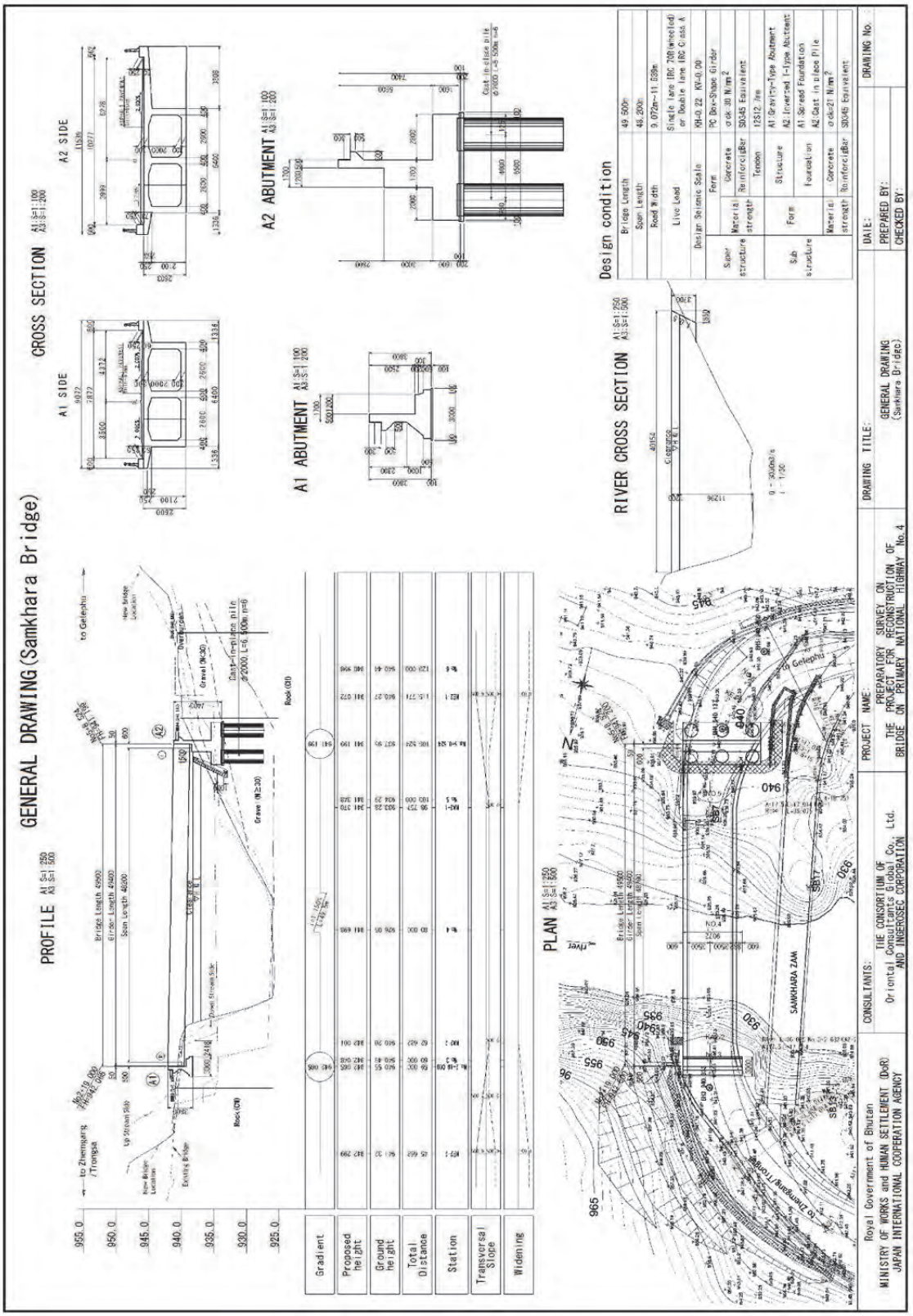
(1) Telegangchu Bridge



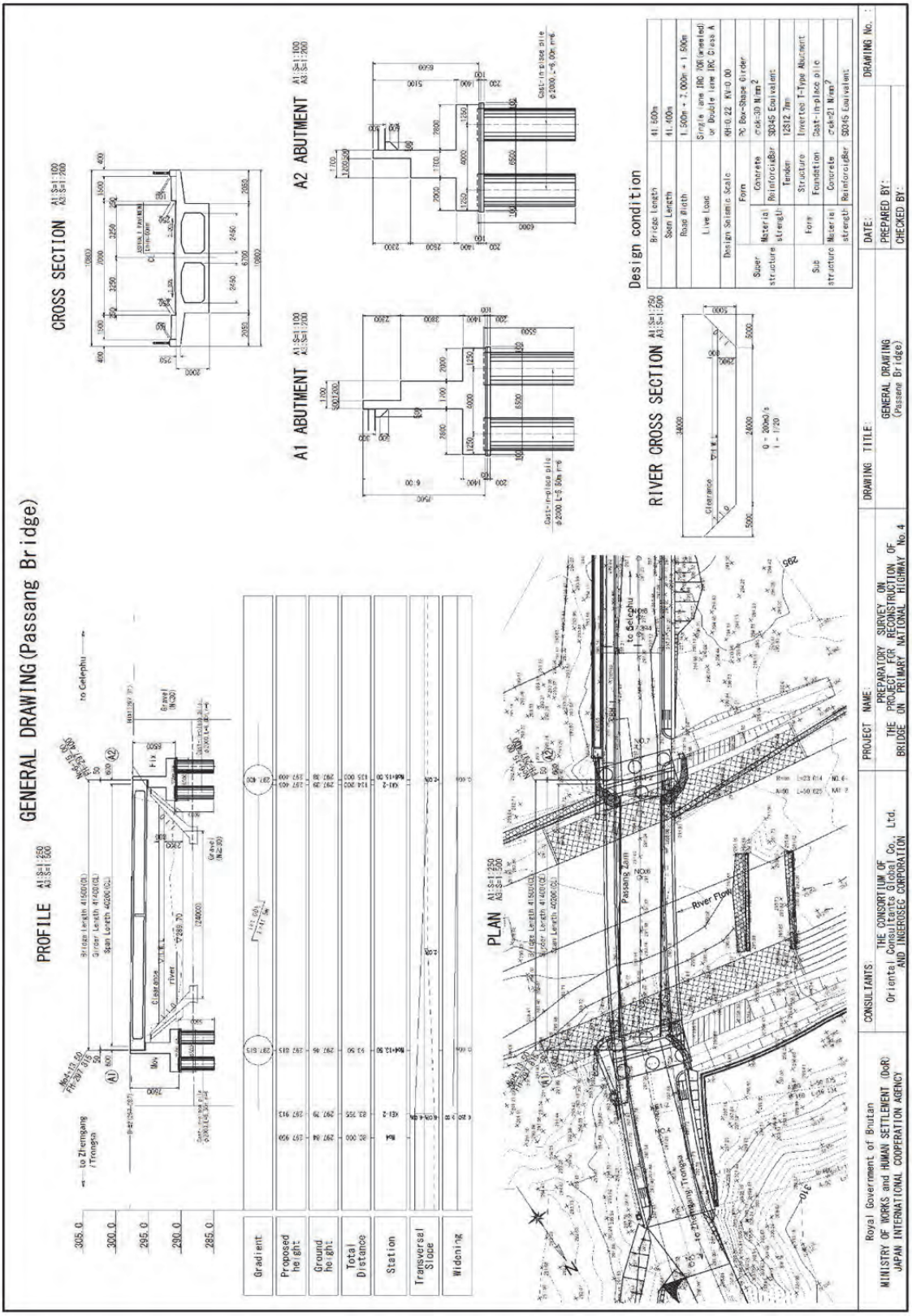
(2) Beteni Bridge



(3) Samkhara Bridge



(4) Passang Bridge



2.2.5 Implementation Plan

2.2.5.1 Implementation Policy

(1) Basic Items in the Construction Plan

The following basic items must be taken into account when the construction plan is to be established.

Compliance with the labor standards	Labor dispute must be avoided by complying with the construction-related laws of Bhutan and by respecting the adequate labor conditions and established practice in the course of employment.
Environmental conservation during construction period	After reception of the "Work Certificate" before commencement of the work, the guidance and supervision of the work must be executed while taking into account the environment-related observances that are prerequisites of certification. Particular attention must be paid on disposal of waste soil, dust/turbid water produced from embankment and pavement works, effect on animals by the noise generated during the use of crushing materials.
Necessity of the communication means in the site	For the purpose of safety management system for staffs engaged in supervision and implementation of the construction work, the minimum required communication means must be established by providing satellite phones in each site to ensure communication between sites.
Respect for locally-established practices	When the construction plan is developed, the work schedule to be planned must respect the local religion and established practices, such as the tshechu festival (the festival held in each Dzongkhag) and religious national holidays unique to each Dzongkhag.
Securing the traffic safety	Due care must be taken to ensure the traffic safety because the construction is to be executed while opening the existing bridge to the traffic of general vehicles. If necessary, the request must be made for the guidance of the Bhutanese police authorities, so as to ensure smooth traffic management and the construction without suffering delay in the schedule.

