Chapter 8 Formulation of a Seismic Resistant Building Guideline, Its Dissemination and Human Resource Development

8.1 Confirmation and Review on the Building Standards to Prepare for Future Earthquake Disasters

8.1.1 Outline of Nepal National Building Code (NBC)

After the 1988 earthquake with a magnitude of 6.7 on the Richter Scale in eastern Nepal resulting in heavy loss of life and numerous buildings including hospitals, and severe damage to schools, the Ministry of Physical Planning and Works (MPPW), the current Ministry of Urban Development (MoUD), which was the Ministry of Housing and Physical Planning at that time, and the Department of Urban Development and Building Construction (DUDBC), which was the Department of Buildings at that time, drew attention to the urgent need for a Nepal National Building Code (NBC) and a draft National Building Code was prepared in 1993.

8.1.2 Categories of NBC

NBC is classified as per application in the construction industry of Nepal, which is given in Table 8.1.1 and Table 8.1.2.

Table 8.1.1 List of NBC and Their Purposes

S.N	Type of Building Code	Purpose
1.	International State-of-Art Applicable codes: NBC 000	The structures must comply with existing international state-of the art building codes
2.	Professionally Engineered Buildings Applicable codes: NBC101, NBC102, NBC103, NBC104, NBC105, NBC106, NBC107, NBC108, NBC109, NBC110, NBC111, NBC112, NBC113, NBC114, NBC206, NBC207, NBC208	Buildings designed and constructed under supervision of engineers, buildings with a footprint area more than 1,000 ft^2, buildings having more than three stories, buildings with a span of more than 4.5 m and buildings with irregular shapes
3	Mandatory Rules of Thumb Applicable codes:, NBC 201, NBC 202, NBC 205	Buildings of a footprint area less than 1,000ft^2, less than three stories, buildings having spans less than 4.5 m and constructed by technicians in the areas
4	Guidelines for Remote Rural Buildings NBC 203, NBC 204	Buildings constructed by local masons in remote areas and not more than two stories

Source: JICA Project Team

Table 8.1.2 Code Number and Titles of NBC

Code No.	Code Title
NBC 000	Requirements for State of the Art Design
NBC 101	Materials Specifications
NBC 102	Unit Weight of Materials
NBC 103	Occupancy Load
NBC 104	Wind Load
NBC 105	Seismic Design of Buildings in Nepal
NBC 106	Snow Load
NBC 107	Provisional Recommendation on Fire Safety
NBC 108	Site Consideration for Seismic Hazards
NBC 109	Masonry: Unreinforced
NBC 110	Plain and Reinforced Concrete
NBC 111	Steel
NBC 112	Timber
NBC 113	Aluminium
NBC 114	Construction Safety
NBC 201	Mandatory Rules of Thumb: Reinforced Concrete Buildings with Masonry infill
NBC 202	Mandatory Rules of Thumb: Load Bearing Masonry
NBC 203	Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry
NBC 204	Guidelines for Earthquake Resistant Building Construction: Earthen Buildings
NBC 205	Mandatory Rules of Thumb: Reinforce Concrete Buildings without Masonry Infill
NBC 206	Architectural Design Requirements
NBC 207	Electrical Design Requirements for Public Buildings
NBC 208	Sanitary and Plumbing Design Requirements

Source: JICA Project Team

8.1.3 Structural Codes in NBC

(1) Seismic Criteria and Methods

1) Seismic Base Shear

Equation for calculation of seismic base shear is below:

V=Cd*Wt

Design horizontal seismic coefficient

Cd=C*Z*I*K

Where:

C = Basic seismic coefficient,

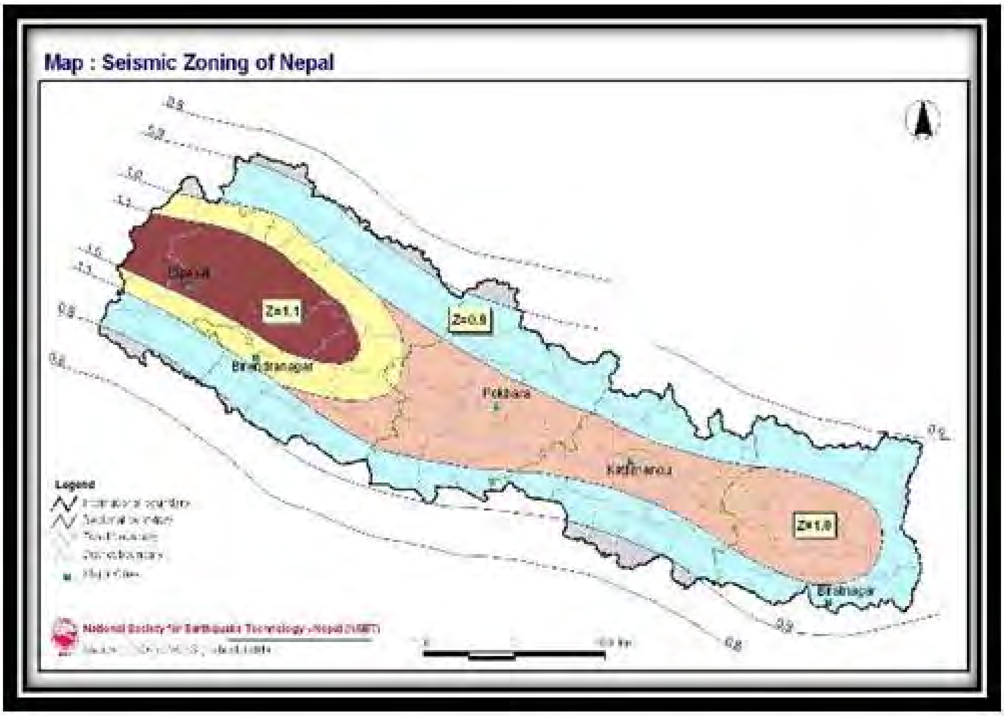
Z = Seismic zoning factor, (shown in Fig.1)

I = Importance factor,

K = Structural performance factor

Therefore, design seismic force coefficient, of wall type masonry structure (K = 4) would be calculated as follows:

Cd=0.08*1*1.0*4(Masonry structure) =0.32



Source: NBC105

Figure 8.1.1 Seismic Zoning Factor

2) Structural Codes

The Structural Codes of NBC are shown in Table 8.1.3.

Table 8.1.3 Structural Codes of NBC

Code No.	Code Title
NBC 105	Seismic Design of Buildings in Nepal
NBC 202	MRT: Load Bearing Masonry
NBC 203	Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry
NBC 204	Guidelines for Earthquake Resistant Building Construction: Earthen Building
NBC 205	MRT: Reinforce Concrete Buildings without Masonry Infill

Source: JICA Project Team

For designing a masonry structure, the use of NBC202 for cement mortar and NBC203 for mud mortar are popular, however these MRT were not based on structural calculation, but guidelines based on experience from past earthquakes.

Therefore, a structural analysis of prototypes by NBC105 as seismic design was conducted.

8.1.4 Review of NBC105

The NBC000, which determines the basic principles of the building code in Nepal, dictates that The return period for the onset of damage for a typical building of ordinary importance has been chosen as 50 years. The return period for the strength of buildings has been chosen as 300 years. This explains that earthquakes with the return period of 50 years and 300 years shall be used in the building code for defining the damage limit and the safety limit, respectively.

The “Seismic Hazard Mapping and Risk Assessment for Nepal” is a document that has been used as reference in the preparation of NBC105, which dictates the building code for seismic resistant buildings. The document indicates a map of estimated Peak Ground Acceleration (PGA) of earthquakes in Nepal with the return period of 50, 300 and 500 years in three different soil types, with reference to an attenuation model by Kazuhiko Kawashima. When applying Type II (Medium Soil Sites) as the soil type, the PGA in around Kathmandu and other areas affected by the earthquake can be estimated as follows:

Table 8.1.4 PGA of Earthquakes with Different Return Periods

Return Period (years)	PGA (gal)
50	130
300	320
500	360

Source: Seismic Hazard Mapping and Risk Assessment for Nepal

The Magnitude of the earthquake that hit Nepal on 25th April 2015 was 7.8 on the Richter scale, and the strongest quake recorded by USGS at Kantipah, which is located in the central part of the Kathmandu Valley, was 164 gal. Furthermore, the seismogram in Kathmandu Valley, which is the only seismogram recorded in the area, also indicates that the PGA was smaller compared to that estimated for a 300 year return period earthquake (320gal). Based on these figures, it can be said that the NBC105 has been developed with the aim of coping with earthquakes larger than the one that hit Nepal in 2015.

On the other hand, the shear force coefficient (base shear coefficient) explained in NBC105 is significantly dependant on the increment rate of the structural performance factor (K factor). In case of masonry structures, the standard becomes more strict compared to that of the neighbouring India, but for structures with high rigidness such as reinforced concrete, the standard becomes more loose because the increment factor is low. Taking into consideration the difference in seismic demand between different types of structures, further discussions should be made focusing on the K factor.

Furthermore, the results of the ERAKV indicate the possibilities of earthquakes larger than that assumed in the NBC may occur in Kathmandu Valley. Discussions on future revisions of the NBC should be continued taking into consideration factors such as PGA, K factor and development of high-rise buildings in the area.

8.1.5 Situation Surrounding NBC

(1) ERRP Final Report proposal on revision of NBC

The Bureau of Crisis Prevention and Recovery (UNDP/BCPR) with the support of the Government of Japan initiated an Earthquake Risk Reduction and Recovery Preparedness (ERRP) programme in five high risk South Asian countries: Nepal, Bhutan, Bangladesh, India and Pakistan. The ERRP project in Nepal is a part of the five country regional programme in South Asia that seeks to support regional cooperation through knowledge sharing and the development of the best practices in the context of the SAARC Comprehensive Framework on Disaster Management agreed in February 2006. The country programme is designed to strengthen the institutional and community level capacity to plan and implement earthquake risk reduction strategies and disaster recovery preparedness in Nepal, a country that stands as 11th in the world with respect to vulnerability to earthquake hazards (BCPR, 2004). The ERRP Project was implemented by the Ministry of Physical Planning and Works (MoPPW) in close coordination with the Ministry of Local Development (MoLD), the Ministry of Home Affairs (MoHA) and Programme Municipalities with the financial support of the Government of Japan and UNDP-Nepal. The project has carried out various activities related to earthquake safe construction, earthquake preparedness, earthquake resistant standards including the NBC and recovery planning in Nepal.

The project supported local governments, specifically, programme municipalities, to enable their capacity for the implementation of NBC to reduce seismic risks to lives and property. Although the project document was signed between UNDP and the Government of Nepal in Oct. 2007, the real implementation only started in Feb 2008. The project period was from 2007 to 2010. ERRP provides a way for the municipalities to solve their own earthquake risk preparedness and motivating risk reduction policy development and implementation by:

- Promoting the understanding of local risk
- Creating collaborative partnerships amongst organizations and stakeholders
- Sharing expertise and experience from other municipalities
- Stimulating and motivating risk reduction policy development and implementation
- Building code implementation and enforcement

In July, 2009, the ERRP project published a report titled “Recommendation for Update of Nepal National Building Code Final Report” submitted by the Khwopa Engineering College, MULTI Disciplinary Consultants Ltd and K.D. Associates Ltd. The conclusions are attached in the Attached Document 1 including detailed recommendations for each NBC.

(2) Key Issues for Earthquake Resistance identified by UNCRD

1) Issues of NBC in Nepal presented on 19 June, 2015 at BRI Presentation

- Only a few municipalities have started the implementation of NBC because of the lack of engineers in the municipalities, etc. There has been a lack of technical staff in municipalities, a lack of dissemination action by national and professional organizations and NGOs, and a lack of understanding by the executive officers or mayors and residents after the 2015 earthquake disaster.
- Even for implementing municipalities, it is difficult to execute final inspections after completion because of illegal additions, etc. Because the municipality has no manpower to inspect, granting permission before construction based on design documents has been made possible. The final procedure for inspection cannot be implemented as there are many illegal constructions that are undertaken after the completion of the formal construction as planned.
- Necessity of dissemination/improvement of Electronic Building Permit System (E-BPS) started in two cities.
- Necessity of revision/review of NBC 1994 by the 2015 earthquake disaster

2) Challenges in Building Code Implementation

In “UNCRD Housing Earthquake Safety Initiative (2008, Jishnu Subedi)” the following points are raised as challenges for building code implementation.

- Capacity of Local Government/stakeholders (Algeria, Nepal, Peru)
- Lack of skill in the building control officers
- Underpaid staff
- No professional training or continuing education
- Lack of skill/understanding of designers, petty contractors and artisans
- Not enough motivation among engineers regarding building codes
- Social and economic obstacles
- Lack of awareness in the public (Nepal, Bangladesh)
- Myth–high cost to follow codes (Nepal)
- Large ratio of self-built informal construction (Peru, Nepal)

(3) Challenges of Building Code Implementation in Nepal claimed by Amod Dixit, 2008

There are mainly four levels in the implementation process for adequate building construction.

- First, is high level awareness, which enables the constructor to do proper work.
- Secondly, is what is considered usually as the code, which transmits the methodologies of (earthquake) safe housing.

- Thirdly, is pre-engineered guidelines, and
- Lastly, there are guidelines for rural housing.

It might be difficult to differentiate many types of buildings from various social and economic backgrounds; from poor to rich populations, but the guidelines ensure that any type of building can be earthquake resistant as long as it can follow adequate modalities with appropriate manpower and materials

8.2 Formulation of a Seismic Resistant Building Guideline

8.2.1 Characteristic and Observations on Collapsed Houses and Schools due to the Earthquake

A 7.8 magnitude earthquake struck Barpak in Gorkha District on 25th April, 2015. Soon after this earthquake, a 7.3 magnitude earthquake occurred in Sindhupalchok District on 12th May, 2015. 31 of the country’s 71 districts have been affected by the earthquakes. The damage situation regarding houses and schools in Nepal and the Target Areas of the Project caused by the earthquakes are as follows.

(1) Housings

1) Damage Situation of Houses Nationwide

Table 8.2.1 shows the housing damage by the earthquakes by damage level and by type of housing material.

A total of 755,549 houses have been damaged by the earthquakes in 31 districts in Nepal. Of which, 498,852 houses (66.0%) were completely destroyed and 256,697 houses (34%) were partially damaged.

The large-scale destruction of houses resulted primarily from the seismic vulnerability of the low strength stone or brick masonry with mud mortar houses that predominate in rural areas in Nepal. In the total of 755,549 damaged houses, 647,892 houses (85.8%) were made of low strength stone or brick masonry with mud mortar.

Table 8.2.1 Nationwide Housing Damage

Level of Damage	Low Strength Masonry	Cement Mortar Masonry	Reinforced Concrete	Total
Fully Destroyed	474,025	18,214	6,613	498,852
Partially Damaged	173,867	65,859	16,971	256,697
Total	647,892	84,073	23,584	755,549

Note: Housing damage information is as of May 28, 2015
Source: Post Disaster Needs Assessment (Vol. A: Key Finding)

2) Damage situation in Gorkha District

The Project Team obtained the data on the damage situation of houses in Gorkha District as shown in Table 8.2.2. According to the data, there are a total of 72,075 houses in 62 VDCs/Municipalities in the district. Of the 72,075 houses, 67,364 houses (93.5%) were damaged by the earthquakes. Details of the housing damage are as follows: A total of 59,523 houses (88.4%) were judged as "Fully Destroyed" and 7,841 houses were judged as "Partially Damaged", and of the 67,364 damaged houses, 66,223 houses (98.3%) used mud mortar and 1,141 houses (1.7%) uses cement mortar.

Table 8.2.2 Housing Damages in Gorkha District

Level of Damage	Low Strength Masonry	Cement Mortar Masonry	Total
Fully Destroyed	59,300	233	59,533
Partially Damaged	6,923	918	7,841
Total	66,223	1,151	67,374

Source: Post Disaster Needs Assessment (Vol. A: Key Finding)

(Ampipal VDC)

(Pandrung VDC)

Gorkha District

Source: The JICA Project Team

Figure 8.2.1 Damage to Masonry Houses in Gorkha District

Damage surveys in affected areas, such as Gorkha and Sindhupalchok Districts were conducted. The most damaged/destroyed houses in these areas were constructed using random rubble masonry and bricks stacked in mud mortar. Most of them had corrugated galvanized iron sheet roofing. No earthquake resisting measures were used.

3) Findings

Findings on damage to houses are summarized below:

- **Non-Engineered Construction**

  This type of construction is spontaneously and informally constructed in the traditional manner without any, or only a little, intervention by qualified architects and engineers in their design. In Nepal, especially in rural areas, most residential houses are built by the house owner and masons who are not educated in engineering. Therefore, most of the damaged houses were Non-Engineered Construction which caused damage by having no regard for earthquake resistance design.

- **Masonry in Mud Mortar**

Unreinforced mud mortar masonry is the structural method most vulnerable to earthquakes. This is because mud as a joint material is very friable when it receives vibrations. In the rural areas, most houses use masonry employing rubble or dressed stone and brick, and the joint material is mud mortar. Even in urban areas, this type of construction, which was built in 1970s to 1990s, still exists.

- **Failure Pattern**

In the masonry walls, out-of-plane is the most typical failure pattern, and diagonal shear cracks as in plane failure also usually occur. But in this earthquake, wall separation (delamination) failure came into prominence. Such houses are destroyed because of the weakness of the mortar used and the absence of bond stones across the thickness of the stone walls resulting in delamination of the inner and outer walls along with the separation of the walls, at the corners. These finally resulted in the total collapse of the buildings.


Source: JICA Project Team

Figure 8.2.2 Damaged Stone Masonry in Mud Mortar Structures in Mountain Areas


Source: JICA Project Team

Figure 8.2.3 Damaged Brick Masonry in Mud Mortar Structures in Urban Areas

Source: JICA Project Team

Figure 8.2.4 Out-of-plane Behaviour and Delamination of Walls

(2) School

The project for the reconstruction of schools has been carried out by JICA and ADB together with DOE. The project covers the damaged schools from the ECD (Early Childhood Development) stage to grade-12[14].

Out of the fourteen districts which were highly affected by the earthquake, JICA decided to support six districts; Gorkha, Dhading, Rasuwa, Nuwakot, Makwanpur, and Lalitpur, and ADB decided to support eight districts; Kathmandu, Bhaktapur, Sindupalchok, Kavrepalanchok, Dolakha, Ramechhap, Sindhuli, and Okhaldunga.

1) Preliminary Damage Survey and Field Survey Regarding Schools in Nepal and in Project Target Areas

DOE made a preliminary survey for school damage immediately after the earthquake immediately. Table 8.2.3 shows the result by damage level in the six districts which JICA decided to support under this Project. There were 2,419 primary, lower secondary, secondary and higher secondary schools in these districts and the total number of classrooms is 25,503. Out of these classrooms, 9,058 (36%) were fully damaged including collapse, 2,819 (11%) suffered major damage, and 3,969 (16%) suffered minor damage. This mean 63% of classrooms have suffered some damages.

The largest number of fully damaged classrooms was in Gorkha, and the second is in Nuwakot. On the other hand, the ratio of fully damaged classroom was highest in Raswa.

[14] Primary school: grade1-5, Lower secondary school: grade 6-8, Secondary school: grade 9-10, and Higher secondary school: grade 11-12.

Table 8.2.3 School Damage List in Six Districts

District	No. of Schools	No. of CRs	Fully Damaged Classroom		Major Damaged Classroom		Minor Damaged Classroom	
			No.	%	No.	%	No.	%
Gorkha	495	5375	2975	55%	99	2%	1187	22%
Dhading	608	5894	2140	36%	946	16%	908	15%
Rasuwa	98	1020	635	62%	13	1%	98	10%
Nuwakot	485	5188	2622	51%	823	16%	807	16%
Makwanpur	533	5572	383	7%	461	8%	969	17%
Lalitpur	200	2454	303	12%	477	19%	0	0%
Total	2,419	25,503	9,058	36%	2,819	11%	3,969	16%

Source: Education Cluster 3W analysis, announced on July 14, 2015

The Project Team visited several schools and made surveys in July 2015. Figure 8.2.5 shows the result of the surveys for damaged buildings in four schools in three districts; Gorkha, Sindhupalchok and Kathmandu.

The structural type of buildings A, C, and D is “tubular steel frame with stone masonry wall” and the stone masonry walls of these three buildings have been damaged due to the earthquake. Whereas the damage to the wall of building A was limited only around the gable, damage of the walls of buildings C and D ran through all walls, where some of the collapsed stones were already moved outside of the buildings. The structural type of building B was “brick masonry wall” and damage to the wall was limited to only around the gable as same as the damage to the wall of building A.

Buildings A, C, and D were constructed by community based organizations instead of local contractors. Since the ordinary people of the organizations carried out the construction of the all-stone masonry walls of these three buildings, the quality may not have been uniform.

There was no “lintel beam” or “top-tie beam” which would increase the strength of masonry walls, in buildings A, B, C, and D. In addition, the joint material of both stone and brick masonry walls was mud mortar. These factors might have affected the collapse of the walls. Also, building D was constructed on sloping land. This also might have affected the collapse.

Buildings E and F were constructed by contractors. The structural type of buildings E and F were “reinforced concrete frame and with brick masonry wall” and there were no cracks on both the concrete frame and brick wall.

District/Village	**Gorkha District, Palungtar Village**	
School	Shree Bhawani Higher Secondary School	
	 Building A	 Building B
Structural Type	Tubular Steel Frame with Stone Masonry Wall	Brick Masonry wall
District/Village	**Sindhupalchok District, Pipal Dada Village**	
	 Building B	 Building D
Structural Type	Tubular Steel Frame with Stone Masonry Wall	Tubular Steel Frame with Stone Masonry Wall
District/Village	**Kathmandu**	
School	Ratna Rajya Secondary School	
	 Building E (exterior)	 Building E (interior)
Structural Type	Reinforced Concrete Frame with Brick Masonry Walls	
District/Village	**Kathmandu**	
School	Sharada Secondary School	
	 Building F (exterior)	 Building F (interior)
Structural Type	Reinforced Concrete Frame with Brick Masonry Walls	

Source: JICA Project Team

Figure 8.2.5 Result of Surveys for Damaged Four Schools in Three Districts

2) Detailed Survey for School Damage

A detailed survey for school damage, named as SIDA[15], was conducted by the World Bank. However the result was not shared as planned. In April 2016, the World Bank (WB) shared the SIDA Report phase 1[16] and the following points were the contents and key findings of the result.

a) Contents of SIDA Report

SIDA Report consists of eight chapters and the contents are shown in Table 8.2.4.

Table 8.2.4 Contents of SIDA

Title: SIDA: Structural Integrity and Damage Assessment of Educational Infrastructure in Nepal, phase 1	
Chapter	Main Contents
1	Scope and objectives
2	Public school infrastructure portfolio
3	School Access
4	Structural characterization and vulnerability 4-1 Overall School Infrastructure 4-2 Masonry School Buildings 4-3 Reinforced concrete framed school buildings 4-4 Steel framed school buildings 4-5 Timber school buildings
5	Damage assessment after the April 25th 2015 earthquake 5-1 Affected vs unaffected school buildings 5-2 Overall damaged state of school buildings 5-3 Re-occupancy of school buildings after the earthquake 5-4 Masonry School Buildings 5-5 RC Framed Structure 5-6 Steel Framed Structure 5-7 Timber Framed Structure
6	Functional needs assessment
7	Emergency planning
8	Principal conclusions of Phase 1 of SIDA

Source: SIDA: Structural Integrity and Damage Assessment of Educational Infrastructure in Nepal, phase 1, results and findings (World Bank, 2016)

b) Key Findings of Each Chapter

Key findings written in the SIDA Report are shown in Table 8.2.5.

15 World Bank, SIDA: Structural Integrity and Damage Assessment of Educational Infrastructure in Nepal

16 Phase 1 targets eight districts out of fourteen damaged districts: Kathmandu, Makwanpur, Lalitpur, Ramechhap, Bhaktapur, Sindhuli, Kavre, and Okhaldhunga

Table 8.2.5 Key Findings of SIDA Report

Key Findings
1. School Infrastructure • There are altogether 3,115 schools, 9,259 school buildings, 24,984 classrooms and 9,256 additional rooms in eight districts. Approximately three-fourths of the total rooms in the school infrastructures are used as classrooms. • The average school facilities in all districts have an average of three buildings per school. • 52% of the overall school facilities are located on lands owned by the school. • The primary funders of school infrastructure are: DoE/MoE, local community and the school, JICA, EAARRP. • 70% of school buildings are constructed by local craftsmen provided by the community. • 90% of school infrastructure is located in rural areas. The majority of urban schools are located in Kathmandu Valley. • The conditions of the roads that provide access to school facilities are generally poor. • About 20% of the total toilet facilities are non-functional. Only half the total functioning toilets have wash facilities which are in a good condition. • Most of the schools have a safe space available to assemble in case of an emergency event. Also there are two or more exit points from the school premises in most of the schools.
2. Basic structural categorization • 52% of school buildings are made of masonry, followed by 29% of steel framed buildings and 12% of reinforced concrete buildings. • Masonry has been the structural typology most used on the construction of schools since it is based on locally available materials and construction technologies well known by the local community. • About 63% of masonry school buildings are made of stone masonry. Among these stone masonry buildings, the majority is laid on mud mortar and more than a half are made of rubble stone. • Almost all of the steel framed structures from all the eight districts are single storied except Lalitpur where two of the steel framed buildings are two storied. Most of these buildings are regular in plan and have a rectangular shape. • Stones are mainly used as the infill masonry for the steel framed buildings. About 72% of the used stone in the masonry are rubble stone. • The infill walls in RC buildings are normally made of brick masonry laid in cement mortar, except in some remote districts of Okhaldhunga and Ramechhap.
3. Vulnerability Assessment • About 50% of masonry school buildings are irregular in plan. Almost 90% of multi-story masonry school buildings are irregular in elevation. • The majority of masonry school buildings have large openings. The presence of large openings makes the building vulnerable to earthquakes. Also, the majority of masonry school buildings have unbraced roof structures that are not properly anchored to the walls. • The inclusion of seismic enhancements in the design and construction of masonry school buildings is not a common practice till now. It is recommended to have such a practice in the future. • Only 6% of masonry school buildings have been retrofitted, the majority of them located in Kathmandu Valley. • About 68% of RC school buildings are non-engineered making them vulnerable to earthquakes. • Most of the steel framed buildings in all districts have large openings in walls making them vulnerable during earthquakes.
4. Damage Assessment • There are about 57% of the buildings (5,157) and about 56% (13,644) class rooms affected by the earthquake. There is either structural damage or major non-structural damage in these buildings. • 54% of single storied and 39% of the multi-storied buildings are affected. Multi-storied timber framed buildings are more affected. • In RC buildings, the damage for non-engineered buildings as compared with engineered buildings is more in number. Cracks around the openings are found in most of the buildings. • In masonry buildings, a limited number of walls (up to 49%) have collapsed out of plane. About 40% of the gable walls are damaged, either fully or partially. • In general, there is no damage to the steel frame structures of the buildings, though some of the frames suffer from corrosion. Cracks around the openings were found in most of the walls. 13% of the walls are collapsed, either completely or partially, and 12% of the walls have major in-plane failure. • More than half of the timber framed buildings are damaged to some extent.

Source: SIDA: Structural Integrity and Damage Assessment of Educational Infrastructure in Nepal, phase 1, results and findings

(3) Utilized findings from surveys by academic institutes

The Project Team is in close cooperation with the survey teams from the Architectural Institute of Japan (AIJ), National Research Institute Earthquake Science and Disaster Prevention (NIED), and members from SATEPS.

8.2.2 Confirmation and Review of the Building Standards to Prepare for Earthquake Disasters

(1) Implementation System of the NBC

The implementation system of the NBC is shown in the below table.

Table 8.2.6 Implementing System of NBC

Legal Mechanism	Responsible organizations	Envisaged role
Building Act 1998 (Rev. 2007)	Building Construction System Improvement Committee	Devise Building Code, facilitate enforcement, disseminate code, monitor implementation, revise NBC code
	MPPW	Approve the Building Code
		Publish notice of mandatory implementation of Building Code
	DUDBC	Implement Building Code in areas outside of municipal jurisdiction
		Supervise compliance with Building Code
	Municipalities	Ensure compliance with the Building Code
Local Self Government Act 1999 (Decentralization Act)	Municipalities	Issue building permits (does not include provision of Building Code)
	House owners in municipal area	Comply with municipal rules and secure formal building permit before construction
National Building Code 2003	All concerned	Approved NBC
Notice of MPPW in Gazette (Feb. 13, 2006)	All municipalities, VDCs District Headquarters	Implementation of Building Act

Source: JICA Project Team

(2) Review of Implementation of NBC

The DUDBC of MPPW developed the NBC in 1993 with the assistance of the United Nations Development Programme (UNDP) and the United Nations Centre for Human Settlement (UN-HABITAT). The Ministry published a notice in the Gazette in 2006 and NBC has become mandatory in all municipalities and some Village Development Committees (VDCs) in Nepal. In 2002, prior to the formal entry to enforce the code, Lalitpur Sub-Metropolitan City (LSMC) initiated the implementation of NBC, becoming the first municipality in Nepal to implement the NBC. Kathmandu Metropolitan City followed in 2004, Dharan Municipality in 2006, Illam in 2008, Hetauda in 2010, Birgunj in 2011, and Byas Municipality in 2011. Other municipalities have also been applying NBC with the passage of time. In total, twelve municipalities have implemented the NBC by 2012 within the 191 total municipalities in Nepal. A total of five municipalities in 2013 and nine municipalities in 2014 have newly started applying the NBC and in total, 26 municipalities have started implementing the NBC in Nepal as of date.

A building permit system exists in Nepal. However, the implementation of the system is limited only to Kathmandu District and some municipalities including Gorkha, Chautara and Melamchi. The system has never been implemented in VDCs. The main reason for not implementing the system is shortage of engineers in the DUDBC in the MOUD and its local offices.

The target of the system is for buildings having a floor area of 1,000 ft^2 and more.

Source: JICA Project Team

Figure 8.2.6 Building Permit System Implemented Municipalities

(3) Implementation of NBC, and Clarification of Both the Background and Mechanism of Illegal Construction

Implementation of NBC can be considered the same with the implementation of building permits in Nepal. A building permit system exists in Nepal, however only some municipalities have been implementing the system as of date[17]. None of the other municipalities and none of the VDCs have been implementing the system. Therefore, it is not possible to determine whether structural design and building usage follow the NBC in these areas or not. There has been a proposal to increase the number of municipalities which implement the system. However, the main problem is the shortage of technical officers in many municipalities.

17 Result of interview for DUDBC, Gorkha municipality and Chautara municipality

8.2.3 Establishment of a Seismic Resistant Building Guidelines

(1) Housings

1) Design Catalogue for the Reconstruction of Earthquake Resistant Houses

a) Outline of the Design Catalogue for the Reconstruction of Earthquake Resistant Houses

The Design Catalogue for the Reconstruction of Rural Housing has been developed to support rural households to commence the reconstruction of their homes from a solid basis, by providing prototypes and flexible house designs which can be adopted and adapted in all earthquake affected communities. The designs provided in the catalogue cover four broad categories of building materials and typology:

- Stone and mud mortar masonry
- Brick and mud mortar masonry
- Stone and cement mortar masonry
- Brick and cement mortar masonry

The designs provided in this catalogue have all been prepared in compliance with the revised National Building Code of Nepal and approved by the DUDBC.

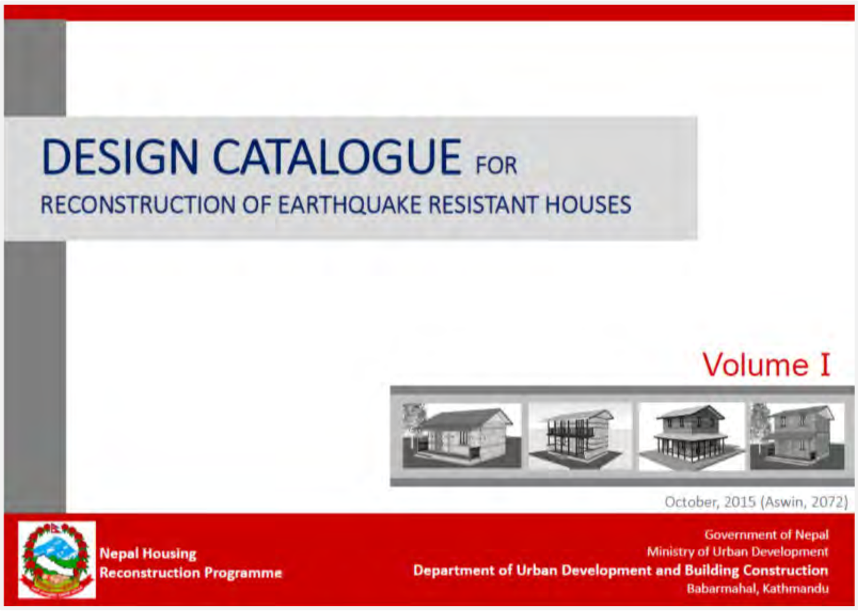
For each design included in the catalogue, the following information is provided:

- 3D view of the design
- Floor plan
- Elevations
- Section
- Technical Details

The number of manpower days for skilled and unskilled labour, as well as the quantity of materials required for the construction of the design was also provided, with a broken down of requirements; to construct up to the plinth level, up to the ring beam level, and for the construction of the roof.

Designs included in the Design Catalogue for Reconstruction of Rural Housing can be selected and used as is, the prototype designs, or can be adapted based on the parameters as defined in the National Building Code of Nepal, as described in the flexible designs. Once a design has been selected, this can be used by the household as part of the building permit application process. The Design Catalogue for Reconstruction of Rural Housing can also provide guidance in terms of budgeting, and estimating the quantity of material required, and as a general guide for basic earthquake resistant construction techniques.

The Project Team has supported the creation of this catalogue by DUDBC, which was published in November, 2015.



Source: Design Catalogue for Reconstruction of Earthquake Resistant Houses Volume 1, DUDBC

Figure 8.2.7 Design Catalogue for Reconstruction of Earthquake Resistant Houses

The list of model houses in this catalogue is shown in Figure 8.2.8. Those models have been approved by the technical working group which was organized by DUDBC.

Structural Type	No. of Floor	Model No.	Designed by	Page
Stone masonry in cement mortar, P5-	1	SMC-1.1	JICA	9
	1	SMC-1.2	JICA	15
	2	SMC-2.1	JICA	21
	2	SMC-2.2	DUDBC	27
	2	SMC-2.3	DUDBC	33
	2	SMC-2.4	DUDBC	39
	2+ATTIC	SMC-2.5	DUDBC	45
	2+TERRACE	SMC-2.6	DUDBC	51
		Technical details		57
		Flexible design		67
Brick masonry in cement mortar P71-	1	BMC-1.1	JICA	75
	1	BMC-1.2	JICA	81
	2	BMC-2.1	JICA	87
	2	BMC-2.2	DUDBC	93
	2	BMC-2.3	DUDBC	99
	2+ATTIC	BMC-2.4	DUDBC	105
	2+TERRACE	BMC-2.5	DUDBC	111
		Technical details		117
		Flexible design		126
Stone masonry in mud mortar, P129-	1	SMM-1.1	DUDBC	135
		Technical details		141
		Flexible design		143
Brick masonry in mud mortar, P147-	1	BMM-1.1	DUDBC	153
		Technical details		159
		Flexible design		161

Source: Design Catalogue for Reconstruction of Earthquake Resistant Houses
Volume 1, DUDBC

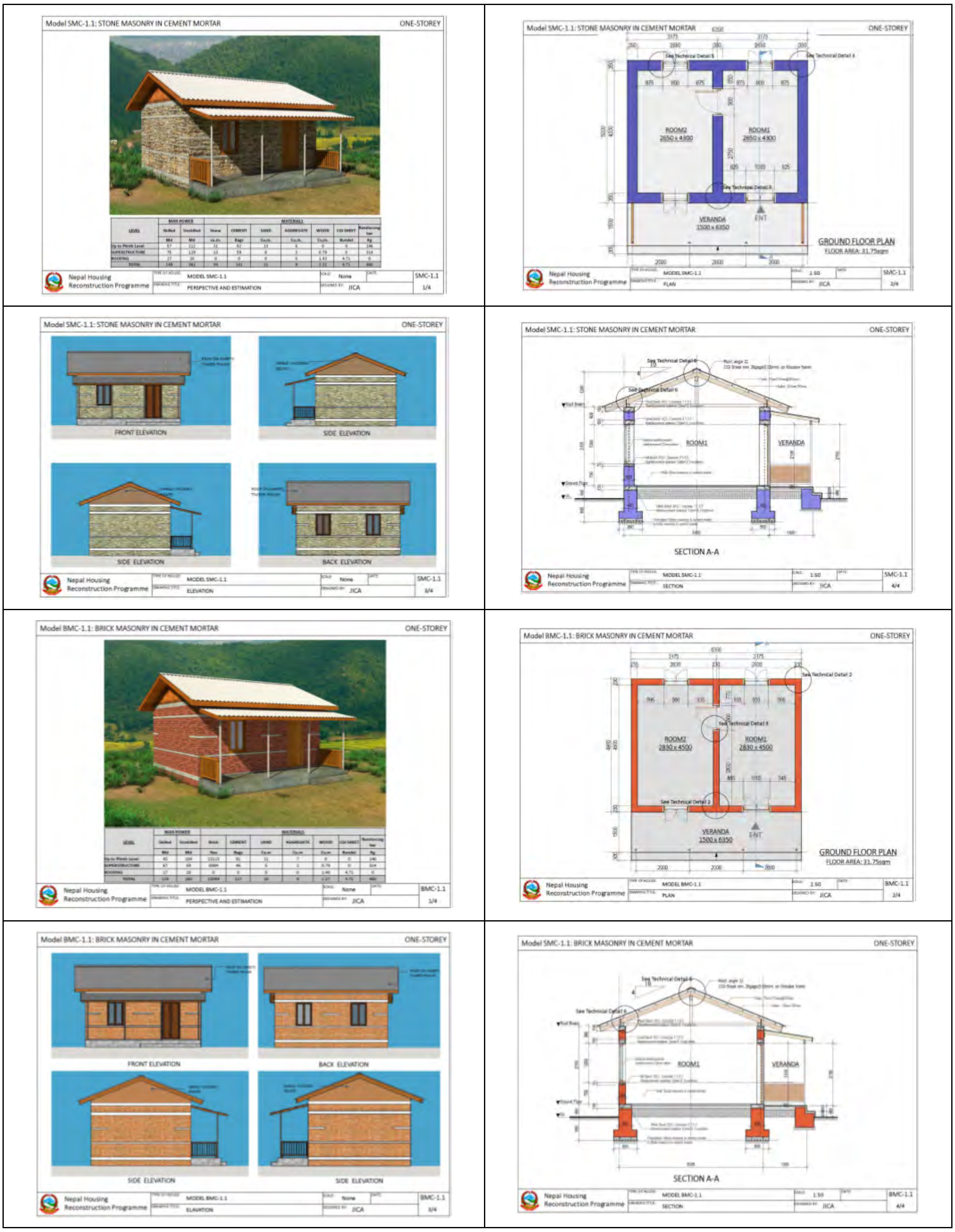
Figure 8.2.8 List of Model Houses in the Design Catalogue

b) JICA Models in the Housing Catalogue Volume 1

JICA has been promoting the implementation of “Build Back Better”, which is one of the priorities for action in the Sendai Framework for Disaster Risk Reduction 2015-2030. The concept has already been discussed in the Nepal Reconstruction Plan through the co-organization of the “Build Back Better Reconstruction Seminar for Nepal” which was held on 25th May, 2015 with the government of Nepal. The design of the JICA prototype models follows this concept.

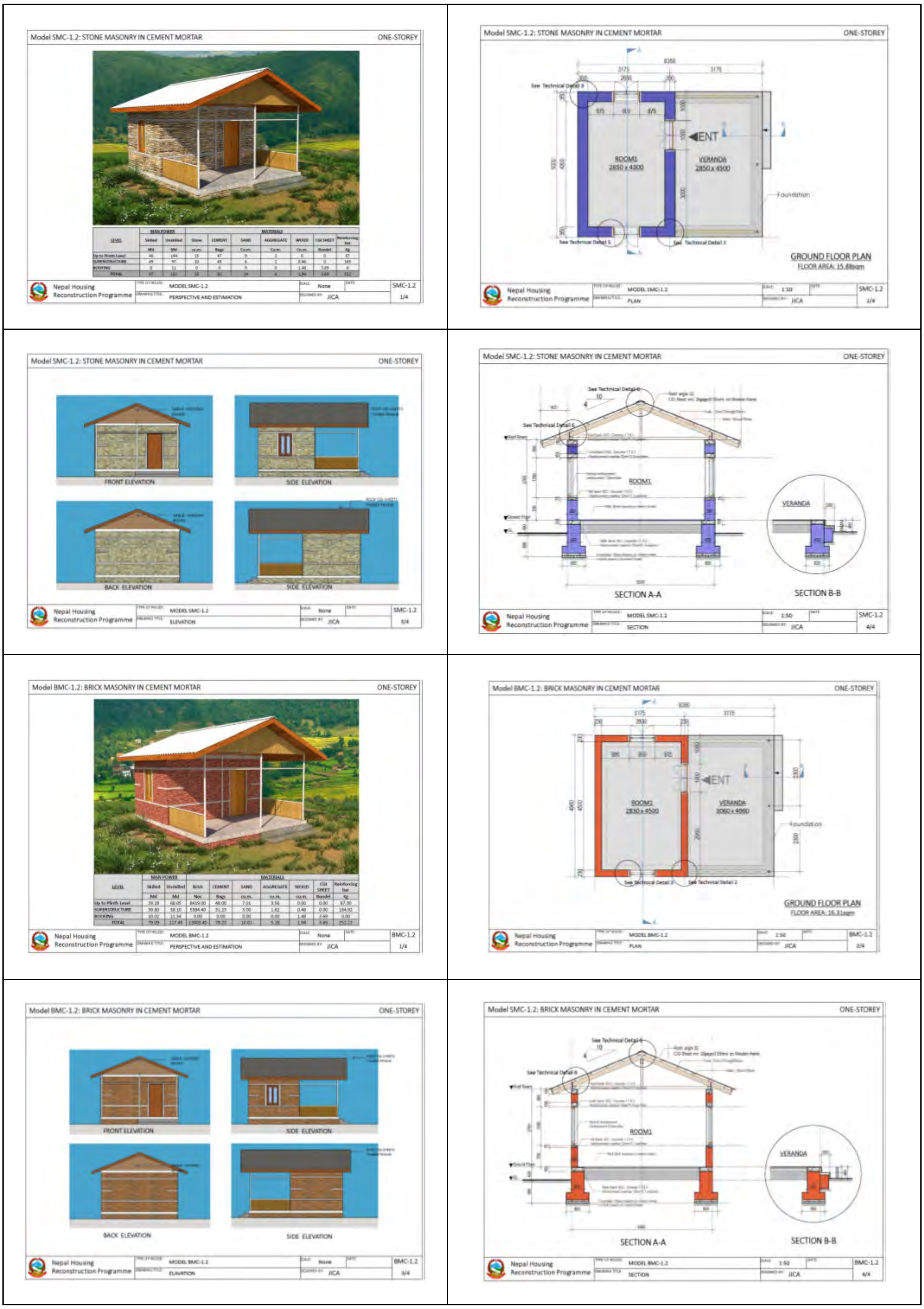
The six prototypes which the Project Team prepared are; SMC-1.1, SMC-1.2, SMC-2.1 with Stone Masonry in Cement Mortar, and BMC-1.1, BMC-1.2, BMC-2.1 with Brick Masonry in Cement Mortar. These prototypes follow the NBC 202, and were presented in the Technical Workshop on Rural Housing Design organized by the NPC on 13th September, 2015.

As an example, Model SMC-1.1 is a one-story house which can accommodate 3-5 people. It consists of two rooms with dimensions of 2650 x 4300 mm, and a veranda with dimensions of 1500 x 6350 mm. The design focuses on earthquake resistant construction using locally available construction materials. Similarly, stone masonry in cement mortar has been used for structural type, where CGI sheet is used for covering the roof along with wooden rafters and purlin. All designs have been based on the NBC in order to ensure that earthquake resistant construction measures were included. This includes the provision of horizontal bands, vertical reinforcement, corner reinforcement, and T-junctions to improve diaphragm effectiveness. The design concept and the objective of the design were to contribute towards resilient models to improve safety in future earthquakes.



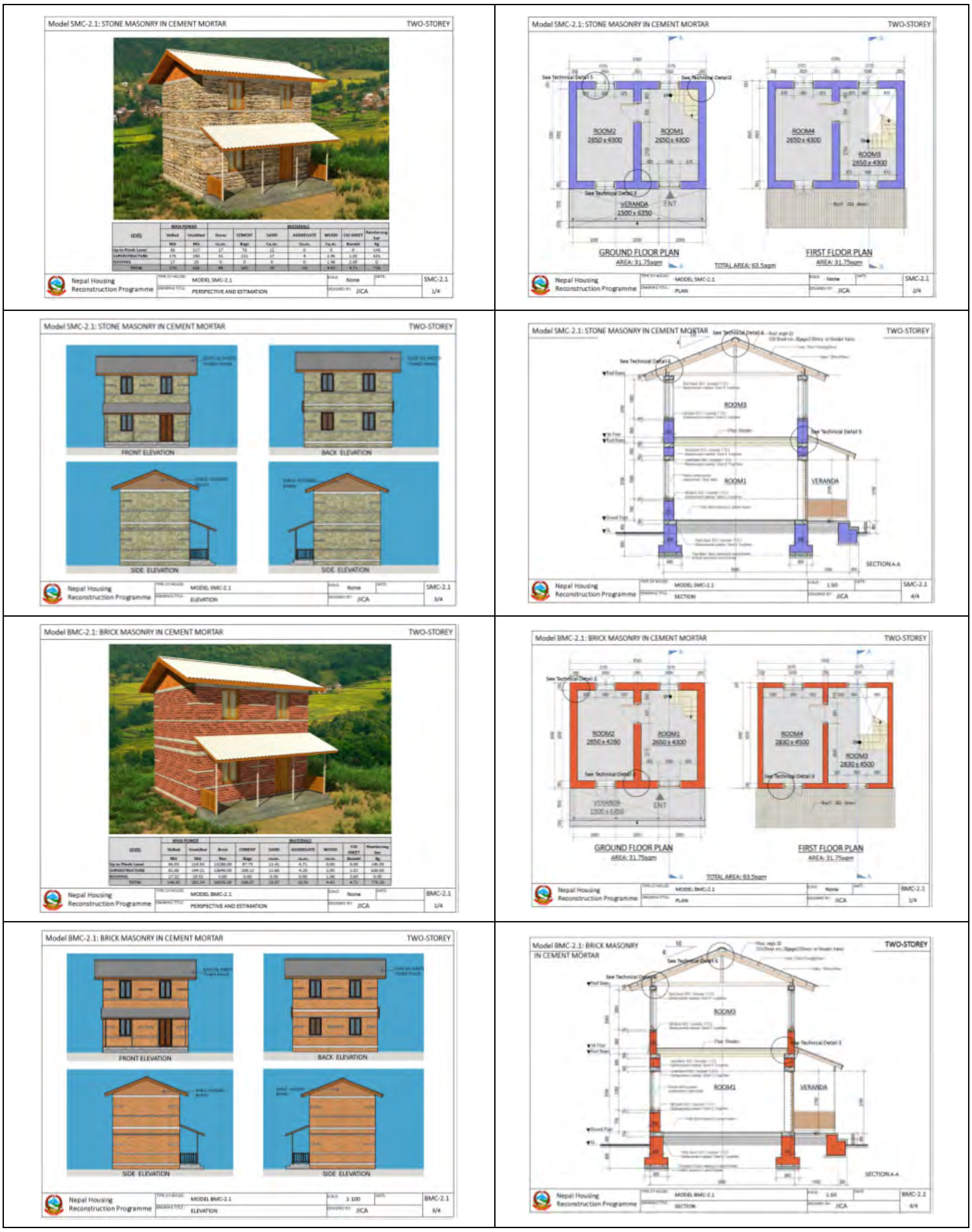
Source: Design Catalogue for Reconstruction of Earthquake Resistant Houses
Volume 1, DUDBC

Figure 8.2.9 Drawings of SMC-1.1 and BMC-1.1



Source: Design Catalogue for Reconstruction of Earthquake Resistant Houses
Volume 1, DUDBC

Figure 8.2.10 Drawings of SMC-1.2 and BMC-1.2



Source: Design Catalogue for Reconstruction of Earthquake Resistant Houses
Volume 1, DUDBC

Figure 8.2.11 Drawings of SMC-2.1 and BMC-2.1

2) Structural Calculation and Analysis

Structural calculations were performed using two methods; static structural calculation and structural analysis using FEM. The list of models of structural analysis is shown in Table 8.2.7.

Table 8.2.7 List of Structural Calculation

Structural Type in Volume 1	No. of Floor	Model No.	Static SC	FEM
Stone masonry in cement mortar	1	SMC-1.1	●	●
	1	SMC-1.2	●	●
	2	SMC-2.1	●	●
	2	SMC-2.2		●
	2	SMC-2.3		●
	2	SMC-2.4		●
	2+ATTIC	SMC-2.5		●
	2+TERRACE	SMC-2.6		●
		Technical Details		
		Flexible design (MR)		
Brick masonry in cement mortar	1	BMC-1.1		●
	1	BMC-1.2		●
	2	BMC-2.1		●
	2	BMC-2.2		●
	2	BMC-2.3		●
	2	BMC-2.4		●
	2	BMC-2.5		●
		Technical Details		
		Flexible design (MR)		
Stone masonry in mud mortar	1	SMM-1.1	●	●
		Technical details		
		Flexible design (MR)		
Brick masonry in mud mortar	1	BMM-1.1		●
		Technical details		
		Flexible design (MR)		

Source: JICA Project Team

a) Static Structural Calculation

The items examined through the static structural calculations were:

- Calculation of wall ratio for shear strength
- Calculation of strength of vertical bar for overturning moment
- Calculation of strength of horizontal bar in seismic band
- Calculation of out-of-plane strength of seismic horizontal band
- Calculation of plinth band
- Calculation of beating capacity of foundation
- Result of Static Calculation of JICA Models

Table 8.2.8 and Table 8.2.9 show the result of the structural calculation of SMC-1.1 and shows SMC-2.1.

