Appendix 12

Geological Investigation

(Attachment)

Detailed Description of the results of the geological investigation

Preface

Generally, the purpose of geological investigation has many points. These include deciding the design parameters for subsequent construction phases by giving detailed geological information using investigation tools. Geological investigation in the road construction especially contributes to decision making of whether the planned routes will be appropriate to the natural conditions on site (Figure 1-a, Figure 1-b).

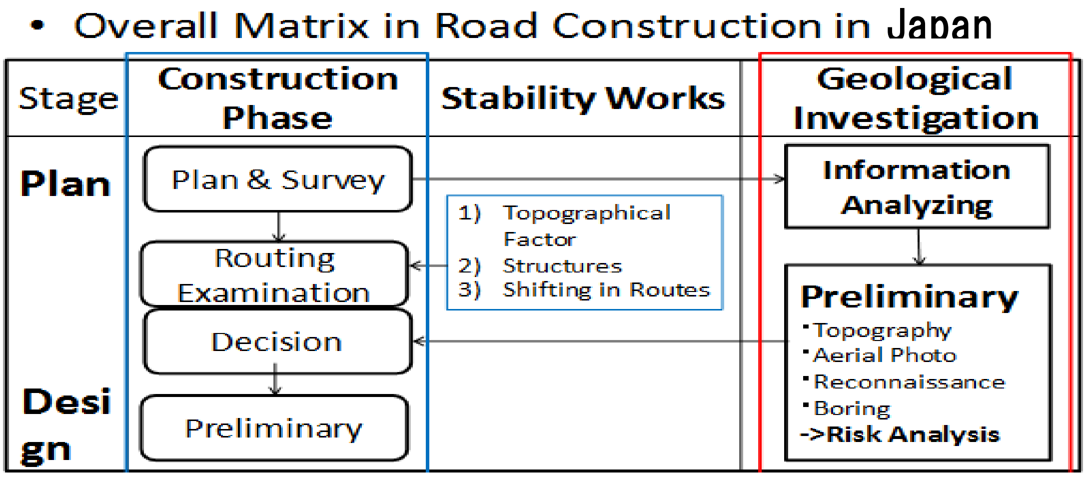

Figure 1-a Overall scheme of relationship between road construction and geological investigation in the road construction phase (from planning phase to design phase) according to "Technical Guideline of Slope Stability Works in Japan (2009)"

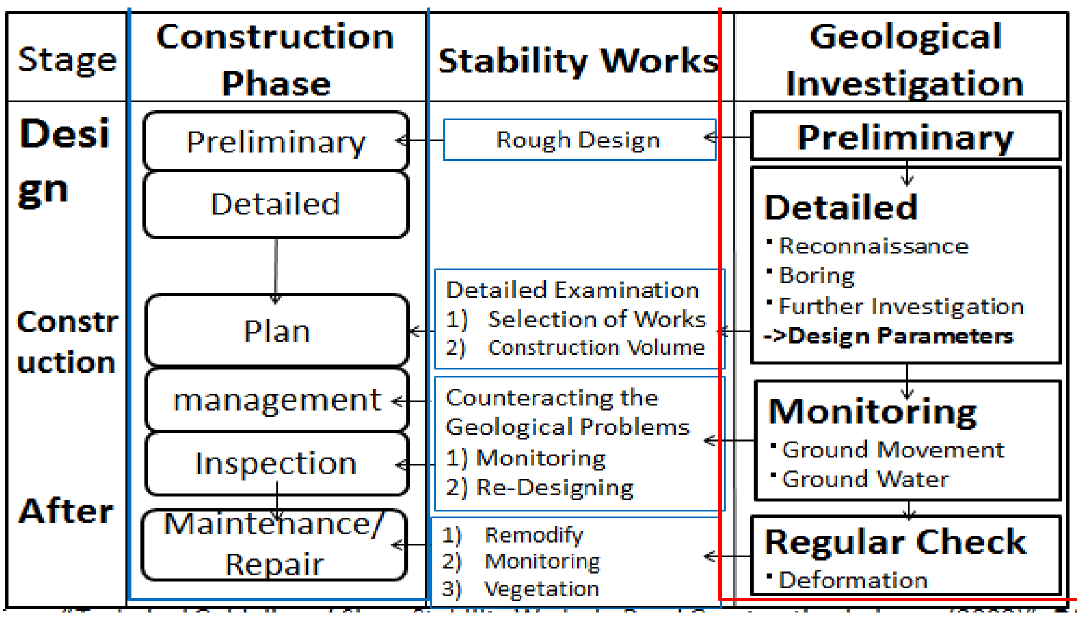

Figure 1-b Overall scheme of relationship between road construction and geological investigation in the road construction phase (from designing phase to maintenance phase) according to "Technical Guideline of Slope Stability Works in Japan (2009)"

The output from Geological Investigation will be closely interrelated to every step in each phase so the level (quality) of the results of the geological investigation will have a positive effect on the output of each phase in the Road Construction.

The basic methodology of the geological investigation is to reduce the uncertainty involved in the road construction by gaining a sound understanding of the geological conditions using numerous survey and measurement techniques, from macro to micro in perspective, such as aerial photography, geophysical exploration, and drilling techniques (Figure 3.2.2). The objective of this methodology is to identify and/or specify, in advance, the geological problems that will affect the road construction works, the future sustainability of the road and the safety of road users.

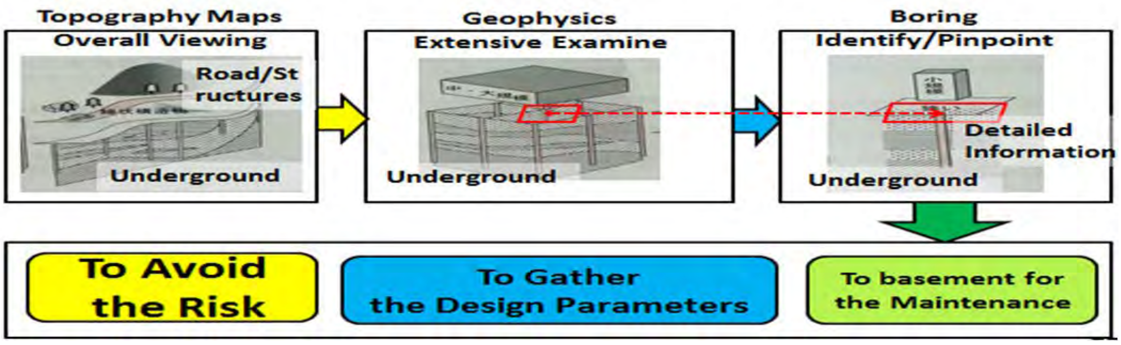

Figure 2 Methodology of geological investigation (Source JET)

The geological investigation was implemented as a show case to demonstrate the above methodology. In the project, the two sites below were selected to showcase the methodology of how geological investigation will be implemented in the road construction project. The two selected sites are shown below (Figure 3.6.3). The scope of the geological investigation includes the subsurface investigation, the laboratory investigation and the geophysical investigation. The subsurface investigation should be carried out to obtain the geological information below the natural ground in the project area. The investigation method to be followed uses surface invasive techniques including the following:

a) Subsurface investigations (core drilling)
b) Standard Penetration Test (SPT)
c) Ground water measurement
d) Collection of undisturbed (UD) samples
e) Laboratory Investigations
f) Geophysical Investigations (Seismic exploration)

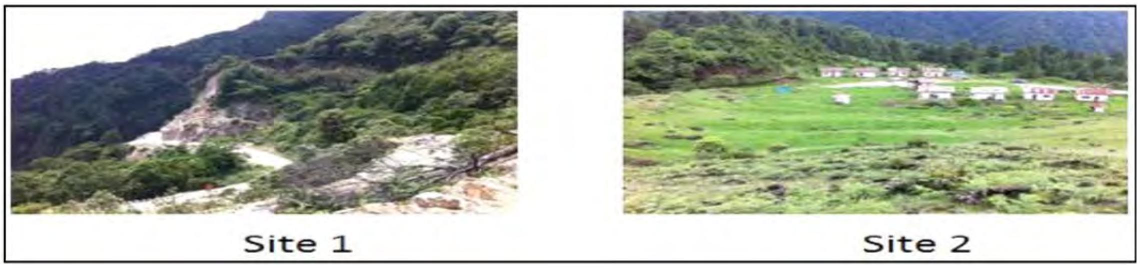

Figure 3 Overview of each site (Site 1: Thumang Cliff, Site 2: Bangla Pokto) (Source JET)

Table 1 Quantity of investigation at each site (Source JET)

Both the study sites fall under the Trongsa Dzongkhag administration. Trongsa Dzongkhag is located in the heart of the country and shares boundaries with Wangduephodrang Dzongkhag to the west, Bumthang Dzongkhag to the northeast and Zhemgang and Sarpang Dzongkhags to the south. Trongsa Town is located on the east-west lateral highway, 189 kilometers east of Thimphu.

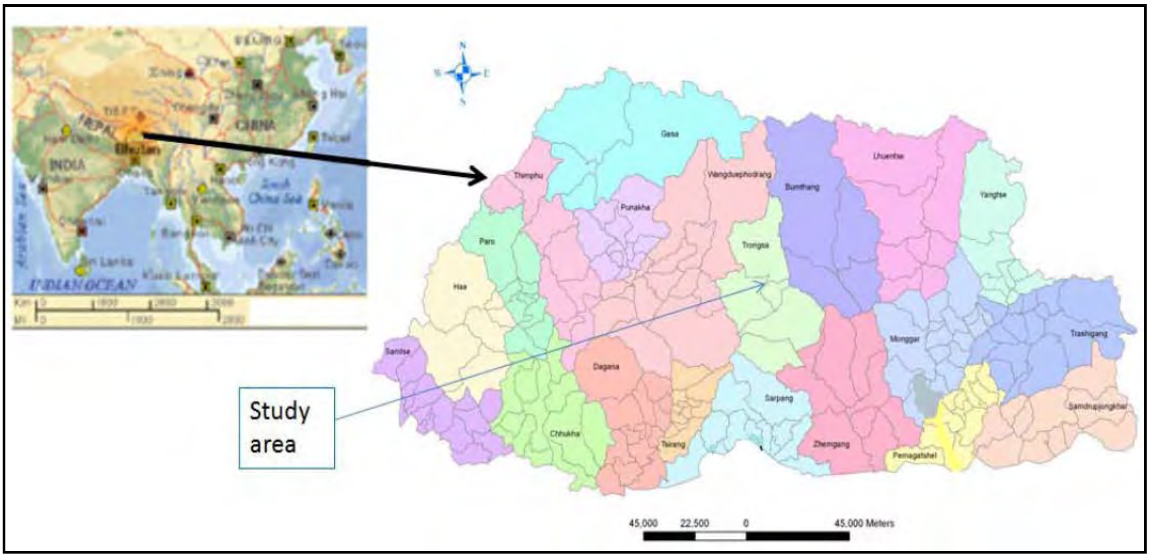

Figure 4 Map of Bhutan showing Trongsa Dzongkhag (Source JET)

Bangla Pokto is located on the east-west highway at a distance of about 30 kilometers from Trongsa towards Wangduephodrang. It is shown by the northern latitude of 27°27’0.90” N and the eastern longitude of 90°24’24.6”E at an approximate elevation of 2428 meters above mean sea level. Thumang Cliff is located on the east-west highway at a distance of about 16 kilometers from Trongsa towards Wangduephodrang. It is shown by the northern latitude of 27°28’41.90” N and the eastern longitude of 90°28’49.90”E at an approximate elevation of 2262 meters above mean sea level.

Figure 5 Google Map showing the study area (Source Google map)

DETAILED REPORT ON THE GEOTECHNICAL WORKS FOR THE

PROJECT OF MASTER PLAN STUDY ON ROAD SLOPE MANAGEMENT IN THE KINGDOM OF BHUTAN

Submitted By:

Progressive Research and Consultancy Services
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(AUGUST 2015)

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1 BACKGROUND INFORMATION

1.1 General

Funded under the grant aid program by the Government of Japan through JICA office in Thimphu, this "**Project for Master Plan study on Road Slope Management in Bhutan**" aims to strengthen the capacity of the Department of Roads (DoR), Ministry of Works and Human Settlement (MoWHS) of the Royal Government of Bhutan (RGoB) in carrying out critical slope investigations along the road to build up inventory and situational analysis and also the identification of problems for slope inspection. This project is being implemented by the Maintenance Division of the Department of Roads with a goal of building capacity in the Department for slope inspection and regular updating, and record cards of slope stability inspection. This is a two years (July 2014-Aug 2016) Technical Cooperation Project (Source http://www.jica.go.jp/bhutan/english/activities/activity01.html).

As a part of this project, two target sites have been identified by the JICA Expert Team (JET) to be taken up for the detailed sub soil investigation by drilling, geophysical (Seismic) exploration, laboratory studies (testing of samples) as well as detailed topographic survey works. One site identified was at Bangla Pokto area where two boreholes of 25 metres each were proposed along with 300 metres of seismic profiling and the other site identified was at Thomang Cliff where 3 boreholes (60, 50, 50 metres depth) along with 600 metres of seismic profiling was to be carried out.

After competitive bidding, the Geotechnical investigation and the topographic survey works for this slope management project was formally awarded to Progressive Research and Consultancy Services (PRCS), a local consultancy firm based in Thimphu.

1.2 Project Objective and Benefits

The main objectives of this project development are:

- To obtain direct information on the sub-surface geology of the area through the works.
- To obtain information on the landslide movement and features of the areas through the works.

1.3 Scope of the present work

The scope of the consultancy services covers the following services associated with the project.

- Subsurface investigations
- Laboratory Investigations
- Geophysical Investigations

1.4 Detailed Scope of the present work

Subsurface investigation is to be carried out to obtain geological information below the natural ground surface in the project area. The investigation method to be followed is by using surface invasive techniques including the following:

a) Subsurface investigations (Core drilling)
b) Standard Penetration Test (SPT)
c) Ground water measurement
d) Collection of undisturbed (UD) samples
e) Laboratory Investigations
f) Geophysical Investigations (Seismic exploration)

1.5 Location of the study area

Both the study sites fall under Trongsa Dzongkhag administration. Trongsa Dzongkhag is located in the heart of the country and shares boundaries with Wangduephodrang Dzongkhag to the west, Bumthang Dzongkhag to the northeast, Zhemgang and Sarpang Dzongkhags to the south. Trongsa town is located on the east-west lateral highway at 189km east of Thimphu.

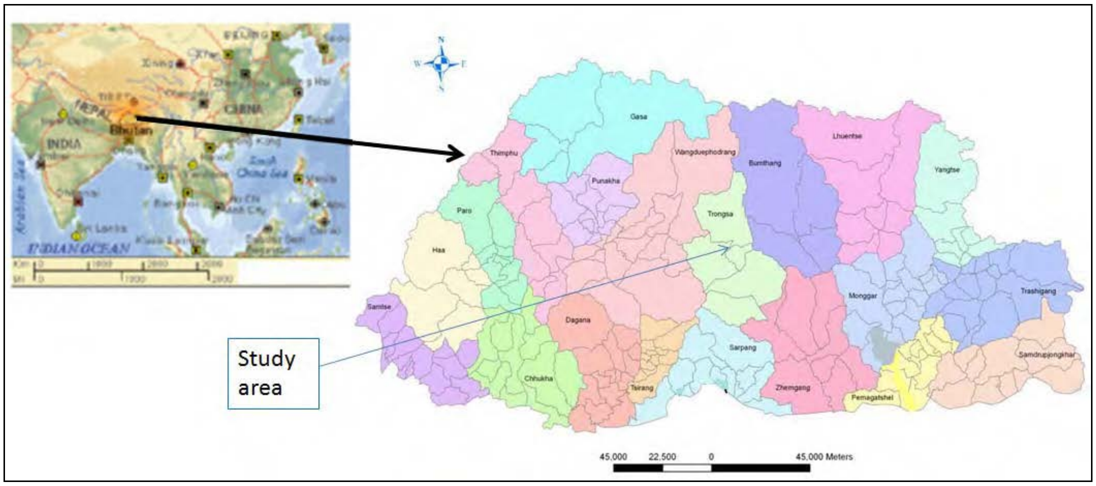


Figure 1: Map of Bhutan showing Trongsa Dzongkhag

Bangla Pokto is located on the east-west highway at a distance of about 30 kilometres from Trongsa towards Wangduephodrang. It is shown by the northern latitude of 27°27'0.90" N and the eastern longitude of 90°24'24.60" E at an approximate elevation of 2428 metres above mean sea level. Thomang Cliff is located on the east-west highway at a distance of about 16 kilometres from Trongsa towards Wangduephodrang. It is shown by the northern latitude of 27°28'41.90" N and the eastern longitude of 90°28'49.90" E at an approximate elevation of 2262 metres above mean sea level

Figure 2: Google Map showing the Study area

2 GENERAL STUDY

2.1 General Geology

In the Bhutan Himalayas, it can be divided into physiographic sub divisions of the Siwalik Hills, the lesser Himalaya and the Higher Himalaya where topography is essentially controlled by geological formations. The stratigraphic Geological sequence of the Bhutan Himalaya is as shown in **Table 1** below.

Quaternary succession		Recent sediments mostly fluvial materials. With clay beds.
-------------------------------------MFT (Main Frontal Fault)--		
Siwalik Group		Sandstone, siltstone, shale, clay, boulder bed (semi-consolidated conglomerate).
-------------------------------------MBT (Main Boundary Thrust)------------------------------------		
Damuda Subgroup		Sandstone, siltstone, shale, coal beds
-------------------------------------Baxa Thrust---		
Baxa Group	Pangsari Formation	Dolomite, Quartzite and Phyllite and local conglomerate
	Phuentsholing Formation	Variegated Phyllite with white, purple and grey quartzite
	Manas Formation	Light grey dolomite, limestone, grey and carbonaceous phyllite
------------------------------------ Shumar Thrust ---		
	Shumar Formation	Interbanded quartzite and phyllite with limestone and basic sills, garnetiferous mica schist, marble, calc-gneiss and graphite schist
-------------------------Jaishidanda Thrust --		
	Jaishidanda Formation	Biotite-garnet-staurolite schist with slivers of granite gneiss.
-------------------------------Thimphu Thrust ---		
Thimphu Group		Augen gneiss, banded gneiss, granite gneiss, mica schist and quartzite
------------------------------- Unconformity Thrust ---		
(Chekha Formation)		Quartzite and phyllite

Table 1: Litho-stratigraphic Divisions of the Lesser Himalayan rocks (Bhargava ed., 1995)

The rocks in this area comprises of Thimphu Group. This Group consists of the crystalline rocks comprising of garnet, kyanite, silliminate paragneiss, schist and flaggy quartzite with basic and igneous intrusions occurring as a thrust sheet. Initially the Thimphu Group of rocks were further divided into Thimphu Formation and the Paro Group (Nautiyal, et al 1964 in Bhargava ed., 1995).

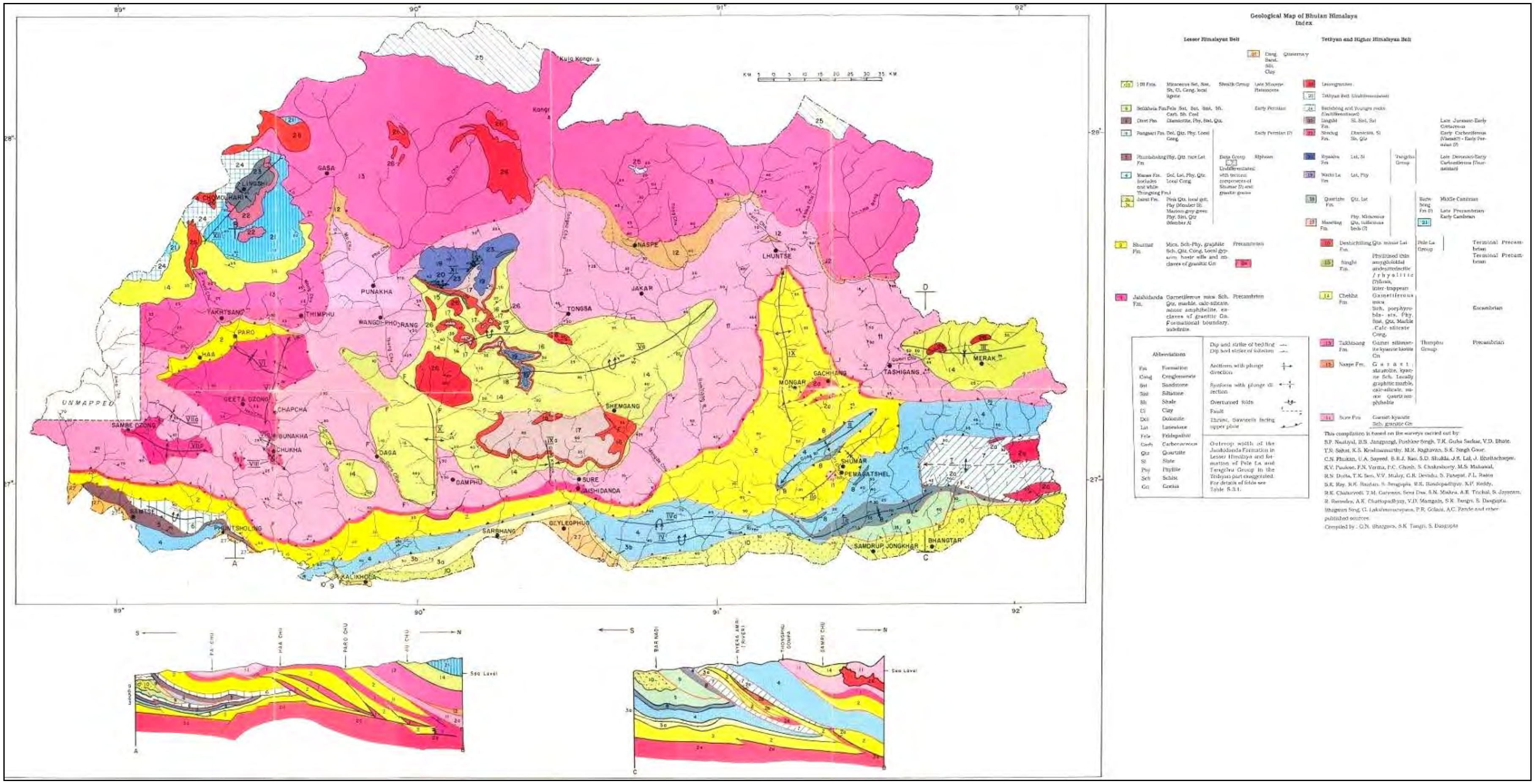


Figure 3: Geological Map of Bhutan by Bhargava, et. al (1995)

The Thimphu Formation rock is predominantly gneiss, whereas the rocks belonging to the Paro Group are a sequence of coarsely crystalline marbles, calc-silicate rocks interstratified with garnetiferous mica schist and quartzites. Later on Golani (in Bhargava ed., 1995), divided the Thimphu Group of rocks as shown in **Table 2** below. The Thimphu Group of rocks occupy about two-third of the total area of Bhutan.

Takhtsang Formation	Biotite granite gneiss. A true migmatitic sequence characterised by frequent occurrence of silliminate-garnet in the biotite gneiss occurring in the northern Bhutan. Subordinate layers of muscovite gneiss.
----------- Takhtsang Thrust ----------	
Naspe Formation	A graphite bearing metapelite-marble lithopack with or without gneiss
Sure Formation	A two mica granite gneiss dominated litho-assemblage widespread in central and southern Bhutan with medium to high grade often containing garnet and kyanite Silliminate is rare.

Table 2: Litho-stratigraphic subdivisions of the Thimphu Group (Bhargava ed., 1995)

2.2 Local Geology

A general surface study indicates that the main litho units existing in the area between the view point and Bangla Pokto area comprise of different types of high grade litho-assemblages that dominantly consist garnet mica (biotite) schist, gneissic units, quartzite including the crystalline limestone lenses at certain places. These rocks have been classified and placed under Sure Formation of the Thimphu Group (Golani, et al, 1995).

A close review of the surface study also indicates that the topographic condition and material type present in the study area are quite consistent in their presence. The topography of the area above the view point is quite gentle. The area in general is densely vegetated with matured pine trees. Below the highway and up to the Mangde chu bed, the terrain is steeply sloping. Below the highway (from view point) -towards Mangde Chu a huge exposure of granitic gneiss & mica (biotite) schist intercalated rock is seen.

The base of the rock rests at the river bed level. The rock exposure extends further upslope up to the base of the highway (view point). This rock exposure (consisting of inter bedding of mica schist, granite gneiss and quartzite) is observed to be of more than 100m thickness.

2.3 General Rock Types

The granitic gneiss, biotite gneiss and augen gneiss has no distinct contact or separations between two units as observed in course of study. The outcrop area are deeply weathered the local contractors are even using in place of sand as was observed in View point area (2013-14). The rocks trend in an almost east-west direction with southerly dips of 30°- 35°. Including the gneissosity, four joint sets could be properly mapped in the field. The trend of their dips along with dip amount is as follows:

1) 140/40 (Foliation/Gneissosity)
2) 315°/75°(J1)
3) 060°/65° (J2 – Slope)
4) 240°/64° (J3- Inside Dipping)

In the rock exposure seen about 400 metres away from Thomang cliff towards Trongsa, a fault with a dip direction of 200° and a dip amount of 80° could also be observed as shown in the photograph below.

Figure 4: Photograph showing the fault in the rock exposure.

2.4 Subsurface Investigation by Core Drilling

Sub-surface investigation was carried out to find out the vertical sections of the different strata. Boreholes were drilled in the areas as specified in the scope of works and the work was completed in spite drilling difficulties like in maintaining core recoveries as is usually seen in highly weathered rocks as in this case is the granitic gneiss which happens to be completely weathered.

By carrying out the detailed sub-surface exploration information on the following was obtained.

(a) Engineering properties of soil/rock

(b) Location and extent of weak layers and cavities, if any.

(c) The sub-surface geological conditions, such as, type of rock, structure of rock i.e. folds, faults, fissures, shears, fractures, joints, dykes and subsidence due to the presence of cavities.

(d) Ground water level

(e) Artesian condition, if any;

Drilling was carried out by using HX, NM and BX size bits in soft and weathered rocks as well as in hard rock formations. Double tube core barrels were used to ensure better core recovery. A very high recovery ratio was aimed at in soft formation where side collapse is observed or anticipated; casing pipes was used to avoid collapsing of hole. As far as possible dry drilling was carried out in soils and soft rocks and wet drilling in hard rock's to ensure maximum core recovery.

Wherever possible, dry drilling with maximum possible core recovery was under taken to determine the under lying strata. Wet drilling was carried out wherever hard rock was intersected. Wherever possible other geotechnical parameter like the existing slope, hazard condition, ground water condition, strike, dip and other structures of rock was also studied.

Drilling Equipment:

Both of the Drilling equipment used is capable of drilling at any angle upwards or downwards and had the capability to drill exploratory holes of about 80 m depth. The rotary type machine is capable of drilling HX (114mm size) holes (if struck than NX [76mm] size holes), utilizing double tube core barrel equivalent and capable of recovering soft or friable materials with maximum core recovery.

The rotary drilling method was used for all the drilling purposes. In this method, the hole is advanced by rotating a drill string consisting of a series of hollow drill rods to the bottom of which is attached either a cutting bit or a core barrel with a coring bit. Cutting bits shears off chips of the materials penetrated and thus was used primarily for penetrating the casings into the drilled holes. Coring bit on the other hand was used to cut an annular hole in rock mass, thereby, creating a cylinder or core of rock that enters the barrel and is retrieved. Thus the core barrel was primarily used in rock which under most circumstances was cored continuously. As the rods with the bit or barrel are rotated, downward pressure was applied to the drill string to obtain penetration and drilling fluid under pressure was introduced into the bottom of the hole through the hollow drill rods and passages in the bit or barrel.

In all case the drilling procedure followed was to bring about the highest percentage recovery. This was ensured by correct pressure applied to it, with the right amount of flushing medium and without vibration. Therefore, to get the highest percentage of recovery, the operator controlled the vibration in the speed of rotation, the downward pressure on core barrel, the pressure at which the drilling fluid is introduced and the hole drilled (run light) prior to removal of the core.

To achieve the desired results, we ensured the following.

(a) Casing

Suitable size casings both HX and NX sizes are extended through all strata, which might cave in was ensured.

(b) Drill Rods and Core Barrels

Drill rods of size not smaller than AW together with double tube swivel design core barrel of size was used for bore holes. The core barrels were of HXM and NXM sizes. It had a core lifter case and a face discharge bit, to reduce the length of core expend to the length of core subjected to twisting action.

(c) Drilling Fluid

Clean sediment free water from the river or nearby available sources was used as drilling fluid.

(d) Type of Bit

For maximum core recovery, correct section of core bit type is absolutely essential. Diamond tipped core of bit of the impregnated type bits were used.

(e) Drill Run

Drill runs did not exceed 1m in length and the core was removed from the drill holes as often as may be required in order to get the best possible core recovery. In few of the cases, the core length recovered was of 1 metre lengths. Under no circumstances the continuous coring was carried out when it became obvious that the core barrel was blocked.

Observations during Drilling.

The case of difficulty in drilling and speed at different depths were carefully observed during drilling. The returning drill water was kept constantly under observation and its character such as, its clarity or its turbidity; its colour etc was also observed. If the returning drill water is turbid, the same was collected and the suspended matter was allowed to settle. The settled matter was preserved in a suitable container and kept in the core box at the appropriate place corresponding to the depth from which it was obtained and recorded in the drill hole log/boring column sheet as ***sludge***. Depth of drill water losses, partial or full was also recorded during drilling.

The boring log containing the following details was included but not limited to and presented in the report so as to ensure that the maximum information is provided.

(i) Project identification, boring number, location, date of start of boring, data of completion of boring, driller's name and the name of the Geotechnical engineer/Engineering Geologist.
(ii) Coordinates of the location
(iii) Elevation of the ground surface
(iv) Angle from horizontal
(v) Elevation or depth to ground water and raising or lowering of level including the dates measured
(vi) Elevations or depth at which drilling fluid returns was partially or totally lost; size, type and design of core barrel used; size, type and length of all casing used, description of any movements of the casing.
(vii) Length of each core run and length or percentage of the core recorded.
(viii) Detail description of the formation recovered in each run.
(ix) Any change in the character of the drilling fluid or drilling fluid return.
(x) All useful remarks and observations made.
(xi) Colour photographs of core boxes.
(xii) RQD (Rock Quality Designation) which is the ratio expressed as a percentage of the aggregate length of the pieces over 100 mm long in a run divided by the length of the run.

Extraction of Cores

Core were held horizontally, while the cores were extruded, which was by applying a constant pressure without vibration and in manner to prevent disturbance to cores.

Each and every piece of core was sequentially placed from top to downward as soon as the core piece were removed from the core barrel. Length of each core pieces were measured and recorded.

Storing of Core Pieces and Core Boxes

The core pieces were placed in core boxes in a book order in correct sequence from top to downward. For some bore holes there are several core boxes depending on the length of the drill holes.

Core boxes are soundly constructed of good quality timber, fitted with stout carrying handles for drilling work, shifting, transport, storing, logging etc.. Each of such boxes is sequentially numbered in the sequence in which the boxes are used to store core pieces. The following are neatly written on the lid of the core boxes on the inside using permanent marker pens.

The details like the name of the project, borehole number, box number, starting date, completion date, collar height, client, contractor and the total drilled lengths for each borehole is inscribed for easy identification.

All the bore holes cores were logged by the geologist and whenever possible field tests like the Standard Penetration Tests were carried out under the supervision of an expert.

Storage of Core Boxes and Facilities for Studies

The core boxes of completed drill holes were kept in the shed covered by plastic sheets till the completion of the field work and after the completion of the field work the core boxes were handed over to the client for future references.

3 DETAILED INVESTIGATIONS

3.1 Drilling in Borehole No. BH-1

This borehole is located at Thomang cliff area and is approximately at 27°28’41.90”N latitude and 090°28’49.90” E longitude at an approximate elevation of 2265 metres above the mean sea level and is named BH-1 by the client. This location is about 60 metres above the Wangdue-Trongsa primary national highway and is about 16 kilometres before Trongsa. This area is shown in the survey of Bhutan Toposheet No. 78 I/7. This part of the area has been explored in detail by drilling a borehole.

Figure 5: Location of BH-1

Drilling work started on 10th July 2015 and completed on 19th July 2015 after drilling a total of 60.00 metres down depth. The detail of the core log is attached as Appendix A.1 and the core photographs as Appendix C.1. At the top for 30 metres are the top soil and boulders.

Sl. No	Depth	Description	Remarks
1	0.0 – 30.00 m (30.00 m)	Overburden consisting of gravelly sand, mostly of grey to light grey colour. Boulders are of light grey fine grained crudely banded gneiss. At few places banded biotitic gneissic and pegmatite boulders were also observed. Except for the top soil formation, the overburden is likely a colluvial deposit.	SOIL LAYER/TOP SOIL CONSISTING OF SAND AND BOULDERS
2	30.00 – 33.00 m (3.00 m)	Here the strata changes and is most likely a highly weathered garnetiferous quartz mica schist. Only sludge of dark grey colour could be collected in the core box.	GARNETIFEROUS QUARTZ MICA SCHIST BED ROCK.
3	33.00 – 49.00 m (16.00 m)	Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 80° to the core axis and is smooth undulating.	
4	49.00 – 55.00 m (6.00 m)	Medium to fine grained, biotite gneiss with conspicuous banding structure seen in the core samples. Slight to moderately weathered.	BIOTITE GNEISS BED ROCK
5	55.00 – 56.00 m (1.00 m)	Hard and compact, light coloured, fine grained granitic gneiss.	PEGMATITIC INTRUSION
6	56.00 – 60.00 m (4.00 m)	Medium to fine grained, biotite gneiss with conspicuous banding structure seen in the core samples. Slight to moderately weathered. Joint is at 40° with the core axis and has smooth undulating surface. Foliation is at 65° to the core axis and it has smooth undulating small scale roughness.	BIOTITE GNEISS BED ROCK

Table 3: Summary of BH-1 borehole

For the first 30 metres, the overburden consisting of gravelly sand, mostly of grey to light grey colour was observed. Boulders are of light grey fine grained crudely banded gneiss. At few places banded biotitic gneissic and pegmatite boulders were also observed. The bed rock consisting of fine grained, grey coloured garnetiferous quartz mica (muscovite) schist could be inferred from 30 metres to 49 metres depths. Garnets are slightly bigger than pin heads. Foliation is at 80° to the core axis and is smooth undulating. The bed rock changes to banded biotite gneiss from 49 metres. A pegmatite intrusion of slightly over a metre thickness could also be observed at 55 metres depth.