(2) Transport Conditions

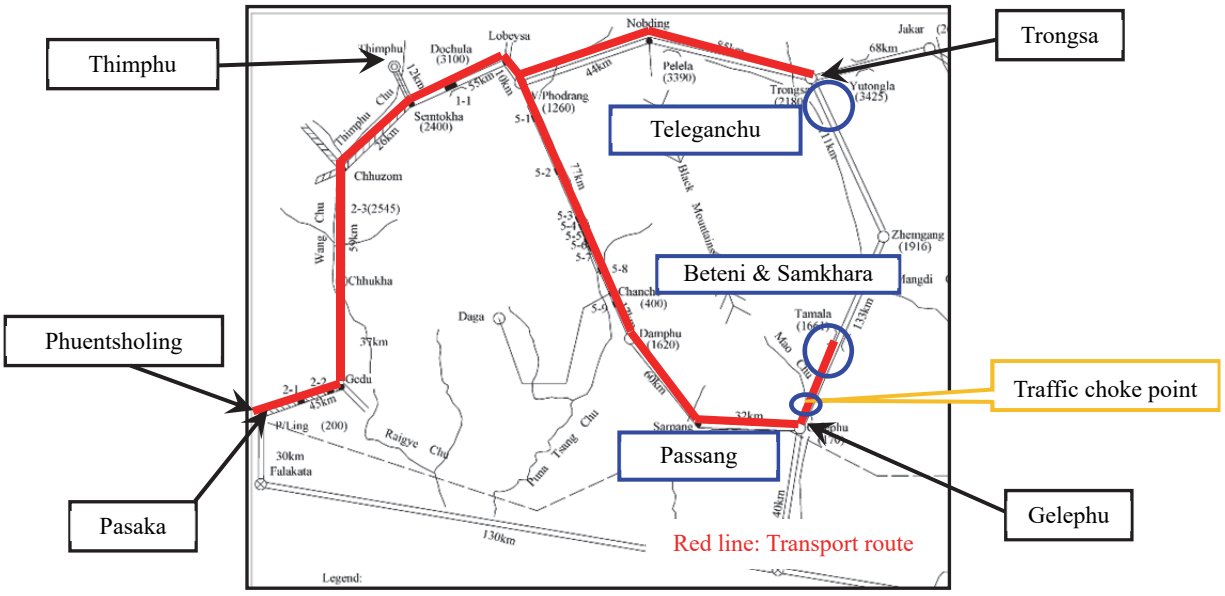
1) Outline

Bhutan has reinforcement bar manufacturing factory in Pasaka, from which reinforcement bars are shipped to various parts of the country. The road from Pasaka to the bridge point is dotted with points under widening work and narrow points. In particular, there is a dangerous choke point (the photo in the right) with frequent landslide between Passang Bridge and Samkhara Bridge, with the road blocked depending on the rainfall state. Heavy vehicles may suffer difficulty of passing due to

Source: Photo taken by the study team

Figure 2.2.32 Traffic Choke Point

effects of rainwater-containing soils on the road or under road conditions (the profile with extremely steep slope and successive curves). In the case of steel bridge, disassembled members are to be transported. If they cannot be transported, construction of the bridge itself becomes impossible, which in turn requires review of the bridge plan. To avoid such an event, studying the possibility of traveling of transporting vehicles must be done to provide the fundamental data for selection of the bridge type.



Source: Prepared by the study team

Figure 2.2.33 Transport Route

Source: Photo taken by the study team

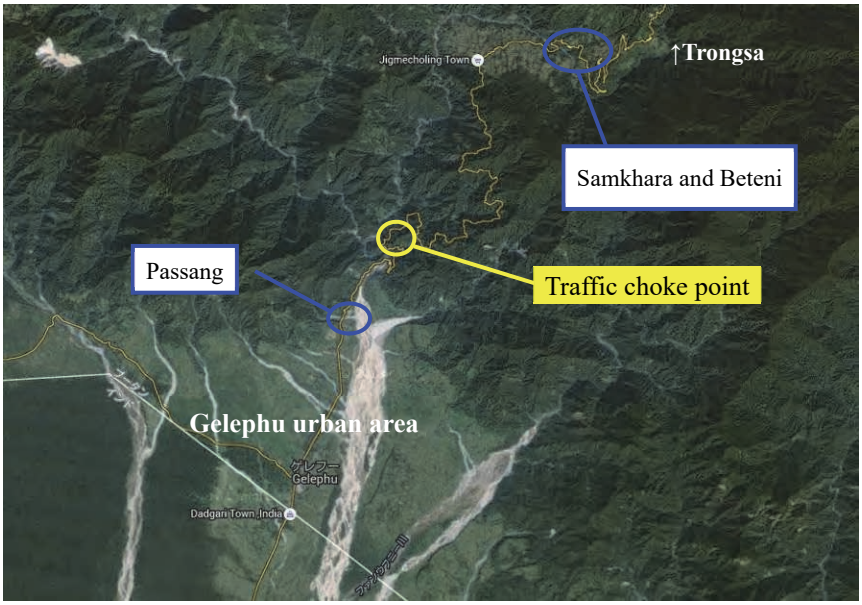
Figure 2.2.34 Traveling Vehicle
(Left: Medium/low floor type trailer, Right: Heavy trucks)

2) Review of Traveling of Heavy Trucks

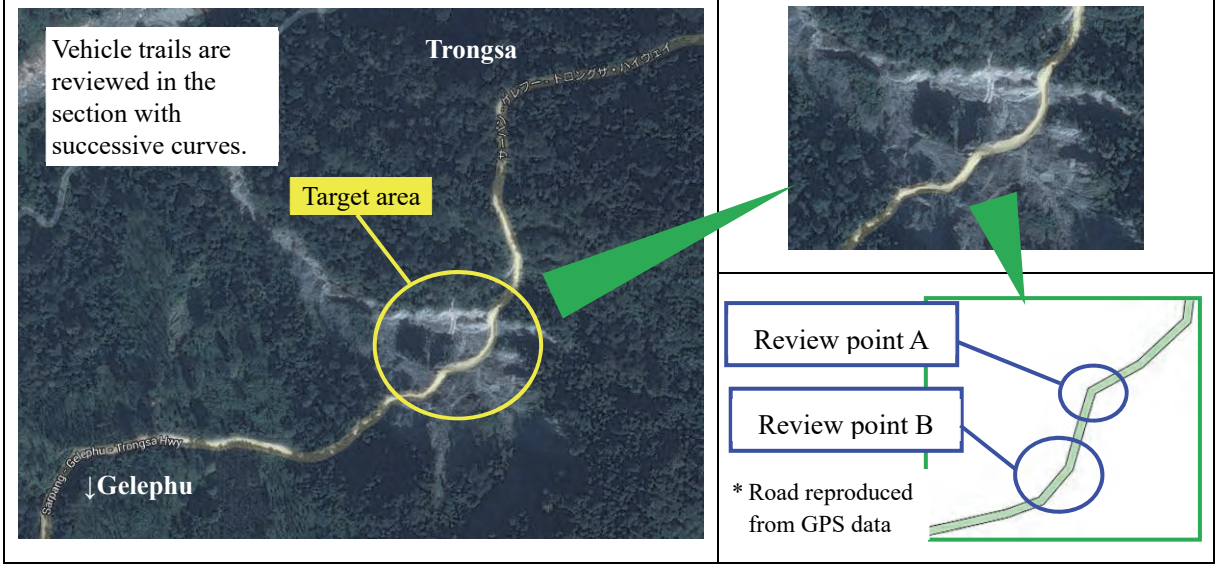
(a) Selection of the Target Location

Among traffic choke points with frequent landslide, review is made on those locations with successive curves whether or not heavy trucks can pass. The width is determined to be 4 m on the basis of current situation.

["Traffic choke point" wide area map]



["Traffic choke point" enlarged view]



Source: Prepared from Google Earth by the study team

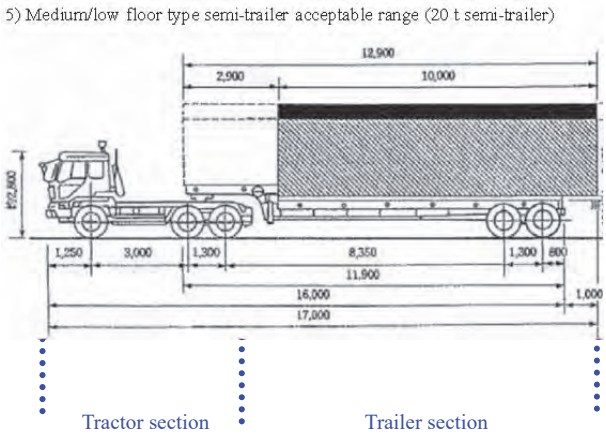
Figure 2.2.35 Target Location

(b) Review Result of Traveling of Semi-trailer Truck

For Primary National Highway No.1, "medium/low floor semi-trailers (20t)" were found to travel locally. If employing a steel girder bridge (slab and box girders), it is necessary to review whether or not the medium/low floor semi-trailers (20 t) used to carry in the girders can travel.

As a result of review described in latter pages, the medium/low floor semi-trailers (20 t) run out of the road and thus their traveling is considered extremely difficult. Namely, the steel girder bridge (slab and box girders) is exempted from selection. It is also considered extremely difficult to carry

in and transport a pile driver to drive cast-in-place piles and a large crane requiring disassembly and reassembly.



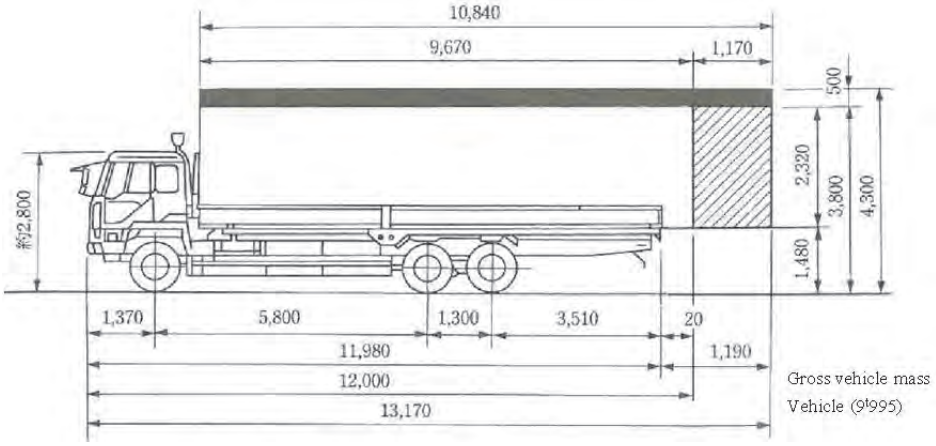
Source: Photo taken by the study team, and Design Data book

Figure 2.2.36 Data of Medium/low Floor Semi-trailer Truck (20 t)

(c) Review of traveling of 10t trucks and review result

As described above, the medium/low floor semi-trainers (20 t) are determined difficult to travel here. Now the review is made of the traveling of 10 t trucks that are expected to use.

The review result shows that the 10t trucks can pass here. The size range of materials and members to be transported must be such as to enable transport with the 10 t trucks. Namely, the materials such as reinforcing bars can be carried in.

