Ⅳ FEASIBLITY STUDY

CHAPTER 2
NATURAL CONDITION ON THE PROJECT AREA

CHAPTER 2 NATURAL CONDITIONS ON THE PROJECT AREA

2.1 Introduction

The main objective of this chapter is to describe the natural conditions on the project area. The surveys have been carried out by the Study Team to assist the preliminary design in the Feasibility Study. The content of the major surveys on natural conditions is as follows.

- Topographic Survey
- Geological Survey
- Material Survey

At the **western part** of the project area, the Damlek mountains being between 500 meters and 700 meters above sea level is extending from north to south and forming the border between Laos and Thailand.

In the **eastern part** of the area, the Louang mountains being between 1,000 meters and 2,000 meters above sea level is ranging from northwest to southeast and forming the border between Laos and Vietnam.

In the **central part** of the area, there is a big table mountain named the Boloven Plateau being between 1,000 meters and 1,700 meters above sea level. Its major axis reaches about 100 kilometers in length from north to south and minor axis reaches about 50 kilometers in length from east to west. This plateau was formed by volcanic activity of basalt and uplift movement during between Tertiary and Quaternary on Paleozoic sedimentary rocks.

In the **north part** of the Boloven Plateau, a flat peneplain widely spreads out toward north.

In the **south** of the project area, there is a mountainous region being between 550 meters and 800 meters above sea level, forming the border between Laos and Cambodia.

Major river system in the project area is as follows. **Makong river** is flowing from north to south between the Damlek mountains and the Boloven Plateau and reaches Cambodia, forming Mekong valley. **Xe Dong river** rises from the Boloven Plateau and flows in the northern and western parts of the Boloven Plateau. Later, Xe Dong river meets with Mekong river at Pakse, forming Xe Dong valley. **Xe Kong river** rises from the Louang mountains and flows in the eastern part of the Boloven Plateau and forms Xe Kong valley.

The project route, **R14A** is passing through on the flood plain of Mekong river being between 100 meters and 110 meters above sea level. Route **R16A** starts from the central part of the Boloven Plateau and reaches the Xe Kong valley after crossing the east part of the Boloven Plateau. Climatologically the project area is located in the wet tropics changing rainy season and dry season. As a result, most of soils is affected by laterization. And residual soils are found on the base rocks in various places.