3.2 Drilling in Borehole No. BH-2

This borehole is located at Thomang cliff area and is approximately at 27°28'42.00"N latitude and 090°28'49.10" E longitude at an approximate elevation of 2280 metres above the mean sea level and is named BH-2 by the client. This location is about 30 to the north west of BH-1. This area is shown in the survey of Bhutan Toposheet No. 78 I/7. This part of the area has been explored in detail by drilling a borehole.

Figure 6: Location of BH-2

Drilling work started on 24th July 2015 and completed on 10th August 2015 after drilling a total of 50.00 metres down depth. The detail of the core log is attached as Appendix A.2 and the core photographs as Appendix C.2. At the top for 33 metres are the top soil and boulders.

Sl. No	Depth	Description	Remarks
1	0.00 – 33.00 m (33.00 m)	Overburden consisting of gravelly sand, mostly of grey to light grey colour. Boulders are of light grey fine grained crudely banded gneiss. At few places banded biotitic gneissic and pegmatite boulders were also observed. Except for the top soil formation, the overburden is likely a colluvial deposit.	SOIL LAYER/TOP SOIL CONSISTING OF SAND AND BOULDERS
2	33.00 – 38.00 m (5.00 m)	Here the strata changes and is most likely a highly weathered garnetiferous quartz mica schist. Only sludge of dark grey colour could be collected in the core box.	GARNETIFEROUS QUARTZ MICA SCHIST BED ROCK.
3	38.00 – 50.00 m (12.00 m)	Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 65° to the core axis and is smooth undulating.	

Table 4: Summary of BH-2 borehole

For the first 33 metres, the overburden consisting of gravelly sand, mostly of grey to light grey colour was observed. Boulders are of light grey fine grained crudely banded gneiss. At few places banded biotitic gneissic and pegmatite boulders were also observed. The bed rock consisting of fine grained, grey coloured garnetiferous quartz mica (muscovite) schist could be inferred from 33 metres depths. Garnets are slightly bigger than pin heads. Foliation is at 65° to the core axis and is smooth undulating.

3.3 Drilling in Borehole No. BH-3

This borehole is located at Thomang cliff area is located very near to the cliff face and is approximately at 27°28’39.30”N latitude and 090°28’49.40” E longitude at an approximate elevation of 2279 metres above the mean sea level and is named BH-3 by the client. This area is shown in the survey of Bhutan Toposheet No. 78 I/7. This part of the area has been explored in detail by drilling a borehole.

Drilling work started on 27th July 2015 and completed on 3rd August 2015 after drilling a total of 50.00 metres down depth. The detail of the core log is attached as Appendix A.3 and the core photographs as Appendix C.3. The summary of the sub surface strata is as shown in the table below.

Sl. No	Depth	Description	Remarks
1	0.0 – 5.00 m (5.00 m)	Medium to fine grained, biotite gneiss with conspicuous banding structure seen in the core samples. Slight to moderately weathered. Pegmatitic intrusion observed within the bed rock.	BED ROCK OF BIOTITE GNEISS
2	5.00 – 6.00 m (1.00 m)	Hard and compact, light coloured, fine grained granitic gneiss.	GRANITIC GNEISS
3	6.00 – 50.00 m (44.00 m)	Medium to fine grained, biotite gneiss with conspicuous banding structure seen in the core samples. Slight to moderately weathered. At the end, the banding becomes blurred (crude banding).	BED ROCK OF BIOTITE GNEISS

Table 5: Summary of BH-3 borehole

Figure 7: Location of BH-3

For the first 5 metres, it is medium to fine grained, biotite gneiss bed rock with conspicuous banding structure seen in the core samples. The rock is slight to moderately weathered. Then there is about metre thick granitic gneiss, hard and compact rock till 6 metres depth. And again from this depth the bed rock of banded biotite gneiss continues till 47 metres depth and then the gneiss shows crude banding structure. There is a cavity of about 4 metres from 23 to 27 metres depth.

3.4 Drilling in Borehole No. BH-4

This borehole is located at Bangla Pokto area is located about 50 metres above the Wangdue - Trongsa highway and is approximately at 27°27'02.80"N latitude and 090°24'24.87" E longitude at an approximate elevation of 2428 metres above the mean sea level and is named BH-4 by the client. This area is shown in the survey of Bhutan Toposheet No. 78 I/7. This part of the area has been explored in detail by drilling a borehole.

Figure 8: Location of BH-4

Drilling work started on 23rd June 2015 and completed on 1st July 2015 after drilling a total of 25.00 metres down depth. The detail of the core log is attached as Appendix A.4 and the core photographs as Appendix C.4. The summary of the sub surface strata is as shown in the table below.

Sl. No	Depth	Description	Remarks
1	0.00– 2.50 m (2.50 m)	Top soil containing humus and organic parts like the roots and leaves of bushes and small plants. The soil is brown coloured clayey sand with few gravels of quartz. The soil is cohesive.	TOP SOIL /OVERBURDEN MATERIAL
2	2.50 – 24.00 m (21.50 m)	Bed rock of highly weathered granitic gneiss which was recovered only as sludge. The core recovery was only of pegmatite, light coloured coarse grained rock which occurs intermittently within the host rock of highly weathered granitic gneiss.	BED ROCK OF GRANITIC GNEISS WITH PEGMATITE INTRUSIONS
3	24.00 – 25.00 m (1.00 m)	Fine grained, moderately weathered biotite schist, darkish coloured	BIOTITE SCHIST BED ROCK

Table 6: Summary of BH-4 borehole

For the first 2.50 metres, it is the top soil containing humus and organic parts like the roots and leaves of bushes and small plants. The soil is brown coloured clayey sand with few gravels of quartz. The soil is cohesive. The Bed rock of highly weathered granitic gneiss occurs from 2.50 metres and extends till 24 metres with intermittent occurrence of pegmatite intrusions. The bed host bed rock is highly weathered and thus could be recovered only as sludge. The actual core recovery was only of pegmatite, which is light coloured coarse grained rock. At the bottom for about a metre thick is the bed rock of fine grained dark grey coloured, moderate to highly weathered biotite schist.

3.5 Drilling in Borehole No. BH-5

This borehole is located at Bangla Pokto area is located just below the Wangdue-Trongsa highway and is approximately at 27°27'00.60"N latitude and 090°24'24.7" E longitude at an approximate elevation of 2417 metres above the mean sea level and is named BH-5 by the client. This area is shown in the survey of Bhutan Toposheet No. 78 I/7. This part of the area has been explored in detail by drilling a borehole.

Figure 9: Location of BH-5

Drilling work started on 11th June 2015 and completed on 17th June 2015 after drilling a total of 25.00 metres down depth. The detail of the core log is attached as Appendix A.5 and the core photographs as Appendix C.5. The summary of the sub surface strata is as shown in the table below.

Sl. No	Depth	Description	Remarks
1	0.00– 4.65 m (4.65 m)	Top soil containing humus and organic parts like the roots and leaves of bushes and small plants. The soil is brown coloured clayey sand with few gravels of quartz. The soil is cohesive.	TOP SOIL /OVERBURDEN MATERIAL
2	4.65 – 25.00 m (20.35 m)	Bed rock of highly weathered granitic gneiss which was recovered only as sludge. The core recovery was only of pegmatite, light coloured coarse grained rock which occurs intermittently within the host rock of highly weathered granitic gneiss.	BED ROCK OF GRANITIC GNEISS WITH PEGMATITE INTRUSIONS

Table 7: Summary of BH-5 borehole

For the first 4.65 metres, it is the top soil containing humus and organic parts like the roots and leaves of bushes and small plants. The soil is brown coloured clayey sand with few gravels of quartz. The soil is cohesive. The Bed rock of highly weathered granitic gneiss occurs from 4.65 metres and extends till 25 metres with intermittent occurrence of pegmatite intrusions. The bed host bed rock is highly weathered and thus could be recovered only as sludge. The actual core recovery was only of pegmatite, which is light coloured coarse grained rock.

3.6 Standard Penetration Test

The guideline as outlined in ASTM D1586 was followed to carry out the Standard Penetration Test. The SPT is a penetration test, by which the blows are counted; necessary to let a standardised sampler a (split-spoon sampler 50mm) penetrates 0.30m into the soil, using a standardised percussion hammer with a mass of 63.5kg with a dropping distance of 0.75m.

The blows are counted over traject of 0.15m, 0.15m and 0.15m by which the first traject does not contribute to the test as it is considered as disturb due to drilling. The next 0.30m is penetrated into undisturbed soil which is considered for the calculation of bearing capacity. In the dense or hard formation the maximum number of blows is generally limited to 50 or 60.

The permeability test results are provided in Appendix B appended at the back of this report.

4 Seismic Refraction Tomography (SRT) Survey

4.1 Introduction

4.1.1 General Introduction

Seismic refraction tomography is one of the significant geophysical methods to investigate subsurface geology and geotechnical properties for engineering purpose. It utilizes differential travel times at different receiver-shot (receiver-source) offsets. Difference in impedance contrasts of different layers with different P-wave velocities generates head-waves at the interface from the critically incident rays. These head-waves refract from the subsurface interface and are recorded in the seismograph deployed along a line on the ground surface.

The travel time curves are prepared for different receiver-source geometries and the velocity profile of subsurface is inverted from the data. The velocity profile is the fundamental output of seismic refraction tomography. This tomogram, based on a-priori geological information is interpreted to infer subsurface geology.

4.1.2 Physical and geological basis of seismic refraction tomography

Speed of seismic waves in a geological medium is controlled by the elastic properties of the materials. When a seismic ray passing through a medium (upper) encounters an interface separating another medium with different seismic velocity, the seismic energy will transmit or reflect from the subsurface, depending upon the seismic velocity and the density of the mediums. If the lower medium has higher velocity than the upper medium, a critically incident ray on the interface generates headwave. Seismic energy will then travel back to the upper medium from the headwaves and will carry information (velocity) regarding the interface and the lower medium. Seismic velocity of the geological materials varies according to the compactness, porosity and mineralogical composition. This is the main basis of the 2D-SRT survey. In 2D-SRT, seismic signal is generated on the ground surface which then passes through the geological subsurface and depending upon the velocity structure of the subsurface seismic energy is refracted back towards the surface where it is recorded on the seismograph system. The speed of seismic wave on geological formations such as clay, silt, sand, gravel, boulders, and bedrock are different. By virtue of different seismic velocity of different material, it is possible to separate different materials from each other. Seismic velocity of a geological material depends both on the matrix (rock and/or sediments) and on the degree of saturation of pore spaces.

In 2D-SRT first arrival time at different geophones (at different offset distances) along the given profile is measured. The shot points and offset distances are fixed according to the objectives of the survey. The first arrivals measured are used to obtain the velocity model during inversion.

In Bangla Pokto area, surface observations show thick residual soil while in Thomang cliff area profile lines exhibit thick colluvium deposits. Location of each SRT line is presented in Table 8 and Figure 10 and Figure 11.

Geophysical Profile		**Length (m)**	**Location**					
			First Geophone			Last Geophone		
			E	N	H	E	N	H
Bangla Pokto	SRT-1	300	290213	3037471	2393.24	290232	3037766	2450.4
Thomang cliff	SRT-1	200	297554	3040685	2216.5	297402	3040746	2312.3
	SRT-2	200	297444	3040637	2260.8	297504	3040808	2264.4
	SRT-3	200	297463	3040644	2285	297523	3040805	2270

**E=easting, N=northing according to DRUK REF 03 coordinate system; H=elevation (m) from msl.*

Table 8: Details of 2D-SRT surveys, Trongsa Area Bhutan

4.1.3 Objectives of the study

The objectives of the 2D-SRT survey are as followings:

1. To show different layers of soil and rocks along the given profiles,
2. To find out possible depth of bedrock,
3. To find out shear zones or any other possible planes of weakness, and
4. To evaluate the slope if there is any deformation or creep.

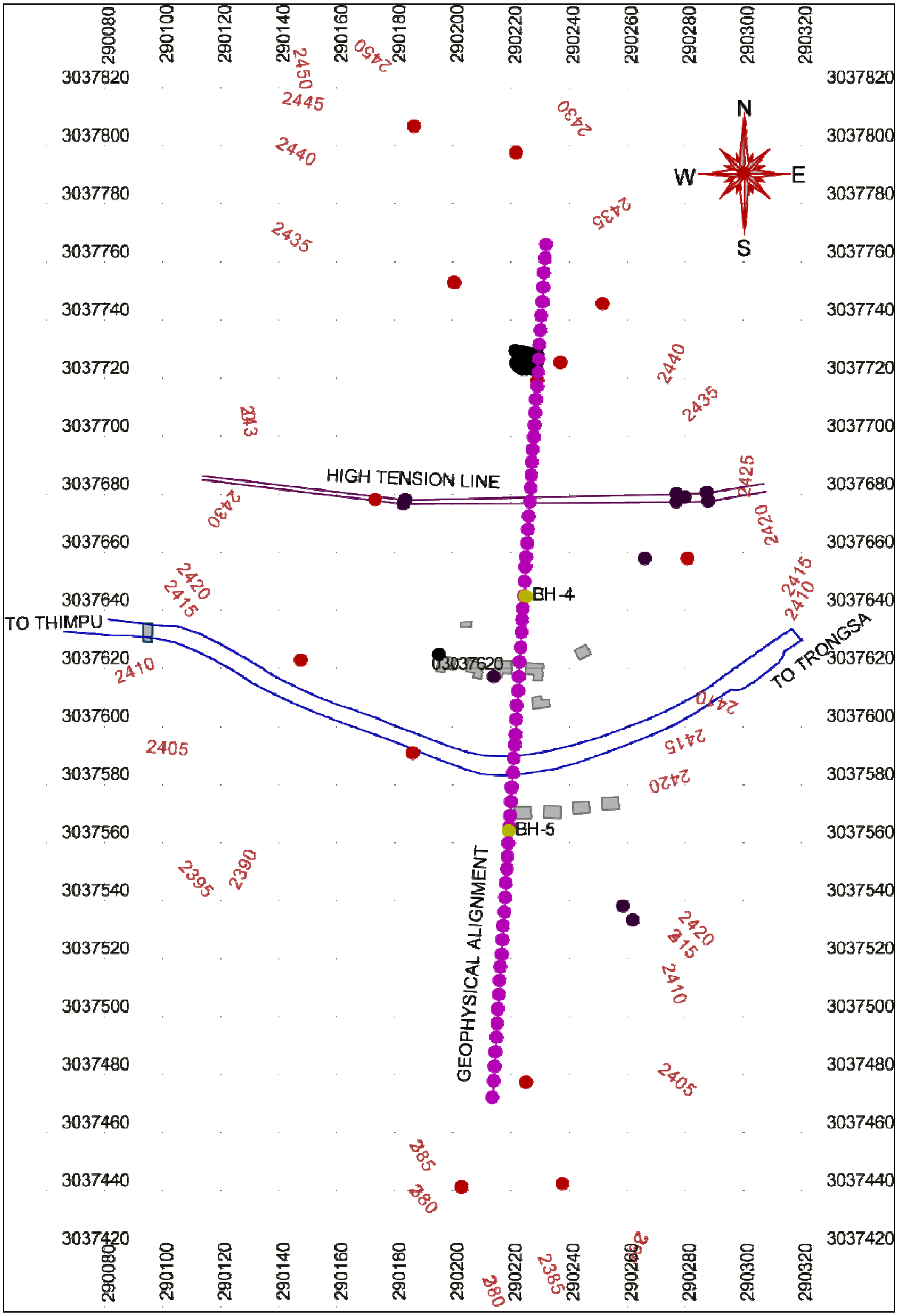


Figure 10: Map showing location of SRT line in the Bangla Pokto Area.

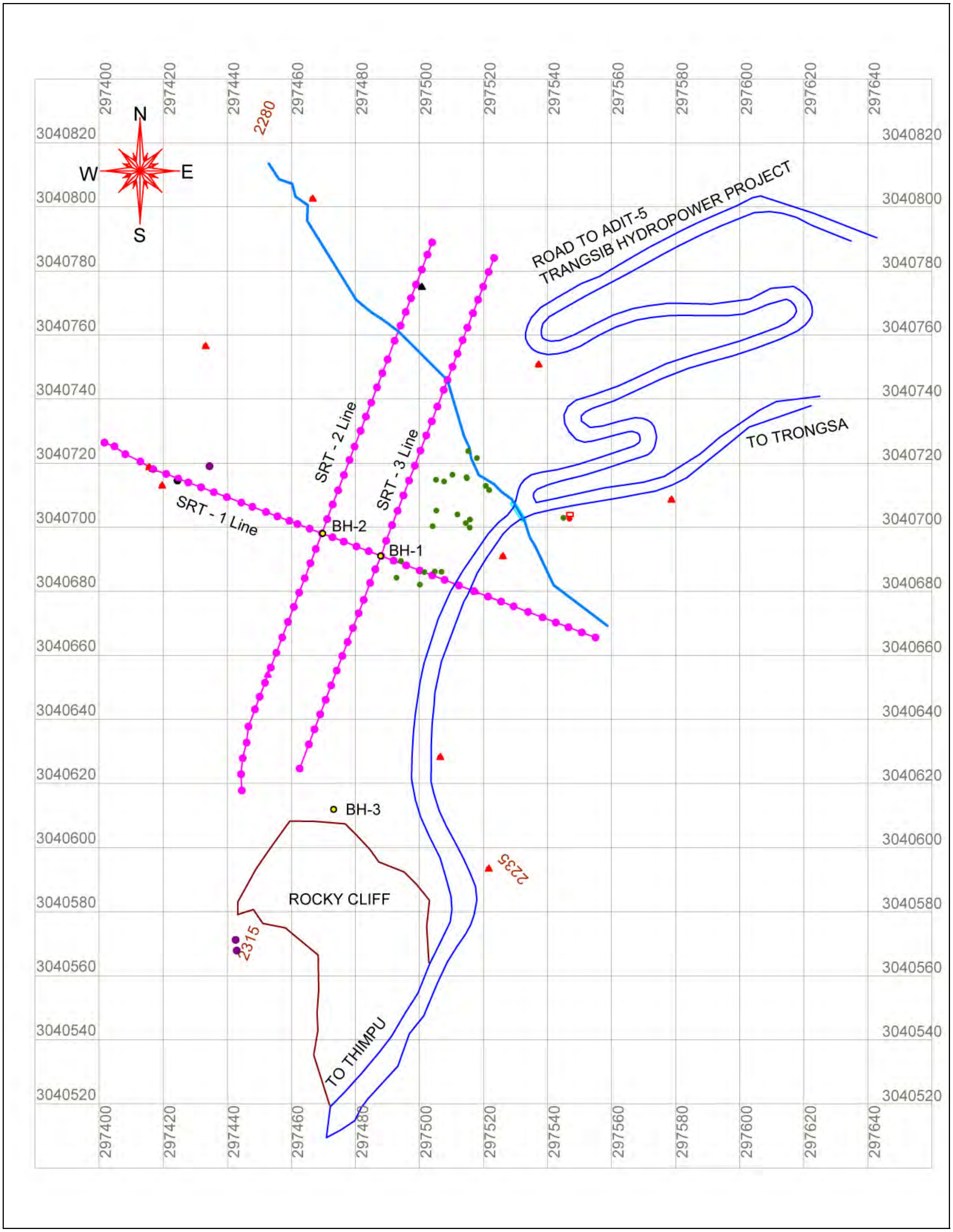


Figure 11: Map showing location of SRT lines in the Thomang cliff area.

4.2 Methodology

4.2.1 Instruments for seismic refraction survey

A 24 channel seismograph system namely ***GEODE-24*** by Geometrics, USA was used for data acquisition. For signal generation explosive was used at different locations along each profile. The offset distance between geophones was set to 5m. One (vertical) component geophones with frequency of 14.5 Hz was used to record the data.

4.2.2 Data acquisition

Seismic refraction survey was carried out along three profiles in Bangla Pokto and Thomang cliff areas as shown in Figure 10 and Figure 11. The amount of explosives for signal generation depends on ground condition and the length of profile. The signal generated at each source location was sufficient to get data throughout the profile. The signal received at each geophone was transmitted to the seismograph which records the signal as waveform and transmit it to the computer.

The data acquisition was carried out with sampling frequency of 600 micro-second and signal length was set to 2s. Since the amplitude of the waveform decreases inversely with respect to the distance of the source the gain of the geophone far away from the source was high with respect to the geophone near to source. The range of the gain was between 48 and 96 dB.

4.2.3 Data processing and analysis

Data processing includes the picking of travel time from seismograms and preparation of travel time curves. Time spent by seismic signals to reach each geophone (first arrival) was picked manually using the software ***Pickwin***. The first arrival data was then inverted using ***Plotrefa*** to prepare the tomogram. Both of this software comes from Geometrics and OYO, USA.

4.3 Results and interpretations

4.3.1 Seismic velocity and subsurface geology

The seismic velocity of a particular material depends on its elastic properties like rigidity, Young's modulus, porosity and the fluid content. In general for earth materials water saturated loose sediments have low seismic velocity. The velocity increases as the soil becomes more compact and dry. In this study the seismic velocity of soil ranges between 300 and 1500 m/s. The seismic velocity of rock is dependent of porosity, water content and compactness and degree of weathering of the rock. Metamorphic rocks like quartzite, gneiss have very high seismic velocity. In this study the velocity of the rock ranges between 1800m/s and 3000m/s.

4.3.2 Interpretation of the results along different profiles

4.3.2.1 Bangla Pokto Area

SRT line lies across the highway from Thimphu to Trongsa. It crosses the borehole BH-4 and BH-5 at the chainages of 174 m and 93 m respectively (Figure 10). Data was recorded along this profile with two consecutive overlaps of 24-channel seismograph system. Geophone interval was fixed at 5 m and signal was generated at every 25 m interval. Figure 12 illustrates the experiment design along this profile. Figure 13, Figure 14 and Figure 15 show the terrain and activities during data acquisition along the SRT profile.

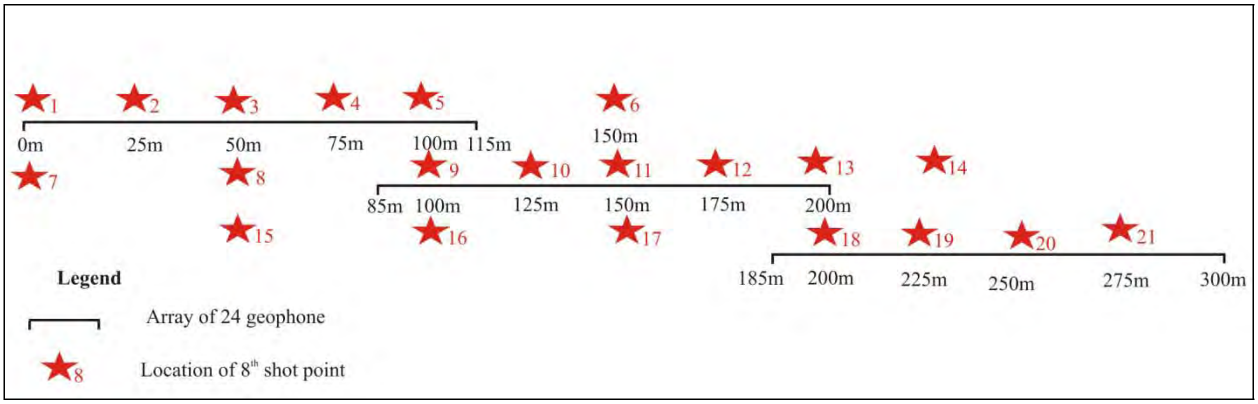


Figure 12: Schematic diagram showing layout of geophone array along SRT profile in Bangla Pokto area (not in scale)

Figure 13: Photograph showing SRT line in the Bangla Pokto Area (view towards N)

Figure 14: Photograph shows conducting blasting operation for SRT profile

Figure 15: Photograph showing data acquisition along SRT line (white dashed line)

Figure 16 shows raw data along the SRT profile with source at 150 m. Data from each shot location was processed and first arrival time was picked for each channel using ***pickwin***. Figure 17 shows the travel-time curves along this profile. Seismic refraction tomogram along this profile was obtained after inverting the travel-time data.

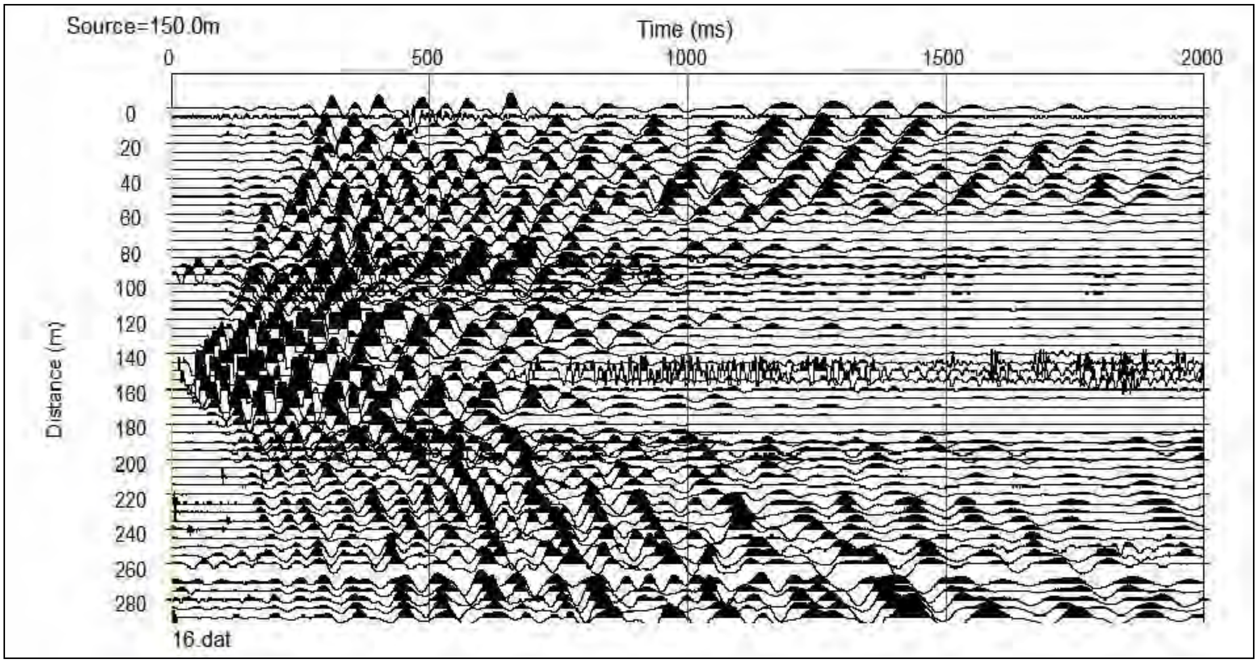


Figure 16: Raw data with source at the chainage of 150 m along the SRT line in the Bangla Pokto area

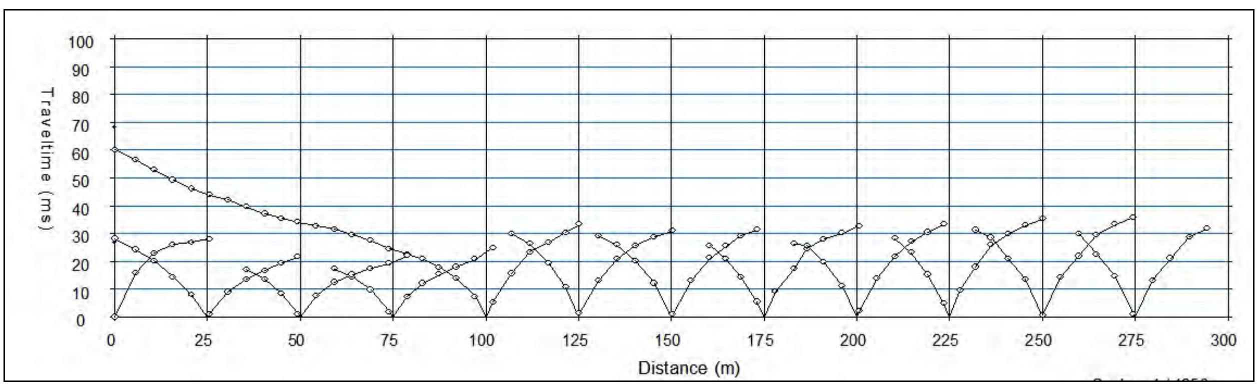


Figure 17: Travel-time curve along SRT line

The tomogram (Figure 18) shows velocity distribution of different subsurface layers along the SRT profile in Bangla Pokto area. The tomogram reveals continuous surface layers of P-wave velocity < 750m/s. This layer is very thin between the chainage of 25m and 95m. Towards NE of BH5 average thickness of this layer is 4.5m while in the south-western corner of the profile thickness of this layer reaches up to 6.6m. These low velocity surface layers represent loose and unconsolidated soil. Velocity of subsurface layers gradually increases to the depth. Layers with P-wave velocities between 750 and

1000m/s are interpreted as compact soil while layers with velocity < 1500 m/s are interpreted as highly compacted soil. On the other hand layers with velocity between 1800 and 2500 m/s are co-relatable with weathered rocks and high velocity layers (Vp > 2500 m/s) are comparable with fresh bedrocks.

P-wave velocity distribution at boreholes BH-4 and BH-5 are shown in Figure 19 and Figure 20 respectively along with inferred lithology of the subsurface materials. As shown in Figure 19, on borehole BH-4 weathered rock is encountered at the depth of 5m. The upper 5m stratum is categorized as loose soil, compact soil and highly compact soil based on the velocity distribution. Fresh bedrocks are found at the depth of 9m. Similarly on BH-5 (Figure 20) the rock soil boundary is estimated at the depth of 6m where the P-wave velocity changes to 1700m/s from 1200m/s of the upper soil layer. Fresh bedrocks are found at the estimated depth of 9.5m.

From slope stability point of view, the entire slope seems stable as the soil thickness is relatively thin (less than 10m) with a gentle topography. No significant slip surface is traced within soil and along soil-rock boundary. In the southernmost part of the profile relatively thick soil (12m) is observed that might move further down slope.

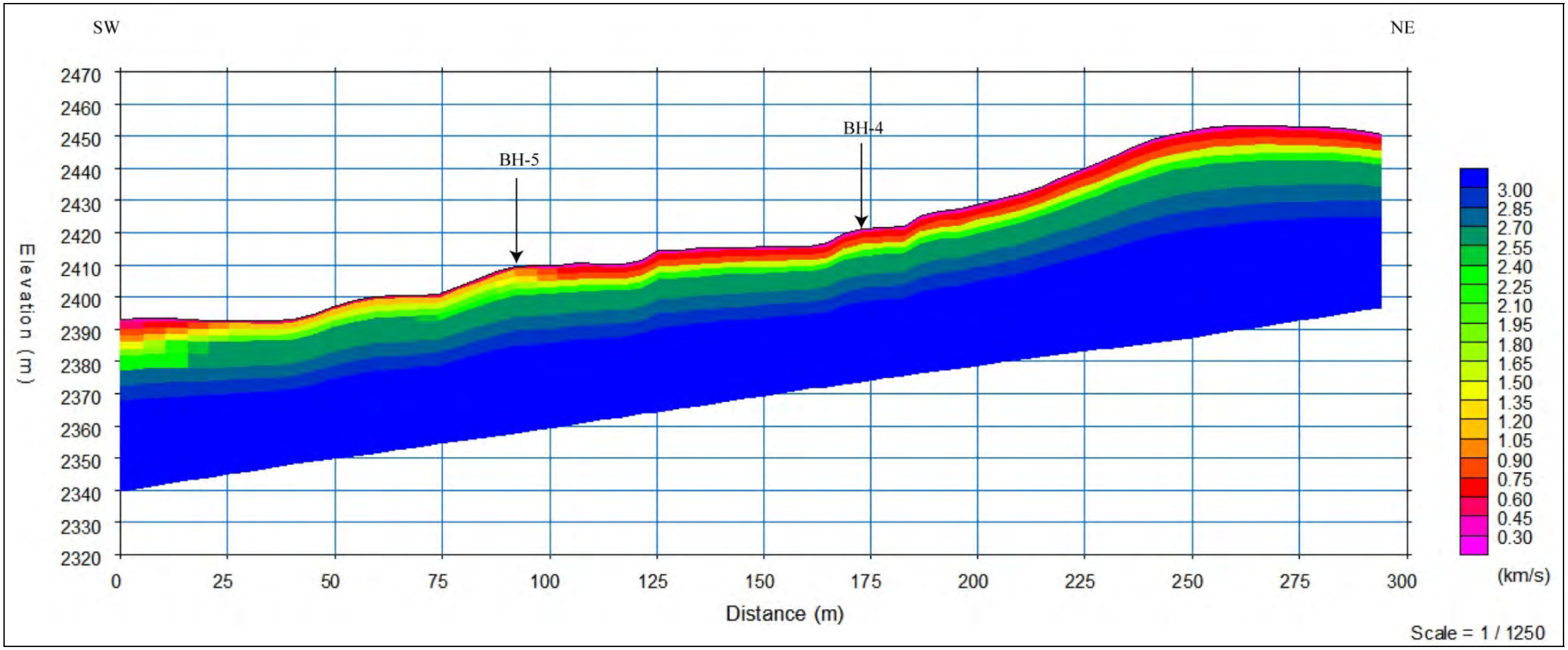


Figure 18: Seismic refraction tomogram along SRT line at Bangla Pokto area.