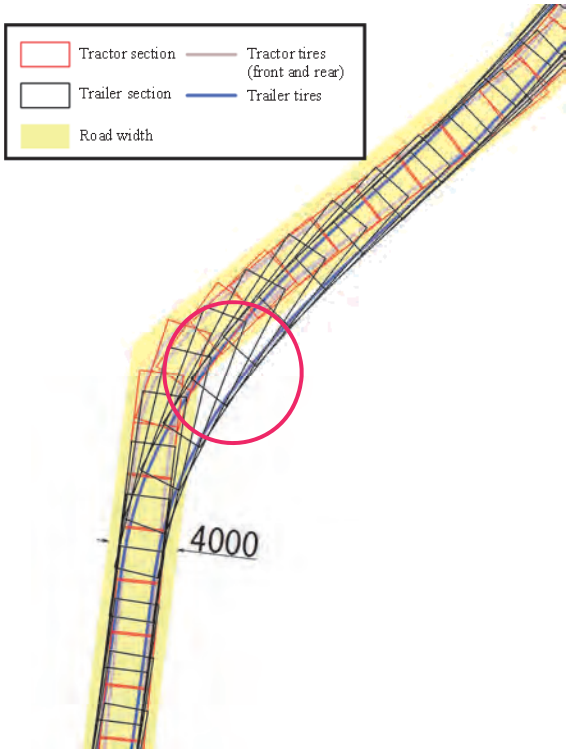
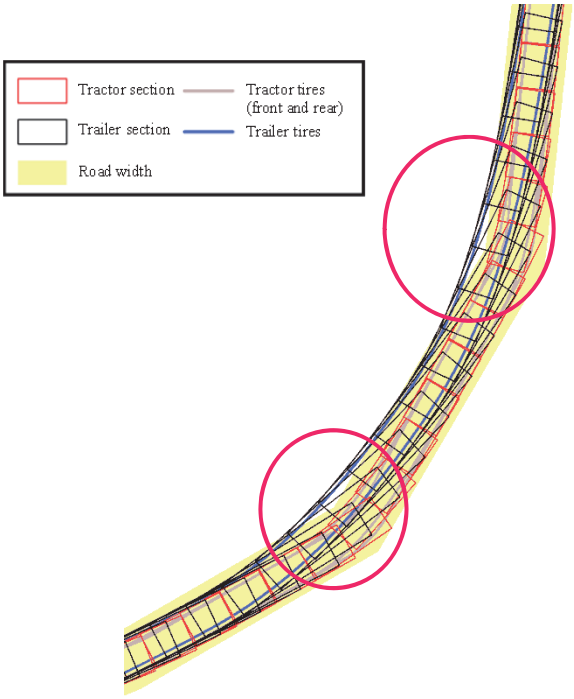


Source: Design Data Book

Figure 2.2.37 Data of 10t Truck

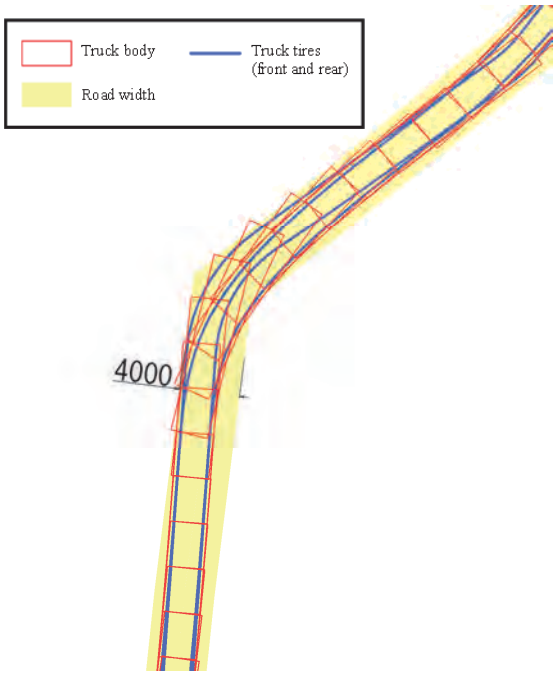
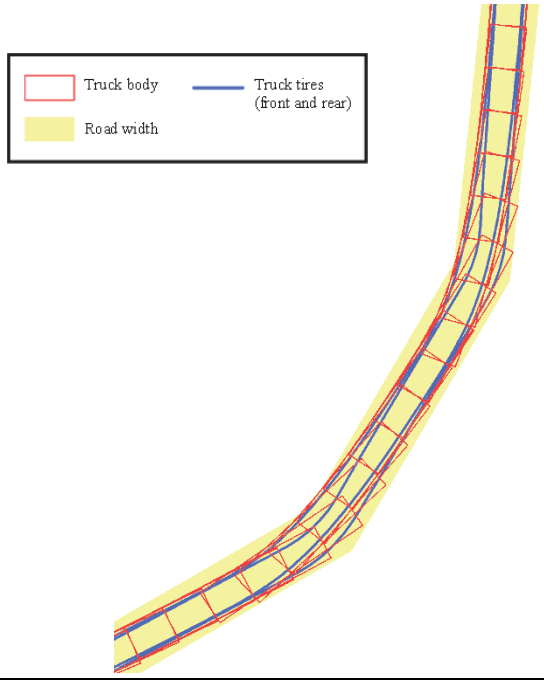
[Review of traveling of semi-trailers] ⇒ Road widening difficult, vehicles running out of the road

[Review of traveling of 10t trucks] ⇒ Traveling possible

	Result and site photograph	Trail review diagram
Review point A	At an encircled point of the figure right, the car body and tires contact the mountain side. Possible measures may include removal of a part of mountain side, widening, etc. Since this is a location with frequent landslides, it is essential to take measures ensuring the road safety by using anchor, etc., instead of applying a temporary measure. 	
Review point B	At an encircled point of the figure right, the vehicle body runs out of the road toward the valley. As the valley is deep, securing the width with embankment is difficult. 	

Source: Prepared from Google Earth and by the study team

Figure 2.2.38 Trail Review Result (Semi-trailer Truck)

	Result and site photograph	Trail review diagram
Review point A	Traveling possible	
		
Review point B	Traveling possible	
		

Source: Prepared from Google Earth and by the study team

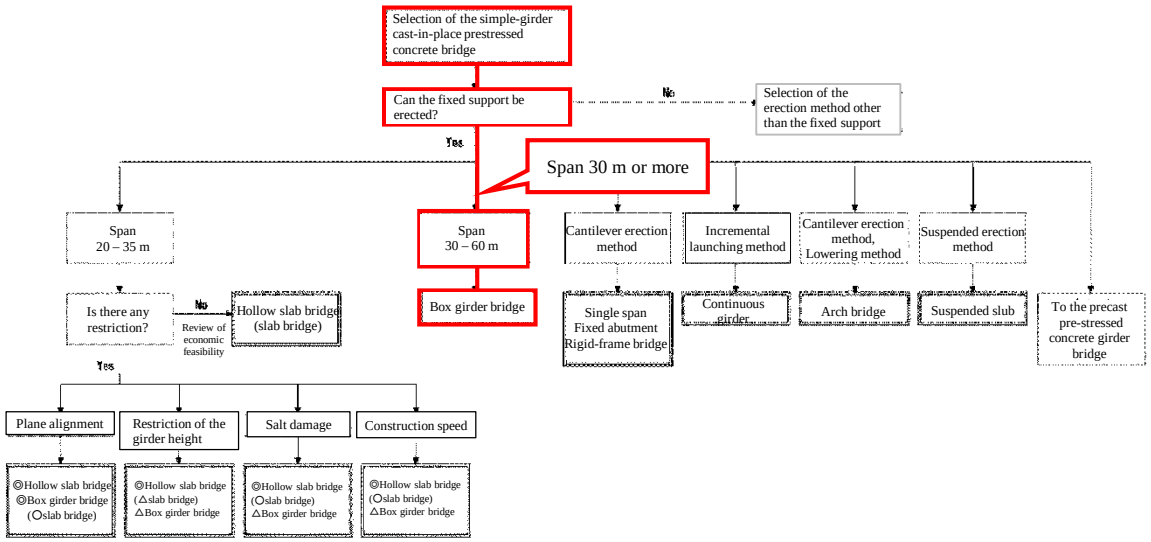
Figure 2.2.39 Trail Review Result (10t-truck)

(3) Superstructure Erection Conditions

The superstructure erection method is selected from various bridge types according to the flow shown below. Note that the "transporter girder-bridge" employed when the bridge length is 30 m or less is excluded from the scope of review this time because the construction yard for a large crane, erection girders, etc. is considered difficult to secure.

Teleganchu, Beteni, Samkhara and Passang:	Prestressed-concrete simple cast-in-place box girder bridge

For the cast-in-place girders, the girder type and constriction method are determined according to the constraints, such as the span length to be erected, with/without support, etc. The "box girder bridge through erection of the fixed support" is selected according to the flow shown below.



Source: Prestressed Concrete Road Bridge Planning Manual (Japan Prestressed Concrete Contractors Association)

Figure 2.2.40 Selection Flow for Superstructure Erection of Cast-in-place Girders

2.2.5.2 Considerations for Construction/Procurement

(1) Considerations for construction

1) Telegangchu Bridge

- For the Gelephu to Trongsa road, the approximate middle portion, that is, the Zhemgang to Trongsa section, is extremely poor in the road conditions due to narrow width, many curves, crossing with vehicles for dam construction, etc. Therefore, materials are carried in from the Trongsa side.
- The right-bank abutment can be accessed from the existing road that is narrow.
- The left-bank abutment can be accessed from the existing road that is much narrower than that on the right- bank. Besides, the road slope is overhanging.
- The construction yard in the rear of both abutments is narrow, in which large crane and erection girder materials cannot be stored.
- Entering the river is possible by constructing an embankment on the river slope on the right bank.
- The water river level is low in the dry season. The support can be constructed while securing the cross-section of flow.
- The bridge is located at high elevation (over 2,000m). The road surface may be frozen in case of very low temperature day.

2) Beteni Bridge

- For the Trongsa to Gelephu road, the section up to Zhemgang at a middle point is extremely poor in the road conditions due to narrow width, many curves, crossing with vehicles for dam construction, etc. Therefore, materials are carried in from the Gelephu side.
- The left-bank abutment can be accessed from the existing road that is narrow. There is an access way into the river on the downstream side of the existing bridge, which can be used for the construction yard.
- The right-bank abutment can be accessed from the existing road. In the rear side of the abutment of the new route, there is a land where a construction yard can be secured.
- In the rear side of abutment of the new route on the right bank, there is some construction yard, which however is narrow for provision of a large crane, erection girder materials.
- There are private houses on the upper side of road slope on the left bank, which requires consideration on the effects of excavation (as a rule, the slope improvement will not be done).
- Entering the river is possible by widening the existing access way on the left bank.
- The river water level is low in the dry season. The support can be constructed while securing the cross-section of flow.
- Road closure(s) due to slope collapse sometimes occur(s) in road section between Passang and Samkhara/Beteni in rainy season. However, the closure is usually resolved within a few hours by machineries of DoR. DoR stands by their machineries for immediate counter action nearby such hazardous sections.

3) Samkhara Bridge

- For the Trongsa to Gelephu road, the section up to Zhemgang at a middle point is extremely poor in the road conditions due to narrow width, many curves, crossing with vehicles for dam construction, etc. Therefore, materials are carried in from the Gelephu side.
- The left-bank abutment can be accessed from the existing road that is narrow.
- The right-bank abutment can be accessed from the existing road that is narrow.
- The construction yard in the rear of both abutments is narrow and is difficult to be used as the yard for erection by launching.
- Entering the river is possible by constructing an embankment on the river slope on the left bank.
- The river water level is low in the dry season. The support can be constructed while securing the cross-section of flow.
- Road closure(s) due to slope collapse sometimes occur(s) in road section between Passang and Samkhara/Beteni in rainy season. However, the closure is usually resolved within a few hours by machineries of DoR. DoR stands by their machineries for immediate counter action nearby such hazardous sections.