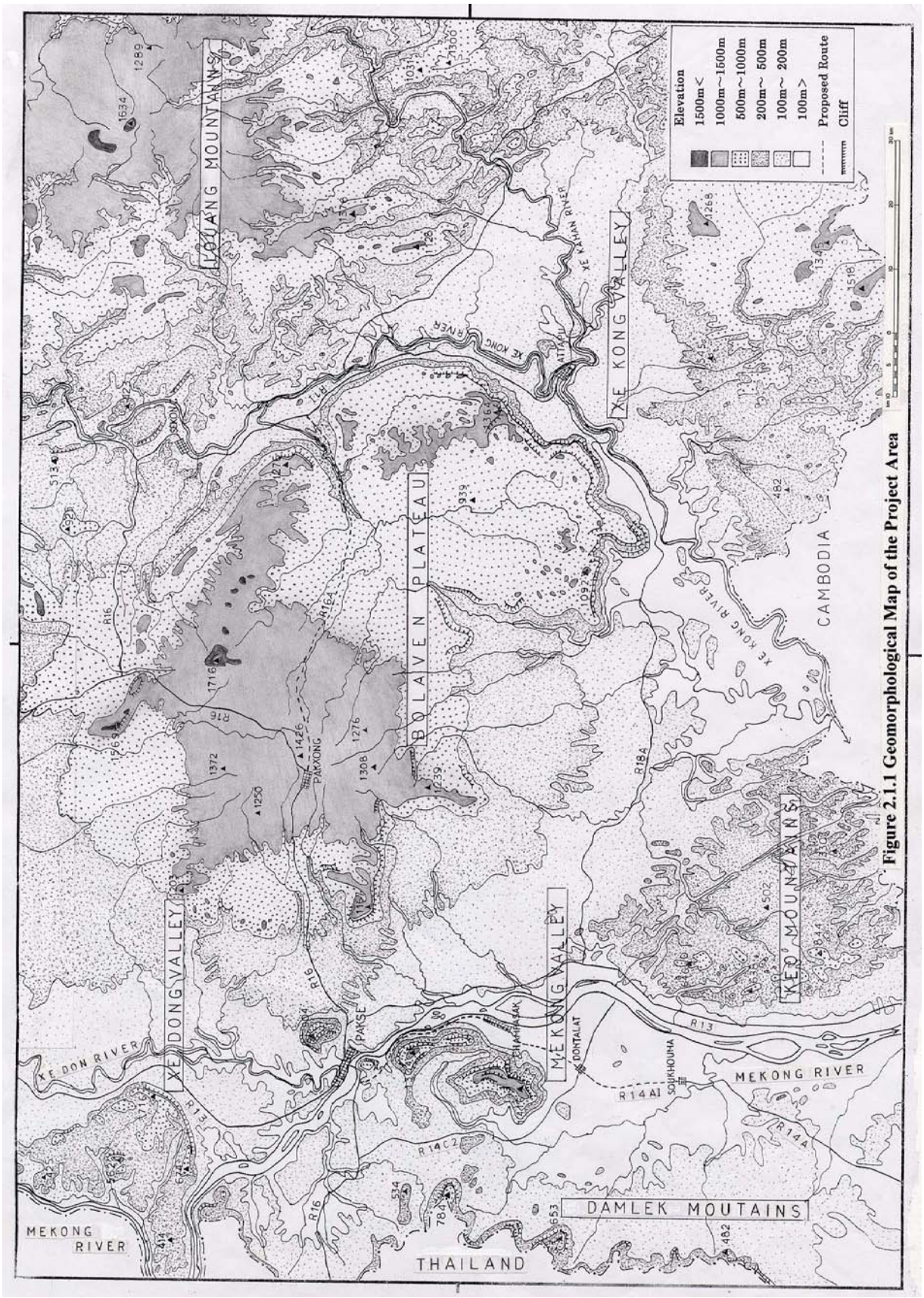


Figure 2.1.1 Geomorphological Map of the Project Area

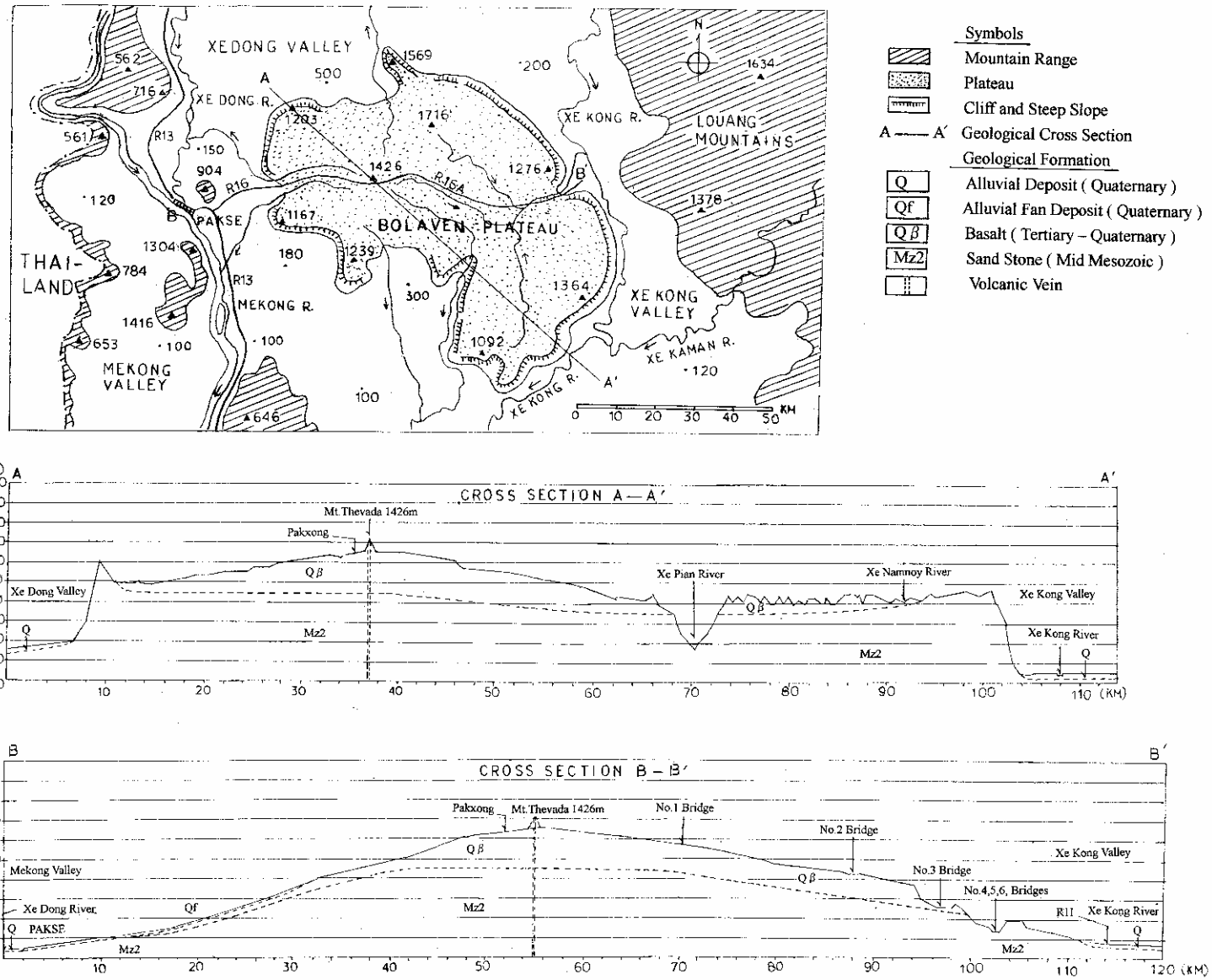


Figure 2.1.2 Geological Profiles of the Bolaven Plateau

2.2 Topographic Survey

2.2.1 Outline of Survey

(1) Survey Location

1) Route 14A

- Starting Point ： Muang-Kao town on the Route 16
- Ending Point ： Sukhuma town on the Route 14A
- Distance of the Survey Route ：59.75 km

2) Route 16A

- Starting Point ： Paksong town on the Route 16
- Ending Point ： Bengphoukham village (Ban Lak 52) on the Route 1I
- Distance of the Survey Route ： Alternative (i) = 64.51km
  Alternative (ii) = 70.07km

Note
Alternative (i) is applied shortcut section.
Alternative (ii) is applied existing road section.

(2) Content of Survey

- Traverse Survey
- Centerline Survey
- Profile Survey
- Cross Section Survey
- River Cross Section Survey
- Topographic Mapping

(3) Quantity of Survey

Table 2.2.1 Quantity of Topographic Survey for Route 14A and Route 16A

Item	Unit	Route 14A	Route 16A			Grand Total
			(i) *1	(ii) *2	Total	
Travers Survey	km	59.756	64.655	13.997	78.652	138.408
Center Line Survey	km	59.747	64.508	13.941	78.449	138.196
Profile Survey	km	59.747	64.508	13.941	78.449	138.196
Cross Section Survey	Section	1,195	1291	279	1,570	2,765
River Cross Section Survey	Point	9	6	0	6	15

Note
*1: Applied shortcut section
*2: Quantities of existing road section

(4) Referring National Bench Mark

Table 2.2.2 List of National Bench Mark

Route	Location	Point Name	Northing	Easting	Elevation
R14A	Pakse	NGD023	1672961.489m	584240.542m	103.306m
R16A	Paksong	NGD051	1678540.995m	631872.099m	1279.832m

(5) Mapping

The results of survey are drawn up according to a scale shown in Table 2.2.3. The interval of contour lines is as follows.

- Contour line ： Interval of 5 meters
- Sub Contour line ：Interval of 2.5 meters (1m at bridge site)

Table 2.2.3 Scale of Mapping

Item	Scale	Remarks
Topographic Mapping	1 / 5000	100 meters in width from the centerline.
Profile Sections Horizontal Vertical	 1 / 5000 1 / 500	50 meter each.
Cross Sections Horizontal Vertical	 1 / 500 1 / 500	50 meter each. 100 meters in width from the centerline.
Topographic map In river area	1 / 500	30 meters in width from riverbanks.
River Cross Sections Horizontal Vertical	 1 / 500 1 / 500	5 cross sections for each river.

2.3 Geological Survey

2.3.1 Outline of Survey

The drilling works were carried out at proposed bridge sites. Number of Proposed bridge are 16 sites for the Route 14A and 6 sites for the Route 16A. Boreholes were drilled at the both bank of big rivers and 1 (one) borehole was drilled at the bank of small river.

Table 2.3.1 List of Boring Sites

Route No.	River No.	River Name	Km Post	Boring No.
R14A	14-1	Thok	5.391	14-1R, 14-1L
	14-8	Imet	11.383	14-8R
	14-11	Thakhong	13.635	14-11R
	14-12	Thapxang	14.544	14-12R
	14-13	Khone liao	15.820	14-13R
	14-14	Khonken	17.037	14-14R
	14-15	Hong	18.316	14-15R
	14-16	He	19.001	14-16L
	14-17	Dua	19.887	14-17L
	14-18	Sai (Xai)	21.428	14-18R, 14-18L
	14-19	Phapin	24.346	14-19R, 14-19L
	14-20	Phabang	29.439	14-20R, 14-20L
	14-21-1	Sahoua	32.214	14-21-1R
	14-21-2	Kok	32.625	14-21-2R
	14-22	Thateng	40.614	14-22R, 14-22L
	14-23	Manpa	45.495	14-23R, 14-23L
R16A	16-1	Makchan-Gnai	17.579	16-1R, 16-1L
	16-2	Namtang	35.550	16-2R, 16-2L
	16-3	Xe Katam	46.009	16-3R, 16-3L
	16-4	Xe Namnoy	51.637	16-4R, 16-4L
	16-5	Xe Namnoy (Old Channel)	51.841	16-5R, 16-5L
	16-6	Katak Tok (Ho)	52.168	16-6R, 16-6L

2.3.2 Geological Stratigraphy

The geological map in the southern part of Lao P.D.R is shown in Figure 2.3.1. And the geological stratigraphy is shown in Table 2.3.2. By these figure and table, Precambrian metamorphic rocks consist of the basement rock in the southern pant of Laos. These metamorphic rocks are partially found in the eastern mountain range. Paleozoic formations consist of marine sedimentary rocks with limestone. These formations are distributed in the eastern mountain range with direction of from NW to SE.

The early Paleozoic contains volcanic rocks and is strongly affected by metamorphism.

The mid Paleozoic consists of marine sedimentary rocks weakly affected by metamorphism.

The late Paleozoic consists of non- metamorphic sedimentary rock containing of volcanic rocks and coals.

Mesozoic formations show most widely distribution in the study area.

These formations mainly consist of sand stone, mudstone and their alternation. The early Mesozoic contains volcanic rocks and is distributed in the southern part of the study area.

The Mid Mesozoic mainly consists of sand stone and covers with all of the study area.

The Late Mesozoic contains rock salt and gypsum and is distributed in the northern part of the study area.