Table 8.2.8 Result of Calculation of SMC-1.1

item	direction			safety ratio	
				Working stress method	Limit state method
Shear strength of masonry wall	X			3.31	4
	Y			5.11	6.18
Flexural strength in plane of	X	Y1	W1	2.05	2.01
			W2	2.33	2.25
		Y2	W1	2.17	2.12
			W2	2.38	2.34
	Y	X1	W1	5.79	5.82
		X2	W1	2.21	2.16
			W2	2.31	2.08
Ratio of designed horizontal band	X			3.54	3.41
	Y			5.5	5.3
Strength of out-of-plane flexural	X	X1		2.17	2.33
	Y	Y1		5.79	5.59
Strength of out-of-plane Shear	X	X1		1.82	2.2
	Y	Y1		2.81	3.37
bearing capacity	X	long time		1.9	1.88
		short time		2.99	3.74
	Y	long time		1.62	1.6
		short time		2.24	3.09

Source: JICA Project Team

Table 8.2.9 Result of Calculation of SMC-2.1

item	direction				safety ratio	
					Working stress method	Limit state method
Shear strength of masonry wall	X	2			2.85	3.43
		1			1.73	2.09
	Y	2			4.50	5.31
		1			2.68	3.24
Flexural strength in plane of	X	Y1	W1	2	2.04	2.73
				1	1.14	1.32
			W2	2	4.99	5.63
				1	2.22	2.09
		Y2	W1	2	2.17	2.88
				1	1.21	1.41
			W2	2	5.30	5.98
				1	2.36	2.63
	Y	X1	W1	2	5.68	6.27
				1	2.68	2.84
		X2	W1	2	2.75	3.14
				1	1.32	1.54
			W2	2	3.47	3.99
				1	1.68	1.96
Ratio of designed horizontal band	X	2			2.16	2.58
		1			1.32	1.40
	Y	2			3.36	4.10
		1			2.04	2.44
Strength of out-of-plane flexural	X	X1			1.49	1.79
	Y	Y1			3.05	3.64
Strength of out-of-plane Shear	X	X1			1.47	1.75
	Y	Y1			2.11	2.53
bearing capacity	X	Y1	long time		1.28	1.03
			short time		1.33	1.35
	Y	Y1	long time		1.03	1.07
			short time		1.13	1.36
		X1	long time		1.07	1.07
			short time		1.02	1.64

Source: JICA Project Team FEM Analysis Method

b) Analysis by FEM

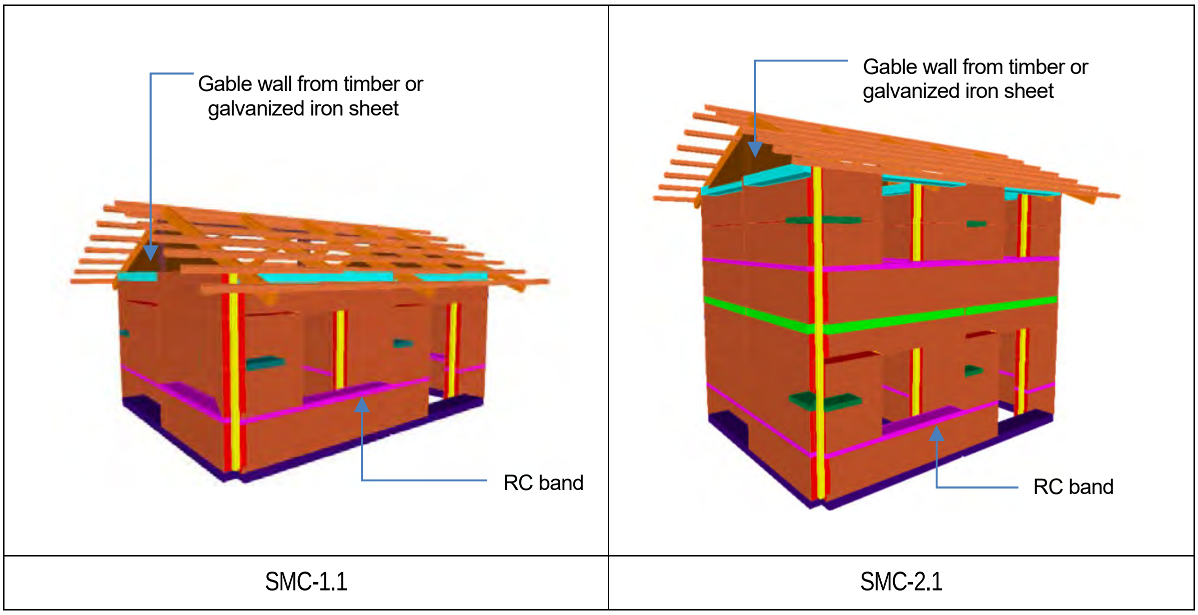
Applied Conditions

The following were the conditions Applied for FEM Analysis

- The modelling is based on the Finite Element Method (FEM) using commercial software SAP2000 Ultimate v18.
- The prototype structures are load-bearing masonry walls with horizontal bands to resist all load combinations, both gravity and lateral.
- Safe bearing capacity for all prototypes of houses is assumed 150 kN/m^2; soft to medium soil. Spring constants are applied at the bottom of the model to represent the soil condition.
- All analysis is based on the assumption that the bonds between walls and horizontal bands are perfect[18].

Applied Seismic standards and codes were as follows:

- NBC105: Nepal Building Code – Seismic Design of Buildings in Nepal
- NBC202: Nepal Building Code – Mandatory Rules of Thumb Load Bearing Masonry
- IS456: Indian Standard – Plain and Reinforced Concrete – Code of Practice
- IS1893: Indian Standard – Criteria for Earthquake Resistant Design of Structures
- IBC2015: International Building Code 2015



Source: JICA Project Team

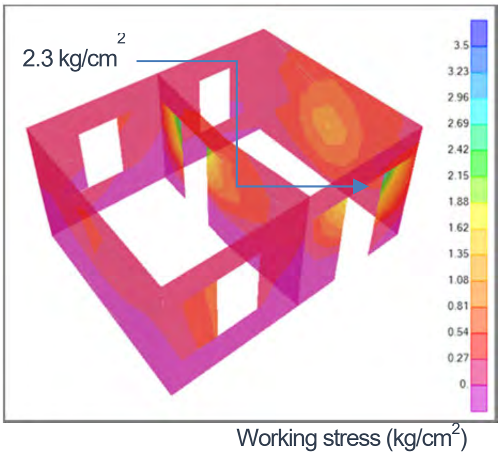
Figure 8.2.12 Modelling of SMC-1.1 and SMC-2.1 for FEM

[18] In reality, this might not be the case, particularly if the mud mortar becomes dry.

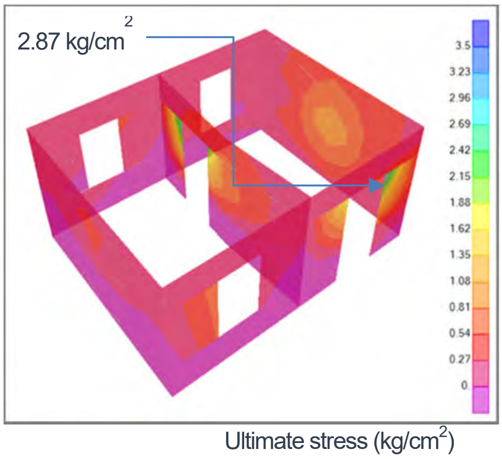
Result of Analysis

The results of FEM analysis are shown in Figure 8.2.13 to Figure 8.2.15.

Around the openings of a wall there was stress, however this stress can make an exception of the area by IS1905-5.4.3.



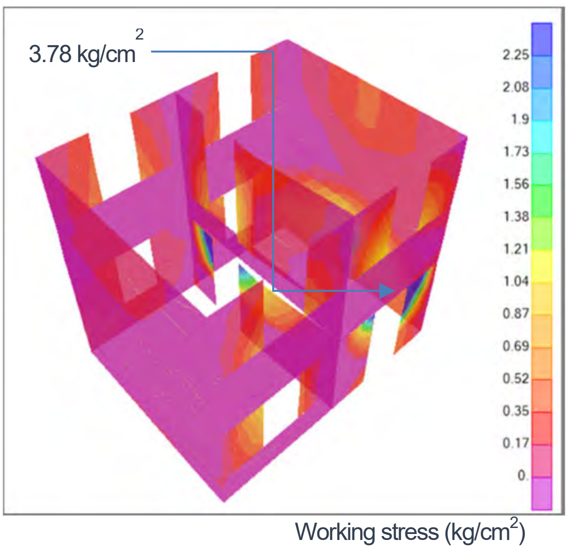
Maximum stress of Working Stress Method



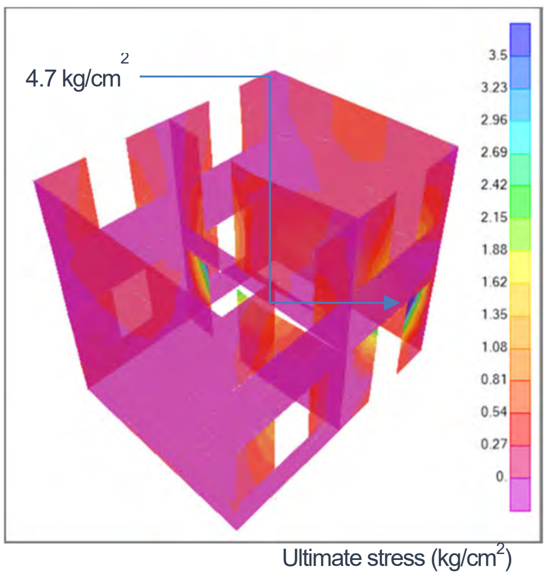
Maximum stress of Limit State Method

Source: JICA Project Team

Figure 8.2.13 Result of FEM Analysis of SMC-1.1



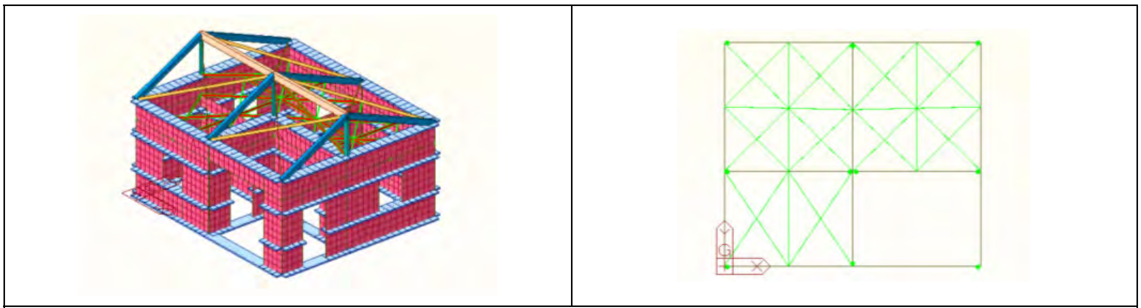
Maximum stress of Working Stress Method



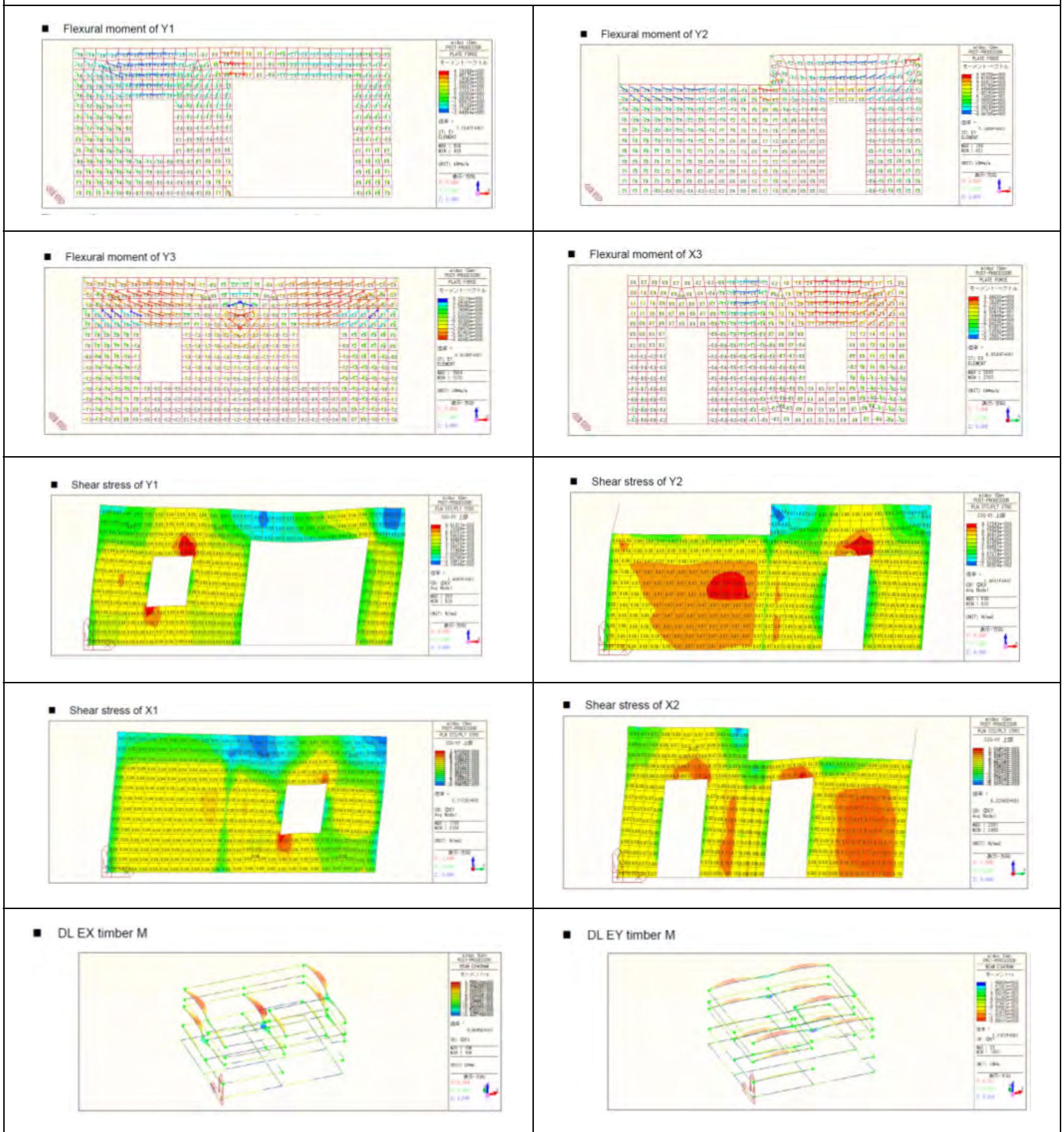
Maximum stress of Limit State Method

Source: JICA Project Team

Figure 8.2.14 Result of FEM Analysis of SMC-2.1



Modelling of SMM-1.1 and modelling of Attic floor



Result of SMM-1.1 by FEM

Source: JICA Project Team

Figure 8.2.15 Result of FEM Analysis of SMC-1.1

c) Conclusions of Structural Calculation and Analysis

According to structural calculations, SMC-1.1 and SMC-2.1 satisfy the NBC105 seismic requirement. The tensile stress and shear stress are below the limit.

On the other hand, SMM-1.1 with a timber band, stress was exceeded as follows:

- For out-of-plane strength, the stone masonry in mud mortar with wooden band cannot prevent the out-of-plane failure of stone masonry in mud mortar walls. This model does not satisfy the criteria of NBC 105.
- The stiffness and integrity of the diaphragm is important for earthquake resistance.
- The diaphragm stiffness of the wall is insufficient for out-of-plane behaviour. For example, adding a buttress to a wall, or a wooden brace on the top of the wall has to be provided to strengthen the diaphragm stiffness.
- Therefore, this model of stone masonry with mud mortar with wooden bands has the possibility of out-of-plane failure during an earthquake. Even if the shear strength of stone masonry in mud mortar are below the limit.

However, in actual reality, mud is the most typical vernacular material and there are several types of mud mortar stone masonry in the fields. In addition, in academics, there are very few studies of mud mortar structures, and the data of material property is not enough for observation.

The result of the structural calculation depends on material properties, so this value is "only advisory". This is the result of structural analysis which has its starting points for a mud mortar structure.

3) Minimum Requirements (MRs) for Residential Buildings

NRA launched its reconstruction programme on 16 January 2016 and organized the TSC (Technical Standardization Committee) at the end of February. In this committee, it was discussed whether NBC105 should be applied to residential buildings in the reconstruction programme as the seismic requirement. Following this discussion, the MRs for residential building in reconstruction programme was developed. There are four MRs by types of construction methods as follows:

- SMC: Stone masonry in cement mortar
- BMC: Brick masonry in cement mortar
- SMM: Stone masonry in mud mortar
- BMM: Brick masonry in mud mortar

For the dissemination of these MRs for residential buildings in the reconstruction programme for the beneficiaries, posters of each model were developed. After this, the Technical Handbook for the Reconstruction of Earthquake Resistant Houses for Masons and Craftsmen, and the Guidebook for the Reconstruction of Earthquake Resistant Houses have been prepared and published.

Table 8.2.10 Minimum Requirements for Stone Masonry in Cement Mortar (SMC) (1/3)

Minimum Requirements for building construction with Stone Masonry in Cement Mortar for Residential Building					
No.	Category				
1	Site selection	It shall be done to minimize risk against natural hazards. A building shall not be constructed if any of the following conditions exist.			
		☐Geological fault or Ruptured Area		☐Steep Slope > 20° (1:3, Vertical : Horizontal)	
		☐Landslide susceptible Area		☐River bank and Water logged Area	
		☐Rock-fall Area		☐Liquefaction susceptible Area	
		☐Filled Area			
		**If it is in these areas, consult with expert.*			
2	Shape/Size of building	No. of storey	Not more than 2 plus attic		
		Clear span of room	Not more than 4.5m.		
		Size of room	Not more than 13.5 sq.m.		
		Height of wall	Floor height shall not be more than 3.0m. In case of attic floor,maximum height from flor level to ridge level shall be 1.8m and maximun height from floor level to eave level shall be 1.0m.		
		Proportion	Simple and regular shaped as square and rectangular. The length of building shall not be more than 3 times of its width. Avoid setbacks.		
3	Materials	Stone	Avoid use of rounded, subrounded, easily breakable soft stone and boulder stones in its natural shape. River stone shall be dressed. Size of stone shall not be smaller than 50mm in thickness and 150mm in length or breadth.		
		Mortar	Cement mortar shall not be leaner than 1:6 (1 part cement and 6 parts sand by volume) for masonry.		
		Concrete	It shall not be leaner than M20grade concrete, or mix ratio of 1:1.5:3. (1 part cement, 1.5 parts sand and 3 parts aggregate by volume)		
		Rebar	High strength deformed bars with fy = 415Mpa /500 Mpa.		
		Timber	Well seasoned hard wood without knots shall be used for structural purpose. Timber treatment such as use of coal tar or any other preservative can prevent timber from being decayed and attacked by insects.		
4	Foundation	General	It shall be countinous strip footing of uniform width at same level throughout the foundation in flat area. ** If the building has to be constructed in existing foundation, consult with expert.*		
		Depth of found. below GL	It shall not be less than 800mm for one storey, 900mm for two storey.		
		Base width	No. of storey	Types of soil	
			One storey	Soft	Not less than 800mm
				Medium	Not less than 600mm
				Hard	Not less than 600mm
			Two storey	Soft	Not recoommended
				Medium	Not less than 800mm
				Hard	Not less than 600mm

Source: Minimum Requirements for building construction with Stone masonry in Cement mortar for residential building

Table 8.2.10 Minimum Requirements for Stone Masonry in Cement Mortar (SMC) (2/3)

5	Vertical member	General	Shall be started right from the foundation and continue up to the roof band. Place vertical member at all corners, junctions of walls and adjacent to all doors and windows.
		Reinforcement	At corners and junctions vertical reinforcing bar shall be 12mm for one storey, and 16mm for two storey . They shall be covered with concrete or 1:4 mortar in cavities made around them during the masonry construction.
		Anchorage	Should be started right from the foundation and continue up to the band. In case of using existing foundation, it shall be anchored to plinth band. The anchorage length shall be 60 times diameter of the bar.
6	Plinth	General	The level of plinth shall not be less than 300mm from existing ground level.
		Thickness	The thickness of band shall be 150mm for medium and soft soil, 75mm band can be used for hard soil.
		Width	Not less than wall thickness.
		Reinforcement	Main reinforcement shall be 4-12 dia.2-12 dia. rebars in case of 150mm and 75mm height.respectively. Use 6mm dia. stirrups at 150mm centres. Bars shall have a clear cover of 25mm concrete.
7	Walls	General	Masonry shall not be laid staggered or straggled in order to avoid continuous vertical joints. At corners or wall junctions, through vertical joints shall be avoided by properly laying the masonry. It shall be interlocked.
		Thickness	It shall not be less than 230mm for one-storey, 350 and 230mm for ground floor and first floor of two-storey respectively.
		Joints	Mortar joints shall not be more than 20mm and less than 10mm in thickness.
		Buttresses	Buttresses should be provided if wall length is longer than above mentioned. Spacing of buttress shall not be more than 3m. Minimum base width shall be equal to one sixth of wall height. Minimum top width shall be equal to thickness of the wall.
		Gable wall	Provide light gables like wood and CGI sheets etc.
8	Doors/windows	General	Keep lintel level same for all doors and windows. Openings are to be located away from inside corners by a clear distance equal to at least 1/4 of the height of the opening, but not less than 600 mm.
		Total length	The total length of openings in a wall is not to exceed 50 % of the length of the wall between consecutive cross-walls in single-storey construction, 42 % in two-storey construction.
		Distance	The horizontal distance (pier width) between two openings is to be not less than one half of the height of the shorter opening, but not less than 600 mm.

Source: Minimum Requirements for building construction with Stone masonry in Cement mortar for residential building

Table 8.2.10 Minimum Requirements for Stone Masonry in Cement Mortar (SMC) (3/3)

9	Horizontal band	General	Horizontal bands shall be provided throughout the entire wall at plinth, sill, lintel, floor and roof level.
		Sill band	A continuous sill band shall be provided through all walls at the bottom level of opening (specially windows) except for doors. The minimum thickness is 75mm.
		Lintel band	A continuous lintel band shall be provided through all walls at the top level of opening. Where opening width do not exceed 1.25m and masonry height above opening do not exceed 0.9m, 75mm lintel is sufficient. For opening width upto 2m and masonry height above opening upto1.2m, 150mm lintel band is necessary.
		Stitch band	At corners and junctions, stitches(dowels) shall be provided addition at a vertical spacing of 500-700mm. The minimum length is 1.2m. The minimum Thickness is 75mm.
		Roof band	It shall be provided at the top-level of walls, so as to integrate them properly at their ends and fix them into the walls. The minimum thickness is 75mm.
		Reinforcement	Main reinforcement shall be 4-12 dia.2-12 dia. rebars in case of 150mm and 75mm Use 6mm dia. stirrups at 150mm centres. Bar shall have a clear cover of 25mm. *For stitch band main reinforcement can be 2-8 dia.rebars.
		Connection	Overlap lengthshall be 60 times diameter of the bar. Eg. Length shall be 480mm for 8mm bars, 600mm for 10mm bars, 720mm for 12mm bars and 960mm for 16mm bars
10	Roof	General	Use light roof comprising wooden or steel truss covered with CGI sheets.
		Connection	All members of the timber truss or joints shall be properly connected. Arrangements shall be done for connecting roof and wall.
		Bracing	Diagonal bracings shall be considered.

Source: Minimum Requirements for building construction with Stone masonry in Cement mortar for residential building

4) Technical Committee (TC) in Japan

a) 1st TC in Japan, 4th December 2015

The 1st TC in Japan was held to share the overall picture of the project, and to exchange opinions for getting advice for the future direction of the Project. The topics discussed in the 1st TC are as follows;

- Summary and factor of housing damages
- Review of the NBC
- Design Catalogue and JICA Models based on the NBC
- Earthquake resistant verification of several types of houses

- Flowchart of the studying structure for the housing reconstruction
- Issue for dissemination of houses with cement mortar
- Comparison of the building cost of each model
- Technical study on strengthening houses with mud mortar to avoid dangerous destruction
- Other issues

In addition, the following were pointed out to further discuss on how to set the targets from the view of BBB.

- The GoN considers the reconstruction of houses following NBC200s as BBB reconstruction. The houses on the Housing Catalogue will be subsidized by the GON. The Catalogue includes brick/stone masonry buildings with mud mortar, NBC203.
- The Project Team proposed brick/stone masonry buildings with cement mortar, NBC 202, based on the engineering and experimental study with the idea of BBB to avoid heavy damage from future earthquakes.

Considering the above gap, the scope of the Project in terms of housing reconstruction was discussed from the view of cost, workability, feasibility including the capacity, social acceptability, and sustainability.

The conclusion of the 1st TC was as follows;

- Further promotion and study of buildings with cement mortar is necessary.
- Reinforcement of buildings with mud mortar needs to be considered, as there is an expectation that approximately 77% of residents would choose buildings with mud mortar for the reconstruction.
- Housing design based on engineering is essential. Each model needs to be evaluated quantitatively with structural calculation and analysis.

b) 2nd Technical Committee in Japan (5th February 2016)

The 2nd TC in Japan was held to finalize the scope of project in terms of housing reconstruction. Based on the conclusion of 1st TC in Japan, the Project Team explained the results of structural calculation and analysis.

The discussed topics were as follows;

- Method for calculating the strength of the materials
- Safety Factor
- Result of structure calculation of Mud mortar

As a result of the discussions, the conclusions of the 2nd TC were as follows;

- NBC105 is the requirement for the BBB.
- Verification of earthquake resistance should be done with structural calculation.
- The models and necessary actions are to be proposed to the GON.
- Additional techniques such as the buttress and the horizontal brace are to be examined.
- Training and support for the inspection to assure the preconditions considered in the calculation is necessary.
- The opinion of the GON for the poor who cannot afford to build the houses using the NBC is to be confirmed. Though the support for those not following the NBC is not acceptable for now, the support which at least saves their lives, such as jacketing, should be discussed with the GON as necessary.

1st TC in Japan

2nd TC in Japan

Source: JICA Project Team

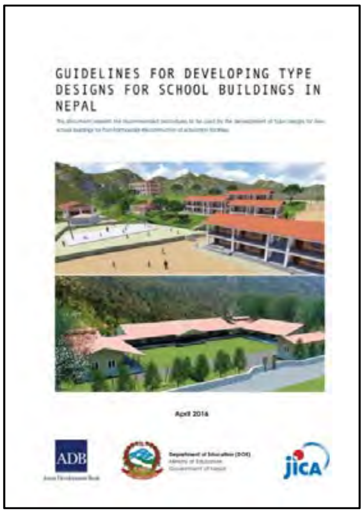
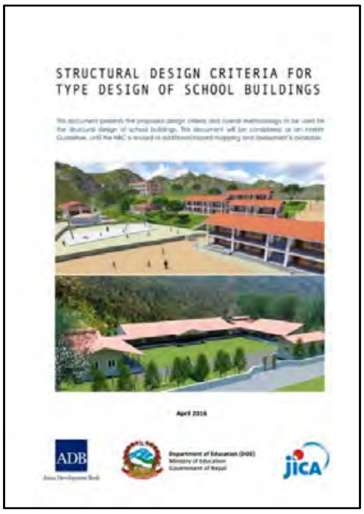
Figure 8.2.16 Technical Committee in Japan

(2) Schools

1) Proposal of Seismic Resistant School Building Guideline and the Outline

The preparation of the Seismic Resistant School Guideline has been carried out through a joint effort of ADB, JICA and DOE. Procedures were repeated to which; ADB prepares a draft of the guideline, which is then reviewed by DOE and JICA, and ADB modifies the draft based on the results of the review. This process was repeated and the guideline was completed in April 2016.

The guideline consists of two volumes. One volume focuses on architectural, mechanical and electrical criteria and the title is "Guidelines for Developing, Type Designs for School Buildings in Nepal". The other volume mentions structural criteria and the title is "School Disaster Risk Reduction, Structural Design Criteria for School Buildings" (see Figure 8.2.17).

Architectural, mechanical and electrical volume	Structural volume
	

Source: DOE

Figure 8.2.17　Seismic Resistant School Building Guideline

Contents of the two volumes are shown in Table 8.2.11 and Table 8.2.12.

Table 8.2.11　Contents of Architectural, Mechanical and Electrical Guideline

Title: Guidelines for Developing, Type Designs for School Buildings in Nepal	
Chapter	Main Contents
1	Introduction
2	Identification of the Needs
3	Architectural and Space Planning Requirements
4	Integrated DR(Disaster Resilience) and ES(Environmental Sustainability) Considerations
5	Materials and Construction Considerations
6	Structural Design Considerations
7	Site Infrastructure Design Considerations

Source: Guidelines for Developing Type Designs for School Buildings in Nepal

Table 8.2.12　Contents of Structural Guideline

Title: School Disaster Risk Reduction, Structural Design Criteria for School Buildings	
Chapter	Main Contents
1	Introduction
2	Design Philosophy and Approach
3	Basic Materials
4	Loads
5	Structural Systems
6	Code-based Design
7	Seismic Performance-based Evaluation

Source: Guidelines for Developing Type for School Buildings in Nepal

2) Concept of Seismic Resistant School Guidelines

The main concepts of architectural, mechanical and electrical criteria of seismic resistant building guidelines which the three organizations (JICA, ADB, and DOE) discussed and decided were as follows:

- Modular sizing and layout of classrooms
- Modular sizing and layout of buildings
- Modular dimensions for most of the building components such as doors, windows, fittings, fixtures, and even size of panels, bricks/blocks etc.

On the other hand, the Study Team's Views on the main concept of structural criteria of seismic resistant school building guidelines were different from ADB's concept and the three organizations decided to include two criteria in the guideline:

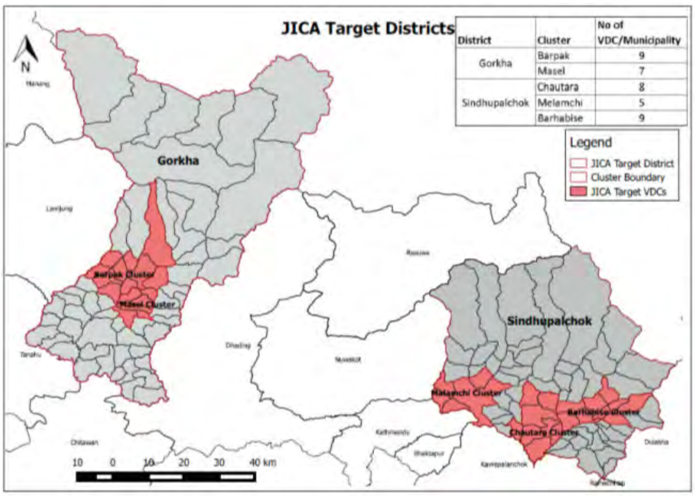
- Structure design by RRNE complies to both NBC and Indian Standards
- Structure design by ADB either complies or refers to the NBC as well as Indian Standards and other international standards (International Building Code, Uniform Building Code, etc.).

The two volumes of seismic resistant school building guidelines will be applied not only for JICA, ADB, and DOE are expected to be adopted by different kinds of development partners which will help with the reconstruction of schools. In addition, each development partner will choose structural design method RRNE or ADB based on the respective decisions.

8.3 Support for the Construction of House and School Models Based on the Earthquake-resistant Building Guidelines.

8.3.1 Housings

The Project targets 46 VDCs in five clusters from the Gorkha and Sindhupalchok Districts. Figure 8.3.1 shows the map of target districts.

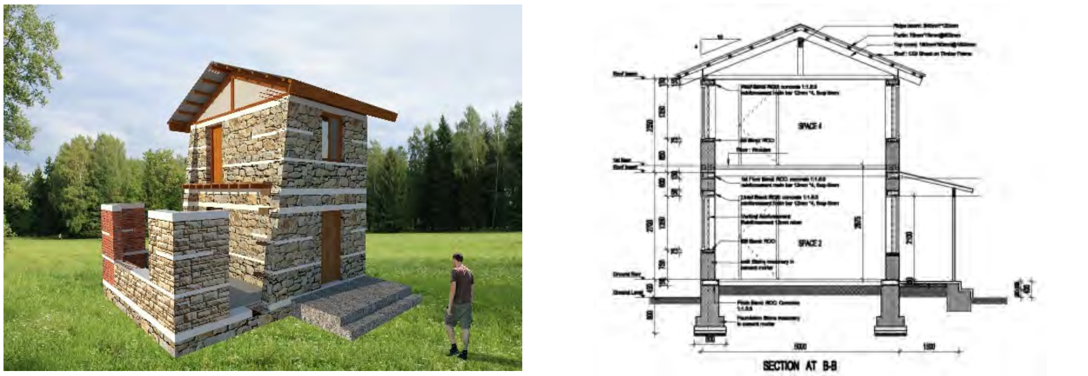


Source: JICA Project Team

Figure 8.3.1 JICA Target Area of the Project

(1) Construction of housing models

The Project Team was initially planning to construct model housing in each of the five target cluster areas. The Project Team prepared a set of design works and bill of quantities for the construction of cutaway models of 1-storey and 2-storey models indicated in the Design Catalogue for the Reconstruction of Earthquake Resistant Houses. However, four were cancelled due to the long time required by the Government of Nepal to secure necessary land. One model housing is being constructed under a Quick Impact Project in Barpak VDC of Gorkha District, as of September 2017.



Source: JICA Project Team

Figure 8.3.2 3D Image and Drawing of Model Housing

(2) Technical Transfer of Model Construction

1) Training

To increase the number of masons with sufficient knowledge and skills to build earthquake resilient houses, the JICA Build Back Better Housing Training was started in Dec, 2015.

a) Training for Masons

The curriculum was formulated based on six days of DUDBC official curriculum, and one day was added for cement work.

b) Training for House Owners

The policy for housing reconstruction is ‘owner driven’, and house owners themselves are responsible for the reconstruction of their own houses. Therefore, awareness of safer house construction is most important.

Table 8.3.1 Training and Beneficiaries

Training	Beneficiaries	No. of training
Training for masons	2,157	72
Refresh training for masons	1,404	49
Training for house owners	6,518	135

Source: JICA Project Team

(3) Brochure for Model Housing Construction

The formulation of the guideline for seismic buildings is fundamental for achieving BBB through recovery and reconstruction. The Project Team has worked on structural calculation and analysis on the model housing construction and other buildings with various types of structures. As a result, the seismic standard for the reconstruction of residential buildings was determined to follow National Building Code (NBC) 105. The Poster of Minimum Requirements was prepared based on this standard. Following this, handbook, guidebooks, and brochure were developed for the publication of the Minimum Requirements.

1) Poster of Minimum Requirements

Posters on Minimum Requirement including ten important points and construction sequence, which were approved by NRA in September, 2016, had been prepared for reconstruction models of Stone Masonry in Mud Mortar (SMM), Brick Masonry in Mud Mortar (BMM), Stone Masonry in Cement Mortar (SMC) and Brick Masonry in Cement Mortar (BMC).

Source: JICA Project Team

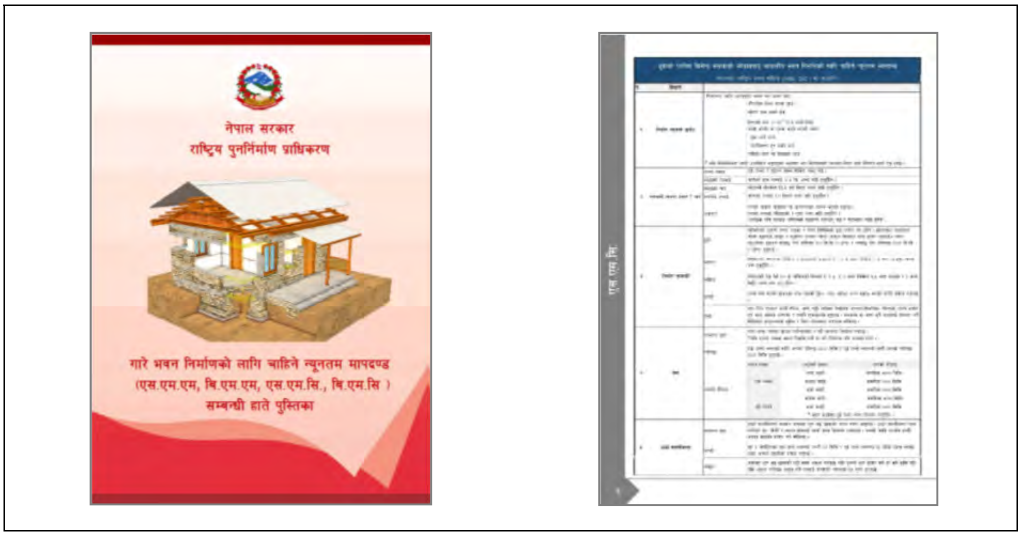
Figure 8.3.3 Poster of Minimum Requirements for Stone Masonry in Cement Mortar

Source: JICA Project Team

Figure 8.3.4 Poster of Minimum Requirements for Stone Masonry in Mud Mortar

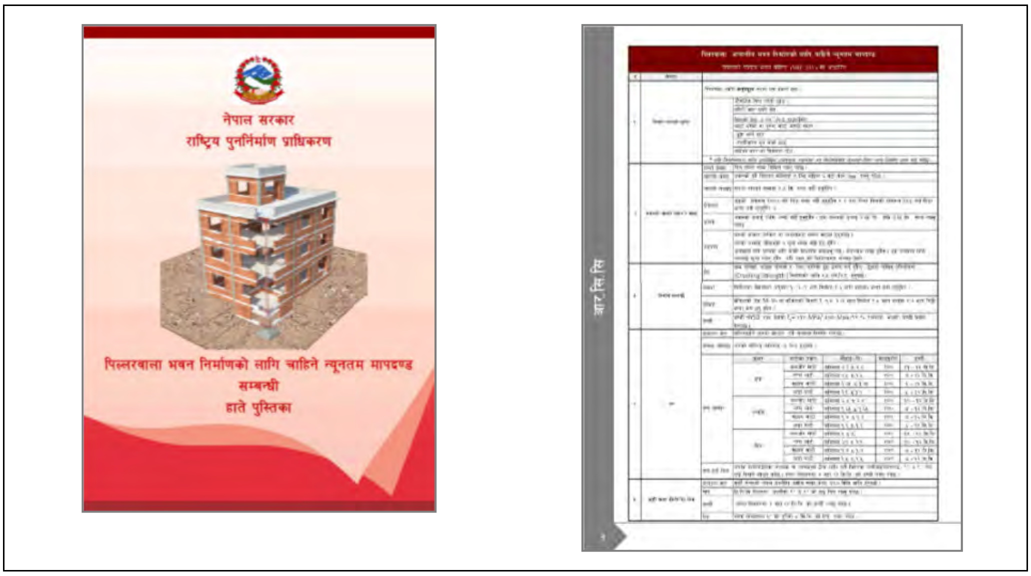
2) Brochure of Minimum Requirements

Brochures for disseminating the Minimum Requirements to all of the earthquake affected areas were prepared. A total of 12,000 sets were printed in December 2016 and have been distributed through the training sessions by TPIS-ERP and VDC offices in order to disseminate the information to local residents.



Source: JICA Project Team

Figure 8.3.5 Brochure of Load Masonry Structure (SMM, BMM, SMC and BMC)

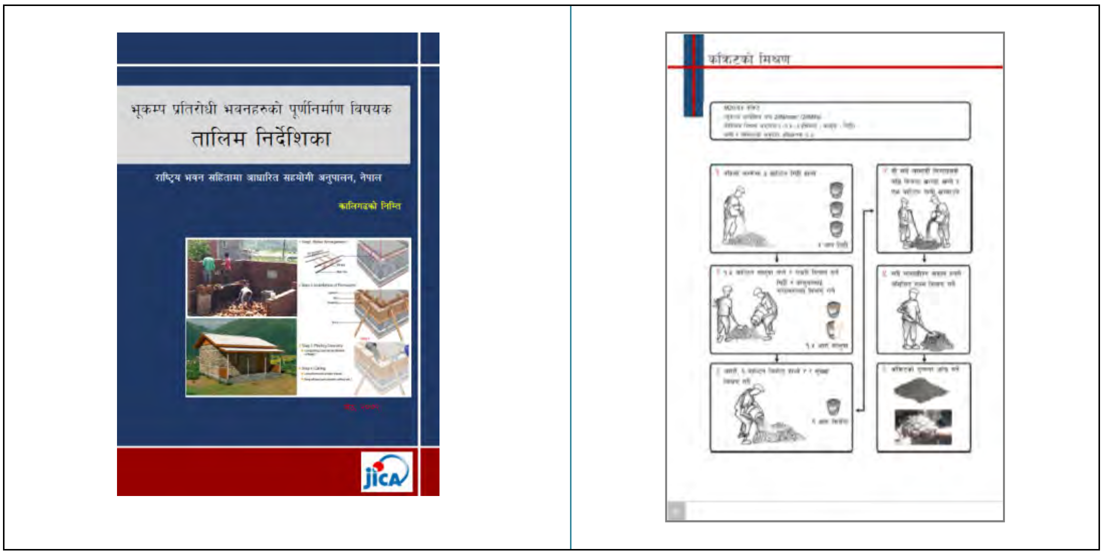


Source: JICA Project Team

Figure 8.3.6 Brochure of RC Frame Structure

3) Technical Handbook for the Reconstruction of the Earthquake Resistant Housings for Masons

- Target: Craftsmen, Masons (unskilled, skilled), Carpenters
- Contents: Earthquake mechanism, typical damage of masonry structure, National Building code, Earthquake resistant house (Design, Construction), etc.
- Purpose: Teaching materials for mason training.



Source: JICA Project Team

Figure 8.3.7 Technical Handbook for the Reconstruction of the Earthquake Resistant Housings for Masons

4) Guidebook for the Reconstruction of the Earthquake Resistant Houses for Housings Owners

- Target: House owners, Land owners
- Contents: Earthquake resistant house (Design, Construction), Standard designs, etc.
- Purpose: Teaching material for house owners.

Source: JICA Project Team

Figure 8.3.8 Guidebook for the Reconstruction of the Earthquake Resistant Housings for House Owners

These materials have been used in training masons and house owners by the TPIS-ERP implemented by JICA. Through the training, 2,726 technical handbooks and 3,478 guidebooks were distributed.

5) Technical Video for Construction of Masonry Structures

The Project Team has also prepared a technical video for visual understanding safer of construction.

- Target: Craftsmen, Masons (unskilled, skilled), Carpenters
- Contents: Earthquake mechanism, typical damage of masonry structure, National Building code, Earthquake resistant house (Design, Construction), etc.
- Purpose: Teaching material for mason training.

Source: JICA Project Team

Figure 8.3.9 Technical Video for Construction of Masonry Structure

8.3.2 Schools

(1) Review of existing prototype of DOE

DOE already had fourteen kinds of classroom prototypes which followed the NBC, and had constructed many classrooms all over the country. The Project Team compared their features in the light of structure type, number of stories, area, dimensions and type of materials, and analysed them. The results of analyses were used for designing the new classroom prototypes.

(2) Planning of new prototype

The original concept of prototype proposed by the Project Team was as follows:

<u>From the user's point of view</u>

- Safety: earthquake, fire, flood and wind
- Amenity: thermal insulation, ventilation, lighting, sound insulation, usability
- Durability: doors, windows, walls, floors, etc.
- Harmonization: adapt to existing situation

<u>From the technical point of view</u>

- Standard construction method
- Standard construction material

<u>Structural type of new prototype</u>

"Reinforced concrete frame with brick masonry walls" was selected for the structural type of the prototype taking into consideration the result of site surveys for damaged schools.

<u>Architectural planning of new prototype</u>

Prototypes for the classrooms, teachers' room, library, laboratory, multi-purpose room, and toilets were required in the Seismic Resistant School Building Guideline. Since DOE did not have any prototype except for the fourteen kinds of classrooms and three toilets, various kinds of prototypes were needed. To adapt the above needs, a "grid plan" was selected for the floor planning of the new prototype.

<u>Mechanical and electrical planning of new prototype</u>

Mechanical and electrical planning of the new prototype followed the Seismic Resistant School Building Guideline.

(3) Variety of new prototypes

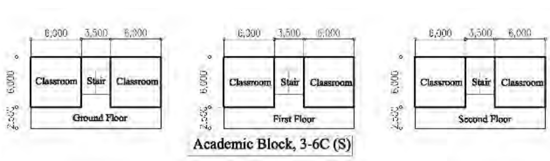
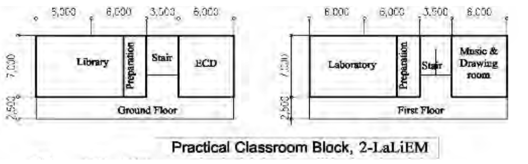
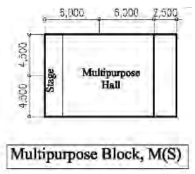
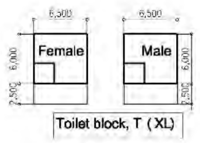
Some new prototypes were designed at the initial stage of the Project. The number was later increased based on the demands of DOE. A total of 37 new prototypes were designed by the Project Team as new prototype in order to cover ECD, primary schools, lower secondary schools, secondary schools, and higher secondary schools.

The numbers of stories were decided from a single floor to three floors and different sizes of rooms were designed in order to fit for various kinds of lands.

Table 8.3.2 List of 37 Prototypes

No	Category	Type Design Code	Description	Floor Area(m^2)
1	Primary & Academic Block	1C(S)	1 small room : Kitchen&Store	56.90
2		2C(S)	2 small rooms : Kitchen&Store, Head&Teacher	110.36
3		3C(S)	3 small rooms : ECD, 2 Classrooms	163.75
4		3C(S)-A	3 small Classrooms	163.75
5		3C(S)-B	3 small rooms : Library, Music&Drawing&PC, Head&Teacher	163.75
6		4C(S)	4 small Classrooms	217.15
7		4C(S)-A	4 small rooms: Library, Music, Drawing&PC, Head&Teacher, Kitchen&Store	217.15
8		2-4C(S)	2 storey 4 small rooms	285.50
9		2-4C(S)-A	2 storey 1Classroom, ECD, Library, Music, Drawing&PC	285.50
10		2-6C(S)	2 storey 6 small Classrooms	392.90
11		3-6C(S)	3 storey 6 small Classrooms	428.25
12		2-4C(M)	2 storey 4 medium Classrooms	357.20
13		2-6C(M)	2 storey 6 medium Classrooms	496.50
14		3-6C(M)	3 storey 6 medium Classrooms	535.80
15		3-9C(S)	3 storey 9 small Classrooms	616.20
16		3-9C(M)	3 storey 9 medium Classrooms	779.97
17	Practical Classroom Block	LaLi	Laboratory, Library	182.15
18		EMC	ECD, Computer, Music&Drawing	167.30
19		2-LaLiEMC	2 storey Laboratory, Library, ECD, Music&Drawing, Computer	436.80
20		2-LaLiEM	2 storey Laboratory, Library, ECD, Music&Drawing	436.80
21		2- LaLi2CM	2 storey Laboratory, Library, Computer, Music&Drawing	556.20
22		3- 3LaLi2CM	3 storey 3 Laboratories, Library, 2 Computers, Music&Drawing	870.00
23	Admin. Block	A(S)	Small Administration	181.55
24		A(M)	Medium Administration	199.36
25		A(L)	Large Administration	241.56
26		2-A(L)	2 story Large Administration	516.40
27		2-AC	2 story Administration with PC	436.80
28	Multipurpose Block	M(S)	Small Multipurpose hall	140.82
29		M(L)	Large Multipurpose hall	182.35
30	Toilet Block	T(S)	2 small Toilet blocks for male and female	68.06
31		T(M)	2 medium Toilet blocks for male and female	79.38
32		T(L)	2 large Toilet blocks for male and female	109.02
33		T(XL)	2 extra large Toilet blocks for male and female	124.02
34	Toilet Block Combine	Tc(S)	1 combine small Toilet blocks for male and female	64.89
35		Tc(M)	1 combine medium Toilet blocks for male and female	77.48
36		Tc(L)	1 combine large Toilet blocks for male and female	105.86
37		Tc(XL)	1 combine extra large Toilet blocks for male and female	119.26

Source: JICA Project Team

No. 11 : 3-6C(S)	No. 20 : 2LaLiEM
	
	
No. 28 : M(S)	**No. 33 : T(XL)**
	
	

Source: JICA Project Team

Figure 8.3.10 Sample of New Prototypes

(4) Structural Analysis of New Prototype

As mentioned, all new prototypes followed the Seismic Resistant School Building Guideline which was proposed by the Project Team, ADB and DOE. In the guideline, the structural design of the prototype by the Project Team had an option to conduct pushover analysis by using computer software in order to analyse the deformation and cracking of the structure in case of an earthquake.

For the pushover analysis, four prototypes (1 storey type, 2 storey type, 3 storey type and Multi hall type) out of 37 prototypes were selected and the actual analysis was carried out by a local consultant contracted under TPIS-ERP.

The results of the pushover analysis of the four prototypes were checked by the Project Team and the results were found to satisfy the Seismic Resistant School Building Guideline.

The project for the reconstruction of schools was implemented under TPIS-ERP until March 2017 and the ESRP (Emergency School Reconstruction Project) has taken over the responsibility since March 2017. There are 83 schools under construction in six districts as of the end of March 2017.

8.4 Study on Dissemination Mechanism

8.4.1 Supporting System for Reconstruction of Housings and Subsidies

Many houses were damaged by the earthquakes. The Government of Nepal (GON) issued lump-sum payments as relief money to the households which lived in those damaged houses. Furthermore, GON is implementing a subsidy payment and a low-interest loan for the reconstruction of a damaged house through the "Nepal Housing Reconstruction Programme".

(1) Lump-sum Payment to the Earthquake Affected Households

GON conducted a simple survey on the housing damage situation shortly after the occurrence of the earthquake and classified the damage to the houses into three categories; totally destroyed, partially damaged and no damage. GON paid NPR 15,000 to households that lived in houses judged totally and/or partially damaged. GON also issued an Earthquake Disaster ID with photographs to all of the earthquake affected people. The payment record of NPR 15,000 is described on the back side of this ID.

(2) Payment of the Subsidy for Reconstruction of Housings

Initially, NPR 200,000 subsidy per household has been decided as support for the reconstruction of damaged houses. The payment of subsidy is divided into three stages (1) NPR 50,000 after signing the Participation Agreement, (2) NPR 80,000 after Plinth Band construction, and (3) NPR 70,000 after completion of wall construction.

In the Grant Distribution Guideline for Completely Destroyed Private Houses by Earthquakes, 2072 (2015) published on 20th May, 2016, the subsidy amount was increased to NPR 300,000; (1) NPR 50,000, (2) NPR 150,000, (3) NPR 100,000 at the reconstruction agency steering committee held in September 26, 2016. In addition, when only engaging in retrofitting work, payment of NPR 100,000 was decided. Subsidies for housing reconstruction are paid to households participating in the programme through bank accounts.

(3) Low Interest Financial Scheme for Housing Reconstruction

The subsidy of NPR 200,000 is generally not sufficient to cover the construction cost of housing to the size of pre-earthquake. Therefore, GON plans to provide a low interest financial scheme to pay for the reconstruction of housings up to its previous size, in addition to the subsidy. The government will provide funds for the low interest loans for housing reconstruction and commercial banks will implement a loan to people and/or groups. The low interest loans fall into two categories. One is a special loan for poor households and the other is for normal households.

To apply for the loan, not only poor households but also other households have to join the programme and they have to select one of the model houses provided by the programme. Poor households will not require any mortgage for the loan. However, banks will require a mortgage from other households for the loan. In many cases, real estate such as a house or land will be the security for a mortgage. The maximum value of the mortgage will be 60% of the assessed property value. If the assessed property value is lower than the loan amount, banks cannot provide loans to those households according to the guideline provided by the central bank.

The loan amount will not be paid in a lump sum, but will be paid step by step based on the progress of the housing construction. However, banks do not have provisions to directly check the progress. Therefore, banks are expected to pay the loan based on the inspection conducted in the programme.

Table 8.4.1 Low Interest Financial Scheme

Household	Max. Credit Line	Interest	Mortgage
Poor	Rp.200,000	2%	No mortgage
Other	Within Kathmandu Valley: Rp.2,500,000 Other areas: Rp.1,500,000	2%	Necessary Mortgage value is 60% of the market price.

Source: Interview with Nabil Bank by the JICA Project Team

(4) Programme Operation Manual (POM) for the Nepal Housing Reconstruction Programme

For the smooth implementation of the programme, GON prepared the first draft Programme Operation Manual (POM) on 25th July, 2015. JICA, the Project Team, WB and other agencies interested in the programme made comments regarding the first draft POM. Based on the comments, GON prepared the second draft POM. The second draft has also been planned to be discussed by GON and the concerned agencies, and be modified and issued by GON for starting the programme.