4) Passang Bridge

- For the Trongsa to Gelephu road, the section up to Zhemgang at a middle point is extremely poor in the road conditions due to narrow width, many curves, crossing with vehicles for dam construction, etc. Therefore, materials are carried in from the Gelephu side.
- The left-bank abutment can be accessed from the existing road. Because of the road slope, the entrance to the office (governmental) and the entrance of the detour route during construction, the use as a construction yard is limited.
- The right-bank abutment can be accessed from the existing road. Because of the road being wedged between private and military sites as well as the entrance to the alternative road during construction, the use as a construction yard is limited.
- For the construction yard in the rear of both abutments, provision of large crane and erection girder materials is impossible because of restrictions (entrance to military and private sites) for general use.
- On both banks, due care must be taken on the effects of excavation on facilities and land.
- Entering the river is possible by constructing an embankment road on the right bank (Gelephu side).
- The river water level is low in the dry season. The support can be constructed while securing the cross-section of flow.

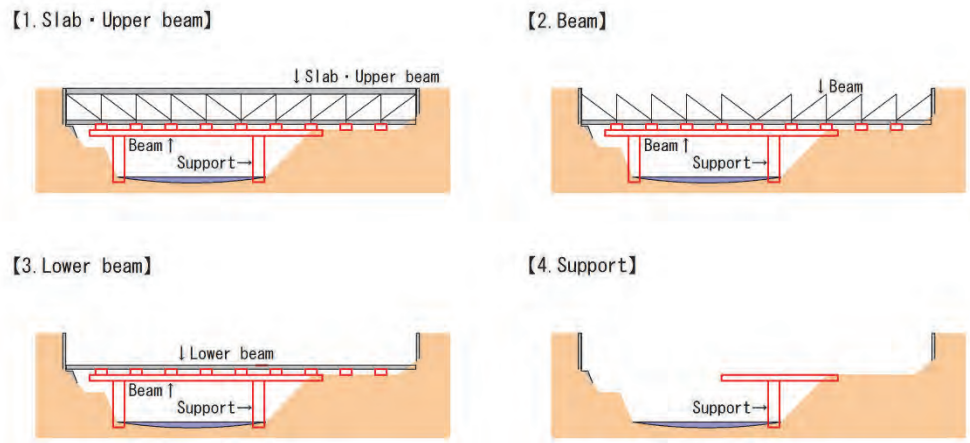
5) Soil Disposal

It is possible to process the soil disposal in the near of the each bridge.

6) Removal of the Existing Bridges

It is recommended to carry out removal of bridges to be removed by Japan according to the procedure described below.

Table 2.2.45 Bridge Removal Method

Bridge name	Removal reason and method
Beteni Bridge	Reason：To interfere with the new bridge Method：With the support provided under the existing bridge, concrete girders are demolished with a backhoe, a concrete cutter, etc. Broken concrete pieces are to be adequately treated for transport to the industrial waste disposal facilities.
Samkhara Bridge	Reason：To need high technical skills for removing the bridge Method：The erection equipment (support) of a new bridge is accommodated for removal after construction of the new bridge. The removal procedure (reference) is shown below. 
Passang Bridge	Reason：To interfere with the new bridge Method：With the support provided under the existing bridge, steel girders (truss structure) are demolished with a backhoe, a concrete cutter, a grinder, etc. Broken concrete and steel pieces on the slab are to be adequately treated for transport to the industrial waste disposal facilities.

Source: Prepared by the study team

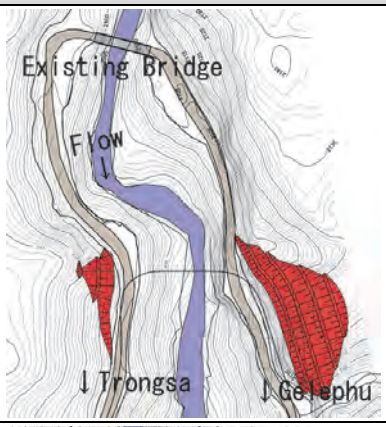
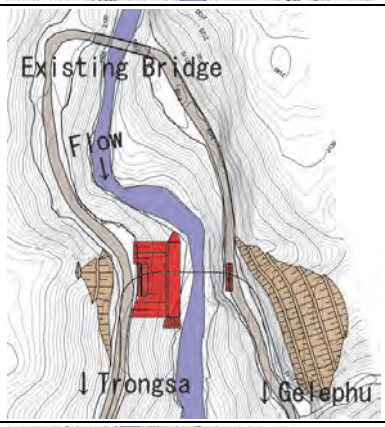
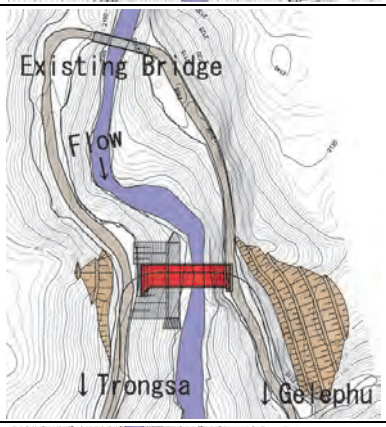
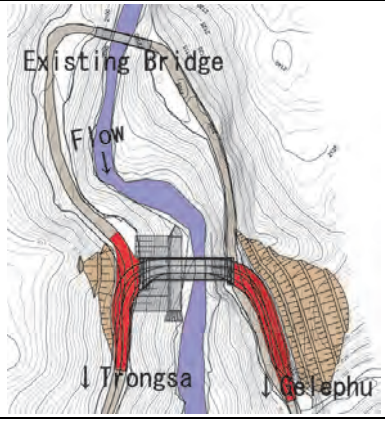
(2) Considerations for procurement

Considerations for procurement related to this plan are described below:

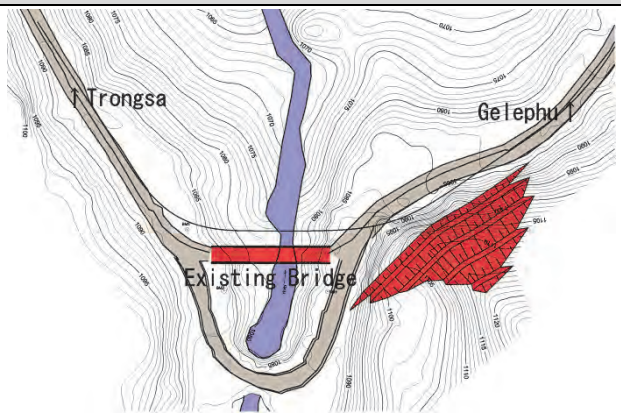
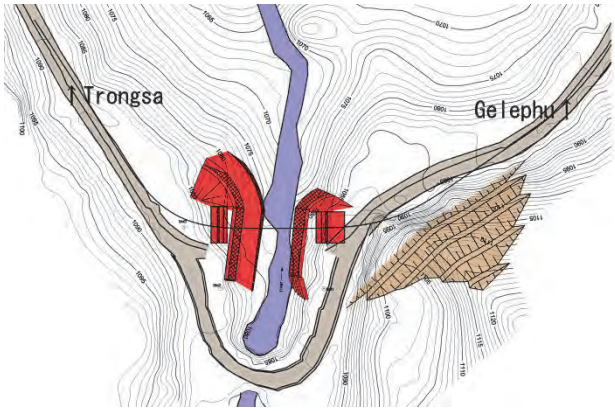
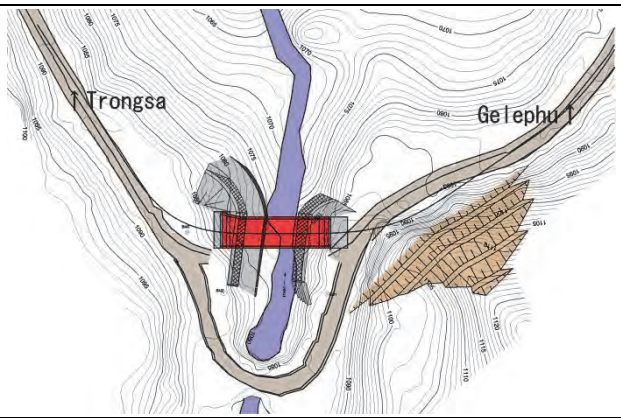
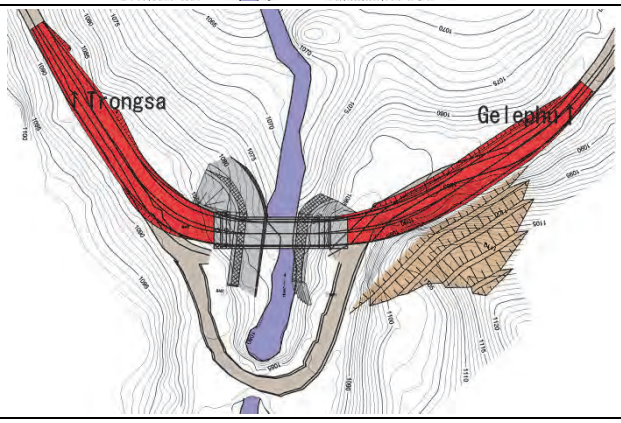
- A procurement plan ensuring smooth construction process must be established.
- Local products must be procured as much as possible to contribute to activation of the regional society.
- For the construction material difficult to procure locally, procurement from Japan or any other countries must be considered while taking into account the qualitative assurance, easiness of procurement, securing of the quality, and economy.
- The products procured from Japan are to be unloaded in Calcutta.