The Boloven Plateau consists of the mid Mesozoic sand stone and mudstone. These sedimentary rocks are widely covered with basalt of the late Tertiary or the early Quaternary.

Table 2.3.2 Geological Stratigraphy

Symbol of Formation	Facies	Geological Age
Q	Alluvial Sediment (Clay, Silt, Sand and Gravel)	Quaternary
Qβ	Volcanic Rock (Basalt)	Tertiary ~ Quaternary
N	Terrestrial, Clastic Sediment (Sandstone and Mudstone)	Tertiary
MZ3	Clastic Sediment (Sandstone and Mudstone)	Late Mesozoic
MZ2	Clastic Sediment (Sandstone with Mudstone)	Mid Mesozoic
MZ1	Clastic Sediment with Limestone and Volcanic Rocks (Rhyolite, Dasite and Tuff)	Early Mesozoic
PZ3	Clastic Sediment with Limestone and Volcanic Rocks (Andesite and Dasite)	Late Paleozoic
PZ2	Marine Sediment with Limestone, weakly metamorphosed	Mid Paleozoic
PZ1	Metamorphosed Marine Sediment with Limestone and Volcanic Rocks (Basic and Ultra-basic Rocks)	Early Paleozoic
PR	Gneiss and Schist	Pre-Cambrian
γ	Granite and Granodiorite	Paleozoic ~ Tertiary

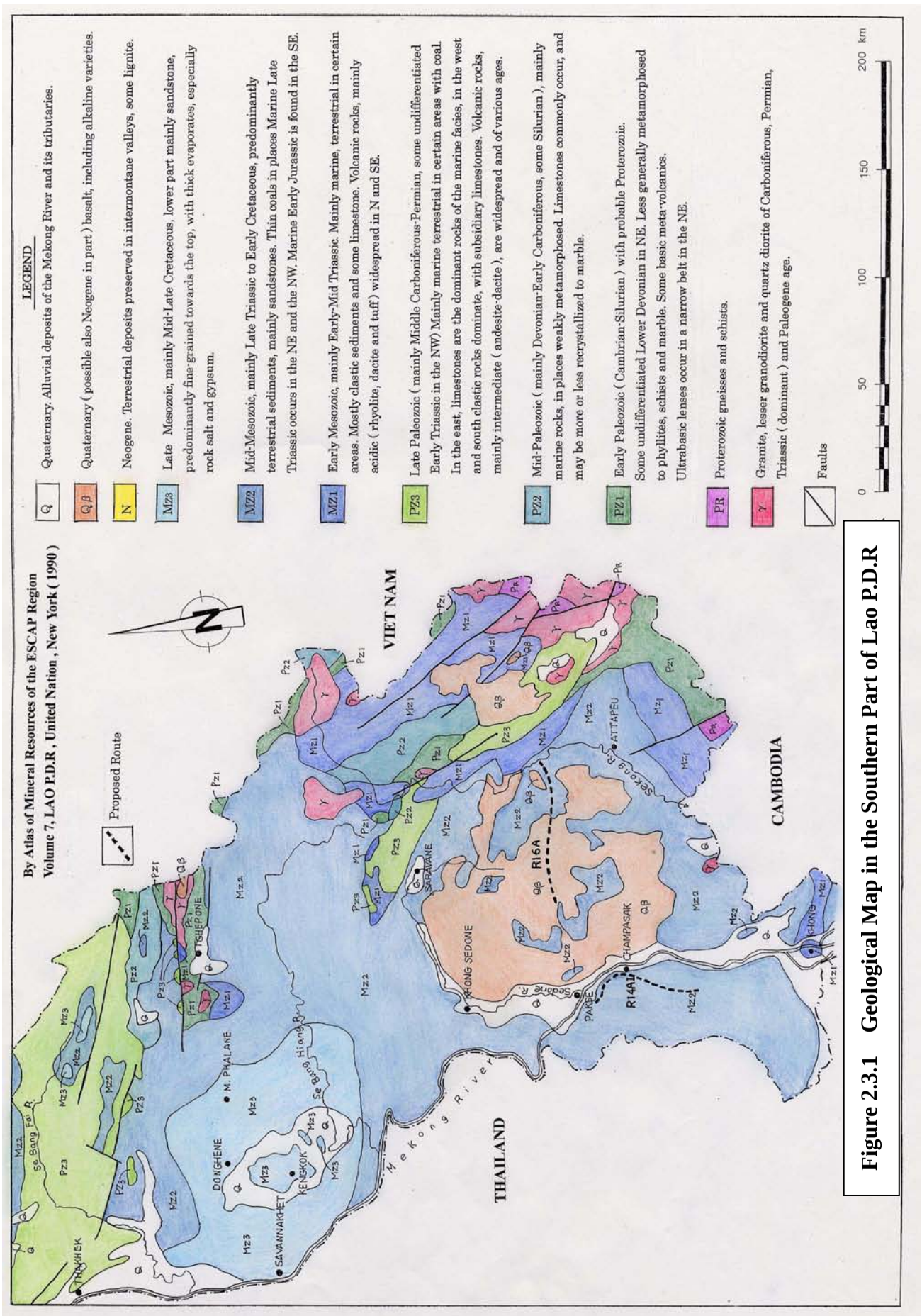


Figure 2.3.1 Geological Map in the Southern Part of Lao P.D.R

2.3.3 Geological Conditions along the Route

(1) Route 14A

This route is passing through narrow hills with distance of 5 kilometers between starting point and Thok river. At this section, the mid Mesozoic sand stone and mudstone directly expose on the route.

At the section with distance of 25 kilometers between Thok river and Champasack town, flood plain being from 500 meters to 2000 meters in width are found along the Mekong river. This flood plain consists of alluvial sand and clay being from 2 meters to 12 meters in thickness.

At the section with distance of 30 kilometers between Champasack town and Sukhuma town, peneplain being 30 kilometers in width is distributed between the Mekong river and the Damlek mountains. Thickness of alluvial soil covering with this peneplain is very thin. Its thickness is about between 4 meters and 6 meters.

Basement rock along the route consist of the mid Mesozoic sand stone and mudstone.

Between the starting point and Dua river with distance of 20 kilometers, sand stone is mainly distributed sometimes inserting thin mudstone.

Between Dua river and the ending point of the route, mudstone is mainly distributed.

These sand stone consist of fine red sand stone and the surfaces of these rocks are sometimes very soft by influence of hard weathering. On the other hand, mudstone consists of clay stone and siltstone and their surfaces looks like hard clays by influence of hard weathering.

Dip and strike of this mid Mesozoic show E－W, 10 S and they incline gently to the south with gentle ups and downs.

(2) Route 16A

The Route 16A is located on the basaltic plateau between Paksong town and Xe Katam river. This section is covered with residual soil and basaltic lava. And the flat surface of this plateau is covered with volcanic fan deposits. These deposits consist of basaltic gravels being from 5 meters to 6 meters in thickness, containing boulder of basalt being from 1 meter to 2 meters in diameter.

Between Xe Katam river and 60 km post, sand stone and mud stone as basement rocks are distributed. At this section, the Route 16A is located at steep mountain slopes and river terraces. On the mountain slopes, there are unstable talus deposits, residual soil and high weathered rocks. At these formations, collapses of slope are found in various places.

River terraces consist of stable gravels being about 10 meters in thickness.

Between 60 kilometers post and the ending point, fan gravels of Xe Namnoy river are found on the basement rocks. Dip strike of this basement rocks show E－W, 20 ° S at the western part of the route and show horizontal dip at the edge of eastern part of plateau.

2.3.4 Geological Condition at River Crossings

(1) Geological Cross Section of Route 14A)

Geological cross section for No.14-21-1 is shown in Figure 2.3.2 as a reference and others are compiled in ANNEX F-16.