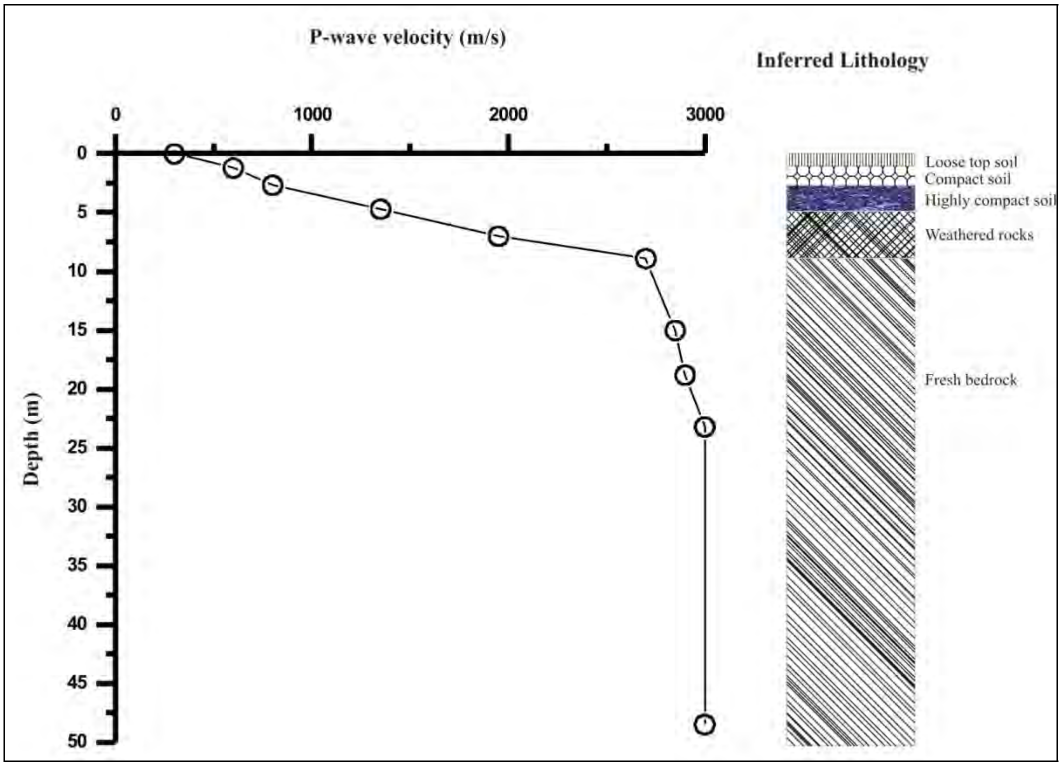


Figure 19: P-wave velocity profile and inferred lithology at borehole BH-04

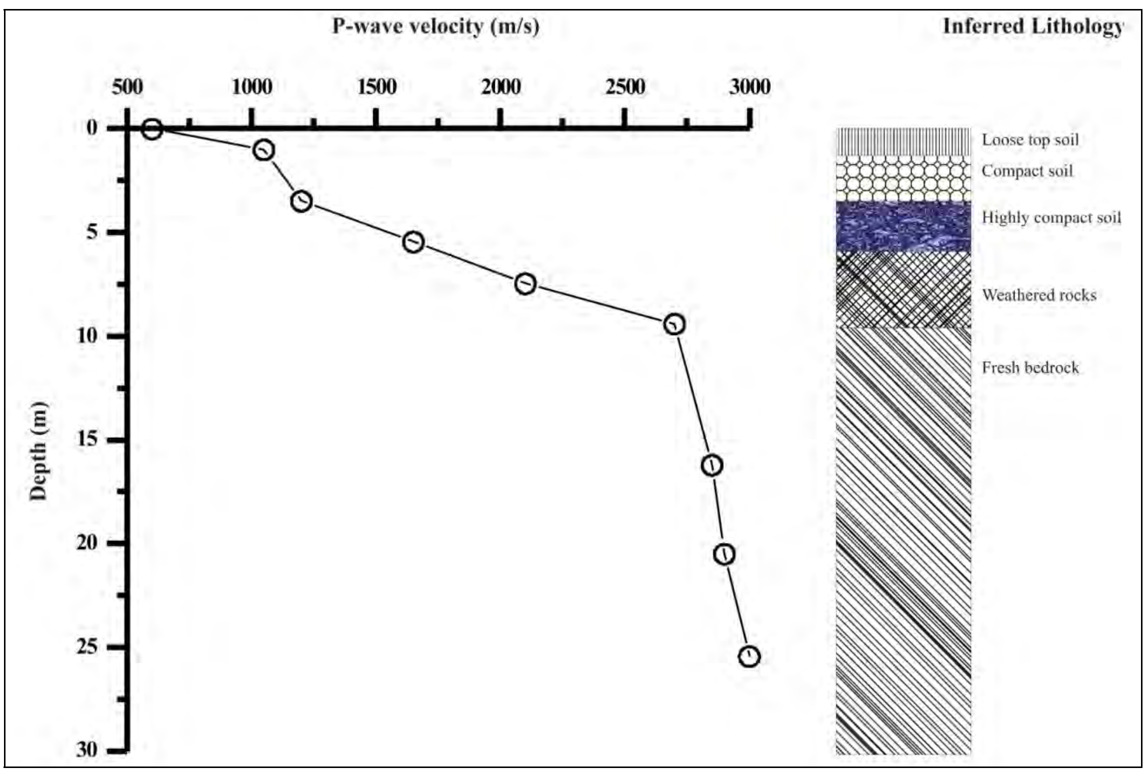


Figure 20: P-wave velocity profile and inferred lithology at borehole BH-05

4.3.2.2 Thomang Cliff Area

In Thomang cliff area SRT was carried out along three profiles each of 200m length namely SRT-1, SRT-2 and SRT-3 (Figure 11). Among them SRT-1 lies across the Trongsa-Thimphu highway and crosses the boreholes BH-1 and BH-2 at the chainages of 70m and 90m respectively. Data was recorded along this profile with one consecutive overlap of 24-channel seismograph system. Geophone interval was fixed at 5 m and signal was generated at every 25 m interval. Figure 20 illustrates the experiment design along this profile. Figure 21 shows the terrain and activities during data acquisition along the SRT profile.

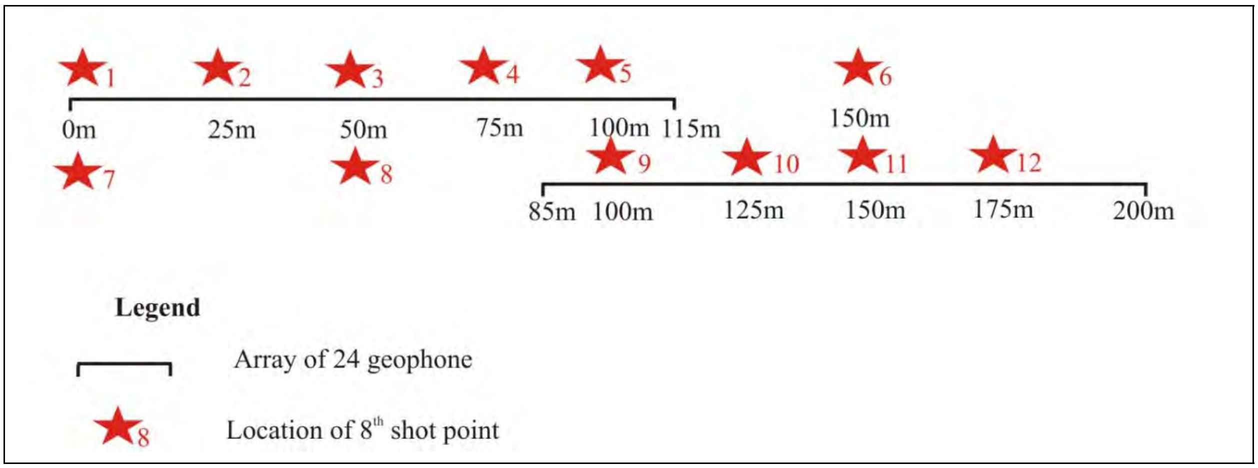


Figure 21: Schematic diagram showing layout of geophone array along SRT-1 profile in Thomang cliff area (not in scale)

Figure 22*: Photograph showing SRT-1 profile at Thomang cliff area.*

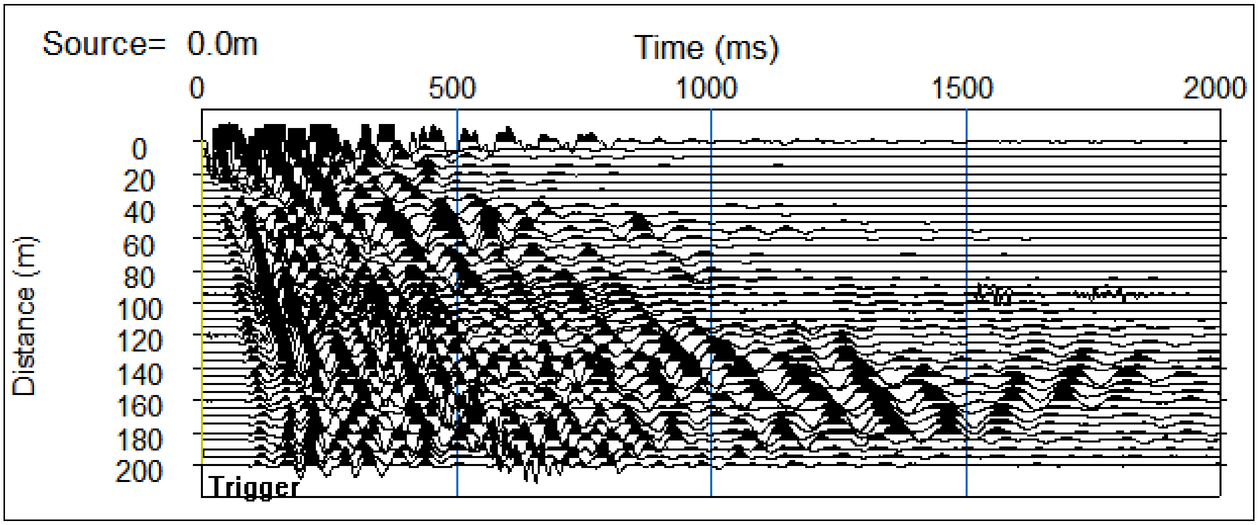


Figure 23: Raw data with source at the chainage of 0 m along the SRT-1 line in the Thomang cliff area.

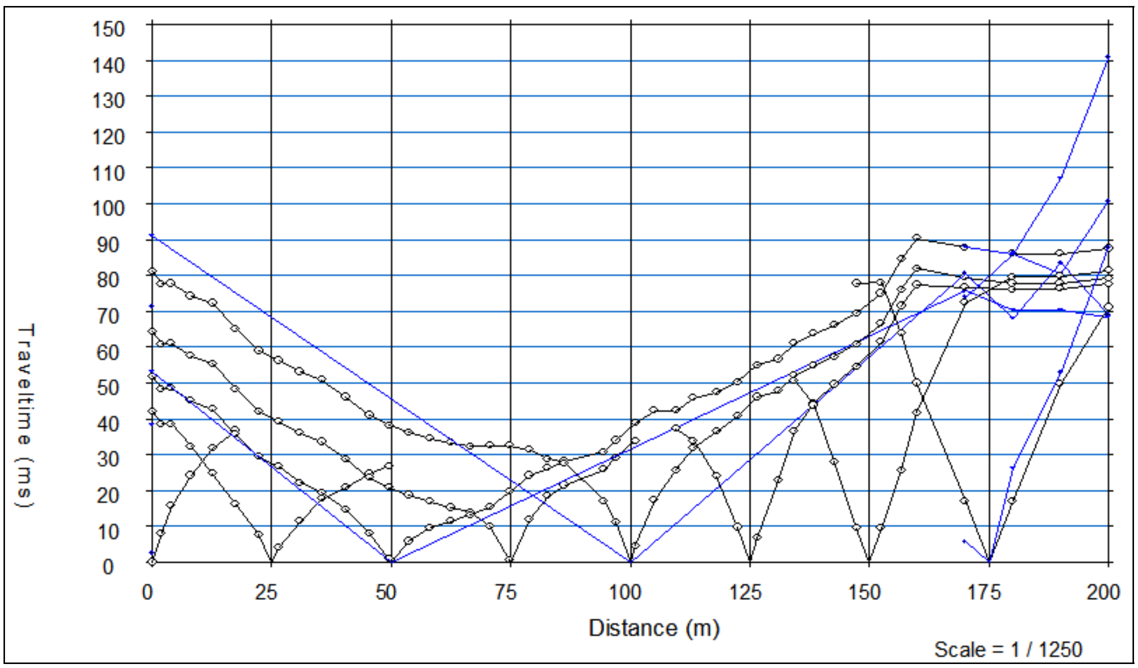


Figure 24: Travel-time curve along SRT-1 line.

Figure 22 shows raw data along the SRT-1 profile with source at 0m. Data from each shot location was processed and first arrival time was picked for each channel using ***pickwin***. Figure 23 shows the travel-time curves along this profile. Seismic refraction tomogram along this profile was obtained after inverting the travel-time data.

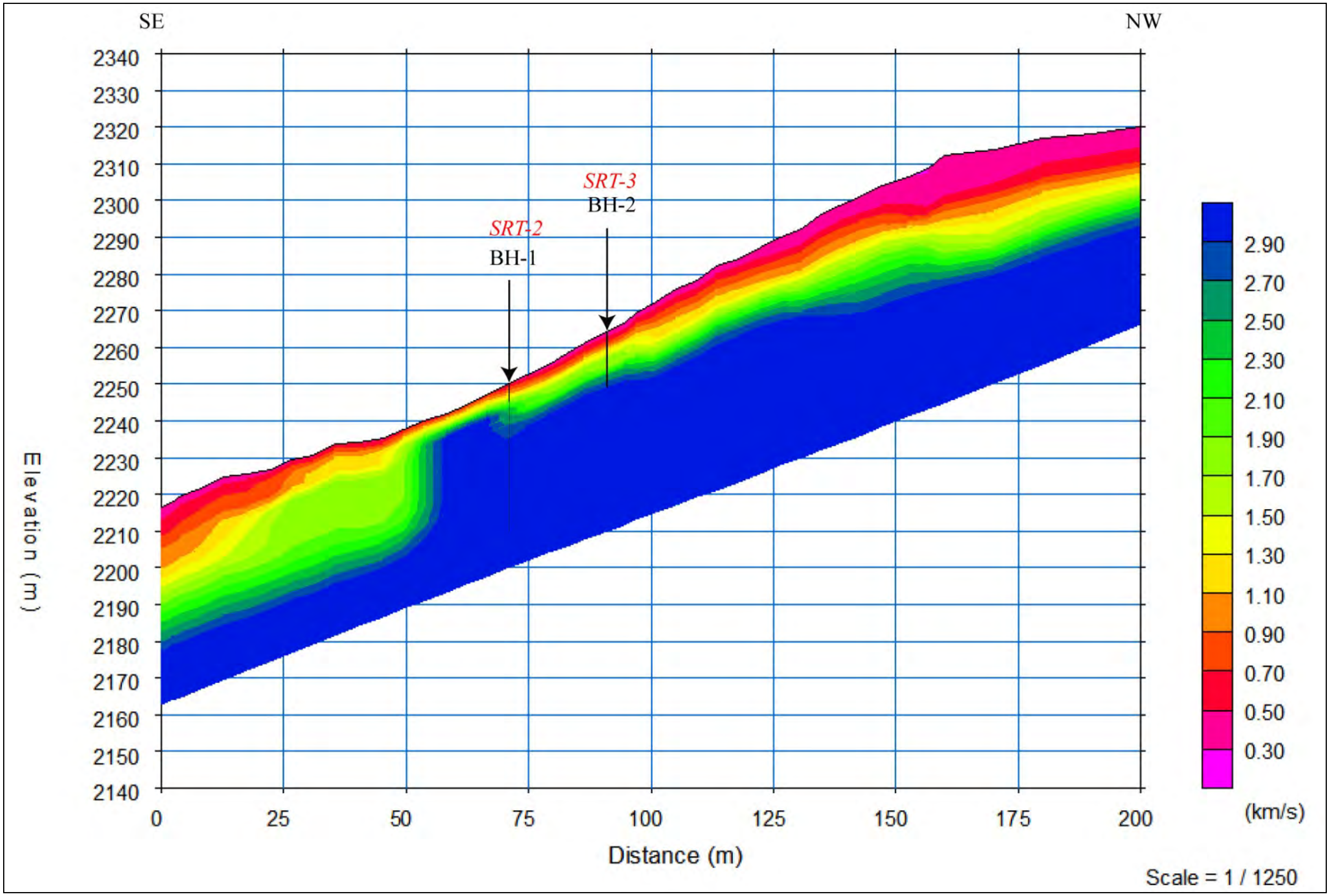


Figure 25: Seismic refraction tomogram along SRT-1.

The tomogram (Figure 24) shows velocity distribution of different subsurface layers along the profile. The tomogram reveals continuous surface layers of P-wave velocity < 700m/s. This layer is very thin between the chainage of 40m and 90m. Towards NW of BH-2 thickness of the low velocity surface layers gradually increase and reaches the maximum of 16.7m. These surface layers are correlatable with loose unconsolidated soil with occasional boulders. In the south-eastern corner of the profile these layers have a thickness of 8.1m. These relatively low velocity layers are underlain by layers with Vp between 800 and 1700m/s correlatable with compact gravel soil based on surface geological observations. Thickness of this compact soil is below 5m between the chainages of 55 and 70m and reaches the maximum of 21m at the chainage of 48m. The high velocity layers underlying the overburden soil are correlatable with the bedrocks.

Along SRT-2 which crosses BH-2 at the chainage of 100m, because of inaccessible terrain data acquisition was carried out from the chainage of 35m. Data was recorded along this profile with one consecutive overlap of 24-channel seismograph system. Geophone interval was fixed at 5 m and signal was generated at the chainages of 35m, 50m, 100m, 150m and 200m. Figure 25 illustrates the experiment design along this profile. Figure 26 shows the terrain along the SRT profile.

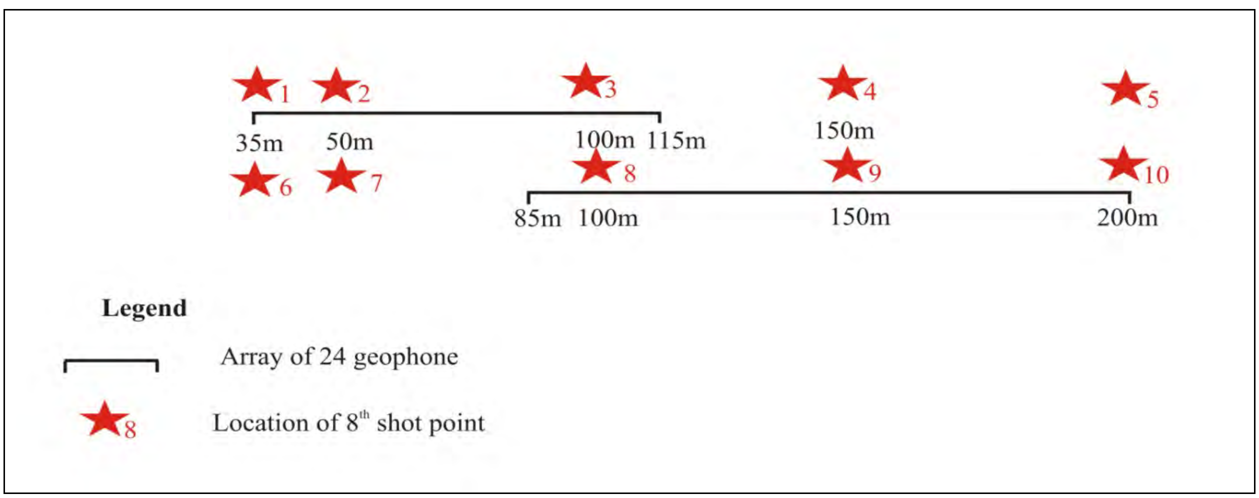


Figure 26: Schematic diagram showing layout of geophone array along SRT-2 profile in Thomang cliff area (not in scale)

Figure 27: Photograph showing SRT-2 profile at Thomang cliff area.

Figure 27 shows the travel-time curves along this profile. Seismic refraction tomogram along this profile was obtained after inverting the travel-time data.

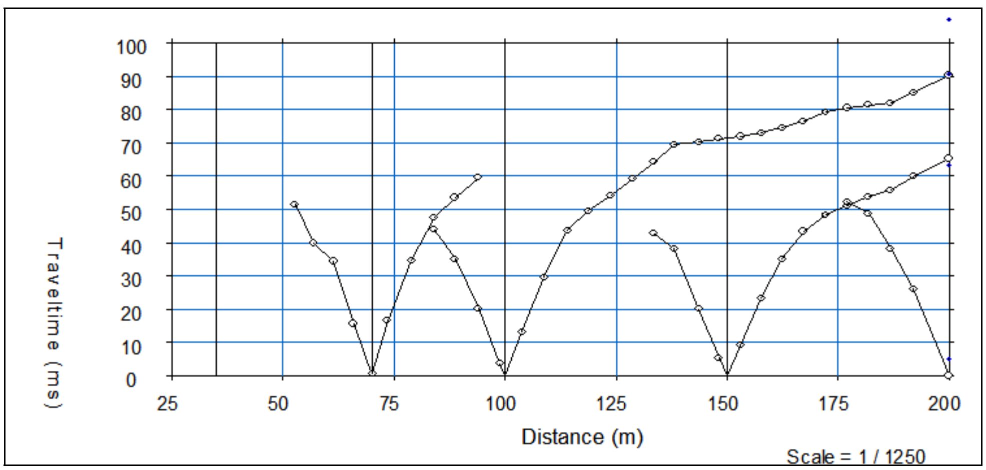


Figure 28*: Travel-time curve along SRT-2*

The tomogram (Figure 28) shows velocity distribution of different subsurface layers along the profile. The tomogram reveals continuous surface layers of P-wave velocity < 750m/s. This layer is somewhat uniform with an average thickness of 9.5m. These surface layers are correlatable with loose unconsolidated soil with occasional boulders and are underlain by about 3m thick layers with Vp between 750 and 1500m/s. High velocity layers (Vp > 2000m/s) in the deeper part are correlatable with bedrocks.

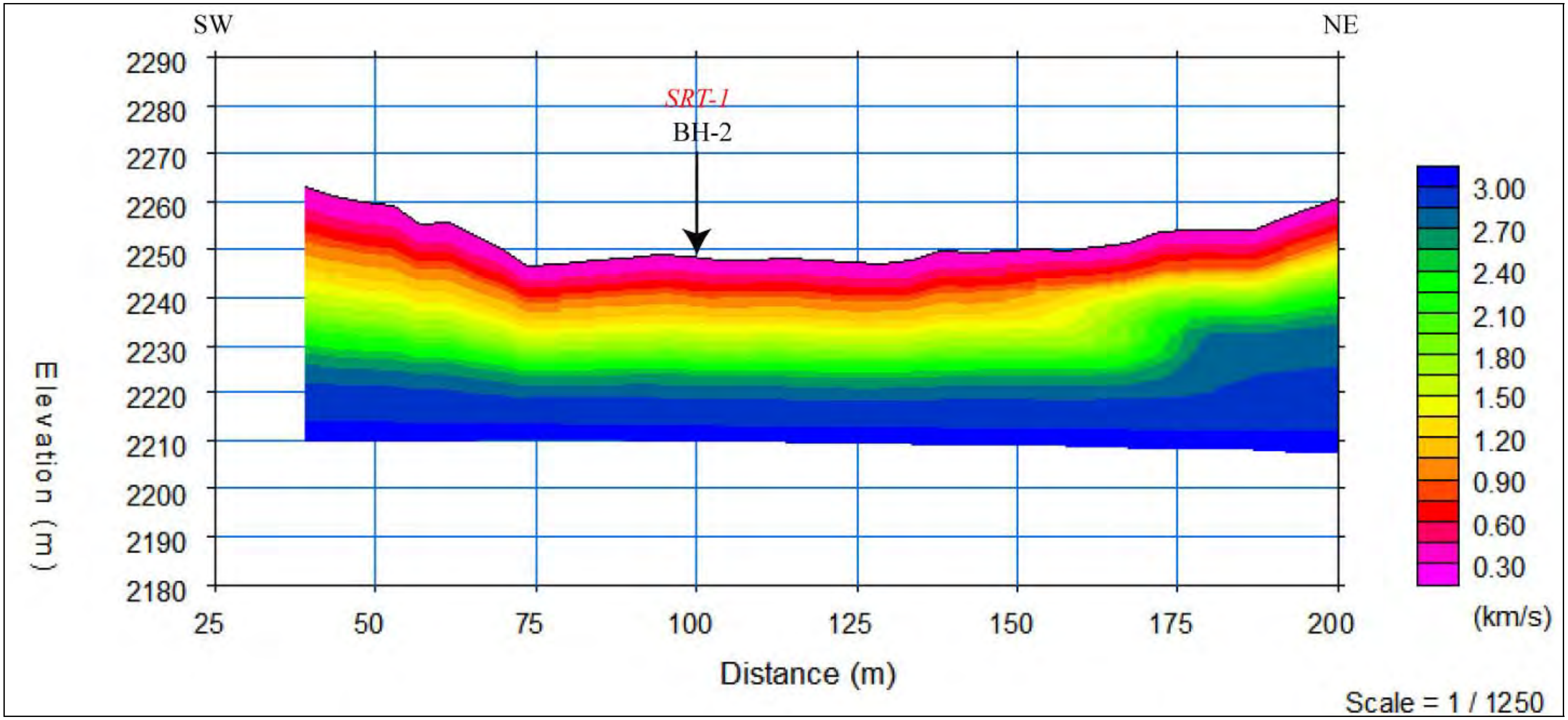


Figure 29: Seismic refraction tomogram along SRT-2 line.

SRT-3 which crosses BH-1 at the chainage of 100 m runs parallel to SRT-2. Data was recorded along this profile with one consecutive overlap of 24-channel seismograph system. Geophone interval was fixed at 5 m and signal was generated at the chainages of 0m, 50m, 100m, 155m and 200m. Figure 29 illustrates the experiment design along this profile. Figure 30 shows the terrain and activities during data acquisition along the SRT profile.

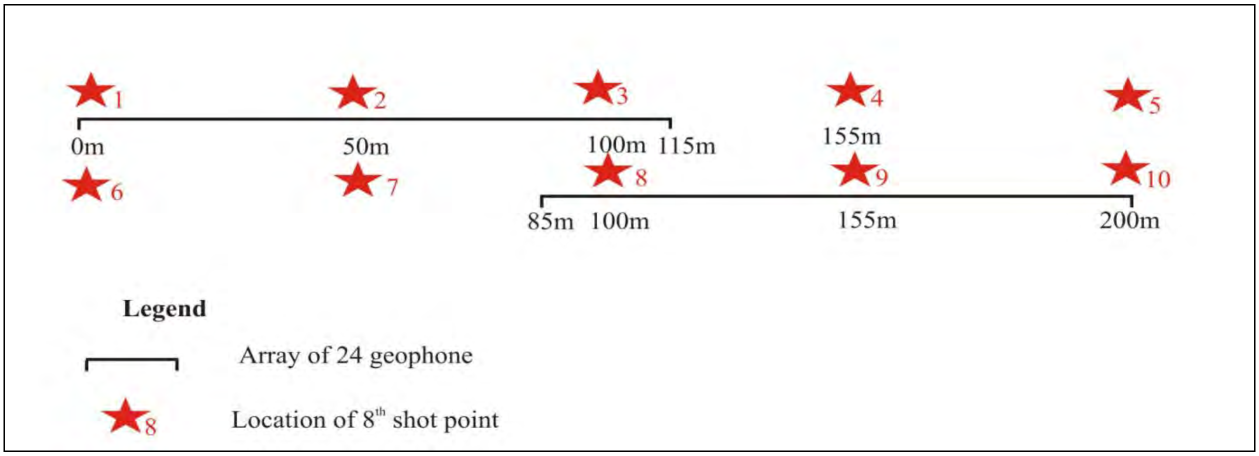


Figure 30: Schematic diagram showing layout of geophone array along SRT-3 profile in Thomang cliff area (not in scale)

Figure 31: Photograph showing SRT-3 profile at Thomang cliff area.

Figure 31 shows the travel-time curves along this profile. Seismic refraction tomogram along this profile was obtained after inverting the travel-time data.

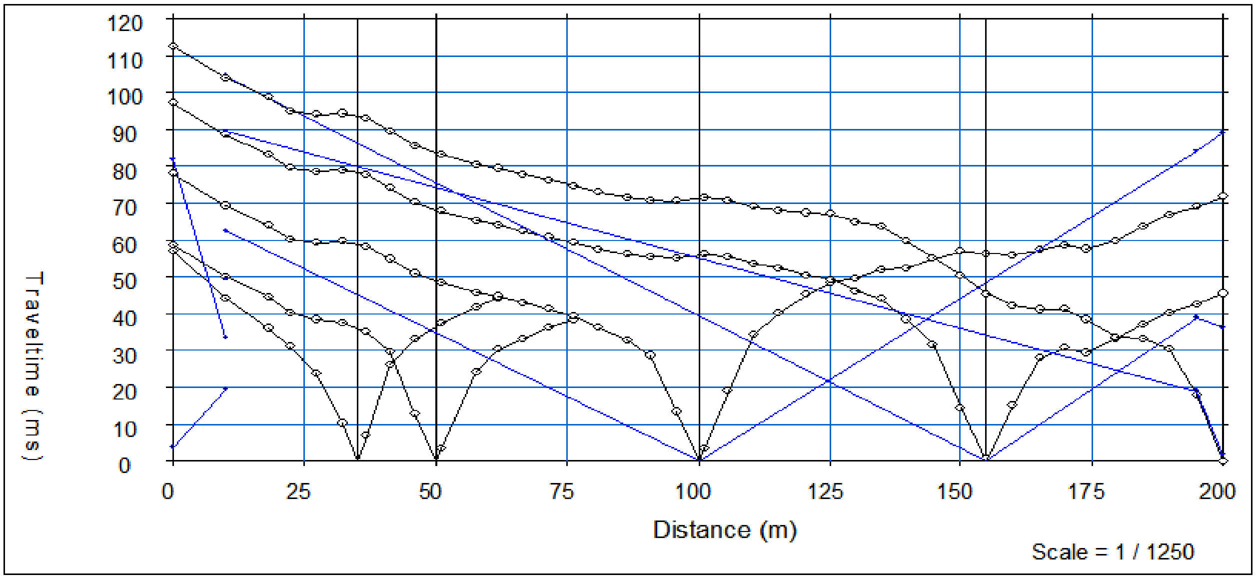


Figure 32*:* Travel-time curve along SRT-3 line.

The tomogram (Figure 32) shows velocity distribution of different subsurface layers along the profile. The tomogram reveals continuous surface layers of P-wave velocity < 750m/s. This layer is somewhat uniform with an average thickness of 6m. At the central part of the profile thickness of these layers is the minimum. These surface layers are correlatable with loose unconsolidated soil with occasional boulders and are underlain by very thin layers with Vp between 750 and 1500m/s. High velocity layers (Vp > 2000m/s) in the deeper part are correlatable with bedrocks.

Based on the velocity profile along three lines, the P-wave velocity log is prepared on borehole BH-1 and BH-2. These logs along with inferred geology are presented in Figure 33 and Figure 34. At borehole BH-1 which lies 20m uphill from the Trongsa-Thimphu highway, an overburden of 4.5m is calculated. The overburden is comprised of a thin loose and unconsolidated top soil and about 3.5m thick compact soil. The overburden is underlain by 1.75m thick layer of weathered rocks. High velocity layers (>2200m/s) are interpreted as fresh bedrocks (Figure 33). On borehole BH-2, the overburden is estimated to 5.75m thick and is underlain by 3.75m thick weathered rocks. High velocity layers below 9.75m are interpreted as fresh bedrocks (Figure 34).

Evaluating the tomograms from three different profile lines, a passive slip surface can be inferred at the depth of 5 to 13m that dips SE (Figure 36).