2.2.5.3 Construction Work Sequences and Key Points

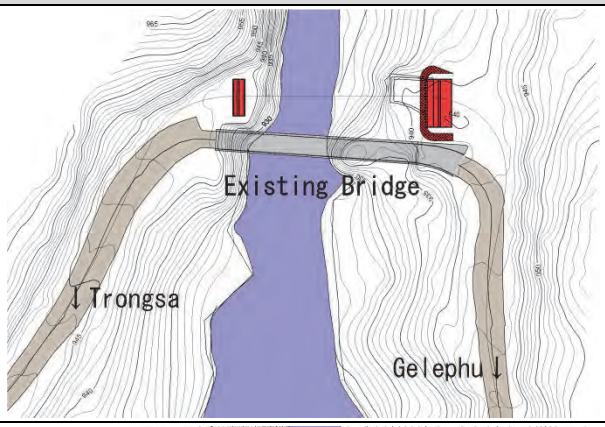
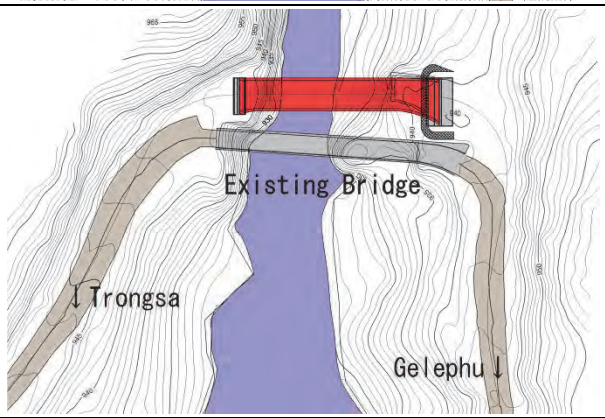
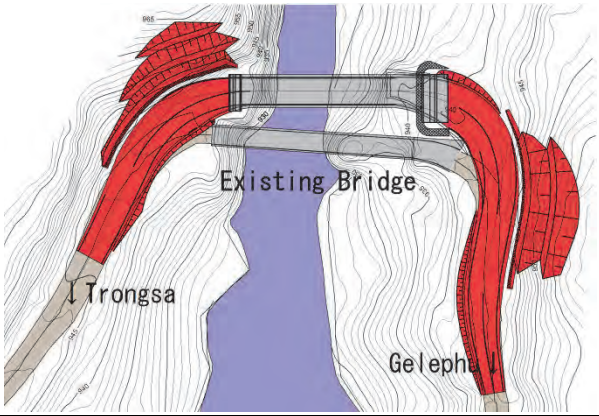
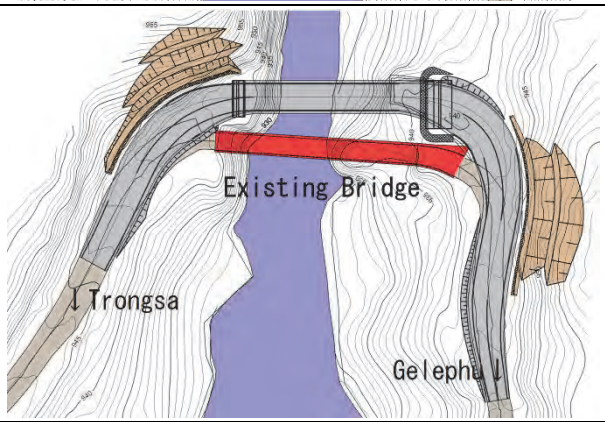
(1) Telegangchu Bridge

Step	Step diagram	Work outline & major work item (red text: task of Bhutan side)
1		[Outline] In the rear of both abutments, the mountain is near and the space is narrow. Carry out cutting of the slope to secure the road for vehicles during work and construction yard. [Work item] Preparation and cutting works
2		[Outline] After securing of the road for vehicles during work and the construction yard, the abutment and revetment are constructed. [Work item] Abutment and revetment works *As the abutment work proceeds, the revetment work can be changed after completion of erection of the superstructure.
3		[Outline] The support is provided in the river for erection of the superstructure. [Work item] As a rule, erection is performed during the drought period. [Construction class] Erection (support) and superstructure works
4		[Outline] Access road is constructed after completion of the bridge. The existing bridge will be removed by Bhutan side after completion of the road and bridge. [Work item] Road work, Removal of existing bridge

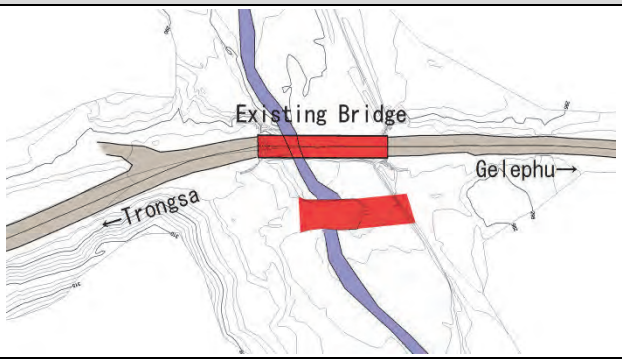
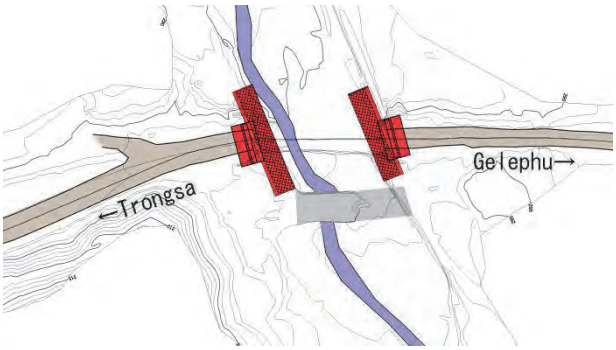
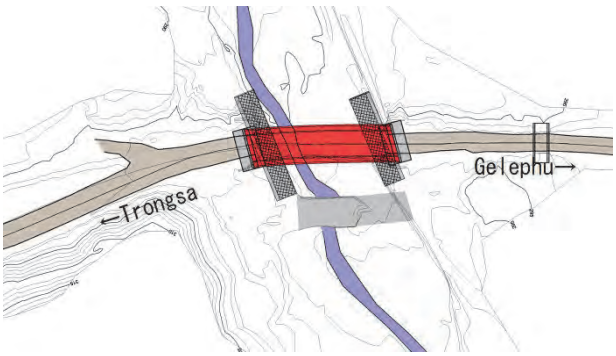
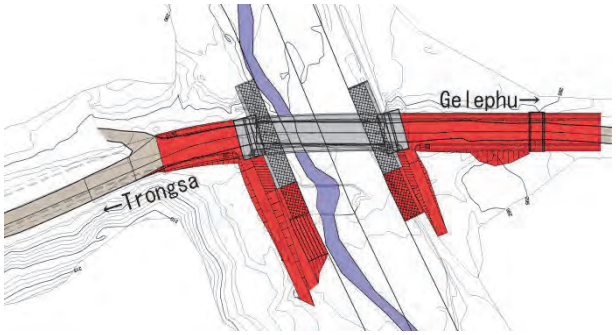
(2) Beteni Bridge

Step	Step diagram	Work outline & major work item (red text: task of Bhutan side)
1		[Outline] Before construction of a new bridge, cutting is made for the existing road on the right bank. This is to secure the road for private passenger vehicles. Subsequently, the existing bridge is removed by Japan's aid. [Work item] Preparation, cutting, and old bridge removal
2		[Outline] The abutment and revetment are constructed. As a rule, they are constructed during the drought period. Detour road will be maintained by Bhutan side. [Work item] Abutment and revetment works *As the abutment work proceeds, the revetment work can be changed after completion of erection of the superstructure. Maintenance work of detour road
3		[Outline] The support is provided in the river for erection of the superstructure. As a rule, the erection work is performed during the drought period. Detour road will be maintained by Bhutan side. [Work item] Erection (support) and superstructure works Maintenance work of detour road
4		[Outline] After completion of the bridge, the access road is constructed. Detour road will be removed by Bhutan side after completion of the road and bridge. [Work item] Road work Removal of detour road

(3) Samkhara Bridge

Step	Step diagram	Work outline & major work item (red text: task of Bhutan side)
1		[Outline] The abutment and retaining wall before abutment are constructed. [Work item] Preparation and abutment works
2		[Outline] The support is provided in the river for erection of the superstructure. As a rule, the erection work is performed during the drought period. [Work item] Erection (support) and superstructure works
3		[Outline] After completion of the bridge, the access road is constructed. [Work item] Road and cutting works
4		[Outline] After construction of the road, the existing bridge is removed by Japan's aid. As a rule, the support used for construction of the bridge is used for removal of the existing bridge. [Work item] Old bridge removal

(4) Passang Bridge

Step	Step diagram	Work outline & major work item (red text: task of Bhutan side)
1		[Outline] A temporary embankment is provided in the river, which is to secure the road for private passenger vehicles. The existing bridge is removed by Japan side. [Work item] Temporary embankment, old bridge removal
2		[Outline] The abutment and revetment are constructed. As a rule, they are constructed during the drought period. Temporary embankment will be maintained by Bhutan side. [Work item] Abutment and revetment works *As the abutment work proceeds, the revetment work can be changed after completion of erection of the superstructure. Maintenance work of temporary embankment
3		[Outline] The support is provided in the river for erection of the superstructure. As a rule, the erection work is performed during the drought period. Temporary embankment will be maintained by Bhutan side. [Work item] Erection (support) and superstructure works Maintenance work of temporary embankment
4		[Outline] After completion of the bridge, the access road is constructed. Temporary embankment will be removed by Japanese side after completion of the road and bridge. Revetment is constructed after removing the embankment. [Work item] Road work and Revetment work

2.2.5.4 Construction Supervision Program

(1) Consulting Service Implementation Process

Implementation of the Project will be implemented based on the concluding the Exchange of Notes (E/N) for the detailed design, tender assistance and construction supervision related to the grant aid of the Project between the Governments of Japan and the Government of Bhutan. After conclusion of E/N, the consultant will make the consultant agreement with the DoR, on the basis of letter of recommendation issued from JICA and according to the scope and procedure of Japanese grant-aid scheme. The agreement will include the detailed design, tender assistance and construction supervision. Principal contents of the agreement are described below:

1) Stage for Preparation of the Tender Documents (Detailed Design Stage)

The detail design is performed for each facility and the tender documents are prepared on the basis of the design result. Documents shown below will be prepared for approval of DoR:

- Design report
- Design drawing
- Tender documents

In addition, the works to be taken over from outline design stage to detailed design stage are shown below.

(a) Additional Boring Survey

Additional boring survey at retaining wall point and slope cutting point shall be conducted in order to obtain the geological information necessary for detailed design based on the design plan at outline design stage. It is necessary to prevent increasing of construction cost to be caused by change in type and scale of retaining wall and slope protection. Regarding the retaining wall, the confirmation of geology is necessary because the original plan of revetment works has been changed to retaining wall and the base of retaining wall located to lower level.

(b) Supplemental Topographical Survey (cross-sectional survey)

At the outline design stage, the location and length of the bridge have not determined yet. Therefore, cross-sectional survey shall be conducted at detailed design stage. The actual measurement is necessary to determine the bridge length and height of abutment accurately because in the mountainous area the change of terrain is large.