1) Thok River (No,14-1)

Alluvial clay (AC) is 1.5 meters in thickness on the left bank and 4.7 meters in thickness on the right bank. Residual soil is from 1.5 meters to 4.1 meters in depth on the left bank. Weathered mud stone as basement rock is 4.1 meters in depth on the left bank and 4.7 meters in depth on the right bank. There is no running water in the river in dry season. Ground water level is not found in the borehole.

2) Imet River (No,14-8)

Alluvial formations are not found here. Hard fine sand stone is distributed on the both banks. There is no running water in the river in dry season. Ground water level is not found in the borehole.

3) Thakhong River (No.14-11)

Alluvial clay (AC) and alluvial sand (AS) being 9.3 meters in thickness are distributed on the right bank. Weathered mudstone is 9.3 meters in depth on the right bank. There is no running water in the river in dry season. Ground water level is found at 4.3 meters in depth in the borehole.

4) Thapxang River (No.14-12)

At the right bank, alluvial silt (AC1) being 3.5 meters in thickness, alluvial sand (AS) being 4.0 meters in thickness and alluvial silt (AC2) being 1.1 meters in thickness are found.
Weathered sand stone (SS) being 8.4 meters in depth is distributed. There is no running water in the river in dry season. Ground water level is found at 3.8 meters in depth balancing with river water level.

5) Khone liao River (No.14-13)

Alluvial clay (AC) being between 1 meter and 2 meters in thickness is found on the right bank. Sand stone (SS) is found at between 1 meter and 2 meters in depth. There is no water in the river in dry season. Ground water level is not found in the borehole.

6) Khonken River (No.14-14)

Alluvial silt (AC) being 7.0 meters in thickness and alluvial sand (AS) being 5.0 meter in thickness are found on the right bank. Sand stone (SS) is found at 12 meters in depth is distributed. There is running water in the river even in dry season. Ground water level is found at 5.0 meters in depth in the borehole, balancing with river water level.

7) Hong River (No.14-15)

Alternation with alluvial clay (AC) and alluvial sand (AS) is found. Total thickness of this alternation is 11.5 meters. Weathered mud stone (MS) is found at 11.5 meters in depth. There is no running water in the river in dry season. Ground water level is not found in the bole hole.

8) He River (No.14-16)

Alluvial clay (AC) being 6.0 meters in thickness and alluvial sand (AS) being 0.8 meters in thickness are found on the left bank. Weathered sand stone (SS) is found at 7.2 meters in depth. There is no running water in the river in dry season. Ground water level is found at 3.2 meters in depth in the bole hale.

9) Dua River (No.14-17)

Alluvial clay (AC) being 5.0 meters in thickness is found on the left bank. Weathered sand stone (SS) is found at 5 meters in depth. There is no running water in the river in dry season. Ground water level is not found in the borehole.

10) Sai River (No.14-18)

Alluvial clay (AC) being 6.0 meters in thickness is found on the left bank. Under the alluvial clay, residual soil (RS) being 6 meters in thickness is found. On the right bank, alluvial clay (AC) being 9.8 meters in thickness is found on the right bank. Weathered mud stone (MS) is found at 12 meters in depth on the left bank and at 9.8 meters in depth on the right bank. There is running water in the river even in dry season. Ground water level is found at 11.6 meters in depth in the borehole on the left bank. Ground water level on the right bank is not sure.

11) Phapin River (No.14-19)

Alluvial clay (AC1) being 6.0 meters in thickness, alluvial sand (AS2) and alluvial clay (AC2) being 4.2 meters in depth are found on the left bank. On the right bank, there are alluvial sand (AS1) being from 0.4 meters to 1.0 meter in thickness, alluvial clay (AC1) being 7.9 meters in thickness and residual soil (RS) being 0.7 meters in depth. Weathered mud stones (MS) are found being 9.0 meters in depth on the right bank and at 12.3 meters in depth on the left bank. There is running water in the river even in dry season. Ground water level is found being 3.4

meters in depth on the right bank and being 5.1 meters in depth on the left bank, balancing with river water level.

12) Phabank River (No.14-20)

Alluvial clay (AC) is found being from 7.5 meters to 8.5 meters in thickness on the both bank. Weathered mud stone (MS) is found with from 7.5 meters to 8.5 meters in depth.

There is running water in the river even in dry season. Ground water level is found being 3.4 meters in depth on the right bank and being 4.6 meters in depth on the left bank, balancing with river water .

13) Sahoua River (No.14-21-1)

Alluvial sand (AS) is found being 6.3 meters in thickness on the right bank. Weathered mudstone (MS) is found being 6.3 meters in depth. There is running water in the river even in dry season. Ground water level is not found in the borehole.

14) Kok River (No.14-21-2)

Alluvial sand (AS) is found being 4.3 meters in thickness and alluvial clay (AC) being 1.7 meters in thickness are found on the right bank. Weathered mudstone (MS) is found being 6.0 meters in depth. There is no running water in the river in dry season. Ground water level is found being 5.6 meters in the borehole.

15) Thateng River (No.14-22)

Alluvial clay (AC) is found being from 2.1 meters to 2.5 meters in depth on the both banks. Under the alluvial clay, there is residual soil (RS) being from 1.9 meters to 2.4 meters in thickness. Weathered mudstone (MS) is found being 4.5 meters in depth. There is running water in the river even in dry season. Ground water level is not found in the borehole.

16) Manpa River (No.14-23)

Banking soil (BS) is found being 1.5 meters in thickness on the both banks as topsoil.

Banking soil (BS) consists of sandy silt. On the left bank, under the banking soil, there are alluvial clay (AC) being 4.5 meters in depth on the left bank and with 3.0 meters in depth on the right bank. Weathered mud stone (MS) is found being 6.0 meters in depth on the left bank and with 4.5 meters in depth on the right bank. There is running water in the river even in dry season. But ground water level is not found in the borehole.

(2) Geological Cross Section of Route 16A

Geological cross section for No.16-2 is shown in Figure 2.3.3 as a reference and others are compiled in ANNEX F-16.

1) Makchan－Gnai River (No.16-1)

Alluvial gravel (AG1) is found being 2.8 meters in thickness on the both banks. This formation contains some boulder of basalt being 1 meter in diameter and alluvial clay (AC) being 1.0 meter in thickness. Under the alluvial clay, alluvial gravel (AG2) is found being 3.4 meters in thickness.

Visicular basalt (BA) is found being 7.5 meters in depth. There is running water in the river.

Ground water level is found being 1.4 meters in depth on the left bank and being 1.1 meters in depth on the right bank, balancing with river water level.

2) Namtang River (No.16-2)

Terrace clay (TC) is found being from 1.4 meters to 2.8 meters in thickness on the both banks. Thickness of this formation is thin on the left bank and thick on the right bank.

Under the terrace clay, terrace gravel (TG) is found. This gravel consists of basalt. At this site, basement rock is not found. But it seems that basalt as basement rock shall be found at shallow depth. There is running water in the river even in dry season. Ground water level is not found in the borehole.

3) Xe Katam River (No.16-3)

Terrace clay (TC) is found being from 3.4 meters to 7.5 meters in thickness on the both banks. Thickness of this formation is thin on the left bank and thick on the right bank. Under the terrace clay, terrace gravel (TG) is found. This gravel consists of basalt containing some boulders being 50 cm in diameter.

4) Xe Namnoy River (No.16-4)

Terrace clay (TC) is found being from 1.3 meters to 1.6 meters in thickness on the both banks. Under the terrace clay, terrace gravel (TG) more than 10 meters in thickness is found. This gravel consists of sand stone and basalt, containing boulder being 50 cm in diameter.