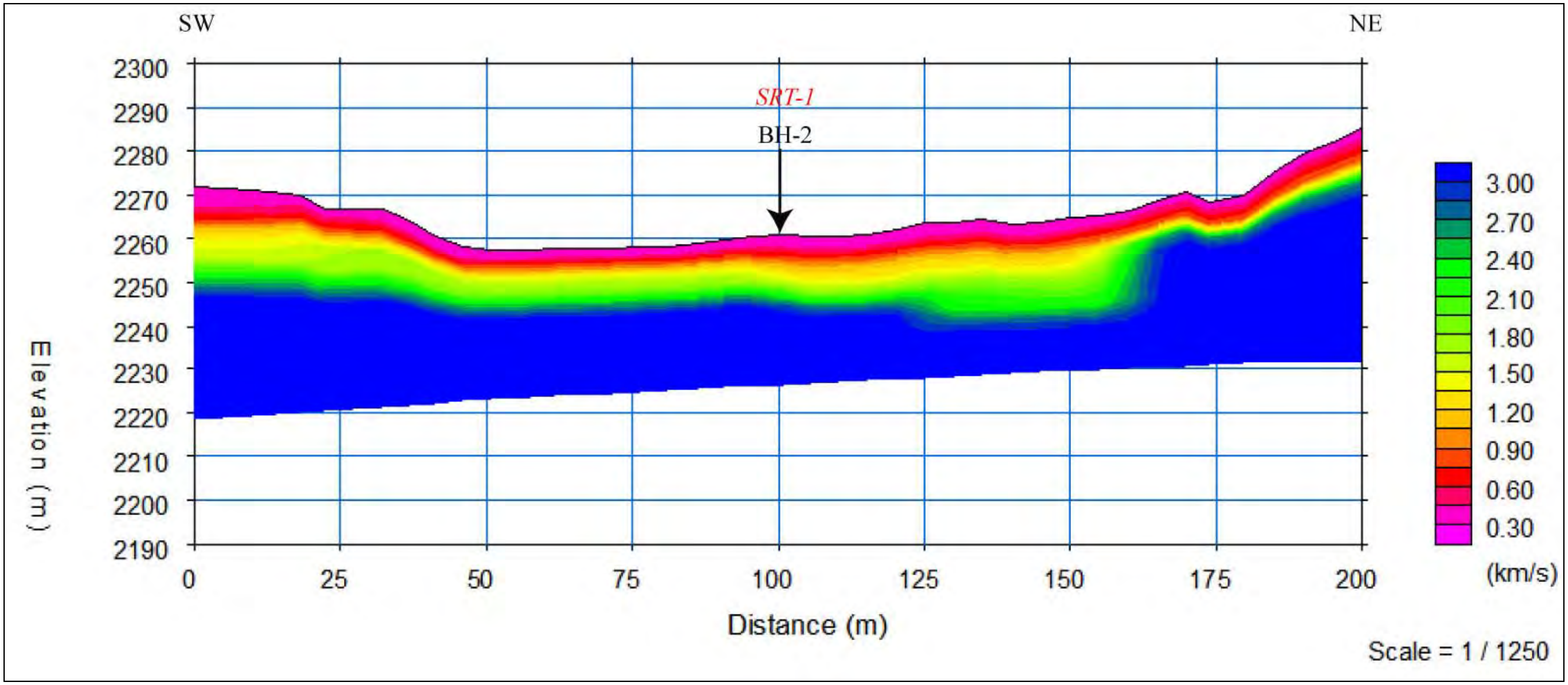


Figure 33: Seismic refraction tomogram along SRT-3 line

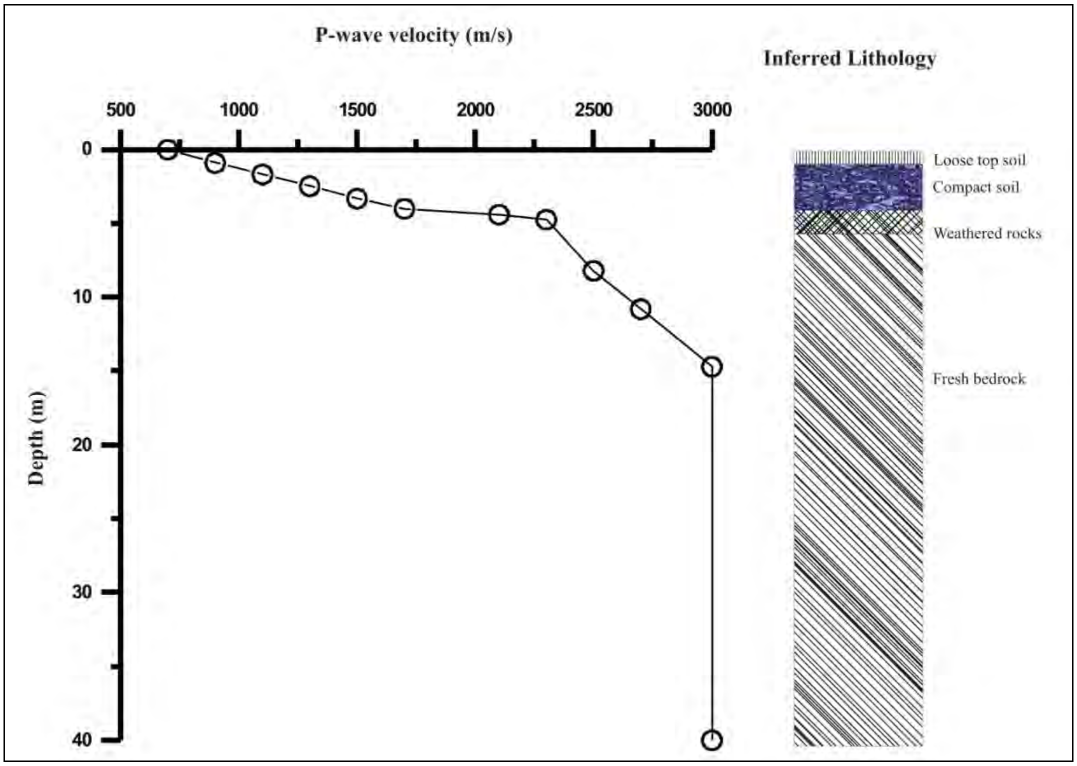


Figure 34*: P-wave velocity profile and inferred lithology at borehole BH-1*

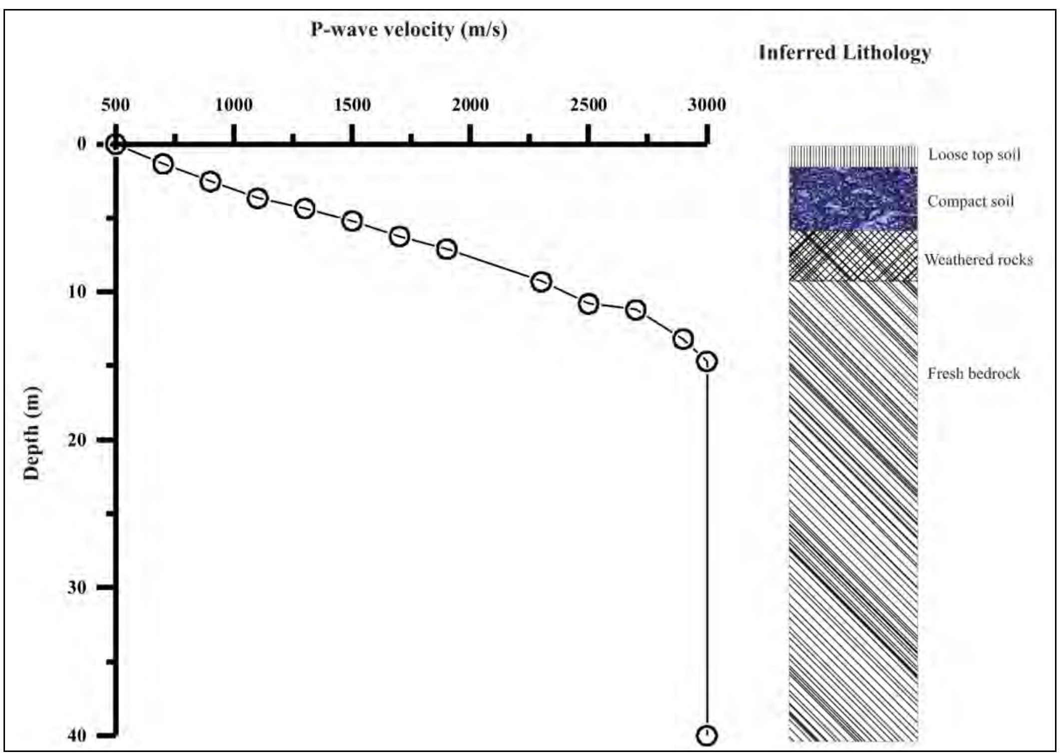


Figure 35: P-wave velocity profile and inferred lithology at borehole BH-1

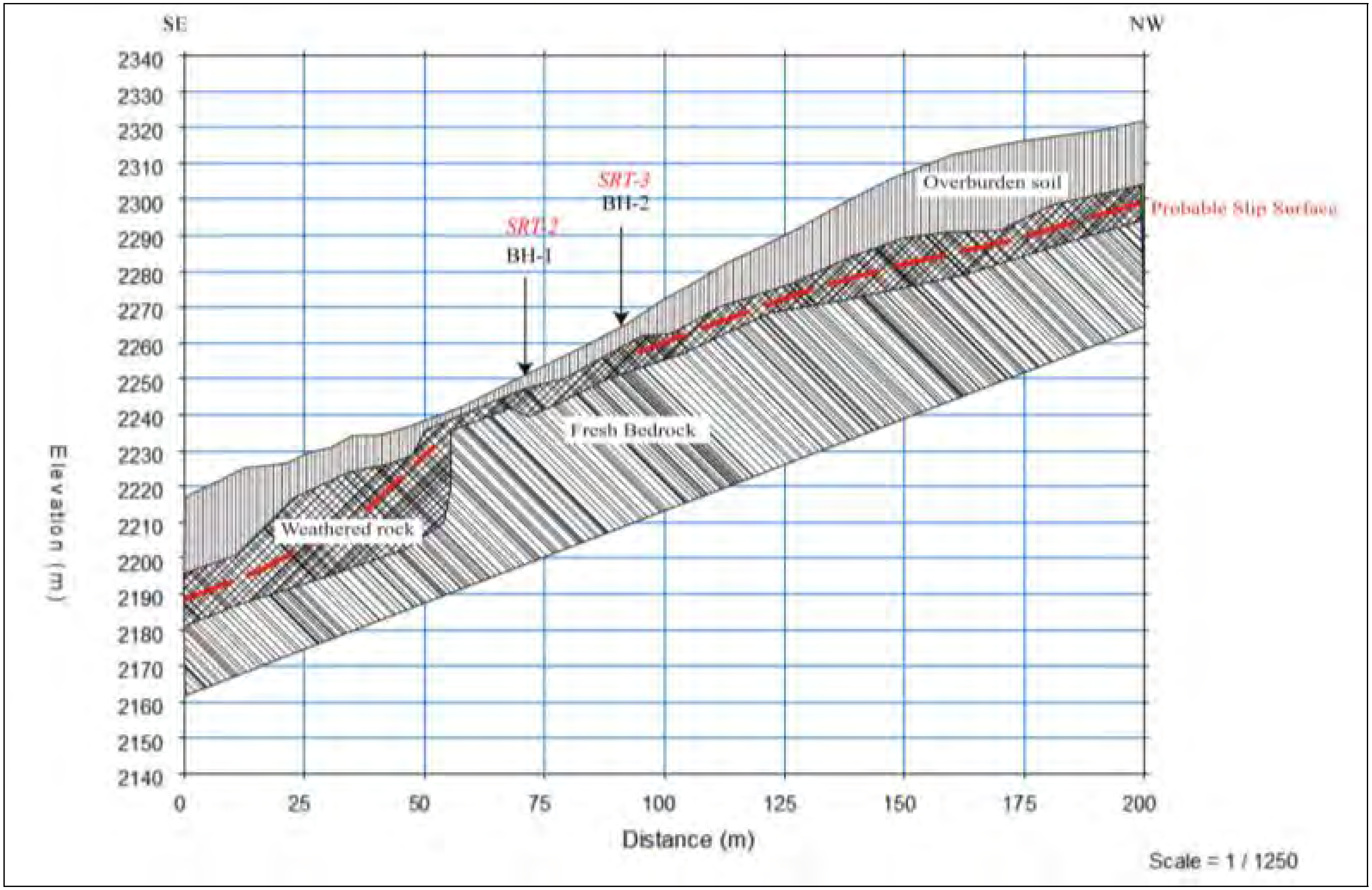


Figure 36*: Interpretative geological section along SRT-1 at Thomang Cliff showing interpreted passive slip surface*

4.4 Conclusions

After interpreting the results of SRT survey along with surface observations during field visit of different sites the following conclusions are made:

1. In Bangla Pokto area bedrocks are found at shallow depth (<6m) and there is no probable slip surface for heavy mass wasting phenomena.

2. In Thomang Cliff area, bedrocks are found at different depths (5m to >40m)

3. In Thomang Cliff area, a passive slip surface is inferred at the depth of 5 to 13m that dips towards southeast.

5 Laboratory Test and other Analysis Results

Samples were collected and tested for different geotechnical parameters in the APECS Test House, Babesa, Thimphu.

Sl. No	Sample No.	Test		Results
1	THOMANG CLIFF; PIT-1	Natural Moisture Content		26.51%
		Specific Gravity		2.04 g/c.c
		Bulk Density		1.73 g/c.c
		Dry Density		1.37 g/c.c
		Liquid limit		43.00%
		Plastic Limit		32.45%
		Plasticity Index		10.55
		Direct Shear Box		c = 0.24 kg/cm^2; Ø = 27°.
		Sieve Analysis	Gravels	24.9%
			Sand	65.42%
			Fines	9.68%
2	THOMANG CLIFF; PIT-2	Natural Moisture Content		24.80%
		Specific Gravity		2.00 g/c.c
		Bulk Density		1.54 g/c.c
		Dry Density		1.23 g/c.c
		Liquid limit		41.20%
		Plastic Limit		30.95%
		Plasticity Index		10.25
		Direct Shear Box		c = 0.22 kg/cm^2; Ø = 28°.
		Sieve Analysis	Gravels	27.95%
			Sand	64.29%
			Fines	7.77%
3	THOMANG CLIFF; PIT-3	Natural Moisture Content		23.32%
		Specific Gravity		2.08 g/c.c
		Bulk Density		1.61 g/c.c
		Dry Density		1.30 g/c.c
		Liquid limit		42.10%
		Plastic Limit		31.63%
		Plasticity Index		10.47
		Direct Shear Box		c = 0.25 kg/cm^2; Ø = 28°.
		Sieve Analysis	Gravels	41.08%
			Sand	55.33%
			Fines	3.59%
4	BANGLA POKTO; PIT-1	Natural Moisture Content		26.65%
		Specific Gravity		2.17 g/c.c
		Bulk Density		1.60 g/c.c
		Dry Density		1.26 g/c.c
		Liquid limit		43.00%
		Plastic Limit		ND
		Plasticity Index		NP
		Direct Shear Box		c = 0.10 kg/cm^2; Ø = 39°11'.
		Sieve	Gravels	16.42%

		Analysis	Sand	78.71%
			Fines	4.87%
3	BANGLA POKTO; PIT-2	Natural Moisture Content		22.88%
		Specific Gravity		2.04 g/c.c
		Bulk Density		1.68 g/c.c
		Dry Density		1.37 g/c.c
		Liquid limit		24.5%
		Plastic Limit		ND
		Plasticity Index		NP
		Direct Shear Box		c = 0.15 kg/cm^2; Ø = 37°46’.
		Sieve Analysis	Gravels	21.76%
			Sand	74.54%
			Fines	3.70%
4	BANGLA POKTO; PIT-3	Natural Moisture Content		32.07%
		Specific Gravity		2.00 g/c.c
		Bulk Density		1.68 g/c.c
		Dry Density		1.28 g/c.c
		Liquid limit		38%
		Plastic Limit		ND
		Plasticity Index		NP
		Direct Shear Box		c = 0.11 kg/cm^2; Ø = 39°11’.
		Sieve Analysis	Gravels	31.36%
			Sand	66.67%
			Fines	2.27%

Table 9: Summary of the test results

5.1 Sieve Analysis

Sieve analysis was carried out on six samples collected from six different sites. The results are discussed below here. To determine the Coefficient of Uniformity (U_c), the formula given in equation 1 below and for the Coefficient of Concavity (U_c’), the formula given by equation 2 is used. The laboratory sieve analysis report along with the graph is attached in appendix as D.1.2 for Thomang Cliff area and D.2.2 for Bangla Pokto areas respectively.

$U_c = D_{60}/D_{10}$ --- Equation 1

$U_c` = (D_{30})^2/D_{10}XD_{60}$ -------------------------------- Equation 2

In the case of sample **Thomang Cliff Pit-1**, the result shows gravelly sand with appreciable amounts of finer fractions. Sand fraction is 65%, gravel is 25% and the rest 10% is silt/clay. From the graph D_{10} is 0.8 mm, D_{30} is 0.26 mm and D_{60} is 0.67 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 0.84, which is less than 10. Therefore the range of size distribution is not wide but is well graded. The Coefficient of Concavity (U_c’) calculated using equation 2 above gives the result as 0.126 which is not between 1 and 3. Here the grain size is not distributed in a wide range (uniform soil). Therefore the character of compaction is not good. ***Therefore it is to be concluded that this soil sample is not distributed in a wide range and thus is a uniform soil with bad compaction characteristic.***

In the case of sample **<u>Thomang Cliff Pit-2</u>**, the result shows gravelly sand with appreciable amounts of finer fractions. Sand fraction is 64%, gravel is 28% and the rest 8% is silt/clay. From the graph D_{10} is 0.09 mm, D_{30} is 0.30 mm and D_{60} is 1.10 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 12.22, which is greater than 10. Therefore the range of size distribution is wide but is not well graded. The Coefficient of Concavity (U_c') calculated using equation 2 above gives the result as 0.91 which is not between 1 and 3. Here the grain size is not distributed in a wide range (uniform soil). Therefore the character of compaction is not good. ***Since it has failed to meet the conditions <u>U_c'=1-3</u> to qualify for a wide range distribution; it is to be concluded that this soil sample is not distributed in a wide range and thus is a uniform soil with bad compaction characteristic.***

In the case of sample **<u>Thomang Cliff Pit-3</u>**, the result shows gravelly sand with low percentage of finer fractions. Sand fraction is 55%, gravel is 41% and the rest 4% is silt/clay. From the graph D_{10} is 0.14 mm, D_{30} is 0.45 mm and D_{60} is 9.20 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 65.71, which is greater than 10. Therefore the range of size distribution is wide but is not well graded. The Coefficient of Concavity (U_c') calculated using equation 2 above gives the result as 0.157 which is not between 1 and 3. Here the grain size is not distributed in a wide range (uniform soil). Therefore the character of compaction is not good. ***Since it has failed to meet the conditions <u>U_c'=1-3</u> to qualify for a wide range distribution; it is to be concluded that this soil sample is not distributed in a wide range and thus is a uniform soil with bad compaction characteristic.***

In the case of **<u>Bangla Pokto Pit-1</u>**, the result shows gravelly sand with low percentage of finer fractions. Sand fraction is 79%, gravel is 16% and the rest 5% is silt/clay. From the graph D_{10} is 0.14 mm, D_{30} is 0.43 mm and D_{60} is 1.5 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 10.7, which is slightly greater than 10. Therefore the range of size distribution is wide but is not well graded. The Coefficient of Concavity (U_c') calculated using equation 2 above gives the result as 0.88 which is not between 1 and 3. Here the grain size is not distributed in a wide range (uniform soil). Therefore the character of compaction is not good. ***Since it has failed to meet the conditions <u>U_c'=1-3</u> to qualify for a***

wide range distribution; it is to be concluded that this soil sample is not distributed in a wide range and thus is a uniform soil with bad compaction characteristic.

In the case of **Bangla Pokto Pit-2**, the result shows gravelly sand with low percentage of finer fractions. Sand fraction is 74%, gravel is 22% and the rest 4% is silt/clay. From the graph D_{10} is 0.16 mm, D_{30} is 0.67 mm and D_{60} is 1.85 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 11.56, which is greater than 10. Therefore the range of size distribution is wide but is not well graded. The Coefficient of Concavity (U_c') calculated using equation 2 above gives the result as 1.52 which is between 1 and 3. Here the grain size is distributed in a wide range (non-uniform soil). Therefore the character of compaction is good. ***Since it has meet both the conditions of $U_c \geq 10$ and U_c` =1-3 to qualify for a wide range distribution; it is to be concluded that this soil sample is distributed in a wide range and thus is a non-uniform soil with good compaction characteristic.***

In the case of **Bangla Pokto Pit-3**, the result shows gravelly sand with low percentage of finer fractions. Sand fraction is 67%, gravel is 31% and the rest 2% is silt/clay. From the graph D_{10} is 0.26 mm, D_{30} is 0.8 mm and D_{60} is 2.90 mm. The Coefficient of Uniformity (U_c) calculated using equation 1 above gives the result as 11.15, which is greater than 10. Therefore the range of size distribution is wide but is not well graded. The Coefficient of Concavity (U_c') calculated using equation 2 above gives the result as 0.85 which is not between 1 and 3. Here the grain size is not distributed in a wide range (uniform soil). Therefore the character of compaction is not good. ***Since it has failed to meet the conditions U_c` =1-3 to qualify for a wide range distribution; it is to be concluded that this soil sample is not distributed in a wide range and thus is a uniform soil with bad compaction characteristic.***

5.2 Coefficient of Permeability

Coefficient of permeability (k value) can be estimated from the result of sieve analysis. Creager Formula establishes relationship between co-efficient of permeability and grain size corresponding to 20% of passing % during sieve analysis (D_{20}). Permeability of subsurface strata is necessary in connection with various engineering problems, such as design of cut off for structures, calculations of pumping capacity for dewatering excavations and determination of aquifer constants of subsurface strata.

D_{20} (mm)	k (cm/sec)	Soil classification	D_{20} (mm)	k (cm/sec)	Soil classification
0.005	3.00×10^{-6}	Coarse grained clay	0.18	6.85×10^{-3}	Fine grained sand
0.01	1.05×10^{-5}	Fine grained silt	0.20	8.90×10^{-3}	
0.02	4.00×10^{-5}	Coarse grained silt	0.25	1.40×10^{-2}	
0.03	8.50×10^{-5}		0.30	2.20×10^{-2}	Medium grained sand
0.04	1.75×10^{-4}		0.35	3.20×10^{-2}	
0.05	2.80×10^{-4}		0.40	4.50×10^{-2}	
0.06	4.60×10^{-4}	Extremely fine grained sand	0.45	5.80×10^{-2}	
0.07	6.50×10^{-4}		0.50	7.50×10^{-2}	
0.08	9.00×10^{-4}		0.60	1.10×10^{-1}	Coarse grained sand
0.09	1.40×10^{-3}		0.70	1.60×10^{-1}	
0.10	1.75×10^{-3}		0.80	2.15×10^{-1}	
0.12	2.60×10^{-3}	Fine grained sand	0.90	2.80×10^{-1}	
0.14	3.80×10^{-3}		1.0	3.60×10^{-1}	
0.16	5.10×10^{-3}		2.0	1.80	Fine grained gravel

Table 10: Relation between D_{20} and co-efficient of permeability (k) (Creager)

Sl. No	Sample No.	Grain size D_{20} (mm)	k (cm/sec) Creager Formula	Soil Classification
1	THOMANG CLIFF: PIT-1	0.14	3.80×10^{-3}	Fine grained Sand
2	THOMANG CLIFF: PIT-2	0.20	8.90×10^{-3}	Fine grained Sand
3	THOMANG CLIFF: PIT-3	0.35	3.20×10^{-2}	Medium grained Sand
4	BANGLA POKTO: PIT-1	0.30	2.20×10^{-2}	Medium grained Sand
5	BANGLA POKTO: PIT-2	0.32	2.60×10^{-2}	Medium grained Sand
6	BANGLA POKTO: PIT-3	0.45	5.80×10^{-2}	Medium grained Sand

Table 11: Table showing the Coefficient of Permeability

Two samples Thomang cliff Pit-1 and Thomang cliff Pit-2 has D20 grain size or the 20% passing of material from the sieve as 0.14 mm and 0.20 mm respectively which correspondingly gives the coefficient of Permeability (k) to be 3.80×10^{-3} cm/sec and 8.90×10^{-3} cm/sec respectively. It falls in Fine grained sand group. The third sample from Thomang cliff Pit-3 has D20 grain size or the 20% passing of material from the sieve as 0.35 mm which correspondingly gives the coefficient of Permeability (k) to be 3.20×10^{-2} cm/sec and it falls in Medium grained sand group.

In the case of three samples from Bangla Pokto their D20 grain size or the 20% passing of material from the sieve is 0.30 mm, 0.32 mm and 0.45 mm which correspondingly gives the coefficient of Permeability (k) to be 2.20×10^{-2} cm/sec, 2.60×10^{-2} cm/sec and 5.80×10^{-2} cm/sec respectively. This falls in Medium grained sand group.

5.3 Moisture Content

The Laboratory test shows the following result for the Moisture content.

Sample No.	Thomang cliff Pit-1	Thomang cliff Pit-2	Thomang cliff Pit-3	Bangla Pokto Pit-1	Bangla Pokto Pit-2	Bangla Pokto Pit-3
Moisture Content	26.51%	24.80%	23.32%	26.65%	22.88%	32.07%

Table 12: Table showing Moisture Content

The natural moisture content for the samples from Thomang Cliff area ranges from 23.32% to 26.51% and for the Bangla Pokto samples, the range is from 22.88% to 32.07%. Therefore the samples from Bangla Pokto shows greater variation than the Thomang cliff samples. This difference could be mainly due to the rain. The test result for Thomang Cliff area is attached in appendix D.1.4 and for Bangla Pokto; it is attached in appendix D.2.4.

5.4 Atterberg limit

The standard tests developed for the determination of these boundary water content values are the **Atterberg limit tests**. The **plastic limit** is the water content (in %) at which the soil passes from the plastic state into the solid state. The **liquid limit** is the water content (in %) at which the soil passes from the plastic into the liquid state. If the liquid limit of a soil is higher than 50% the soil is said to have a high plasticity, at a liquid limit lower than 50 % the plasticity is low. The Laboratory test shows the following result for the Atterberg limits.

Liquid Limit = the water content at the transition between the liquid and the plastic behaviour of the soil and
Plastic Limit = the water content at the transition between the plastic and the solid state of the soil
Plasticity Index = the range of water content when the soil is plastic (LL – PL)

Sample No.	Thomang cliff Pit-1	Thomang cliff Pit-2	Thomang cliff Pit-3	Bangla Pokto Pit-1	Bangla Pokto Pit-2	Bangla Pokto Pit-3
Liquid Limit	43%	41.20%	42.10%	43%	24.5%	38%
Plastic Limit	32.45%	30.95%	31.63%	ND	ND	ND
Plasticity Index	10.55	10.25	10.47	NP	NP	NP

Table 13: Table showing the Atterberg Limits

The plasticity for the samples collected for Atterberg limit test shows below 50%, which can be considered as low plasticity with medium plasticity index of about 42% for most of the samples as can be seen in the table above. The test result for Thomang Cliff area is attached in appendix D.1.6 and for Bangla Pokto; it is attached in appendix D.2.6.

5.5 Bulk and Dry Densities

The Laboratory test was carried out on six samples to determine the Bulk and Dry densities. The result is as shown in the table given below.

Sample No.	Thomang cliff Pit-1	Thomang cliff Pit-2	Thomang cliff Pit-3	Bangla Pokto Pit-1	Bangla Pokto Pit-2	Bangla Pokto Pit-3
Bulk Density (g/cc)	1.73	1.54	1.61	1.60	1.68	1.68
Dry Density (g/cc)	1.37	1.23	1.30	1.26	1.37	1.28
Difference	0.36	0.31	0.31	0.34	0.31	0.40

Table 14: Table showing densities

The result shows bulk densities ranging from 1.54 to 1.73 g/cc for Thomang cliff samples and for the Bangla Pokto samples the bulk density ranges from 1.60 to 1.68 g/c.c. This range could be because of the wet condition (due to rain) while sampling from the pits. The range for dry density is from 1.23 to 1.37 g/c.c for Thomang cliff samples and from 1.26 to 1.37 for Bangla Pokto samples. The test result for Thomang Cliff area is attached in appendix D.1.5 and for Bangla Pokto; it is attached in appendix D.2.5.

5.6 Specific Gravity Test

This laboratory test is performed to determine the specific gravity. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil. This is also used when determining the volume of soil or rock.

Sample No.	Thomang cliff Pit-1	Thomang cliff Pit-2	Thomang cliff Pit-3	Bangla Pokto Pit-1	Bangla Pokto Pit-2	Bangla Pokto Pit-3
Specific Gravity (g/cc)	2.04	2.00	2.08	2.17	2.04	2.00

Table 15: Specific Gravity Test result

The result shows specific gravity ranging from 2.00 to 2.08 g/cc for Thomang cliff samples and for the Bangla Pokto samples the bulk density ranges from 2.00 to 2.17 g/c.c. The test result for Thomang Cliff area is attached in appendix D.1.7 and for Bangla Pokto; it is attached in appendix D.2.7.

5.7 Direct Shear Box Test

A direct shear test is a laboratory or field test used by geotechnical engineers to measure the shear strength properties of soil material, or of discontinuities in soil or rock masses. The test is performed by placing a specimen is placed in a *shear box* which has two stacked rings to hold the sample; the contact between the two rings is at approximately the mid-height of the sample. A *confining stress* is applied vertically to the specimen, and the upper ring is pulled laterally until the sample fails, or through a specified strain. The load applied and the strain induced is recorded at frequent intervals to determine a stress-strain curve for each confining stress. Several specimens are tested at varying confining stresses to determine the shear strength parameters, the soil cohesion (c) and the angle of internal friction, ø (commonly *friction angle*). The results of the tests on each specimen are plotted on a graph with the peak (or residual) stress on the x-axis and the confining stress on the y-axis. The y-intercept of the curve which fits the test results is the cohesion, and the slope of the line or curve is the friction angle.

The advantages of the direct shear test over other shear tests are the simplicity of setup and equipment used, and the ability to test under differing saturation, drainage, and consolidation conditions. These advantages have to be weighed against the difficulty of measuring pore-water pressure when testing in undrained conditions, and possible spuriously high results from forcing the failure plane to occur in a specific location.

The table below shows the test result for 6 samples collected from 2 different places of the study area. The result shows cohesion values ranging from 0.10 kg/cm^2 to as high as 0.25 kg/cm^2 and the internal friction angle ranges from 27° to as high as 39°11'. Taking these obtained shear parameters, bearing capacity may be calculated as per the requirement of the designs.

Sample No.	**Thomang cliff Pit-1**	**Thomang cliff Pit-2**	**Thomang cliff Pit-3**	**Bangla Pokto Pit-1**	**Bangla Pokto Pit-2**	**Bangla Pokto Pit-3**
Cohesion (c), kg/cm^2	0.24	0.22	0.25	0.10	0.15	0.11
Friction angle (Ø),	27°	28°	28°	39°11'	37°46'	39°11'

Table 16: Table showing c and ø values

The test result for Thomang Cliff area is attached in appendix D.1.3 and for Bangla Pokto; it is attached in appendix D.2.3.