1) Objectives of the Programme

The objectives of the programme are to restore houses damaged during the April and May 2015 earthquakes in Nepal using earthquake resistant building techniques, and materials, through an owner-driven approach, and improving long-term resilience and a culture of safer and sustainable housing and settlements.

2) Principles of the Programme

The following are the principles of the programme:

- Owner-driven construction
- Uniform and simple housing reconstruction and rehabilitation policy
- Updating and dissemination of earthquake safer construction standards, design, and construction practices
- Primarily in-situ reconstruction
- Effective communication
- Third party monitoring and evaluation

3) Main Contents of the Second Draft POM

Table below shows main contents of the second draft POM.

Table 8.4.2 Main Contents of the 2nd Draft POM

No.	Main Contents
1	Objective and Principles of the Project
2	Housing reconstruction policy
3	Implementation Roles and Responsibilities
4	Implementation Procedures
4-1	Enrolment
4-2	Housing Reconstruction
	1) Housing Technical Guidelines and Construction Options 2) Training of engineers, masons, artisans, and beneficiaries 3) Logistics Hub and facilitating building material markets 4) Assistance for the implementation 5) Inspection, and Cash transfer mechanism
5	Communication
6	Grievance Redress Mechanism (GRM)
7	Monitoring, Reporting and Evaluation
8	Management Information System (MIS)

Source: Nepal Housing Reconstruction Programme Operation Manual, 15th August, 2015

(5) Issues

There are some issues for implementing the programme. These should be solved and cleared before the implementation of the programme.

1) In-situ Reconstruction of a House

In-situ housing reconstruction is one of the principles of the programme. However, a detailed explanation of "in-situ" is not mentioned in the POM.

2) Damage Evaluation

An Earthquake Household Damages and Characteristics (EHDC) Survey for clarifying the degree of housing damage will be implemented in the programme. The result of the survey is one of the most important pieces of data and information to judge eligibility. A damage evaluation form for the survey is provided in the POM. However, the criteria of damage judgement are not clear. Pictures and/or figures showing the degree of housing damage should be provided for fair damage judgement. Engineers who judge the degree of housing damage should be trained before the implementation of the survey.

3) No Eligibility to Join the Programme

It is said that only owners of a house categorized as “completely destroyed/in need of demolition” have eligibility to join the programme. Owners of a house categorized as “partially damaged” and “not damaged” have no eligibility to join the programme and cannot receive any support from the government for restoring a partially damaged house and/or for implementing seismic strengthening work to an undamaged house.

Objectives of the programme are improving long-term resilience and culture of safer and sustainable housing and settlements. Therefore, to achieve the objectives, GON should study and develop another housing support scheme such as a subsidy for the rehabilitation and reconstruction for partially damaged houses and a subsidy for seismic strengthening work for undamaged houses. Income tax credit or reduction of interest should also be studied for housing owners who take a loan from a bank for repairing and/or seismic retrofitting their house.

4) Building Permits

In the POM, it is mentioned that simplified building permits will be applied to beneficiaries who choose a design from the project catalogue. However, the process of the permit is not mentioned in the POM.

A shortage of engineers and/or architects to check documents submitted for construction of houses is the biggest problem to implement a building permit system at present. For the smooth implementation of the system in the programme, the necessary number of engineers and/or architects should be provided and staffed at local level offices.

5) Inspection of Housing Reconstruction

In the POM, it is said that the inspection of housing reconstruction will be conducted by designated government officials in three stages; completion of the foundation, completion up to the ground floor level, and completion of the roof. However, it is not mentioned how to inspect the buildings or the completion of each stage, criteria for the inspection and criteria for judgement. These should be clarified and necessary documents for inspection should be provided in the POM. Training for inspectors using the documents should be conducted before the implementation of the inspection.

6) Opening of a Bank Account and Receiving a Subsidy

Beneficiaries are required to open a bank account irrespective of the presence of a financial institute qualified to participate as a payment service provider in their respective VDC or municipality. Beneficiaries receive the subsidy through the bank account that they have opened. However, the number of municipalities and VDCs where financial institutes, especially class A and B, exist is very limited. As an example, the locations and number of commercial banks of class A and B in Sindhupalchok and Gorkha Districts are shown in the table below. There are 21 and thirteen banks in Sindhupalchok District and Gorkha District, respectively. However, the number of VDCs and municipalities which have banks in Sindhupalchok District and Gorkha District is seven and four, respectively. Many beneficiaries that have joined the programme live in VDCs far from those VDCs/municipalities which have banks. Most of them have no transportation means.

Visiting a bank for opening a bank account and getting a subsidy forces them to spend enormous time and effort. Some way to reduce their burden, such as establishment of temporary branch offices at VDCs or introduction of mobile banks, should be studied and found before implementing the programme.

Table 8.4.3 Banks in Sindhupalchok and Gorkha Districts

District	VDC/Municipality	Village	No. of Banks	Remarks
Sindhupalchok	Melamchi Municipality	Melamchi Bazar	3	
	Chautara Municipality	Chautara	3	
	Sanghachok	Sukute	1	
	Mangkha	Khadichaur	4	
	Tatopani	Tatopani	2	Not operating at present
	Barhabise	Barhabise	7	
	Jethal	Mude	1	
	Total: 21 banks in 7 VDCs/Municipalities			
Gorkha	Gorkha Municipality	Gorkha	9	
	Aaruchanaute	Arughat	2	
	Palungtar Municipality	Palungtar	1	
	Masel	Ghyampesal	1	
	Total: 13 banks in 4 VDCs/Municipalities			

Source: JICA Project Team

(6) Distribution Guideline

NRA published Grant Distribution Guideline for Completely Destroyed Private Houses by Earthquakes, 2072 (2015) on 20th May, 2016.

(7) Inspection SOP

This SOP is prepared to make the inspection easy and systematic for safer and stronger construction on the basis of Grant Distribution Guidelines 2015, for the reconstruction of houses that were damaged by the earthquake of April 25, 2105. To facilitate all the stakeholders, house owners, beneficiaries, and local bodies, a Technical Inspection team was formulated to create uniformity in the understanding of the procedure of the grant distribution for construction of safer houses .

8.4.2 Supporting System for Reconstruction of Houses not Based on a Subsidies

A study on low cost construction models with the jacketing method to avoid brittle fracture, which can be used even with earthquake resistant reinforcement, was conducted.

Chapter 9 Programme Grant Aid

9.1 Objective of this Component

The objective of this component is to investigate damaged facilities for recovery and facilities to contribute to the recovery from damage due to Nepal Earthquake and to select facilities to be recovered and constructed by the Programme Grand Aid Projects.

The implementation schedule and cost through the refining and incorporation based on the outline design and the cost estimation for each sub-project under the Japan's Grant Aid on the basis of the site survey and natural condition survey was summarized.

In this chapter, the selection result of sub-projects components and results of the outline design and cost estimation are explained.

9.2 Selection of the Programme Grant Aid Projects

9.2.1 Selection of Building Construction Projects

(1) Background of the Selection and the Result

A long-list of the damaged public facilities in the target areas was prepared based on the damaged public facility list from DDCs and interviews with MOUD and concerned DDCs, and 66 facilities were inspected by the JICA Project Team. The number of long-listed facilities in each district is as follows:

- Sindhupalchok : 21 facilities
- Lalitpur District : 17 facilities
- Bhaktapur District : 7 facilities
- Kathmandu District : 8 facilities
- Gorkha District : 13 facilities

Among the long-listed facilities, the government facilities assisted by Asian Development Bank (ADB) and the district hospitals assisted by other donors were eliminated from the selection of Grant Aid Projects, and a short-list was prepared.

Possible candidates for Grant Aid Projects were carefully examined in accordance with the 19 criteria in Table 9.2.1, with consultation with relevant ministries and agencies, examination of project cost and consideration of the balance with the Civil Work Projects. Table 9.2.1 shows the Priority Order of the short-listed facilities. Finally, the following facilities were selected for JICA Grant Aid Projects (building construction).

- Paropakar Maternity and Women's Hospital
- Bir Hospital

In Nepal, 5 Public Hospitals and 16 Specialized Hospitals, including Paropakar Maternity and Women's Hospital and Bir Hospital selected for JICA Grant Aid Projects, are categorized as level 3 National Hospitals. Paropakar Maternity and Women's Hospital is the Central/Specialized Public Hospital, and Bir Hospital is the oldest Central Public Hospital in Nepal. These two hospitals are important hospitals responsible for the central medical treatment of the country.

Paropakar Maternity and Women's Hospital
(Main Building)

Bir Hospital
(New ICU Building and Cancer Ward)

Source: JICA Project Team

Figure 9.2.1 Photographs of Paropakar Maternity and Women's Hospital and Bir Hospital

Table 9.2.1 Priority Order of Candidate Facility

Criteria	Paropakar Maternity and Women's Hospital	Bir Hospital	Kathmandu Metropolitan City Office	Durbar High School	Gorkha District Hospital	DOR Office*	DOLIDAR Office*	Harihar Bhawan Government Office Complex*
	Kathmandu	Kathmandu	Kathmandu	Kathmandu	Gorkha	Kathmandu	Lalitpur	Lalitpur
1) Heavy damage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2) Contribution to rehabilitation and repair from Nepal Earthquake	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3) Other donor's support	No	No (Previously India and USAID)	No	Yes (ADB, China)	Yes (KfW)	No (WB in case not supported by JICA)	No (WB in case not supported by JICA)	No
4) Large number of beneficiary	26,494,504 (Nepal Total)	26,494,504 (Nepal Total)	975,453 (Kathmandu)	500+ (Students and neighbour)	271,061 (Gorkha)	Government officer	Government officer	Government officer, visitor
5) Easy access to the site during construction (not rural area)	Yes	Yes	Yes	Yes	4-5 hours from Kathmandu	Yes	Yes	Yes
6) Project cost more than JPY5Million	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7) Appropriate for Japanese contractor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8) JICA environmental category C	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9) Temporary facilities for construction period	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10) No scattered sites	No	No	No	No	No	No	No	No
11) Consideration of Basic Human Needs	Yes	Yes	Not Directly	Yes	Yes	No	No	Not Directory
12) Required conservation of historical design	No	No	Partially	Yes	No	No	Partially	Partially
13) Function as disaster management base	Yes	Yes	Yes	Yes	Yes	No	No	No
14) Number of related organizations	1	1	1	1	1	1	1	4
15) Approval from governing organization	Yes	Yes	Yes	No	No	Yes	Yes	Yes
16) Nepal side can cover the required work	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
17) Good site condition (does not require complex construction plan)	Access road is narrow	Yes	Surrounded by buildings	Yes	Yes	Yes	Yes	Yes
18) Visibility from outside of site	Yes	Behind the existing building	No	Yes	Yes	Yes	No	Partially
19) Other appeal points	N/A	Central hospital	Various public services	Very popular historical building	Rehabilitation at District	Highly visible site	N/A	N/A
PRIORITY	**1**	**2**	**3**	**Not eligible**	**Not eligible**	**4**	**5**	**6**

Note: The shaded cells mean negative result. Source: JICA Project Team *DOR: Department of Roads, DOLIDAR: Department of Local Infrastructure Development and Agricultural Roads
*Hari Har Bhawan Government Office Complex consists of the National Human Rights Commission, National Judicial Academy, Department of Civil Personnel Record and National Library

9.2.2 Selection of Civil Work Projects

(1) Background of the Selection and the Result

Based on site investigations and interviews with the relevant organizations in five districts, Gorkha District, Sindhupalchok District and Kathmandu Valley, a long-list for the Programme Grant Aid Projects for civil work was formulated. Projects for the local road improvement, large scale landslide protection in Jure, and local power distribution network improvement, etc., were included in the long-list as facilities of possible candidates for Grant Aid Projects.

JICA Project Team conducted a survey for collection of basic information for 23 facilities indicated in the long-list. The number of facilities in each district is as follows:

- Kathmandu Valley : 8
- Sindhupalchok District : 6
- Gorkha District : 9

Among the long-listed facilities, facilities not suited to the scale of Grant Aid scheme, and facilities assisted by other development partners were eliminated from the selection of Grant Aid Projects, and the short-list was prepared.

Short-listed projects were carefully examined in accordance with the criteria for selection as a Grant Aid candidate facility, with consultation with the relevant ministries and agencies, examination of project cost and consideration of the balance with the construction project. Table 9.2.3 shows the comparison of evaluation results of short-listed projects.

Thus, the following two sub-projects were proposed to be applied for the Programme Grant Aid Project from the candidates for the civil work component.

- Rehabilitation of Water Transmission System in Chautara
- Bridge Construction along Barhakilo - Barpak Road

Regarding the sub-project "Bridge Construction at District Road", it was difficult to apply for a Grant Aid scheme because the construction sites are widely spread in the Gorkha and Sindhupalchok Districts. However, considering the total construction cost for the sub-project "Bridge Construction along Barhakilo - Barpak Road," one more candidate bridge, which is the Daraudi Khola Bridge, was included from the candidate bridges from the sub-project "Bridge Construction at District Road." In case this bridge is constructed, Saurpani Village, which is located at the epicentre of the Nepal Earthquake and had been seriously damaged, will become easier to access the Barhakilo - Barpak Road, and it will contribute greatly to the earthquake disaster reconstruction. Therefore, it was decided by the Project Team that the sub-project "Bridge

Construction along Barhakilo – Barpak Road" to be selected from the "Bridge Construction at District Road."

On the other hand, as a result of adjustment within the upper limit of the grant amount of the programme, the sites in the table below were eliminated from the selected sub-projects, but as an alternative, it will be implemented by the Quick Impact Projects (QIPs) or by government budget.

Table 9.2.2 Deleted Components in Consideration of the Total Project Cost

Sub-project	Eliminated Sites	Substitute Resource
Water Transmission System	Thalkharka Transmission Pipe No. 1 and No. 2	GON
	Thalkharka Transmission Pipe No. 3 and No. 4	GON
	Majuwa Transmission Pipe	QIPs
Bridge Construction	Khahare Bridge	QIPs
	Jhyalla Bridge	QIPs

Table 9.2.3 Evaluation Result Comparison of Short-Listed Projects

Criteria	Water Transmission System in Chautara	Bridge Construction along Barhakilo - Barpak Road	Slope Protection at Barhakilo - Barpak	Bridge Construction along District Road
Reconstruction from damage by Earthquake	PASSED	NO	NO	NO
Contribution to Recovery	PASSED	PASSED	PASSED	PASSED
No Duplication with other donner	PASSED	PASSED	PASSED	PASSED
Large Number of Beneficially	PASSED	PASSED	PASSED	NO
Easiness of access to the site	PASSED	PASSED	PASSED	PASSED
Certain Scale of Work	PASSED	PASSED	PASSED	NO
Application of Japanese Technology	PASSED	PASSED	PASSED	PASSED

Source: JICA Project Team

9.3 The Subproject of Reconstruction of Paropakar Maternity and Women's Hospital, and Reconstruction of Bir Hospital

9.3.1 Design Conditions and Natural Conditions

(1) Outline of Targeted Hospitals

1) Paropakar Maternity and Women's Hospital (PMWH)

This hospital is the only public obstetrics and gynaecology specialized hospital in Nepal and it is located in southern Kathmandu, along the Bagmati River. It was founded in 1959. The Hospital accepted referral pregnant women and children from all over the country and has been established as a teaching hospital of the National Academy of Medical Sciences for specializing in obstetrics and gynaecology and also educational institution for physicians and post graduated nurses.

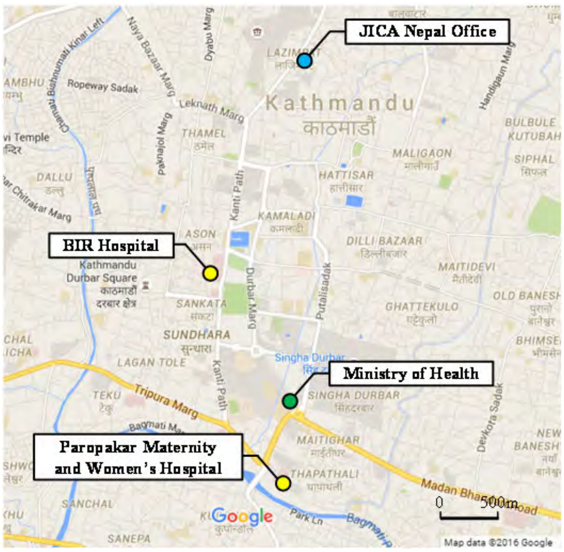
The Hospital provides the following medical services; OPD, delivery, operations, ultrasound examination, pathology, physiology, ER, abortion care and infertility treatment.The Hospital had a total of 415 beds before the last earthquake: obstetrics ward 241-beds, gynaecology ward 61-beds, new-born 34 beds, and 79 other service beds, but the hospital is no longer useable according to the assessment of the government authority. All hospital functions of the damaged buildings were relocated to other buildings due to the assessment. Therefore, there are a total of 360 hospital beds at the time of the survey.The number of birthing cases was more than 200 thousand every year, but it has been decreasing in the most recent 2 years. However, the number of birthing cases is approximately 50 a day, and Caesarean section delivery cases are more than 25%. The rate of maternal mortality became a half of the rate of 10 years ago and neonatal mortality rate is also decreasing year after year.

The implementation organization of the sub project for this hospital is PMWH under the Ministry of Health.

2) Bir Hospital (BH)

This hospital, founded in 1889, is the oldest public general hospital located in the central part of Kathmandu. The hospital is not only the top referral hospital in Nepal, but a main teaching hospital under the National Academy of Medical Sciences. The hospital is an authorized institute to grant master's degrees to graduating doctors and nurses. The hospital has 535 beds with 16 medical departments. This hospital is performing skin grafts and kidney transplantations with those surgical specialties. The hospital has a haemodialysis centre with 12 beds free of charge. The subproject covers cardiology, gastrology / endoscopy unit and haemodialysis.

The implementation organization of the subproject for this hospital is Bir Hospital under the Ministry of Health.The location map of the PMWH and the Bir Hospital is shown below.



Source: JICA Project Team

Figure 9.3.1 Location Map

(2) Natural Condition Survey

1) Topographic Survey

Topographic surveys which show the information about boundary walls, existing facilities and elevations were conducted in both hospital sites. Several benchmarks in each site were newly installed so as to make the surveyed points precise for design and construction.

2) Boring Survey

A boring survey and standard penetration test (SPT) which show the hardness of the foundation and liquefaction were carried out in both sites.

The boring survey which was carried out to a depth of 30m from the current ground level showed that N-values which show the hardness of the foundation were 6-9 on average in PMWH and 7-10 on average in Bir Hospital. It was recognised from the result that though the foundation was a loose foundation, there is no necessity for piling to support the reconstructed building.

Detailed liquefaction tests based on the SPT result shows that there are many points which have no possibility of liquefaction. Thus, it is comprehensively judged there is little possibility of liquefaction in both sites.

(3) Plate Loading Test

The team carried out plate loading tests to confirm whether the foundation near the ground can support the reconstructed building using a spread foundation method.

The level was at a depth of 2.0 m from the current ground level for the test. The test results are as below.

Table 9.3.1 Plate Loading Test Results

PMWH	Allowable Bearing Capacity = 106 kN/m^2
Bir Hospital	Allowable Bearing Capacity = 94 kN/m^2

Source: JICA Project Team

(4) Water Quality Testing

Raw water of the existing wells in both hospital sites has high colour, turbidity, suspended solids, ammonia, manganese, iron and microbiological counts.

Pressure filtration and disinfection treatment shall be applied along with activated carbon filters, colour removal, organic scavenger filtration, and ammonia removal filtration systems for the well water in both hospitals.

9.3.2 Outline Design

(1) Design Policy

Discussions with related organizations and site surveys have been held based on the following design policies:

Policy 1: The following codes, standards, guidelines and manuals are principally used in establishing design conditions of the structures.

- General Regulation: National Building Code (NBC)*
- Bylaws: Bylaws 2064 of Kathmandu Valley
- Indian Standard
- Japanese building code and standards
    * In addition to the NBC, standard values shall be set in consideration of the importance of the hospitals and the standards adopted for the reconstruction project of schools to be implemented by a Japanese loan.

Policy 2: As the model type of hospitals, it shall be designed as a disaster resistant building with features that will protect against earthquake to allow the continuous function of operations of the hospital that has a standby generator, UPS and water reservoir tank.

Policy 3: The building grade shall be set to enable the adequate selection of materials, construction methods and applicable techniques based on the Build Back Better policy.

(2) Facility Design

1) Paropakar Maternity and Women's Hospital

The damaged building had functions such as obstetrics, gynaecology, a low-risk delivery room and neonatal intensive care units which were mixed together in the same building before the earthquake. After the earthquake, the high-risk delivery room and operation theatre were relocated to a separate building.

The new building has been planned to accommodate all the obstetrics and academic functions in the same building with an obstetrics emergency department, operating room and delivery room, excluding a part of the postnatal ward, such as the maternity ward and the intensive care unit, which will be inside the specialized building for obstetrics and academic functions that were constructed before the earthquake.

Table 9.3.2 shows the functions to be included in the new building.

Table 9.3.2 Function of new building of PMWH

Floor	Function
GF	ANC Ward, ER, Labour & Analgesia, OT, Utility Rm
1F	Birthing Centre, Post Op Ward, MICU, Blood Bank, Emergency Lab, Pharmacy, Medical Store, Academic Function (Common Conference), Dep Director's Rm
2F	Postnatal Ward, New Born Care, NICU, SBCU, Academic Function (Class Rm, Faculty Rm)
RF	Electrical Rm, Lift Machine Rm

Source: JICA Project Team

Before the earthquake, the academic function was accommodated in the old building making it difficult to incorporate the wards and other functions. Thus, the academic function is to be shifted to the new building where spaces allocated for academic functions can be used as a disaster transfer area in the future if required.

After the construction of the new building, the old building will be demolished by the GON and the space will be used for a place for temporary refuge and triage in case of another disaster.

2) Bir Hospital

Bir Hospital had a renewal master plan for the facility that was created before the earthquake. This hospital site extends across three city blocks that are aligned in a north/south direction.

- According to the master plan, there are plans to build a surgical complex in the northern city block. That facility includes an emergency room, operation theatre and surgical intensive care unit etc.
- Preparation of construction has started this year because budgetary measures for this year was also taken. (Master plan: Phase1, 2)
- The block where the re-construction of the buildings is starting is located in the middle of the 3 city blocks. This city block is devoted to an outpatient department and medical complex. (Master plan: Phase 3, 4)
- The plan is intended to play a part in the medical complex of Phase 3 of the master plan, and the building design should be functional and efficiently planned to fulfil its function for examinations and treatment and provide wards that are organ-specific centres on each floor.

The functions that are to be provided in the new building are shown below;

Table 9.3.3 Functions of new building of Bir Hospital

Floor	Function
GF	Ward, Haemodialysis
1F	Gastrology Ward, Endoscopy Suite, Common Conference Rm
2F	Cardiology Ward, Cath Lab.
RF	Electrical Rm, Lift Machine Rm, Suction Pump Rm
Utility Building	Well Water Treatment, Water Reservoir, Medical Gus Rm, Generator Space

Source: JICA Project Team

In addition, the south block holds the existing trauma centre. It is not included in the renewal master plan.

(3) Subproject Sites

The outline of the subproject sites is shown below;

Table 9.3.4 Outline of the Subproject Sites

Site Name	Location	Construction Area
Paropakar Maternity and Women's Hospital	Thapathai, Kathmandu	Approx. 3,810 m^2
Bir Hospital	Kantipath, Kathmandu	Approx. 2,850 m^2

Source: JICA Project Team

(4) Outline of Facilities

Through the discussions with the hospitals, the outline of facilities has been determined as follows.

1) PMWH

Table 9.3.5 Outline of Facilities (PMWH)

Facility	No. of Bed	Structure	No. of Stories	Area [㎡]	
Reconstructed building	192	Reinforced Concrete	3	GF	1,799
				1F	1,700
				2F	1,700
				RF	207
				Total	5,406

Source: JICA Project Team

2) Bir Hospital

Table 9.3.6 Outline of Facilities (Bir Hospital)

Facility	No. of Bed	Structure	No. of Story	Area [㎡]	
Reconstructed building	94	Reinforced Concrete	3	GF	959
				1F	917
				2F	917
				RF	152
				Total	2,945
Utility Building		Ditto	1	GF	174
				Total	174
				Grand Total	3,119

Source: JICA Project Team

(5) Outline of Finish Schedule

Finishing materials for the subproject facilities were planned in consideration with procurement, maintenance and the level of local construction technologies to make the work as possible in Kathmandu. The outline is shown below.

1) PMWH

Table 9.3.7 Exterior Finishes

Pavement	Wall	Roof
Asphalt / Interlocking Blocks	Brick Tile / Plaster with Multi-Layer Coating	Asphalt Waterproofing with Protective Concrete Layer

Source: JICA Project Team

Table 9.3.8 Interior Finishes

Room	Floor	Wall	Ceiling
Ward	Vitrified Ceramic Tile	Paint	Rock Wool Acoustic Board
Labour Rm	Non Wax PVC Sheet	Paint	Rock Wool Acoustic Board
OT	Non Wax PVC Sheet	Decorative Calcium Silicate Board	Decorative Calcium Silicate Board
Academic	Carpet Tile	Paint	Rock Wool Acoustic Board

Source: JICA Project Team

2) Bir Hospital

Table 9.3.9 Exterior Finishes

Pavement	Wall	Roof
Asphalt / Interlocking Blocks	Brick Tile / Plaster with Multi-Layer Coating	Asphalt Waterproofing with Protective Concrete Layer

Source: JICA Project Team

Table 9.3.10 Interior Finishes

Room	Floor	Wall	Ceiling
Ward	Vitrified Ceramic Tile	Paint	Rock Wool Acoustic Board
X-ray Rm	Non Wax PVC Sheet	X-ray Protective RC Wall with Paint	Rock Wool Acoustic Board
Endoscopy Suit	Vitrified Ceramic Tile	Decorative Calcium Silicate Board	Decorative Calcium Silicate Board

Source: JICA Project Team

(6) Outline of Structural Design

Structural design policies are planned as below.

Design Standard and Aseismic Design Factor

The structural design of the subproject buildings conforms to the NBC and IS. PMWH and Bir Hospital are top referral hospitals in Nepal and are designated as medical service bases for disaster. Thus, the importance factor is set as follows; I = 2.0

Foundation Method

Mat foundation, effective method for reducing construction cost and time, is adopted based on the result of the standard penetration tests and plate loading tests.

Structural Type

Ductile moment-resisting frame with reinforced concrete shear walls which have strength and toughness will be used.

Material Grade

Materials which can be provided within the domestic area will be used. The material grade is as below.

- Design Concrete Strength : @28days fc=25(N/mm^2)
- Reinforcement Bar : Fe500 (σy=510N/mm 2 class)

(7) Utilities and Building Systems Planning

1) Connection to Infrastructure

Electric and Telecommunications in PMWH

The power supply source to the reconstructed building is the existing power receiving line of 250KVA, 1φ230V, or 3φ400V. They will continue to be used until the switch board is replaced during construction.

The switchboard is to be provided in the electrical room of the specialized O.P.D building. Power supply cables are connected to the reconstructed building by overhead wiring along the site boundary line. These cables are fixed on poles. Telephone and internet cables are wired to the reconstructed building by overhead wiring from the telephone switchboard room of the admission block. Television and broadcast cables are also wired the same way.

Electric and Telecommunications in Bir Hospital

Construction of a 500KVA substation is planned by Bir Hospital for April 2016 within the premises. Cabling to the reconstructed building is an overhead and underground wiring system from the branch circuit of the switchboard of the new substation. Telephone and internet cables are connected to the reconstructed building using overhead wiring along the south site boundary from the existing telephone switchboard. Television and broadcast cables are also wired the same way.

2) Water Supply and Drainage / Sewage

Both hospitals will connect to the existing water supply system. For Bir Hospital, the well which was the main water source has some trouble and has not been functional since May 2016. Therefore, a test well of 300 m depth was made from June to July 2017 to search the possibility of a stable water source, and pumping test was conducted. It was confirmed that the water source was enough to cover the demand of the main building of the hospital. Drainage which will be treated to standard water quality will be discharged to public sewers by connecting to the existing sewage basin in the premises.

3) Outline of Electrical Facilities

Electric Power Supply

The reconstruction facilities are supplied with commercial power by a low-voltage power source (400V/230V) from a substation in their premises. A diesel generator is also planned as a back-up emergency power supply in consideration of the frequent power outages, easy procurement of fuel and maintenance. An uninterruptible power supply system (UPS) is provided in the haemodialysis room, CCU, Cath. Lab, NICU, MICU, and OT.

Table 9.3.11 Design Capacity

Equipment	PMWH	Bir Hospital
Demand Power	250 kVA	200 kVA
Generator Capacity	250 kVA	200 kVA
UPS Capacity	15 kVA	15 kVA

Source: JICA Project Team

Telecommunications

Telephone service is provided to the reconstructed building through use of the existing telephone exchange. Broadcast equipment and television receivers are provided as with the existing hospital. LAN wiring is laid in the nurse station and main staff room. A monitoring camera system is installed for the purpose of security, supervising of staff, and education. Fire alarm equipment which is based on the law is provided.

4) Water Tank

A "Reservoir Tank and Elevated Tank System" is applied for water supply to sanitary appliances and medical equipment. A well water treatment system is introduced in consideration of maintenance. The reservoir tank capacity is 50% of daily water consumption. The water consumption calculation is based on Nepal National Building Code (NBC) 206: 2015.

Table 9.3.12 Daily Water Consumption and Water Tank Capacity

Hospital	No. of Beds	Daily Consumption per Bed (NBC206:2015)	Daily Consumption	Reservoir Tank Capacity
PMWH	192	450L/Bed	86,400L	44m^3
Bir Hospital	94	450L/Bed	42,300L	22m^3

Source: JICA Project Team

For the Haemodialysis Department in Bir Hospital, an exclusive elevated water tank and water supply pipeline are installed so that tank service can be used in case of breakdown of the well facilities.

Hot water is generally supplied to staff's working sink, scrub basin, shower, and bathing sink using local electric water heaters.

5) Drainage / Sewage

A septic tank for the reconstructed facilities is provided for both sites, and treated water is discharged to public sewers. The treated water quality shall be within the tolerance limits based on the Environmental Protection Act- 2054 Government of Nepal.

Table 9.3.13 Tolerance Limits of Discharged Water

Category	Water Quality
For Industrial Effluents to be Discharge into Public Sewers	BOD400mg/L, COD1,000mg/L, SS600mg/L

Source: JICA Project Team

6) Air Conditioning

Electrical package air conditioning systems are provided in both hospitals. Rooms with air conditioning are shown below. Central control system is planned to prevent overuse.

Ceiling fan are installed in rooms without air conditioning.

Table 9.3.14 Targeted Room to Install Air Conditioning

PMWH	ER / Labour Room / OT / Birthing Centre / Pharmacy / Blood Bank / Emergency Lab / MICU / NICU / SBCU/New born / POW
Bir Hospital	Haemodialysis / Endoscopy Suit / CCU / Cath. Lab. / Common Conference

Source: JICA Project Team

Temperature condition for calculation of air conditioning capacity is as below. Average maximum and minimum temperature during thirty years are referred to Monthly Weather Data in Kathmandu.

Table 9.3.15 Monthly Weather Data in Kathmandu

Summer	dry bulb: 29.1°C (June)	**Winter**	dry bulb: 2.4°C (January)

Source: JICA Project Team

Table 9.3.16 Temperature-Humidity Condition for Planning (Target Value)

	Normal Room	Baby Care (PMWH)		OT (Bir Hospital)	
	Temp	Temp	Humid	Temp	Humid
Summer	26.0°C	26.0°C	55%	25.0°C	55%
Winter	22.0°C	25.0°C	55%	25.0°C	55%

Source: JICA Project Team

7) Medical Gas

Oxygen (O) and Vacuum (V) are provided as medical gas supplies.

Oxygen supply is planned with a central piping system and manifold setting. Vacuum supply is planned with a central piping system and vacuum pump setting.

Table 9.3.17 Departments Provided with Medical Gas in PMWH

Department	Allocated Number
ER	Special Treatment : O,V/bed Examination : O,V/bed Observation: O,V/6beds
Labour Room	Labour : O,V/3bed New born Care : O,V
OT	OT : O,V/OT×3 units PRE/POST Operative : O,V/bed New born Care: O, V×1set
ANC	O,V/3beds
Birthing Centre	O,V/bed New born Care: O, V
Post Delivery	O, V×1set
Post-Operative	O, V/ 5 beds
SBCU/New born, NICU	SBCU & New born : O,V×30sets NICU : O,V×10sets Kangaroo Care : O,V/2beds
MICU	O,V/bed

Source: JICA Project Team

Table 9.3.18 Departments Provided with Medical Gas in Bir Hospital

Department	Allocated Number
Haemodialysis	O,V/bed
Endoscopy Suite	Endoscopy RM : O,V/RM ERCP : O,V
CCU	O,O,V/bed
Ward Nephrology Gastrology Cardiology	O,V/bed×4/10beds O,V/2bed×6/10beds

Source: JICA Project Team

(8) Equipment Planning

Medical equipment for the subproject is planned for selection of model and quantity based on the planned function of the reconstructed buildings and the equipment list which the hospital requested for the reconstructed buildings. Planning policies are as follows;

- Functions in the reconstructed building shall be able to work appropriately using the equipment provided.
- Specifications and quantities of equipment shall match with staffing and skill of the

reconstructed buildings and their functions.

- Maintenance cost for the equipment shall be considered so that the hospital budget is able to cover it.
- Existing equipment and the quantity shall be harmonized with the subproject.
- The reconstructed buildings and those functions shall work continuously with the equipment in case of another disaster.

Table 9.3.19 Planned Equipment (PMWH)

Department	Equipment	Specifications
Emergency, Maternity	- Infant warmer - Patient Monitor - Doppler Foetal Detector - Ultrasound Machine - Others	- Open type - Heart rate, SpO_2,BP, - Handy type - Portable type - Suction machine
Birthing Centre	- Labour Table - Patient Monitor - Doppler Foetal Detector - Ultrasound Machine - Others	- Stainless Steel - ECG, SpO_2,BP, Temp - Handy type - Portable type, 2 probe ports Patient - Suction machine
Labour Room	- Labour Table - Patient Monitor - Doppler Foetal Detector - Others	- Stainless Steel - ECG, SpO_2,BP, Temp Mobile Lamp - Handy type - Suction machine
Operation Theatre CSSD	- Operation Lamp - Operation Table - Anaesthesia Machine - Patient Monitor - Sterilizer - Others	- LED type - Electro Hydronic type - 3 flow meters, Two Vaporizers Electric driven ventilation - ECG, SpO_2, $ETCO_2$, NIBP, Temp - Steam Generator incorporated - Electro Surgical Unit, Infusion pump, Defibrillator
Maternal ICU NICU	- Central Monitoring System - Ventilator - Blood Gas analyser - Others	- ECG,SpO_2, Respiratory, Blood pressure, Temperature - Tidal Vol. 2000ml, Electric or Gas driven - pH, pCO_2, pO_2 - Infusion and Syringe pump, Pulse Oximeter, Suction Machine, Stretcher
Ward Post Operation, Antenatal, Postnatal	- Mobile lamp - Others	- LED type - Infusion and Syringe pump
Laboratory	- Biochemistry Analyser - Chemiiluminescence Analyser - Others	- Colorimetric, Open reagent type, Semiautomatic type - Automatic type, Immunoassay test (Harmon, ToRCH Reproductive Endocrinology) - Binocular Microscope
Blood Bank	- Centrifuge - Deep Freezer - Others	- Component separation - Temp. -40°C Blood donation couch

Source: JICA Project Team

Table 9.3.20 Planned Equipment (Bir Hospital)

Department	Equipment	Specifications
Maternal ICU NICU	- Central Monitoring System - Ventilator - Others	- ECG, SpO_2, Respiratory, Blood pressure, Temperature - Adult type for MIC ICU bed, Infusion and Syringe pump Pulse Oximeter, Suction Machine
Cardiology Ward	- ECG	- 12 lead, Digital display
Endoscopy unit	- Video Endoscope	- Field of View; larger than 100°, Working length; 50mm Xenon light source, Video processer, Suction unit, TV monitor, Electro surgical unit and mobile rack included
Nephrology unit	- Haemodialysis unit	- Single patient type, Water treatment unit included

Source: JICA Project Team

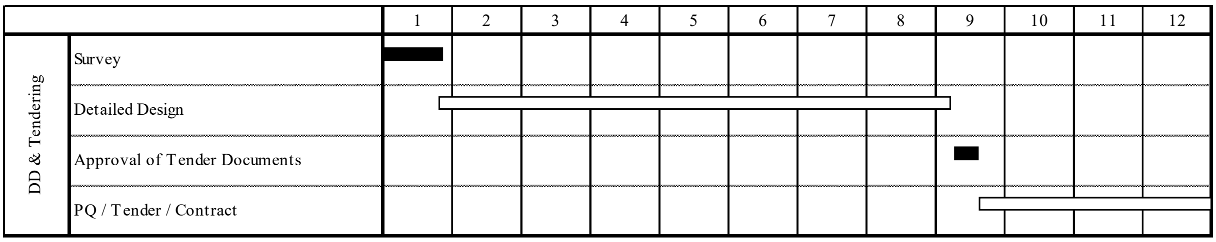
9.3.3 Construction Plan / Procurement Plan

(1) Construction Policy / Procurement Policy

1) Principle

- With the approval of the Japanese government, the Exchange of Note (E/N) shall be entered into between the Government of Japan and the GON. A Grant Agreement (G/A) shall be entered into between JICA and the GON in order for the subproject to be formally committed to and to be implemented.
- Following conclusion of the G/A, consultant firms of Japanese nationality and the GON will conclude a detailed design and supervisory agreement, and immediately start detailed design work.

Table 9.3.21 Schedule (Detailed Design and Tendering)



Source: JICA Project Team

2) Tendering

- The tender will take place in accordance with the JICA procurement guidelines for Japanese Grant Aid.
- It is thought that the tendering method will be either a consortium between Japanese construction and trading companies that combines facility construction and equipment, or a stand-alone method dividing facilities and equipment. Coordinating facility and equipment construction work schedules for the subprojects is important, so it is considered that choosing the former method would be desirable to avoid disagreements.
- The party executing the tender will be the implementing agency, but it is necessary for

consultants to cooperate sufficiently while taking instructions from JICA.

3) Construction of Facilities and Procurement of Equipment

- From survey results, it was found that several construction materials like PVC flooring sheet for the Operation Theatre and X-ray protective glass window needs to be imported mainly from Japan because of the difficulty of procurement in Nepal. And many kinds of material and equipment will be distributed through India. Consequently, cost effectiveness due to the route and method of transportation needs to be considered carefully.
- For the labour management planning of construction and equipment installation, dispatch of technicians for specific works such as the above mentioned work items should be carefully considered because it is difficult to find skilled workers in Nepal. But the workers of general work items can be secured in Nepal.
- The work schedule needs to be adhered to for smooth work progress in the construction as well as procurement and installation of equipment.
- The Nepal side has implemented the demolition work of the existing buildings at the sites before the commencement of work under this sub-project. A JICA technical advisor under the RRNE has been dispatched for supporting the safety and appropriate implementation of demolition work.

4) Implementing Agencies

This subproject will be implemented by the following agencies.

- The Ministry of Health administrates this subproject.
- The organizations for implementation for this subproject are PMWH and Bir Hospital.

(2) Undertakings by Both Governments

Demarcation of undertakings for the subproject by both governments is shown as follows;

Table 9.3.22 Demarcation of Undertakings

Japan Side	Nepal Side
1. Facilities (1) Construction Works Concrete Works, Finishing Works, Furniture etc. (2) Electric Works Power receiving and transformer facility, trunk line, generator, lighting circuit, outdoor lighting within the subproject area, telecommunication, public address, telephone and intercom, lightning protection, solar photovoltaic generation system etc. (3) Mechanical Works a) Utility Works 1) Water Supply Well water treatment system, water reservoir, elevated water tank, sanitary facility, solar & electric hot water system etc. 2) Drainage / Sewage Septic tank 3) Fire Extinguishing System b) Air Conditioning Air conditioning system, electric heater, ventilation system, ceiling fan etc. (4) Exterior Works Road construction within the sites, exterior drainage, planting spaces (5) Water and Electricity for Construction Stage 2. Equipment (1) Medical Equipment	(1) Site Preparation a) Preparation and management b) Land plots for the subproject c) Demolition of the existing buildings and site preparation work d) Access road to the sites e) Shifting and preservation of specific items (2) Infrastructure a) Power supply line b) Telecommunication line (3) Permission for building construction and utility line connection (4) Tax Exemption and Custom Clearance (5) Issue Authorization to Pay (A/P) based on Banking Arrangement (B/A) (6) Operation and Maintenance, and Cost (7) Procurement and installation of furnishings (8) Provision of convenience for immigration and residence of Japanese nationals and persons from third countries involved in the subproject (9) Curtain works for general parts of the buildings (10) Plantings

Source: JICA Project Team

(3) Supervisory Service Plan

Consultants' supervision services include the items mentioned below.

1) Work Planning / Safety Planning / Approval of Working Drawings

Work plans, progress schedules and working drawings will be submitted by the contractor to the consultant for approval. The consultant will approve them if they conform their compliance to the contract, drawings and specifications.

2) Safety Control

Safety control during the construction stage shall follow the "Guidelines for Safety Control of ODA Project Construction". The contractor will submit the "Safety Measures Plan" for comprehensive construction works and the "Safety Work Plan" for each work item. The consultant and the implementing agencies will review these plans. Safety control policies are as follows;

- Safety First: The first priority is the safety of hospital users and construction works in both hospital realms that include construction areas because the construction works will be executed in working hospital complex areas.

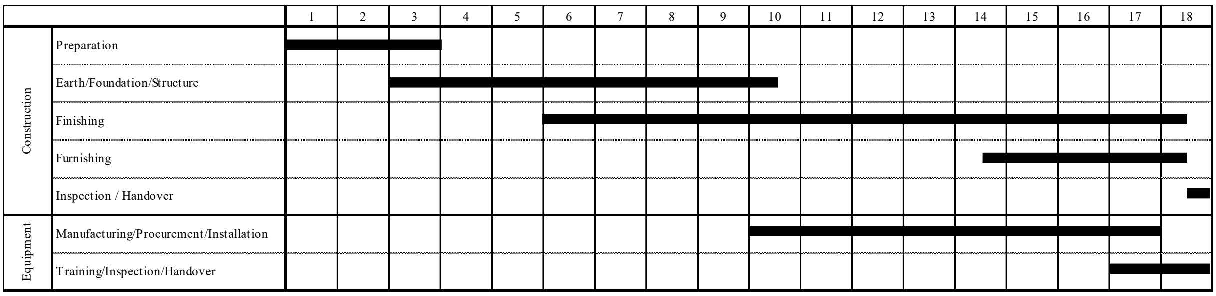
- Secure the safety of access to the sites: Since the vehicles and machineries for the construction need to pass through the hospital realm, traffic control should be carefully managed. Only 1 gate for the construction area shall be set and it shall be separated from the hospital user's circulation. And seamless control organization with multiple security guards shall be established for safe access control so as to avoid any failure.
- Site protection fence: Temporary fences with panels shall be installed at sites to prevent persons from going into the construction area and prevent hospital users from casually entering into the area. These fences will prevent accidents caused by collision and flying objects.
- Protect hospital environment: Hospitals are working 24 hours a day and have inpatients. Hence, noise, vibration and dusts from the construction areas shall be minimized and night work, except specific works such as interior works that disturb no one, shall basically not be done.

3) Progress Management

Monthly progress reports based on a comprehensive work schedule shall be submitted by the contractor. They shall reflect processes implemented by the month-end in a predicted performance curve, and be monitored so that delays and progress can be shown quantitatively. If there are serious delays in the planned schedule, the cause shall be traced and grasped, and appropriate instructions shall be given to deal with the problem and catch up with the planned schedule.

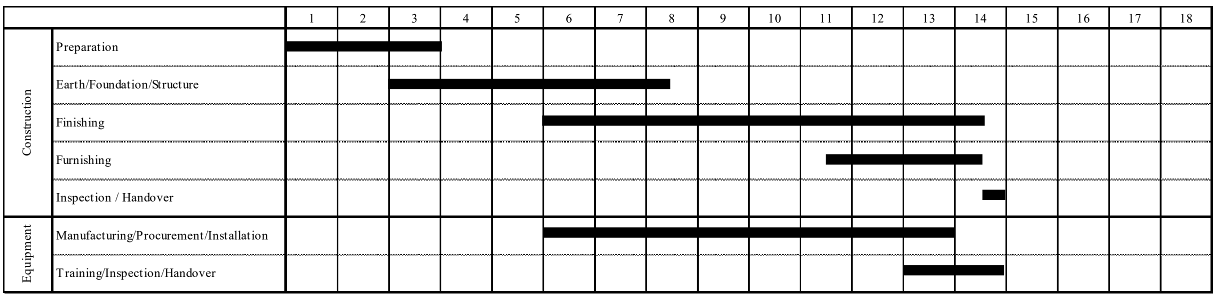
4) Schedule

Table 9.3.23 Schedule: Construction and Procurement for PMWH



Source: JICA Project Team

Table 9.3.24 Schedule: Construction and Procurement for Bir Hospital



Source: JICA Project Team

5) Others

The Minutes of Discussion between JICA and GON stipulate that EIA/IEE shall be conducted by the GON in accordance with the regulations of Nepal. The Process of EIA/IEE was confirmed by MOH to NRA, and the Bir Hospital was exempted from conducting the EIA/IEE as per the "Working Guideline for Environmental Impact Assessment of Reconstruction of Structure Affected by Earthquake, 2072" in August 2016. As for PMWH, however, the EIA was deemed unnecessary, and the IEE was required at that time. Finally in February 2017, PMWH was also exempt from conducting the EIA/IEE as per the revised "Guideline for Environmental Impact Assessment of Reconstruction Work of Structure Affected by Earthquake, 2072."

9.3.4 Demolition and Removal of Existing Facilities

(1) Advisory Work for Demolition

Demolition work of the existing buildings within the two hospital sites damaged by the earthquake was undertaken by the Nepalese side. The two hospitals which were selected as the JICA Grant Aid Projects are:

- Paropakar Maternity and Women's Hospital (PMWH) reconstruction (Kathmandu)
- Bir Hospital reconstruction (Kathmandu)

Technical advisory work on the demolition work had been carried out in accordance with Nepalese requirements from March, 2016. Through the cooperation with the relevant organizations regarding the demolition of existing buildings for the construction of the new hospitals, after the field survey, the issues of the Demolition Plan was confirmed as TECHNICAL NOTE ON THE DEMOLITION PLAN (Here in after Demolition T/N) dated 11th April, 2016. Demolition monitoring and advice regarding demolition and coordination of the schedule in the field have been conducted for four times, a total 50 days by the end of August 2016. The completion of demolition work was 31st August, 2016, but since there were unfinished items, the Government of Nepal (GON) and the Consultant have agreed to extend the deadline of the schedule to 30th November, 2016, and to complete all the agreed items on the Demolition T/N, in a written agreement "AMENDMENT ATTACHMENT" on 22nd August. The points to note of demolition of damaged hospital buildings were as follows;

- The demolition work will be carried out while the hospital continues in operation. Therefore advisory work on the demolition work will be carried out to ensure not only to safe construction, but also to ensure the safety of the patients and the staff.
- Disposal of the industrial waste arising from the demolition in the appropriate manner according to Nepalese law.

- Services cables and piping shall be rerouted and the demolition work carried out while minimizing the environmental load, and without causing any hindrance to the operation of the existing hospitals.
- After removal, the site shall be in an appropriate condition as a construction site for reconstructing the buildings.

1) Summary of the Survey

The Advisory Work has been done with the following items in four survey periods;:1) Define Services cables and piping to be rerouted, 2) Ensuring construction safety, 3) Environmental considerations, 4) Coordination regarding demolition schedule, 5) Preservation of the foundation bed for the reconstructed building.

1st Survey: 23rd March to 13th April 2016 (21 days)

The Demolition T/N was signed on 11th April 2016, with agreement on the following: 1) Demolition Site Plan, 2) List of Existing Buildings to be demolished, 3) Demolition Schedule, 4) Responsible Organization and Implementing Organization, 5) the security of the hospital users and safety of the demolition[19], 6) Flow of Demolition Work (Draft).

International Organization for Migration (IOM), who has continued to remove damaged buildings by the earthquake throughout Nepal, had been in charge of PMWH. The Project Team had several meetings with IOM, and surveyed the IOM's demolition site at the damaged Tribhuvan University school building which has four stories, where the IOM demolition condition such as putting protective gear when using heavy machine was confirmed. Since IOM has prompted the policy to reuse the foundation including the first floor upon removal of the damaged buildings, it has been determined not to remove the foundation for PMWH. Thus, it was not clear which organization will remove the foundation of PMWH.

Regarding Bir Hospital, "Umesh Singrh Jorpati, Nayabasti, Kathmandu" as one private enterprise had already started demolishing work from February 2016, and the top floor of the NEW ICU BUILDING had been demolished manually by hammers and vibrators.

2nd Survey: 22nd to 31st May 2016 (10 days)

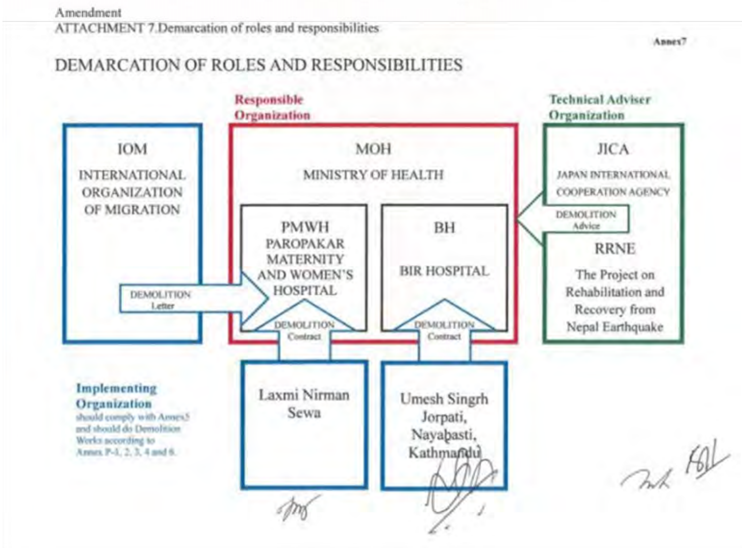
Attended a meeting "Safety of Hospital Users and Safety during Demolition".

3rd Survey : 16th to 24th July 2016 (9 days)

"AMENDMENT of TECHNICAL NOTE ON THE DEMOLITION PLAN" (Amendment of

[19] Refer from Safety Guideline ODA, Sep. 2014., JICA

Demolition T/N) was issued on 21st July 2016. IOM had demolished above the plinth level. So next, it was decided that Laxmi Nirman Sewa as a private enterprise, will start demolishing the foundation and underground structure including the plinth level by the report of MOH and PMWH.



Source: JICA Project Team

Figure 9.3.2 The Demarcation of Roles and Responsibilities

4th Survey: 21st to 31st August 2016 (11 days)

"THE CERTIFICATE OF SUBSTANTIAL DEMOLITION COMPLETION with confirmation of unfinished items" was issued on 22nd August and the unfinished items were clarified according to the "Demolition T/N dated 11th April, 2016". GON and the Project Team have agreed to extend the deadline of completing all the demolition as agreed in "Demolition T/N", from 31st August to 30th November 2016. The unfinished demolition items that needed correct of information were concluded in "AMENDMENT ATTACHMENT". Extension of the demolition schedule was decided by consideration of the operating procedure for the arrangement of Tender of both Hospitals in the middle of December as originally planned.