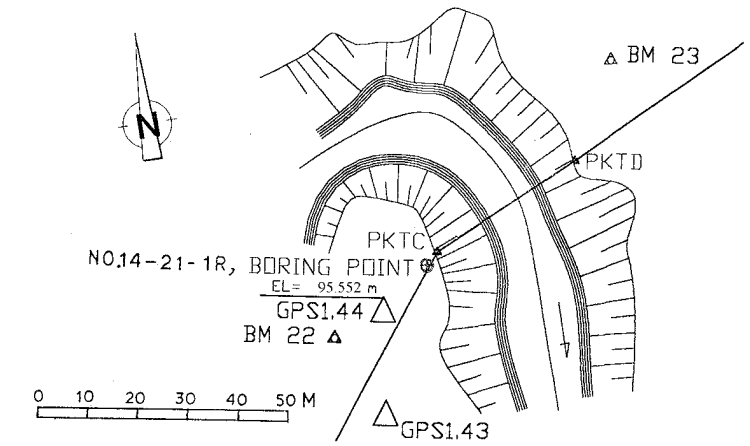
At this site, basement rock is not found. It seems that sand stone as basement rock shall be found at shallow depth. There is running water in the river even in dry season. But ground water level is not found in the boreholes.

5) Xe Namnoy River (Old Channel) (No.16-5)

Terrace clay (TC) and terrace sand (TS) being 0.4 meters in thickness as topsoils on the both banks. Under the top soil, terrace gravels (TG) being 7.1 meters in thickness on the left bank and being more than 10 meters in thickness on the right bank are found. These gravels consist of sand stone and basalt, containing boulder being 50 cm in diameter. Sand Store is found being 7.5 meters in depth on the left bank. There is running water in the river even in dry season. But ground water level is not found in the boreholes.

6) Katak－Tok (Ho) River (No.16-6)

Alternation of terrace clay (TC1,TC2) and terrace gravel (TG1, TG2) is found on the both banks. Terrace clay contains many granule and pebbles. Terrace gravel consists of basalt and sand stone, containing boulder being 1 mater in diameter. Total thickness of these formations are 6.7 meters on the left bank and 7.5 meters on the right bank. Weathered mudstone (MS) is found on the riverbed. There is running water in the river d even in dry season. But ground water level is not found in the boreholes.



Symbol of Boring Log	Symbol of Geological Formation	Others
Banking Soil	BS: Banking Soil (Silt, Sand and Gravel)	Water Level
Clay	RD: River Deposit (Clay ,Silt Sand and Gravel)	Max. Water Level
Silt	AC: Alluvial Silt and Clay	UD Undisturbed Sampling
Sand	AS: Alluvial Sand	N N Value (SPT)
Gravel (ϕ <30cm)	AG: Alluvial Gravel	N Value > 50
Boulder (ϕ >30cm)	TC: Terrace Silt and Clay	
Basalt	TS: Terrace Sand	
Sand Stone	TG: Terrace Gravel	
Mud Stone (Silt Stone and Clay Stone)	TL: Talus Deposit (Clay, Silt, Sand and Gravel)	
Clayey	RS: Residual Soil (Clay, Silt and Sand)	
Silty	SS: Sand Stone	
Sandy	MS: Mud Stone (Silt Stone and Clay Stone)	
Gravelly	BA: Basalt	

Note: The diagonal lines in rocks show the estimated dips of geological formations.

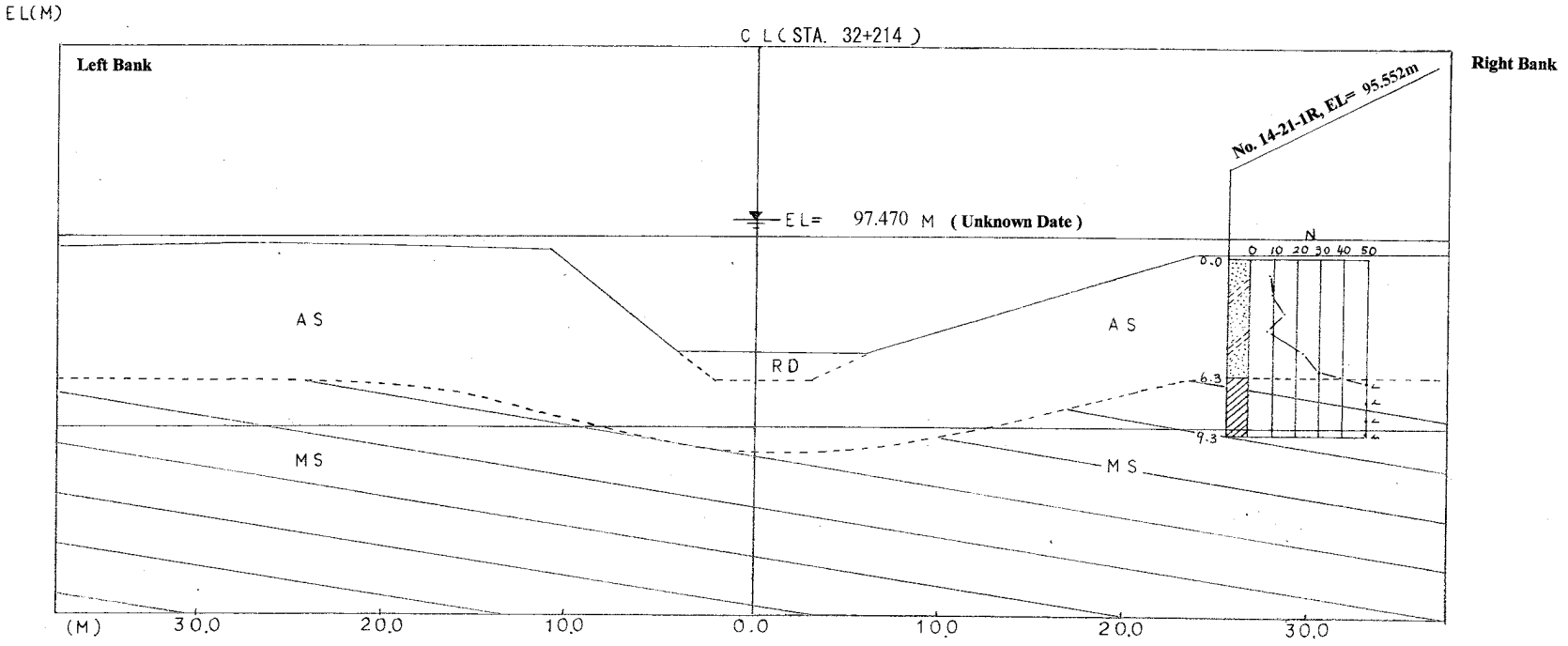
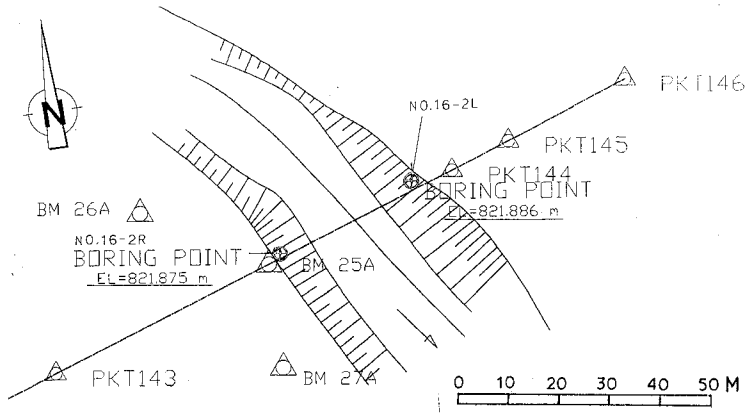


Figure 2.3.2 Geological Cross Section for the Sahoua River (No. 14-21-1)