APPENDIX

A Bore Hole Logs

A.1 Borehole No BH-1: (Thomang Cliff, above the highway)

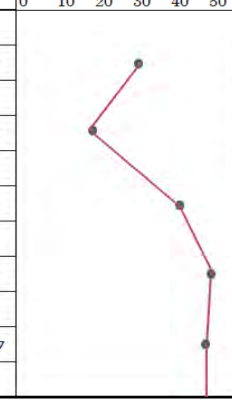
BORING COLUMN

SURVEY NAME : Geotechnical works on the project of Master plan study on road slope management in the kingdom of Bhutan

PROJECT NAME : Project of Master plan study on road slope management in the kingdom of Bhutan

BORING NAME: BOREHOLE NO. 1	LOCATION: Thomang Cliff (Trongsa)- away from the cliff; Lower one; above the highway
SURVEY COMPANY: Progressive Research and Consultancy Services (PRCS)	NORTHING: 27° 28' 41.90" / EASTING: 90° 28'49.90"
LEVEL IN THE DRILL HOLE: 2265 m	SURVEY PERIOD: 10/07/2015 to 19/07/2015
ALL BORING LENGTH: 60.00 metres	LOGGED BY: Indra Kumar Chhetri

Level rod(m)	From	To	Core Length	Core Recovered	Recovery (%)	Rock Quality Designate (RQD)	column	soil sort	soil color	relative density	remarks	water level in the drill hole(m)	Standard Penetration Test: depth(m)	blow number of times every 15cm: 0~15	blow number of times every 15cm: 15~30	blow number / Insert 30(cm)	0 10 20 30 40 50	Undisturbed soil sampling: depth(m)	Undisturbed soil sampling: sampling number	boring date
1	0.00	1.00	1.00	0.65	65%	-		top soil	Brown	Medium	Brown coloured, top soil containing organic parts with boulders of gneiss									10/7/2015
	1.00	1.45	0.45	0.15	33%	-		Overburden material	light grey	Medium	SPT CORE; Gravelly clayey sand, brown colour	0.80	1.00	17	17	34				11/7/2015
2	1.45	2.00	0.55	0.50	91%	-					Gravelly clayey sand, brown colour									
	2.00	2.45	0.45	0.25	56%	-					SPT CORE; Gravelly clayey sand, brown colour		2.00	9	11	20				
3	2.45	3.00	0.55	0.00	0%	-					Gravelly clayey sand, brown colour									
	3.00	3.45	0.45	0.10	22%	-					SPT CORE; Gravelly clayey sand, brown colour		3.00	21	23	44				
4	3.45	4.00	0.55	0.00	0%	-					Sludge of light grey, medium to fine sand									
	4.00	4.45	0.45	0.10	22%	-					SPT CORE; Gravelly clayey sand, brown colour		4.00	24	28	52				
5	4.45	5.00	0.55	0.40	73%	-					Sludge of light grey, medium to fine sand									
	5.00	5.30	0.30	0.00	0%	-					SPT CORE; NO RECOVERY		5.00	50	-	50/7				
6	5.30	6.00	0.70	0.65	93%	-					Boulders of leucocratic, crudely banded gneiss, fine grained									



	6.00	6.20	0.20	0.00		-					SPT CORE; NO RECOVERY	4.10	6.00	50	-	50/5				12/7/2015
7	6.20	7.00	0.80	0.00	0%	-					Sludge of light grey, medium to fine sand									
	7.00	7.75	0.75	0.00		-		Overburden material	light grey	Hard	Sludge of medium to coarse grained grey sand		7.00	50	-	50/4				
8	7.75	8.00	0.25	0.25	25%	-					Boulder of crudely banded gneiss, fine grained. Slight to moderately weathered.									
9	8.00	9.00	1.00	0.90	90%	-					Boulders of crudely banded gneiss, fine grained. Slight to moderately weathered.		8.00							
	9.00	9.85	0.85	0.00	15%	-					Sludge of medium to coarse grained grey sand		9.00							
10	9.85	10.00	0.15	0.15		-					Cobbles and gravels of crudely banded gneiss, fine grained. Moderately weathered.									
	10.00	10.90	0.90	0.00		-					Sludge of medium to coarse grained grey sand		10.00							
11	10.90	11.00	0.10	0.10	10%	-					Cobbles and gravels of crudely banded gneiss, fine grained. Moderately weathered.									
	11.00	11.95	0.95	0.00	5%	-		Overburden material	light grey	Hard	Sludge of medium to coarse grained grey sand		11.00							
12	11.95	12.00	0.05	0.05		-					Cobbles and gravels of crudely banded gneiss, fine grained. Moderately weathered.									
	12.00	12.30	0.30	0.30	30%						Boulders and gravels of crudely banded gneiss, fine grained. Moderately weathered.	6.90								13/7/2015
13	12.30	13.00	0.70	0.00		-					Sludge of medium to coarse grained grey sand		12.00							
	13.00	13.35	0.35	0.35	35%	-					Cobbles and gravels of crudely banded gneiss, fine grained. Moderately weathered.		13.00							

	14	13.35	14.00	0.65	0.00		-					Sludge of medium to coarse grained grey sand									
		14.00	14.40	0.40	0.00	60%	-					Sludge of medium to fine grained, grey sand		14.00							
	15	14.40	15.00	0.60	0.60		-		Overburden material	grey	Hard	Boulders of banded Gneiss, fine grained; slight to moderately weathered.									
	16	15.00	16.00	1.00	1.00	100%	-					Boulders of banded Gneiss, fine grained; slight to moderately weathered.	7.30	15.00							14/7/2015
		16.00	16.55	0.55	0.55	55%	-					Boulders of banded Gneiss, fine grained; slight to moderately weathered.									
	17	16.55	17.00	0.45	0.00		-					sludge of medium grained, light grey sand		16.00							
	18	17.00	18.00	1.00	0.00	0%	-		Overburden material	light grey	Medium	sludge of medium grained, light grey sand		17.00							
	19	18.00	19.00	1.00	0.00	0%	-							18.00							
	20	19.00	20.00	1.00	0.00	0%	-							19.00							
	21	20.00	21.00	1.00	0.00	0%	-							20.00							
	22	21.00	22.00	1.00	0.00	0%	-		Overburden material	light grey	Medium			21.00							
	23	22.00	23.00	1.00	0.00	0%	-							22.00							
	24	23.00	24.00	1.00	0.00	0%	-							23.00							
	25	24.00	25.00	1.00	0.00	0%	-						5.30	24.00							15/7/2015
	26	25.00	26.00	1.00	0.00	0%	-							25.00							
	27	26.00	27.00	1.00	0.00	0%	-							26.00							
Inferred	28	27.00	28.00	1.00	0.00	0%	-							27.00							
bed rock	29	28.00	29.00	1.00	0.00	0%	-							28.00							
Contact	30	29.00	30.00	1.00	0.00	0%	-							29.00							

31	30.00	31.00	1.00	0.00	0%	-		Bed rock (?) of highly weathered mica Schist	Dark grey	Medium	Sludge of medium to fine grained dark grey sand	12.80	30.00							16/7/2015
32	31.00	32.00	1.00	0.00	0%	-							31.00							
33	32.00	33.00	1.00	0.00	0%	-							32.00							
34	33.00	34.00	1.00	0.55	55%	10%		Bed rock of moderately weathered garnetiferous quartz mica (muscovite) Schist	Dark grey	Hard	Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 80° to the core axis and is smooth undulating.		33.00							
35	34.00	35.00	1.00	0.95	95%	41%							34.00							
36	35.00	36.00	1.00	1.00	100%	24%							35.00							
37	36.00	37.00	1.00	0.90	90%	52%							36.00							
38	37.00	38.00	1.00	0.90	90%	26%							37.00							
39	38.00	39.00	1.00	0.45	45%	12%		Bed rock of moderately weathered garnetiferous quartz mica (muscovite) Schist	Dark grey	Hard	CORE LOSS OF ABOUT 54 CMS; REST MICA SCHIST BED ROCK		38.00							
40	39.00	40.00	1.00	1.00	100%	52%					Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 80° to the core axis and is smooth undulating.		39.00							
41	40.00	41.00	1.00	1.00	100%	28%						Nil	40.00							17/7/2015
42	41.00	42.00	1.00	1.00	100%	78%							41.00							
43	42.00	43.00	1.00	1.00	100%	-							42.00							
44	43.00	44.00	1.00	1.00	100%	14%							43.00							
45	44.00	45.00	1.00	1.00	100%	45%		Bed rock of moderately weathered garnetiferous quartz mica (muscovite) Schist	grey	Hard	Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 80° to the core axis and is smooth undulating.		44.00							
46	45.00	46.00	1.00	1.00	100%	57%							45.00							
47	46.00	47.00	1.00	1.00	100%	17%							46.00							

48	47.00	48.00	1.00	0.65	65%	35%		Bed rock of moderately weathered garnetiferous quartz mica	grey	Hard	35 cms is quartz intrusion in schist. The rest is sludge of grey fine grained sand		47.00							
49	48.00	49.00	1.00	0.05	5%	-					The first 95 cms is sludge of grey fine grained sand and the last 5 cms is crudely banded gneiss.		48.00							
50	49.00	50.00	1.00	1.00	100%	58%		Banded Gneiss	Grey	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to		49.00							
51	50.00	51.00	1.00	0.90	90%	64%		Bed rock of banded gneiss	Grey	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered		50.00							
52	51.00	52.00	1.00	0.90	90%	41%						49.00	51.00							18/7/2015
53	52.00	53.00	1.00	0.47	47%	47%							52.00							
54	53.00	54.00	1.00	0.85	85%	29%							53.00							
55	54.00	55.00	1.00	0.95	95%	-							54.00							
56	55.00	56.00	1.00	1.00	100%	79%		Granitic gneiss	white	Hard	Hard and compact, light coloured, fine grained granitic gneiss		55.00							
57	56.00	57.00	1.00	1.00	100%	88%		Bed rock of banded gneiss	grey	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered. Joint is at 40˚ with the core axis and has smooth undulating surface. Foliation is at 65˚ to the core axis and it has smooth undulating small scale roughness.		56.00							
58	57.00	58.00	1.00	1.00	100%	100%						Nil	57.00							19/7/2015
59	58.00	59.00	1.00	1.00	100%	85%							58.00							
60	59.00	60.00	1.00	1.00	100%	91%							59.00							

A.2 Borehole No BH-2: (Directly above BH-1)

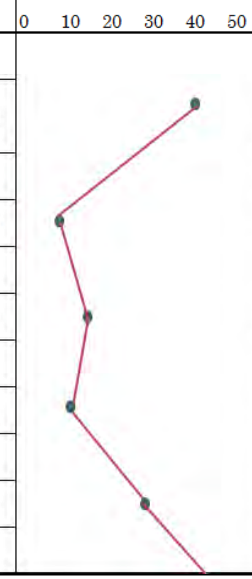
BORING COLUMN

SURVEY NAME : Geotechnical works on the project of Master plan study on road slope management in the kingdom of Bhutan

PROJECT NAME : Project of Master plan study on road slope management in the kingdom of Bhutan

BORING NAME: BOREHOLE NO. 2	LOCATION: Thomang Cliff (Trongsa)- away from the cliff; Upper one
SURVEY COMPANY: Progressive Research and Consultancy Services (PRCS)	NORTHING: 27° 28' 42.00" EASTING: 90° 28'49.10"
LEVEL IN THE DRILL HOLE: 2280 m	SURVEY PERIOD: 24/07/2015 to 10/08/2015
ALL BORING LENGTH: 50.00 metres	LOGGED BY: Indra Kumar Chhetri

Level rod(m)	From	To	Core Length	Core Recovered	Recovery (%)	Rock Quality Designate (RQD)	column	soil sort	soil color	relative density	remarks	water level in the drill hole(m)	Standard Penetration Test: depth(m)	blow number of times every 15cm: 0~15	blow number of times every 15cm: 15~30	blow number / Insert 30(cm)	Undisturbed soil sampling: depth(m)	Undisturbed soil sampling: sampling number	boring date
1	0.00	1.00	1.00	1.00	100%	-		top soil	Dark	medium	Dark coloured, top soil containing humus with boulders of granitic gneiss								24/07/2015
	1.00	1.45	0.45	0.25	56%	-		Overburden material	grey	medium	SPT CORE; Gravelly sand, grey colour		1.00	13	30	43	2.00	Pit-1, Pit-2, Pit-3	
2	1.45	2.00	0.55	0.50	91%	-					Boulders of leucocratic granitic gneiss, fine grained								
	2.00	2.45	0.45	0.25	56%	-					SPT CORE; Gravelly sand, grey colour	Nil	2.00	3	7	10			04/08/205
3	2.45	3.00	0.55	0.00	0%	-					Boulders of leucocratic granitic gneiss, fine grained								
	3.00	3.45	0.45	0.20	44%	-					SPT CORE; Gravelly sand, grey colour		3.00	6	11	17			
4	3.45	4.00	0.55	0.00	0%	-					Boulders of leucocratic granitic gneiss, fine grained								
	4.00	4.45	0.45	0.20	44%	-					SPT CORE; Gravelly sand, grey colour		4.00	5	9	14			
5	4.45	5.00	0.55	0.40	73%	-					Boulders of leucocratic pegmatite, coarse grained								
	5.00	5.45	0.45	0.00	0%	-					SPT CORE; NO RECOVERY		5.00	12	19	31			
6	5.45	6.00	0.55	0.55	100%	-					Boulders of leucocratic granitic gneiss, fine grained								



	6.00	6.35	0.35	0.00	65%	-		Overburden material	light grey	hard	Sludge of medium to coarse grained grey sand		6.00	50	-	50/4				
7	6.35	7.00	0.65	0.65		-					Boulders and gravels of leucocratic granitic gneiss, fine grained. Hard and Compact.									
	7.00	7.65	0.65	0.00	35%	-					Sludge of medium to coarse grained grey sand	6.50	7.00							5/8/2015
8	7.65	8.00	0.35	0.35		-					Boulders and gravels of leucocratic granitic gneiss, fine grained. Hard and Compact.									
	8.00	8.80	0.80	0.00	20%	-					Sludge of fine grained grey sand		8.00							
9	8.80	9.00	0.20	0.20		-					Boulders and gravels of gneiss, fine grained. Hard and Compact.									
	9.00	9.85	0.85	0.00	15%	-					Sludge of medium to fine grained grey sand		9.00							
10	9.85	10.00	0.15	0.15		-		Overburden material	light grey	hard	Boulders and gravels of Gneiss + Schist, fine grained.									
	10.00	10.50	0.50	0.00	50%	-					Sludge of medium to fine grained grey sand		10.00							
11	10.50	11.00	0.50	0.50		-					Boulders and gravels of Gneiss and leucocratic granitic gneiss, fine grained.									
	11.00	11.70	0.70	0.00	30%	-					Sludge of medium to fine grained grey sand		11.00							
12	11.70	12.00	0.30	0.30		-					Boulders and gravels of Gneiss, fine grained.									
13	12.00	13.00	1.00	0.75	75%	-					Boulders and gravels of Gneiss, fine grained.		12.00							
	13.00	13.70	0.70	0.00	30%	-					Sludge of medium to fine grained, light grey sand		13.00							

	14	13.70	14.00	0.30	0.30		-		Overburden material	light grey	hard	Boulders and gravels of Gneiss, fine grained.									
		14.00	14.75	0.75	0.00	25%	-					Sludge of medium to fine grained, light grey sand		14.00							
	15	14.75	15.00	0.25	0.25		-					Boulders and gravels of Gneiss, fine grained.									
		15.00	15.80	0.80	0.00	20%	-					Sludge of medium to fine grained, light grey sand	5.00	15.00							6/8/2015
	16	15.80	16.00	0.20	0.20		-					Boulders and gravels of Gneiss, fine grained.									
	17	16.00	17.00	1.00	0.00	0%	-					sludge of medium grained, light grey sand		16.00							
	18	17.00	18.00	1.00	0.00	0%	-		Overburden material	light grey	medium			17.00							
	19	18.00	19.00	1.00	0.00	0%	-							18.00							
	20	19.00	20.00	1.00	0.00	0%	-							19.00							
	21	20.00	21.00	1.00	0.00	0%	-							20.00							
	22	21.00	22.00	1.00	0.30	30%	-		Overburden material	light grey	medium	Boulders of leucocratic granitic gneiss + pegmatite, fine grained with sludge of light grey fine sand.	21.60	21.00							7/8/2015
	23	22.00	23.00	1.00	0.00	0%	-					sludge of medium grained, light grey sand		22.00							
	24	23.00	24.00	1.00	0.00	0%	-							23.00							
	25	24.00	25.00	1.00	0.35	35%	-					Boulders of leucocratic granitic gneiss, fine grained with sludge of light grey fine sand.		24.00							
	26	25.00	26.00	1.00	0.00	0%	-					sludge of medium grained, light grey sand		25.00							
	27	26.00	27.00	1.00	0.00	0%	-							26.00							
	28	27.00	28.00	1.00	0.30	30%	-		Overburden material (?)	grey	hard	Pieces of crudely banded gneiss, fine grained with sludge of light grey fine sand.	12.00	27.00							8/8/2015
	29	28.00	29.00	1.00	0.25	25%	-					Pieces of crudely banded gneiss and garnetiferous quartz mica schist, fine grained with sludge of grey fine sand.		28.00							
	30	29.00	30.00	1.00	0.30	30%	-					Pieces of garnetiferous quartz mica schist, fine grained with sludge of grey fine sand.		29.00							
	31	30.00	31.00	1.00	0.00	0%	-					Sludge of medium to fine grained grey sand		30.00							
Inferred bed rock	32	31.00	32.00	1.00	0.00	0%	-		Overburden material (?)	grey	hard	Sludge of medium to fine grained grey sand		31.00							
	33	32.00	33.00	1.00	0.00	0%	-					Sludge of medium to fine grained grey sand		32.00							

34	33.00	34.00	1.00	0.10	10%	-		Bed rock (?) of highly weathered garnetiferous quartz mica (muscovi	grey	medium	Pieces of garnetiferous quartz mica (muscovite) schist, fine grained with sludge of grey fine sand.		33.00							
35	34.00	35.00	1.00	0.05	5%	-							34.00							
36	35.00	36.00	1.00	0.20	20%	-							35.00							
37	36.00	37.00	1.00	0.35	35%	-							36.00							
38	37.00	38.00	1.00	0.20	20%	-							37.00							
39	38.00	39.00	1.00	0.20	20%	-		Bed rock (?) of highly weathered garnetiferous quartz mica (muscovite) Schist	grey	medium	Pieces of garnetiferous quartz mica (muscovite) schist, fine grained with sludge of grey fine sand.	13.5	38.00							9/8/2015
40	39.00	40.00	1.00	0.40	40%	-							39.00							
41	40.00	41.00	1.00	0.00	0%	-					Sludge of medium to fine grained grey sand		40.00							
42	41.00	42.00	1.00	0.00	0%	-							41.00							
43	42.00	43.00	1.00	0.00	0%	-						14	42.00							10/8/2015
44	43.00	44.00	1.00	0.00	0%	-							43.00							
45	44.00	45.00	1.00	0.85	85%	29%		Bed rock of moderately weathered garnetiferous quartz mica (muscovite) Schist	grey	hard	Fine grained, grey coloured garnetiferous quartz mica (muscovite) schist. Several pieces broken along the foliation. Garnets are slightly bigger than pin heads. Foliation is at 65° to the core axis and is smooth undulating.		44.00							
46	45.00	46.00	1.00	0.90	90%	10%							45.00							
47	46.00	47.00	1.00	0.90	90%	21%							46.00	50	-	50/4				
48	47.00	48.00	1.00	0.95	95%	26%							47.00	50	-	50/3				
49	48.00	49.00	1.00	0.95	95%	10%							48.00	50	-	50/2				
50	49.00	50.00	1.00	0.95	95%	-							49.00							

A.3 Borehole No BH-3: (Near to the Thomang cliff face)

BORING COLUMN

SURVEY NAME : Geotechnical works on the project of Master plan study on road slope management in the kingdom of Bhutan

PROJECT NAME : Project of Master plan study on road slope management in the kingdom of Bhutan

BORING NAME: BOREHOLE NO. 3	LOCATION: Thomang Cliff on Wangdue - Trongsa Highway (Trongsa)- near to the cliff
SURVEY COMPANY: Progressive Research and Consultancy Services (PRCS)	NORTHING: 27° 28' 39.30" / EASTING: 90° 28'49.40"
LEVEL IN THE DRILL HOLE: 2279 m	SURVEY PERIOD: 27/07/2015 to 3/08/2015
ALL BORING LENGTH: 50.00 metres	LOGGED BY: Indra Kumar Chhetri

BED ROCK INFERRED AT 0.00 METRES DEPTH

Level rod(m)	From	To	Core Length	Core Recovered	Recovery (%)	Rock Quality Designate (RQD)	column	soil sort	soil color	relative density	remarks	water level in the drill hole(m)	Standard Penetration Test: depth(m)	blow number of times every 15cm: 0~15	blow number of times every 15cm: 15~30	blow number / Insert 30(cm)	0 10 20 30 40 50	Undisturbed soil sampling: depth(m)	Undisturbed soil sampling: sampling number	boring date
1	0.00	1.00	1.00	0.60	60%	-		Bed rock of biotite gneiss	dark, banded	hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered. Pegmatitic intrusion observed within the bed rock.									27/07/2015
2	1.00	2.00	1.00	0.80	80%	39%						0.80	1.00	50	-	50/3		2.00	Pit-1, Pit-2, Pit-3	30/07/2015
3	2.00	3.00	1.00	0.85	85%	34%							2.00							
4	3.00	4.00	1.00	0.50	50%	24%							3.00							
5	4.00	5.00	1.00	0.40	40%	15%							4.00							
6	5.00	6.00	1.00	0.90	90%	55%		Granitic gneiss	white	hard	hard and compact, light coloured, fine grained granitic gneiss		5.00							
7	6.00	7.00	1.00	0.15	15%	41%		Bed rock of biotite gneiss	dark, banded	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered. Due to poor core recovery, sludge is also collected, which is light grey, medium to fine sand.		6.00							
8	7.00	8.00	1.00	0.50	50%	24%							7.00							
9	8.00	9.00	1.00	0.15	15%	-							8.00							
10	9.00	10.00	1.00	0.50	50%	-						0.70	9.00							31/07/2015
11	10.00	11.00	1.00	0.25	25%	-							10.00							
12	11.00	12.00	1.00	0.85	85%	-							11.00							

13	12.00	13.00	1.00	0.15	15%	-		Gneiss	light	Moderate	Crudely banded light grey coloured gneiss, sludge is medium to fine grained grey sand.		12.00							
14	13.00	14.00	1.00	0.00	0%	-							13.00							
15	14.00	15.00	1.00	0.55	55%	-							14.00							
16	15.00	16.00	1.00	0.10	10%	-							15.00							
17	16.00	17.00	1.00	0.15	15%	-							16.00							
18	17.00	18.00	1.00	0.35	35%	-							17.00							
19	18.00	19.00	1.00	0.00	0%	-							18.00							
20	19.00	20.00	1.00	0.00	0%	-							19.00							
21	20.00	21.00	1.00	0.00	0%	-							20.00							
22	21.00	22.00	1.00	0.95	95%	-							21.00							
23	22.00	23.00	1.00	0.00	0%	-							22.00							
24	23.00	24.00	1.00	0.00	0%	-	CAVITY ?				FULL LOSS OF CORE; NEITHER SLUDGE COULD BE RECOVERED. POSSIBLY A CAVITY IN THE FORMATION	Nil	23.00							1/8/2015
25	24.00	25.00	1.00	0.00	0%	-							24.00							
26	25.00	26.00	1.00	0.00	0%	-							25.00							
27	26.00	27.00	1.00	0.00	0%	-							26.00							
28	27.00	28.00	1.00	0.00	0%	-		Bed rock of biotite gneiss	dark, banded	Hard	Sludge of fine grained, dark grey sand. Indication of weathered biotite gneiss		27.00							
29	28.00	29.00	1.00	0.00	0%	-							28.00							
30	29.00	30.00	1.00	0.00	0%	-							29.00							
31	30.00	31.00	1.00	0.00	0%	-							30.00							
32	31.00	32.00	1.00	0.00	0%	-							31.00							
33	32.00	33.00	1.00	0.00	0%	-							32.00							

34	33.00	34.00	1.00	0.95	95%	-		Bed rock of biotite gneiss	dark, banded	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered. Due to poor core recovery, sludge is also collected, which is light grey, medium to fine sand.		33.00							
35	34.00	35.00	1.00	0.95	95%	-							34.00							
36	35.00	36.00	1.00	0.95	95%	-							35.00							
37	36.00	37.00	1.00	0.45	45%	-						31.00	36.00							2/8/2015
38	37.00	38.00	1.00	1.00	100%	63%							37.00							
39	38.00	39.00	1.00	0.00	0%	-							38.00							
40	39.00	40.00	1.00	0.60	60%	28%		Bed rock of biotite gneiss	dark, banded	Hard	Medium to fine grained, biotite gneiss with conspicous banding structure seen in the core samples. Slight to moderately weathered.		39.00							
41	40.00	41.00	1.00	1.00	100%	39%							40.00							
42	41.00	42.00	1.00	0.95	95%	59%							41.00							
43	42.00	43.00	1.00	0.95	95%	62%							42.00							
44	43.00	44.00	1.00	1.00	100%	72%							43.00							
45	44.00	45.00	1.00	1.00	100%	74%							44.00							
46	45.00	46.00	1.00	1.00	100%	41%							45.00							
47	46.00	47.00	1.00	1.00	100%	25%						nil	46.00							3/8/2015
48	47.00	48.00	1.00	1.00	100%	35%		Gneiss	light	hard	Crudely banded light grey coloured, slight to moderately weathered gneiss, sludge is medium to fine grained grey sand.		47.00							
49	48.00	49.00	1.00	1.00	100%	12%							48.00							
50	49.00	50.00	1.00	1.00	100%	78%							49.00							

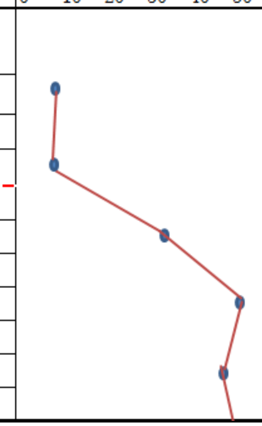
A.4 Borehole No BH-4: (Bangla Pokto, above the highway)

SURVEY NAME : Geotechnical works on the project of Master plan study on road slope management in the kingdom of Bhutan

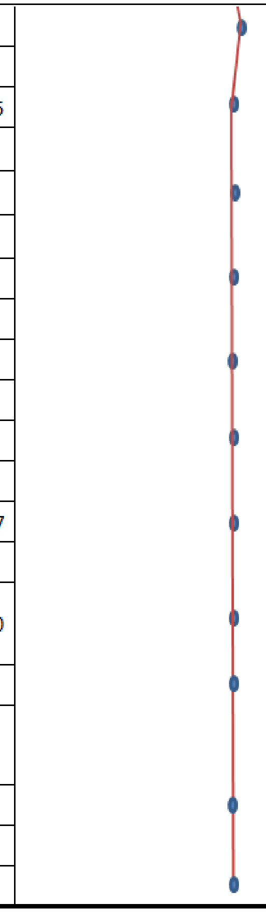
PROJECT NAME : Project of Master plan study on road slope management in the kingdom of Bhutan

BORING NAME: BOREHOLE NO. 4	LOCATION: Bangla Pokto on Wangdue - Trongsa Highway (Trongsa)-above camps
SURVEY COMPANY: Progressive Research and Consultancy Services (PRCS)	NORTHING: 27° 27' 02.8" EASTING: 90° 24' 24.87"
LEVEL IN THE DRILL HOLE: 2428 m	SURVEY PERIOD: 23/06/2015 to 1/07/2015
ALL BORING LENGTH: 25.00 metres	LOGGED BY: Indra Kumar Chhetri

	Level rod(m)	From	To	Core Length	Core Recovered	Recovery (%)	Rock Quality Designate (RQD)	column	soil sort	soil color	relative density	remarks	water level in the drill hole(m)	Standard Penetration Test: depth(m)	Standard Penetration Test: blow number of times every 15cm: 0~15	Standard Penetration Test: blow number of times every 15cm: 15~30	Standard Penetration Test: blow number / Insert 30(cm)	Standard Penetration Test: 0 10 20 30 40 50	Undisturbed soil sampling: depth(m)	Undisturbed soil sampling: sampling number	boring date
Inferred bed rock contact at 2.50 m	1	0.00	1.00	1.00	1.00	100%	-		Clayey sand with few gravels	brown	loose	Brown coloured clayey sand with few gravels of quartz, cohesive soil.									23/6/2015
		1.00	1.45	0.45	0.27	60%	-					SPT core; gravelly silty/clayey sand, sticky		1.00	3	6	9				
	2	1.45	2.00	0.55	0.54	98%	-					Clayey sand with few gravels, cohesive soil							2.00	Pit-1, Pit-2, Pit-3	
		2.00	2.45	0.45	0.17	38%	-					SPT core; gravelly silty/clayey sand, sticky		2.00	4	5	9				
	3	2.45	3.00	0.55	0.54	98%	-		Bed rock of Granitic Gneiss	light grey	loose	Highly weathered, grey, medium grained granitic gneiss									
		3.00	3.45	0.45	0.16	36%	-					SPT core; highly weathered, grey granitic gneiss	Nil	3.00	10	25	35				24/06/2015
	4	3.45	4.00	0.55	0.54	98%	-					Highly weathered, grey, medium grained granitic gneiss									
		4.00	4.45	0.45	0.20	44%	-					SPT core; highly weathered, grey granitic gneiss		4.00	24	29	53				
	5	4.45	5.00	0.55	0.54	98%	-					Highly weathered, grey, fine grained granitic gneiss									
		5.00	5.45	0.45	0.24	53%	-					SPT core; highly weathered, grey granitic gneiss		5.00	13	36	49				
	6	5.45	6.00	0.55	0.55	100%	-					Highly weathered,light, medium grained granitic gneiss									



	6.00	6.45	0.45	0.16	36%	-		pegmatite	white	Hard	SPT core; gravels of pegmatite, light coloured		6.00	18	34	52				
7	6.45	7.00	0.55	0.55	100%	-					Sludge of pegmatite and granitic gneiss.									
	7.00	7.45	0.45	0.00	0%						SPT carried out; no core recovered	Nil	7.00	30	-	50/15				25/06/2015
8	7.45	8.00	0.55	0.55	100%	-					Sludge of pegmatite and granitic gneiss.			-	-	-				
	8.00	8.45	0.45	0.00	0%			Bed rock of Granitic Gneiss	light grey	loose	SPT carried out; no core recovered		8.00	50	-	50/8				
9	8.45	9.00	0.55	0.55	100%	-					Sludge of medium grained highly weathered granitic gneiss.			-	-	-				
	9.00	9.45	0.45	0.00	0%	-					SPT carried out; no core recovered	Nil	9.00	50	-	50/6				26/06/2015
10	9.45	10.00	0.55	0.50	91%	-					Sludge of medium grained highly weathered granitic gneiss.									
	10.00	10.45	0.45	0.00	0%	-					SPT carried out; no core recovered		10.00	50	-	50/3				
11	10.45	11.00	0.55	0.55	100%	-					Sludge of medium grained highly weathered granitic gneiss.									
	11.00	11.45	0.45	0.28	62%	-					SPT core; highly weathered, light grey granitic gneiss	5.00	11.00	50	-	50/1				29/06/2015
12	11.45	12.00	0.55	0.50	91%	-					Sludge of fine grained highly weathered granitic gneiss.									
	12.00	12.45	0.45	0.17	38%	-					SPT core; highly weathered, grey granitic gneiss		12.00	45	50	50/17				
13	12.45	13.00	0.55	0.50	91%	-					Sludge of medium grained highly weathered granitic gneiss.									
14	13.00	14.00	1.00	1.00	100%	0%		Pegmatite	White	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss		13.00	50	50	50/20				
	14.00	14.45	0.45	0.00	0%	-		Bed rock of Granitic Gneiss + Pegmatite	Light grey	loose	SPT core; no core recovered	6.00	14.00	50	-	50/2				30/06/2015
15	14.45	15.00	0.55	0.50	91%	-					25 cm is sludge of fine grained highly weathered granitic gneiss and the resr 25 cm is pegmatite pieces.									
	15.00	15.45	0.45	0.00	0%	-					SPT core; no core recovered		15.00	50	-	50/3				
16	15.45	16.00	0.55	0.50	91%	-					Sludge of medium grained highly weathered granitic gneiss.									
	16.00	16.63	0.63	0.63	100%	-					Sludge of medium grained highly weathered granitic gneiss.		16.00	50	0	50/2				



17	16.63	17.00	0.37	0.37	100%	-		Pegmatite	white	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss									
	17.00	17.85	0.85	0.85	100%	-		Gneiss	grey	loose	Sludge of medium grained highly weathered granitic gneiss.									
18	17.85	18.00	0.15	0.15	100%	-		pegmati	white	Hard	Light coloured, coarse grained pegmatitic intrusion									
19	18.00	19.00	1.00	1.00	100%	-		Granitic Gneiss	light grey	loose	Sludge of medium grained highly weathered granitic gneiss.									
20	19.00	20.00	1.00	1.00	100%	-					Sludge of medium grained highly weathered granitic gneiss.									
21	20.00	21.00	1.00	1.00	100%	-		Pegmatite	White	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss									
	21.00	21.80	0.80	0.80	100%	-		Gneiss	grey	loose	Sludge of medium grained highly weathered granitic gneiss.	8.00								1/7/2015
22	21.80	22.00	0.20	0.20	100%	-		Pegmatite	Light	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss									
23	22.00	23.00	1.00	1.00	100%	-		Granitic Gneiss	grey	loose	Sludge of medium grained highly weathered granitic gneiss.									
	23.00	23.15	0.15	0.15	100%	-														
24	23.15	24.00	0.85	0.85	100%	-		Pegmatite	light	hard	Light coloured, coarse grained pegmatitic intrusion									
	24.00	24.75	0.75	0.73	97%	-		mica schist	dark grey		Sludge of fine grained highly weathered mica schist									
25	24.75	25.00	0.25	0.25	100%	43%			Light	Hard	Pieces of moderately weathered mica schist									

A.5 Borehole No BH-5: (Bangla Pokto, below the highway)

BORING COLUMN

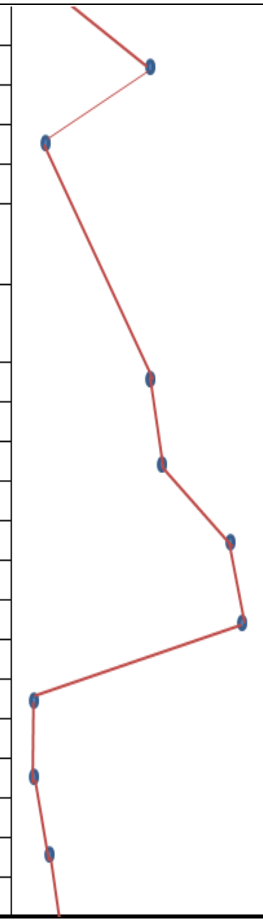
SURVEY NAME : Geotechnical works on the project of Master plan study on road slope management in the kingdom of Bhutan

PROJECT NAME : Project of Master plan study on road slope management in the kingdom of Bhutan

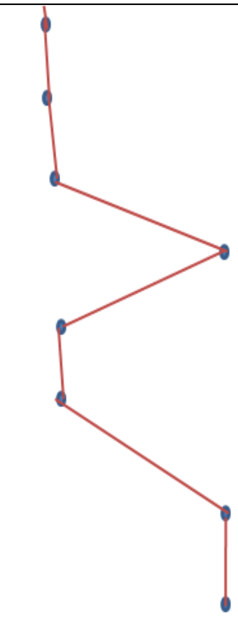
BORING NAME: BOREHOLE NO. 5	LOCATION: Bangla Pokto on Wangdue - Trongsa Highway (Trongsa)	
SURVEY COMPANY: Progressive Research and Consultancy Services (PRCS)	NORTHING: 27° 27' 00.6"	EASTING: 90° 24' 24.7"
LEVEL IN THE DRILL HOLE: 2417 m	SURVEY PERIOD: 11/06/2015 to 17/06/2015	
ALL BORING LENGTH: 25.00 metres	LOGGED BY: Indra Kumar Chhetri	

	Level rod(m)	From	To	Core Length	Core Recovered	Recovery (%)	Rock Quality Designate (RQD)	column	soil sort	soil color	relative density	remarks	water level in the drill hole(m)	standard penetration test: depth(m)	blow number of times every 15cm: 0~15	blow number of times every 15cm: 15~30	blow number / Insert 30(cm)	0 10 20 30 40 50	Undisturbed soil sampling: depth(m)	Undisturbed soil sampling: sampling number	boring date
Inferred bed rock contact at 4.65 metres depth	1	0.00	1.00	1.00	1.00	100%	-					Brown coloured clayey sand with few gravels of quartz mica schist, cohesive soil.									11/6/2015
		1.00	1.45	0.45	0.20	44%	-					SPT core; gravelly silty/clayey sand, sticky	0.80	1.00	3	1	4				12/6/2015
	2	1.45	2.00	0.55	0.50	91%	-					Clayey sand with few gravels, cohesive soil									
		2.00	2.45	0.45	0.10	22%	-		Clayey sand with few gravels	brown	dense	SPT core; gravelly silty/clayey sand, sticky		2.00	3	5	8				
	3	2.45	3.00	0.55	0.50	91%	-					Clayey sand with few gravels, cohesive soil									
		3.00	3.45	0.45	0.20	44%	-					SPT core; gravelly silty/clayey sand, sticky		3.00	3	4	7				
	4	3.45	4.00	0.55	0.50	91%	-					Clayey sand with few gravels, cohesive soil									
		4.00	4.45	0.45	0.16	36%	-					SPT core; gravelly silty/clayey sand, sticky		4.00	4	5	9				

5	4.45	5.00	0.55	0.50	91%	-		Bed rock of Granitic Gneiss	grey	loose	Highly weathered, grey, fine grained granitic gneiss									
	5.00	5.45	0.45	0.20	44%	-					SPT core; highly weathered, grey granitic gneiss	3.00	5.00	4	28	32				13/6/2015
6	5.45	6.00	0.55	0.52	95%	-					Highly weathered, grey, medium grained granitic gneiss									
	6.00	6.45	0.45	0.15	33%	-					SPT core; highly weathered, grey granitic gneiss		6.00	3	5	8				
7	6.45	7.00	0.55	0.52	95%	-					Highly weathered, grey, medium grained granitic gneiss									
8	7.00	8.00	1.00	1.00	100%	-		Bed rock of Granitic Gneiss	light grey	loose	Highly weathered, grey, fine grained granitic gneiss with about 3 cm long quartzite, medium to fine grained grey			-	-	-				
9	8.00	9.00	1.00	1.00	100%	-			light grey		Sludge of light coloured, medium grained granitic gneiss which seems highly weathered.	7		-	-	-				14/6/2015
	9.00	9.45	0.45	0.10	22%	-			light	loose	SPT core; highly weathered, granitic gneiss		9.00	10	22	32				
10	9.45	10.00	0.55	0.50	91%	-					Sludge of medium grained highly weathered granitic gneiss.									
	10.00	10.45	0.45	0.10	22%	-			light grey	loose	SPT core; highly weathered, light grey granitic gneiss		10.00	15	20	35				
11	10.45	11.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.									
	11.00	11.45	0.45	0.10	22%	-					SPT core; highly weathered, light grey granitic gneiss		11.00	20	30	50				
12	11.45	12.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.									
	12.00	12.45	0.45	0.11	24%	-		Bed rock of Granitic Gneiss	grey	loose	SPT core; highly weathered, grey granitic gneiss	12	12.00	20	33	53				15/6/2015
13	12.45	13.00	0.55	0.53	96%	-					Sludge of medium grained highly weathered granitic gneiss.									
	13.00	13.45	0.45	0.10	22%	-					SPT core; highly weathered, grey granitic gneiss		13.00	2	4	6				
14	13.45	14.00	0.55	0.53	96%	-					Sludge of coarse grained highly weathered granitic gneiss.									
	14.00	14.45	0.45	0.09	20%	-					SPT core; highly weathered, grey granitic gneiss		14.00	1	4	5				
15	14.45	15.00	0.55	0.53	96%	-					Sludge of fine grained highly weathered granitic gneiss.									
	15.00	15.45	0.45	0.09	20%	-					SPT core; highly weathered, grey granitic gneiss		15.00	3	6	9				
16	15.45	16.00	0.55	0.53	96%	-					Sludge of medium grained highly weathered granitic gneiss.									