2) Completion of the Demolition Work

After the 4th Survey, the Project Team monitored the condition of the demolition work in Japan by using email, and the completion of the demolition and removal of existing facilities for both hospitals were confirmed. The completion date of the demolition work is as below.

Table 9.3.25 Completion Date of the Demolition Work

Hospital	Item	Responsible Organization	Confirmation Method	Completion Date
PMWH	Foundation and Underground Structure Demolition	MOH, PMWH	Monitoring Report with Photographs	Completed on 23rd October, 2016
	CANOPY OF OLD BUILDING Demolition			Completed on 23rd October, 2016
	Removal of Waste Water Piping			Completed on 27th December, 2016
	A temporary wall of South Property Line			Completed on 2nd November, 2016
Bir Hospital	Foundation and Underground Structure Demolition	MOH, Bir Hospital	Site inspection by the JICA Nepal Office	Completed on 19th January, 2017

Source: JICA Project Team

3) The Site Survey Map Including Piping & Cable

MOH has prepared the Site Survey Map including piping & cable lines after the demolition work of both PMWH and Bir Hospital according to the agreement document between RRNE and MOH.

9.4 The Subproject of Bridge Construction along Barhakilo-Barpak Road

9.4.1 Scope of Work

Although Khahare Bridge and Jhyalla Bridge will not be implemented by Programme Grant Aid, but by QIPs as explained in Chapter 9.2.2, the outline of the survey and the result of the outline design are explained the as same as the other three bridges in this Chapter.

9.4.2 Design Condition / Natural Condition

(1) Meteorological Condition

1) General

According to Köppen climate classification system, the study area of 5 bridges is classified as a "Warm temperate climate with dry winter and warm summer" ("Cwb")[20].

Nepal’s climate is influenced by maritime and continental factors, and it has four distinct seasons. The spring lasts from March to May, and it is warm with rain showers. The summer, from June to August, is the monsoon season when the hills turn a lush green. The autumn, from September to November, is cool with clear skies. In the winter, from December to February, it is cold at night with temperatures sometimes below zero. However, the maximum temperatures can still reach up to 20°C. Then the mountains are covered with snow including some high hills.

[20] The Rampur Station which is downstream has a "Warm temperate climate with dry winter and hot summer; Cwa".

Nepal has been affected by extreme weather events etc., resulting in natural disasters such as floods, debris-flows and landslides. Nepal's fragile geological conditions, topographical extremities, climatic extremities and seismic activities coupled with deforestation, unscientific agricultural practices, unscientific land use changes, and developmental activities such as construction of roads, irrigation systems and hydro-powers make it vulnerable to several natural disasters.

Extreme precipitation events during monsoon periods are common in Nepal. Extreme rainstorms in the past years have been induced by abnormal behaviour of monsoon depression paths originating from the Bay of Bengal when associated with low-pressure systems in Nepal.

2) Data Collection Items

Meteorological stations and gauging stations are arranged in the study area and surrounding basin, as shown in Figure 9.4.1. The Department of Hydrology and Meteorology (DHM), a subordinate organization of the Ministry of Science, Technology and Environment, carries out meteorological observations and river discharge measurements. A few meteorological stations are also equipped with a thermometer, a hygrometer, an anemometer and an evaporation pan, while the other stations are provided with only a rain gauge. Among the meteorological stations in the table, only the Rampur Station measures all of items, and the others measure only rainfall.

The data collection items and period at the related meteorological / hydrological stations at the study area and surrounding basin are shown in Table 9.4.1 and Table 9.4.2.

Table 9.4.1 Collected Data at Each Meteorological Station

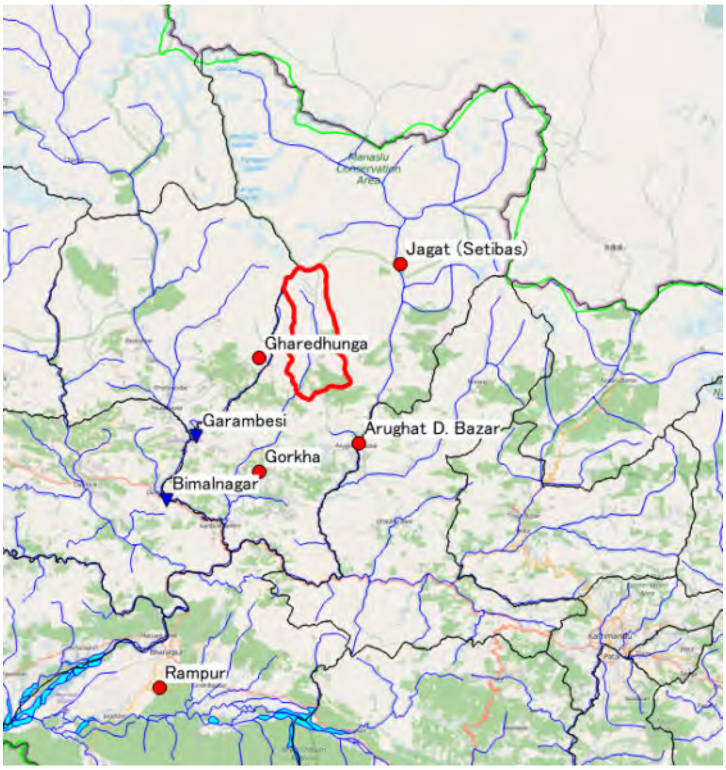
S.N.	Station Name	District	Log. (X)	Lat. (Y)	Elevation (m)	Established Date	Collected Items							Remarks
							Monthly Temperature	Monthly Relative Humidity	Monthly Wind Speed	Monthly Evaporation	Monthly Rainfall	Daily Rainfall	Annual Maximum Daily Rainfall	
118	Jagat (Setibas)	Gorkha	84.90000	28.36667	1334	Jul-57	-	-	-	-	1985-2014	1995-2014	1990-2014	
125	Gorkha	Gorkha	84.61667	28.00000	1097	Jun-56	-	-	-	-	1985-2014	1995-2014	1990-2014	
136	Gharedhunga	Lamjung	84.61667	28.20000	1120	Jul-76	-	-	-	-	1985-2010, 12, 14	1993-2014	1990-2010, 12, 14	
167	Arughat D. Bazar	Dhading	84.81667	28.05000	518	Jun-57	-	-	-	-	1985-2008	1991-2008	1990-2008	
146	Rampur	Chitawan	84.41667	27.61667	256	Jan-67	1985-2014	1985-2014	1968-2012	2001-2010	1985-2014	1995-2014	1990-2014	

Source: DHM

Table 9.4.2 Collected Data at Each Hydrological Station

S.N.	Station No.	River Name	Station Name	Log. (X)	Lat. (Y)	Elevation (m)	Established Date	Instru-ments	Collected Items			Remarks
									Monthly Discharge (Minimum, Average, Maximum)	Daily Discharge	Annual Maximum Discharge (Extreme)	
17	439	Marsandi River	Bimalnagar	84.43000	27.95000	354	Mar-87	Cable Way	1987-2010	1988-2010	1988-2010	
18	440	Chepe Khola	Garambesi	84.48972	28.06139	442	Nov-63	Cable Way	1964-2010	1964-2010	1964-2010	

Source: DHM



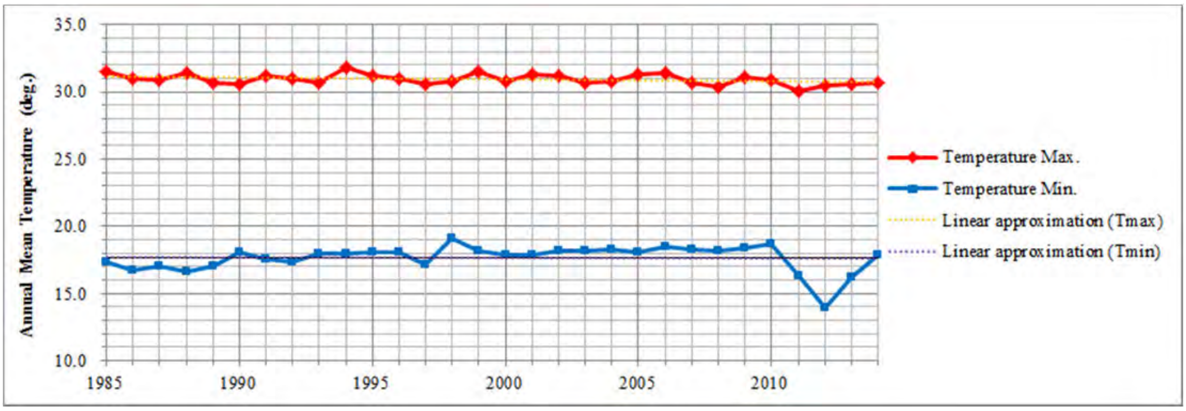
Source: JICA Project Team

Figure 9.4.1 Location of Meteorological and Hydrological Stations

3) General Weather Conditions

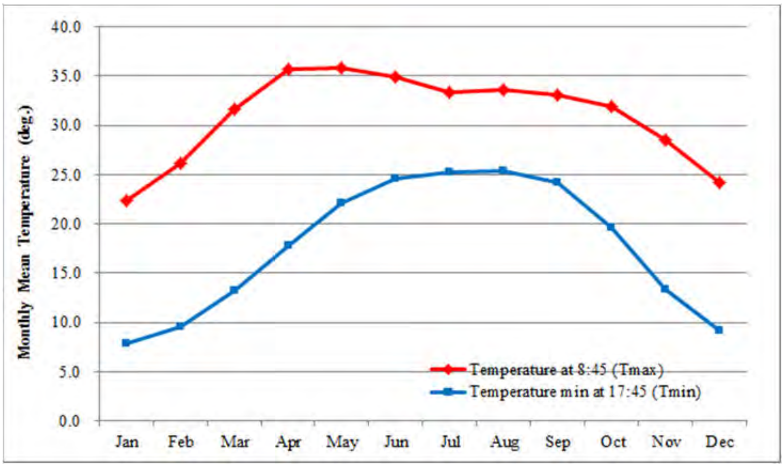
a) Temperature

The monthly mean maximum/minimum temperature during 1985-2014 is shown in Figure 9.4.2. The maximum temperature varies from 22 degrees to 36 degrees, and its peak occurs in April to June. On the other hand, the minimum temperature varies from 8 to 25 degrees, and its nadir is from June to August. Although long-term fluctuation of annual mean temperature shows in Figure 9.4.3, signs suggesting the global warming are not particularly seen.



Source: DHM

Figure 9.4.2 Monthly Mean Temperature at Rampur Station

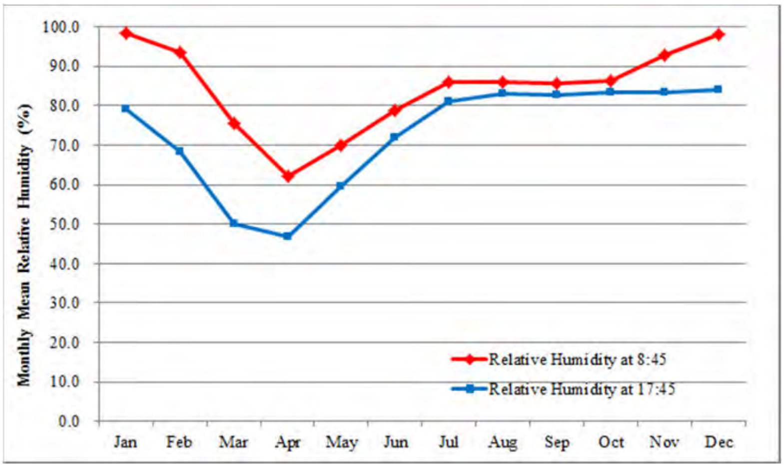


Source: DHM

Figure 9.4.3 Long-term Fluctuation of Annual Mean Temperature at Rampur Station

b) Relative Humidity

The monthly mean relative humidity at 8:45 and 17:45 during 1985-2014 is shown in Figure 9.4.4. As the pattern of relative humidity, the periods of high humidity continue throughout the year except for spring season from March to May, and its peak occurs from December to January.

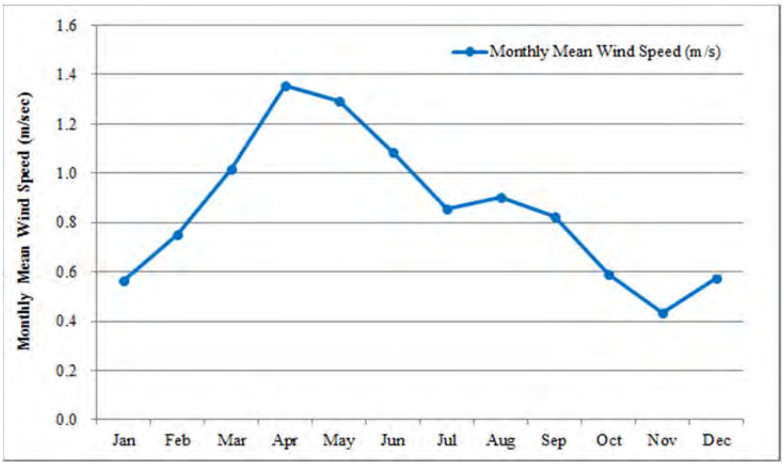


Source: DHM

Figure 9.4.4 Monthly Mean Relative Humidity at Rampur Station

c) Wind Speed

The monthly mean wind speed during 1968-2012 is shown in Figure 9.4.5. The monthly mean wind speed varies from 0.4m/s to 1.4m/s, and its peak occurs in spring season from March to June.



Source: DHM

Figure 9.4.5 Monthly Mean Wind Speed at Rampur Station

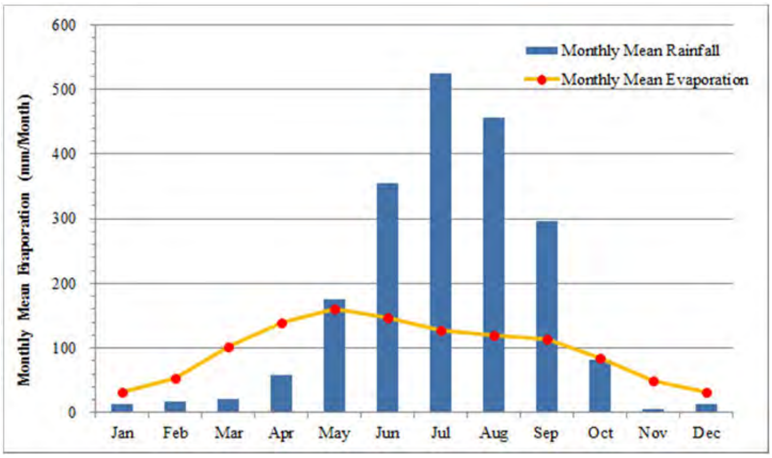
d) Evaporation

The monthly mean evapotranspiration during 2001-2010 is shown in Table 9.4.3 and Figure 9.4.6. The monthly mean evaporation varies from 32 mm to 160 mm, and its peak occurs from May to July while the peak of rainfall occurs from June to September. It is understood that the season from October to April is dry, in terms of the rate of evaporation and rainfall.

Table 9.4.3 Monthly Mean Evaporation at Rampur Station (2001-2010)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Evaporatioon (mm)	Annual Rainfall (mm)	Remarks (Evapo./Rain.)
2001	(gap)	(gap)	(gap)	(gap)	(gap)	**171.0**	127.1	102.3	96.0	74.4	45.0	27.9	(643.7)	2340.1	-
2002	37.2	61.6	102.3	129.0	127.1	123.0	120.9	**133.3**	111.0	86.8	51.0	37.2	1120.4	2643.9	42.4%
2003	31.0	53.2	86.8	129.0	**148.8**	114.0	117.8	99.2	81.0	77.5	45.0	34.1	1017.4	2693.5	37.8%
2004	31.0	52.2	93.0	117.0	**173.6**	111.0	55.8	120.9	87.0	71.3	42.0	31.0	985.8	2042.0	48.3%
2005	31.0	50.4	114.7	150.0	**186.0**	150.0	111.6	89.9	99.0	71.3	42.0	37.2	1133.1	1732.0	65.4%
2006	31.0	53.2	114.7	135.0	**151.9**	144.0	139.5	124.0	129.0	96.1	51.0	27.9	1197.3	1997.2	59.9%
2007	27.9	47.6	96.1	144.0	145.7	**198.0**	155.0	124.0	150.0	102.3	63.0	34.1	1287.7	2742.6	47.0%
2008	43.4	58.0	114.7	150.0	186.0	171.0	**198.4**	161.2	138.0	96.1	60.0	49.6	1426.4	1786.0	79.9%
2010	24.8	50.4	99.2	159.0	**164.3**	135.0	117.8	127.1	132.0	86.8	39.0	15.5	1150.9	2399.5	48.0%
Monthly Mean Evaporation	32.2	53.3	102.7	139.1	**160.4**	146.3	127.1	120.2	113.7	84.7	48.7	32.7	1161.2	2023.6	57.4%
Monthly Mean Rainfall	14.1	18.0	21.3	59.2	176.4	355.0	**525.4**	457.0	295.9	81.6	5.7	14.0	-	2023.6	1985-2014
Evaporation / Rainfall	228.8%	295.9%	482.0%	235.1%	91.0%	41.2%	24.2%	26.3%	38.4%	103.8%	850.3%	234.1%	-	-	

Source: JICA Project Team based on DHM data



Source: DHM

Figure 9.4.6 Monthly Mean Evaporation at Rampur Station (in mm)

e) Rainfall

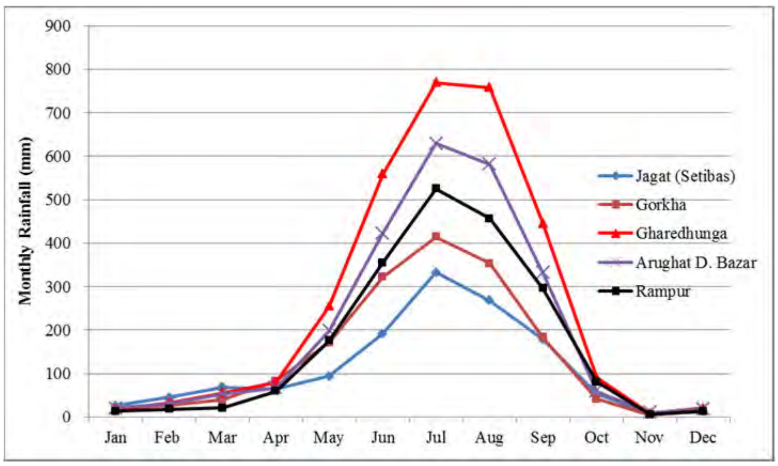
Daily, Monthly and Annual Rainfall

The monthly mean rainfall at 5 stations is shown in Table 9.4.4 and Figure 9.4.7. The monthly mean rainfall varies from 5 mm to 769 mm/month, and its peak occurs from June to September. The annual mean rainfall at 5 stations varies from 1,347 mm at Jagat Setibas to 3,096 mm at Gharedhunga Station.

Table 9.4.4 Monthly Mean Rainfall at 5 Stations

Station Name	Observed Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Jagat (Setibas)	1985-2014	26.9	45.4	68.9	65.5	93.9	191.7	**333.2**	268.0	178.8	53.8	7.6	12.9	1347
Gorkha	1985-2014	20.3	26.6	40.1	83.2	171.1	322.2	**414.5**	353.5	183.4	41.6	5.3	13.9	1676
Gharedhunga	1985-2010, 2012, 2014	18.7	32.9	55.8	80.0	254.9	559.4	**769.2**	758.1	445.6	92.0	9.0	21.0	3096
Arughat D. Bazar	1985-2008	20.7	31.0	53.7	67.6	198.1	422.7	**629.6**	581.3	332.1	59.6	10.7	19.2	2426
Rampur	1985-2014	14.1	18.0	21.3	59.2	176.4	355.0	**525.4**	457.0	295.9	81.6	5.7	14.0	2024
Average		20.1	30.8	48.0	71.1	178.9	370.2	**534.3**	483.6	287.2	65.7	7.7	16.2	2114

Source: JICA Project Team by using DHM data



Source: DHM

Figure 9.4.7 Monthly Mean Rainfall Pattern at 5 Stations

As reference for the construction program, the unworkable days are estimated based on the total annual days in which daily rainfall is more than 10 mm. The estimated quantities based on the past daily rainfall at 5 stations are shown in Table 9.4.5.

Table 9.4.5 Rainy Days with more than 10mm/day at 5 Stations

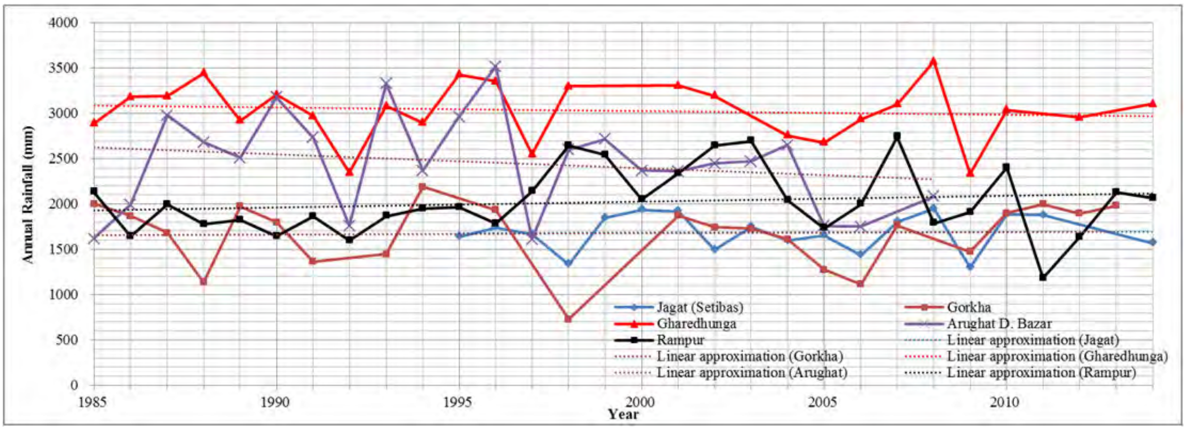
Station Name	Collected Records	Rainy days more than 10mm/day	Rate of Rainy Days	Remarks
		a	b=a/365	
Jagat (Setibas)	1995-2014	65.5	0.179	
Gorkha	1995-2014	51.4	0.141	
Gharedhunga	1993-2014	82.5	0.226	
Arughat D. Bazar	1991-2008	72.7	0.199	
Rampur	1995-2014	55.2	0.151	

Note. Unworkable days assume that daily rainfall is higher than 10mm.

Source: JICA Project Team based on DHM data

Long-term Fluctuation of Annual Rainfall

The long-term fluctuation of annual rainfall at 5 stations is shown in Figure 9.4.8. The annual rainfall at 5 stations varies from 728 mm to 3,573 mm. From this, increased signs suggesting global warming are not particularly seen.



Source: DHM

Figure 9.4.8 Long-term Fluctuation of Annual Rainfall at 5 Stations

Exceedance Probability and Intensity Curve of Rainfall at Gauging Stations

The probability rainfalls at 5 stations are calculated from the past annual maximum rainfall (extreme values) which was collected, as shown in Table 9.4.6 and Figure 9.4.9. The probability rainfall is calculated according to the following:

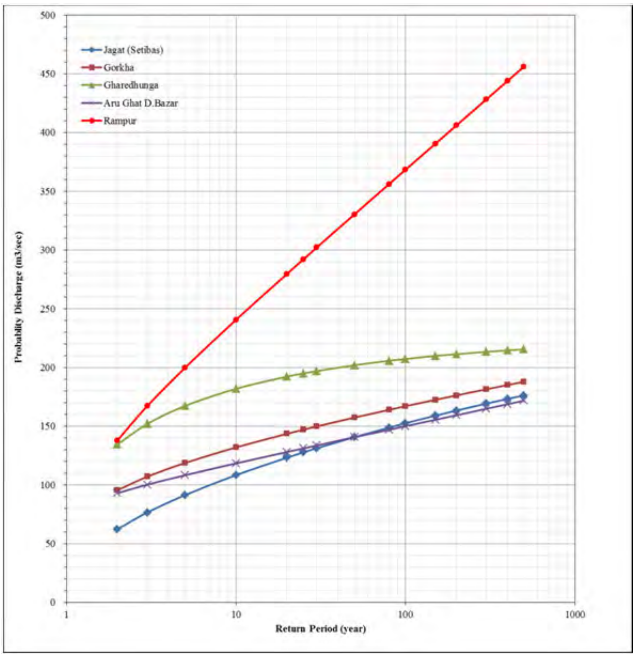
- Appropriate model for probability distribution from several methods. - Exponential distribution, Gumbel distribution, SQRT-exponential type maximum distribution, Generalized extreme value distribution, Log Pearson type III distribution (Real space method or Logarithmic space method), Iwai's method, Ishihara and Takase's method, 3-parameter log-normal distribution (Quantile method or Slade II method), etc.

- Distribution model selected by reference to SLSC (Standard Least Squares Criterion) value or adequacy of probability value, etc. (SLSC value of 0.04 or less is desirable.)
- Calculation of rainfall for return periods of 2, 3, 5, 10, 20, 25, 30, 50, 80, 100, 150, 200, 300, 400 and 500 years.

Table 9.4.6 Probability of Daily Rainfall at 5 Stations

Station Name			Jagat (Setibas)	Gorkha	Gharedhunga	Aru Ghat D.Bazar	Rampur	Remarks
River Name			Buri Gandaki	Daraudi	Chepe	Buri Gandaki	Narayani	
Station S.N.			118	125	136	167	146	
Long. (X) of Location			84.9000	84.6167	84.6167	84.8167	84.4167	
Lat. (Y) of Location			28.3667	28.0000	28.2000	28.0500	27.6167	
Elevation of Station (m)			1,334	1,097	1,120	518	256	
Data No. of Extreme Value			25	25	23	19	25	
Probable Daily Rainfall (mm/day)	(Year)	(%)						
	2	50%	62.4	95.6	134.6	93.1	138.1	
	3	33.3%	76.6	107.1	152.0	100.3	167.3	
	5	20%	91.3	118.7	167.3	108.3	199.7	
	10	10%	108.4	132.0	181.9	118.4	240.6	
	20	5.0%	123.3	143.6	192.3	128.1	279.7	
	25	4.0%	127.8	147.1	195.0	131.2	292.1	
	30	3.33%	131.3	149.9	197.0	133.7	302.3	
	50	2.0%	140.7	157.4	202.0	140.7	330.4	
	80	1.25%	148.9	164.0	205.8	147.0	356.2	
	100	1.0%	152.6	167.1	207.3	150.1	368.4	
	150	0.667%	159.0	172.5	209.9	155.5	390.5	
	200	0.5%	163.4	176.3	211.4	159.4	406.2	
	300	0.333%	169.3	181.5	213.4	164.9	428.3	
	400	0.25%	173.3	185.1	214.6	168.8	444.0	
	500	0.2%	176.3	187.9	215.5	171.8	456.2	
X-COR(99%)			0.981	0.993	0.976	0.945	0.984	
P-COR(99%)			0.983	0.997	0.319	0.961	0.990	
SLSC(99%)			0.040	0.024	0.039	0.069	0.035	
Probabilistic Distributed model			Generalized extreme value distribution	Iwai's method	Log Pearson type III distribution (Real space method)	Gumbel distribution	Gumbel distribution	

Source: JICA Project Team based on DHM data

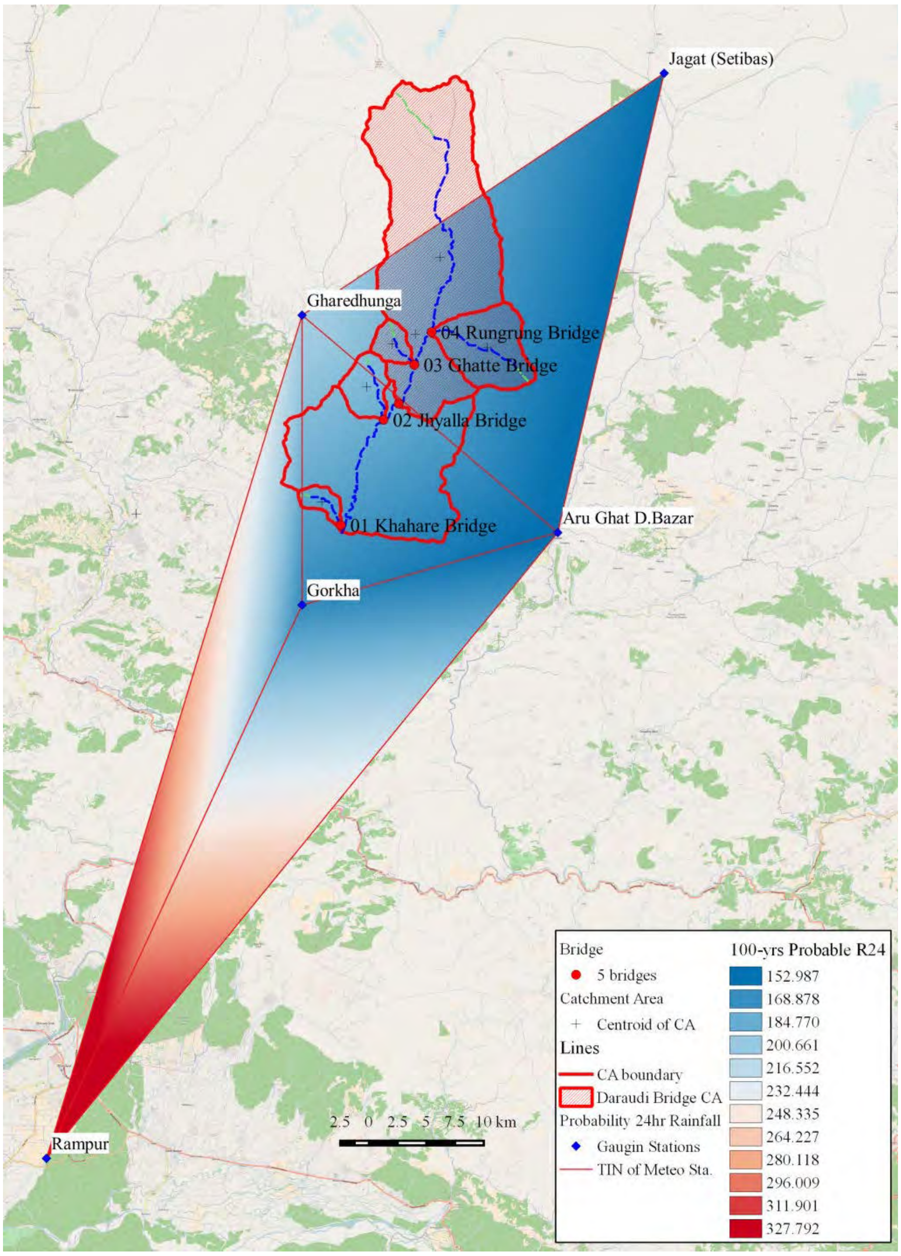


Source: DHM

Figure 9.4.9 Probability of Daily Rainfall at 5 Stations

Exceedance Probability and Intensity Curve of Rainfall at each Bridge Location

As one example, the spatial distribution of 100-year probability rainfall of Table 9.4.6 is plotted in Figure 9.4.10. The 2-100 years probability rainfalls of each bridge are estimated by reading the probability values of the centroid of each catchment area on the TIN (Triangulated Irregular Network) of GIS software.



Source: JICA Project Team

Figure 9.4.10 Spatial Distribution of Probability Rainfall (Case of 100-year Flood)

And then, the Mononobe's equation is applied in order to derive the correlation between intensity of short term rainfall duration and 24-hour probability rainfall. This equation has also been proved to perform well in Nepal.

The probability rainfall intensities at the locations of each proposed bridge is shown in Table 9.4.7. And the IDF curve at whole catchment area is shown in Figure 9.4.11.

Table 9.4.7 Probability Rainfall Intensity at each Proposed Bridge Location

100-yrs Probability Rainfall Intensity

Bridge No.	Chainage	Bridge (River) Name	Catchment Area (km^2)	100-yrs Probable Dairy Rainfall: R_{24} (mm/day)	100-years Probable Rainfall Intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3													Remarks
				24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	It= $A/t^{2/3}$	
				1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10		
1	km16	Khahare Khola	5.72	178.94	7.5	11.8	15.5	18.8	29.8	39.1	47.3	62.0	75.2	98.5	129.0	204.8	A= 62.035	
2	km27	Jhayalla Khola	13.94	190.17	7.9	12.6	16.5	20.0	31.7	41.5	50.3	65.9	79.9	104.7	137.1	217.7	A= 65.927	
3	km31	Ghatte Khola	7.43	188.86	7.9	12.5	16.4	19.8	31.5	41.2	50.0	65.5	79.3	103.9	136.2	216.2	A= 65.474	
4	km37	Rungrung Khola	34.43	171.27	7.1	11.3	14.8	18.0	28.5	37.4	45.3	59.4	71.9	94.3	123.5	196.1	A= 59.377	
5	km29	Daraudi Khola	214.5	184.26	7.7	12.2	16.0	19.3	30.7	40.2	48.7	63.9	77.4	101.4	132.9	210.9	A= 63.880	
-	km16	Daraudi Khola	347.9	185.09	7.7	12.2	16.0	19.4	30.8	40.4	49.0	64.2	77.7	101.9	133.5	211.9	A= 64.167	

50-yrs Probability Rainfall Intensity

Bridge No.	Chainage	Bridge (River) Name	Catchment Area (km^2)	50-yrs Probable Dairy Rainfall: R_{24} (mm/day)	50-years Probable Rainfall Intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3													Remarks
				24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	It= $A/t^{2/3}$	
				1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10		
1	km16	Khahare Khola	5.72	170.73	7.1	11.3	14.8	17.9	28.5	37.3	45.2	59.2	71.7	94.0	123.1	195.4	A= 59.188	
2	km27	Jhayalla Khola	13.94	183.56	7.6	12.1	15.9	19.3	30.6	40.1	48.6	63.6	77.1	101.0	132.4	210.1	A= 63.637	
3	km31	Ghatte Khola	7.43	181.99	7.6	12.0	15.8	19.1	30.3	39.7	48.1	63.1	76.4	100.2	131.2	208.3	A= 63.094	
4	km37	Rungrung Khola	34.43	162.77	6.8	10.8	14.1	17.1	27.1	35.5	43.1	56.4	68.4	89.6	117.4	186.3	A= 56.430	
5	km29	Daraudi Khola	214.5	176.45	7.4	11.7	15.3	18.5	29.4	38.5	46.7	61.2	74.1	97.1	127.2	202.0	A= 61.170	
-	km16	Daraudi Khola	347.9	177.81	7.4	11.8	15.4	18.7	29.6	38.8	47.0	61.6	74.7	97.9	128.2	203.5	A= 61.644	

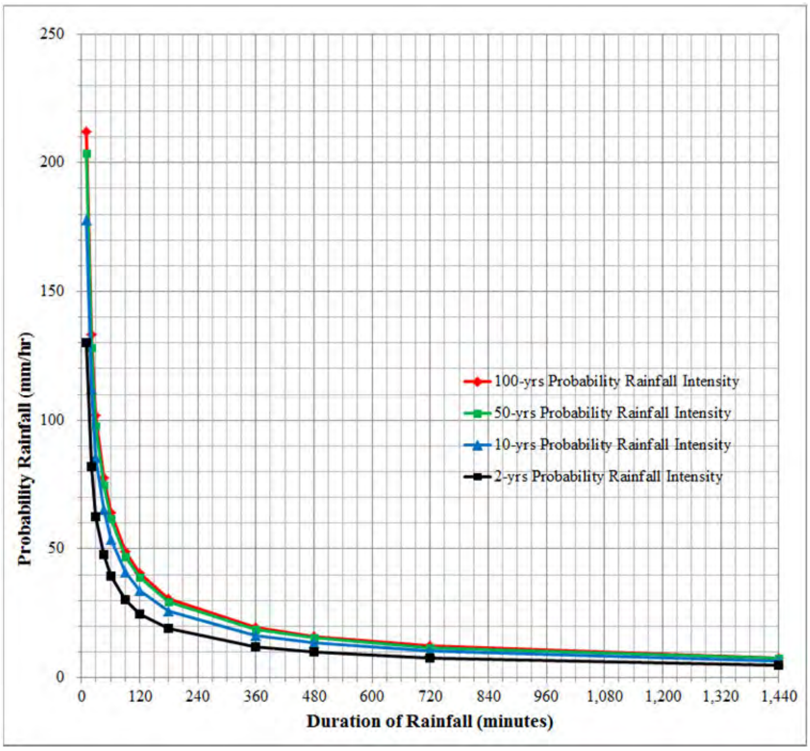
10-yrs Probability Rainfall Intensity

Bridge No.	Chainage	Bridge (River) Name	Catchment Area (km^2)	10-yrs Probable Dairy Rainfall: R_{24} (mm/day)	10-years Probable Rainfall Intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3													Remarks
				24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	It= $A/t^{2/3}$	
				1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10		
1	km16	Khahare Khola	5.72	147.36	6.1	9.7	12.8	15.5	24.6	32.2	39.0	51.1	61.9	81.1	106.3	168.7	A= 51.088	
2	km27	Jhayalla Khola	13.94	162.61	6.8	10.8	14.1	17.1	27.1	35.5	43.0	56.4	68.3	89.5	117.3	186.1	A= 56.374	
3	km31	Ghatte Khola	7.43	160.27	6.7	10.6	13.9	16.8	26.7	35.0	42.4	55.6	67.3	88.2	115.6	183.5	A= 55.561	
4	km37	Rungrung Khola	34.43	138.95	5.8	9.2	12.0	14.6	23.2	30.3	36.8	48.2	58.4	76.5	100.2	159.1	A= 48.172	
5	km29	Daraudi Khola	214.5	152.20	6.3	10.1	13.2	16.0	25.4	33.2	40.3	52.8	63.9	83.8	109.8	174.2	A= 52.766	
-	km16	Daraudi Khola	347.9	155.40	6.5	10.3	13.5	16.3	25.9	33.9	41.1	53.9	65.3	85.5	112.1	177.9	A= 53.874	

2-yrs Probability Rainfall Intensity

Bridge No.	Chainage	Bridge (River) Name	Catchment Area (km^2)	2-yrs Probable Dairy Rainfall: R_{24} (mm/day)	2-years Probable Rainfall Intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3													Remarks
				24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	It= $A/t^{2/3}$	
				1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10		
1	km16	Khahare Khola	5.72	108.33	4.5	7.2	9.4	11.4	18.1	23.7	28.7	37.6	45.5	59.6	78.1	124.0	A= 37.555	
2	km27	Jhayalla Khola	13.94	121.67	5.1	8.0	10.5	12.8	20.3	26.6	32.2	42.2	51.1	67.0	87.7	139.3	A= 42.180	
3	km31	Ghatte Khola	7.43	118.26	4.9	7.8	10.2	12.4	19.7	25.8	31.3	41.0	49.7	65.1	85.3	135.4	A= 41.000	
4	km37	Rungrung Khola	34.43	100.94	4.2	6.7	8.7	10.6	16.8	22.0	26.7	35.0	42.4	55.6	72.8	115.6	A= 34.995	
5	km29	Daraudi Khola	214.5	107.39	4.5	7.1	9.3	11.3	17.9	23.5	28.4	37.2	45.1	59.1	77.4	122.9	A= 37.232	
-	km16	Daraudi Khola	347.9	113.79	4.7	7.5	9.9	11.9	19.0	24.9	30.1	39.4	47.8	62.6	82.1	130.3	A= 39.449	

Source: JICA Project Team based on DHM data



Source: JICA Project Team

Figure 9.4.11 Intensity Duration Frequency (IDF) Curve of Whole Catchment Area

(2) Topographical Condition

In order to ensure the required accuracy in topographic surveys in the vicinity of the target bridges a topographic survey was performed. Using this survey, topographical conditions of the project site have been accurately grasped to determine the structure and scale of the facility design and construction planning.

Topographical surveys for 5 bridge sites were carried out for:

- Khahare Khola Bridge
- Jhyalla Khola Bridge
- Ghatte Khola Bridge
- Rangrung Khola Bridge
- Daraudi River Bridge

Table 9.4.8 to Table 9.4.12 shows the summary of the topographic survey and Figure 9.4.12 to Figure 9.4.16 represents the topographic map of the 5 bridges.

Table 9.4.8 Topographic Survey Summary for Khahare Khola Bridge

Items	Summary	Unit	Quantity
Topographic Survey	Total area of Topographical Surveying (Basically covers terrain up to 500 m upstream, 200 m downstream and 200 m from the river banks on either side of the river banks)	m^2	274,040
River Survey	Cross Section (Covering 200 m beyond HFL lines from about 500 m upstream to about 200m downstream at 50m intervals)	m	5,325
	- River Profile (500m u/s and 200 m d/s from the proposed bridge axis)	m	750
Road Survey	Road Profile (total length of approach road plus 100m before beginning point and 100 m after the ending point of approach road)	m	477
	- Cross Section (at an interval of 20 m covering 15 m on either side of centre line of the road throughout the road)	m	715

Source: JICA Project Team

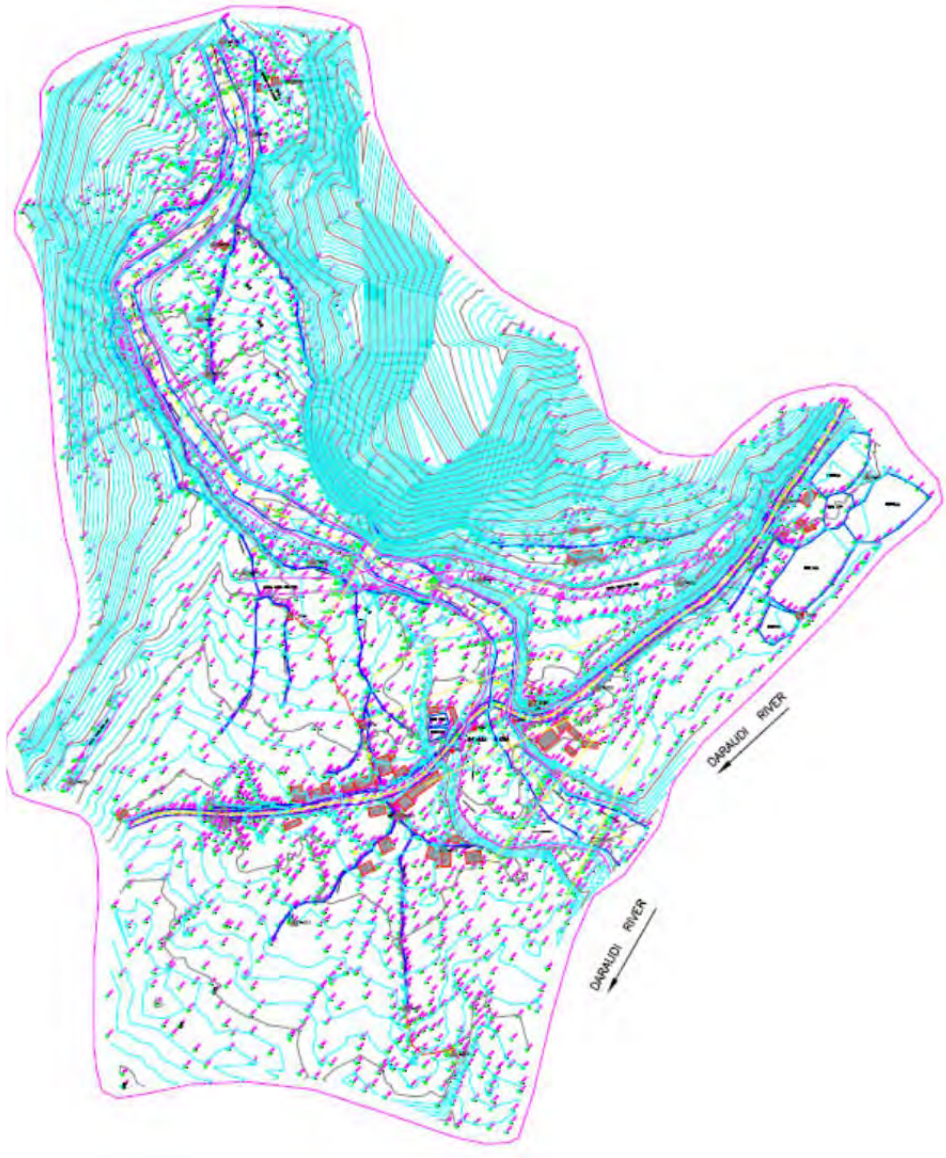
Source: JICA Project Team

Figure 9.4.12 Topographic Map for Khahare Khola Bridge Site

Table 9.4.9 Topographic Survey Summary for Jhyalla Khola Bridge

Items	Summary	Unit	Quantity
Topographic Survey	Total area of Topographical Surveying (Basically covers terrain up to 500 m upstream, 200 m downstream and 200 m from the river banks on either side of the river banks)	m^2	253,450
River Survey	Cross Section (Covering 200 m beyond HFL lines from about 500 m upstream to about 200m downstream at 50m intervals)	m	4,940
	- River Profile (500m u/s and 200 m d/s from the proposed bridge axis)	m	685
Road Survey	Road Profile (total length of approach road plus 100m before beginning point and 100 m after the ending point of approach road)	m	542
	- Cross Section (at an interval of 20 m covering 15 m on either side of centre line of the road throughout the road)	m	813

Source: JICA Project Team



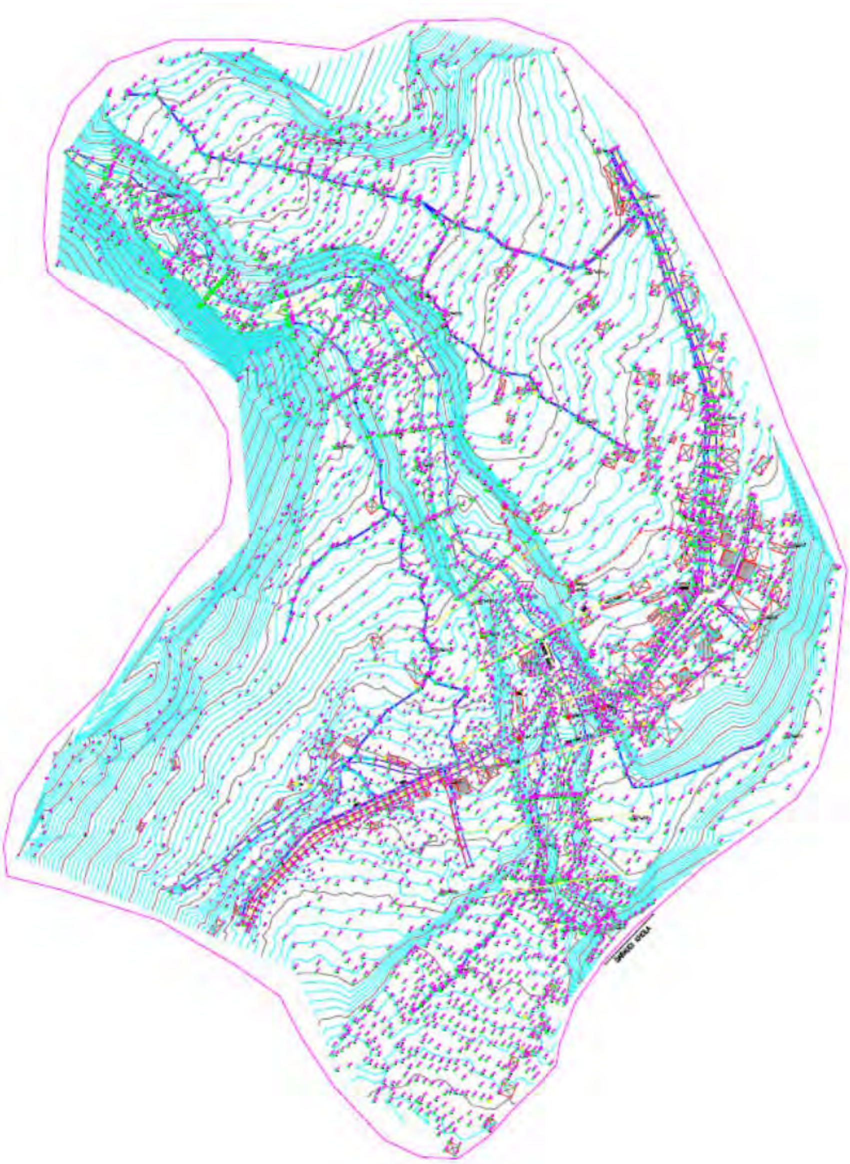
Source: JICA Project Team

Figure 9.4.13 Topographic Map for Jhyalla Khola Bridge Site

Table 9.4.10 Topographic Survey Summary for Ghatte Khola Bridge

Items	Summary	Unit	Quantity
Topographic Survey	Total area of Topographical Surveying (Basically covers terrain up to 500 m upstream, 200 m downstream and 200 m from the river banks on either side of the river banks)	m^2	210,880
River Survey	Cross Section (Covering 200 m beyond HFL lines from about 500 m upstream to about 200m downstream at 50m intervals)	m	5,600
	- River Profile (500m u/s and 200 m d/s from the proposed bridge axis)	m	695
Road Survey	Road Profile (total length of approach road plus 100m before beginning point and 100 m after the ending point of the approach road)	m	659
	- Cross Section (at an interval of 20 m covering 15 m on either side of the centre line of the road throughout the road)	m	989

Source: JICA Project Team



Source: JICA Project Team

Figure 9.4.14 Topographic Map for Ghatte Khola Bridge Site

Table 9.4.11 Topographic Survey Summary for Rangrung Khola Bridge

Items	Summary	Unit	Quantity
Topographic Survey	Total area of Topographical Surveying (Basically covers terrain up to 500 m upstream, 200 m downstream and 200 m from the river banks on either side of the river banks)	m^2	195,000
River Survey	Cross Section (Covering 200 m beyond HFL lines for about 500 m upstream to about 200m downstream at 50m intervals)	m	5,625
	- River Profile (500m u/s and 200 m d/s from the proposed bridge axis)	m	660
Road Survey	Road Profile (total length of approach road plus 100m before beginning point and 100 m after the ending point of the approach road)	m	1,492
	- Cross Section (at an interval of 20 m covering 15 m on either side of the centre line of the road throughout the road)	m	995

Source: JICA Project Team

Source: JICA Project Team

Figure 9.4.15 Topographic Map for Rangrung Khola Bridge Site

Table 9.4.12 Topographic Survey Summary for Daraudi Khola Bridge

Items	Summary	Unit	Quantity
Topographic Survey	Total area of Topographical Surveying (Basically covers terrain up to 500 m upstream, 200 m downstream and 200 m from the river banks on either sides of the river banks)	m^2	331,850
River Survey	Cross Section (Covering 200 m beyond HFL lines from about 500 m upstream to about 200m downstream at 50m intervals)	m	5,850
	- River Profile (500m u/s and 200 m d/s from the proposed bridge axis)	m	786
Road Survey	Road Profile (total length of the approach road plus 100m before the beginning point and 100 m after the ending point of the approach road)	m	2,700
	- Cross Section (at an interval of 20 m covering 15 m on either side of the centre line of the road throughout the road)	m	4,051

Source: JICA Project Team

Source: JICA Project Team

Figure 9.4.16 Topographic Map for Daraudi Khola Bridge Site

(3) Geological Condition

1) Investigation Summary

In order to understand the soil composition, condition and profile, drilling surveys were carried out in the proposed abutment/pier locations. In total 15 bore holes were drilled in all the 5 bridge sites for an average of 3 per site.