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Mud Stone (Silt Stone and Clay Stone)	TL: Talus Deposit (Clay, Silt, Sand and Gravel)	
Clayey	RS: Residual Soil (Clay, Silt and Sand)	
Silty	SS: Sand Stone	
Sandy	MS: Mud Stone (Silt Stone and Clay Stone)	
Gravelly	BA: Basalt	

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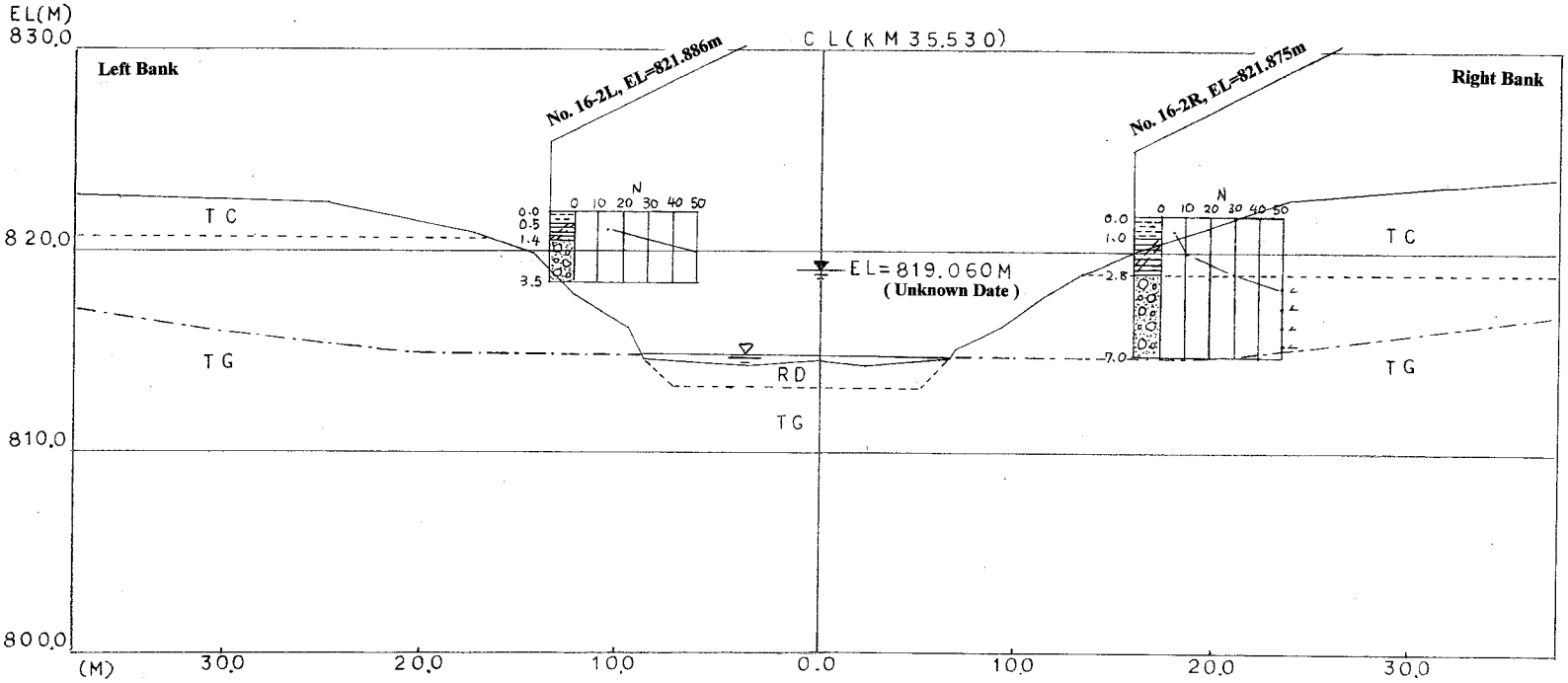

Figure 2.3.3 Geological Cross Section for the Namtang River (No. 16-2)

(3) Result of Standard Penetration Test

Result of standard penetration test is shown in Table 2.3.3. At this table, N values more than 50 are converted into N value for 30 cm depression. Banking soil (BS) is distributed in the R14A. This formation consists of laterite and average N value shows 25.

Alluvial silt and clay (AC) are widely distributed in the R14A. This formation is affected by laterization. So, average N value shows 15. Soft layer showing less than N value 10 is distributed between Sai river (N0.14-18) and Kok river (No.14-21-2).

Alluvial sand (AS) is distributed in the R14A. Generally, N value of alluvial sand shows higher value than alluvial clay. But average N value of this sand shows 12. This sand is generally loose.

Alluvial gravel (AG) is distributed in the R16A. Average N value of this formation shows 707. This high value is caused by high content of gravels.

Terrace gravel (TG) is distributed in the R16A. Average N value of this formation shows 447. This value is low compared with N value of alluvial gravel. This fact is caused by existence of many fine materials as matrix.

Residual soil is distributed in the R14A. This formation consists stiff or hard silt and clay. So, average value of this formation shows 33. Sand stone and mudstone are distributed in the R14A and the R16A. And basalt is distributed in the R16A. By the minimum N Value, mudstone has the weakest resistance to weathering among the basement rocks. Sand stone has the strongest resistance for weathering among the basement rocks. Generally fresh basalt also has strong resistance for weathering. But basalts in the study area are vesicular basalts. By that reason, these basalt show low resistance. Although, N value of basement rocks show high values compared with N values of soils.

Table 2.3.3 Result of Standard Penetration Test

Formation	Symbol	Number of Times	Maximum Value	Minimum Value	Average Value
Banking Soil	BS	2	35	15	25
River Deposit	RD	-	-	-	-
Alluvial Silt and Clay	AC	95	29	2	15
Alluvial Sand	AS	30	30	4	12
Alluvial Gravel	AG	7	1380	137	707
Terrace Silt and Clay	TC	20	22	6	15
Terrace Sand	TS	-	-	-	-
Terrace Gravel	TG	58	1500	30	447
Talus Deposit	TL	-	-	-	-
Residual Soil	RS	17	51	15	33
Sand Stone	SS	4	1350	690	1050
Mud Stone	MS	37	1320	51	425
Basalt	BA	5	1440	161	539

Note: All N values showing more than 50 are corresponding to the standard penetration depth of 30 cm.

(4) Result of Laboratory Test

1) Undisturbed Sample

Average N value of alluvial clay (AC) shows 15. Because of that reason, undisturbed sampling was hardly taken. On drilling works at the R14A, only 5 undisturbed samples were obtained. And surface materials on the R16A mainly consist of alluvial clay with gravel, alluvial gravel and terrace gravel. Therefore, at the R16A, undisturbed samples were not obtained. Result of laboratory test for undisturbed samples of the R14A is shown in Table 2.3.4 and result of laboratory test for standard disturbed samples is shown in ANNEX F-4. Figure 2.3.4 shows soil classification on the basis of these results.

(a) Specific Gravity

General specific gravities of silt and clay are within from 2.5 to 2.7. Average value of specific gravity for alluvial clay (AC) shows 2.72.

(b) Moisture Content

General moisture contents of silt and clay are within from 50 % to 100 %. Average value of moisture content for alluvial clay (AC) shows 22 %.

(c) Particle Size Analysis

Content by percentage of sand for 5 samples are within from 0.6 % to 36.5%. Average value of content by percentage for sand shows 13.8%.

(d) Atterberg Limit

General liquid limits of silt and clay are within from 40 % to 120 % and plastic limits are within from 30 % to 70 %. Average value of liquid limit for alluvial clay (AC) shows 28.7 %. And average value of plastic limit for alluvial clay (AC) shows 19.6%.

(e) Unified Soil Classification

By unified soil classification system, alluvial clay (AC) shows CL.