	16.00	16.45	0.45	0.17	38%	-					SPT core; highly weathered, grey granitic gneiss		16.00	4	7	11			
17	16.45	17.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.								
	17.00	17.45	0.45	0.11	24%	-					SPT core; highly weathered, grey granitic gneiss		17.00	3	8	11			
18	17.45	18.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.								
	18.00	18.45	0.45	0.14	31%	-		Bed rock of Granitic Gneiss	grey	loose	SPT core; highly weathered, grey granitic gneiss	9.3	18.00	4	9	13			16/6/2015
19	18.45	19.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.								
	19.00	19.45	0.45	0.14	31%	-					SPT core; highly weathered, grey granitic gneiss		19.00	20	33	53			
20	19.45	20.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.								
	20.00	20.45	0.45	0.16	36%	-					SPT core; highly weathered, grey granitic gneiss		20.00	5	10	15			
21	20.45	21.00	0.55	0.54	98%	-					Sludge of medium grained highly weathered granitic gneiss.								
	21.00	21.45	0.45	0.14	31%	-					SPT core; highly weathered, grey granitic gneiss		21.00	6	9	15			
22	21.45	22.00	0.55	0.50	91%	-		Pegmatitic intrusion	Light	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss								
23	22.00	23.00	1.00	1.00	100%	-						18							17/6/2015
	23.00	23.45	0.45	0.00	0%	-					No SPT core recovery		23.00	50	-	50/10			
24	23.45	24.00	0.55	0.53	96%	-					Sludge of medium grained highly weathered granitic gneiss.								
25	24.00	25.00	1.00	0.80	80%	43%		Pegmatitic intrusion	Light	Hard	Light coloured, coarse grained pegmatitic intrusion within the highly weathered granitic gneiss		24.00	50	-	50/7			



B Standard Penetration Test Results

B.1 Standard Penetration Test Report for BH-1

SPT VALUES FOR BOREHOLE NO- BH-1 (THOMANG CLIFF; ABOVE THE HIGHWAY)					
SL NO.	DEPTH	N VALUES FOR DIFFERENT PENETRATIONS		TOTAL N	TOTAL PENETRATION DEPTH
		FIRST 15CM	SECOND 15 CM		
1	1 M	17	17	34	30
2	2 M	9	11	20	30
3	3 M	21	23	44	30
4	4 M	24	28	52	30
5	5 M	50	REFUSAL	50	7
6	6 M	50	REFUSAL	50	5
7	7 M	50	REFUSAL	50	4
8	8 M	REFUSAL			
9	9 M				

B.2 Standard Penetration Test Report for BH-2

SPT VALUES FOR BOREHOLE NO- BH-2 (THOMANG CLIFF; DIRECTLY ABOVE BH-1)					
SL NO.	DEPTH	N VALUES FOR DIFFERENT PENETRATIONS		TOTAL N	TOTAL PENETRATION DEPTH
		FIRST 15CM	SECOND 15 CM		
1	1 M	13	30	43	30
2	2 M	3	7	10	30
3	3 M	6	11	17	30
4	4 M	5	9	14	30
5	5 M	12	19	31	30
6	6 M	50	REFUSAL	50	4
7	7 M	REFUSAL			
8	8 M				
9	9 M				
10	46 M	50	REFUSAL	50	4
11	47 M	50	REFUSAL	50	3
12	48 M	50	REFUSAL	50	2

B.3 Standard Penetration Test Report for BH-3

SPT VALUES FOR BOREHOLE NO- BH-3 (THOMANG CLIFF; NEAR TO THE CLIFF FACE))					
SL NO.	DEPTH	N VALUES FOR DIFFERENT PENETRATIONS		TOTAL N	TOTAL PENETRATION DEPTH
		FIRST 15CM	SECOND 15 CM		
1	1 M	50	REFUSAL	50	3
2	2 M	REFUSAL			
3	3 M	REFUSAL			
4	4 M				

B.4 Standard Penetration Test Report for BH-4

SPT VALUES FOR BOREHOLE NO- BH-4 (BANGLA POKTO - ABOVE THE CAMPS)					
SL NO.	DEPTH	N VALUES FOR DIFFERENT PENETRATIONS		TOTAL N	TOTAL PENETRATION DEPTH
		FIRST 15CM	SECOND 15 CM		
1	1 M	3	6	9	30
2	2 M	4	5	9	30
3	3 M	10	25	35	30
4	4 M	24	29	53	30
5	5 M	13	36	49	30
6	6 M	18	34	52	30
7	7 M	50	REFUSAL	50	15
8	8 M	50	REFUSAL	50	8
9	9 M	50	REFUSAL	50	6
10	10 M	50	REFUSAL	50	3
11	11 M	50	REFUSAL	50	1
12	12 M	45	REFUSAL	50	17
13	13 M	45	REFUSAL	50	20
14	14 M	50	REFUSAL	50	2
15	15 M	50	REFUSAL	50	3
16	16 M	50	REFUSAL	50	2

B.5 Standard Penetration Test Report for BH-5

SPT VALUES FOR BOREHOLE NO- BH-5 (BANGLA POKTO - ROAD SIDE BOREHOLE)					
SL NO.	DEPTH	N VALUES FOR DIFFERENT PENETRATIONS		TOTAL N	TOTAL PENETRATION DEPTH
		FIRST 15CM	SECOND 15 CM		
1	1 M	3	1	4	30
2	2 M	3	5	8	30
3	3 M	3	4	7	30
4	4 M	4	5	9	30
5	5 M	4	28	32	30
6	6 M	3	5	8	30
7	9 M	10	22	32	30
8	10 M	15	20	35	30
9	11 M	20	30	50	30
10	12 M	20	33	53	30
11	13 M	2	4	6	30
12	14 M	1	4	5	30
13	15 M	3	6	9	30
14	16 M	4	7	11	30
15	17 M	3	8	11	30
16	18 M	4	9	13	30
17	19 M	20	23	43	30
18	20 M	5	10	15	30
19	21M	6	9	15	30
20	23 M	50	REFUSAL	50	10
21	24 M	50	REFUSAL	50	7

C Core Photographs

C.1 Photographs for BH-1


BH-1; BOX NO- 3


BH-1; BOX NO- 4


BH-1; BOX NO- 5
54cm CORE LOSS
BH-1; BOX NO- 6


BH-1; BOX NO- 7

BH-1; BOX NO- 8

BH-1; BOX NO- 9

C.2 Photographs for BH-2


BH-2; BOX NO- 3
BH-2; BOX NO- 4
BH-2; BOX NO- 5


BH-2; BOX NO- 6
BH-2; BOX NO- 7
BH-2; BOX NO- 8
BH-2; BOX NO- 9

C.3 Photographs for BH-3


BH-3; BOX NO- 3


Core lose because of gaving!
Core lose because of gaving!
No core because of gaving!!
BH-3; BOX NO- 4
Core lose because of gaving!


BH-3; BOX NO- 5


BH-3; BOX NO- 6


BH-3; BOX NO- 7

C.4 Photographs for BH-4


BH-4; BOX NO-3


BH-4; BOX NO-4


BH-4; BOX NO-5

C.5 Photographs for BH-5

BH-5; BOX NO. 3

BH-5; BOX NO. 4

BH-5; BOX NO. 5

D Laboratory Test Results

D.1 Test Results for BH-1(THOMANG CLIFF)

D.1.1 Summary of Test Results for BH-1

Govt. Reg. No: 1028198

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TEST RESULTS

A. Agency/Client/Customer Details
1. Name of Client/Agency/Contractor: *Progressive Research & Consultancy Services.*
2. Name of works/project: *Road Slope Management in Bhutan*
3. Location of works/project: Trongsa, Thomong cliff (Site-1)

B. Material Sample Details
4. Sample type: *Soil*
5. Location of Sample: *Pit-1, Pit-2 & Pit-3*
6. Collected/Inspected/delivered by: *Mr. Bijoy Chhetri*

C. Date collected/Inspected/delivered

D. Test Details
1. Date of Test: 28-03/08/2015
2. Job No.: *ATH/July/2015/69*

Sl.No	Test type	Results obtained	Maximum/minimum allowable Limits
1.	Water Content/ Nature Moisture Content	Pit-1: 26.51% Pit-2: 24.80% Pit-3: 23.32%	Refer specification/code of practice for interpretation of test results
2.	Sieve Analysis	Refer Annex- A, B & C	
3.	Bulk Density	Pit-1: 1.73 g/cc Pit-2: 1.54 g/cc Pit-3: 1.61 g/cc	
4.	Atterberg Limits	Pit-1: Plasticity index(I_p): 10.55% Pit-2: Plasticity index(I_p): 10.25% Pit-3: Plasticity index(I_p): 10.47%	
5.	Specific Gravity	Pit-1: 2.04 Pit-2: 2.00 Pit-3: 2.08	
6.	Direct Shear Test	Pit-1: Cohesion, C (Kg/cm^2) : 0.24 Angle of internal friction, Ø : 27° Pit-2: Cohesion, C (Kg/cm^2) : 0.22 Angle of internal friction, Ø : 28°	

Post Box 1675, Babesa, Thimphu, Bhutan
Telefax: 00975 2 332199, Mob: 00975 17600313/17362311
Email: apecsconsult@yahoo.com, Website: www.apecsconsult.com

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		Pit-3: Cohesion, C (Kg/cm^2) : 0.25 Angle of internal friction, Ø : 28°	

Note:

1. Soil samples have been submitted by contractor/client.
2. The test result issued is for the samples tested and does not guarantee the quality of the entire quantity of materials from the site.
3. The test result shall be interpreted by a qualified Engineer
4. The report in full or in part, shall not be used for advertising or legal action.

Tested by: Checked & verified by:

APECS TEST HOUSE * THIMPHU *

[Kinley Chophel] [H.N. Adhikari]

Lab Technician Research Officer

Post Box 1675; Babesa, Thimphu: Bhutan

Telefax: 00975 2 332199, Mob: 00975 17600313/17362311

Email: apecsconsult@yahoo.com, Website: www.apecsconsult.com

D.1.2 Sieve Analysis Results for BH-1

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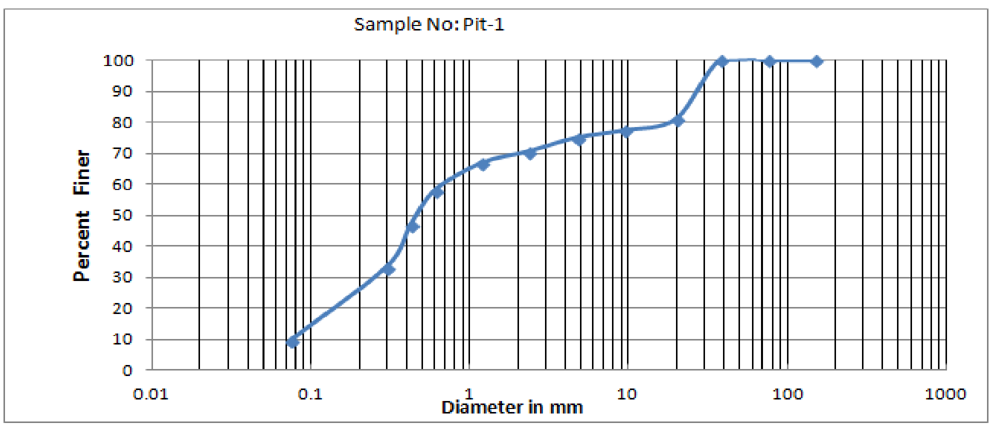
Annex-A

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-1
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-1
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 31/*07/2015*	Sample by: Mr. Bijay Chhetri

Original Test I *650.5*

Sieve size (SI metric)	Weight Retained		Cumulative percent passing	Cumulative percent passing
(mm)	(g)	%	%	%
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	122.5	18.83	18.83	81.17
9.5	24.5	3.77	22.60	77.40
4.75	15.0	2.31	24.90	75.10
2.36	29.0	4.46	29.36	70.64
1.18	25.0	3.84	33.21	66.79
0.600	57.5	8.84	42.04	57.96
0.425	71.5	10.99	53.04	46.96
0.300	88.5	13.60	66.64	33.36
0.075	154.0	23.67	90.32	9.68
Pan	63.0			
Total	**650.5**			



Silt & clay	Sand			Gravel	
	F	M	C	Fine	coarse
9.68	37.28	23.04	5.10	6.07	18.83

Tested by: Checked & verified by:

[Chhabi Lal Khatiwara]
Sr. Lab. Technician

[H .N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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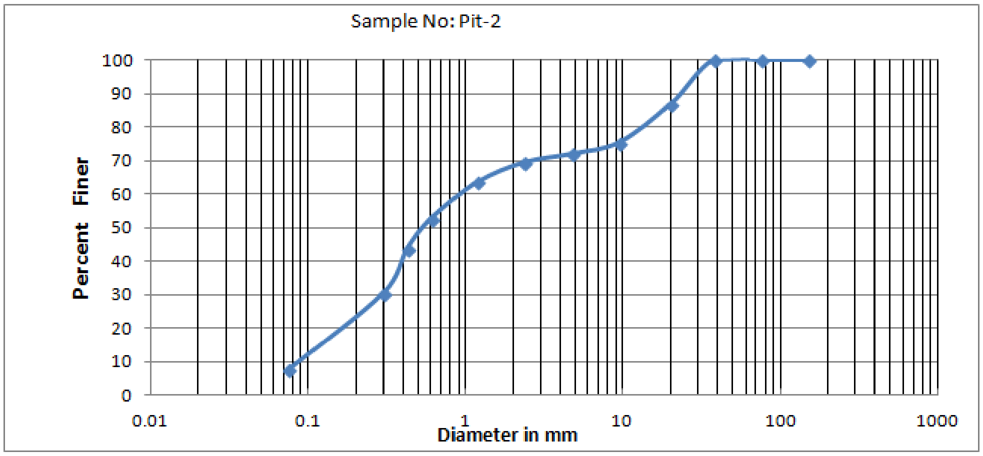
Annex-B

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-2
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-2
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: *31/07/2015*	Sample by: Mr. Bijay Chhetri

Original Test W *637.0*

Sieve size (SI metric)	Weight Retained		Cumulative percent passing	Cumulative percent passing
(mm)	(g)	%	%	%
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	84.0	13.19	13.19	86.81
9.5	72.0	11.30	24.49	75.51
4.75	22.0	3.45	27.94	72.06
2.36	16.0	2.51	30.46	69.54
1.18	38.0	5.97	36.42	63.58
0.600	69.5	10.91	47.33	52.67
0.425	56.0	8.79	56.12	43.88
0.300	85.0	13.34	69.47	30.53
0.075	145.0	22.76	92.23	7.77
Pan	49.5			
Total	**637.0**			



Silt & clay	Sand			Gravel	
	F	M	C	Fine	coarse
7.77	36.11	25.12	3.06	14.76	13.19

Tested by: Checked & verified by:

[Chhabi Lal Khatiwara]
Sr. Lab. Technician

[H .N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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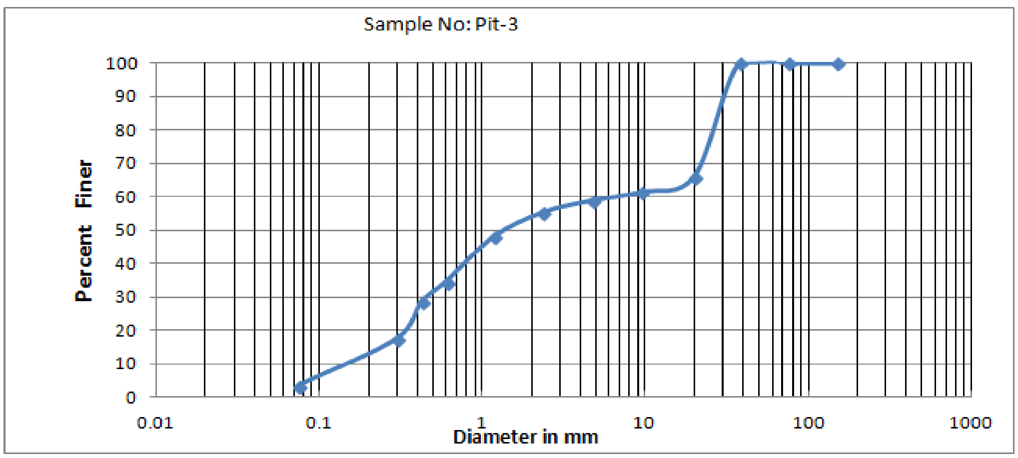
Annex-C

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-3
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-3
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 31/*07/2015*	Sample by: Mr. Bijay Chhetri

Original Test W *501.5*

Sieve size (SI metric)	Weight Retained		Cumulative percent passing	Cumulative percent passing
(mm)	(g)	%	%	%
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	169.5	33.80	33.80	66.20
9.5	24.0	4.79	38.58	61.42
4.75	12.5	2.49	41.08	58.92
2.36	18.0	3.59	44.67	55.33
1.18	36.0	7.18	51.84	48.16
0.600	67.5	13.46	65.30	34.70
0.425	30.0	5.98	71.29	28.71
0.300	55.5	11.07	82.35	17.65
0.075	70.5	14.06	96.41	3.59
Pan	18.0			
Total	**501.5**			



Silt & clay	Sand			Gravel	
	F	M	C	Fine	coarse
3.59	25.12	23.29	6.92	7.28	33.80

Tested by: Checked & verified by:

[Chhabi Lal Khatiwara]
Sr. Lab. Technician

[H .N. Adhikari]
Research Officer

D.1.3 Direct Shear Box Test Result for BH-1

Govt. Reg. No: 1028198

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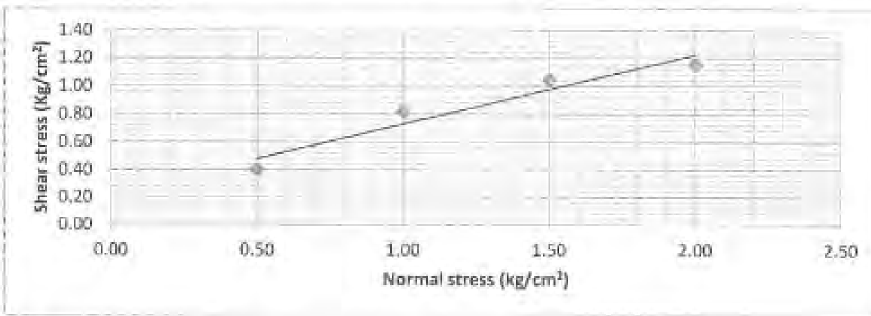
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-1
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-1
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/07/2015	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm²*	Rate of strain: *0.625 mm/minute*	

Slno	Normal stress applied (Kg/cm²)	Shear dial gauge observation at failure	Shear force (Kg)	Corrected area, A_c (Cm²)	Shear stress (kg/cm2) (4/5)	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0.50	850	14.448	36	0.40	
2	1.00	939	29.412	36	0.82	
3	1.50	1040	37.41	36	1.04	
4	2.00	1097	41.538	36	1.15	



Shear Parameters:

Cohesion, c (kg/cm²)= 0.24

Angle of internal friction, Ø= 27°

[Kinley Chophel]
Lab Technician

[H.N. Adhikari]
Research Officer

APECS TEST HOUSE THIMPHU

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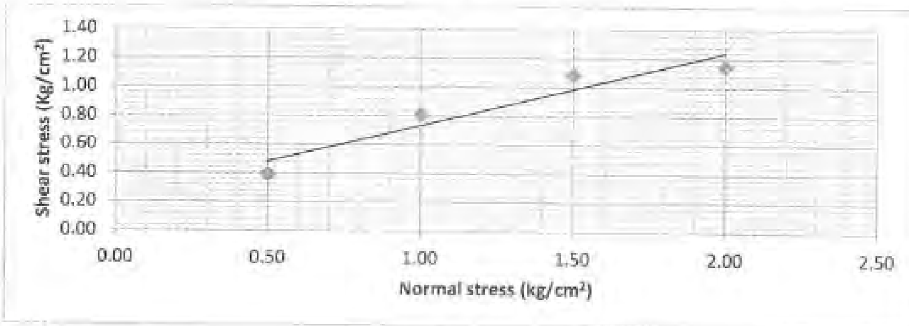
(Approved by BSB Board)

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-2
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-2
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/07/2015	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm²*	Rate of strain: *0.625 mm/minute*	

Slno.	*Normal stress applied (Kg/cm^2)*	*Shear dial gauge observation at failure*	*Shear force (Kg)*	*Corrected area, A, (Cm^2)*	*Shear stress (kg/cm2) (4/5)*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1	0.50	940	14.19	36	0.39	
2	1.00	1015	29.154	36	0.81	
3	1.50	1092	39.216	36	1.09	
4	2.00	1102	41.28	36	1.15	



Shear Parameters;

Cohesion, c (kg/cm^2)= 0.22

Angle of internal friction, Ø= 27°36'

[Kinley Chophel]
Lab Technician

APECS TEST HOUSE THIMPHU

[H.N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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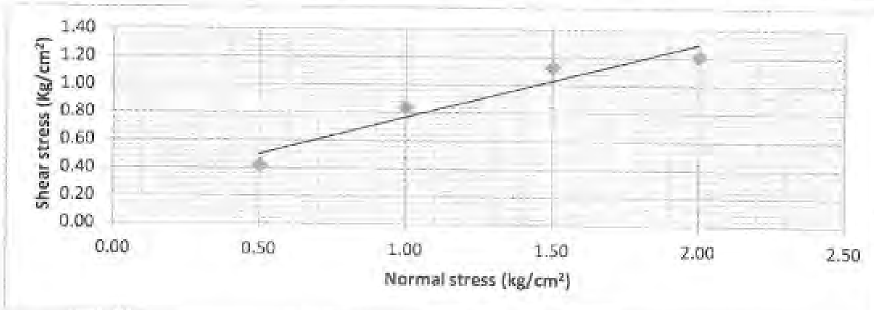
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-3
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-3
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/07/2015	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm²*	Rate of strain: *0.625 mm/minute*	

Slno	*Normal stress applied (Kg/cm²)*	*Shear dial gauge observation at failure*	*Shear force (Kg)*	*Corrected area, A_c (Cm²)*	*Shear stress (kg/cm2) (4/5)*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1	0.50	992	15.222	36	0.42	
2	1.00	1002	30.186	36	0.84	
3	1.50	1240	40.764	36	1.13	
4	2.00	1253	43.602	36	1.21	



Shear Parameters:

Cohesion, c (kg/cm²)= 0.25

Angle of internal friction, Ø= 27°34'

[Kinley Chophel]
Lab Technician

[H.N. Adhikari]
Research Officer

D.1.4 Natural Moisture Content Test Result for BH-1

Babesa (Opp. to Dr. Tobgyel School & Below Expressway), Thimphu

[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: As below
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: As below
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri

Natural Moisture content

	Sample No./Location of Sample:	Pit-1	Pit-2	Pit-3
1	Crucible No.	A8	A11	A7
2	Weight of crucible, (g)	17.5	17.1	17.4
3	Wt. of crucible +soil before drying, (g)	71.9	48.8	72.4
4	Wt. of crucible + soil after drying, (g)	60.5	42.5	62.0
5	Weight of moisture (7-8), (g)	11.40	6.30	10.40
6	oven dry weight of soil = (8-6), g	43.00	25.40	44.60
7	Moisture content = (9/10)x100, %	**26.51**	**24.80**	**23.32**

Tested by: Checked & verified by:

[ATH Group]
Lab Techinicians

[H. N. Adhikari]
Research Officer

D.1.5 Bulk and Dry Density Test Result for BH-1

Govt. Reg. No: 1028198

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: As below
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: As below
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri

Field density by Core cutter
Observation and calculations

0	Trial Pit no. *(as appropriate)*	Pit-1	Pit-2	Pit-3	
1	Weight of core cutter+soil, (g)	2744.5	2545.0	2612.5	
2	weight of cutter, (g)	972.5	972.5	972.5	
3	Weight of soil (1-2), (g)	1772	1573	1640	
4	Volume of soil (volume of cutter) cm^3	1021.48	1021.48	1021.48	
5	**Bulk density of soil = (3/4) cm^3**	**1.73**	**1.54**	**1.61**	
6	Crucible No.	A8	A11	A7	
7	Weight of crucible, (g)	17.5	17.1	17.4	
8	Wt. of crucible +soil before drying, (g)	71.9	48.8	72.4	
9	Wt. of crucible + soil after drying, (g)	60.5	42.5	62.0	
10	Weight of moisture (7-8), (g)	11.40	6.30	10.40	
11	oven dry weight of soil = (8-6), g	43.00	25.40	44.60	
12	Moisture content = (10/11)x100, %	27	25	23	
13	**Dry density, r_d =(5)/1+(11/100), g/cm^3**	**1.37**	**1.23**	**1.30**	

Average Value:

Tested by:

Checked & verified by:

Kinley Chophel
Lab Techinician

[H. N. Adhikari]
Research Officer

D.1.6 Atterberg Limits Test Result for BH-1

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-1
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-1
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/07/2015	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	35	27	19	
Dish No.	A19	A22	A12	
Wt. of Dish + Wet Soil, (gm)	41.10	63.00	45.40	
Wt. of Dish + Dry Soil, (gm)	32.50	47.30	36.70	
Mass of Dish, (gm)	10.80	10.20	17.60	
Moisture	8.60	15.70	8.70	
Wt. of Dry Soil, (gm)	21.70	37.10	19.10	
Moisture Content (%)	**39.63**	**42.32**	**45.55**	

Liquid limit (LL) test summery

Trial no.	Moisture Content	No. of Blows
1	39.63	35
2	42.32	27
3	45.55	19

Plastic limit test (PL)

Trial No.	1	2		Average (P_L)
Dish No.	A1	A5	A9	
Wt. of Dish + Wet Soil,(gm)	54.50	43.00	65.00	
Wt. of Dish + Dry Soil, (gm)	45.30	36.80	53.50	
Mass of Dish, (gm)	17.80	17.40	17.50	
Moisture	9.20	6.20	11.50	
Wt. of Dry Soil, (gm)	27.50	19.40	36.00	
Moisture Content (%)	33.45	31.96	31.94	**32.45**

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	43.00
Plastic Limit, W_p, %	32.45
Plasticity Index, I_p (W_L - W_p), %	**10.55**
Linear Shrinkage (%)	

Tested by:

[Kinley Chophel]
Lab Techinician

Checked by:

[H. N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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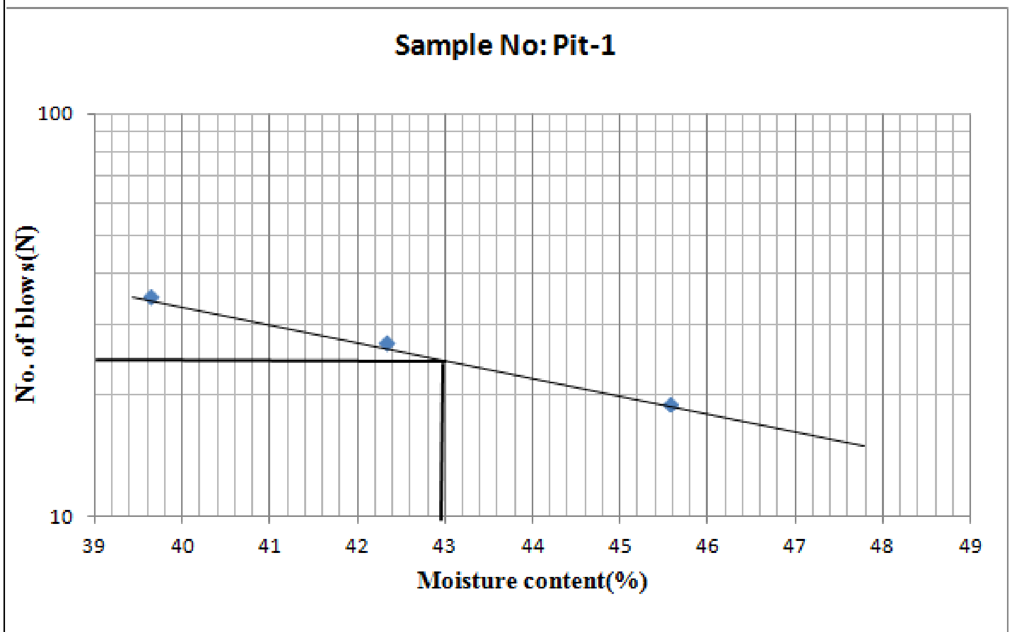
CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-1
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-1
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri



Liquid limit= 43.00

Tested by:

[Kinley Chophel]
Lab Technician

Checked & verified by:

[H N Adhikari]
Research Officer

Govt. Reg. No: 1028198

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-2
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-2
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	31	25	17	
Dish No.	A15	A22	A18	
Wt. of Dish + Wet Soil, (gm)	35.30	34.90	29.90	
Wt. of Dish + Dry Soil, (gm)	28.40	27.70	24.00	
Mass of Dish, (gm)	11.10	10.20	10.50	
Moisture	6.90	7.20	5.90	
Wt. of Dry Soil, (gm)	17.30	17.50	13.50	
Moisture Content (%)	**39.88**	**41.14**	**43.70**	

Liquid limit (LL) test summery

Trial no.	Moisture Content	No. of Blows	
1	39.88	31	
2	41.14	25	
3	43.70	17	

Plastic limit test (PL)

Trial No.	1	2		Average (P_L)
Dish No.	A5	A1	A9	
Wt. of Dish + Wet Soil,(gm)	34.00	33.60	32.70	
Wt. of Dish + Dry Soil, (gm)	29.90	29.60	29.50	
Mass of Dish, (gm)	17.40	17.70	17.40	
Moisture	4.10	4.00	3.20	
Wt. of Dry Soil, (gm)	12.50	11.90	12.10	
Moisture Content (%)	32.80	33.61	26.45	**30.95**

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	41.20
Plastic Limit, W_p, %	30.95
Plasticity Index, I_p (W_L - W_p), %	**10.25**
Linear Shrinkage (%)	

Tested by: | Checked by:

[Kinley Chophel] | [H. N. Adhikari]
Lab Techinician | Research Officer

Govt. Reg. No: 1028198

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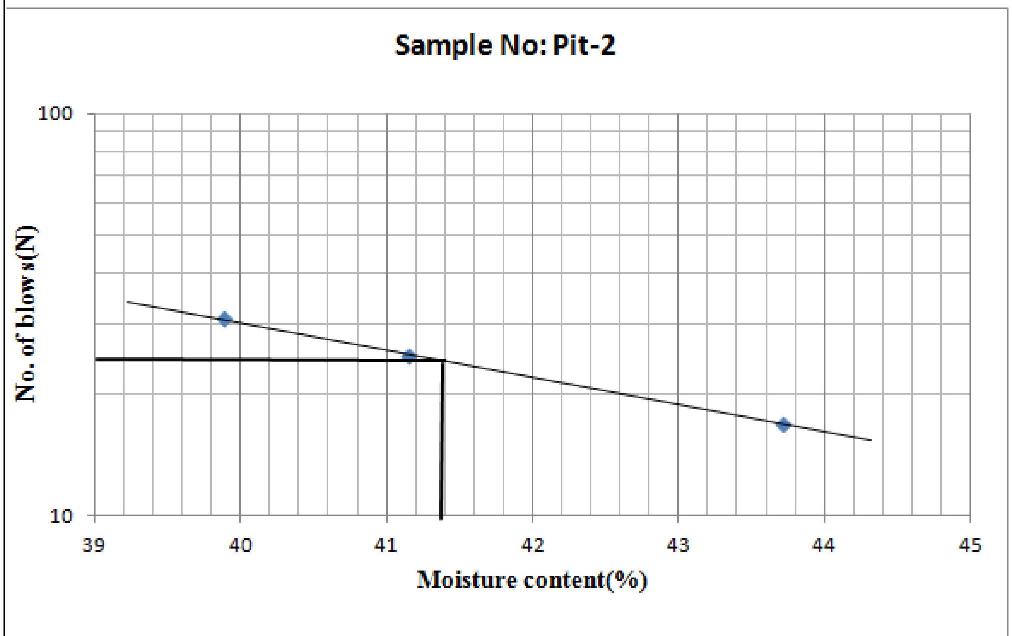
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-2
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-2
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri



Liquid limit= 41.20

Tested by:

[Kinley Chophel]
Lab Technician

Checked & verified by:

[H N Adhikari]
Research Officer

Govt. Reg. No: 1028198

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-3
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-3
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	28	24	15	
Dish No.	A20	A16	A17	
Wt. of Dish + Wet Soil, (gm)	28.30	32.60	31.40	
Wt. of Dish + Dry Soil, (gm)	23.10	25.90	24.80	
Mass of Dish, (gm)	10.20	10.30	10.20	
Moisture	5.20	6.70	6.60	
Wt. of Dry Soil, (gm)	12.90	15.60	14.60	
Moisture Content (%)	**40.31**	**42.95**	**45.21**	

Liquid limit (LL) test summery

Trial no.	Moisture Content	No. of Blows
1	40.31	28
2	42.95	24
3	45.21	15

Plastic limit test (PL)

Trial No.	1	2		Average (P_L)
Dish No.	A13	A21	A23	
Wt. of Dish + Wet Soil,(gm)	22.40	20.50	19.10	
Wt. of Dish + Dry Soil, (gm)	19.50	18.10	17.10	
Mass of Dish, (gm)	10.60	10.90	10.20	
Moisture	2.90	2.40	2.00	
Wt. of Dry Soil, (gm)	8.90	7.20	6.90	
Moisture Content (%)	32.58	33.33	28.99	**31.63**

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	42.10
Plastic Limit, W_p, %	31.63
Plasticity Index, I_p (W_L - W_p), %	**10.47**
Linear Shrinkage (%)	

Tested by: Checked by:

[Kinley Chophel] [H. N. Adhikari]
Lab Techinician Research Officer

Govt. Reg. No: 1028198

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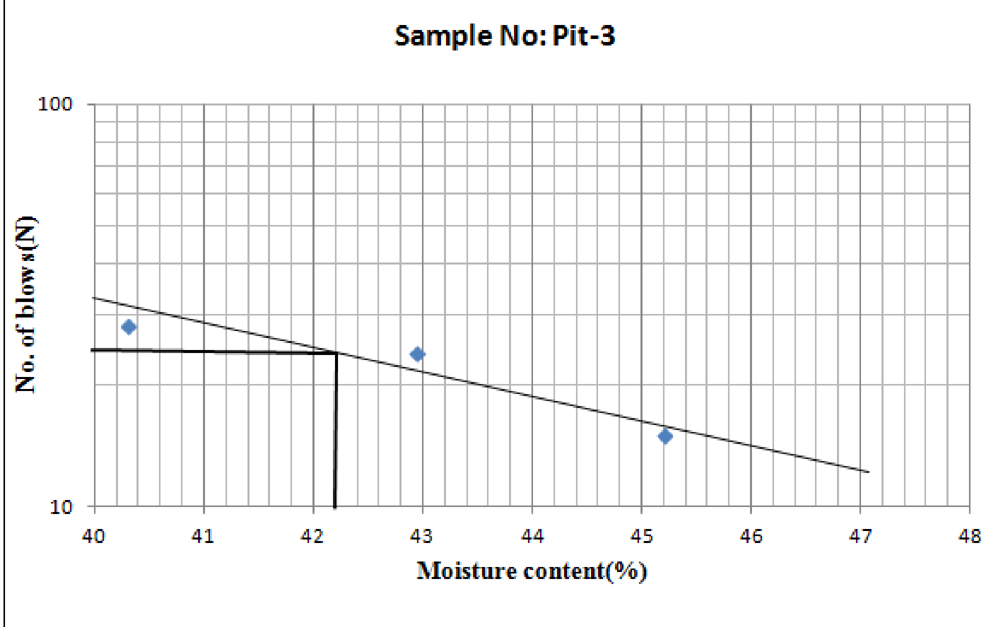
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management in Bhutan	Location of Sample: Pit-3
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: Pit-3
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri



Liquid limit= 42.10

Tested by:

[Kinley Chophel]
Lab Technician

Checked & verified by:

[H N Adhikari]
Research Officer

D.1.7 Specific Gravity Test Result for BH-1

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management	Location of Sample: As below
Location: Trongsa, Thomong cliff [Site-1]	Source of Sample: As below
Job No.: *ATH/July/2015/69*	Type of Sample: *Soil*
Date of Test: 29/*07/2015*	Sample by: Mr. Bijay Chhetri

Specific gravity (Density bottle)

	Location of Sample / Sample No:	Pit-1	Pit-2	Pit-3
Sln	Particulars			
1	Weight of density bottle, W1 g	13.20	13.20	13.20
2	Wt of bottle with dry soil, W2 g	23.20	23.20	23.20
3	Wt of bottle soil and water, W3 g	77.80	77.70	77.90
4	Wt of bottle full of water, W4 g	72.70	72.70	72.70
5	Wt of dry soil (W2-W1) g	10.00	10.00	10.00
6	Wt of an equal volume of water (W2-W1)-(W3-W4) g	4.90	5.00	4.80
7	Specific gravity of soil G= (5)/(6)	**2.04**	**2.00**	**2.08**

Tested by: Checked by:

[Kinley Chophel] [H. N. Adhikari]
Lab Techinician Research Officer

D.2 Test Results for BH-4 (BANGLA POKTO AREA)

D.2.1 Summary of Test Results for BH-4

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TEST RESULTS

A. **Agency/Client/Customer Details**
1. Name of Client/Agency/Contractor: *Progressive Research & Consultancy Services.*
2. Name of works/project: *Road Slope Management [Trongsa]. JICA*
3. Location of works/project: Bangla Pokto, Trongsa

B. **Material Sample Details**
4. Sample type/No.: *Soil*
5. Location of Sample: *Bangla Pokto (Sample-1, Sample-2 & Sample-3)*
6. Collected/Inspected/delivered by: *Mr. Bijay Chhetri*

C. Date collected/inspected/delivered:

D. **Test Details**
1. Date of Test: 21/07/2015
2. Job No.: *ATH/July/2015/63*

Sl.No	Test type	Results obtained		Maximum/minimum allowable Limits
1.	Water Content/ Nature Moisture Content	Bangla Pokto (Sample-1): Bangla Pokto (Sample-2): Bangla Pokto (Sample-3):	26.65% 22.88% 32.07%	Refer specification/code of practice for interpretation of test results
2.	Sieve Analysis	Refer Annex- A, B & C		
3.	Bulk Density	Bangla Pokto (Sample-1): Bangla Pokto (Sample-2): Bangla Pokto (Sample-3):	1.60 g/cc 1.68 g/cc 1.69 g/cc	
4.	Atterberg Limits	Bangla Pokto (Sample-1): Bangla Pokto (Sample-2): Bangla Pokto (Sample-3):	NP NP NP	
5.	Specific Gravity	Bangla Pokto (Sample-1): Bangla Pokto (Sample-2): Bangla Pokto (Sample-3):	2.17 2.04 2.00	
6.	Direct Shear Test	**Bangla Pokto (Sample-1)** Cohesion, C (Kg/cm^2) : Angle of internal friction, Ø : **Bangla Pokto (Sample-2)** Cohesion, C (Kg/cm^2) : Angle of internal friction, Ø : **Bangla Pokto (Sample-3)** Cohesion, C (Kg/cm^2) : Angle of internal friction, Ø :	 0.10 39°11' 0.15 37°46' 0.11 39°11'	

Post Box 1675; Babesa, Thimphu: Bhutan
Telefax: 00975 2 332199, Mob: 00975 17600313/17362311

Govt. Reg. No: 1028198

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[Approved by BSB Board]

Note:

1. Soil samples have been submitted by contractor/client.
2. The test result issued is for the samples tested and does not guarantee the quality of the entire quantity of materials from the concrete batching plant.
3. The test result shall be interpreted by a qualified Engineer
4. The report in full or in part, shall not be used for advertising or legal action.

Tested by:

[Kinley Chophel]
Lab Technician

Checked & verified by:

[H.N. Adhikari]
Research Officer

Post Box 1675; Babesa, Thimphu: Bhutan
Telefax: 00975 2 332199, Mob: 00975 17600313/17362311
Email: apecsconsult@yahoo.com, Website: www.apecsconsult.com

D.2.2 Sieve Analysis Result for BH-4

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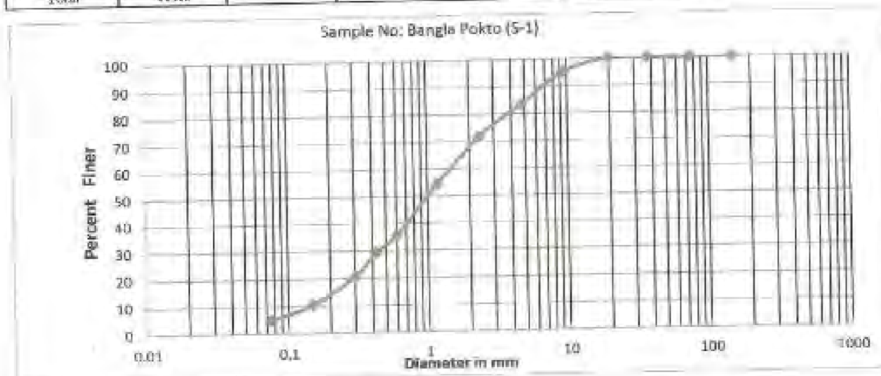
Annex-A

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 16/07/2015	Sample by: Mr. Bijay Chhetri

Original Test Wt 411.0

Sieve size (SI metric) (mm)	Weight Retained (g)	Weight Retained %	Cumulative percent passing %	Cumulative percent passing %
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	0.0	0.00	0.00	100.00
9.5	19.5	4.74	4.74	95.26
4.75	48.0	11.68	16.42	83.58
2.36	48.5	11.80	28.22	71.78
1.18	71.0	17.27	45.50	54.50
0.600	78.0	18.98	64.48	35.52
0.425	25.5	6.20	70.68	29.32
0.300	36.0	8.76	79.44	20.56
0.150	41.5	10.10	89.54	10.46
0.075	23.0	5.60	95.13	4.87
Pan	20.0			
Total	411.0			



Silt & clay	Sand F	Sand M	Sand C	Gravel Fine	Gravel coarse
4.87	24.45	38.68	15.58	16.42	0.00

Tested by:

[Chhabi Lal Khatiwara]
Sr. Lab. Technician

Checked & verified by:

[I. N. Adhikari]
Research Officer

APECS TEST HOUSE THIMPHU

Govt. Reg. No: 1028198

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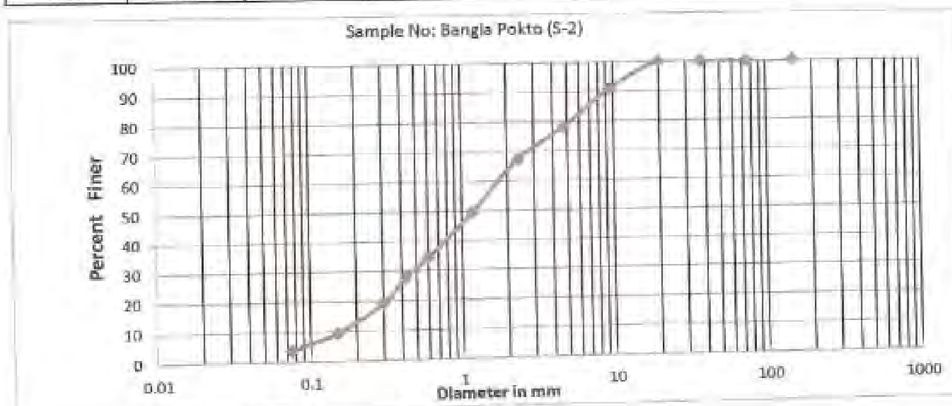
Annex-B

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-2)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-2)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: *16/07/2015*	Sample by: Mr. Bijay Chhetri

Original Test We 432.0

Sieve size (SI metric)	Weight Retained		Cumulative percent passing	Cumulative percent passing
(mm)	(g)	%	%	%
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	0.0	0.00	0.00	100.00
9.5	39.5	9.14	9.14	90.86
4.75	54.5	12.62	21.76	78.24
2.36	47.5	11.00	32.75	67.25
1.18	76.5	17.71	50.46	49.54
0.600	66.0	15.28	65.74	34.26
0.425	28.5	6.60	72.34	27.66
0.300	37.5	8.68	81.02	18.98
0.150	42.0	9.72	90.74	9.26
0.075	24.0	5.56	96.30	3.70
Pan	16.0			
Total	432.0			



Silt & clay	Sand			Gravel	
	F	M	C	Fine	coarse
3.70	23.96	34.34	16.24	21.76	0.00

Tested by:

[Chhabi Lal Khatiwara]

Checked & verified by:

[H .N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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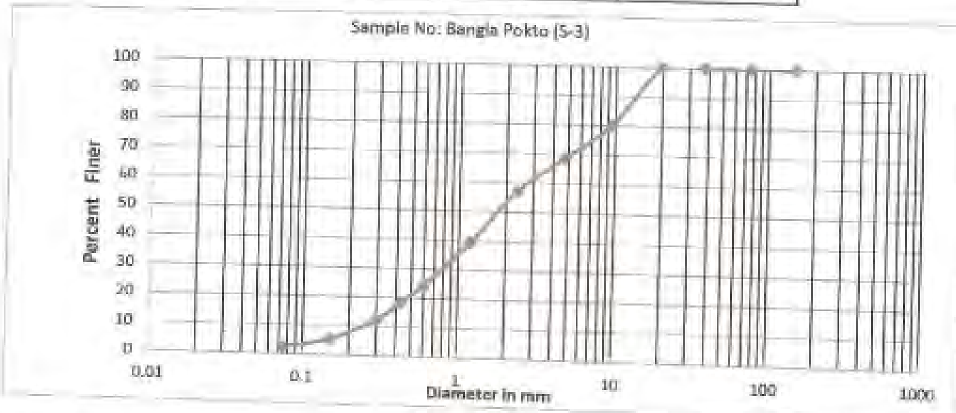
Annex-C

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-3)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-3)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: *16/07/2015*	Sample by: Mr. Bijay Chhetri

Original Test Wt 330.0

Sieve size (SI metric) (mm)	Weight Retained (g)	Weight Retained %	Cumulative percent passing %	Cumulative percent passing %
150	0	0.00	0.00	100.00
75	0	0.00	0.00	100.00
37.5	0	0.00	0.00	100.00
20	0.0	0.00	0.00	100.00
9.5	65.5	19.85	19.85	80.15
4.75	38.0	11.52	31.36	68.64
2.36	38.5	11.67	43.03	56.97
1.18	58.5	17.73	60.76	39.24
0.600	49.5	15.00	75.76	24.24
0.425	19.5	5.91	81.67	18.33
0.300	20.0	6.06	87.73	12.27
0.150	23.0	6.97	94.70	5.30
0.075	10.0	3.03	97.73	2.27
Pan	7.5			
Total	330.0			



Silt & clay	Sand F	Sand M	Sand C	Gravel Fine	Gravel coarse
2.27	16.06	32.67	17.64	31.36	0.00

Tested by:

[Chhabi Lal Khatiwara]
Sr. Lab. Technician

Checked & verified by:

[H.N. Adhikari]
Research Officer

APECS TEST HOUSE THIMPHU

D.2.3 Direct Shear Box Test Result for BH-4

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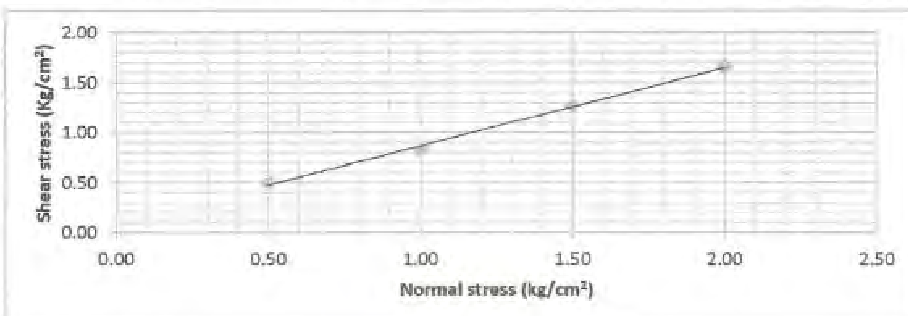
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: *21/07/2015*	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm^2*	Rate of strain: *0.625 mm/minute*	

Slno	*Normal stress applied (Kg/cm^2)*	*Shear dial gauge observation at failure*	*Shear force (Kg)*	*Corrected area, A_c (Cm^2)*	*Shear stress (kg/cm2) (4/5)*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1	0.50	1317	18.06	36	0.50	
2	1.00	1353	29.67	36	0.82	
3	1.50	1290	45.666	36	1.27	
4	2.00	1376	59.598	36	1.66	



Shear Parameters:

Cohesion, c (kg/cm^2)= 0.10

Angle of internal friction, Ø= 39°11'

[Kinley Chophel]
Lab Technician

[H.N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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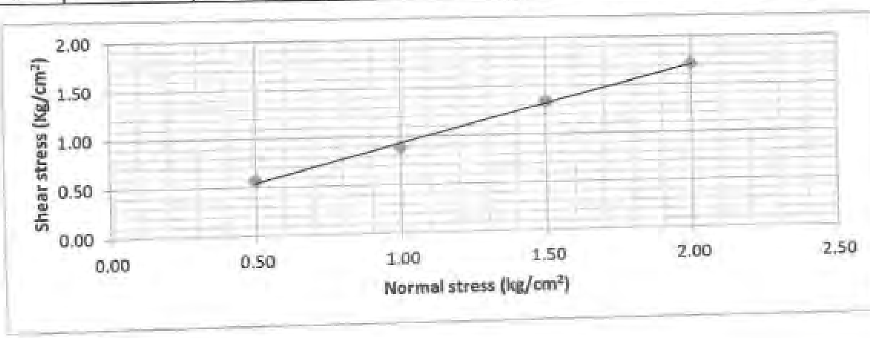
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-2)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-2)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/07/2015	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm²*	Rate of strain: *0.625 mm/minute*	

Slno	*Normal stress applied (Kg/cm²)*	*Shear dial gauge observation at failure*	*Shear force (Kg)*	*Corrected area, A_c (Cm²)*	*Shear stress (kg/cm2) (4/5)*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1	0.50	1332	20.382	36	0.57	
2	1.00	1372	31.992	36	0.89	
3	1.50	1086	47.988	36	1.33	
4	2.00	1443	61.404	36	1.71	



Shear Parameters:

Cohesion, c (kg/cm²)= 0.15

Angle of internal friction, Ø= 37°46'

[Kinley Chophel]
Lab Technician

APECS TEST HOUSE THIMPHU

[H.N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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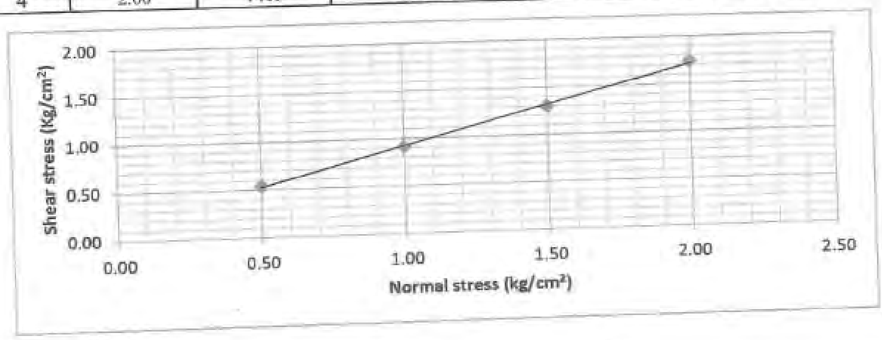
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-3)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-3)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/07/2015	Sample by: Mr. Bijay Chhetri

Direct Shear Test

Shearing Condition: *undrained test*		Proving Ring Constant:	*0.00258*
Sample Thickness: *2.5cm*	Initial Shear Box area: *36 cm²*	Rate of strain: *0.625 mm/minute*	

Slno	*Normal stress applied (Kg/cm²)*	*Shear dial gauge observation at failure*	*Shear force (Kg)*	*Corrected area, A_c (Cm²)*	*Shear stress (kg/cm2) (4/5)*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
1	0.50	1322	19.35	36	0.54	
2	1.00	1355	32.766	36	0.91	
3	1.50	1075	46.698	36	1.30	
4	2.00	1465	62.436	36	1.73	



Shear Parameters:

Cohesion, c (kg/cm²)= 0.11

Angle of internal friction, Ø= 39°11'

[Kinley Chophel]
Lab Technician

[H.N. Adhikari]
Research Officer

D.2.4 Natural Moisture Content Test Result for BH-4

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[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: As below
Location: Bangla Pokto, Trongsa	Source of Sample: As below
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 14/*07/2015*	Sample by: Mr. Bijay Chhetri

Natural Moisture content

	Sample No./Location of Sample:	Bangla Pokto (S-1)	Bangla Pokto (S-2)	Bangla Pokto (S-3)
1	Crucible No.	A4	A8	A10
2	Weight of crucible, (g)	17.5	17.5	16.8
3	Wt. of crucible +soil before drying, (g)	63.6	65.3	79.4
4	Wt. of crucible + soil after drying, (g)	53.9	56.4	64.2
5	Weight of moisture (7-8), (g)	9.70	8.90	15.20
6	oven dry weight of soil = (8-6), g	36.40	38.90	47.40
7	Moisture content = (9/10)x100, %	**26.65**	**22.88**	**32.07**

Tested by:

Checked & verified by:

[ATH Group]
Lab Techinicians

[H. N. Adhikari]
Research Officer

D.2.5 Bulk Density Test Result for BH-4

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[Approved by BSB]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 14/*07/2015*	Sample by: Mr. Bijay Chhetri

Field density by Core cutter
Observation and calculations

0	Trial Pit no. *(as appropriate)*	Bangla Pokto (S-1)	Bangla Pokto (S-2)	Bangla Pokto (S-3)	
1	Weight of core cutter+soil, (g)	2608.5	2688.5	2695.0	
2	weight of cutter, (g)	972.5	972.5	972.5	
3	Weight of soil (1-2), (g)	1636	1716	1723	
4	Volume of soil (volume of cutter) cm^3	1021.48	1021.48	1021.48	
5	**Bulk density of soil = (3/4) cm^3**	**1.60**	**1.68**	**1.69**	
6	Crucible No.	A4	A8	A10	
7	Weight of crucible, (g)	17.5	17.5	16.8	
8	Wt. of crucible +soil before drying, (g)	63.6	65.3	79.4	
9	Wt. of crucible + soil after drying, (g)	53.9	56.4	64.2	
10	Weight of moisture (7-8), (g)	9.70	8.90	15.20	
11	oven dry weight of soil = (8-6), g	36.40	38.90	47.40	
12	Moisture content = (10/11)x100, %	27	23	32	
13	**Dry density, r_d =(5)/1+(11/100), g/cm^3**	**1.26**	**1.37**	**1.28**	

Average Value:

Tested by:

Checked & verified by:

Kinley Chophel
Lab Techinician

[H. N. Adhikari]
Research Officer

D.2.6 Atterberg Limits Test Result for BH-4

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CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/*07/2015*	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	35	27	19	
Dish No.	A19	A22	A12	
Wt. of Dish + Wet Soil, (gm)	41.10	63.00	45.40	
Wt. of Dish + Dry Soil, (gm)	32.50	47.30	36.70	
Mass of Dish, (gm)	10.80	10.20	17.60	
Moisture	8.60	15.70	8.70	
Wt. of Dry Soil, (gm)	21.70	37.10	19.10	
Moisture Content (%)	**39.63**	**42.32**	**45.55**	

Liquid limit (LL) test summery

Trial no.	Moisture Content	No. of Blows
1	39.63	35
2	42.32	27
3	45.55	19

Plastic limit test (PL)

Trial No.	1	2		Average (P_L)
Dish No.				
Wt. of Dish + Wet Soil,(gm)				
Wt. of Dish + Dry Soil, (gm)				
Mass of Dish, (gm)				
Moisture				
Wt. of Dry Soil, (gm)				
Moisture Content (%)				

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	43.00
Plastic Limit, W_p, %	0.00
Plasticity Index, I_p (W_L - W_p), %	**NP**
Linear Shrinkage (%)	

Tested by: Checked by:

[Kinley Chophel] [H. N. Adhikari]
Lab Techinician Research Officer

Govt. Reg. No: 1028198

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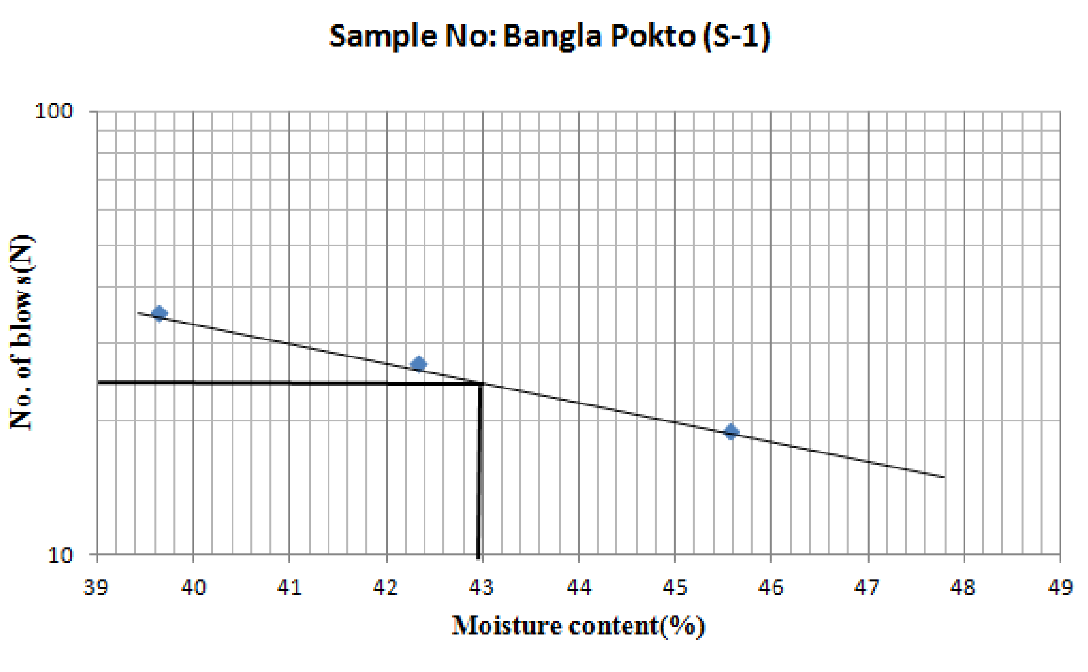
CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa),	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 23/04/2015	Sample by: Mr. Bijay Chhetri



Liquid limit= 43.00

Tested by:

Checked & verified by:

[Kinley Chophel]
Lab Technician

[H N Adhikari]
Research Officer

Govt. Reg. No: 1028198

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[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-2)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-2)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/07/2015	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	21	15	12	
Dish No.	A3	A1	A4	
Wt. of Dish + Wet Soil, (gm)	23.10	24.70	27.50	
Wt. of Dish + Dry Soil, (gm)	21.90	23.10	25.10	
Mass of Dish, (gm)	17.40	17.70	17.50	
Moisture	1.20	1.60	2.40	
Wt. of Dry Soil, (gm)	4.50	5.40	7.60	
Moisture Content (%)	**26.67**	**29.63**	**31.58**	

Liquid limit (LL) test summery

Trial no.	No. of Blows	Moisture Content (%)
1	21	26.67
2	15	29.63
3	12	31.58
4	0	0.00

Plastic limit test (PL)

Trial No.	1	2	3	Average (P_L) in %
Dish No.				
Wt. of Dish + Wet Soil,(gm)				
Wt. of Dish + Dry Soil, (gm)				
Mass of Dish, (gm)		Not determinable		
Moisture				
Wt. of Dry Soil, (gm)				
Moisture Content (%)				

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	24.5
Plastic Limit, W_p, %	ND
Plasticity Index, I_p (W_L - W_p), %	**NP**
Linear Shrinkage (%)	

Tested by:

Checked & Verified by

[Bikash Gurung]
Lab Techinician

[H. N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

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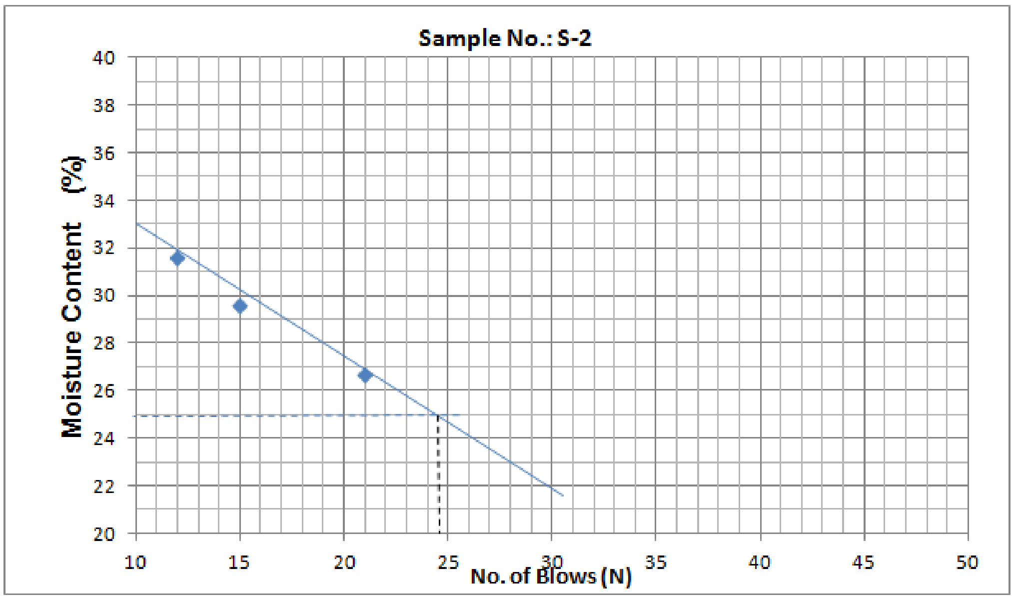
[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa),	Location of Sample: Bangla Pokto (S-2)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-2)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/*07/2015*	Sample by: Mr. Bijay Chhetri



Liquid limit=	**24.5**	%

Tested by:

Checked & Verified by:

[Chhabi Lal Khatiwara]
Lab Technician

[H. N. Adhikari]
Research Officer

Govt. Reg. No: 1028198

APECS TEST HOUSE

Building a Safer Place for Future....