Table 9.4.13 Survey Summary for Khahare Khola Bridge

Item	Location	Quantity
Boring	Right Bank Left Bank	Surface Soil: 1m Gravel Layer: 15m Gravel Layer: 10m
Standard Penetration Test	Right Bank Left Bank	6 Number 9 Number
Laboratory Test for soil	Right Bank Left Bank	1 Sample 1 Sample
Laboratory Test for Rock	Right Bank Left Bank	2 Sample 2 Sample

Source: JICA Project Team

Table 9.4.14 Survey Summary for Jhyalla Khola Bridge

Item	Location	Quantity
Boring	Right Bank (Far from river shoreline) Right Bank (in river) Left Bank	Surface Soil: 1m Gravel Layer: 4.5m Rock Layer:9.5m Gravel Layer: 7.5m Rock Layer: 9.5m Surface Soil: 1m Gravel Layer: 7m Rock Layer: 7m
Standard Penetration Test	Right Bank (Far from river shoreline) Right Bank (in river) Left Bank	5 Number 8 Number 8 Number
Laboratory Test for Soil	Right Bank (Far from river shoreline) Right Bank (in river) Left Bank	1 Sample 2 Sample 2 Sample
Laboratory Test for Rock	Right Bank (Far from river shoreline) Right Bank (in river) Left Bank	1 Sample - 2 Sample

Source: JICA Project Team

Table 9.4.15 Survey Summary for Ghatte Khola Bridge

Item	Location	Quantity
Boring	Right Bank In River Left Bank	Gravel Layer: 15m Gravel Layer: 15m Gravel Layer: 15m
Standard Penetration Test	Right Bank In River Left Bank	11 Number 11 Number 11 Number
Laboratory Test for Soil	Right Bank In River Left Bank	1 Sample 2 Sample -
Laboratory Test for Rock	Right Bank In River Left Bank	- 2 Sample -

Source: JICA Project Team

Table 9.4.16 Survey Summary for Rungrung Khola Bridge

Item	Location	Quantity
Boring	Left Bank Left Bank (in river) Right Bank	Surface Soil: 1m Gravel Layer: 5m Rock Layer: 9m Surface Soli: 1m Gravel Layer: 7.5m Rock Layer: 6.5m Gravel Layer: 15m
Standard Penetration Test	Left Bank Left Bank (in river) Right Bank	11 Number 11 Number 11 Number
Laboratory Test for Soil	Left Bank Left Bank (in river) Right Bank	1 Sample - 1 Sample
Laboratory Test for Rock	Left Bank Left Bank (in river) Right Bank	1 Sample 2 Sample 1 Sample

Source: JICA Project Team

Table 9.4.17 Survey Summary for Daraudi Khola Bridge

Item	Location	Quantity
Boring	Right Bank at Hill	Surface Soil: 1.5m Gravel Layer: 13.5m
	Right Bank at River	Gravel Layer: 15m
	Left Bank at River	Gravel Layer: 15m
	Left Bank at Hill	Gravel Layer: 9.5m Rock Layer: 5.5m
Standard Penetration Test	Right Bank at Hill	9 Number
	Right Bank at River	11 Number
	Left Bank at River	11 Number
	Left Bank at Hill	11 Number
Laboratory Test for Soil	Right Bank at Hill	-
	Right Bank at River	-
	Left Bank at River	1 Sample
	Left Bank at Hill	-
Laboratory Test for Rock	Right Bank at Hill	1 Sample
	Right Bank at River	1 Sample
	Left Bank at River	-
	Left Bank at Hill	-

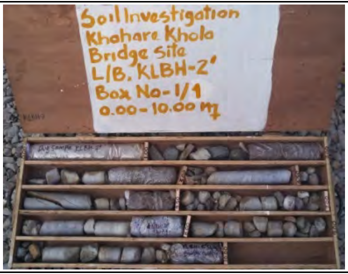
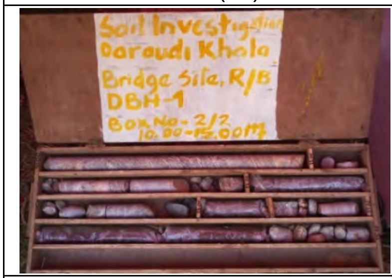
Source: JICA Project Team

2) Site Photographs

Photographs taken during the geological investigation are shown below, and, photographs for core samples are shown following.

Source: JICA Project Team

Figure 9.4.17 Photographs of the Site Survey

KLBH-1	KLBH 2	JBH 1
		
JBH 1	JBH 2 (1/2)	JBH 2 (2/2)
		
JBH 3 (1/2)	JBH 3 (2/2)	DBH 1 (1/2)
		
DHB 1 (2/2)	DBH 2 (1/2)	DBH (2/2)
		
DBH 3 (1/2)	DBH 3 (2/2)	DBH 4 (1/2)
		

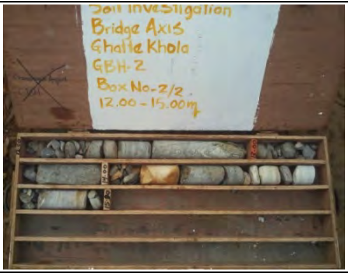
DBH 4 (2/2)

GBH 1 (1/2)

GBH 1 (2/2)

GBH 2 (1/2)

GBH 2 (2/2)



GBH 3 (1/2)

GBH 3 (2/2)

RBH 1 (1/2)

RBH 1 (2/2)

RBH 2 (1/2)

RBH 2 (2/2)

RBH 3 (1/2)

RBH 3 (2/2)

Source: JICA Project Team

Figure 9.4.18 Collected Core-samples

(4) Hydrology

1) Hydraulic Design Criteria

a) Hydraulic Design Criteria

In the "Nepal Bridge Standards -2067", it is described that all permanent bridges shall be designed for a discharge of 100 years return-period. Therefore, the 100 years return-period is applied.

b) Design Freeboard and Clearance

In the same way as above, the design minimum freeboard with the bottom of superstructure is applied from Nepal standards. (See Table 9.4.18.)

Table 9.4.18 Design Minimum Freeboard for Bridges

Discharge m^3/sec	Minimum Free board, mm
Less than 200	1000
201-500	1200
501-2000	1500
2001-5000	2000
5000 and above	More than 2000 (depending on the reliability of the available data for the calculation of discharge)

Source: Nepal Bridge Standards-2067 (Ministry of Physical Planning and Works, Nepal)

c) Design Criteria of Bridge Hydraulics

The size of the flood opening is determined by the magnitude of the design discharge. In order to design the opening for the bridge waterway, the following design criteria for hydraulics must be met.

- The backwater does not significantly increase the flood damage to properties upstream of the bridge.
- The velocity through the bridge does not damage the road facility or increase the damages to downstream properties.
- The existing flow distribution is maintained to the greatest extent practicable.
- The pier and abutment are designed to minimize the flow disruption.
- Potential local scour is within acceptable limits.
- Clearance at the structure is adequately designed to safely pass any anticipated debris.

In this study, the design standards are based on the HEC series of FHWA, which are highly recognized international standards.

2) River and Characteristics of River Flow

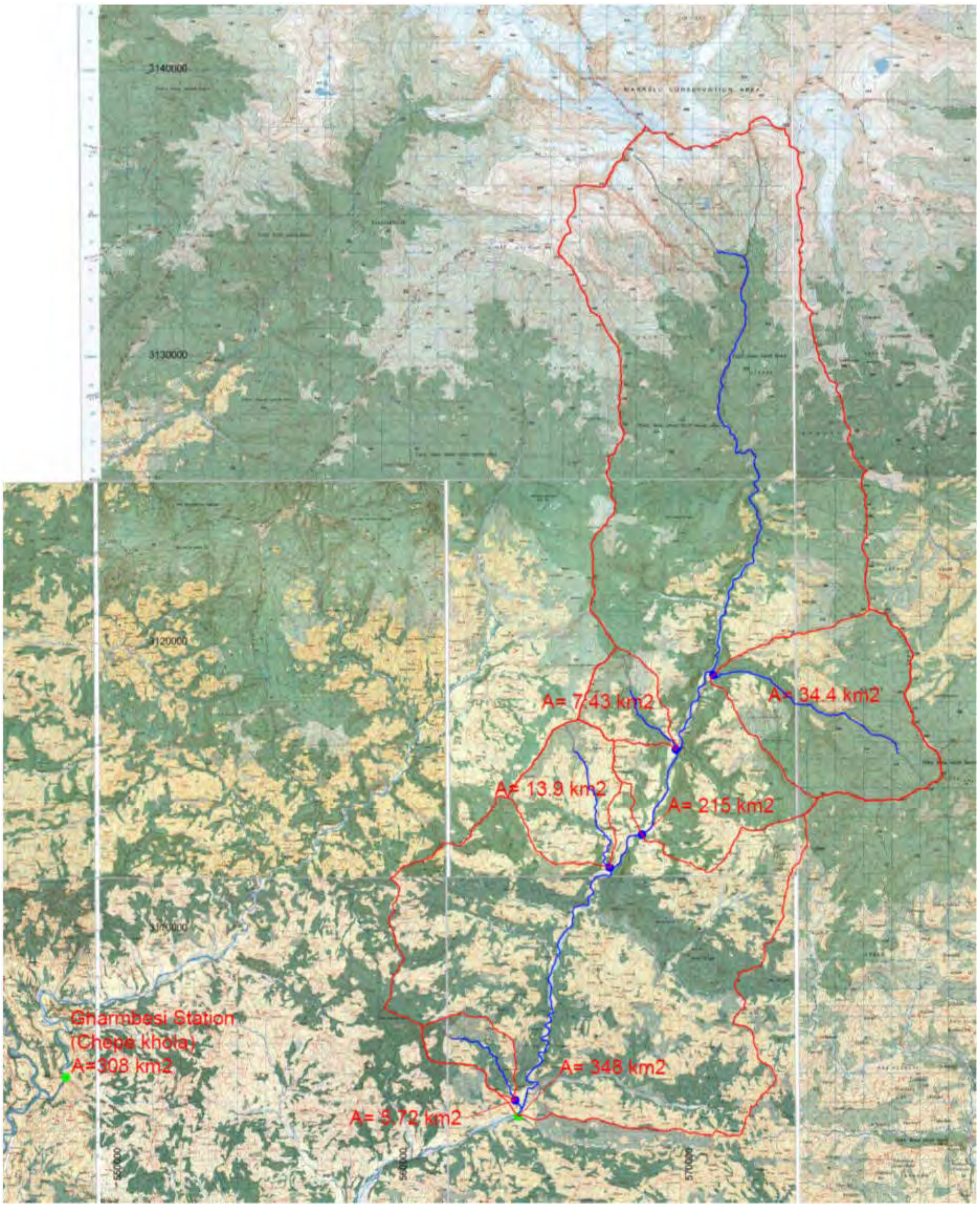
a) Targeted Rivers

The proposed 5 bridges in the study area are planned in the Daraudi River and its tributaries.

The Daraudi River (Khola) basin is a sub-basin of Narayani (also known as the Gandaki in India) Riverine system. It is located in the western development region of the country and passes through the Gandaki district. The Daraudi River originates from the south of Mountain massif Manaslu, flows southward through the Daraudi valley, and merges into the lower reaches of the Marsyangdi, 8 km above its confluence with the Trishuli. The total length of the river is about 60 km and its catchment area is bordered to the east by the Budhigandaki and to the west with that of Chepe, another tributary of the Marsyangdi.

The catchment areas that are related to the proposed 5 bridges are shown in Figure 9.4.19, and the catchment basin for the Daraudi mainstream at a point just downstream of the Khahare Bridge - No.1 is 347.9 km^2. Although there is no hydrological gauging station in this Daraudi basin, the Garambesi Station - ID 440, in the adjoining Chepe River basin has been operating under the DHM from 1964.

Chepe River is a tributary of the same Marsyangdi River. It originates south of Mt. Manaslu and the river flows in a southerly direction. A significant part of the Chepe river basin lies below 3000 m. The total catchment area is 308 km^2, and the total length of the river from its origin to the gauging station at Garambesi is 32 km. At the gauging station, the water levels have been recorded and discharges measured regularly, hence daily as well as average monthly flow data is available. The hydrological data of the Garambesi Station will be collected in order to carry out the comparative verification of the flow characteristics with the Daraudi River.



Source: JICA Project Team

Figure 9.4.19 Catchment Area Map of Target Rivers

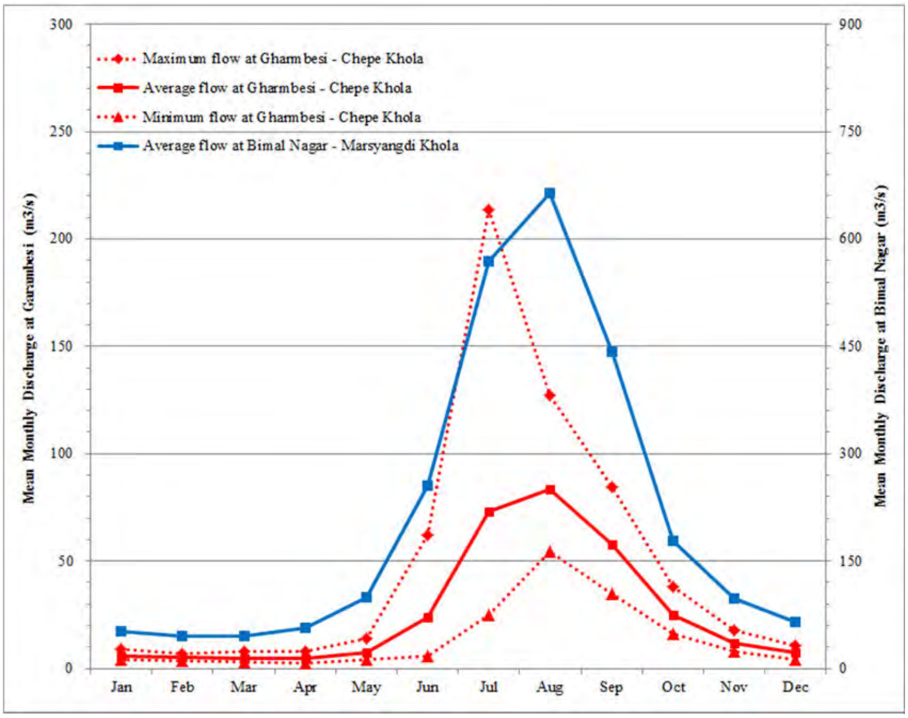
b) River Characteristics

<u>Chepe River Flow Characteristics</u>

- Monthly / Daily Flow Pattern

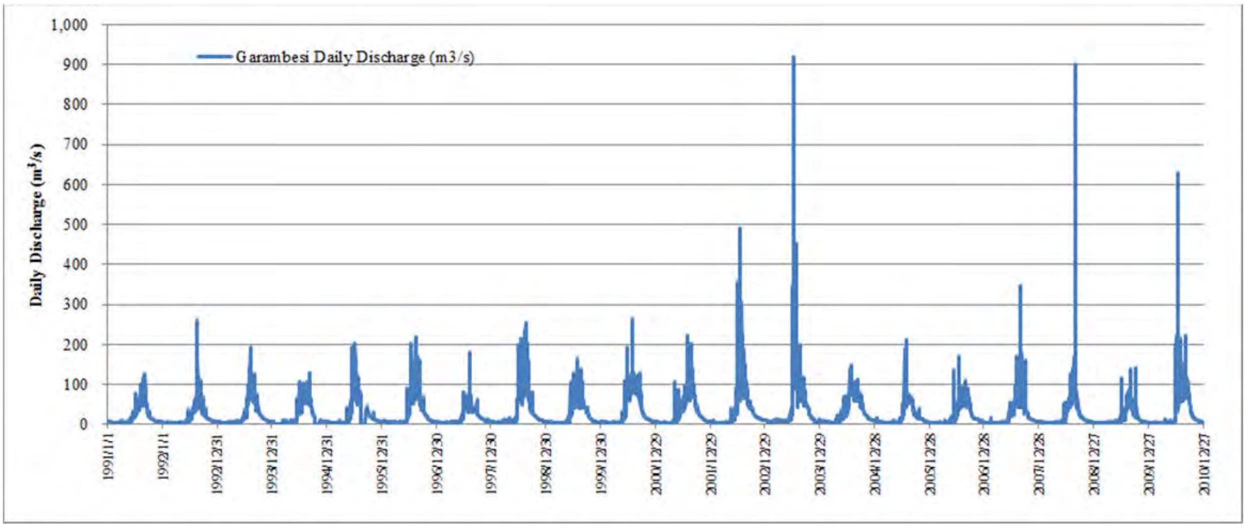
The mean monthly flow pattern from the data of the most recent 20 years at Garambesi and Bimalnagar gauging stations are shown in Figure 9.4.20. Also, the long-term fluctuations for daily discharge at the stations are shown in Figure 9.4.21 and Figure 9.4.22.

The maximum instantaneous discharge occurs in June to September, and maximum extreme discharge among them is recorded as 1,040 m^3/s (Aug 2008) at the Garambesi Station and 2,520 m^3/s (Jun 2000) at the Bimalnagar Station.



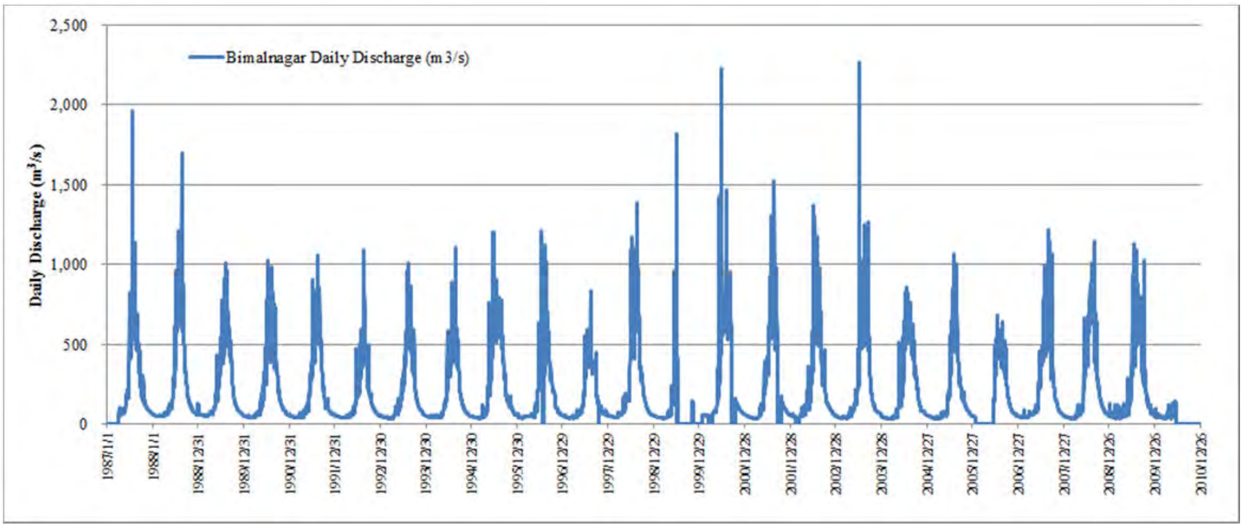
Source: JICA Project Team based on DHM data

Figure 9.4.20 Mean Monthly Flow Pattern at Garambesi and Bimalnagar Stations during 1991-2010



Source: JICA Project Team based on DHM data

Figure 9.4.21 Long-term Fluctuation of Daily Mean Discharge at Garambesi during 1991-2010



Source: JICA Project Team based on DHM data

Figure 9.4.22 Long-term Fluctuation of Daily Mean Discharge at Bimalnagar during 1987-2010

- Flow Regime

The discharge-duration curve is examined in order to understand the potential surface water characteristics of the river through the year. The flow regime shows the annual flow condition using the daily discharge at each hydrological station, and is indicated by the daily discharge and the number of exceeding days. The annual flow regime is defined as follows;

- High discharge (95th daily discharge from the greatest)
- Normal Discharge (185th daily discharge from the greatest)
- Low Discharge (275th daily discharge from the greatest)
- Drought Discharge (355th daily discharge from the greatest)

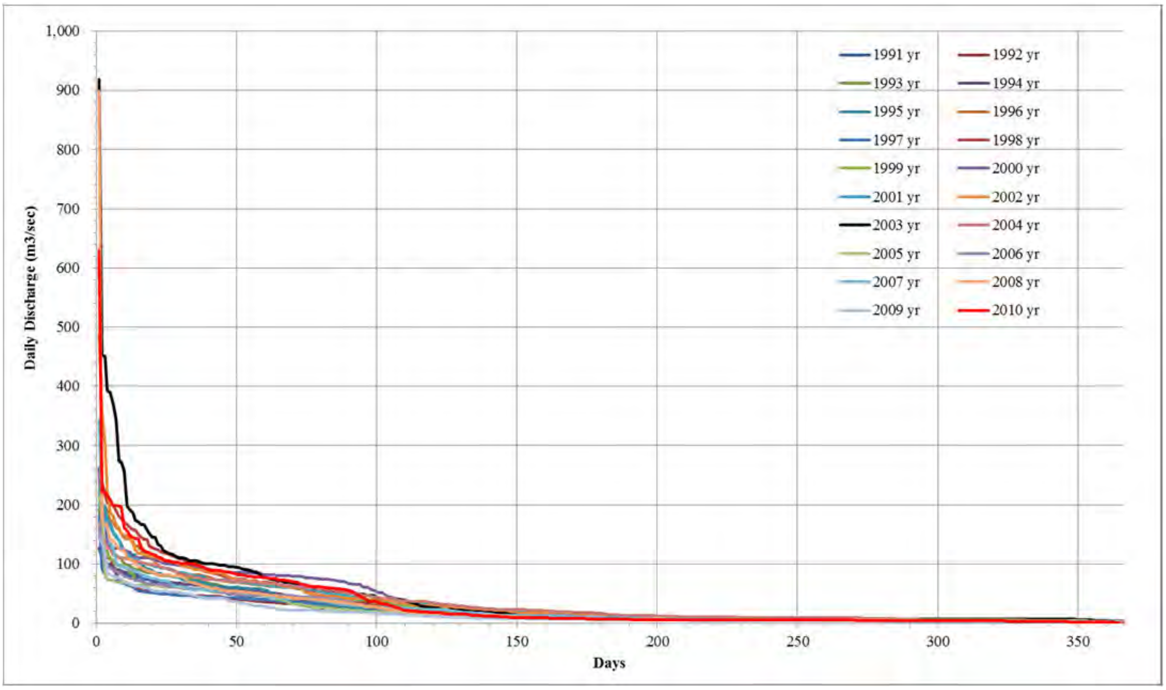
The coefficient of a river regime is the ratio of the minimum flow and the maximum flow rate at an optional point of the river, and shows the stability of the river flow quantitatively. The magnitude of the coefficient of the river regime indicates that the flow fluctuation is large, and if it is large, it indicates that full year water intake is difficult to achieve and flood damage can easily occur.

The flow regime which was calculated at Garambesi - Chepe River, and Bimalnagar - Marsandi River stations during 20 years more, is summarized in Table 9.4.19 - Table 9.4.20 and Figure 9.4.23 - Figure 9.4.24. The Chepe River is a steep river, which is the same as the Daraudi River, and the coefficient of the river regime is high. On the other hand, the coefficient of the Bimalnagar Station which is located in the midstream of the Marsandi River is lower, compared with the Garambesi Station of the Chepe River.

Table 9.4.19 Discharge Rates at Garambesi Station (Chepe River)

Year	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
1991	127.00	24.20	7.06	5.06	4.06	3.80	33.42	
1992	260.00	20.90	7.40	4.06	2.55	2.22	117.12	
1993	194.00	25.00	8.40	4.81	3.80	3.30	58.79	
1994	128.00	30.30	7.06	4.81	-	-	-	89days missing
1995	201.00	24.20	7.73	4.56	-	-	-	31days missing
1996	217.00	41.00	7.74	5.67	4.36	4.14	52.42	
1997	180.00	27.90	8.60	4.90	3.59	3.15	57.14	
1998	255.00	35.00	9.04	6.21	4.57	4.25	60.00	
1999	164.00	39.40	6.87	4.57	3.37	3.15	52.06	
2000	263.00	62.00	10.80	5.56	4.57	4.57	57.55	
2001	223.00	40.70	10.80	5.56	1.37	1.37	162.77	
2002	490.00	41.30	12.80	5.23	3.44	2.26	216.81	
2003	**919.00**	48.80	9.47	7.40	5.23	3.06	300.33	
2004	148.00	47.30	14.40	8.52	2.79	2.79	53.05	
2005	213.00	20.50	8.14	5.16	3.84	3.06	69.61	
2006	172.00	28.90	9.13	4.37	1.87	1.87	91.98	
2007	345.00	29.20	8.38	4.20	3.51	3.28	105.18	
2008	899.00	30.10	7.54	5.14	3.08	2.57	349.81	1day missing
2009	143.00	17.90	5.92	4.10	2.74	2.40	59.58	
2010	629.00	43.20	6.63	4.79	1.84	**1.28**	491.41	
Average	308.50	33.89	8.70	5.23	3.37	2.92	105.73	
Maximum	919.00	62.00	14.40	8.52	5.23	4.57	491.41	
Minimum	127.00	17.90	5.92	4.06	1.37	1.28	33.42	

Source: JICA Project Team based on DHM data



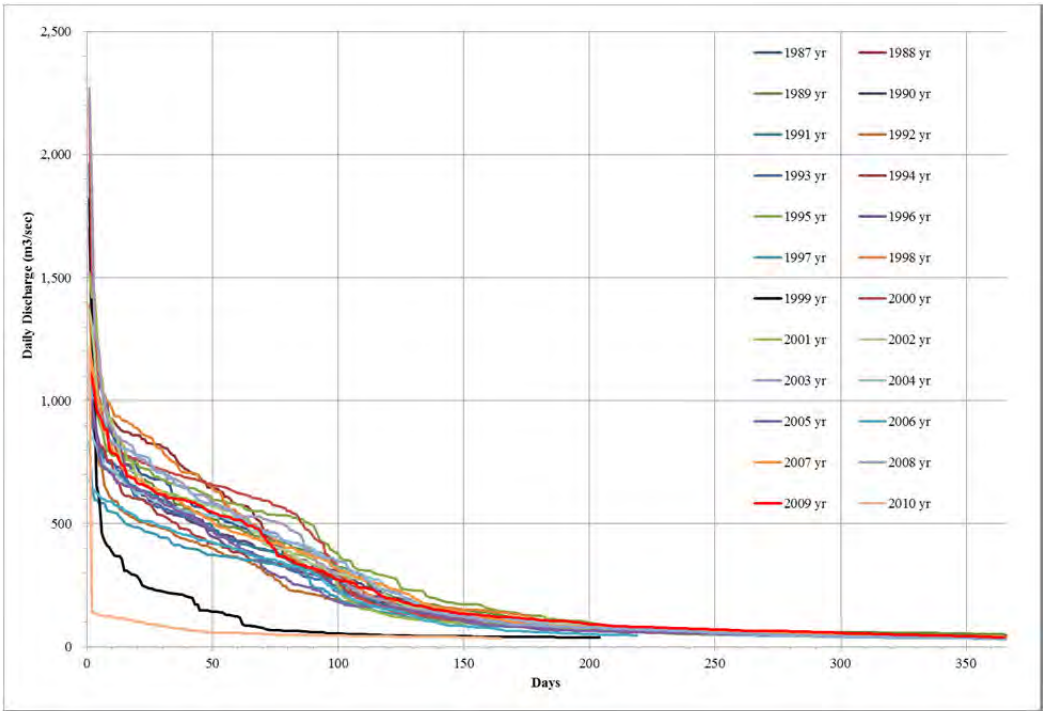
Source: JICA Project Team based on DHM data

Figure 9.4.23 Discharge Duration Curve at Garambesi Station (Chepe River)

Table 9.4.20 Discharge Rates at Bimalnagar Station (Marsyangdi River)

Year	Annual Maximum Discharge	Plentiful Discharge	Ordinary Discharge	Low Discharge	Drought Discharge	Annual Minimum Discharge	Coefficient of River Rregime	Remarks
	1-day	95-day	185-day	275-day	355-day	365-day	Max/Min	
1987	1960.00	280.00	96.00	51.70	-	-	-	89days missing
1988	1700.00	302.00	93.70	62.00	47.90	46.30	36.72	
1989	1010.00	367.00	102.00	62.00	51.70	50.20	20.12	
1990	1030.00	320.00	96.00	52.60	41.20	39.00	26.41	
1991	1060.00	288.00	87.90	50.90	40.50	39.70	26.70	
1992	1090.00	197.00	74.40	50.70	42.60	40.70	26.78	
1993	1010.00	269.00	86.90	47.90	36.30	34.40	29.36	
1994	1110.00	291.00	73.40	47.90	39.00	38.30	28.98	
1995	1200.00	419.00	114.00	47.90	38.30	36.90	32.52	
1996	1210.00	272.00	68.90	49.90	-	-	-	13days missing
1997	832.00	226.00	73.00	47.20	38.30	-	-	4days missing
1998	1390.00	307.00	99.80	55.60	43.30	42.10	33.02	
1999	1820.00	57.90	39.70	-	-	-	-	161days missing
2000	2230.00	380.00	76.60	52.40	-	-	-	88days missing
2001	1520.00	316.00	78.70	44.30	-	-	-	30days missing
2002	1370.00	314.00	99.30	56.10	-	-	-	30days missing
2003	**2270.00**	325.00	90.40	49.60	40.00	37.50	60.53	
2004	855.00	364.00	89.80	44.10	33.70	**30.40**	28.13	
2005	1070.00	207.00	71.70	49.00	35.90	34.90	30.66	
2006	679.00	261.00	56.60	-	-	-	-	146days missing
2007	1220.00	352.00	85.20	56.90	42.30	39.20	31.12	
2008	1150.00	361.00	83.60	48.90	37.00	35.30	32.58	
2009	1130.00	305.00	106.00	63.80	42.00	37.30	30.29	
2010	1220.00	46.10	-	-	-	-	-	200days missing
Average	1297.33	284.46	84.50	51.97	40.63	38.81	31.59	
Maximum	2270.00	419.00	114.00	63.80	51.70	50.20	60.53	
Minimum	679.00	46.10	39.70	44.10	33.70	30.40	20.12	

Source: JICA Project Team based on DHM data

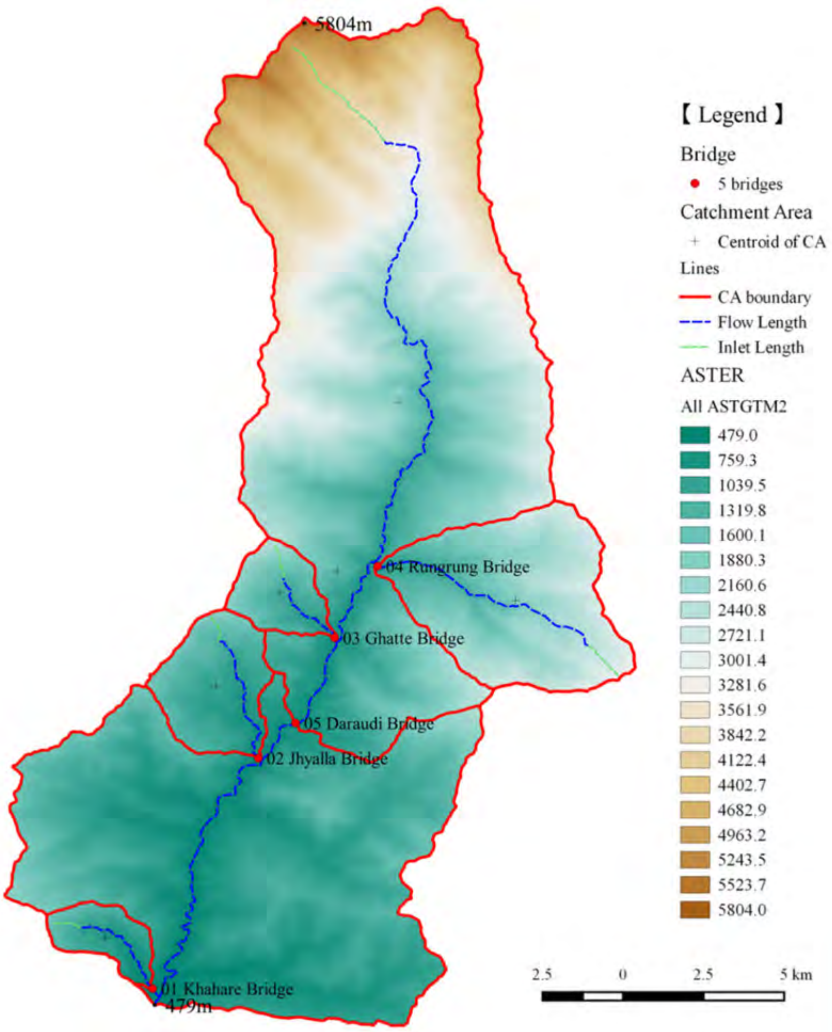


Source: JICA Project Team based on DHM data

Figure 9.4.24 Discharge Duration Curve at Bimalnagar Station (Marsyangdi River)

Daraudi River Morphology

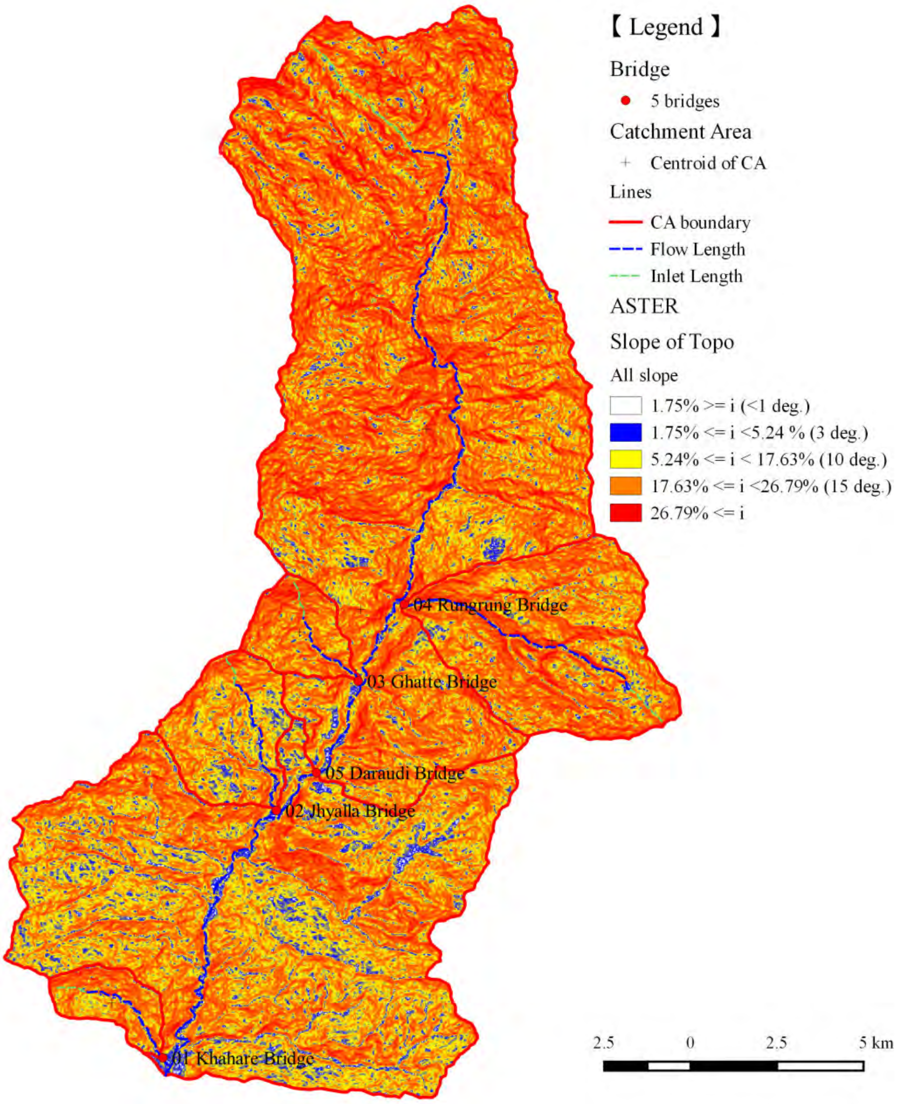
The elevation distribution map for the study area in the Daraudi Khola is shown in Figure 9.4.25. The targeted Daraudi River originates at an elevation of 5,804 m southerly of Mt. Manaslu, and the river flows to an elevation of 479 m in a southerly direction. The catchment area is classified as 30% for cultivated area, 22% for grassland and 48% for forestland in terms of the category of the land cover as indicated in Table 9.4.21 and Figure 9.4.27. These percentages are used for the estimation of runoff coefficients of the rational formula.



Source: JICA Project Team based on ASTER GDEM data (Advanced Space-borne Thermal Emission and Reflection radiometer - Global Digital Elevation Model, METI of Japan and NASA of USA)

Figure 9.4.25 Spatial Distribution of Elevations in the Daraudi Catchment Basin

Most of the catchment area is sloping land, and its slope is very high. The percentage of the area of each gradient is 0.1% for 1 degree or less, 1.1% for 1-3 degrees, 17% for 3-10 degrees, 29% for 10-15 degrees and 53% for 15 degrees or more as shown in Figure 9.4.26. According to the debris flow countermeasure guidelines of Japan, it is described that the debris flow will occur at sites higher than 15 degree slope and the sedimentation will start from about 10 degrees and will stop at up to 3 degrees. Debris flows occur in a variety of forms depending on the conditions of the site and the factors contributing to their occurrence. When classified by the contributing factors, debris flows are roughly divided into "Riverbed sediment movement", "Slope failure/Landslide", "Natural dam collapse" and "Volcanic activity" types. Except for the natural dam collapse type, all types of debris flows are primarily related to the short-term rainfall intensity. As described in these guidelines, it is estimated that the occurrence risk for debris flow of this study area is high, and there is the fear of degradation and river course shifting of rivers with high flow-velocity and its erosive action. Furthermore, at the proposed bridges except for the Daraudi Khola Bridge, since the slope of the stream bed is steeper than 3 degrees, it is estimated that the risk of debris-flow is high.



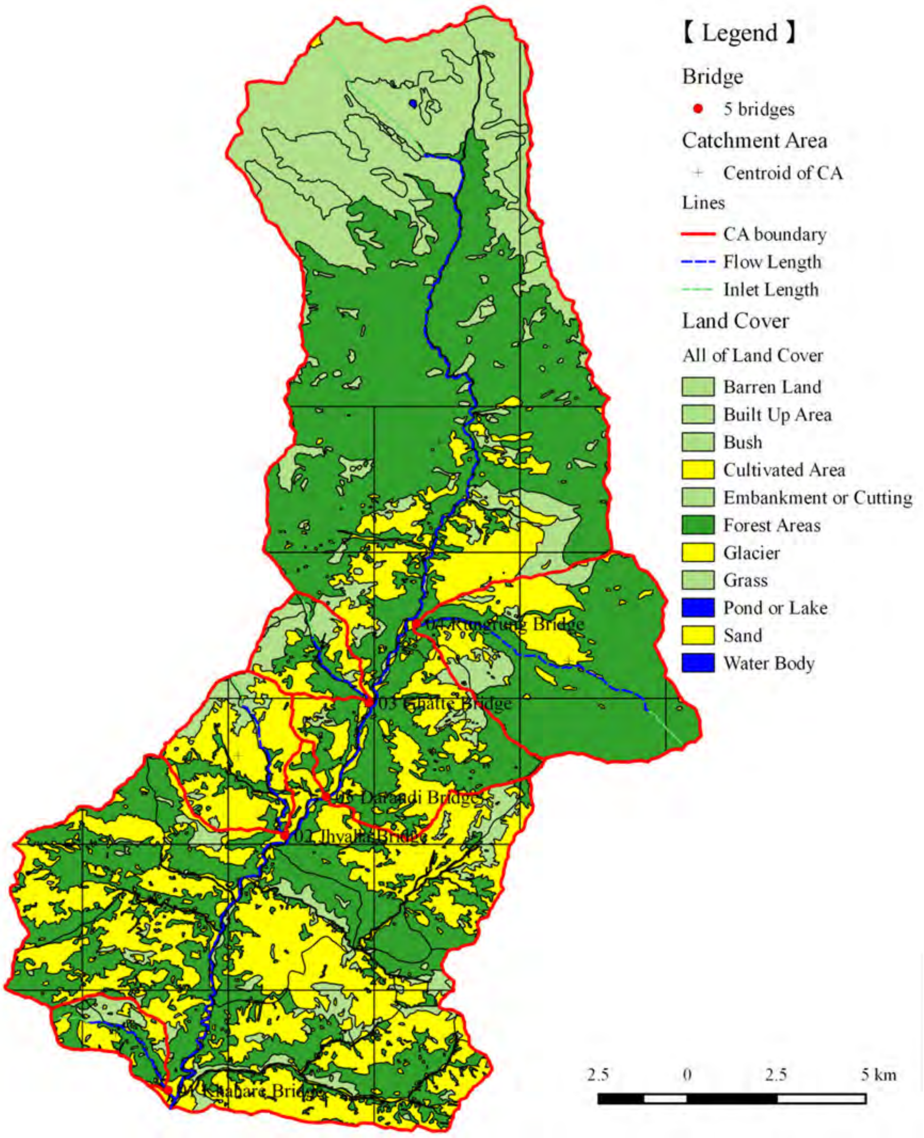
Source: JICA Project Team based on GIS data

Figure 9.4.26 Spatial Distribution of Slope of Daraudi Catchment Basin

Table 9.4.21 Land Cover Classifications of Catchment Areas of Each Proposed Bridge

Land Cover Classification		No.1 Khahare Khola			No.2 Jhayalla Khola			No.3 Ghatte Khola			No.4 Rungrung Khola			No.5 Daraudi Khola			Low Point of Daraudi Khola			Remarks
		Area (km^2)		(%)	Area (km^2)		(%)	Area (km^2)		(%)	Area (km^2)		(%)	Area (km^2)		(%)	Area (km^2)		(%)	
Cultivation	Cultivated Area	1.90	1.92	33.62%	9.38	9.49	68.07%	2.22	2.30	31.03%	6.72	6.80	19.76%	31.46	32.86	15.32%	98.79	102.17	29.37%	
	Glacier	0.00			0.00			0.00			0.00			0.09			0.09			
	Sand	0.02			0.11			0.08			0.08			1.31			3.30			
Grass, Barren	Barren Land	0.00	1.32	23.01%	0.00	2.28	16.33%	0.00	2.71	36.44%	0.03	2.69	7.82%	21.89	65.09	30.35%	21.90	78.13	22.46%	
	Built Up Area	0.00			0.00			0.00			0.00			0.00			0.00			
	Bush	1.30			2.25			1.80			2.52			9.74			22.05			
	Embankment or Cutting	0.00			0.00			0.01			0.00			0.54			0.64			
	Grass	0.01			0.03			0.89			0.15			32.92			33.54			
Forest	Forest Areas	2.48	2.48	43.37%	2.18	2.18	15.60%	2.42	2.42	32.53%	24.94	24.94	72.42%	116.24	116.24	54.20%	166.79	166.79	47.94%	
Water	Pond or Lake	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.04	0.27	0.13%	0.06	0.80	0.23%	
	Water Body	0.00			0.00			0.00			0.00			0.23			0.74			
	Total Area (km2)	5.72	5.72	100.0%	13.94	13.94	100.0%	7.43	7.43	100.0%	34.43	34.43	100.0%	214.5	214.5	100.0%	347.9	347.9	100.0%	

Source: JICA Project Team based on GIS data



Source: JICA Project Team based on GIS data

Figure 9.4.27 Spatial Distribution of Land Cover of Daraudi Catchment Basin

3) Estimation of Probability Floods

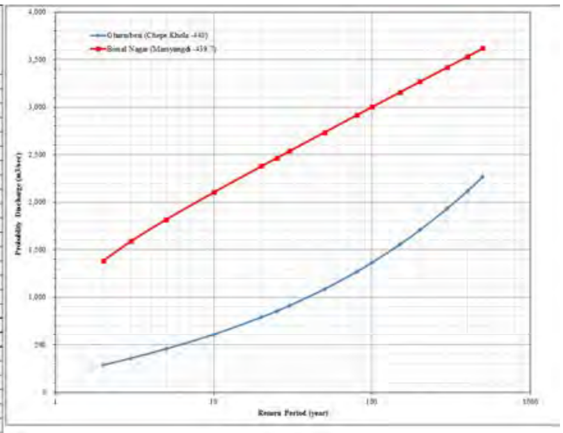
There are many methods and procedures for flood estimation in general. The theories for many methods have been developed by various institutions, and are either based on measured / statistical data or a deterministic basis or are empirical relationships. Except for the statistical method, the methods were "calibrated" for certain regions and flood events, and are limited in terms of the size of catchment areas on which they could be applied. In case of this study area, it is made up of mountainous areas, and therefore the flood prediction shall be considered using its own unique formulae which are applied in mountainous regions such as Nepal, in addition to the general flood prediction formulae.

a) Probability Floods at Gauging Stations by Statistical Data

If time series extreme discharge data are available at gauged basins, frequency analysis is the preferred method for computing design peak flood discharge. Although there is no hydrological gauging station in this study area, there is a gauging station in Garambesi - ID 440 in the Chepe River basin which is located next to the Daraudi River of the study area. The catchment areas of both rivers are nearly the same and they originate from the same Mt. Manaslu, and it can be expected that both flood characteristics are relatively similar.

In the same process used for the calculation of the probable rainfall, the probable discharges at gauging stations are calculated from annual maximum discharges / extreme values. The calculation result at Garambesi is shown in Figure 9.4.28, along with a result of Bimal-Nagar station for reference.

Station Name			Gharmbesi	Bimal Nagar	Remarks
River Name			Chepe Khola	Marsyangdi	
Station ID			440	439.7	
Long. (X)			84.4897	84.4300	
Lat. (Y)			28.0614	27.9500	
Catchment Area (km2)			308	N/A	
Data No. of Extreme Value			47	23	
Probable Discharge (m3/s)	(Year)	(%)			
	2	50%	287	1384	
	3	33.3%	359	1589	
	5	20%	457	1817	
	10	10%	608	2103	
	20	5.0%	789	2378	
	25	4.0%	854	2465	
	30	3.33%	911	2536	
	50	2.0%	1085	2734	
	80	1.25%	1289	2915	
	100	1.0%	1365	3001	
	150	0.667%	1556	3156	
	200	0.5%	1705	3266	
	300	0.333%	1936	3421	
	400	0.25%	2116	3531	
	500	0.2%	2266	3617	
Unit Probable Discharge (m3/s/km²)	(Year)	(%)			
	2	50%	0.9318	-	
	3	33.3%	1.1656	-	
	5	20%	1.4838	-	
	10	10%	1.9740	-	
	20	5.0%	2.5617	-	
	25	4.0%	2.7727	-	
	30	3.33%	2.9578	-	
	50	2.0%	3.5227	-	
	80	1.25%	4.1201	-	
	100	1.0%	4.4318	-	
	150	0.667%	5.0519	-	
	200	0.5%	5.5357	-	
	300	0.333%	6.2857	-	
	400	0.25%	6.8701	-	
	500	0.2%	7.3571	-	
X-COR(99%)			0.973	0.984	
P-COR(99%)			0.993	0.988	
SLSC(99%)			0.032	0.035	
Probabilistic Distributed model			Log Pearson type III distribution (Logarithmic space method)	Gumbel distribution	



Source: JICA Project Team

Figure 9.4.28 Calculation Results of Probability Floods at Gauging Stations

b) Design Discharge / Probability Floods at the Proposed Bridges

In addition to the above-mentioned frequency analysis by the statistical data, the other empirical formulae which are often used for un-gauged basins of Nepal are shown in the following. In this study, the typical 3 prediction formulae among them are used.

- Rational Method
- WECS/DHM Method
- Modified Dicken's Method
- (PCJ Method)
- (Sharma and Adhikari Method), etc.

As shown in 9.3.1.4(2), the risk of debris flow is high except for the Daraudi Bridge - No.5, because there are many steep slope sites in the drainage area. Hence, in addition to the above, the debris-flows for 4 bridges are estimated using the Japanese standards.

The probability flood calculation by each formula is shown in Table 9.4.23, and the design discharge for each proposed bridge is summarized in Table 9.4.22. The ordinary/low/drought discharges are calculated by the discharge per unit drainage area, from past discharge-duration curve at Garambesi Station.

Table 9.4.22 Probability Floods of each Proposed Bridge

Bridge No.	Chainage	Bridge (River) Name	Drainage Area (km^2)	Design Discharge								Remarks
				Debris 100yrs	100yrs	50yrs	10yrs	2yrs	Ordinary Dis.	Low Dis.	Drought Dis.	
Barakilo - Barpak Road									0.0282321	0.0169935	0.0109271	Chepe Khola
1	km16	Khahare Khola	5.72	**98.81**	52.66	47.14	40.69	29.91	0.162	0.097	0.063	
2	km27	Jhayalla Khola	13.94	**186.61**	101.26	90.06	79.78	59.70	0.394	0.237	0.152	
3	km31	Ghatte Khola	7.43	**170.42**	85.21	82.11	72.31	53.36	0.210	0.126	0.081	
4	km37	Rungrung Khola	34.43	**356.45**	195.30	169.38	144.59	105.04	0.972	0.585	0.376	
District Road to Saurpani												
5	km29	Daraudi Khola	214.5	1,764.4	**950.5**	844.8	728.7	514.2	6.055	3.644	2.343	
-	km29	Daraudi Khola	347.9	2,007.5	1,541.8	964.3	842.7	617.1	9.822	5.912	3.801	

Note. Numerical values listed in boldface shows the design discharge.

Source: JICA Project Team

Table 9.4.23 Calculation Results of Probability Floods and Debris Flows at each Proposed Bridge

Bridge No.	Chainage	Bridge (River) Name	Drainage Area (km^2)	Design Scale	1. Catchment Area Ratio Method (to 100-yrs flood of Chepe Khola)		2. Rational Formula														3. WECS/DHM Method		4. Modified Dicken's Method				Design Discharge: 100-yrs Q (m^3/s)	Applied Estimation Method	Necessary Bridge Opening: B (m)	Remarks
					100-yrs Unit Discharge ($m^3/s/km^2$)	Peak Discharge: Q_{100}' (m^3/s)	Concent-ration Time: T	Inlet Time: T1	Travel Time: T2	Inlet Length (m)	Flow Length (m)	Rainfall Intensity: I_2 (mm/hr)	Rainfall Intensity: I_{10} (mm/hr)	Rainfall Intensity: I_{50} (mm/hr)	Rainfall Intensity: I_{100} (mm/hr)	Runoff Coefficient	Peak Discharge: Q_2' (m^3/s)	Peak Discharge: Q_{10}' (m^3/s)	Peak Discharge: Q_{100}' (m^3/s)	Drainage Area under 3000 m elevation: A_{3000} (km^2)	Peak Discharge: Q_{100}' (m^3/s)	Snow Cover Area: As (km^2)	% of Snow-fed Area: P	Dicken's Coefficient: C_{100}	Peak Discharge: Q_{100}' (m^3/s)				
Barakilo - Barpak Road																													
1	km16	Khahare Khola	5.72	**100 yrs**	4.43182	25.36	41.21	19.20	22.00	897	3,653	48.24	65.63	76.03	79.69	0.39	29.91	40.69	49.40	5.72	52.66	0.0	104.848	8.39	31.03	52.7	WECS/DHM Method	34.5	Minimum Freeboard is 1 m
2	km27	Jhayalla Khola	13.94	**100 yrs**	4.43182	61.80	49.17	18.61	30.57	971	4,983	48.16	64.37	72.66	75.28	0.32	59.70	79.78	93.30	13.94	101.26	0.0	43.030	10.00	72.13	101.3	WECS/DHM Method	47.8	Freeboard is 1 m
3	km31	Ghatte Khola	7.43	**100 yrs**	4.43182	32.92	37.36	20.58	16.78	1,300	2,904	56.23	76.20	86.53	89.79	0.46	53.36	72.31	85.21	7.43	63.77	0.0	80.785	8.86	39.85	85.2	Rational Formula	43.8	Freeboard is 1 m
4	km37	Rungrung Khola	34.43	**100 yrs**	4.43182	152.60	61.78	26.33	35.46	1,463	7,813	34.32	47.24	55.34	58.23	0.32	105.04	144.59	178.23	34.11	195.30	0.0	17.425	11.63	165.34	195.3	WECS/DHM Method	66.4	Freeboard is 1 m
District Road to Saurpani																													
5	km29	Daraudi Khola	214.5	**100 yrs**	4.43182	950.5	156.89	45.64	111.25	4,619	25,272	19.62	27.80	32.23	33.66	0.44	514.2	728.7	882.2	149.1	576.8	2.1	3.775	14.40	806.9	950	Catchment Area Ratio Method (Specific Discharge)	146.44	Freeboard is 1.5 m
-	km29	Daraudi Khola	347.9	**100 yrs**	4.43182	1,541.8	224.38	45.64	178.74	4,619	38,924	16.37	22.36	25.59	26.63	0.39	617.1	842.7	1003.8	282.5	922.2	2.1	2.327	15.27	1,230.3	1,542	Catchment Area Ratio Method (Specific Discharge)	-	

Note. 1. In the calculation of Catchment Area Ratio Method by using the statistical data of Gharmbesi (Chepe Khola) station, the extreme value prediction method is adopted the Log Pearson type Ⅲ distribution (Logarithmic space method) from among several methods.