(f) Unit Weight (Wet density)

General unit weight of silt and clay are within from 1.4 g/cm^3 to 1.8 g/cm^3. Average value of unit weigh for alluvial clay (AC) shows 1.99 g/cm^3.

(g) Unconfined Compression

Strengths of unconfined compression for 5 samples are within from 0.4 kg/cm^2 to 1.30 kg/cm^2. Average value of unconfined compression strength shows 0.98 kg/cm^2.

2) Result of Rock Test

Rock test was carried out for sand stone (SS) and basalt (BA). Rock test for mudstone was impossible because of bad condition of core samples. Result of rock test is shown in Table 2.3.5. Generally compressive strength of fresh sand stone are within from 700 kg/cm^2 to 2000

kg/cm^2. And that of fresh basalt are within from 1000 kg/cm^2 to 3000 kg/cm^2. Average strength of red sand stone (SS) shows 653 kg/cm^2 and average strength of basalt (BA) shows 737 kg/cm^2. By the result of rock test, drop in strength by weathering is recognized for these samples. Absorption of the samples are within from 1 % to 3 % except vesicular basalt.

Table 2.3.4 Result of Laboratory Test for Undisturbed Samples

Result of Laboratory Test for Undisturbed Samples (1)

Route No.	Boring No.	Sample No.	Depth (m)	Symbol of Formation	Particle Size			Specific Gravity	Moisture Content(%)	Atterberg Limit		
					Gravel(%)	Sand(%)	Silt･Clay(%)			LL(%)	PL(%)	PI
R14A(i)	14-16L	S5	4.30-4.50	AC	0.0	6.0	94.0	2.70	23.20	31.7	19.7	12.0
R14A(i)	14-18R	S6	5.60-5.80	AC	0.0	17.6	82.4	2.70	17.80	23.1	15.9	7.2
R14A(i)	14-19L	S6	5.15-5.35	AC	0.0	36.5	63.5	-	19.30	23.3	16.4	6.9
R14A(i)	14-20L	S4	3.60-3.80	AC	0.0	8.5	91.5	2.72	26.60	28.1	21.4	6.7
R14A(i)	14-20R	S4	3.60-3.80	AC	0.0	0.6	99.4	2.74	25.30	37.3	24.6	12.7
-	-	-	-	Average	0.0	13.8	86.2	2.72	22.44	28.7	19.6	9.1

LL = Liquid Limited, PL = Plastic Limited, PI = Plasticity Index

Result of Laboratory Test for Undisturbed Samples (2)

Route No.	Boring No.	Sample No.	Depth (m)	Symbol of Formation	Soil Classification	Unit Weight (g/cm^3)		Unconfined Comprression (kg/cm^2)	N Value
						Wet	Dry		
R14A(i)	14-16L	S5	4.30-4.50	AC	CL	1.80	1.46	1.30	10
R14A(i)	14-18R	S6	5.60-5.80	AC	CL	2.01	1.70	0.70	10
R14A(i)	14-19L	S6	5.15-5.35	AC	CL	2.22	1.86	1.30	7
R14A(i)	14-20L	S4	3.60-3.80	AC	CL-ML	1.92	1.52	0.40	2
R14A(i)	14-20R	S4	3.60-3.80	AC	CL	1.99	1.59	1.21	15
-	-	-	-	-	Average	1.99	1.63	0.98	9

Table 2.3.5 Result of Laboratory Test for Rocks

Rute No.	River No.	River Name	Boring No.	Depth (m)	Geological Formation	Wet Unit Weight (g/cm^3)	Dry Unit Weight (g/cm^3)	Compressive Strength (kg/cm^2)	Apparent Specific Gravity	Absorption (%)
R14A(i)	14-8	Imet	14-8R	0.50-0.70	Sand Stone	2.66	2.61	731	2.58	2.42
	14-11	Thakhong	14-11R	9.30-10.30	Silt Syone	-	-	-	2.64	2.81
	14-12	Thapxang	14-12R	9.10-9.30	Sand Stone	2.64	2.59	360	2.54	3.00
	14-13	Khone Liao	14-13R	2.40-2.60	Sand Stone	2.64	2.59	598	2.57	2.56
	14-14	Khone Ken	14-14R	12.60-12.80	Sand Stone	2.75	2.67	342	-	2.63
	14-16	He	14-16L	7.20-8.20	Sand Stone	2.53	2.45	507	2.58	1.94
	14-17	Dua	14-17L	4.00-4.20	Sand Stone	2.61	2.57	558	2.59	1.76
R16A	16-1	Makchan	16-1R	2.10-2.30	Vesicular Basalt	2.62	2.58	671	2.57	4.82
	16-2	Namtang	16-2L	1.55-1.65	Boulder Basalt	2.52	2.47	574	2.65	2.11
	16-2	Namtang	16-2L	2.20-2.30	Boulder Basalt	2.80	2.77	1044	2.72	1.06
	16-4	Xe Namnoy	16-4L	5.30-5.50	Boulder Basalt	3.00	2.98	658	2.57	1.55
	16-5	Xe Namnoy	16-5L	8.00-8.15	Sand Stone	2.54	2.51	563	2.62	1.28
	16-5	Xe Namnoy	16-5L	8.85-8.95	Sand Stone	2.48	2.45	573	-	1.21
	16-6	Katak-Tok	16-6R	6.70-6.90	Sand Stone	2.59	2.57	1146	2.67	1.44
	16-6	Katak-Tok	16-6L	9.30-9.50	Sand Stone	2.65	2.63	1153	2.68	0.93
		Average			Basalt	2.74	2.70	737	2.63	2.39
		Average			Sand Stone	2.61	2.56	653	2.61	2.00