Babesa (Opp. to Dr. Tobgyel School & Below Expressway), Thimphu

[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-3)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-3)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/*07/2015*	Sample by: Mr. Bijay Chhetri

Liquid limit (LL) Test

No. of Blows	22	27	31	35
Dish No.	A4	A2	A8	A1
Wt. of Dish + Wet Soil, (gm)	45.30	37.30	31.30	48.50
Wt. of Dish + Dry Soil, (gm)	37.30	31.80	28.00	41.60
Mass of Dish, (gm)	17.40	17.40	17.60	17.80
Moisture	8.00	5.50	3.30	6.90
Wt. of Dry Soil, (gm)	19.90	14.40	10.40	23.80
Moisture Content (%)	**40.20**	**38.19**	**31.73**	**28.99**

Liquid limit (LL) test summery

Trial no.	No. of Blows	Moisture Content (%)
1	22	40.20
2	27	38.19
3	31	31.73
4	35	28.99

Plastic limit test (PL)

Trial No.	1	2	3	Average(P_L) %
Dish No.				
Wt. of Dish + Wet Soil,(gm)				
Wt. of Dish + Dry Soil, (gm)				
Mass of Dish, (gm)				**NP**
Moisture				
Wt. of Dry Soil, (gm)				
Moisture Content (%)				

SUMMARY:

Liquid Limit, W_L (From Flow chart) %	38.00
Plastic Limit, W_p, %	
Plasticity Index, I_p (W_L - W_p), %	
Linear Shrinkage (%)	

Tested by: Checked & Verified by

[Kinley Chophel] [H. N. Adhikari]

Lab Techinician Research Officer

Govt. Reg. No: 1028198

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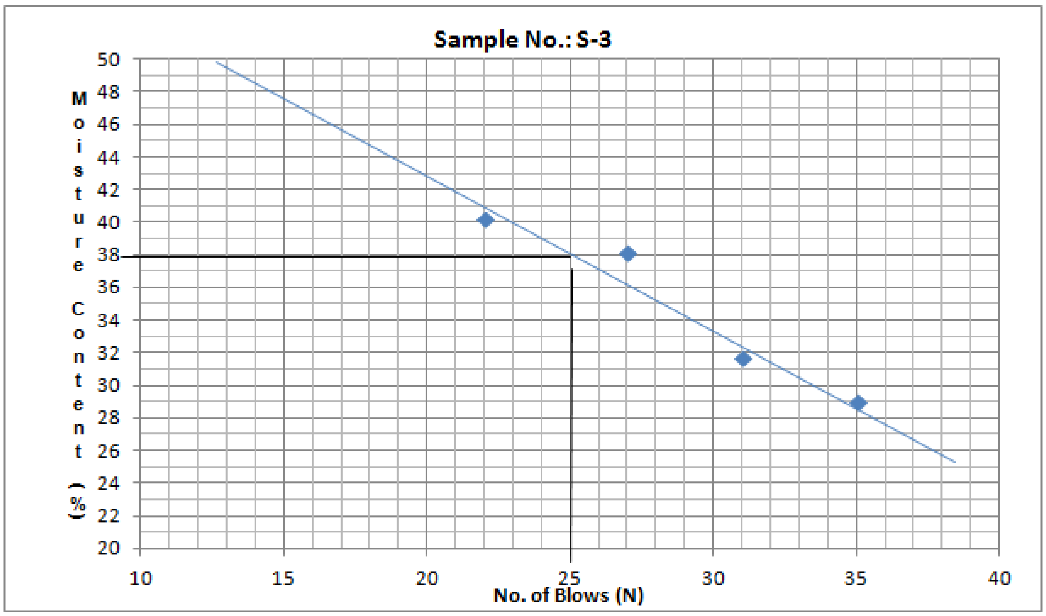
Babesa (Opp. to Dr. Tobgyel School & Below Expressway), Thimphu

[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa),	Location of Sample: Bangla Pokto (S-2)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-2)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 21/*07/2015*	Sample by: Mr. Bijay Chhetri



Liquid limit= 38.0 %

Tested by:

Checked & Verified by:

[Kinley Chophel]
Lab Technician

[H. N. Adhikari]
Research Officer

D.2.7 Specific Gravity Test Result for BH-4

Govt. Reg. No: 1028198

APECS TEST HOUSE

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[Approved by BSB Board]

CLIENT/CUSTOMERS DETAILS:	SAMPLE DETAILS:
Name of Client/Contractor: PRCS	Date of Sampling:
Name of Project: Road slope Management (Trongsa), JICA	Location of Sample: Bangla Pokto (S-1)
Location: Bangla Pokto, Trongsa	Source of Sample: Bangla Pokto (S-1)
Job No.: *ATH/July/2015/63*	Type of Sample: *Soil*
Date of Test: 16/7/2015	Sample by: Mr. Bijay Chhetri

Specific gravity (Density bottle)

	Location of Sample / Sample No:	Bangla Pokto (S-1)	Bangla Pokto (S-1)	Bangla Pokto (S-1)
Sln	Particulars			
1	Weight of density bottle, W1 g	13.20	13.20	13.20
2	Wt of bottle with dry soil, W2 g	23.20	23.20	23.20
3	Wt of bottle soil and water, W3 g	78.10	77.80	77.70
4	Wt of bottle full of water, W4 g	72.70	72.70	72.70
5	Wt of dry soil (W2-W1) g	10.00	10.00	10.00
6	Wt of an equal volume of water (W2-W1)-(W3-W4) g	4.60	4.90	5.00
7	Specific gravity of soil G= (5)/(6)	**2.17**	**2.04**	**2.00**

Tested by:

[Kinley Chophel]
Lab Techinician

Checked by:

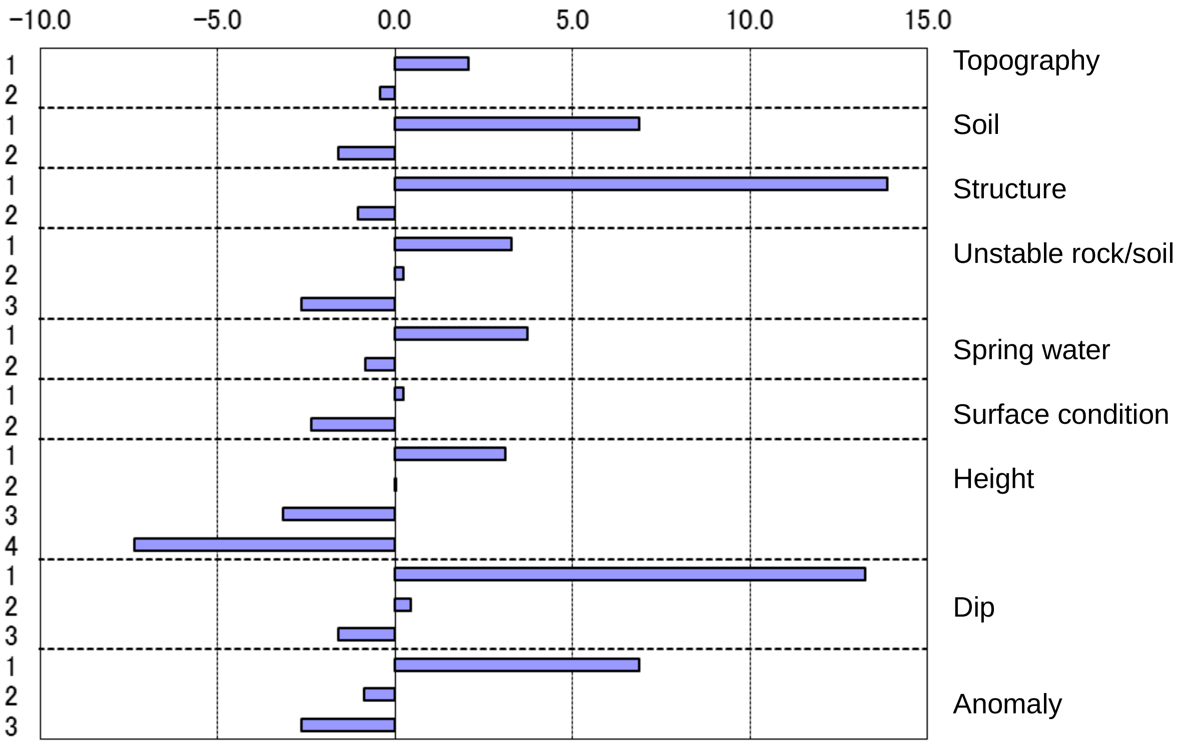
[H. N. Adhikari]
Research Officer

Appendix 13

Results of the Risk Analysis

The results of the risk analysis for DEBRIS SLOPE FAILURE

	A	B	D	F	G	H	I	J	K
	Topography	Geological conditions		Surface condition			Profile		Anomaly
	Collapsed factor	Soil	Structure	Unstable rock/soil (Topsoil, detached rock and unsteady rock)	Spring water	Surface condition	Height (H), dip (i)		Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure
	Talus slope, clear convex break of slope, eroded toe of slope, overhang, water catchment slope	Susceptible to erosion less strength with water	Dip slope of bedding plane				Height	Dip	
1	2 or more correspondences	marked	It corresponds.	instability	notable spring waster or seepage	bare land with minor vegetation or intermediate (bare/grass/ tree)	H≧50m	i≧70°	2 or more correspondences/ clarity
2	1 or less correspondences	a little marked or none	none	a little unstable	none	mainly structure, mainly tree	30≦H＜50m	45°≦i＜70°	certain/unclarity
3				stability			15≦H＜30m	i＜45°	none
4							H＜15m		



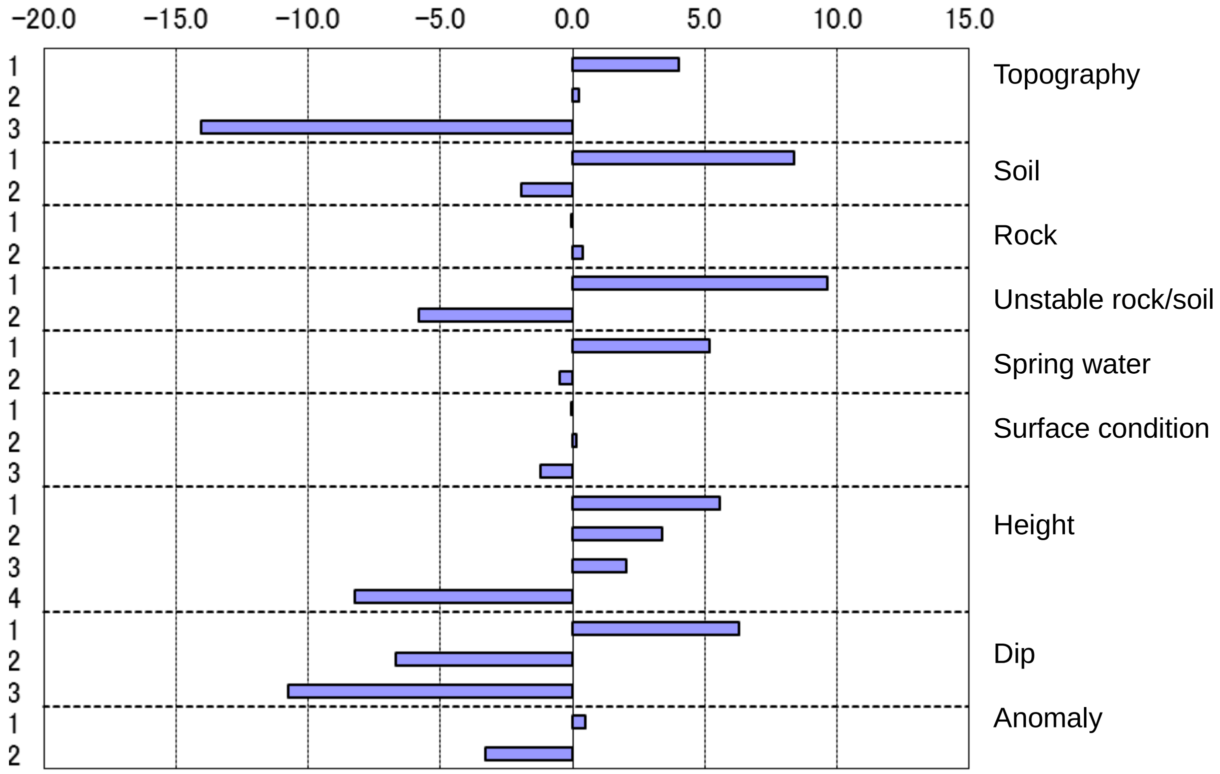
Category score of debris slope failure

Category range and partial correlation coefficient of debris slope failure

Item	Category range		Partial correlation coefficient	
Topography	2.493	9th	0.063	8th
Soil	8.501	5th	0.219	5th
Structure	14.929	1st	0.244	1st
Unstable rock/soil	5.924	6th	0.097	7th
Spring water	4.571	7th	0.114	6th
Surface condition	2.586	8th	0.052	9th
Height	10.427	3rd	0.228	4th
Dip	14.855	2nd	0.236	2nd
Anomaly	9.508	4th	0.231	3rd

The results of the risk analysis for ROCK SLOPE FAILURE

	A	B	C	F	G	H	I	J	K
	Topography	Geological conditions		Surface condition			Profile		Anomaly
	Collapsed factor	Soil	Rock	Unstable rock/soil (Topsoil, detached rock and unsteady rock)	Spring water	Surface condition	Height (H), dip (i)		Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure
	Talus slope, clear convex break of slope, eroded toe of slope, overhang, water catchment slope	Susceptible to erosion less strength with water	High density of cracks and a weak layers, susceptible to erosion, fast weathering				Height	Dip	
1	2 or more correspondences	marked	marked or a little marked	instability	notable spring waster	bare land with minor vegetation	H≧50m	i≧70°	2 or more correspondences/ clarity or certain/unclarity
2	1 correspondences	a little marked or none	none	a little unstable or stability	seepage or none	intermediate (bare/grass/ tree)	30≦H＜50m	45°≦i＜70°	none
3	no correspondences					mainly structure, mainly tree	15≦H＜30m	i＜45°	
4							H＜15m		



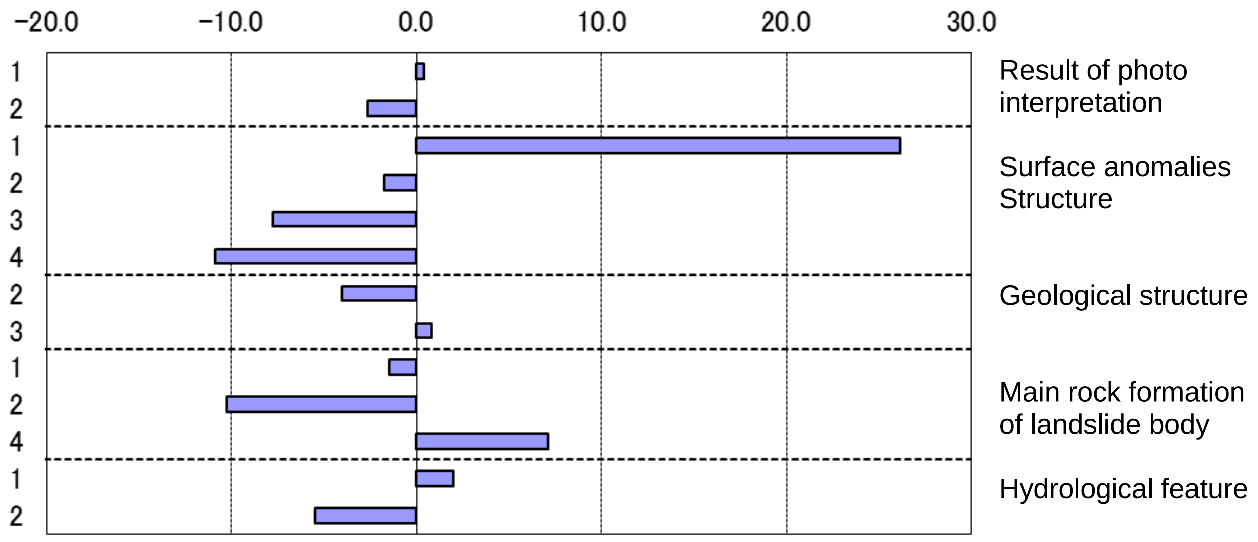
Category score of rock slope failure

Category range and partial correlation coefficient of rock slope failure

Item	Category range		Partial correlation coefficient	
Topography	18.071	1st	0.313	3rd
Soil	10.329	5th	0.216	5th
Rock	0.424	9th	0.008	9th
Unstable rock/soil	15.457	3rd	0.352	1st
Spring water	5.655	6th	0.094	6th
Surface condition	1.349	8th	0.014	8th
Height	13.790	4th	0.292	4th
Dip	17.094	2nd	0.338	2nd
Anomaly	3.778	7th	0.070	7th

The results of the risk analysis for LANDSLIDE

	A	B	C	D	E
	Topographical factor		Geological conditions		
	Result of photo interpretation	Surface anomalies	Geological structure	Main rock formation of landslide body	Hydrological feature
1	exist clearly or exist but partial and not clear	large and new cracks, steps and subsidence	fault, fracture zone	metamorphic rock (schist, quartzite, phyllite etc.)	much springs/much seepage or little springs/little seepage or trace of water
2	exist but not clear	small and old cracks, steps and subsidence	dip slope	sedimentary rock (sandstone, limestone etc.)	no water observed
3		slight deformation	undip slope/ no characteristic feature	igneous rock (granite etc.)	
4		no anomalies		quaternary deposit (colluvial deposit etc.)	



Category score of landslide

Category range and partial correlation coefficient of landslide

Item	Category range		Partial correlation coefficient	
Result of photo interpretation	3.007	5th	0.064	5th
Surface anomalies Structure	37.022	1st	0.630	1st
Geological structure	4.885	4th	0.118	4th
Main rock formation of landslide body	17.367	2nd	0.247	2nd
Hydrological feature	7.517	3rd	0.216	3rd

Appendix 14

Check List of Environmental and Social Considerations and Impacts

	Items	Contents	Yes or No	Impact			Mitigation measure
				Plan	constructions	Maintenance	
Pollution	Air pollution	Air pollution by traffic	Yes			Vehicles for maintenance and inspection could release pollution materials.	The volume of the air pollution materials is estimated based on the past traffic. However, the construction work for the countermeasures for slope disasters is the same as normal constructions, which means that it does not release worse pollution materials.
		Air pollution by constructions	Yes		Construction vehicles could release pollution materials.		Use of low-emission vehicles, decent ration of construction sites, and deconcentration of construction periods are useful. In case of resident areas, watering for the slopes and the roads is necessary to control the dust. Smaller machines for construction are selected, and idling for the machine is stopped. Sound insulating walls are available to avoid spreading pollution materials.
		Air pollution by countermeasures	No Pollution materials are NOT released from the countermeasures.				
	Water pollution	Water pollution by constructions	Yes		Mud water could flow out with debris by cutting and filling.		Quality standard of discharge water is set. Facilities for purification and filtration are installed. Smaller machines for construction are selected to decrease rolling debris A temporary ditch is constructed to prevent debris from flowing out by cutting and filling with rainfall.
		Water pollution by drainage water	No 'Pollution materials are NOT released from the countermeasures.				
		Water pollution by drainage water from parking	No 'Parking is NOT constructed by the countermeasures.				
		Water quality impact by drainage	Yes		Flow of surface water could be changed by the constructions		Drainage countermeasures are designed based on the detailed investigation and analysis. The concept of the drainage is not to change the current water flow. Monitoring during/after constructions is needed.
		Water pollution by countermeasures	No Pollution materials are NOT released from the countermeasures.				
	Waste	Waste from parking	No 'Parking is NOT constructed by the countermeasures.				
		Waste by constructions	Yes		Waste could be generated with the constructions.		The contractor is educated about waste, and prepares and submits check sheets.
		Waste soil by constructions	Yes		Waste soil could be generated with the constructions.		Less waste soil is considered when designing the countermeasures. Waste soil is recycled for other construction sites. Waste sites are selected for certain areas. The contractor is educated about waste soil, and prepares and submits check sheets.
	Noise and vibrations	Noise and vibrations by constructions	Yes		Construction vehicles, drilling machines etc. could generate noise and vibrations		The noise and vibrations are not avoidable, it is explained to the local residents. The construction period is limited only to the daytime. Sound insulating walls are available to avoid noise.
	Ground subsidence	Ground subsidence by groundwater drainage	Yes		Ground subsidence could occur from groundwater drainage with the constructions.	Ground subsidence could occur from groundwater drainage.	Drainage countermeasures are designed based on the detailed investigation and analysis. The concept of the drainage is not to change the current ground water level. Monitoring during/after construction is needed. However, a slope disaster would occur due to excessive ground water. Understanding that slope disasters and ground subsidence is a trade-off relationship is needed.

	Items	Contents	Yes or No	Impact			Mitigation measure
				Plan	constructions	Maintenance	
	Offensive odors	Offensive odors by constructions	No Offensive odors are NOT released from the countermeasures.				
	Bottom sediment	Pollution of bottom sediment by constructions	No The countermeasures are not affect the bottom sediment.				
	Accidents	Traffic accidents under constructions	Yes		Risk of traffic accidents could increase due to traffic regulation from the constructions.		The contractor is educated about the risk of traffic accidents. Fluorescent panels are installed.
		constructions accidents	Yes		Slope disasters could happen.		Excessive cutting is avoided. The construction is tentatively suspended when it is raining or the snow is melting, and when cracks are opening on the slope. Monitoring during/after construction is needed.
Natural environment	Protected areas	Protected area by law or international regulation	Yes		Constructions could destroy protected areas.		Confirmation is needed when planning. Countermeasure are considered if needed.
	Biota and ecosystems	Protecting habitat of wild animals/plants	Yes		Constructions could destroy protected habitats.		Confirmation is needed when planning. Countermeasure are considered if needed.
		Habits of rare species	Yes		Constructions could destroy habitats.		Confirmation is needed when planning. Countermeasures are considered if needed.
		Ecological impact	Yes		Wild animals could invade the construction sites. Constructions could affect nest building.	Vegetation for slope stability could affect the ecosystem in the area.	Original wild vegetation is available. Nests are transferred to safer areas. The construction is postponed to winter season when not nest building. A Fence preventing wild animals from entering is needed. Nest boxes are installed for birds.
		Interception of wild animals/ livestocks/ habits	Yes			Animals/ livestocks/ habits could be intercepted by the countermeasures.	Bridge(S) and fences are needed for water ditches. Bigger box culverts are installed to avoid the interception of wild animals/ livestock/ habitats
		Exotic species	Yes			Exotic species could effect the ecosystem.	Original wild vegetation is available.
		Environmental impact in untouched areas	Yes		Constructions could affect environmental impact in untouched areas.	Construction could affect environmental impact in untouched areas.	Confirmation is needed when planning. Countermeasures are considered if needed.
	Water usage	Negative impact for surface water and groundwater	Yes		Negative impact could happened for surface water and groundwater by the drainage.	Negative impact could happened for surface water and groundwater by the drainage.	Drainage countermeasures are designed based on the detailed investigation and analysis. The concept of the drainage is not to change the current ground water level. Monitoring during/after construction is needed. However, slope disasters would occur due to excessive surface and ground water. Therefore it is necessary to understand that the change of water conditions is not avoidable.
	Geographical features	Slope disasters by bad geology	Yes		Constructions could be a trigger of slope disasters		Slope disasters and countermeasure are considered beforehand under bad geology. Covering by plastic sheets is useful to avoid the penetration of rainfall.
		Slope disasters by cutting/filling	Yes		Constructions could be a trigger of slope disasters		Slope disasters and countermeasures are considered beforehand under cutting/filling construction. A surface ditch is installed on a landslide block to avoid flowing into the roads.
		Discharge of sediment by constructions	Yes		Constructions could be a trigger of discharge of sediment		The contractor is educated about the procedure. Temporary protection fencing is installed.
		Modification of topography and geological structure by constructions	Yes		Topography and geological structure could be heavily modified by the constructions		Excessive cutting is avoided. However, it is necessary to understand that modification of topography and geological structures are not avoidable.

	Items	Contents	Yes or No	Impact			Mitigation measure
				Plan	constructions	Maintenance	
Social environment	Involuntary resettlement	Involuntary resettlement	Yes	Involuntary resettlement and compensation for farming and grazing could be necessary for the constructions.			Involuntary resettlement is avoided as much as possible when planning. Several stakeholder meetings are available to persuade the local residents. Compensation for resettlement, farming and grazing are necessary beforehand. Relocation destination is secured and relocation cost is compensated.
	Lifestyle and livelihood	Lifestyle and livelihood	Yes	Land acquisition could be necessary for the constructions.			Land acquisition is avoided as much as possible when planning. Several stakeholder meetings are available to persuade the local residents. Compensation for resettlement, farming and grazing are necessary beforehand. Relocation destination is secured and relocation cost is compensated.
	Heritage	Cultural heritage	No The countermeasure is constructed on current roads, not near heritage sites.				
	Landscape	Landscape	Yes			Countermeasures could impair landscape.	Excessive impairing is avoided when planning, such as greening of slope surface. However, understanding that modification of landscape is not avoidable is needed.
	Ethnic minorities and indigenous peoples	Ethnic minorities and indigenous people	No The countermeasure is constructed on current roads, not near residential areas				
	Working conditions	Working conditions	Yes		Poor working conditions and lack of safety measures/education could be a trigger of accidents Labor could usurp local residents.		The contractor is educated about the working conditions and safety measures. The manual is useful for the laborers.

Appendix 15

Degree of the Impacts for each Countermeasure

			LANDSLIDE											
	Item	contents	Surface Drainage (Open ditch)	Open-Blind Ditch (French drain)	Horizontal Drainage	Drainage Well	Drainage Tunnel	Earth Removal	Counterweight Fill	Steel Pile work	Cast-in place concrete Shaft (Caisson)	Ground Anchor	Surface Drainage	Re-vegetation
Pollution	Air pollution	Air pollution by constructions	3	3	3	3	3	3	3	3	3	3	3	3
	Water pollution	Water pollution by constructions	4	4	3	4	4	2	2	4	4	4	4	4
		Water quality impact by drainage	3	3	2	2	2	3	3	4	4	4	3	4
	Waste	Waste by constructions	3	3	3	2	2	1	3	3	2	3	3	3
		Waste soil by constructions	3	3	3	2	2	1	3	3	2	3	3	3
	Noise and vibrations	Noise and vibrations by constructions	2	2	2	1	1	2	2	1	2	2	2	3
	Ground subsidence	Ground subsidence by groundwater drainage	3	3	1	1	1	4	4	4	4	4	4	4
	Accidents	Traffic accidents under constructions	2	2	2	2	2	2	2	2	2	2	2	2
		Construction accidents	2	2	2	2	2	2	2	2	2	2	2	2
Natural environment	Protected areas	Protected area by law or international regulation	2	2	2	2	2	2	2	2	2	2	2	2
	Biota and ecosystems	Protecting habitat of wild animals/plants	2	2	2	2	2	2	2	2	2	2	2	2
		Habits of rare species	2	2	2	2	2	2	2	2	2	2	2	2
		Ecological impact	2	2	2	2	2	2	2	2	2	2	2	2
		Interception of wild animals/ livestocks/ habits	2	3	3	3	3	2	2	3	3	3	2	2
		Exotic species	4	4	4	3	3	3	3	4	4	4	4	2
		Environmental impact in untouched areas	3	3	3	2	2	2	2	3	3	3	3	3
	Water usage	Negative impact for surface water and groundwater	2	2	1	1	1	3	3	4	4	4	2	4
	Geographical features	Slope disasters by bad geology	3	3	3	3	2	1	1	3	3	3	3	3
		Slope disasters by cutting/filling	3	3	3	3	2	1	1	3	3	3	3	3
		Discharge of sediment by constructions	3	3	3	3	2	1	1	3	3	3	3	3
		Modification of topography and geological structure	3	3	3	3	2	1	1	3	3	3	3	3
Social environment	Involuntary resettlement	Involuntary resettlement	2	2	2	2	2	2	2	2	2	2	2	2
	Lifestyle and livelihood	Lifestyle and livelihood	2	2	2	2	2	2	2	2	2	2	2	2
	Landscape	Landscape	3	3	3	2	2	1	1	2	2	2	3	2
	Working conditions	Working conditions	2	2	2	2	2	2	2	2	2	2	2	2

Impact
1 Large
2 Middle
3 Small
4 No

			DEBRIS SLOPE FAILURE									ROCK SLOPE FAIL		
	Item	contents	Wicker Fence	Wooden Log Crib	Stone Pitching	Retaining Wall	Barrier Wall	Re-shaping slope with Benching	Concrete Crib	Shotcrete	Ground Anchor	Rock Removal	Retaining Wall	Barrier Wall
Pollution	Air pollution	Air pollution by constructions	3	3	3	3	3	3	3	3	3	3	3	3
	Water pollution	Water pollution by constructions	4	4	4	4	4	4	4	4	4	4	4	4
		Water quality impact by drainage	4	4	4	4	4	4	4	4	4	4	4	4
	Waste	Waste by constructions	3	3	3	3	3	3	3	3	3	1	3	3
		Waste soil by constructions	3	3	3	3	3	3	3	3	3	1	3	3
	Noise and vibrations	Noise and vibrations by constructions	3	3	2	2	2	2	2	2	2	1	2	2
	Ground subsidence	Ground subsidence by groundwater drainage	4	4	4	4	4	4	4	4	4	4	4	4
	Accidents	Traffic accidents under constructions	2	2	2	2	2	2	2	2	2	2	2	2
		Construction accidents	2	2	2	2	2	2	2	2	2	2	2	2
Natural environment	Protected areas	Protected area by law or international regulation	2	2	2	2	2	2	2	2	2	2	2	2
	Biota and ecosystems	Protecting habitat of wild animals/plants	2	2	2	2	2	2	2	2	2	2	2	2
		Habits of rare species	2	2	2	2	2	2	2	2	2	2	2	2
		Ecological impact	2	2	2	2	2	2	2	2	2	2	2	2
		Interception of wild animals/ livestocks/ habits	2	2	2	2	2	2	2	2	3	2	2	2
		Exotic species	2	2	4	4	4	4	4	4	4	3	4	4
		Environmental impact in untouched areas	3	3	3	3	3	3	3	3	3	2	3	3
	Water usage	Negative impact for surface water and groundwater	4	4	4	4	4	4	4	4	4	3	4	4
	Geographical features	Slope disasters by bad geology	3	3	3	3	3	2	3	3	3	1	3	3
		Slope disasters by cutting/filling	3	3	3	3	3	2	3	3	3	1	3	3
		Discharge of sediment by constructions	3	3	3	3	3	2	3	3	3	1	3	3
		Modification of topography and geological structure	3	3	3	3	3	2	3	3	3	1	3	3
Social environment	Involuntary resettlement	Involuntary resettlement	2	2	2	2	2	2	2	2	2	2	2	2
	Lifestyle and livelihood	Lifestyle and livelihood	2	2	2	2	2	2	2	2	2	2	2	2
	Landscape	Landscape	2	2	2	2	2	2	1	1	2	1	2	2
	Working conditions	Working conditions	2	2	2	2	2	2	2	2	2	2	2	2

Impact
1 Large
2 Middle
3 Small
4 No

			JRE		DEBRIS FLOW						ROCK FALL			
	Item	contents	Protection Rock Net	Rock Bolt (Nailing)/Anchor	Sabo Dam	Check Dam	French Cascade	Culvert	Buffer Forest	Shed Work	Rock Removal	Protection Wall	Rock Catch Net	Fixing Work by shotcrete
Pollution	Air pollution	Air pollution by constructions	3	3	3	3	3	3	3	3	3	3	3	3
	Water pollution	Water pollution by constructions	4	4	4	4	4	4	4	4	4	4	4	4
		Water quality impact by drainage	4	4	3	3	3	3	4	4	4	4	4	4
	Waste	Waste by constructions	3	3	2	2	2	3	3	3	1	3	3	3
		Waste soil by constructions	3	3	2	2	2	3	3	3	1	3	3	3
	Noise and vibrations	Noise and vibrations by constructions	3	2	2	2	2	2	3	2	1	2	3	2
	Ground subsidence	Ground subsidence by groundwater drainage	4	4	4	4	4	4	4	4	4	4	4	4
	Accidents	Traffic accidents under constructions	2	2	2	2	2	2	2	2	2	2	2	2
		Construction accidents	2	2	2	2	2	2	2	2	2	2	2	2
Natural environment	Protected areas	Protected area by law or international regulation	2	2	2	2	2	2	2	2	2	2	2	2
	Biota and ecosystems	Protecting habitat of wild animals/plants	2	2	2	2	2	2	2	2	2	2	2	2
		Habits of rare species	2	2	2	2	2	2	2	2	2	2	2	2
		Ecological impact	2	2	2	2	2	2	2	2	2	2	2	2
		Interception of wild animals/ livestocks/ habits	2	3	2	2	2	2	3	2	2	2	2	2
		Exotic species	4	4	4	4	4	4	2	4	3	4	4	4
		Environmental impact in untouched areas	3	3	3	3	3	3	3	3	2	3	3	3
	Water usage	Negative impact for surface water and groundwater	4	4	4	4	4	4	4	4	3	4	4	4
	Geographical features	Slope disasters by bad geology	3	3	3	3	3	3	3	3	1	3	3	3
		Slope disasters by cutting/filling	3	3	3	3	3	3	3	3	1	3	3	3
		Discharge of sediment by constructions	3	3	3	3	3	3	3	3	1	3	3	3
		Modification of topography and geological structure	3	3	3	3	3	3	3	3	1	3	3	3
Social environment	Involuntary resettlement	Involuntary resettlement	2	2	2	2	2	2	2	2	2	2	2	2
	Lifestyle and livelihood	Lifestyle and livelihood	2	2	2	2	2	2	2	2	2	2	2	2
	Landscape	Landscape	1	2	2	2	3	2	3	1	1	2	1	1
	Working conditions	Working conditions	2	2	2	2	2	2	2	2	2	2	2	2

Impact
1 Large
2 Middle
3 Small
4 No

				OTHERS		
	Item	contents	Shed Work	Tunnel -Route Shift-	Bridge -Route Shift-	Advanced Traffic Control (Early Warning
Pollution	Air pollution	Air pollution by constructions	3	1	2	4
	Water pollution	Water pollution by constructions	4	3	3	4
		Water quality impact by drainage	4	3	4	4
	Waste	Waste by constructions	3	1	1	4
		Waste soil by constructions	3	1	1	4
	Noise and vibrations	Noise and vibrations by constructions	2	1	1	4
	Ground subsidence	Ground subsidence by groundwater drainage	4	3	4	4
	Accidents	Traffic accidents under constructions	2	2	2	4
		Construction accidents	2	2	2	4
Natural environment	Protected areas	Protected area by law or international regulation	2	2	2	4
	Biota and ecosystems	Protecting habitat of wild animals/plants	2	2	2	4
		Habits of rare species	2	2	2	4
		Ecological impact	2	2	2	4
		Interception of wild animals/ livestocks/ habits	2	2	2	4
		Exotic species	4	3	3	4
		Environmental impact in untouched areas	3	2	2	4
	Water usage	Negative impact for surface water and groundwater	4	2	4	4
	Geographical features	Slope disasters by bad geology	3	1	2	4
		Slope disasters by cutting/filling	3	1	2	4
		Discharge of sediment by constructions	3	1	2	4
		Modification of topography and geological structure	3	1	2	4
Social environment	Involuntary resettlement	Involuntary resettlement	2	2	2	4
	Lifestyle and livelihood	Lifestyle and livelihood	2	2	2	4
	Landscape	Landscape	1	1	1	4
	Working conditions	Working conditions	2	2	2	4

Impact
1 Large
2 Middle
3 Small
4 No