2. In the calculation of Rational Formula, the time of concentration is calculated by Kirpich formula for Travel time and Kerby formula for Inlet time. The rainfall intensity formula use the Mononobe equation, the extreme value prediction method of daily rainfall is adopted a preferred method from among several distribution-models. Also, the probable 24hr-rainfall amount of each site / station is adjusted by considering the spatial distribution of them.

3. Necessary Bridge Opening Width is calculated by Lacey's equation, in order to prevent contraction scour.

No.	Target / River Bridge	Cobbles Density	Water Density	Internal Friction Angle	Slope of Stream Bed		Slope of Down-Stream Bed		Cardinality of Debris Flow		Cardinality of Deposited Debris	Unit Weight of Debris Flow	$C_*/(C_*-C_d)$	Discharge only Water flow	Debris Flow Discharge	Remarks
		σ (t/m^3)	ρ (t/m^3)	φ (deg.)	tan θ	θ (deg.)	tan θ	θ (deg.)	C_d'	C_d	C_*	ρd (t/m^3)	α	Qp (m^3/s)	Qsp (m^3/s)	
	Barakilo - Barpak Road															
1	Khahare Khola	2.60	1.2	30.0	0.0714	4.085	0.0701	4.011	0.121	0.300	0.6	2.18	2.00	49.404	98.808	
2	Jhayalla Khola	2.60	1.2	30.0	0.0383	2.194	0.0648	3.710	0.061	0.300	0.6	2.18	2.00	93.304	186.608	
3	Ghatte Khola	2.60	1.2	30.0	0.0862	4.924	0.1185	6.759	0.150	0.300	0.6	2.18	2.00	85.211	170.423	
4	Rungrung Khola	2.60	1.2	30.0	0.0669	3.827	0.1022	5.835	0.112	0.300	0.6	2.18	2.00	178.227	356.454	
	District Road to Saurpani															
5	Daraudi Khola	2.60	1.2	30.0	0.0140	0.800	0.0257	1.470	0.021	0.300	0.6	2.18	2.00	882.21	1764.41	
-	Daraudi Khola	2.60	1.2	30.0	0.0108	0.617	0.0108	0.617	0.016	0.300	0.6	2.18	2.00	1003.77	2007.53	

Source: JICA Project Team

4) Hydraulic Calculations and Design High Flood Level at the Proposed Bridges

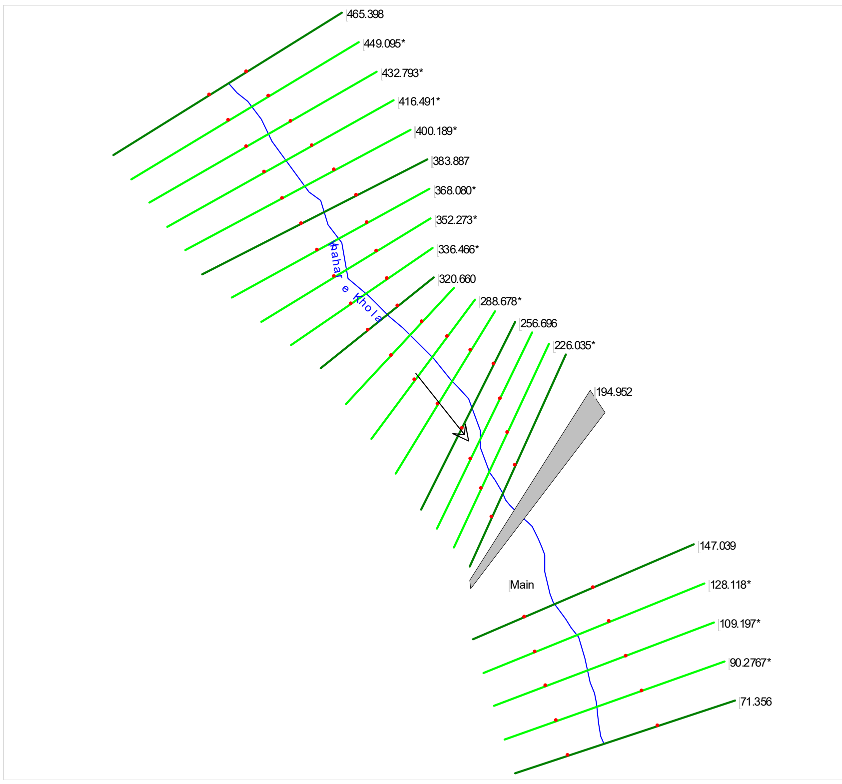
a) Hydraulic Calculations

The 1-dimensional hydraulic analyses are performed under the average flow condition at 5 bridges of the study area, for confirming of the several hydraulic quantities and the bridge scour. For the 1-dimensional hydraulic analyses, the Hydrologic Engineering Centre - River Analysis System (HEC-RAS) model developed by US Army Corps of Engineers, is used.

The hydraulic calculation models for the 5 bridges are shown from Figure 9.4.29 to Figure 9.4.33. The cross-sections for the hydraulic calculations are from the topographic survey results.

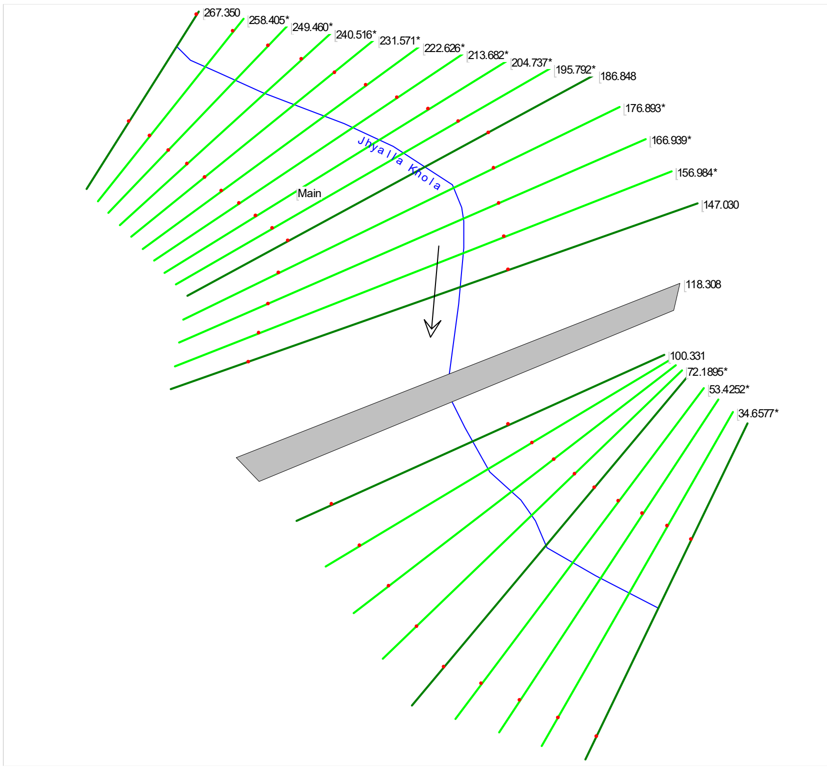
Hydraulic analysis is performed under the following conditions and the resulting hydraulic profiles are shown in Figure 9.4.34 - Figure 9.4.38.

- Calculation Case - 2 cases of 'With Bridge' and 'Without Bridge',
- Discharge - Drought discharge, Low discharge, ordinary discharge, 2, 10, 50, 100 year floods and 100 year debris flows. The design scale applied the debris flow of 100-year floods for No.1 - No.4 bridges and just the 100 year flood for No.5 bridge of the Daraudi main stream.



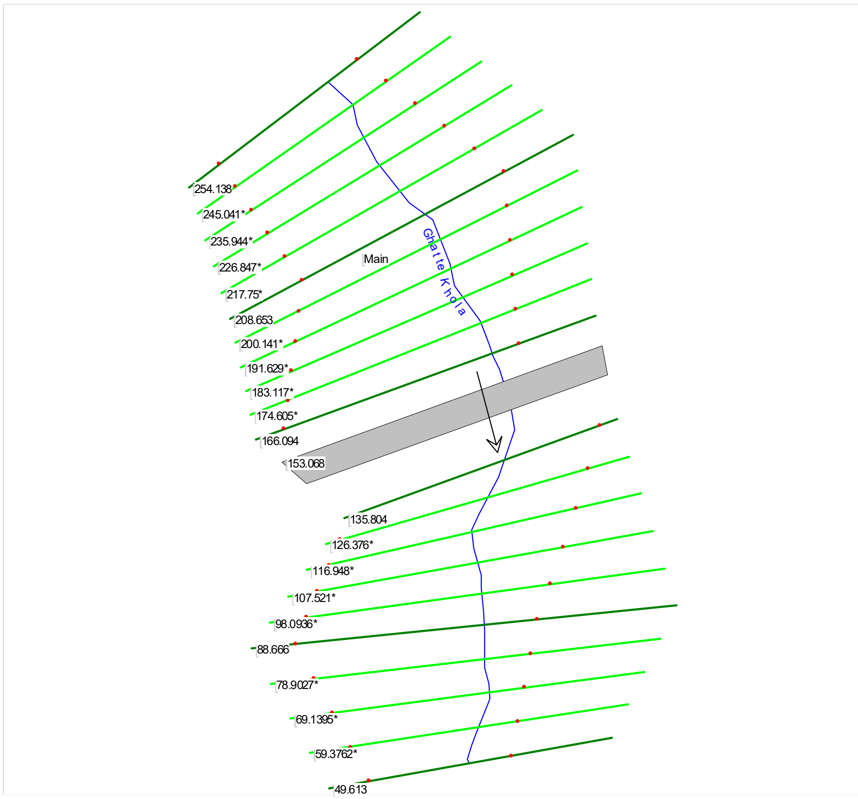
Source: JICA Project Team

Figure 9.4.29 Hydraulic Calculation Model of No. 1 Bridge (Khahare Khola)



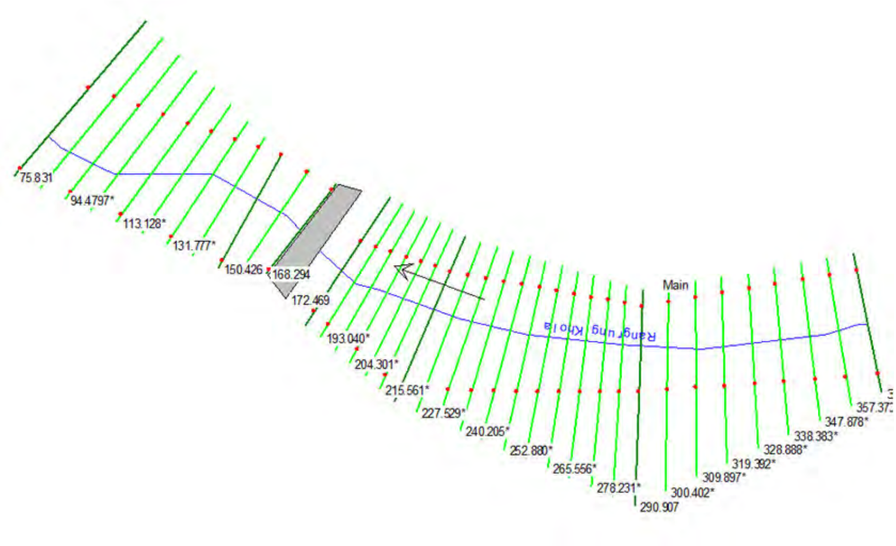
Source: JICA Project Team

Figure 9.4.30 Hydraulic Calculation Model of No. 2 Bridge (Jhyalla Khola)



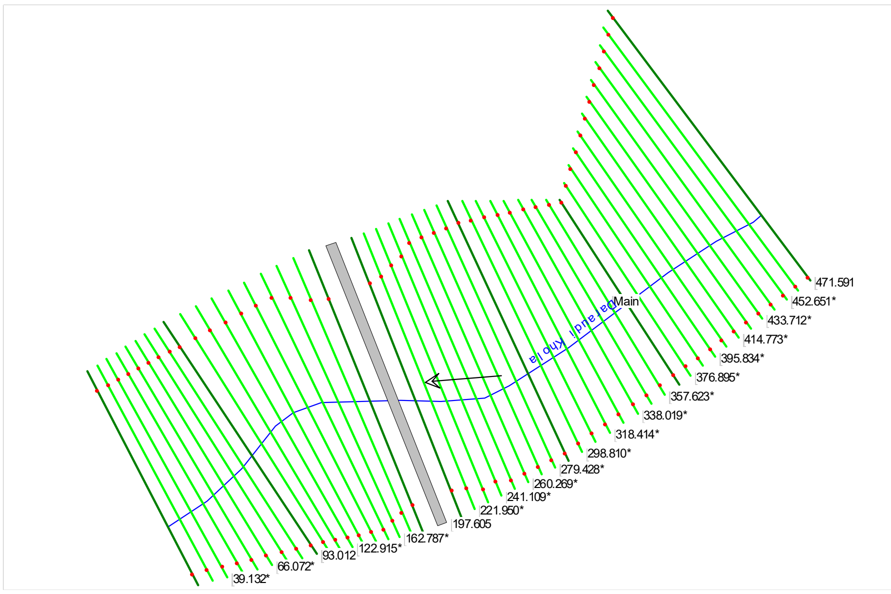
Source: JICA Project Team

Figure 9.4.31 Hydraulic Calculation Model of No. 3 Bridge (Ghatte Khola)



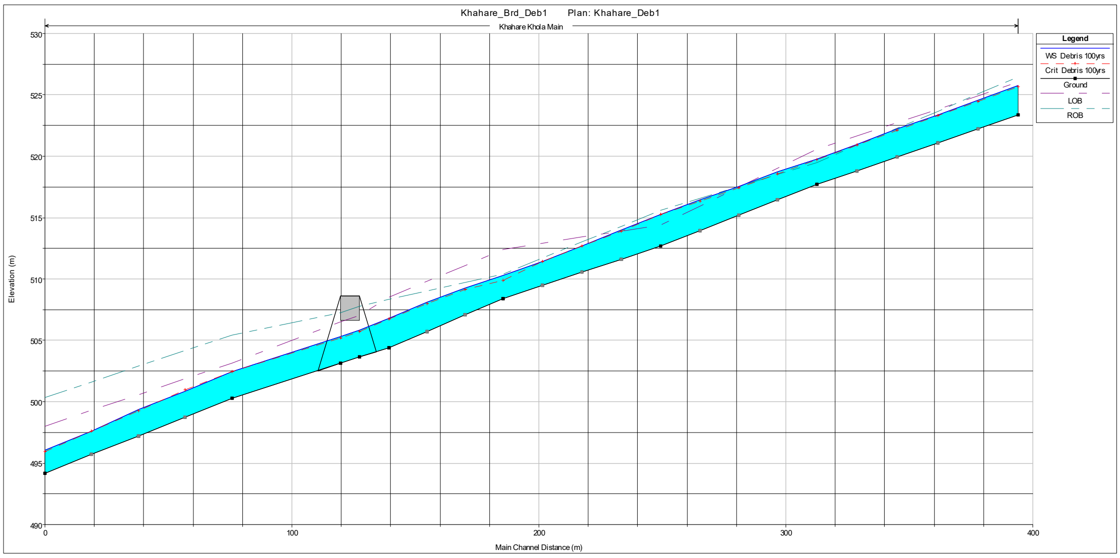
Source: JICA Project Team

Figure 9.4.32 Hydraulic Calculation Model of No. 4 Bridge (Rangrung Khola)



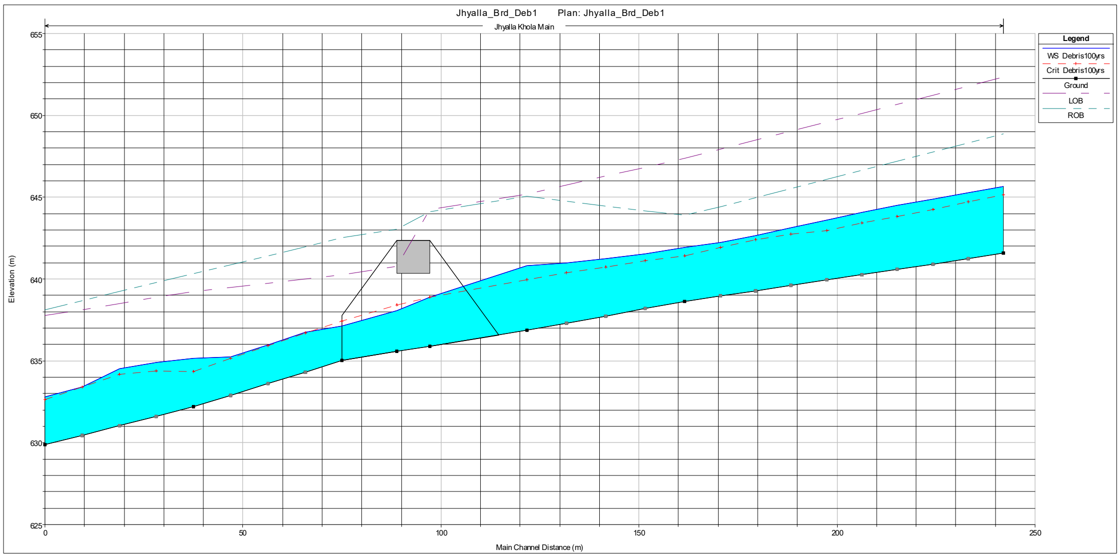
Source: JICA Project Team

Figure 9.4.33 Hydraulic Calculation Model of No. 5 Bridge (Daraudi Khola)



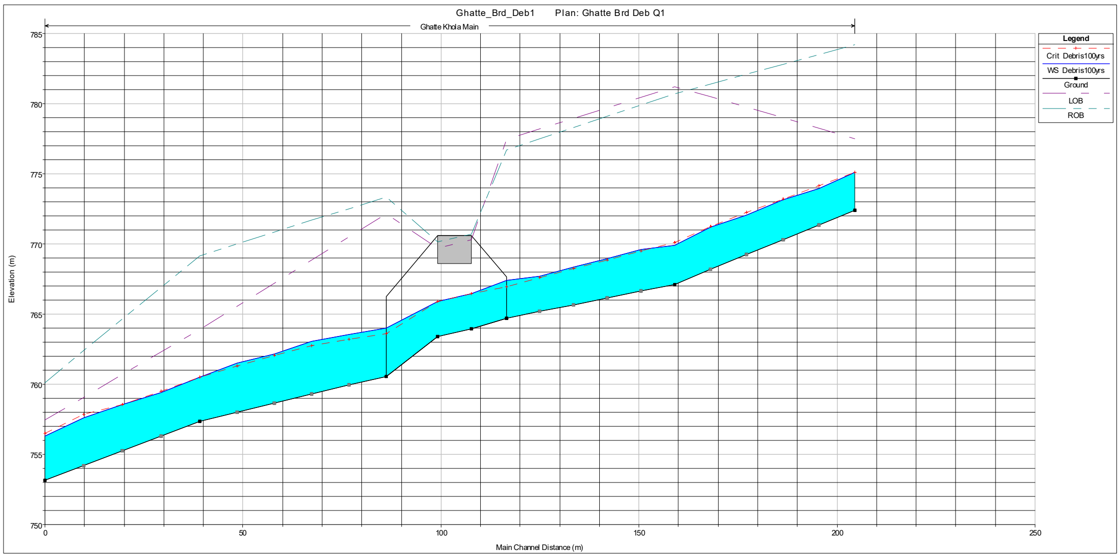
Source: JICA Project Team

Figure 9.4.34 Hydraulic Calculation Results (Longitudinal Profile) of No. 1 Bridge (Khahare Khola)



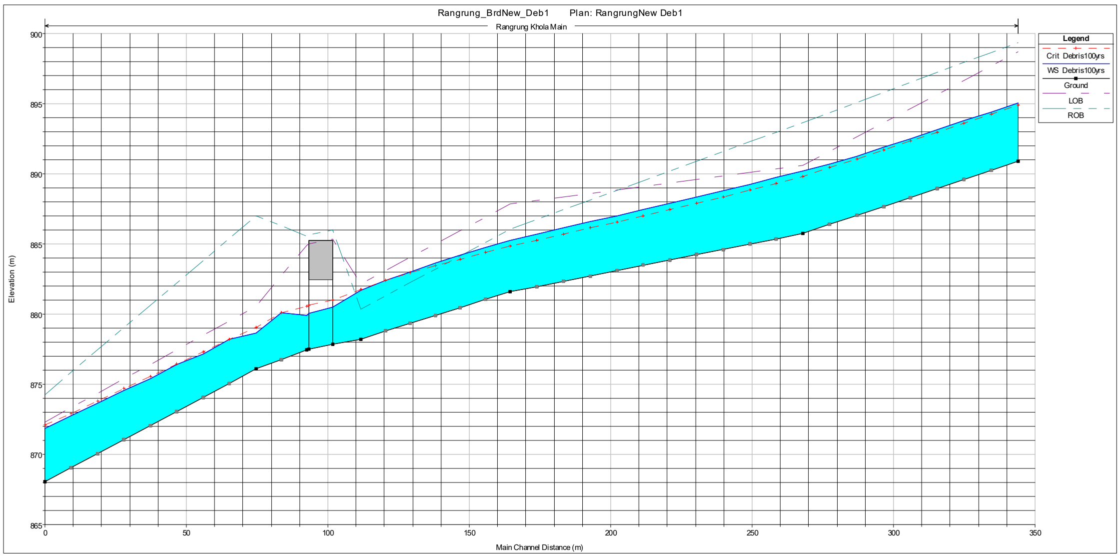
Source: JICA Project Team

Figure 9.4.35 Hydraulic Calculation Results (Longitudinal Profile) of No. 2 Bridge (Jhyalla Khola)



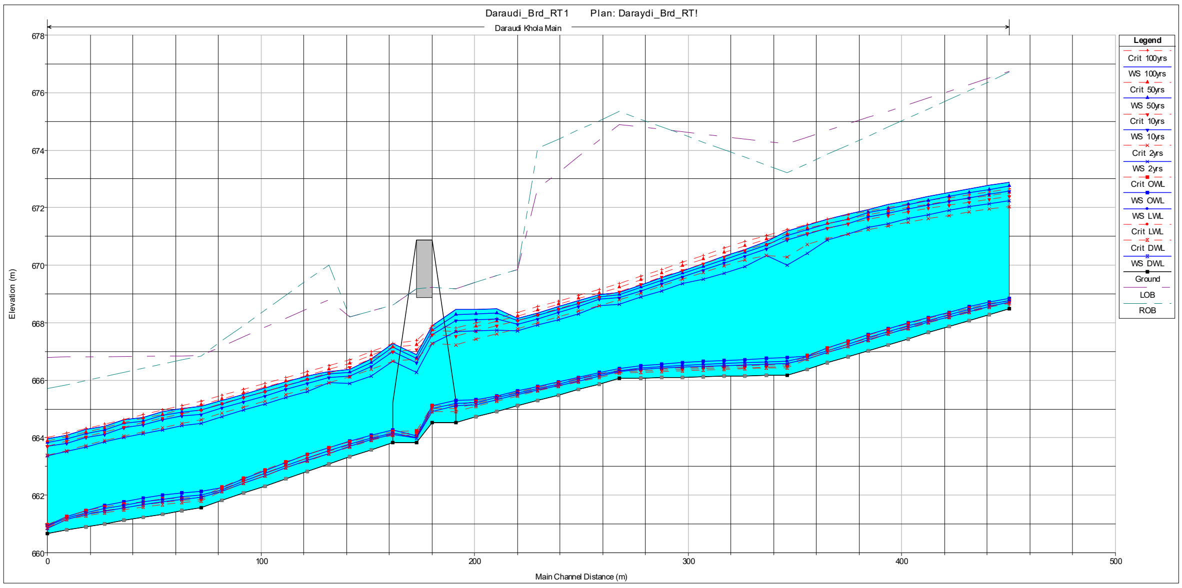
Source: JICA Project Team

Figure 9.4.36 Hydraulic Calculation Results (Longitudinal Profile) of No. 3 Bridge (Ghatte Khola)



Source: JICA Project Team

Figure 9.4.37 Hydraulic Calculation Results (Longitudinal Profile) of No. 4 Bridge (Rungrung Khola)



Source: JICA Project Team

Figure 9.4.38 Hydraulic Calculation Results (Longitudinal Profile) of No. 5 Bridge (Daraudi Khola)

b) Design High Flood Level (HFL) at the Proposed Bridges

The design High Flood Levels (HFL) at each proposed bridge is shown in Table 9.4.24. The scale of design return period applied the 100-year flood in anticipation of debris flow for 4 bridges and the pure 100-year flood (without debris flow) for the Darudi Khola (No.5) bridge.

Table 9.4.24 Design High Flood Level (HFL) at each Proposed Bridge

Bridge No.	Chainage	Bridge (River) Name	Bridge Width (m)	Bridge Up Chainage	Water Level with Bridge (existing)							
					Debris 100yrs	100yrs	50yrs	10yrs	2yrs	Ordinary Dis.	Low Dis.	Drought Dis.
Barakilo - Barpak Road										0th days	0th days	0th days
1	km16	Khahare Khola	8.45	0+129.218	505.99	504.89	504.84	504.78	504.64	503.86	503.84	503.83
2	km27	Jhayalla Khola	8.45	0+099.731	639.06	638.20	638.05	637.93	638.00	636.20	636.17	636.13
3	km31	Ghatte Khola	8.45	0+108.095	766.49	765.47	765.45	765.41	765.29	764.15	764.12	764.10
4	km37	Rungrung Khola	8.45	0+124.905	882.70	881.02	880.89	880.76	880.53	879.31	879.27	879.24
District Road to Saurpani												
5	km29	Daraudi Khola	7.20	0+180.033	-	667.89	667.75	667.59	667.28	665.11	665.01	664.92
-	km29	Daraudi Khola	-	-	-	-	-	-	-	-	-	-

Source: JICA Project Team

(5) Design Condition

1) Applicable Standard

Design condition of this subproject was decided in accordance with major standards, specifications and guidelines in Nepal.

- Nepal Bridge Standard – 2067 specified by DOR in 2010

- Nepal Road Standards 2070, Design Standards for Feeder Roads (Third Revision) specified by DOR in 2013
- Nepal Rural Road Standard (2055), 2nd Revision, 2071 specified by DOLIDAR in 2014
- Other related Japanese standards and specifications

2) Design Condition of Road

a) Road Classification

Four bridges located along Barhakilo-Barpak road, which is specified as a "Feeder Road" and one bridge crossing Daraudi River will be constructed in this subproject. Because of the classification as a "Feeder Road" which is classified as "Class III", design speed will be considered to be 30 km/h as for mountainous and steep terrain. On the other hand, the road classification for the bridge across Daraudi River is considered to be a "District Road" which is classified as "Class IV". Therefore, design speed for this road is 30 km/h, also.

Table 9.4.25 Road Classification

Road Classification	Description	Remarks
Feeder Road	Feeder roads are important roads of localized nature. These serve the community's wide interest and connect District Headquarters, Major economic centres, and Tourism centres to National Highways or to other feeder roads.	Barhakilo-Barpak Road
District Road	District Roads are important roads within a district serving areas of production and markets, and connecting with each other or with the main highways.	Swara-Saurpani-Barpak Road

Source: JICA Project Team

b) Road Specifications

Class III and IV are applied for this subproject.

Table 9.4.26 Road Specifications

Road Specification	Description	Remarks
Class III	Class III roads are those with ADT of 2,000-5,000 PCU in a 20 year perspective period. Design speed adopted for design of this class of roads in plain terrain is 80 km/h	Barhakilo-Barpak Road
Class IV	Class IV roads are those with ADT of less than 2,000 PCU in a 20 year perspective period. Design speed adopted for design of this class of roads in plain terrain is 60 km/h.	Swara-Saurpani-Barpak Road

※PCU: Passenger Car Unit (Passenger Car Equivalent)
Source: JICA Project Team

c) Design speed

The design speed of the approach road on the basis of the table below is Vs = 30km/h.

Table 9.4.27 Design Speed

Road Specification	Plain	Rolling	Mountainous	Steep	Remarks
Class I	120	100	80	60	Barhakilo-Barpak Road and Swara-Saurpani-Barpak Road
Class II	100	80	60	40	
Class III	80	60	40	30	
Class IV	60	40	30	20	

Source: JICA Project Team

d) Minimum radius of horizontal curves

The minimum radius of horizontal curves of the approach road on the basis of the table below is adopted as R_{min} = 30m. However, when used in a hair pin bend, it is reasonable to use the value of R_{min} = 15m as for the Daraudi River approach road.

Table 9.4.28 Radius of Horizontal Curves

<table>
<tr><th colspan="2" rowspan="2">Road Specification</th><th rowspan="2">Design Speed V_s km/hour</th><th colspan="3">Minimum Recommended Radius R_{min} m</th><th rowspan="2">Remarks</th></tr>
<tr><th>When no super-elevation provided (2.5% camber i.e. negative super-elevation)</th><th>When Maximum Super-elevation of 10% provided</th><th>From the comfort criteria of passengers (Max lateral force 15% of vertical force)</th></tr>
<tr><td rowspan="4">Class III</td><td></td><td>80</td><td>440</td><td>210</td><td>190</td><td rowspan="5">Barhakilo-Barpak Road and Swara-Saurpani-Barpak Road</td></tr>
<tr><td rowspan="4">Class IV</td><td>60</td><td>200</td><td>110</td><td>190</td></tr>
<tr><td>40</td><td>70</td><td>40</td><td>90</td></tr>
<tr><td>30</td><td>30</td><td>20</td><td>50</td></tr>
<tr><td></td><td>20</td><td>20</td><td>10</td><td>30</td></tr>
</table>

Source: JICA Project Team

e) Maximum gradients

The maximum gradient of the approach road on the basis of the table below is imax = 10%. However, when leader gradient of the existing road is used, it is possible to use a value of more than the default maximum gradient as a special case.

Table 9.4.29 Maximum Gradients

Design Speed V_s km/hour	20	30	40	60	80	100	120
Maximum Gradients i_{max} %	12	10	9	7	6	5	4

Source: JICA Project Team

f) Carriageway

The standard width of the carriageway of the approach road on the basis of the table below is W_{cw} = 3.75m.

Table 9.4.30 Width of Carriageways

Carriageway Width of Single Lane Road m	Intermediate Lane m	Multilane Pavements Width per Lane m
3.75	5.5	3.5

Source: JICA Project Team

g) Shoulder

The standard width of shoulder of the approach road is Ws = 1.875m. Also, the standard shoulder width of the design standard is a 2.00m in the road of class III, and is 1.50m in the road of the class IV.

h) Extra-widening

The value the design criteria for extra widening in short radius curves is defined as 0.6m at R = 20-40m. On the other hand, for approach road design, because of the adequate width of the shoulder and the reduction of the project cost, there is no extra widening in the curved sections.

3) Design Condition for Bridge

In accordance with the Bridge Design Standard in Nepal as mentioned before, the load applied to the bridge shall be based on the IRC Standard specified in India. Therefore, the design conditions of this subproject are specified in accordance with IRC standards as shown in the following;

a) Live Load

Class 70R and Class A loading specified in “Standard Specifications and Code of Practice for Road Bridges - IRC: 6-2014” will be applied.

b) Seismic Force

Seismic force will be calculated as follows, in accordance with “Standard Specifications and Code of Practice for Road Bridges - IRC: 6-2014”

- Importance Factor: 1.20
- Seismic Zone: Class V (=0.36)

c) Pavement Load

In general, there is no pavement structure applied for Asphalt Concrete. Moreover, only Double Bituminous Surface Treatment (DBST) is applied along Barhakilo-Barpak Road, and there is no pavement applied in the bridge sections. Therefore, pavement structure will not be applied in this subproject either. However, according to DOR, there is a plan to apply asphalt concrete to the whole section of Barhakilo-Barpak Road in the future. Therefore, a 75mm thickness of road pavement will be considered in the bridge design in order to accept installation of asphalt pavement to the bridge surface in the future.

d) Material

Material standards applied to this subproject are shown below;

- Concrete strength for Pre-stressed Concrete Superstructure:

  Concrete strength applied to Pre-stressed Concrete Superstructure is 36 [N/mm^2].

- Concrete strength for Substructure and Foundation:

  Concrete strength applied to substructure and foundation is 24 [N/mm^2].

- Concrete strength for Non-Reinforced Concrete:

  Concrete strength for lean concrete and filling concrete at sidewalks is 18 [N/mm^2].

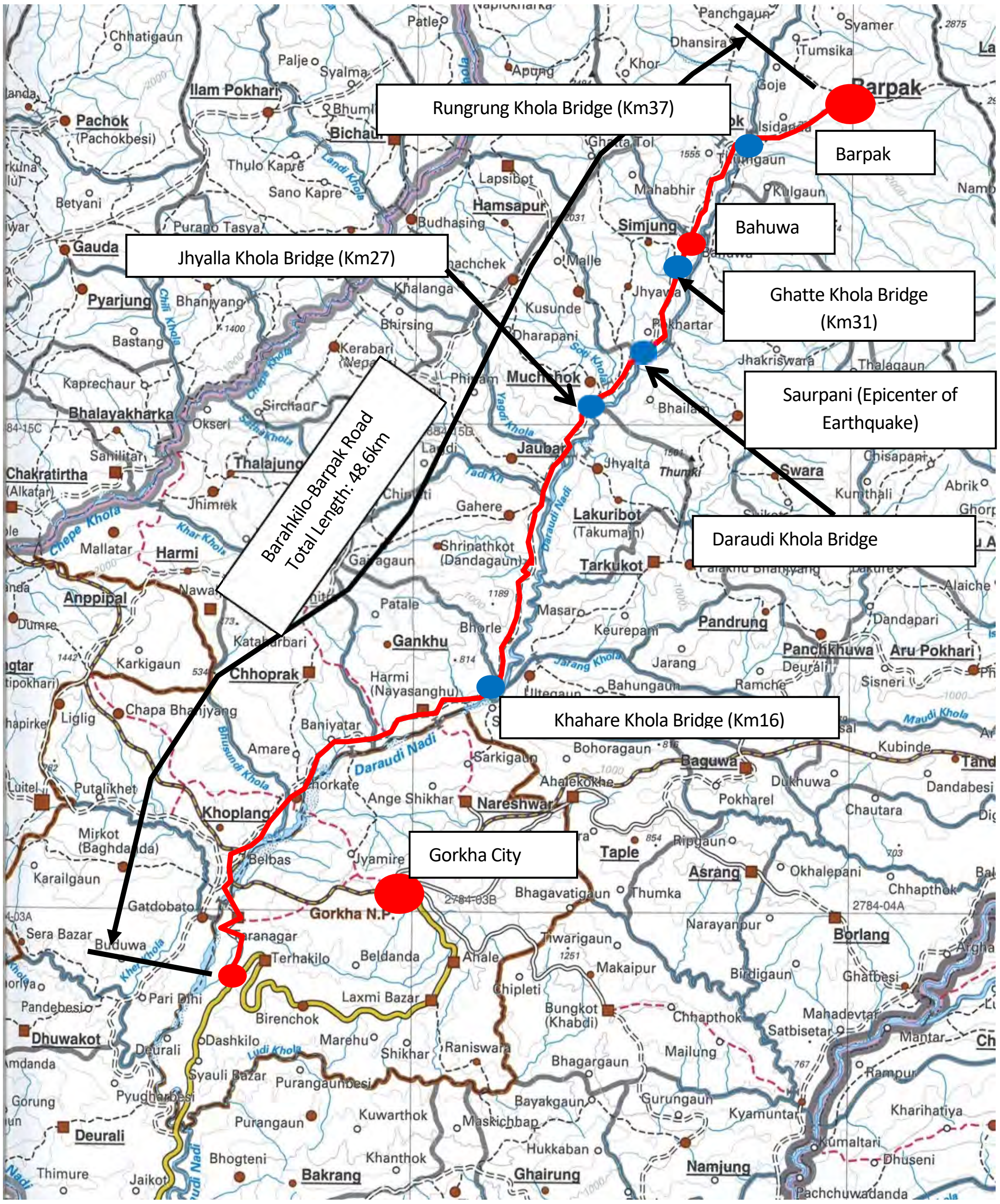
- Reinforcement Bar:

  Grade 500 specified in IS 1786: 2008, an Indian Standard, is applied in consideration of availability in Nepal.

9.4.3 Outline Design

(1) Bridges to be Constructed

Locations for 5 bridges to be constructed by this subproject are shown in Figure 9.4.39 and the current condition for each crossing point is explained as follows;



Source: JICA Project Team

Figure 9.4.39 Location Map for Bridges

1) Khahare Khola Bridge

Khahare Khola Bridge is located at Km16 of Barhakilo-Barpak Road. There is almost no water in the river; however, there is water flow when it rains. According to observation of the flood status at the site, current speed is about 3-4m/sec. Based on observations of a few ten cm sized rocks on the riverbed; current speed is considered fast at flood time. There are a few dozen houses near the left bank of Khahare river and about a dozen houses within a few hundred meters of the right bank of Khahare River.

2) Jhyalla Khola Bridge

Jhyalla Khola Bridge is located at Km27 of Barhakilo-Barpak Road. Width of the river is about

10-15m during normal flow, water depth is a few dozen cm and current speed is about 2-3m/sec. Because several rocks from tens of centimetres to one meter were observed on the riverbed, it is considered that the current speed in a flood will be fast. There are about 10 houses on the right bank of Jhyalla River and, there are agricultural fields upstream of the current river crossing point on both the right and left banks of Jhyalla River.

3) Ghatte Khola Bridge

Ghatte Khola Bridge is located at Km31 of Barhakilo-Barpak Road. Width of the river is about 10-15m during normal flow, water depth is a few dozen cm and current speed is about 2-3m/sec. Because several rocks from tens of centimetres to one meter were observed on the riverbed, it is considered that the current speed during a flood will be fast. There are about 100 houses in Baluwa Village on the left bank of Ghatte River and agriculture fields on the right bank of Ghatte River.

4) Rangrung Khola Bridge

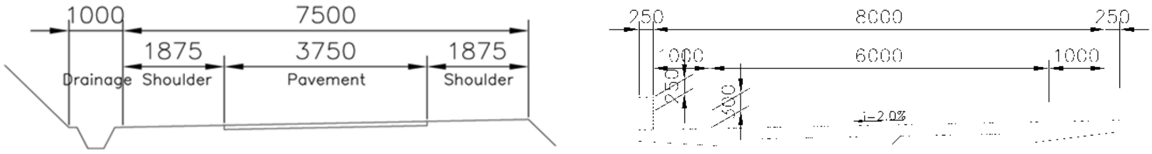
Rangrung Khola Bridge is located at Km37 of Barhakilo-Barpak Road. Width of the river is about 20m during normal flow, water depth is a few dozen cm and current speed is about 3m/sec. Because several rocks from tens of centimetres to one meter were observed on the riverbed, it is considered that the current speed during a flood will be fast. There are a few residents living around the Rangrung Bridge construction site and most of the area is forest area. The area after crossing Rangrung River to go to Barpak is precipitous mountains; Barhakilo-Barpak Road becomes a winding road after crossing Rangrung River.

5) Daraudi Khola Bridge on Swara-Saurpani-Barpak Road

Construction of Daraudi Khola Bridge is proposed in order to cross Daraudi River and connect Saurpani with the Km29 point of Barhakilo-Barpak Road. Saurpani was in the epicentre area of the Nepal Earthquake. Width of the river is about 30m, water level is 1-2m, and current speed is 2-3m/sec in normal flow. There are no residents living near this point. A Hydro Power Plant Construction Project is in progress about 1km downstream from the crossing point of the river. Construction of a dam and installation of a supply pipeline is being carried out by this project.

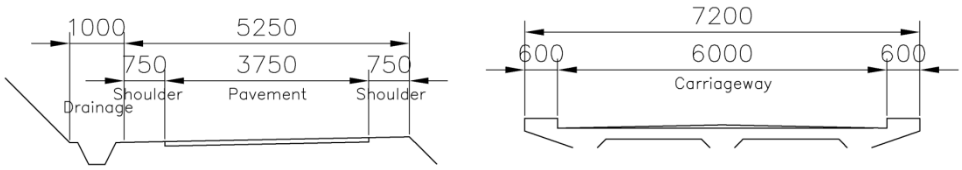
(2) Typical Cross Section

Typical cross sections decided based on design conditions explained in previous sections are shown in Figure 9.4.40 and Figure 9.4.41.



Source: JICA Project Team

Figure 9.4.40 Typical Cross Section for Barhakilo-Barpak Road (Approach Road and Bridge)



Source: JICA Project Team

Figure 9.4.41 Typical Cross Section for District Road (Approach Road and Bridge)

(3) Outline Design for Road

The adopted geometric design values and control-points of each approach road are shown below. The approach road design is carried out keeping in mind the reduction of construction costs and the adjustment of the control-points.

Table 9.4.31 Design of Khahare Khola bridge approach road (Plan and Profile)

Road Classification	Road Specification	Design Speed Vs km/hr	Minimum radius of horizontal curve R_{min} m		Maximum gradient i_{max} %	
			Specified minimum value	Adopted value	Specified minimum value	Adopted value
Feeder Road	Class III	30	30	20 in hair pin bend	10	10.00

Control-points

Plan/Profile	Chainage (Sta.)	Name of control-point	Descriptions
Plan	0+00	Beginning point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m.
	0+30 - 0+55	Road alignment of bridge section	To adopt a hair pin bend (R=20) in order to shorten the bridge length.
	0+110 Both sides	Houses along the road	This is a control point to avoid.
	0+120	End point of design	To coordinate the centre line of the existing road and planning road. Also it matches the pavement width and road width at a distance of 20m.
Profile	0+00	Beginning point of design	To match with the height of the existing road.
	0+30 - 0+55	Road alignment of bridge section	Considering that the elevation of the Khahare River flow at HFL=505.80m, and taking into account the free board from the HFL=1.0m and the assumed depth of the girder of the bridge =1.8m, the proposed road elevation is set at H ≥508.60m.
	0+120	End point of design	To match with the height of the existing road.

Source: JICA Project Team

Table 9.4.32 Design of Jhyalla Khola bridge approach road (Plan and Profile)

Road Classification	Road Specification	Design Speed Vs km/hr	Minimum radius of horizontal curve R_{min} m		Maximum gradient i_{max} %	
			Specified minimum value	Adopted value	Specified minimum value	Adopted value
Feeder Road	Class III	30	30	60	10	5.25

Control-points			
Plan/Profile	**Chainage (Sta.)**	**Name of control-point**	**Descriptions**
Plan	0+00	Beginning point of design	To coordinate the centre line of the existing road and the planned road. Also it matches the pavement width and road width at a distance of 20m.
	0+00 - 0+50 Both	Houses along the road	This is a control point to avoid.
	0+70 Left	Fish pond	This is a control point to avoid. And to protect the fish pond by installing Gabions.
	0+81 - 0+111	Road alignment of bridge section	To cross the river alignment and the road alignment at a right angle as much as possible in order to shorten the bridge length.
	0+140 Right	Houses along the road	This is a control point to avoid.
	0+190	End point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m.
Profile	0+00	Beginning point of design	To match with the height of the existing road.
	0+81 - 0+111	Road alignment of bridge section	Considering that the elevation of the Jhyalla River flow at HFL=638.84m, and taking into account the free board from the HFL=1.0m and the assumed depth of the girder of the bridge =2.0m, the proposed road elevation is H ≥641.84m.
	0+190	End point of design	To match with the height of the existing road.

Source: JICA Project Team

Table 9.4.33 Design of Ghatte Khola bridge approach road (Plan and Profile)

Road Classification	Road Specification	Design Speed Vs km/hr	Minimum radius of horizontal curve R_{min} m		Maximum gradient i_{max} %	
			Specified minimum value	Adopted value	Specified minimum value	Adopted value
Feeder Road	Class III	30	30	60	10	8.77

Control-points			
Plan/Profile	**Chainage (Sta.)**	**Name of control-point**	**Descriptions**
Plan	0+00	Beginning point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m.
	0+00 Right	Houses along the road	This is a control point to avoid.
	0+39- 0+69	Road alignment of bridge section	To cross the river alignment and the road alignment at a right angle as much as possible in order to shorten the bridge length.
	0+106 Right	Houses along the road	This is a control point to avoid.
	0+120	End point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m.
Profile	0+00	Beginning point of design	To match with the height of the existing road. On this occasion, the road gradient is 10% or more (i=20.73%) in order to match the existing road height and gradient. Therefore, the K value is satisfied by extending the length (L=60) of the vertical curve.
	0+39- 0+69	Road alignment of bridge section	Considering that the elevation of the Ghatte River flow at HFL=768.78m, and taking into account the free board from the HFL=1.0m and the assumed depth of the girder of the bridge =2.0m, the proposed road elevation is H ≥768.78m
	0+120	End point of design	To match with the height of the existing road.

Source: JICA Project Team

Table 9.4.34 Design of Rangrung Khola bridge approach road (Plan and Profile)

Road Classification	Road Specification	Design Speed Vs km/hr	Minimum radius of horizontal curve R_{min} m		Maximum gradient i_{max} %	
			Specified minimum value	Adopted value	Specified minimum value	Adopted value
Feeder Road	Class III	30	30	200	10	7.00

Control-points

Plan/Profile	Chainage (Sta.)	Name of control-point	Descriptions
Plan	0+00	Beginning point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m. To avoid a private house (barn) by adjusting the road alignment.
	0-07 Left	Houses along the road	This is a control point to avoid.
	0+35-0+55 Right	Existing ground would require a cut	This is a control point to avoid.
	0+60- 0+110	Road alignment of bridge section	To design a nearly straight bridge alignment (R=200) in consideration of the workability.
	0+110-0+130	Existing ground would require a cut	This is a control point to avoid.
	0+150	End point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m.
Profile	0+00	Beginning point of design	To match with the height of the existing road. On this occasion, the road gradient is 10% or more (i=22.17%) in order to match the existing road height and gradient. Therefore, the K value is satisfied by extending the length (L=60) of the vertical curve.
	0+60- 0+110	Road alignment of bridge section	Considering that the Rangrung River flow at HFL=881.34m, and taking into account the free board from the HFL=1.0m and the assumed depth of the girder of the bridge =2.8m, the proposed road elevation is set at H ≥885.14m
	0+120	End point of design	To match with the height of the existing road.

Source: JICA Project Team

Table 9.4.35 Design of Daraudi Khola bridge approach road (Plan and Profile)

Road Classification	Road Specification	Design Speed Vs km/hr	Minimum radius of horizontal curve R_{min} m		Maximum gradient i_{max} %	
			Specified minimum value	Adopted value	Specified minimum value	Adopted value
District Road	Class IV	30	30 15 in hair pin bend	200 15 in hair pin bend	10	7.65

Control-points

Plan/Profile	Chainage (Sta.)	Name of control-point	Descriptions
Plan	0+00	Beginning point of design	To form a 3-leg at grade intersection with the Barhakilo-Barpak road. In the point of view of the turning of vehicles near the intersection to adopt a minimum curve radius R=15.
	0+140	Near the A_1 Abutment	To adopt a hair pin bend (R=15) in order to straighten the shape of the bridge.
	0+156- 0+288	Road alignment of bridge section	To design a straight bridge alignment in consideration of the workability.
	0+300	Near the A_2 Abutment	To adopt a hair pin bend (R=15) in order to straighten the shape of the bridge.
	0+320	End point of design	To coordinate the centre line of the existing road and planned road. Also it matches the pavement width and road width at a distance of 20m. To fit the height of the existing road/terrain.
Profile	0+00	Beginning point of design	To match the height of Barhakilo-Barpak road. Also designed in easy grade around the intersection. (i=1.5%≤2.5%)
	0+00-0+150	Approach section of the bridge	To set the profile (vertical alignment) higher than the HFL of Daraudi River.
	0+200.5	Crossing of the existing road	In the point of view of the traffic on the existing road to ensure the clearance under the girder of H=3m.
	0+156- 0+288	Road alignment of bridge section	Considering that the elevation of the Daraudi River flow at HFL=667.37m, taking into account the free board from the HFL=1.5m and the assumed depth of the girder of the bridge =2.0m, the proposed road elevation is set at H ≥670.87m
	0+320	End point of design	To match with the height of the existing road.

Source: JICA Project Team

(4) Outline Design of Bridge

1) Basic policy of Bridge Planning

Bridge planning is carried out based on the policies shown below;

- Structure type and material which have advantage in earthquake resistance and durability are applied in accordance with BBB policy
- Due to the very steep gradient of the river profile, except for Daraudi River, there is a high possibility of receiving debris flow during high flood. Therefore, a single span bridge is applied in order to avoid negative impact on the substructure from debris flow.

2) Study on Superstructure type selection

a) Study on primary Superstructure type selection

Based on the study result of the road alignment and river condition, the necessary span length for each bridge is decided as follows;

- Khahare Bridge: 25m
- Jhyalla Bridge: 30m
- Ghatte Bridge: 30m
- Rangrung Bridge: 50m

Recommended superstructure types are selected from Table 9.4.36 which shows the relationship between superstructure type and recommended span length.

Table 9.4.36 Relationship Between Superstructure Type and Recommended Span Length

Superstructure Type		Recommended Span Length [m] (50m / 100m / 150m)	Ratio of Girder depth and Span length
Steel Bridge	Simple Composite Girder		1/18
	Simple I-Girder		1/17
	Simple Box Girder		1/22
	Simple Truss		1/9
	Langer Arch		1/6.5
	Rose Arch		1/6.5
	Arch		1/6.5
PC Bridge	Pre-tension Girder		1/22
	Hollow Slab		1/18
	2 Main Girder		1/18
	Simple T-shape		1/18
	Simple Box Girder		1/18
	π-shape Rahmen		1/32

Source: JICA Project Team

Based on above table, recommended superstructure types are selected as follows, in consideration with above mentioned span length.