2) Tendering Stage

With the assistance of the Consultant, DoR selects the contractor of Japanese nationality via the open competitive tendering. The agent of Bhutanese Government, who takes part in this tender and the construction contract, must have the approval authority concerning the contract and must be

capable of making decisions in the technical field. The services of the Consultant in the tender stage are as follows:

- P/Q notification
- P/Q evaluation
- Tender assistance and evaluation
- Assist the Contract signing between the DoR and the Contractor

3) Construction Supervision Stage

Subject to verification of the construction contract by the Japanese Government, the Consultant issues the notice to proceed to start the work and starts supervisory services. In the course of supervisory services, the Consultant reports the progress of the work to DoR. For the Contractor, the Consultant provides the services related to the work progress, quality, safety, and payment as well as the proposal of improvement measures. In one year after completion of the stage for construction supervision, the inspection is made for any defect. With this inspection, the Consultant service will be terminated.

(2) Implementation Framework

The consultant's personnel assignment and the duties in each stage of detailed design, tender, and supervision of construction work are as follows:

1) Detailed Design and Preparation of the Tender Documents

The design team organized under the chief consultant undertakes detailed design. The detailed design service also includes preparation of tender documents. Tender documents are to be prepared with the attention paid on the fact that this project is subject to the grant aid while taking into account the following items;

- The form of instruction to bidders and contract must comply with the Japanese Grant-aid Guideline.
- The staffs of preparing the tender documents are mainly those thoroughly familiar with the details related to basic design survey and detailed design.

2) Implementation Framework of the Tender Assistance

The staffs necessary for assistance of tender services and their role are described below;

- Chief consultant: General responsible person in charge of all matters of coordination for smooth implementation of tender services
- Preparation of tender documents: Services related to verification of tender documents, tender work, tender, and tender evaluation

3) Implementation Framework of the Construction Supervision

The engineers necessary for implementation of the supervision of construction work and their role are described below:

- Chief consultant: Includes generally the coordination for smooth execution of the service, management of resident supervisor, and supervisory services, in addition to witnessing in site to the inspection at commencement, intermediate and completion
- Resident engineer: Reside in the project site for the purpose of safety management, schedule control, completed amount, and quality control services. As there are many target bridges and their sites are distanced mutually, the area of responsibility is divided into two parts (north and south) for supervision of construction work. The resident supervisor in charge of the southern part supervise 3 bridges namely Beteni, Samkhara and Passang bridge and also acts as a person responsible for the whole of local supervisory services The resident supervisor in charge of the northern performs supervision of Teleganchu Bridge.
- Construction supervision: Since construction of 3 bridges in the south are implemented at the same time during second dry season, one construction supervisor is assigned additionally.
- Superstructure engineer: For the superstructure, there are a total of four pre-stressed-concrete bridges in the north and south in total. Therefore, one pre-stressed-concrete bridge engineer is assigned to the site during construction of superstructure.

2.2.5.5 Quality Control Plan

The quality control is performed concerning the material quality and the manufacturing and erection accuracies for the construction materials and products. Control items and their frequency are shown in the table below.

Table 2.2.46 Quality Control Plan

Type	Item	Description	Frequency
Material inspection	Aggregate	Grain size, specific gravity, hardness, stability	Every producing area, every 250m^3
	Cement	Grain size, specific gravity, strength	Every manufacturer
	Reinforcing bars	Strength, bending workability	Every diameter, every lot
	Pre-stressed concrete steels	Strength	Every lot
	Asphalt	Viscosity, penetration, softening point	Every lot
	Embankment materials	Grain size, specific gravity, water content, plasticity, fluidity, compaction, CBR	Every producing area, every 500m^3
Product inspection	Ready-mixed concrete	Temperature, slump, air content	Every 10m^3 in each construction site
	Hardened concrete	Strength, unit weight	7/28-day strength sample prepared every 30m^3
	Bituminous mixture	Temperature, asphalt content	Every 30t at the construction site
	Filled-up ground	In-situ density	2 points of each bridge (Every access road)
	Pile bearing layer	Position, bearing capacity	Entire layer concerning position. One point per pile group concerning the bearing capacity
	Girder	Dimensions, linearity	100%
	Pile	Dimensions, linearity	100%
	Foundation, substructure	Dimension, position, height	100%
	Superstructure	Dimension, position, height	Every 5m in the road direction
	Asphalt pavement	Thickness, flatness, height	Every 100m^2 concerning thickness Every 5m concerning the flatness Every 5 m in the road direction concerning the height

Source: JICA Study Team

2.2.5.6 Procurement Plan of Equipment and Material

(1) Construction Materials and Equipment Procurement Plan

1) Construction Materials

Procurement of principal materials in Bhutan is outlined below.

Table 2.2.47 Procurement Sources of Principal Materials

Material	Specification	Source			Remarks
		Bhutan	Japan	Third country	
Embankment materials		✓			
Asphalt	For site mixing	✓			Import from India
Asphalt emulsion		✓			Import from India
Base course material	Broken stone	✓			
Cement	Ordinary portland cement	✓			
Additive	Water reducing agent		✓		
Fine aggregates	Sand	✓			
Coarse aggregates	Broken stone	✓			
Miscellaneous broken stones	20-25cm	✓			
Liner plate	Circular 2m, 3m		✓		
Reinforcing bars	IS-415, IS-500	✓			India standard
Prestressed-concrete steel wire			✓		
Sheath			✓		
Bridge railing	Steel made		✓		
Bearing	With bearing accessories		✓		
Expansion device			✓		
Stormwater inlet on the bridge face	With vertical drain pipe		✓		
Gabion		✓			Import from India
Plywood for form		✓			
Falsework materials	H steel, single line pipe, etc.	✓	✓		Import from India
Scaffold materials	Scaffold plate, separator	✓	✓		Separator and others to be procured from Japan
Woods	For form, for temporary work	✓			
Sandbag	For temporary work	✓			Import from India
Fuel		✓			Import from India

Source: JICA Study Team

2) Construction Machinery

Regarding procurement of the construction machinery, CDCL, which is an enterprise of large organization privatized from the Machine Division of DoR, and the general construction enterprises (major construction enterprises) have the construction machinery. Note that general vehicles and small equipment of the machinery are made in India, and most of special vehicles are made in Japan. The assumed procurement classification of principal construction machinery at present is shown below.

Table 2.2.48 Procurement Sources of Principal Equipment

Equipment	Specification	Source			Remarks
		Bhutan	Japan	Third country	
Bulldozer	15, 21 tons	✓			Earthwork
Backhoe	0.8 m^3	✓			Earthwork
Large breaker	1,300 kg class	✓			Earthwork
Wheel loader	1.4 m^3	✓			Material transport
Dump truck	10 tons	✓			Earthwork
Truck	4-4.5 tons	✓			Material transport
Rough terrain crane	16 tons, 25 tons		✓		Substructure, superstructure
Grout mixer			✓		Foundation, superstructure (prestressed concrete), slope protection
Grout pump			✓		
Boring machine	55 kW		✓		Slope protection
Mortar sprayer		✓			Slope protection
Motor grader	3.1 m	✓			Pavement
Road roller	10-12 tons	✓			Pavement
Rubber-tired compactor	8-20 tons	✓			Earthwork, pavement
Vibratory roller	0.8-1.1tons	✓			Earthwork, pavement
Tamper	60-100kg	✓			Earthwork, pavement
Concrete mixer	0.5 m^3	✓			
Sprinkler truck	10 m^3	✓			Earthwork, pavement
Air compressor	5 m^3/min		✓		Earthwork
Motor generator	75 kiva or less		✓		
Pre-stressed concrete girder fabrication equipment			✓		Superstructure
Pre-stressed concrete girder erection equipment			✓		Superstructure

Source: JICA Study Team

3) Custom Clearance Condition

Locally procured construction materials and equipment will be delivered to the materials production site, materials warehouse, motor pool. The transportation plan for the construction materials and equipment that are to be procured mainly from abroad is described below:

The custom house of Bhutan is located in Phuentsholing (a border city in the south west of Bhutan), and several transport companies are engaged in transport of international cargoes. Customs clearance is done as follows by providing the documents for import clearance procedure:

From Japan: Waiting offshore, unloading, temporary admission at Kolkata Port *1

Final clearance at Phuentsholing*2 after transport within India

Note) *1: This project uses Kolkata Port as previously.
*2: Phuentsholing is the largest border trading point in Bhutan.

	
State around the custom house – 1	State around the custom house - 2
	
State around the custom house – 3	State around the custom house - 4

Source: JICA Study Team

Figure 2.2.41 Customs Clearance Site

(a) Transportation from Kolkata to Phuentsholing

The materials and equipment procured overseas, with the exception of those procured from India, will be transported from Kolkata Port to Phuentsholing (about 785km) by the transport vehicles shown in the table below. Four or five days will be required for transportation.

Table 2.2.49 Transport Vehicles (Kolkata-Phuentsholing)

Vehicle type	Load shape (m)			Maximum load (MT)
	Length	Width	Height	
Truck	5	2.1	2.1	13
Trailer	12	2.4	2.4	24
Low slung trailer	6	3	3	30
Special low slung trailer	8	3.75	3.75	40

Source: JICA Study Team

(b) Transportation from Phuentsholing to Each Bridge Site

Transportation routes from Phuentsholing (which is located on the border with India) to each bridge site are using domestic roads as described in the "2.2.4.1 Implementation Policy". These routes take two days.

(c) Transportation Route and Period of Materials and Equipment from Japan

There are many container vessels travelling from Japanese ports to Kolkata Port, but a break-bulk vessel service is available about once a month. The number of days required for transportation from a warehouse/factory in Japan to the site is as follows:

Warehouse/factory – Port in Japan	:	7 days
Departure – Kolkata Port	:	30 days
Waiting at anchor offshore and unloading at Kolkata	:	7 days
Temporary customs clearance at Kolkata	:	1 days
Inland transportation from Kolkata to Phuentsholing	:	4-5 days
Permanent customs clearance at Phuentsholing	:	2 days
Transfer of cargo to Bhutanese truck at Phuentsholing	:	2-3 days
Phuentsholing - Site	:	2 days
Total	55-57days =	2 months

(2) Implementation Schedule

For implementation of the Project through grant aid, the following items must be taken into account for preparation of the work schedule;

- The construction schedule must be practical by taking into account the rainfall and snowfall pattern, the period necessary for procurement of materials and equipment, and employment of an adequate construction method.
- The construction schedule and site operation process must not hinder the existing traffic and must not present any inconvenience as much as possible.