- Steel Bridge (Span Length: 30m and 50m): Simple Composite Girder, Simple I-Girder and Simple Box Girder
- PC Bridge (Span Length: 30m): Hollow Slab, 2 Main Girders, Simple T-shape and Simple Box Girder
- PC Bridge (Span Length: 50m): Simple Box Girder and π-shape Rahmen

b) Study on secondary Superstructure type selection

The result of the comparison study on superstructure type is shown in Table 9.4.37. Based on the study result, PC 2 Main Girder type and PC Box Girder type are recommended to span 30m and 50m bridges, respectively.

Table 9.4.37 Comparison Study Result on Secondary Superstructure Type Selection

Superstructure Type	Evaluation	Judgement
Steel Bridge Simple Composite Girder	- Because most of the structure needs to be fabricated in Japan, the cost for ocean and land transport becomes higher. Therefore, this type is economically disadvantaged compared with the PC Bridge type. - Construction sites are located in mountainous areas. There is an issue for transportation of members to the site. - There are many items for future maintenance work such as deck slab, steel girder and bearings.	×
Steel Bridge Simple I-Girder	- Ditto	×
Steel Bridge Simple Box Girder	- Ditto	×
PC Bridge Hollow Slab	- There is no issue on material transportation in mountainous area because of cast-in-site structure type. - Additional cost needs to be considered for transportation of hollow material.	×
PC Bridge 2 Main Girders	- There is no issue on material transportation in mountainous area because of cast-in-site structure type.	○
PC Bridge T-shape	- There is an issue for transportation of precast girders from casting yard to each bridge site after fabrication of the girder. - There is no equipment for erection of PC precast girder in Nepal. Therefore, this type is economically disadvantaged because necessary equipment needs to be imported from outside of Nepal.	×
PC Bridge Box Girder	- There is no issue on material transportation in mountainous area because of cast-in-site structure type.	○
PC Bridge π-shape Rahmen	- There is no issue on material transportation in mountainous area because of cast-in-site structure type. - This type is economically disadvantaged because the profile needs to be raised in order to prevent the strut member from encroaching into the river cross section.	×

Source: JICA Project Team

3) Foundation Type

The geological condition of this subproject is considered to be good, because a firm gravel layer can be observed at 1~2m depth below the surface soil layer. Therefore, the foundation type of these bridges is the direct foundation type.

(5) Result of Outline Design

Results of the outline design are summarized in Table 9.4.38 and the outline design drawings are attached as Appendix 9 -2.

Table 9.4.38 Summary of Outline Design Result

Bridge Name	Bridge Length [m]	Approach Road Length [m]	Superstructure Type
Khahare Bridge	25	BP side: 30m EP side: 65m	PC 2 Main Girders
Jhyalla Bridge	30	BP side: 81m EP side: 79m	PC 2 Main Girders
Ghatte Bridge	30	BP side: 39m EP side: 51m	PC 2 Main Girders
Rangrung Bridge	50	BP side: 60m EP side: 40m	PC Box Girder
Daraudi Bridge	134 (4@32.5)	BP side: 154m EP side: 32m	PC 2 Main Girders

Source: JICA Project Team

(6) Outline Design for River Training Works

1) General

The main purpose of the construction of revetments and dikes is to protect the bridge from flooding. This means that no river bank erosion should occur. Secondary effects are to protect agricultural land and infrastructures in the existing protected area, etc.

In the case of the 5 proposed bridges, the slope of the stream-bed is very steep and the flow velocity is very fast, and hence its flow regime almost reaches super-critical flow, and its risk of erosion is high. In addition, the risk of debris-flow at 4 bridge site, except for the Daraudi, is high. In the project area of Khahare 25 years ago, the debris flow occurred as a real event.

As the method to control debris flows, three methods are generally considered: (i) to prevent the start of debris flow movement; (ii) to prevent the growth of debris flow movement that has already started; (iii) to dissipate the energy of debris flow movement and put it under control.

Primary preventive measures to be taken in each area are described below:

- ✓ Occurrence area: soil retaining works, ground sill works, etc.
- ✓ Flow area: sabo dam with a sedimentation reservoir, sabo dam with slits, sand pocket, etc.
- ✓ Sedimentation area: revetment works, training dike works, channel works, dam works, etc.

A sabo dam is the principal measure to be taken against debris flows. It can provide a variety of functions, ranging from the storage function like arrest and accumulation of debris flow, control function of sediment load, erosion control function, conversion function of transportation mode, and grading function of grains. However, its countermeasure work is large-scale and the construction cost is huge.

In this study, the main purpose of the project is the construction of bridges that provide earthquake safety, and it will be established as a primary goal that the debris-flow will be allowed to pass through the bridge opening. The countermeasure to allow the debris-flow to pass through the bridge opening will decrease the total bridge cost. Also, the sweeping measures, namely, structural measures or development of warning / evacuation systems for debris-flow, shall be separately considered as another project. Hence, the revetment work only having the function of allowing passage of the debris-flow will be examined.

2) Scour Calculations

The most common cause of bridge failures is from floods eroding bed material from around bridge foundations; abutments and piers. Therefore, safe bridge design must account for scour conditions that may occur over the life of the bridge. Scour estimation by steady flow analysis of HEC-RAS is conducted, based on Hydraulic Engineering Circular No. 18 (HEC 18) of the Federal Highway Administration (FHWA), USA, by using the value of probable maximum discharge and probable high water level. A sample image of the calculation is shown in Figure 9.4.42.

The results of scour estimation are as shown in Table 9.4.39. At the Daraudi Bridge, river training works (RTW) shall be conducted in order to diminish the encroachment or hydraulic-loss due to the road embankment construction blocking a portion of flow. Therefore, the result after installing the RTW is shown in this Table.

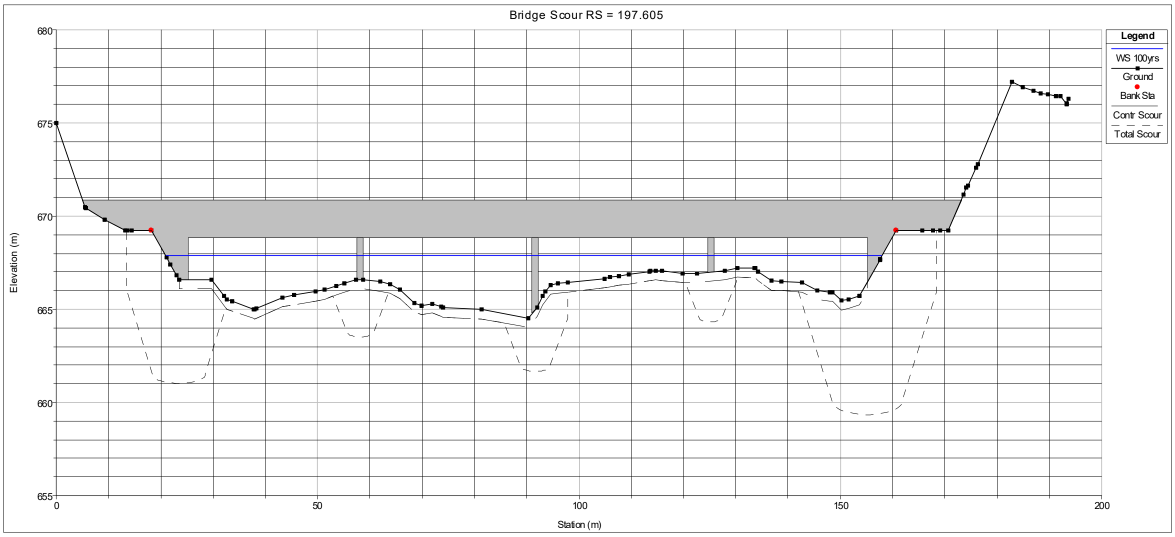
In all bridges, the estimated bridge scour depth is relatively deep, and the river bank/bed of each bridge will need to be protected by the appropriate protection works such as Gabion or Riprap, etc.

Table 9.4.39 Computation Results of Bridge Scour

Location	Scouring Items	No.1 Khahare Khola	No.2 Jhayalla Khola	No.3 Ghatte Khola	No.4 Rungrung Khola	No.5 Daraudi Khola
Abutment-1 (Left Bank)	Contraction Scour	0.01	1.14	0.06	0.60	0.50
	Local Scour	-	1.55	-	-	5.07
	Total Scour	0.01	2.69	0.06	0.60	5.57
Pier-1	Contraction Scour	-	-	-	-	0.50
	Local Scour	-	-	-	-	2.57
	Total Scour	-	-	-	-	3.07
Pier-2	Contraction Scour	-	-	-	-	0.50
	Local Scour	-	-	-	-	2.84
	Total Scour	-	-	-	-	3.34
Pier-3	Contraction Scour	-	-	-	-	0.50
	Local Scour	-	-	-	-	2.18
	Total Scour	-	-	-	-	2.68
Abutment-2 (Right Bank)	Contraction Scour	0.01	1.14	0.06	0.60	0.50
	Local Scour	4.87	5.31	-	6.96	6.61
	Total Scour	4.88	6.45	0.06	7.56	7.11
Remarks						with RTW

Note. Flow condition is under 100-years flood with debris-flow for 4 bridges except Daraudi and 100-years flood for Daraudi Bridge.

Source: JICA Project Team



Source: JICA Project Team

Figure 9.4.42 Calculation Example of Daraudi Bridge Scour

3) Scour Countermeasures

For erosion and scouring protection in river beds, riprap or gabions are considered as alternatives since flexible revetment is the most advisable one. However, if the riprap protection-works are adopted, the necessary rip-rap size is very large and is hard to construct; e.g. the necessary mean diameter of rip-rap is from 1.0 to 3.2 m, even if the bank angle with horizontal is assumed as "1:2". (See Table 9.4.40.) Therefore, the gabion protection, for which the permissible velocity for erosion is relatively high, will be applied as the typical revetment type. The permissible maximum velocity for gabion protection is 6 m/s for riverbed material of "shingle with gravel". Although galvanized or vinyl-coated wire will be adopted, the wire will deteriorate in the future, or individual baskets might be shifted downstream and deformed as the material moves under use in high-velocity flow. Hence, the reliability will be lost as a result, and their maintenance or replacement will be recommended periodically. For the Rangrung Khola Bridge only, since the ground is on solid footing and the flow-velocity is the fastest, a concrete revetment will be adopted.

The revetment type is divided into three types based on the place where it will be set up, and the typical cross section of the revetment is shown in Figure 9.4.43 - Figure 9.4.45.

Table 9.4.40 Calculation of Mean Diameter (D50) of Riprap (Reference)

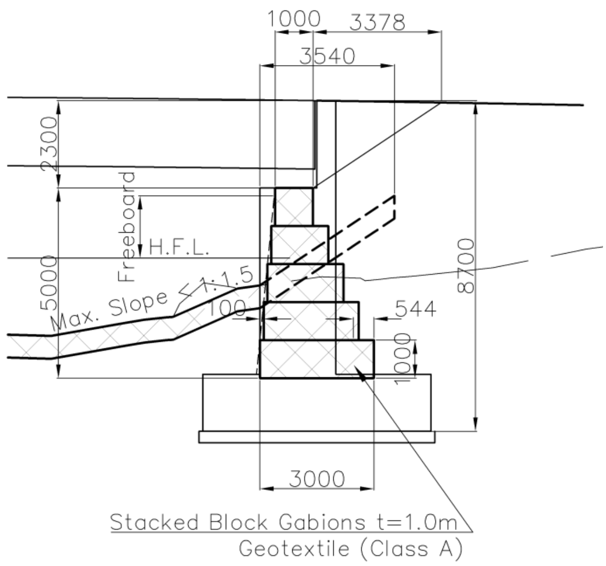
Installation slope of riprap = 1: 2

No.	Location		Slope of Stream Bed Upstream 200m	Slope of Stream Bed Downstream 100m	Velocity	Average Flow Depth	Bank angle with horizontal	Riprap material's angle of repose	Coefficient	Correction factor	Median Riprap particle size	Remarks
			tanθ (m/m)	tanθ (m/m)	V (m/s)	d_{avg} (m)	θ (H: L) (1: m)	ϕ (deg.)	K_1	C	D_{50} (m)	
	Barakilo - Barpak Road							41.0		1.00		
1	Khahare Khola	0+000.355	0.07142	0.07012	5.44	0.61	2.0	41.0	0.73	1.00	1.96	
2	Jhayalla Khola	0+000.866	0.03831	0.06485	5.03	1.41	2.0	41.0	0.73	1.00	1.02	
3	Ghatte Khola	0+000.461	0.08615	0.11851	4.90	0.69	2.0	41.0	0.73	1.00	1.34	
4	Rungrung Khola	0+002.138	0.06689	0.10219	7.04	1.06	2.0	41.0	0.73	1.00	3.22	
	District Road to Saurpani											
5	Daraudi Khola	0+013.313	0.01396	0.02565	5.76	1.31	2.0	41.0	0.73	1.00	1.58	

Installation slope of riprap = 1: 0 (0 deg.)

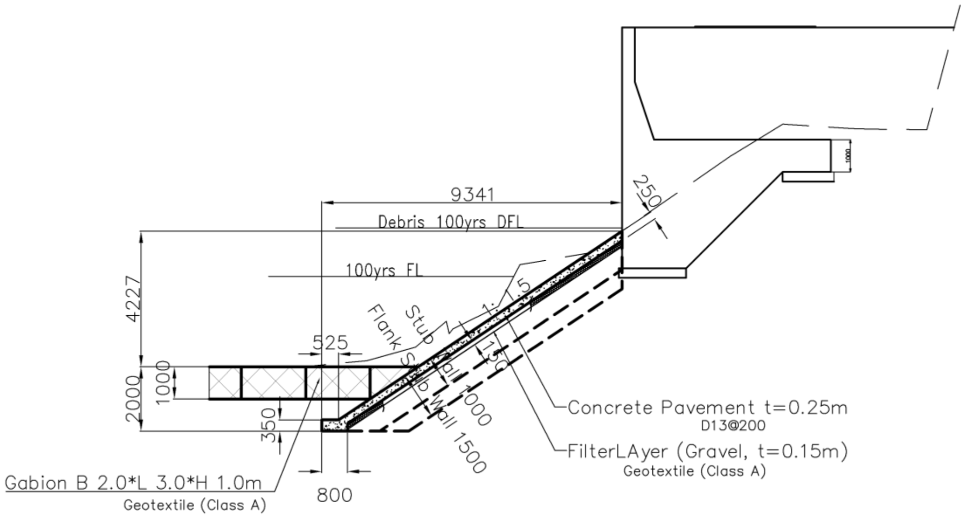
No.	Location		Slope of Stream Bed Upstream 200m	Slope of Stream Bed Downstream 100m	Velocity	Average Flow Depth	Bank angle with horizontal	Riprap material's angle of repose	Coefficient	Correction factor	Median Riprap particle size	Remarks
			tanθ (m/m)	tanθ (m/m)	V (m/s)	d_{avg} (m)	θ (H: L) (1: m)	ϕ (deg.)	K_1	C	D_{50} (m)	
	Barakilo - Barpak Road							41.0		1.00		
1	Khahare Khola	0+000.355	0.07142	0.07012	5.44	0.61	99999.0	41.0	1.00	1.00	1.22	
2	Jhayalla Khola	0+000.866	0.03831	0.06485	5.03	1.41	99999.0	41.0	1.00	1.00	0.64	
3	Ghatte Khola	0+000.461	0.08615	0.11851	4.90	0.69	99999.0	41.0	1.00	1.00	0.84	
4	Rungrung Khola	0+002.138	0.06689	0.10219	7.04	1.06	99999.0	41.0	1.00	1.00	2.01	
	District Road to Saurpani											
5	Daraudi Khola	0+013.313	0.01396	0.02565	5.76	1.31	99999.0	41.0	1.00	1.00	0.99	

Source: JICA Project Team



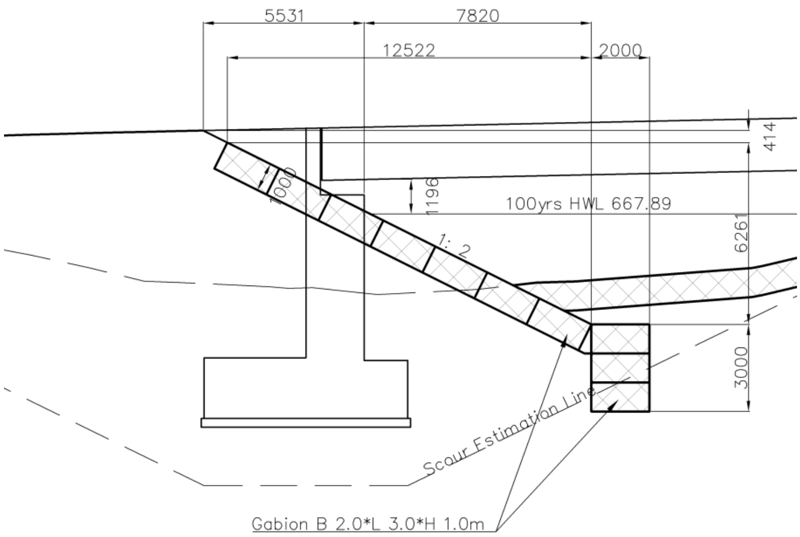
Source: JICA Project Team

Figure 9.4.43 Typical Cross Section of Stacked Block Gabions Revetment for Bridges



Source: JICA Project Team

Figure 9.4.44 Typical Cross Section of Concrete Revetment for Rangrung Bridge



Source: JICA Project Team

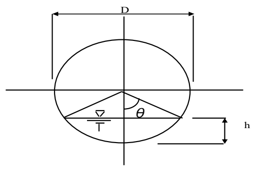
Figure 9.4.45 Typical Cross Section of Gabion Revetment for Daraudi Bridge

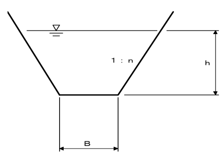
4) Temporary Diversion Channel

At the time of construction of each bridge, the main stream of the river will be diverted, since the construction will be performed by the open cut method. The magnitude of the diversion channel is decided by considering the statistical maximum flow-rate during the construction period. In this study, among the statistical discharges per drainage area of the past 20 years of the Chepe River, the 125th daily flow-rate from annual maximum, in other words the 240th flow-rate from annual minimum, is adopted as the criterial flow-rate at the construction time. The scale / dimensions of the temporary diversion channel of each bridge are shown in Table 9.4.41.

Table 9.4.41 Hydraulic Calculations and Sections for Temporary Diversion Channel

Bridge Name / Items		125th Average Q during 20 yrs records	125th Average Q during 20 yrs records	**125th Maximum Q during 20 yrs records**	**125th Maximum Q during 20 yrs records**	Remarks
No.1 Khahare Khola Bridge						
・ Circular section item						
Total flow rate	Q=	0.355	0.355	**0.591**	**0.591**	(m3/s)
Cell No.	N=	2	1	2	1	
flow rate:	Q=	0.178	0.355	0.295	0.591	(m3/s)
Diameter:	D=	0.60	0.60	0.60	0.60	(m)
Roughness coefficient :	n=	0.024	0.024	0.024	0.024	Coorrugated-metal pipe
Gradient of channel:	I=	70.12	70.12	70.12	70.12	(‰) Existing slope
・ Calculation result						
neutral depth :	h=	0.183 30.5%	0.265 44.2%	0.239 39.9%	0.360 59.9%	(m)
Area :	A=	0.073	0.121	0.105	0.177	(m2)
hydraulic radius :	R=	0.104	0.138	0.128	0.166	(m)
Water Velocity :	V=	2.437	2.948	2.807	3.339	(m/s)
full bobbin flow rate	Qm=	0.881	0.881	0.881	0.881	(m3/s)
Frude No.:	Fr=	2.144	2.094	2.118	1.945	
surface width :	T=	0.552	0.596	0.588	0.588	(m)
No.2 Jhayalla Khola Bridge						
・ Circular section item						
Total flow rate	Q=	0.866	0.866	**1.440**	**1.440**	(m3/s)
Cell No.	N=	2	1	2	1	
flow rate:	Q=	0.433	0.866	0.720	1.440	(m3/s)
Diameter:	D=	0.60	0.80	0.80	1.00	(m)
Roughness coefficient :	n=	0.024	0.024	0.024	0.024	Coorrugated-metal pipe
Gradient of channel:	I=	38.31	38.31	38.31	38.31	(‰) Existing slope
・ Calculation result						
neutral depth :	h=	0.358 59.6%	0.455 56.9%	0.406 50.8%	0.539 53.9%	(m)
Area :	A=	0.176	0.295	0.256	0.432	(m2)
hydraulic radius :	R=	0.166	0.216	0.202	0.262	(m)
Water Velocity :	V=	2.463	2.935	2.807	3.337	(m/s)
full bobbin flow rate	Qm=	0.651	1.402	1.402	2.542	(m3/s)
Frude No.:	Fr=	1.441	1.536	1.584	1.620	
surface width :	T=	0.589	0.792	0.800	0.997	(m)
No.3 Ghatte Khola Bridge						
・ Circular section item						
Total flow rate	Q=	0.461	0.461	**0.767**	**0.767**	(m3/s)
Cell No.	N=	2	1	2	1	
flow rate:	Q=	0.231	0.461	0.383	0.767	(m3/s)
Diameter:	D=	0.60	0.60	0.60	0.70	(m)
Roughness coefficient :	n=	0.024	0.024	0.024	0.024	Coorrugated-metal pipe
Gradient of channel:	I=	86.15	86.15	86.15	86.15	(‰) Existing slope
・ Calculation result						
neutral depth :	h=	0.198 33.1%	0.290 48.3%	0.261 43.5%	0.359 51.2%	(m)
Area :	A=	0.082	0.135	0.118	0.198	(m2)
hydraulic radius :	R=	0.111	0.147	0.137	0.178	(m)
Water Velocity :	V=	2.824	3.403	3.245	3.865	(m/s)
full bobbin flow rate	Qm=	0.976	0.976	0.976	1.473	(m3/s)
Frude No.:	Fr=	2.373	2.288	2.326	2.319	
surface width :	T=	0.564	0.600	0.595	0.700	(m)
No.4 Rangrung Khola Bridge						
・ Circular section item						
Total flow rate	Q=	2.138	2.138	**3.555**	**3.555**	(m3/s)
Cell No.	N=	2	1	2	1	
flow rate:	Q=	1.069	2.138	1.778	3.555	(m3/s)
Diameter:	D=	0.80	1.00	1.00	1.20	(m)
Roughness coefficient :	n=	0.024	0.024	0.024	0.024	Coorrugated-metal pipe
Gradient of channel:	I=	66.89	66.89	66.89	66.89	(‰) Existing slope
・ Calculation result						
neutral depth :	h=	0.436 54.5%	0.579 57.9%	0.517 51.7%	0.705 58.8%	(m)
Area :	A=	0.280	0.472	0.410	0.691	(m2)
hydraulic radius :	R=	0.211	0.273	0.255	0.330	(m)
Water Velocity :	V=	3.816	4.531	4.337	5.143	(m/s)
full bobbin flow rate	Qm=	1.852	3.359	3.359	5.462	(m3/s)
Frude No.:	Fr=	2.057	2.094	2.163	2.148	
surface width :	T=	0.797	0.987	0.999	1.181	(m)
No.5 Daraudi Khola Bridge						
・ Trapezoid section item						
flow rate :	Q =	13.313	13.313	**22.142**	**22.142**	(m3/s)
Bottom width :	B =	3	8	5	13	(m)
Side gradient :	1: n =	2.000	2.000	2.000	2.000	
Roughness coefficient :	n =	0.03	0.03	0.03	0.03	Riprap
Gradient of channel :	I =	1.396	1.396	1.396	1.396	(%) Existing Slope
channel height :	H =	1.60	1.20	1.60	1.20	(m)
Upper width :	B2=	9.40	12.80	11.40	17.80	(m)
・ Calculation result						
neutral depth :	H =	0.938 58.6%	0.583 48.6%	0.991 61.9%	0.597 49.8%	(m)
Area :	A =	4.574	5.344	6.919	8.474	(m2)
hydraulic radius :	R =	0.636	0.504	0.734	0.541	(m)
Water Velocity :	V =	2.911	2.493	3.203	2.614	(m/s)





Source: JICA Project Team

9.4.4 Construction Plan / Procurement Plan

(1) Construction Policy

1) Principle

The executive agency of the project is DoR under the MoPIT and the local supervision of the construction work is carried out by the project management office for the improvement project of Barhakilo-Barpak Road.

- In accordance with the Japan's Grant Aid Scheme, the E/N was signed between the Japanese Government and GoN, and the signing of the G/A between JICA and GoN followed the E/N.
- The Japanese consultant assigned by JICA assumes the detail design, preparation of the tender documents, support for tendering, and supervision of the construction work.
- The contractor was selected through tendering and be adjudicated by the client. After signing of the contract, the contractor started procurement of materials, preparation of yards near the construction sites, and the construction work followed the arrival of materials.
- After signing of the E/N, the Nepal side shall conclude the Banking Arrangement (B/A) with the Bank in Japan immediately, issue the Authorization to Pay (A/P), and take necessary measures in cooperation with the MoF to exempt customs duties, internal taxes and other fiscal levies which may be imposed in Nepal with respect to the purchase or import of materials procured by the contractor.

2) Construction Method

Daraudi Khola Bridge is located in the middle of the project area, 2 bridges are located upstream of the Daraudi Khola Bridge and 2 bridges are located downstream. Therefore, construction of these bridges are recommended to be completed by 3 construction teams, one is in charge of the construction of Daraudi Khola Bridge, one is in charge of the construction of Khahare Khola Bridge and Jhyalla Khola Bridge and the last one is in charge of the construction of Ghatte Khola Bridge and Rangrung Khola Bridge.

It will be necessary to secure a large scale construction yard near Daraudi Khola Bridge construction site, therefore, a site office for both the Contractor and the Consultant and a stock yard for material and equipment are recommended at this location.

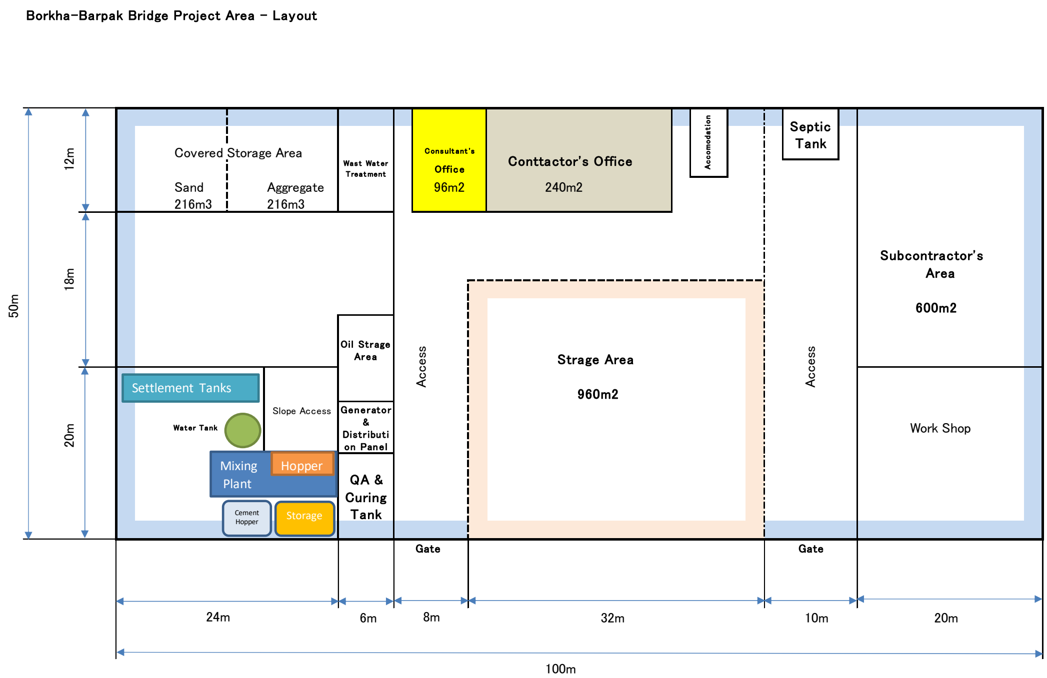
In addition, the pre-stressed concrete bridges which will be built in this project are rare in Nepal. Therefore, the Japanese side will arrange technical transfer to local technicians and counterparts.

(2) Direct Construction Work

1) Preparation

As explained in previous sections, it is planned to prepare a main construction yard which includes site offices for both the contractor and the consultants and a stock yard for equipment and material at the construction site for Daraudi Khola Bridge.

Expected area for the main construction yard is 100m x 50m as shown in Figure 9.4.46. Temporary fences will be installed around this main construction yard. Because local villages and the existing Barhakilo-Barpak Road are near this main construction yard, a resident guard will be assigned in order to avoid property loss.



Source: JICA Project Team

Figure 9.4.46 Plan View of Main Construction Yard (Draft Idea)

2) Foundation and Substructure

a) Structural Excavation

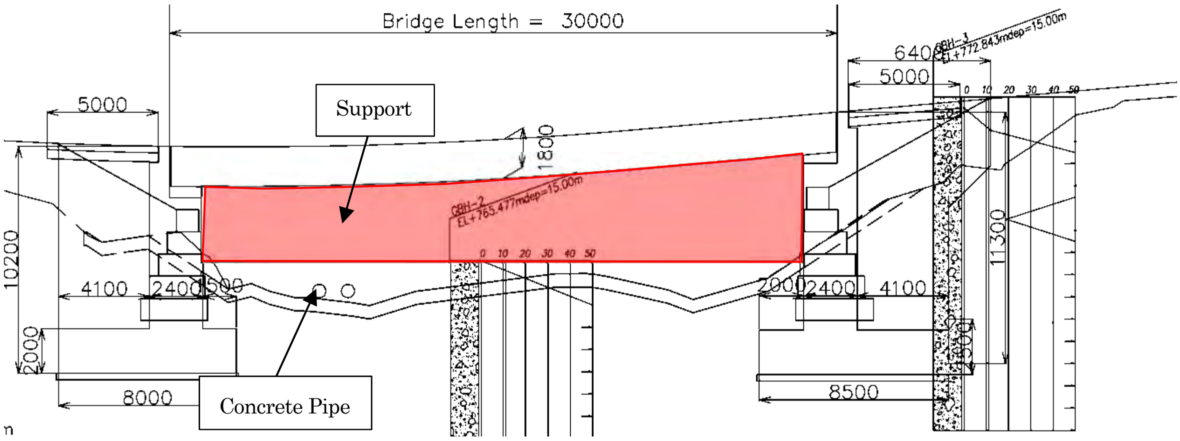
Due to deep excavation (3 to 4m depth), installation of a temporary cofferdam of steel sheet pile is considered for structural excavation work. However, the geological condition at the site is a very hard gravel layer, therefore, installation of steel sheet pile is planned to be carried out by a compress machine with an auger all of which is imported from Japan.

b) Production of Fresh Concrete

The construction site is located in a mountainous area, and it is impossible to purchase fresh concrete from a manufacture. However, it is necessary to use concrete produced with good quality control, because this subproject is for construction of bridges. Therefore, a batching plant for concrete will be mobilized at the main construction yard. From this construction yard, fresh concrete will be transported by concrete mixer car to each bridge construction site.

3) Superstructure

The superstructure type for this subproject is PC 2 Main Girders and PC Box Girder which will be constructed by the All Staging Method. Basically, casting of concrete will be executed in the dry season. During construction of the superstructure, concrete pipe will be installed in the river bed as shown in Figure 9.4.47, in order to secure the space for river water flow.



Source: JICA Project Team

Figure 9.4.47 Sketch for Construction of Superstructure

(3) Supervisory Service Plan

1) Consultant's Supervision

For smooth implementation of the project, the consultant will execute its professional service including the following;

- To completely understand the contents of the E/N signed between GoN and Japanese Government
- To completely understand the contents of the G/A signed between GoN and JICA
- To confirm the details of the obligations of the Nepal Side and its progress, and to coordinate with the Client to complete some matters that should be done before commencement of the work, in accordance with the construction schedule.
- To confirm the implementation of measures for exemption of tax or customs imposed in Nepal for import of materials and to obtain the necessary support for the executive agency.

2) Detail Design

The detail design consists of local study and analysis in Japan.

a) Field Survey

The following information should be collected and confirmed in the site for the detail design;

Natural condition, Geological condition, Procurement condition of materials, Procurement condition of labour, Topographic data, and other issues that were not confirmed in the basic design stage.

Furthermore, the obligations to be covered by the Nepal side should be confirmed in this stage, including the responsible division and prospect of budget.

b) Analysis in Japan

Following the survey in Nepal, structural calculations, hydraulic analysis, detail drawing and tender documents are prepared and the construction schedule is planned.

3) Supporting Work for Tender

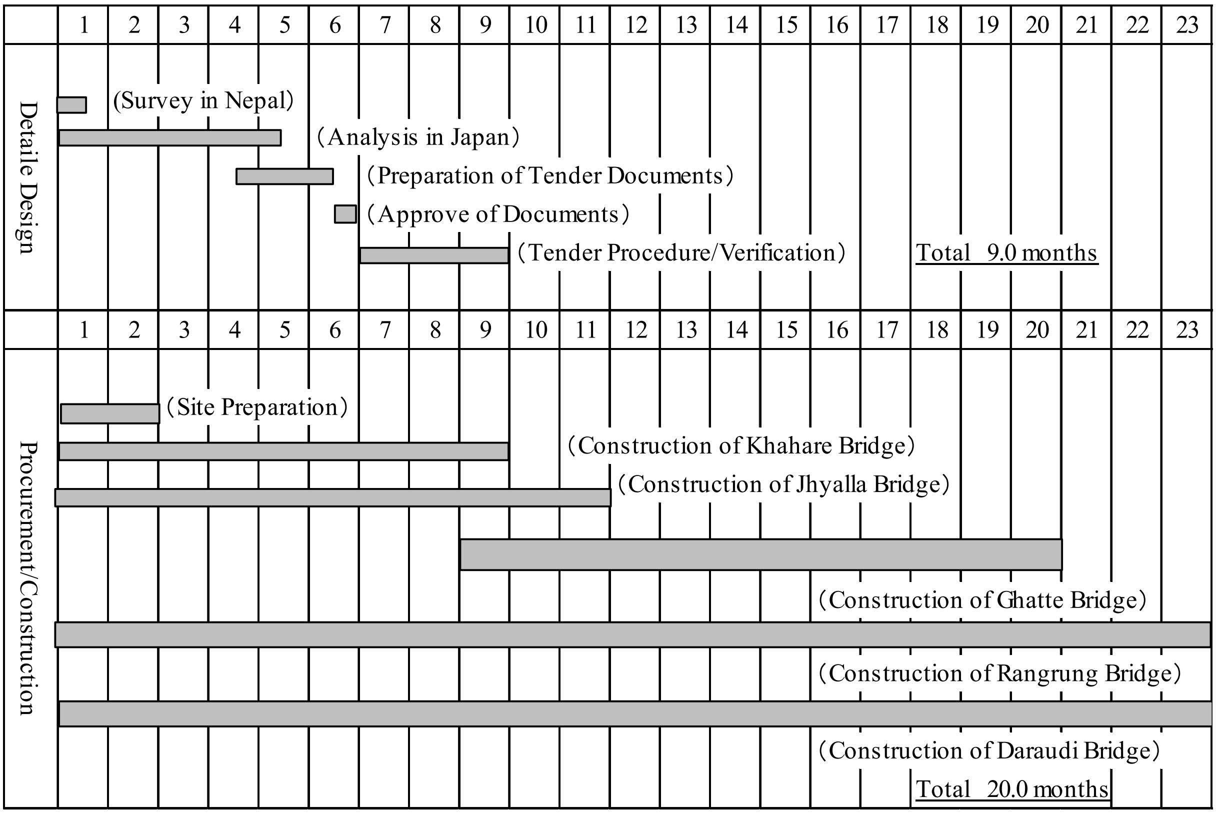
The consultant shall assist the client in the following manner; preparation of the tender documents, approval by the client, distribution of the tender documents, evaluation of the tender and conclusion of the contract.

4) Supervision

The consultant will enter Nepal country in accordance with the construction schedule prepared by the contractor for site investigation and coordination with the related agencies in Nepal. After that the consultant’s permanent supervisor will execute its supervisory work.

(4) Implementation Schedule

Table 9.4.42 Implementation Schedule



Source: JICA Project Team

The basic construction for this implementation schedule is shown below;

Table 9.4.43 Preconditions of estimated schedule

Items	Time
Exchange of Note (E/N)	End of December 2015
Grant Agreement (G/A)	Middle of February 2016
Agreement for Consulting Service	Beginning of March 2016
Prequalification	Beginning of August 2016
Contract for Contraction Work	End of October 2016
Starting of the works	Beginning of November 2016
Completion of the works	End of June 2018

Source: JICA Project Team

9.5 The Subproject of Rehabilitation of Water Transmission System in Chautara

9.5.1 Design Condition / Natural Condition

(1) General

Chautara Municipality, known as a central city in the Sindhupalchok District, is one of the cities that were seriously damaged by the Nepal Earthquake. Most of the public and private buildings were destroyed and various forms of assistance are required for recovery of their standard of living.

Three water sources are located in the mountain area more than 10 km away from Chautara city. The water transmission pipeline was damaged by a landslide, unexpected movement and disconnection of joints, so that the water supply had to be suspended for two weeks due to this serious damage. Immediately after the earthquake, these transmission pipelines were repaired temporarily by efforts of WSSDO and WUSC with support from the Nepal Military Force.

However these pipelines were repaired by a simple method with simple materials that were easy to procure at that time. In addition, the actual pipeline route is in danger and could easily be damaged by further landslide and the major part of the pipeline is exposed on top of the ground. The existing pipeline is at a great and obvious risk of being damaged by earthquake and land slide.

This project aims at the enhancement of the transmission capacity, stability and toughening of transmission system through changing existing pipes for ductile iron pipes with earthquake resistant mechanism through Japan's Programme Grant Aid Scheme.

<u>Actual Scheme of Transmission Pipeline</u>

The facilities to be rehabilitated are the water intake chambers located in the northern area, transmission pipeline and miscellaneous facilities such as air valves and washout valves.

1) Holche Transmission Scheme

The Holche scheme highly needs to be renewed among the existing schemes.

This pipeline was constructed around 40 years ago and is the oldest scheme in Chautara. The major part of the pipeline consists of cast iron and galvanized steel. Many sections are exposed on the surface of the earth and risk damage by land slide.

Some damaged parts were temporally repaired with polyethylene pipe, but there is still a high risk of rock falling or load by a passing vehicle.

2) Majuwa and Thalkharka Transmission Scheme

These schemes were constructed after operation of the Holche line, and about 25 years have passed since their construction. Each line was constructed at a different time and has an independent water source. Both transmission lines are equally important but the actual situation after repairing is similar to the Holche line. The installation route of the Majuwa line is very close to the Thalkharka line, and their hydraulic conditions are similar to each other. Therefore, it will be possible to unify the two lines into one line for further efficient operation unless the demand for water becomes much higher than the actual flow.

However, there are many branch points directly connected with the transmission pipe for water supply to some small settlements located near the pipeline, and it will be necessary to prepare tapping saddles to supply water from the new pipeline.

3) Area surrounding the water sources

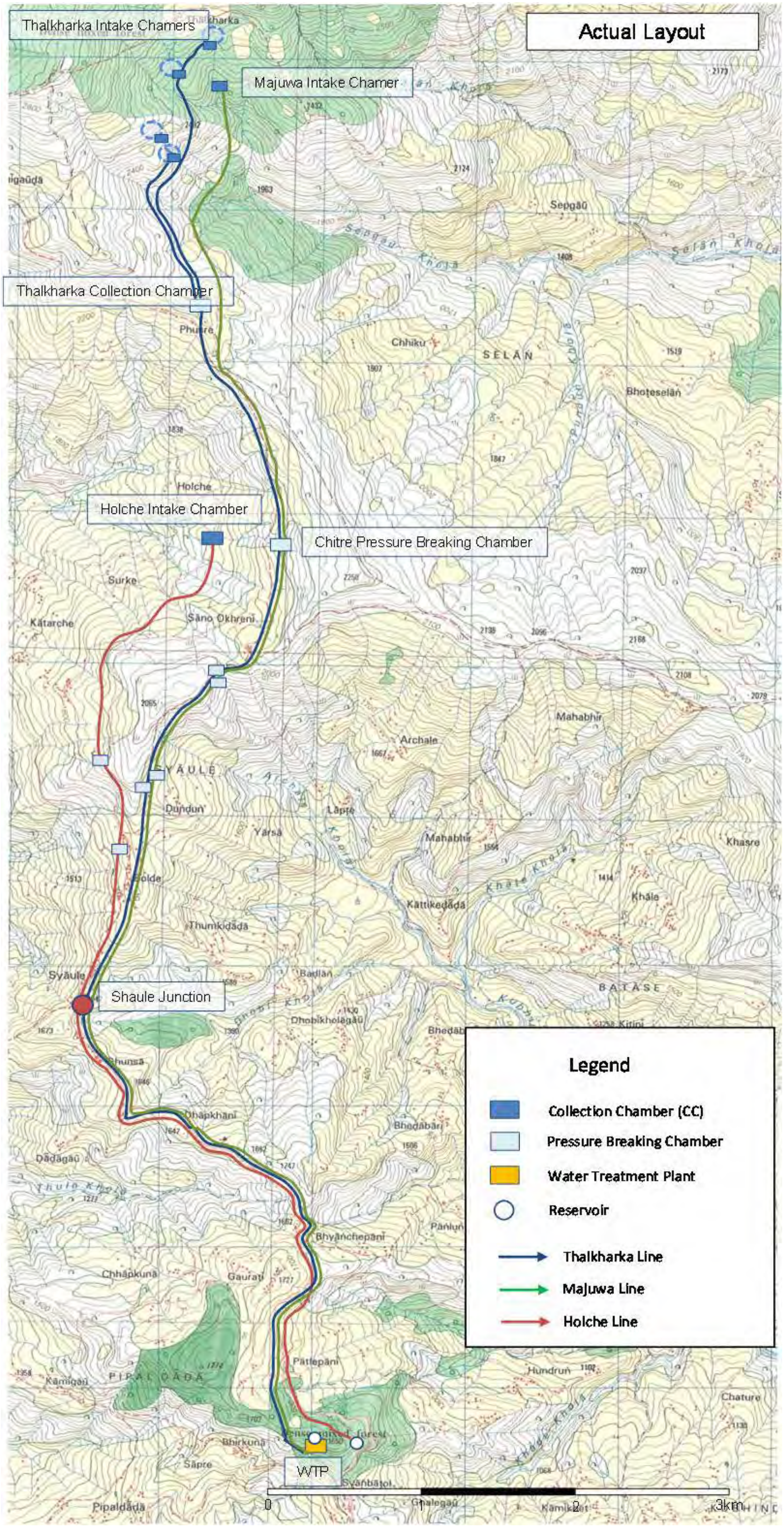
Each water source has a collection chamber to collect water from the intake. The chamber located in Majuwa is in normal condition and no significant damage was observed. However, the chamber of Thalkharka has been damaged by the earthquake and some leakage from the wall is observed, and the chamber of Holche has also big leaks on the base slab and wall, and it is impossible to repair the chamber.

Considering the above mentioned situation, the chambers of Thalkharka need to be repaired by constructing a new reinforced concrete structure inside the existing stone masonry chamber. The chamber of Holche needs to be newly constructed.

The existing pipelines located near the water source were also damaged seriously, but now they have been temporally repaired by the WSSDO. However, most of the pipelines are located on the slope of the mountain with weak support and is always in danger of landslides.

In consequent of the study in Japan, the renewal of these pipelines located in the water source area has been excluded from this Grant Aid Programme, but other possible measures remain under consideration for other cooperation schemes.

The current layout of the transmission pipeline system is shown in the next page.



Source: JICA Project Team

Figure 9.5.1 Locations of the Existing Transmission Pipelines

(2) Basic Policy

1) Superior Objective and Project Objective

Superior objective : The water supply condition in Chautara is improved.

Project objective : Stable water supply is available to residents in Chautara and settlements located along the supply pipeline.

2) BBB Concept

It is important to rebuild a society stronger after a disaster than before. At this time when many restoration and reconstruction projects have been started following the emergency recovery work implemented immediately after the earthquake, the BBB Concept should be materialized through this sub-project.

3) Target year

This project is being implemented to contribute to stabilize the water supply in Chautara and to provide the basic infrastructure for smooth restoration activities in the future, through improvement of water conduction facilities that were damaged by the earthquake.

This project is an assistance that aims principally at smooth restoration of damaged facilities. Confusion caused by the earthquake still remains in the project area, such as many destroyed buildings, involuntary resettlement, or debris clearance problems. Therefore it is unreasonable to establish a concrete target year for this project.

However, the potential of new water sources for future development should be considered in determining the design capacity, in addition to the actual intake capacity of water and to the capacity of the existing water treatment plant, to make the future extension of the water supply service projected by WSSDO possible.

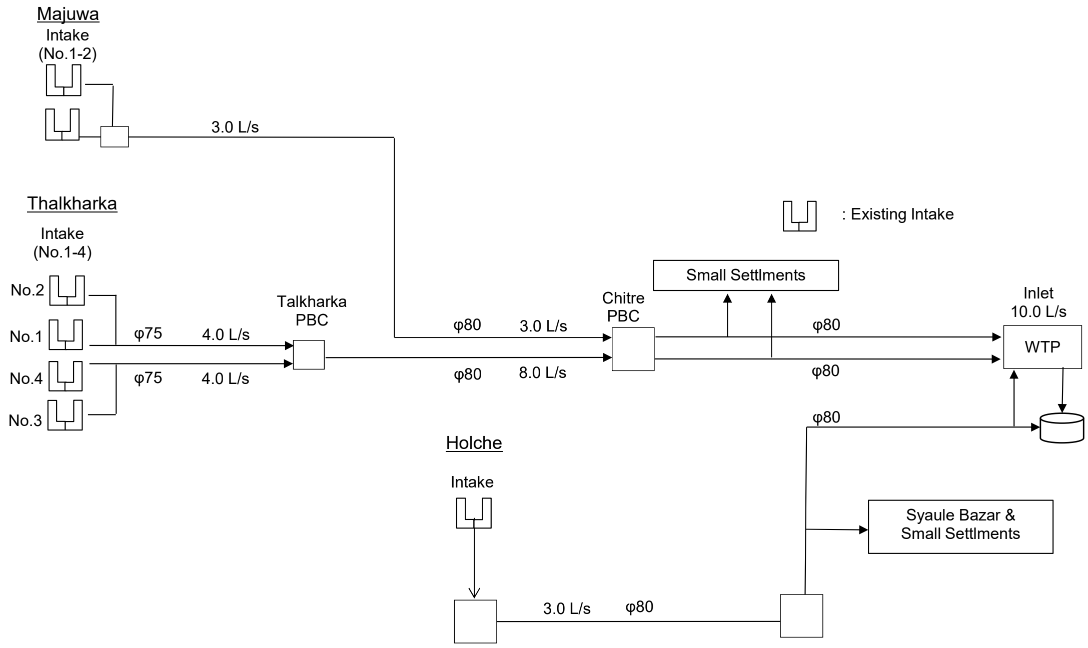
(3) Actual Water Source and Transmission Facilities

Raw water collected by the chambers in the three water sources, Holche, Majuwa and Thalkharka is transmitted by galvanized iron pipes of 75/80mm in diameter, where some parts consist of HDPE, to Chautara City.

On the way to Chautara, there are many branch connections with 20mm diameter to supply water to some small villages and settlements.

Since constructing the actual system, the water flow has not been measured, so that the water supply volume is estimated from the water source capacity at the time of construction.

The actual system of water transmission in Chautara is shown below, and the capacity of each pipeline is estimated based on the topographical survey result;



Source: JICA Project Team

Figure 9.5.2 Actual System of Water Supply

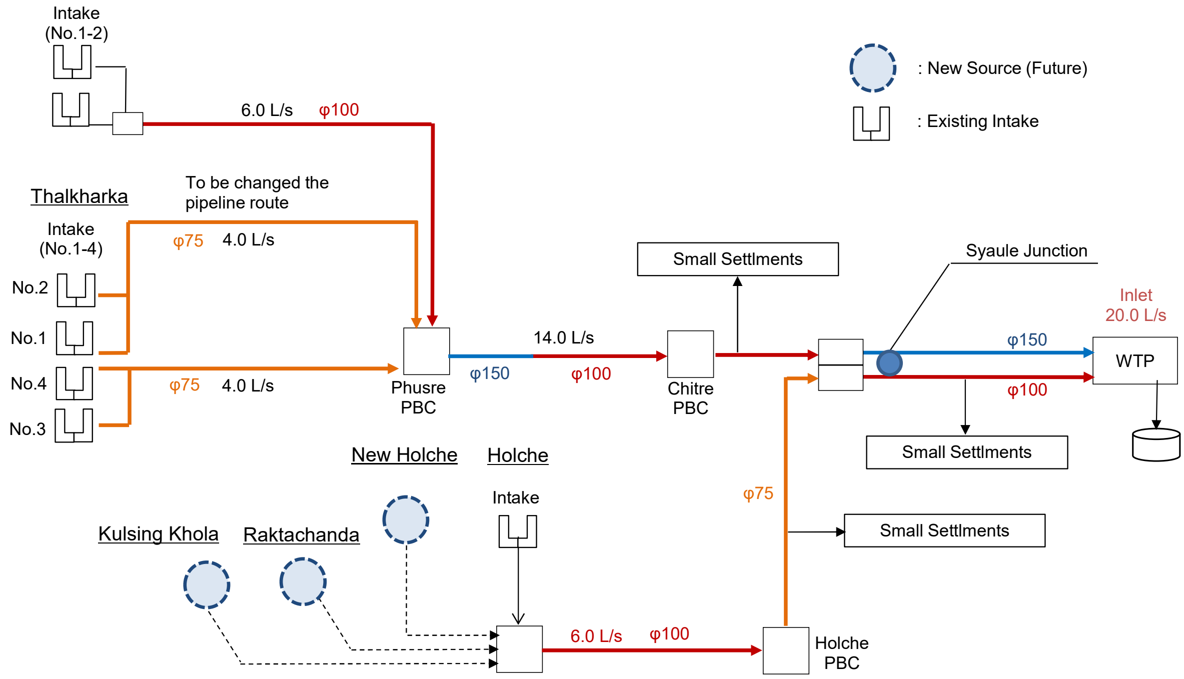
Table 9.5.1 Evaluation of Pipeline Capacity

Section		Evaluation
Origin	Destination	
Majuwa Collection Chamber	Chitre Pressure Breaking Chamber	In the actual route, one short section of 600m in length has the highest elevation and 3 L/sec is the approximate maximum flow due to the actual hydraulic condition. There are two inlet lines from the intakes. Although only one intake line is used in the rainy season, the water overflows from the chamber due to abundant supply. Therefore, it is recommended to change the pipeline to a larger diameter to make the hydraulic condition favourable.
Thalkharka Collection Chamber	Thalkharka Pressure Breaking Chamber	For the actual water flow is 4 L/sec by each line so there is no problem in the actual hydraulic condition with sufficient difference of elevation between both chambers.
Thalkharka Pressure Breaking Chamber	Chitre Pressure Breaking Chamber	For the actual water flow, there is no problem in the actual hydraulic condition with sufficient difference of elevation between both chambers.
Chitre Pressure Breaking Chamber	Water Treatment Plant	There are several chambers to reduce pressure in this section, because of the large difference in elevation. For the actual water flow, there is no problem in the hydraulic condition.
Holche Intake Chamber	Water Treatment Plant	In the section from the Holche chamber to a point 3 km from the origin, the difference in ground elevation is very small and it is estimated that the water flow is limited to 3 L/sec. In the Holche area, some new water sources were founded by the WSSDO, but these sources have not been developed due to the limitation of water transmission capacity. Beyond the point 3 km from the origin, there are several chambers to reduce pressure in this section, because of the large difference in elevation. For the actual water flow (3 L/sec), there is no problem in the actual hydraulic condition.