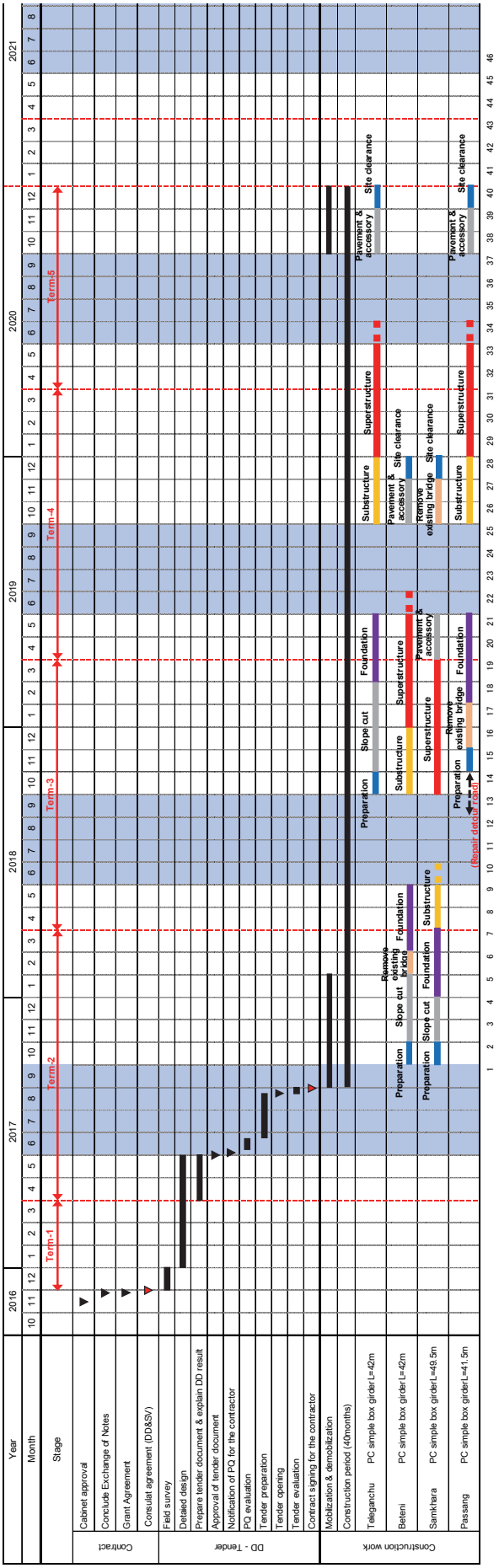


Figure 2.2.42 Project Implementation Schedule

Source: JICA Study Team

2.3 Obligations of Recipient Country

The Obligations to be undertaken by Bhutan side under the Project are as described below.

(1) General

- To open bank account known as Bank Arrangement (B/A).
- To announce an Authorization to Pay (A/P) to the bank in Japan and bear the bank commission fees.

(2) Project Implementation Matters

- To remove and/or relocate any obstacles effecting the Project implementation.
- To give permission to the Contractor for procurement of raw materials (e.g. sand, soil, stone and so on) for the construction work.
- To approve result of the detailed design to be submitted by the Consultant.
- To provide lands to be used for the disposal site.
- To apply Environmental Clearance (EC) by DoR with attaching IEE report.
- To approve Environmental Clearance (EC) by Dzongkhags.
- To ensure prompt unloading and customs clearance procedure for imported items.
- To accord Japanese nationals and/or physical persons of the third countries whose services may be required in connection with supply of the products and the services under the verified contract for the Project such facilities as may be necessary for their entry in to Bhutan and stay therein for the performance of their work.
- To ensure that customs duty, internal taxes and other physical levies those may be imposed in Bhutan with respect to the purchase of the products and/or the services to be borne for the Project. Such taxes include VAT, commercial tax, income tax of Japanese nationals, resident tax, fuel tax, but not limited, which may be imposed in Bhutan with respect to the supply of the products and the services under the verified contract for the Project.
- To arrange approval of the applications by the Contractor concerning installation and/or relocation of electricity, water supply, sewage and other facilities required for the Project implementation nearby the site.
- To implement proper maintenance works of roads and bridges excluding the Project sections.
- To bear all the expenses other than those to be borne by the Grant Aid.
- To submit the Project Monitoring Report (PMR) to JICA office every month.
- To repair the detour road in the site of Passang Bridge before the Tender, and maintain the road during the construction work.

- To maintain the detour road in the site of Beteni Bridge during the construction work.
- To implement the Environmental Management Plan (EMP) and the Environmental Monitoring of Plan (EMoP) during the construction period and the post-construction period.
- To submit the Environmental Monitoring Report in attaching to the PMR to JICA office quarterly basis during the construction period.
- To submit the Environmental Monitoring Report to JICA office semiannually basis within three years during the post-construction period.
- To implement proper maintenance work of the facilities constructed under the Grant Aid.
- To remove existing Telegangchu Bridge and the detour road in the site of Beteni Bridge within three years during the post-construction period.
- To submit result of the quantitative effect indicator to JICA office according to the effect described in the MD.

(3) Others

- To secure the budget for the construction work to be borne by Bhutan.
- To make an agreement with the Consultant in charge of the detailed design and the construction supervision work.
- To make a contract with the Contractor in charge of the construction work.

2.4 Project Operation and Maintenance Plan

2.4.1 Operation and Maintenance System

Large-scale repair work will not be required for 20 to 30 years after the completion of the Project, provided that routine inspection and maintenance as shown in this chapter are properly executed.

Under existing conditions, however, it is difficult for DoR to maintain properly because their technical capability of the maintenance framework is insufficient and also due to a lack of engineers and budget. Then JICA has planned to conduct the Technical Cooperation Project for three years from this fiscal year, which is related to the bridge maintenance for DoR. After the Technical Cooperation Project, DoR (mainly Trrongsa regional office, Zhemgang regional office, Sarpang regional office) who improved their capacity and enhanced their organization is supposed to maintain the bridge constructed in this project. Therefore it is important to cooperate with DoR in order to transfer technology considering the type and characteristics of the bridge of this project.

2.4.2 Inspection and Maintenance Method

(1) Periodic Inspection and Maintenance

Bridge structures, approach roads and retaining wall will have to be maintained by DoR regional office. Table 2.4.1 shows the recommended intervals for the inspection and maintenance activities of the proposed four bridges. Note that it is recommended to execute inspections before and after the rainy season.

Table 2.4.1 Contents of Maintenance & Inspection

Inspection type	Frequency	Implementation agency	Inspection point
Routine Inspection	Once/week	DoR Regional office	Bridge deck, Beam, Bearing, Abutment Ditch, Catch basin, Pavement
Periodic inspection	Once/two years, before/ after rainy season	DoR Regional office	Erosion, scour of abutment etc. Surface condition, marking
Special Inspection	In case of emergency	DoR Headquarter	Bridge defects and damages Damage of slope and wall

Item		Contents
Annual maintenance	1. Inspection and cleaning of drainage systems:	By inspecting catch basins on the bridges, gutters and pipes of approach roads, to remove and clean any sediment.
	2. Inspection and cleaning of expansion joints:	Although a surface drainage system is installed on expansion joints on the bridge surface, to inspect and if necessary remove and clean mud or sand accumulated in joint gaps.
	3. Inspection and repair of bridge face:	By inspecting conditions of bridge pavement, to repair cracks, etc.
	4. Inspection and cleaning of bearings:	To inspect, clean and remove mud accumulated around bearings below girders if necessary.
	5. Inspection and repair of approach road pavement:	To inspect and repair pot holes on asphalt pavement.
	6. Inspection and cleaning of approach road gutters:	To remove mud accumulated in gutters.
	7. Inspection and cleaning of box culvert	To remove and clean any sediment in box culvert
Maintenance every five years	1. Repair of steel handrails:	To partially repair handrails damaged by vehicle collisions.
	2. Repair of revetments:	To inspect and replace gabions if necessary.
	3. Re-painting of road markings:	To periodically repaint road markings.
Maintenance every ten years	1. Re-paving of approach road surface	To repave damaged approach road surface
Maintenance every twenty years	1. Re-paving of bridge surface	To repave damaged bridge surface
	2. Installation of water proof sheet at deck slab	To replace deteriorated water poof sheet
	3. Replacement of expansion joint	To replace damaged expansion joint

Source: JICA Survey Team

It is important to keep records of periodic inspections conducted by DoR regional office for the assessment of the conditions of the facilities for establishment of a repair schedule. Accordingly, proper inspection procedures including checking methods, intervals and reporting should be established at the initial work stage.

2.5 Project Cost Estimation

2.5.1 Initial Cost Estimation

(1) Cost Estimation

The total cost of the Project by the Japanese Grant Aid is confidential until the contractor for construction will be verified by the Ministry of Foreign Affairs in Japan.

Table 2.5.1 Approximate Project Cost

Bridge Name	Major Work Item	Cost (Million Japanese yen)
Telegangchu Bridge (42m)	(Bridge) Foundation/Substructure/Superstructure Revetment work (Approach road) Pavement/Slope protection (Others) Accessories/Drainage	
Beteni Bridge Bridge (30m)	(Bridge) Foundation/Substructure/Superstructure Revetment work (Approach road) Pavement/Slope protection (Others) Accessories/Drainage	
Samkhara Bridge (49.5m)	(Bridge) Foundation/Substructure/Superstructure Revetment work (Approach road) Pavement/Slope protection (Others) Accessories/Drainage	
Passang Bridge (41.5m)	(Bridge) Foundation/Substructure/Superstructure Revetment work (Approach road) Pavement (Others) Accessories/Drainage	
	Consultant Fee (DD/Tender assistance/CS)	
	Contingency	
	Total Project Cost	

Source: JICA Survey Team

(2) Premises of Estimation

Time of estimate	September, 2015
Exchange rate	US$1.00=JPY124.29, BTN1.00=JPY2.08
Implementation period	Refer Figure 2.2.42
Others	On the condition that the Project is implemented with Japanese Grant Aid. The above-mentioned exchange rate is to be reviewed by the Government of Japan.

(3) Cost Borne by Bhutan Government Side

The approximate costs required for the tasks to be undertaken by the GOL are shown in Table 2.5.2.

Table 2.5.2 Estimated Cost Borne by Bhutan Government Side

Item	Cost (Nu)	Remarks
Payment of bank commission	1,613,000	
To refund custom duties, internal taxes and other fiscal levies	19,000,000	
To remove and relocate obstacles at sites	1,500,000	
Removal of the existing bridge (Teleganchu bridge)	1,000,000	
Removal of the detour road (Beteni bridge)	1,000,000	
To repair the detour road (Passang bridge)	1,000,000	
Total	25,113,000	Exchange rate: 1Nu. = 2.08 yen

Nu = Ngultrum

Source: JICA Survey Team

2.5.2 Operation and Maintenance Cost

Table 2.5.3 shows the maintenance costs estimated in accordance with the maintenance plan of the Project.