Source: JICA Project Team

(4) Water Transmission Scenario

Prior to determination of the renewal planning for the transmission pipeline, the following scenario was projected as a design basis. The below mentioned flow value is established in consideration of the request of the Nepal side, the possible capacity of water sources in the future and the capacity of the existing water treatment plant



Source: JICA Project Team

Figure 9.5.3 Water Transmission Scenario

[Holche Transmission Line]

The possible volume of water intake is established as 6.0 L/sec including surrounding water sources. To improve the actual hydraulic condition, the diameter of the pipes should be changed to 100mm in the principal section. The short section with steep slope is designed with the diameter of 75mm to assure a balance of water flow and velocity.

[Majuwa Transmission Line]

The possible volume of water intake is established as 6.0 L/sec considering the actual overflow of water in the rainy season. To enable the pipes to be connected with the New Phusre pressure breaking chamber (PBC), the route of a part of the section needs to be changed to a diameter of 100mm for good hydraulic condition.

[Thalkharka Transmission Line]

The possible volume of water intakes (No.1 to No.4) is established as 8.0 L/sec, and the future intake volume is assumed to be the same as the current capacity.

However, there is a possibility of changing the pipeline alignment that comes from the Intakes No.1 and No.2 for a safer route near the Majuwa line, and this new route has been proposed in the outline design stage.

[Common Line of Thalkharka and Majuwa Line]

The pipeline between the Phusre PBC and the Chitre PBC will consist of 150mm diameter on upstream section and 100mm on other section.

The section between the Phusre PBC and the Syaule Junction has a favourable hydraulic condition due to the large difference in ground elevation, so that the existing 2 pipelines can be unified into 1 line. In this case, the upstream short section will be 150mm diameter and the remaining section will be 100mm diameter.

The section beyond the Syaule Junction to the water treatment plant follows the road slope gently down and the pipe diameter should be 150mm to secure the suitable hydraulic condition.

(5) Miscellaneous Facilities

1) Pressure Breaking Chamber (PBC)

In this design, 2 PBCs in the Holche transmission line and 5 PBCs in Thalkharka/Majuwa Line are projected. The detail locations and their quantities were determined based on the topographical survey carried out in the dry season.

However, it is important that the locations for these chambers shall be secured and provided by the Nepal side in the implementation stage.

2) Capacity of the Existing Water Treatment Plant

The water treatment plant located in the northern part of Chautara City was constructed about 10 years ago by the DWSS/WSSDO. This plant consists of 1 rough filtering basin and 3 slow sand filtering basins. The quality of water is fully pure even in rainy season, and the appearance of high turbidity is seldom observed. For this reason, the water condition is suitable for slow sand filtering systems.

The dimension of the sand filtering basin is 15.5 m x 8.2 m (127.1 m^2), and with the two basins, the treatment capacity will be about 15 L/sec under the filtering ratio of 5 meters per day.

In the above mentioned water conduction scenario, the total volume of transmitted water is established as 20 L/sec, but the practical amount of water that can reach the treatment plant will be less than 20 L/sec, due to many branch connections along the pipeline. Therefore, the existing treatment plant has an adequate capacity for the estimated scenario.

3) Branch Connection for the small settlements

On the Holche Line, there are some branch connections to supply water for the small settlements located along the pipeline route. One of these settlements is known as Syaule Village.

This village has been accustomed to enjoying the benefit of Holche Water for a long time, and is not willing to change their water source or mix with the different sources. For this reason, it is difficult to unify the existing three pipelines into one line and the Holche line has to be maintained independently.

On the other hand, the Thalkharka line and Majuwa line also have service branches for other small settlements, but mixing the water will not cause problems because the water sources of the two lines are located in the same area.

For the above mentioned reason, the tapping saddles for branch connections should be installed on the pipeline that will be newly constructed by this project.

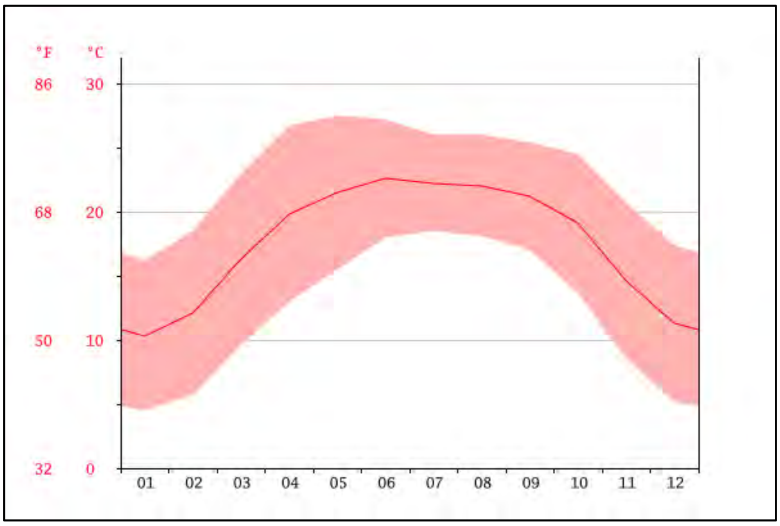
(6) Policy for the Natural Condition

The climate of the project site belongs to the subtropical type, and a year is clearly divided into monsoon season (from June to September) and dry season (from October to May).

The annual precipitation is around 2,500mm, and 80 % of the annual precipitation concentrates in the rainy season.

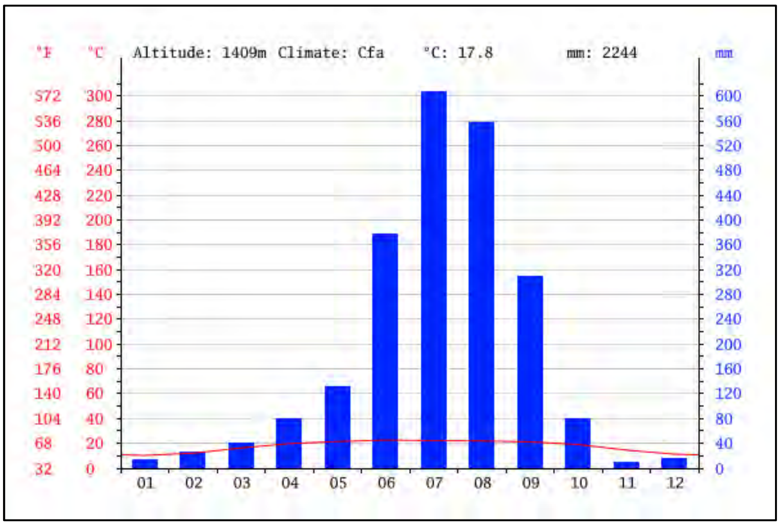
There are especially many sections damaged by landslide on the transmission pipeline route. Some parts of the pipeline must be located in the mountainous area characterized by its steep slope, and the working condition is extremely severe.

Therefore such special conditions should be considered in planning of the material transportation and construction schedule.



Source: http//en.climate-data.org

Figure 9.5.4 Average Temperature in Chautara



Source: http//en.climate-data.org

Figure 9.5.5 Average Precipitation in Chautara

(7) Policy for the Social-economical Condition

The water supply system is operated by gravity flow, and there will be no cost for electricity even after rehabilitation. The condition for daily maintenance, operation and control of service branch connections will also stay the same.

There are some settlements along the new pipeline route with less than one hundred households, and it is necessary to install some branch saddles on the new pipeline to maintain the water service condition for such settlements.

(8) Policy for Laws, Norms and Standards

This project aims at rehabilitation of the existing transmission pipeline, and it is not especially required to consider laws, norms and standards.

Although it is unavoidable to change topographical features on the pipeline route, the most part of the construction work is on the existing roads or unused lands, and the negative impact to the environment is expected to be very small.

(9) Capacity of Executive Agency for Operation and Maintenance

The piping materials for this project have been commonly used in Kathmandu, and special techniques or special experience in operation will not be required.

For installation of the service branches for water supply to small settlements, an exclusive branch material for the ductile iron pipe shall be needed. It is necessary to guide the local technical staff to maintain suitable maintenance through installation work with staff of the executive agency.

(10) Policy for Grade of Facilities and Equipment

Most parts of the existing pipeline consists of galvanized iron pipe (steel pipe) with screw type couplings.

This steel pipe has an advantage in its light weight, high strength in tension and bending, and high shock resistance, but most of the pipes have been damaged by earthquake due to of lack of flexibility and elasticity.

Although the ductile iron pipe has a disadvantage in its weight, it is commonly used for water transmission lines because it has a high shock resistance and a flexibility to be able to follow the ground movement. The push-on joint of ductile iron pipe is easy to connect, and has the option of an advanced joint design which can avoid joint separation by ground movement. Furthermore, the pipe can be installed and directly backfilled with earth in the trench if the base of the excavated trench is almost smooth.

Considering the above mentioned matters, the ductile iron pipe should be adopted for this project under the BBB Concept to minimize the risk of disasters, such as further earthquake or natural land slide. The joint system of such pipe shall be the push-on type with anti-separation mechanism (earthquake-resistant).

(11) Policy for Construction Method, Procurement Method and Work Period

1) Security of Construction Work

Some areas of the construction site are located in a mountainous area, so the accessibility is very difficult in the rainy season.

Furthermore, most parts of the roads are narrow and impassable for large construction machines, such as a dump trucks or crane vehicles, so that the major part of excavation and installation works depends on human power.

The sufficient amount of materials for temporary works will be also needed for worker's security in the mountain area.

2) Suitable Installation Depth

The existing road is located in a mountainous area and its surface is not paved. This surface condition is one cause of land corrosion by strong rainfall and unexpected pipeline damage is then caused by vehicle load.

Considering the above mentioned condition, the projected depth of the new pipeline shall be resistant to such natural phenomenon. Therefore, the depth of 1.0 meter in the traffic road and 0.6 meter on the mountain trail will be projected.

3) Ground Installation

During installing the pipeline on the trail, some difficulty of work is expected due to exposing of rock or steep slope, or impossibility of access by vehicle. In this case, the ground installation with concrete support should be applied.

(12) Policy for Construction in the Land Slide Section

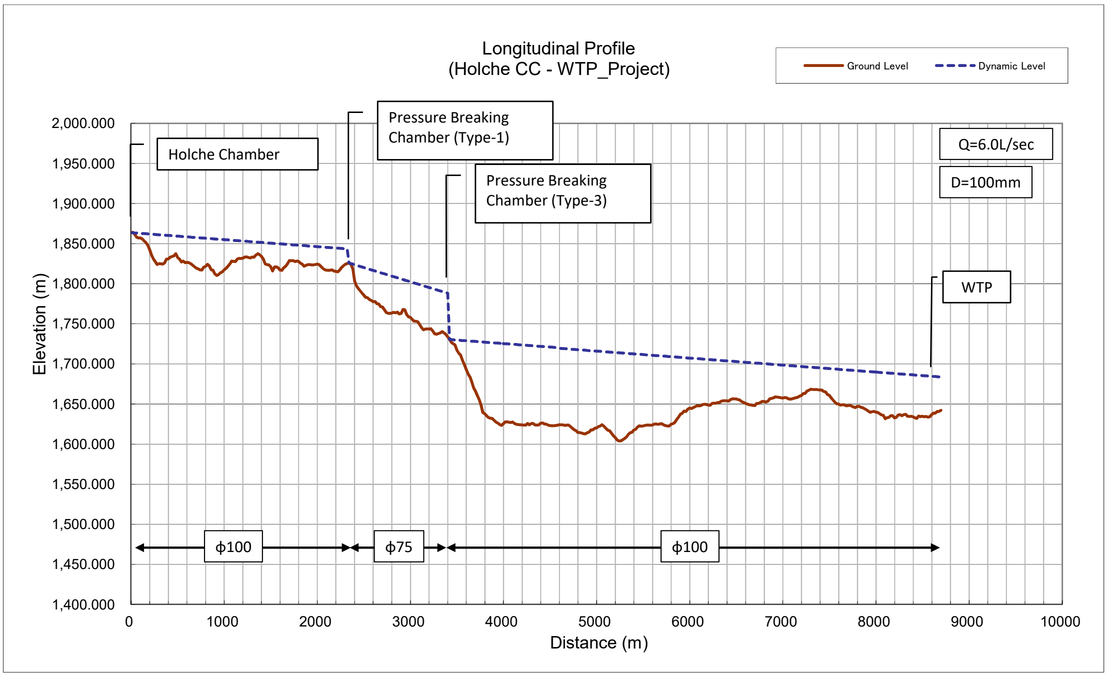
Among the existing three pipelines, the Holche line has a section that was damaged by a large scale rock slide about 150 meters long. Now this section is in a dangerous situation and the full consideration of safety will be needed.

If it is considered to be difficult to assure safety in this section at the time of detail design stage, the work of pipeline that corresponds to such condition shall be excluded from the scope of work designated for a Japanese Contractor, and this section should be installed with temporary polyethylene pipe. However, the material for the pipes (DIP) should be procured by the Japanese side and handed over to the Nepal side for future installation on a community basis.

9.5.2 Outline design

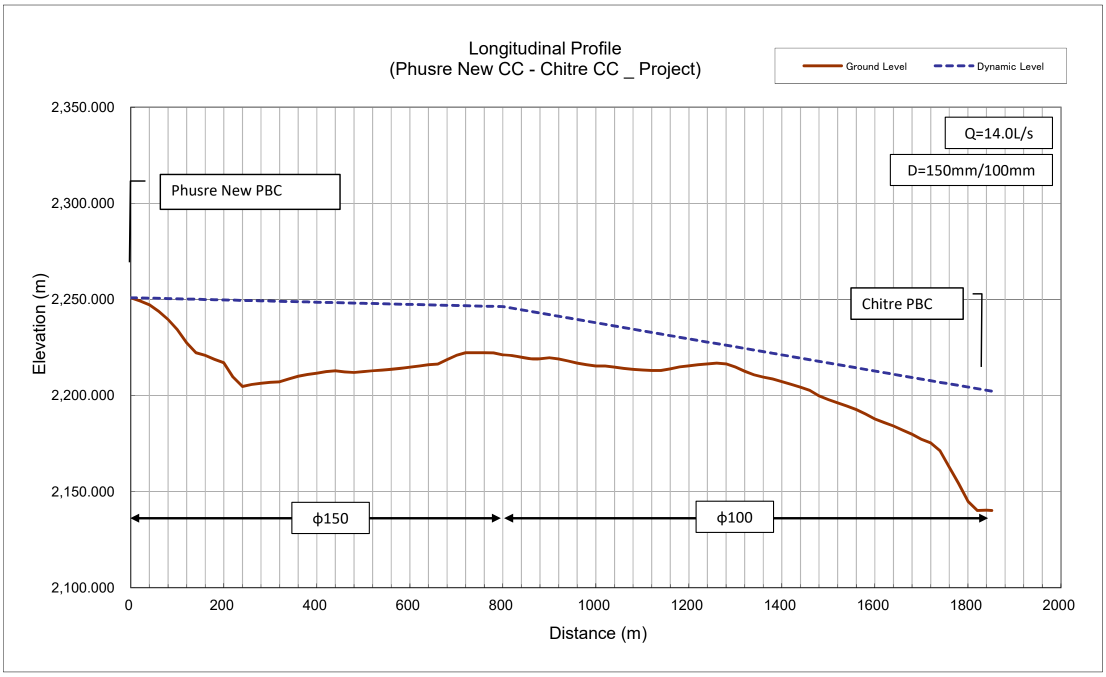
The drawings for the outline design are attached in the annex.

The hydraulic condition of the targeted pipeline is confirmed by the topographical survey conducted between October and November 2016 as shown below.



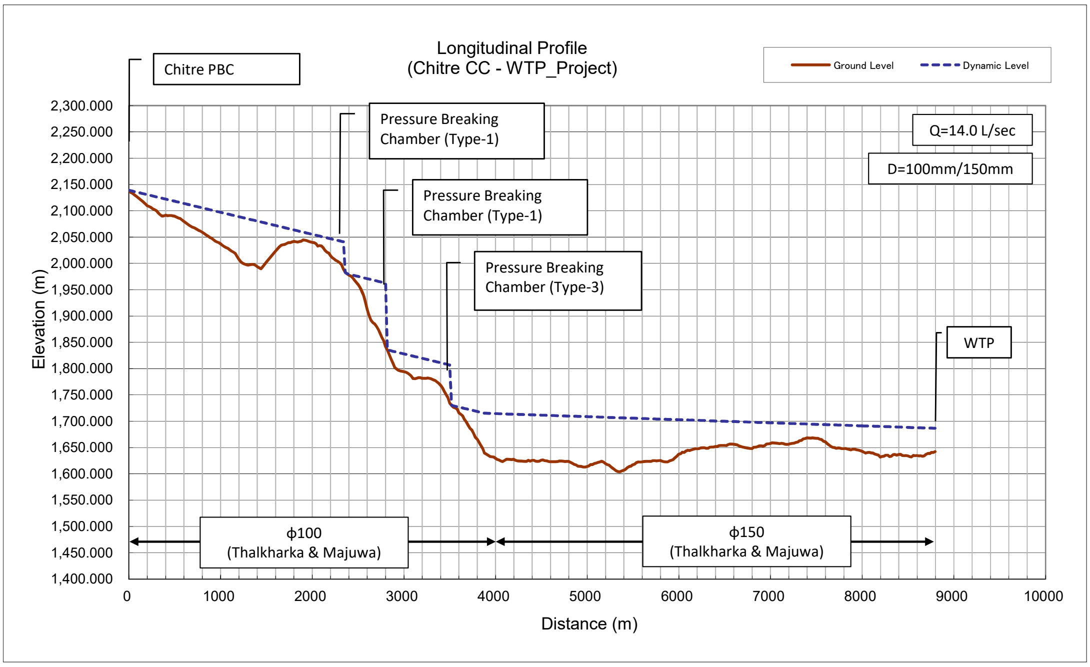
Source: JICA Project Team

Figure 9.5.6 Hydraulic Gradient (C2-C1, Between Holche Intake and WTP)



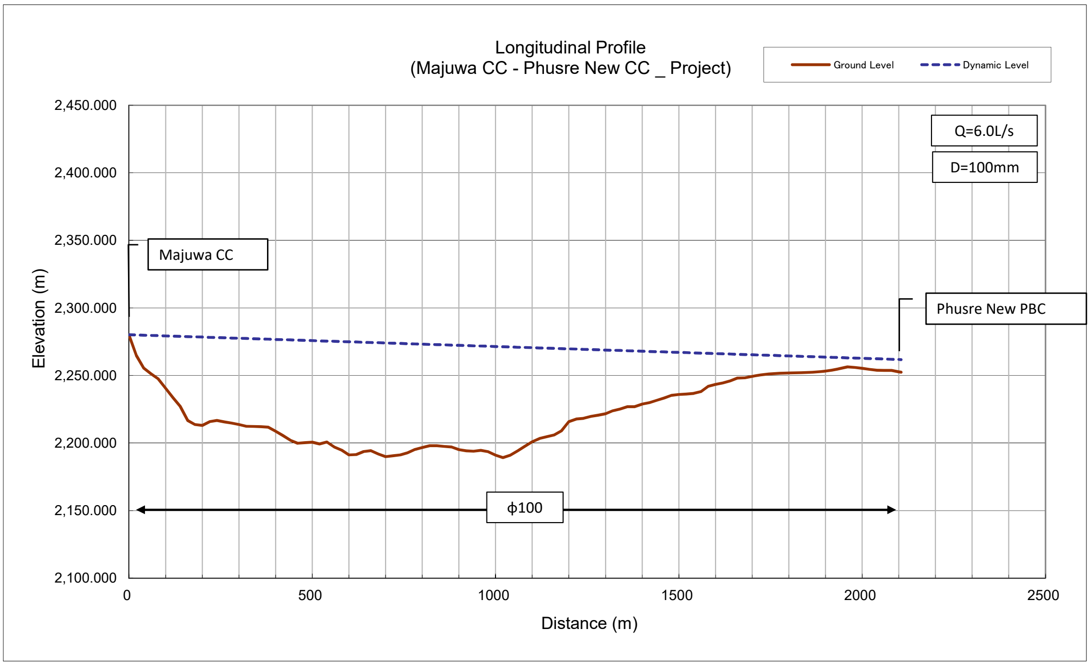
Source: JICA Project Team

Figure 9.5.7 Hydraulic Gradient (C4, Between Phusre PBC and Chitre PBC)



Source: JICA Project Team

Figure 9.5.8 Hydraulic Gradient (C3-C1, Between Chitre PBC and WTP)



Source: JICA Project Team

Figure 9.5.9 Hydraulic Gradient (Between Majuwa Intake and Phusre PBC)

Table 9.5.2 Detail of Pipe Installation Work

［C1: From Shaule to WTP］

Station No.	Pipe	Condition	Type	Air Valve	Washout	PBC
0+000 – 3+840 (L=3,840m)	φ100 (Holche)	Traffic Road	Underground	9	9	-
	φ150 (Thalkharka)	Traffic Road	Underground	9	9	-
3+840 – 4+080 (L=240m)	φ100 (Holche)	Trail	Underground	-	-	-
	φ150 (Thalkharka)	Trail	Underground	-	-	-
4+080 – 4+280 (L=200m)	φ100 (Holche)	Trail	Ground	-	-	-
	φ150 (Thalkharka)	Trail	Ground	-	-	-
4+280 – 4+730 (450m)	φ100 (Holche)	Trail	Underground	2	3	-
	φ150 (Thalkharka)	Trail	Underground	2	3	-
4+730 – 4+760 (30m)	φ100 (Holche)	Trail	Ground	1	-	-
	φ150 (Thalkharka)	Trail	Ground	1	-	-
4+760 – 4+918 (158m)	φ100 (Holche)	Trail	Underground	-	1	-
	φ150 (Thalkharka)	Trail	Underground	-	1	-
L=4918m			Total	24	26	-

Source: JICA Project Team

［C2: From Holche Intake to Shaule］

Station No.	Pipe	Condition	Type	Air Valve	Washout	PBC
0+000 – 0+130 (L=130m)	φ100 (Holche)	Trail	Underground	1		
0+130 – 0+400 (L=270m)	φ100 (Holche)	Trail	Ground	(in chamber)	-	-
0+400 – 0+440 (L=40m)	φ100 (Holche)	Trail	Underground	-	1	-
0+440 – 0+800 (L=360m)	φ100 (Holche)	Trail	Ground	-	-	-
0+800 – 1+260 (L=460m)	φ100 (Holche)	Trail	Underground	2(Pipe)	2	-
1+260 – 1+400 (L=140m)	φ100 (Holche)	Trail	Ground	1(Pipe)	1	-
1+400 – 2+350 (L=950m)	φ100 (Holche)	Trail	Underground	1(Pipe)	-	-
2+350 – 2+600 (L=250m)	φ75(Holche)	Trail	Ground	3(Pipe)	4	1
2+600 – 3+420 (L=820m)	φ75(Holche)	Trail	Underground	3(Pipe)	3	1
3+420 – 3+480 (L=60m)	φ100 (Holche)	Trail	Underground	(Type-3)		
3+480 – 3+778 (L=298m)	φ100 (Holche)	Trail (Slope)	Ground (Anchor)	1		
L=3778m			Total	(in chamber)	-	-

Source: JICA Project Team

［C3: From Chitre PBC to Shaule］

Station No.	Pipe	Condition	Type	Air Valve	Washout	PBC
0+000 – 1+445 (L=1445m)	φ100 (Thalkharka)	Traffic Road	Underground	1		
1+445 – 2+040 (L=595m)	φ100 (Thalkharka)	Trail	Underground	(in chamber)		
2+040 – 2+240 (L=200m)	φ100 (Thalkharka)	Trail	Ground	1(Pipe)	-	-
2+240 – 2+320 (L=80m)	φ100 (Thalkharka)	Trail	Underground	2(Pipe)	2	-
2+320 – 2+360 (L=40m)	φ100 (Thalkharka)	Trail	Ground	-	-	-
2+360 – 2+500 (L=140m)	φ100 (Thalkharka)	Trail	Underground	-	-	-
2+500 – 2+900 (L=400m)	φ100 (Thalkharka)	Trail (Slope)	Underground (Anchor)	-	-	-
2+900 – 3+400 (L=500m)	φ100 (Thalkharka)	Trail	Underground	1		
3+400 – 3+520 (L=120m)	φ100 (Thalkharka)	Trail (Slope)	Underground (Anchor)	(in chamber)	-	1
3+520 – 3+877 (L=357m)	φ100 (Thalkharka)	Trail	Underground	1		
L=3877m			Total	(in chamber)	-	1

Source: JICA Project Team

［C4: From Phusre PBC to Chitre PBC］

Station No.	Pipe	Condition	Type	Air Valve	Washout	PBC
0+000 – 0+200 (L=200m)	φ150 (Thalkharka)	Trail	Underground	1(Chamber)	-	-
0+200 – 0+240 (L=40m)	φ150 (Thalkharka)	Trail (Slope)	Underground (Anchor)	-	1	-
0+240 – 0+800 (L=560m)	φ150 (Thalkharka)	Traffic Road	Underground	1(Pipe)	-	-
0+800 – 1+740 (L=940m)	φ100 (Thalkharka)	Traffic Road	Underground	1(Pipe)	1	-
1+740 – 1+800 (L=60m)	φ100 (Thalkharka)	Trail (Slope)	Underground (Anchor)	-	-	-
1+800 – 1+851 (L=51m)	φ100 (Thalkharka)	Trail	Underground	-	1	1
L=1851m			Total	(Type-1)		

Source: JICA Project Team

9.5.3 Construction Plan / Procurement Plan

(1) Construction Policy

1) Principle

The executive agency of the project is the Department of Water Supply and Sewerage (DWSS) under the MoUD and the local supervision of the construction work is carried out by the Water Supply and Sanitation Division Office (WSSDO) in Chautara.

- In accordance with the Japan's Grant Aid Scheme, the E/N was signed between the Japanese Government and GoN, and the signing of the G/A between the JICA and GoN followed the E/N.
- The agreement for the supervisory service and the contract for the construction is administrated by the DWSS delegated by the MoUD.
- The Japanese consultant assigned by JICA assumes the detail design, preparation of the tender documents, support for tendering and supervision of the construction work.
- The contractor was selected through tendering and be adjudicated by the client. After signing of the contract, the contractor started procurement of materials, preparation of a yard near the construction site, and the construction work followed the arrival of materials.
- After signing of the E/N, the Nepal side shall conclude the B/A with the bank in Japan immediately, issue the A/P, and take necessary measures in cooperation with MoF to exempt customs duties, internal taxes and other fiscal levies which may be imposed in Nepal with respect to the purchase or import of materials procured by the contractor.

2) Construction Method

As mentioned above, some parts of the construction site have difficult conditions for work due to difficult accessibility in the rainy season. The work projected at these sites such as pipe installation and rehabilitation of intake chambers should be done in the dry season.

In addition, ductile iron pipe with earthquake resistant mechanisms will be applied for this project, which requires technical transfer to local technicians and counterparts regarding its special connecting method and usage of tools. The Japanese side will arrange this procedure and work for its promotion.

(2) Direct Construction Work

1) Preparation

a) Stockyard of equipment and material

The ductile iron pipes, accessories and other construction material and equipment will be transported from Japan by sea and land packed in containers.

The equipment and material which arrive at Nepal will be temporally stocked in the stockyard of Bhaktapur as proposed by DWSS. After that it will be transported by trucks in small lots to the construction site in Chautara according to the construction schedule.

Confirmed at the time of outline design, this stockyard has an area of 50m by 50m approximately and should be surrounded by a temporary fence. This area faces the principal traffic road, and needs to be controlled by a guard against unauthorized person's entry.

b) Sub-yard of Chautara

The material transported from Bhaktapur will be stocked in Chautara in small lots and be supplied to the sites. It is assumed that this temporary stockyard will be provided to the contractor from the Nepal Side officially without compensation, such as a public area or other vacant land with an area of 20m by 20m. In this case, the contractor will prepare a temporary fence.

2) Foundation and Earth Work

a) Installation of Pipe

The earth work will be performed by open drain cutting. The back hoe can be used only on the traffic road, and on other trails the earth should be excavated by man power.

Although the road has not been paved, the excavated soil contains stones and conglomerate. Therefore the pipes installed in the trench should be covered by sand or selected soil up to 10 cm over the top of pipe. After backfilling with the sand, the excavated soil can be used to backfill to the original surface level with compaction (each 30cm of depth).

b) Construction of Chambers

The construction site for the chambers has no vehicular access. Therefore all the excavation and backfilling should be performed by man power. After smoothly bedding the bottom, a gravel layer will be laid with 15cm of thickness, after that the base concrete will be set with 5 cm of thickness.

After setting the formwork panels and reinforcement bars, mixed concrete will be placed.

3) Concrete Work

a) Temporary Work

The projected chambers are all of small size and their height does not exceed 2 m, except for the Holche intake chamber, so that no special scaffold will be needed. If the height of the upper slab is less than 4 m, the concrete will be placed into the slab supported by pipes with formwork panels.

b) Production of Concrete

Being located on a mountain, it is impossible to procure fresh concrete mixed by a factory. Therefore all the concrete that is used for this project should be made at the site using a portable mixer (pot mixer).

The placing of concrete will be performed in order, such as base slab, wall, upper slab etc. and the placed concrete will be carefully consolidated with a vibrator. At the construction joint of the concrete, a water stop sheet made of PVC will be installed for water proofing. If the ambient temperature is high at the time of curing, the concrete should be kept moisturized with water sprinkling.

4) Piping Work

a) Process of Piping Work

In principle, the pipe installation method should be in accordance with the instruction issued by the Japan Ductile Iron Pipe Association.

The base of the trench for the pipeline should be a flat-bottomed channel and no special foundation is needed, unless rock or stone is observed. However, if the bottom of the trench is solid rock or contains stones or cobbles, the contractor shall lay a sand bed with a thickness greater than 0.10m.

For the installation on the traffic road, a truck with a crane can be used for transport and laying of pipes, but for the other sites, all the installation should be done by man power.

If the ground surface has a hard rock or a steep slope and does not permit normal excavation of the trench, the pipes can be set as a ground installation by providing concrete supports. And if the inclination of the ground surface exceeds 20 grades, a concrete anchor should be prepared underground and cover the pipes

b) Miscellaneous Facilities

The pipeline work includes the following miscellaneous facilities; air release valve, washout valve, pressure breaking chamber.

(3) Supervisory Service Plan

1) Consultant's Supervision

For smooth implementation of the project, the Consultant will execute its professional service including the following;

- To completely understand the contents of the E/N signed between GoN and the Japanese Government
- To completely understand the contents of the G/A signed between GoN and JICA
- To confirm the details of the obligations of the Nepal Side and its progress, and to coordinate with the client to complete some matters that should be done before commencement of the work in accordance with the construction schedule.
- To confirm the progress in implementing the measures for exemption of tax or customs imposed in Nepal for import of materials and to obtain the necessary support for the executive agency.

2) Detail Design

The detail design consists of local study and analysis in Japan.

a) Field Survey

The following information should be collected and confirmed in the site for the detail design; natural condition, geological condition, procurement condition of materials, procurement condition of labour, topographic data, and other issues that were not confirmed in the basic design stage.

Furthermore, the obligations to be covered by the Nepal side should be confirmed in this stage, including the responsible division and prospect of budget.

b) Analysis in Japan

Following the survey in Nepal, structural calculations, hydraulic analysis, detail drawing and tender documents will be prepared and the construction schedule will be planned.

3) Supporting Work for Tender

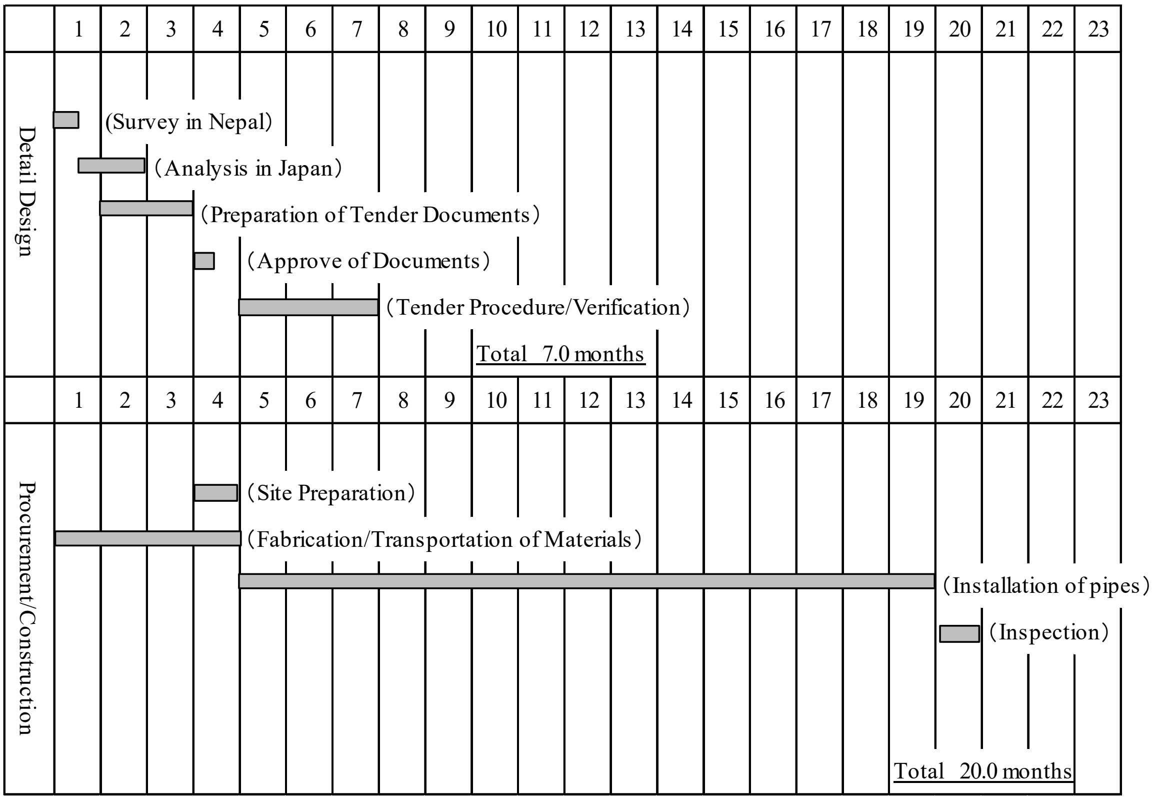
The consultant shall assist the client with the following items; preparation of the tender documents, approval by the client, distribution of the tender documents, evaluation of the tender, and conclusion of the contract.

4) Supervision

The consultant will enter Nepal in accordance with the construction schedule prepared by the contractor for site investigation and coordination with the related agencies in Nepal. After that the consultant's permanent supervisor will execute its supervisory work.

(4) Implementation Schedule

Table 9.5.3 Implementation Schedule



Source: JICA Project Team

1) Order of works

Once the dry season starts, the work will be commenced. In principle, the pipeline work will start from sections with difficult accessibility. For pipe laid along the traffic route, if permitted by the site condition, the installation work will be performed by two parties using back hoes and trucks with cranes, from the northern part toward the city in order.

The section between Shaule and the water treatment plant has good accessibility compared with the other sections even in the rainy season, and the work on this section can be done in the rainy season with low risk of delay.

For the sections along the trail, it is necessary to work in parallel in different sites to shorten the construction period. However, the number of parties that work simultaneously needs to be limited to 3 parties as a maximum to ensure the quality control.

The construction of chambers will be executed at the same time as the pipeline work. It is necessary to carefully coordinate these works for smooth execution of the leakage test of the pipeline and chambers.

The construction and rehabilitation of the intake chambers will be done in the dry season only.

2) Basic Condition for Implementation Schedule

The basic construction for this implementation schedule is shown below;

Table 9.5.4 Preconditions of estimated schedule

Items	Time
Exchange of Note (E/N)	End of December 2015
Grant Agreement (G/A)	Middle of February 2016
Agreement for Consulting Service	Beginning of March 2016
Prequalification	Beginning of June 2016
Contract for Contraction Work	End of August 2016
Starting of the works	Beginning of October 2016
Completion of the works	End of May 2018

Chapter 10 Lessons Learnt and the Way Forward

Many valuable lessons were learnt through the various challenges encountered during the implementation of the Project. The lessons learnt through component 1 to 3 and further steps for the forward are summarised below.

10.1 Component 1: Various Plan Formulation

10.1.1 Kathmandu Valley Resilience Plan (KVRP)

KVRP is a comprehensive policy framework based on the concept of Build-Back-Better (BBB) to reduce possible damage from large scale earthquake disasters that may occur in Nepal in the future. It is the first planning document in Nepal which incorporates the concepts of the Sendai Framework for Disaster Risk Reduction addressing to build a resilient society against large-scale natural disasters.

One of the important issues for the KVRP is how to link resilience in the government expenditure for development. Currently, there is no single organization in charge of disaster management in Nepal. In addition, KVRP currently does not have legal grounds for its implementation. Under such circumstances, it was strongly recognized that the central government's strong leadership is necessary to realize medium- and long-term measures to promote resilience.

KVRP is planned to be positioned as an appendix of the Strategic Development Master Plan (SDMP) to be formulated by the Kathmandu Valley Development Authority (KVDA), and KVDA is a subordinate to the Ministry of Urban Development (MOUD), where its responsibility is up to the preparation of development guidelines.

Until now, the importance of KVRP has been confirmed in JCCs and TCs chaired by the National Reconstruction Agency (NRA). In order to advance the resilience of Kathmandu Valley, NRA shall take the lead and coordinate with related ministries and agencies to implement KVRP in the short term. Furthermore, it is necessary to consider the establishment of a permanent organization that has jurisdiction over all disaster management for advancing resilience in the long perspective.

10.1.2 Rehabilitation and Recovery Plan (RRP) of the Two Districts

(1) Institutionalisation of RRP

In Nepal, RRPs are not defined by law, and the process of RRP preparation followed by activities for recovery and rehabilitation in accordance to the plan has not been conventionally applied. Under such circumstances, ensuring the effectiveness of the RRPs was a major issue from the beginning of the Project. In this context, the Project Team actively coordinated with MoFALD and the authorities of Gorkha and Sindhupalchok in order to align the formulation of RRP with the PDDP, which is a legally defined development plan. As a result, aspects of RRP have been included in the PDDPs, where implementing the PDDPs will also mean the implementation of RRPs. Formulation of RRPs are dictated in PFRP. It has started to be understood that the first step in reconstruction is the formulation of plans.

(2) Understanding Disaster Risk

In a reconstruction plan, it is necessary not only to restore the physical damage by the disaster but also to consider the risk of future disasters based on the concept of BBB. In the RRP, landslide Hazard Maps were generated to scientifically understand disaster risk and to realise the concept of BBB. Under scientific verification, RRP was developed, including considerations for the risk of future landslides. The importance of the Hazard Map was also understood by the Nepalese side, and the technology of a Landslide Hazard Map was transferred through workshops on the utilization of the Hazard Maps and outline of Hazard Map preparation. Further generation of Hazard Maps for other affected areas is currently planned within the budget of Nepal. The understanding on propelling reconstruction based on scientific basis has been deepened for the Nepalese side through RRP preparation.

(3) Understanding the Reconstruction Planning

PDDP is formulated in a bottom-up method, valuing the planning of the process. Not only government officials but also politicians and local residents could gain understanding through the process of formulating RRPs together with the PDDP planning. Moreover, the understanding that reconstruction does not aim only at physical reconstruction but also contains a broad concept including the revival of livelihoods and the economy has been deepened as well.

(4) Towards Implementation of RRPs

At the final stage of RRP formulation, due to reforms of the local government, the responsibilities and authorities of the Districts were delegated to Municipalities and Rural-Municipalities. Therefore, it is necessary to divide the formulated PDDP/RRP as to fit each local government body. It is hoped that these divisions will be carried out by the Nepalese side and the contents of the RRPs will be implemented at an early stage.

10.1.3 Hazard Maps

(1) Development of Hazard Maps

Based on the interpretation of satellite images and confirmation at representing sites, Hazard Maps of the landslide disaster hazards of Gorkha and Sindhupalchok were prepared and handed over to GoN. It was a rare case in JICA's international cooperation projects that completed a Hazard Map at a practical level for a vast area. Such interventions can be considered to be an area to expand in the future.

Since there was no precedent in the work, the Project Team first examined the combination of category and scores in order to increase the discrimination rate of the Hazard Map. Then, the results were explained to the related organizations in Nepal who further provided feedback.

In the course of Hazard Map preparation, the trial and error process was repeated for a considerable time at the initial stage. The relationship between slopes and slope inclination, inclination direction, and geological structure and relationship with the epicentre, which were the final extracted categories, can be considered to be utilised as universal categories to be applied to evaluate slope stability in other areas.

In further opportunities to provide similar Hazard Maps in countries other than Nepal, it will be more effective if analysis will be done after the categories are comprehensively selected with those above as a basis, and by adding other area specific categories in consultation with the organizations related to geology and disaster risk reduction of the target country

For this purpose, it is an important lesson that in the early stages of the project, the procedures and goals of work should be clarified and a system to consult and cooperate with experts from related organizations of the relevant country should be established to create a Hazard Map.

(2) Utilization of Hazard Maps in the Gorkha and Sindhupalchok Districts

When preparing and utilizing Hazard Maps in a specific area, the Hazard Map has to clearly indicate important points of notice such as how the topographic data was utilized, how the map was prepared, and what its applicability and limitations are. The Hazard Maps prepared for the Gorkha and Sindhupalchok Districts already indicate such information, and this practice should be continued for the Hazard Maps which will be developed in the future. Important points to be indicated are as follows:

- Information used as general factors: General factors used are map and landslide information identified from the satellite images captured after the April 2015 Nepal Earthquake.
- Method: Slope failure risks are evaluated for each 50m x 50m square on the overlaid grid and coloured from blue to red in gradation.
- Applicability and limitations: This Hazard Map is for globally indicative purposes only. By overlaying additional information as needed, this Hazard Map can be utilized as a decision making tool for DRR planning. However, for site specific planning or designs, further studies are necessary for reducing the landslide risks.

(3) Preparation of Hazard Maps in the Remaining Nine Districts

In the fiscal year of 2017/18, NRA has budgeted for the development of Hazard Maps in the remaining nine districts, but it is not yet clear when this will be conducted. In order to realize the concept of BBB in the affected areas, it is desirable to develop Hazard Maps as soon as possible. For preparing Hazard Maps for the remaining nine districts, the following process is recommended:

- Overlay satellite imagery, landslide distribution and DEM data provided from JICA to NRA. Divide each district map by 50m x 50m square mesh.
- Calculate slope inclination, slope direction, distance from epicentre and distance from MCT. Analyse the relationship between each factor and landslide.
- Consider other general factors to be introduced in each district if they a have high relationship with landslides.
- After deciding the factors to be introduced, determine the weight allocation by using the quantification programme provided to NRA.
- Prepare each hazard map by weighted factors of each district.
- After the completion of Hazard Maps, hold a presentation seminar to review the problems faced in each district and to raise the technical level of each district engineer.

10.2 Component 2: Promoting Seismic Architecture and Structures

10.2.1 Seismic Resistant Housing

(1) Policy Making for Housing Design

It was re-recognised that in the process of urgent recovery and reconstruction from earthquake disasters, early recovery and reconstruction of the living environment and building a resilient city for the future is the most important challenge. For this, multiple reconstruction programmes are necessary. These are, for example the formulation and implementation of eligibility analysis systems, grand-in-aid systems for reconstruction of housing, building permit application systems and developing seismic designs for housing.

In the case of reconstruction in Nepal, it took quite a while for the Household Registration for Housing Reconstruction Survey (HRHRS) to re-verify the victims of affected households, and it took until the end of June 2016 to complete the survey in the eleven districts which were heavily affected. The Vol.1 design catalogue for reconstruction of earthquake resistant housings as fixed design was published in October 2015, and then in March 2016, the minimum requirements for flexible design of masonry structures and RC structure were developed by NRA. However, the completion of Building Inspection Standard Operation Procedure (SOP) was completed in September 2016, and 2,000 engineers as inspectors were newly recruited. The building inspection was finally started after one and a half years had passed since the earthquake.

Although one reason of the delay is that the establishment of NRA took some time, until December 2015, regarding the implementation of an early reconstruction programme, early completion of eligibility survey, formulation of grant-aid system, and establishment of building permit application system and developing seismic design also should have been discussed and conducted simultaneously. Although it is more likely that discussion on developing seismic design draws more attention, the importance of establishing and implementing the institutional framework and implementation structure at the earliest stage must not be neglected.

(2) Design for Seismic Resistant Housing

Not only in this Nepal earthquake but also in past earthquakes around the world, most human casualties are caused by the collapse of buildings, particularly by the vulnerable masonry constructions in developing countries. Most of these buildings are categorized into "Non-Engineered Construction", which are built by local masons or the house owners themselves.

In Nepal, activities for dissemination of earthquake safer design for Non-Engineered Construction were attempted by the Government of Nepal (GoN) lead by NSET. Seismic resistant construction methods suitable for the land have been adopted as building standards, and based on those standards, the verification of the structure and design proposals have been made. However, many of the construction methods have not sufficiently spread, and the understanding of the seismic resistant method of residents is not enough. This caused many houses to be damaged and collapsed in this earthquake.

In order to build a seismic resilient society, not only buildings should be constructed during the reconstruction assistance period, but also the method and knowledge of seismic resistant building should be instilled to the local people. Particularly in the case of masonry, since it largely depends on the elements of materials and workability, sufficient consideration should be given to locally produced and locally consumed materials. In order to disseminate highly seismic resistant buildings in non-engineered construction in developing countries, it is a prerequisite to technically ensure seismic resistance, but it is also necessary to propose reconstruction houses which are endowed with affordability, feasibility and adaptability.

(3) The Importance of Building Human Resources for Housing Reconstruction

When a disaster affected area is wide spread, the human resource development of engineers involved is inevitable. Technical trainings sessions and workshops should be held for all stakeholders such as government engineers, professionals such as architects and civil engineers, construction workers and house owners to widely disseminate knowledge.

Since government-related engineers who review buildings in various places are temporarily hired after the disaster, young graduate engineers accounted for their majority, and there are only a few engineers with practical experience. Still, their technical ability greatly affects the quality of the rebuilt housing. Technical training is conducted at the central level in Kathmandu and the local level in each district, but because young newly graduated engineers with scarce practical experience occupy the majority, it is necessary to take sufficient time before implementation. Because there are only a few teachers to lecture in this training, the training of human resources such as ToT is also necessary.

Earthquake safety will not be achieved unless a bottom up approach is taken in which the house owners and common people attain sufficient knowledge, especially in owner driven construction such as non-engineered construction. The first step for disaster rick reduction is to understand the disaster risk. For the dissemination of earthquake resilient techniques, technical matters should be understood not only by masons, but also by house owners. Because housing reconstruction also relates to the financial matters of the house owner, knowledge of the house owner on the necessity of proper construction will directly influence the quality of the construction. In addition, the skill of workers to appropriately implement seismic construction is also very important.

(4) The Process of Seismic Design

To establish a unified standard for seismic resistant construction and widely disseminate this up to the residents where there are a mix of different ways of thinking between implementation partners and NGOs, technical elements related to seismic design must be set step by step from the fundamental principles.

Fixed designs of seismic structures were introduced through the Housing Catalogue, using many images to facilitate easy understanding by local residents and focusing on methods with seismic elements added to conventional construction methods. Further, after the formulation of a common understanding that the seismic construction should be based on NBC 105, Minimum Requirements, where seismic standards were summarised into ten points for flexible design of masonry structures was developed, followed by inspection sheets of masonry. The ‘Correction and Exception manual’ which consists of exceptional and correctional measures for specific non-compliant cases were also developed. This manual has helped to correspond to field situations of reconstructed houses without compromising the seismic requirements. Through these step by step activities, the regulations of techniques for seismic design were unified and disseminated to people concerned to the reconstruction programme. The important point is to follow the order so as to first solidify the fundamental principles for BBB without the premise of mitigation or compromise, and then consider measures to improve the effectiveness of its implementation.

(5) Structural Analysis

The main structural method in the areas affected by the earthquake is masonry structure using stone and mud mortar. For stone with mud mortar masonry structures, there is not enough elemental property data in the academic field. A considerable amount of time was required to analyse the material property because factors such as the shapes of individual stones influence the load bearing capacity. A full scale shaking table test of a stone with mud mortar masonry structure would be useful to find out the actual behaviour until the structure collapses by earthquakes which is a major cause of human casualty. Japan is one of the leading countries in shaking table tests, and therefore such tests on stone masonry should be conducted utilizing its knowledge.

(6) Network of Research Institutes and Academia

In consideration of future networking of research institutes and academia, particularly with those of Japan, the subject/target such as historical building, engineered construction, vernacular architecture etc., should be made clear. In the academic field in Japan, studies on masonry structure have not progressed compared to other structural methods. Therefore, international studies and literature should be referred to.

10.2.2 Seismic Resistant Schools

(1) The Procedure of Establishment of a Seismic Resistant Building Guideline

Regarding the procedure of the establishment of a seismic resistant building guideline for school reconstruction, the Project followed four phases: damage survey and the analysis, review of existing prototype of school designs, proposal of a seismic resistant building guideline, and design of new school prototypes based on the guideline. These phases should be referred to when implementing similar interventions.

(2) Field Survey on Affected Schools to be Reconstructed

After the commencement of the Transitional Project Implementation Support for Emergency Reconstruction Projects (TPIS-ERP), it has become clear that most of the schools had smaller land for reconstruction than initially expected. This issue could be coped with because the Project Team had proposed 37 prototypes with a range of single to three storeys and also with different sizes of rooms in order to fit for various kinds of lands. On the other hand, ADB had initially proposed only single floor prototypes and therefore had to later prepare multi-floor prototypes, and also had to apply some of the 37 prototypes proposed by RRNE for their project. It is desirable to conduct prior sampling field surveys which include basic information such as access of road, number of students, grade of school, topography of school site and area of land in order to avoid such issues in similar projects in the future.

10.3 Component 3: Prioritized Reconstruction Projects (Programme Grant Aid)

10.3.1 Grant Aid Project Formulation Phase

At the initial stage of the formation of potential Grant Aid Projects, it has become evident that other development partners had already started to provide assistance ahead of JICA. Therefore, it was very difficult to identify projects. This was because neither the Project Team nor JICA had the necessary information before hand and considerable time was therefore necessary to obtain such information. In emergency projects, information on the movements of other development partners should be gathered in detail, in parallel with project identification, from the earliest stages of the survey, in order to make the offering of projects faster.

Also, it was difficult to propose well-balanced projects in different fields, namely as civil engineering and architecture, with pre-defined target cost of four billion yen as Programme Grant Aid. Making the budget flexible will enable a quick response to combinations of projects. In addition, since the original target projects were formulated using the results of site reconnaissance and before the basic data collection through geological and topographic surveys etc., it was necessary to modify the project based on the results of subsequent surveys. It is necessary to deal with such problems by determining the target project after the basic survey such as topographic and geological surveys as required.

10.3.2 The Handling of Items to be Burdened by the Recipient Country

Since it was just after the disaster, GoN was unable to prepare the necessary budget urgently after the selection of the Grant Aid Projects, and it was also difficult to organise the implementation structure. As a result, considerable time was required for the removal work of existing buildings and the work was not done with due quality. There should be a system that allows flexible handling of work items, where some items to be under the responsibility of recipient countries in normal Grant Aid Projects could be included in the scope of the Japanese side in consideration of the nature of emergency aid projects.