Table 2.5.3 Major Maintenance Items and Cost

Term	Object	Location subject to inspection, Frequency	Maintenance Description	Unit	Unit cost (Nu)	Workload	Maintenance Cost (Nu)
Inspection	Bridge	Once/week	Routine Inspection	Lump sum	-	-	100,000
		Once/2 years	Periodic inspection	Lump sum	-	-	50,000
		In case of emergency	Special Inspection	Lump sum	-	-	50,000
	Road	Once/week	Routine Inspection	Lump sum	-	-	50,000
		Once/2 years	Periodic inspection	Lump sum	-	-	25,000
		In case of emergency	Special Inspection	Lump sum	-	-	25,000
	(1) Sub total						300,000
Annual	Bridge	Drainage	Cleaning of catch basin and drainage pipe	No.	100	21	2,100
		Expansion joint	Cleaning, repair of rubber portion	No.	500	8	4,000
		Bridge surface	Small-scale repair	m^2	220	132	29,040
		Bearing	Cleaning	No.	100	8	800
		Existing bridge (Telegangchu bridge)	Inspection/cleaning/ repair	1 unit	-	-	25,000
	Road	Road surface	Repair of pavement	No.	620	50	31,000
		Ditch	Removal of soil	m	50	432	21,600
	(2) Sub total						113,540
5 years	Bridge	Handrail	Repair	m	1,000	15	15,000
	Road	Marking	Repainting	m	30	2,136	64,080
	(3) Subtotal						79,080
	(4) Average amount of each year ((3) / 5year)						15,816
10 years	Road	Road surface	Repaving	m^2	1,000	5,326	5,326,000
	(5) Sub total						5,326,000
	(6) Average amount of each year((5) / 10year)						532,600
20 years	Bridge	Bridge surface	Repaving	m^2	1,000	1,323	1,323,000
		Deck slab	Installation of waterproof sheet at deck slab	m^2	1,300	1,323	1,719,900
		Expansion joint	Replacement	m	35,000	80	2,800,000
	(7) Subtotal						5,842,900
	(8) Average amount of each year((7) / 20year)						292,145
Total amount for each year ((1) + (2) + (4) + (6) + (8))							**1,254,101**
							Equivalent to JPY2,608,530 / year

Source: JICA Survey Team

Chapter 3 Project Evaluation

3.1 Preconditions

The preconditions required for the Project implementation are described as follows;

- ✧ Project implementation agency (i.e. DoR) will apply to Dzongkhags who have jurisdiction over the construction sites namely: Trongsa (Teleganchu) and Sarpang (Beteni, Samkhara and Passang) in order to obtain Environmental Clearance (EC).
- ✧ DoR will effectively support the Consultant and the Contractor for a smooth implementation of custom clearance and tax exemption procedures for importing materials/equipment to be used for the Project. Further details are explained in Chapter 2.3.
- ✧ In order to ensure effectiveness of the Project such as smooth and safe traffic flow, and sound functioning of the facilities constructed in the project, DoR will be charged with executing maintenance works of the facilities. Maintenance works include routine (e.g. daily inspection, removal of obstacles, cleaning etc) and periodic inspection to check for defects on the facilities at the initial stage. DoR is expected to execute repair work as soon as defects are observed. Therefore, DoR will be required to secure staff and budget for a continous execution of the above works. Detailed contents are given in Chapter 2.4.

DoR should be capable of accomplishing the above tasks in accordance with the study and the discussions during this survey.

3.2 Necessary Inputs by Recipient Country

Necessary inputs to ensure the realization and sustainability of the Project effects are described as follows;

- ✧ The RGoB will secure the budget necessary for smooth implementation of the Project prior to the Project commencement. The details are as stated in Chapter 2.3.
- ✧ In order to sustain sound function of the facilities, the RGoB will secure a sufficient annual budget and permanent staff charged with the maintenance works stated in Chapter 2.4 during the post-Project period.
- ✧ DoR will assign the staff(s) in charge of environmental and social matters for certain implementation of the Environmental Clearance procedures.

3.3 Important Assumptions

Important assumptions for the realization and sustainability of the Project effects are described as follows;

- ✧ Survey results show that traffic volume will increase after completion of the Project. Therefore, DoR will continuously implement 2 types of maintenance works namely: routine and periodic maintenance, for the designed facilities to ensure safety of the facilities.
- ✧ In order to secure smooth traffic flow on the PNH-4, the RGoB will implement road widening work and bridge reinforcement/reconstruction work in the sections excluding the Project.
- ✧ The RGoB will properly restrict the vehicles those exceeding the design loading capacity of the new bridges.
- ✧ The rainfall intensity will not exceed 100 years in the catch basin areas the new bridges.

The Project effects will be obvious should DoR accomplish the above assumptions.

3.4 Project Evaluation

3.4.1 Relevance

The principal road network in Bhutan comprises only of: PNH-1, running east to west and four PNHs (2 to 4 and AH48) running south to the Indian border (total length = approximately 1,860 km (2013)). PNH-4, connecting Trongsa (a major city in the Central region) and Gelephu (a major city in the Southern region) is one of the most important trunk roads in passenger and cargo transport. Also, a national scale project, Mangdechu Hydropower Plant Construction Project is currently under implementation along this road. This project is expected to accomplish further development of the national economy and PNH-4 is playing a vital role as a transportation route for goods and equipment essential to its success. However, there are many bridges facing several issues such as deterioration due to age (many bridges were constructed before 1980), insufficient width and loading capacity according to the current design standards. This survey examined the relevance of the Project (i.e. reconstruction of the 4 requested bridges) in the following aspects:

(1) Comfortability with Superordinate Plan in Bhutan

MoWHS developed “Road Sector Master Plan (2007-2027)”. Over the 20-year period up to 2027, intends to expand the prefectural and national road network, and improve feeder roads. Furthermore, “11th Five Year Plan (2013 – 2018)” indicates implementation of maintenance work of existing roads (3,522 km) and reconstruction of bridges under the jurisdiction of DoR. This plan also indicates road widening project on PNH-1 and improvement of accessibility to the hydropower plant construction sites. The Project components highly conform to the above plan; underlining the relevance of the Project implementation.

(2) Importance of PNH-4 in the road network

As described above, PNH-4 being a one trunk road (i.e. no diversion route) connecting Trongsa and Gelephu, plays an important role in the Mangdechu Hydropower Plant Construction Project. Given such importance, strengthening the connectivity on this road is very necessary.

(3) Improvement of the Width and Loading Capacity

According to the existing design standards in Bhutan, PNH-4 is classified as "Primary National Highway." Therefore, its bridges are expected to have an effective width of 7.0m and to meet the loading condition of IRC 70R (100t, single lane) or IRC Class A (double lane) in accordance with the Indian Design Standards (IRC standards). However, most of the existing bridges on PNH-4 including the four target bridges, actually do not comply with the above requirements. Implementation of the Project is considered highly relevant because the Project will contribute to traffic safety and connectivity on PNH-4 by improving the widths and loading capacities of the target bridges.

(4) Breakthrough of technological difficulties

Three of the four target bridges (Telegangchu, Beteni and Samkhara) are located in quite severe mountainous road sections. Therefore, construction work will be implemented with high technological difficulties as shown below.

- Safe work implementation within a limited construction area due to severe terrain conditions.
- Control of tensioning work of the PC cable and quality control of the casting concrete by applying in-situ construction of the PC box girder.
- Safe dismantling and removal of the existing steel bridges.
- Implementation of slope protection works by applying slope frame-work with anchor bolts.
- Traffic control to aid in organizing construction vehicles and the ordinary vehicles manoeuvering narrow spaces.

The construction work of Passang Bridge also contains the above difficulties except terrain constraints.

Considering the above difficulties, the Project implementation will be very difficult, with the current technical capacity of Bhutan. Therefore, the Project implementation by applying Japanese technology and methodology is in order.

(5) Reconstruction of Damaged Bridges

As described above, in accordance with this survey, the deterioration of the four target bridges is ongoing. However, the survey results indicate that risk of immediate bridge collapse is not high in

all of them. Therefore, considering the risk, partial reinforcement is applicable instead of full reconstruction work. However, increasing the loading capacity from the existing 40R/55t to the designated 70R/100t capacity will be very difficult with only reinforcing work. Furthermore, three of the four target bridges (Telegangchu, Beteni and Samkhara) contain insufficient widths for 2-way traffic of large vehicles. Consequently, reconstruction of new bridges is considered appropriate in this project.

(6) Relationship with the National Projects

Construction of the hydropower plant is the most critical factor for economic development in Bhutan. Ten hydropower plant construction projects are planned in the 11th Five-year plan. At present, the Mangdechu Hydropower plant is being constructed in Trongsa, for which PNH-4 is playing a vital role as a transportation route of goods and equipment. This makes improving the bridge loading capacity especially essential for smooth transportation of the heavier components of the plant such as transformers. Hence, reconstruction of Telegangchu Bridge will contribute to promotion of important national projects and is therefore considered highly relevant.

3.4.2 Effectiveness

(1) Quantitative Effects

Quantitative effects expected from the grant-aid project are summarized in Table 3.4.1.

Table 3.4.1 Quantitative effects from the grant-aid project

Index		Standard value (measured in 2015)	Target value (2024) [In three years after completion of the project]
Average traveling speed* (km/h)	Telegangchu Bridge	13	20
	Beteni Bridge	12	20
	Samkhara Bridge	14	20
	Passang Bridge	19	60
Bridge loading capacity (total axle load) (t)	All bridges	55	100
Annual average daily traffic (vehicles/day)	Trongsa – Zhemgang	190	245
	Zhemgang – Gelephu	233	301
Annual average daily passengers (numbers/day)	Trongsa – Zhemgang	640	826
	Zhemgang – Gelephu	785	1,014
Annual average daily cargo (ton/day)	Trongsa – Zhemgang	382	493
	Zhemgang – Gelephu	469	606

* Determined by actual measured speed.

Source: JICA Study Team

(2) Qualitative Effects

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

- ✧ Improvement of traffic safety

  Improving width and loading capacity of the bridges and strengthening of slope stability on the approach roads by the Project will promote traffic safety.

- ✧ Promotion and smoothing of logistics

  PNH-4 is one of the most important trunk roads to Bhutanese economy. The Project will promote stable and smooth logistics by eliminating traffic bottlenecks. Subsequently, it will contribute to the development of local economy.

- ✧ Securing the safety of pedestrians

  There are local communities near Passang Bridge. Therefore, many pedestrians cross the bridge. Construction of sidewalks will ensure the safety of pedestrians (especially, vulnerable road users, such as women and children).

In conclusion, the Project is expected to be relevant.