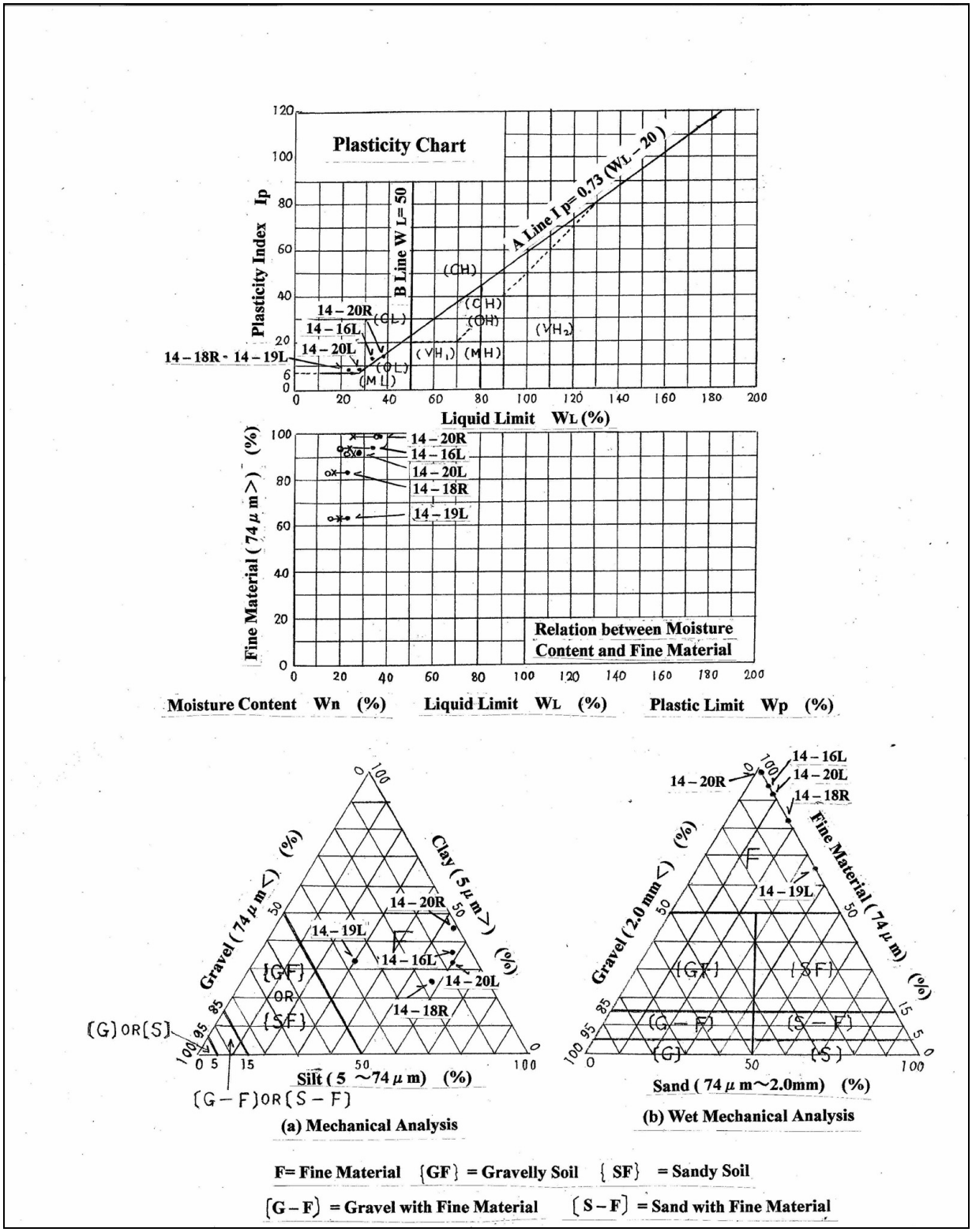

Figure 2.3.4 Soil Classification

2.3.5 Design Value

Base on the following formulas, the design value could be determined and the results are shown in Table 2.3.6.

(1) Calculation by N value

- Clayey soil cohesion $C = 1/15 \cdot N$ ($\phi = 0$)
- Sandy soil angle of internal friction

$$\phi = \sqrt{15N} + 15 \quad (N > 5, \ \phi \leqq 45, C = 0)$$

(2) Calculation by Unconfined Compression Test

- Cohesion $C = 1/2\ qu$ ($\phi = 0$)

qu = unconfined compression strength

(3) Cohesion of Rock

Cohesion of rock is calculated by compressive strength and tensile strength. But tensile strength test was not carried out for the rock samples. So, tensile strength was obtained by estimate. The formula for cohesion of rock is as follows.

Cohesion $C = Sc \cdot St/2 \sqrt{St(Sc - 3St)}$

Sc = Compressive strength (kg/cm^2)

St = tensile strength (kg/cm^2)

$St = 1/10 \cdot Sc \sim 1/20 \cdot Sc$ 0.075 Sc

Table 2.3.6 Design Values for Geological Formations

Formation	Symbol	Average N Value (time/30cm)	Unit Weight r t(g/cm^3)	Uniconfined Compression qu(kg/cm^2)	Compressive Strength Sc(kg/cm^2)	Cohesion C(kg/cm^2)	Angle of Internal Friction φ(°)
Banking Soil	BS	25	[1.70]	-	-	1.7	0
River Deposit	RD	-	-	-	-	-	-
Alluvial Silt and Clay	AC	15	1.63	1.0	-	0.5	0
Alluvial Sand	AS	12	[1.80]	-	-	0.0	28
Alluvial Gravel	AG	707	[1.80]	-	-	[0.0]	[35]
Terrce Silt and Clay	TC	15	[1.70]	-	-	1.0	0
Terrce Sand	TS	[20]	[1.90]	-	-	0.0	32
Terrce Gravel	TG	447	[2.00]	-	-	[0.0]	[40]
Talus Deposit	TL	-	-	-	-	-	-
Residual Soil	RS	33	[1.70]	-	-	2.2	0
Sand Stone	SS	1050	2.61	-	653	102	-
Mud Stone	MS	425	2.00	-	70	10	-
Basalt	BA	539	2.74	-	737	114	-

[ ] = Estimated Value

2.3.6 Consideration for Design Works

(1) Cutting Slope

The following figure is recommended to apply for cutting slope.

Soil and Rock	Slope
Soil	1：1
Weathered Rock	1：0.5
Sound Rock	1：0.3
Talus Deposit	1：1.2 ～ 1：1.5
Residual Soil (Clay)	1：1.2
Cracky and Weathered Rock	1：0.5 ～ 1：0.7

Talus deposit is very unstable material for structure. It is therefore necessary to pay attention for cutting works of talus deposit. Some collapse of slope has been recognized at steep mountain section of the R16A.

Dip of sand stone and mud stone at the section above mentioned shows between 0 ° and 20 ° . It seems that geologically structure looks like stable. However, it is necessary to pay attention for cutting work with treatment of ground water.

(2) Issues for Future

1) In this Feasibility Study, only one borehole was drilled for proposed bridge site at small river on R14A. It is recommend that the drilling for the geological survey should be done at both banks of river in detail design stage.

2) Consolidation settlement often occurs on soft layer which N value is less than 10. At the R14A, soft layer is found between Sai river (No.14-18) and Kok river (No.14-21-2). It is recommended that consolidation test should be carried out for designing of embankment in detail design stage.

3) It is recommended that detail soil investigation on cutting section between 42 km and 55 km-post on R16A, should be carried out in detail design stage.

2.4 Material Survey

2.4.1 Outline of Survey

An existing road material and borrow pit material, were tested to confirm their quality for road embankment. Those materials were taken for the test near the proposed road i.e., R14A and R16A.

Sample from existing road

R14A	5 sites	5 samples
R16A	6 sites	6 samples
Total	11 sites	11 samples

Sample from borrow pit near the proposed road

R14A	6 sites	7 samples
R16A	6 sites	12 samples
Total	12 sites	19 samples

2.4.2 Existing Road Bed

Test pitting was carried out to confirm the condition of sub-grade of the existing road. The result of test pitting is shown in Table 2.4.1 and the test pit logs are shown in ANNEX F-5.

(1) Test Pit Logs

R14A is mainly located in flood plain of Mekong river and its tributaries. For that reason, sub-grade of the existing road consists of alluvial sand and alluvial clay supplied from these rivers except some places. These soils show high strength by shrinking in dry season. But its strength falls down drastically if the soils contain enough quantity of water in rainy season.

On the other hand, R16A is located in high land being from 500 meters to 1200 meters above sea level. So, the existing road is not covered with water by flood. For that reason the soils of R16A change to laterite smoothly. These soils containing many particles of iron and aluminum oxides are very hard. And strength of laterite dose not fall down by rainfall.

(2) Laboratory Test Results

Laboratory test results are shown in Table 2.4.2.

R14A

By soil classification, these soils are divided into from CL to GM. By particle size analysis, content of sand and gravel show 44.2 %. Average value of liquid limited shows 25.4% and plastic limited shows 16.8%. Average CBR value shows 43.

R16A

By soil classification, these soils are divided into from CL to CG. By particle size analysis, content of sand and gravel show 43.7 %. Average value of liquid limit shows 43.8 % and plastic limit shows 26.4 %. Average CBR value shows 39.

Among these soils distributed along the existing road, it seems that GM and GC have enough bearing capacity as sub-grade. Also they have enough stability by compaction. CL has enough stability but it has not enough bearing capacity.

Table 2.4.1 Test Pits for the Route 14A and the Route 16A

Test Pit	Km Post	Village Name	Land Form	Form of Road	Sampling Soil	Sampling Depth
TP14-1	55.35	Samkhanaboua	Flood Plane	Banking	Fine Sand with Laterite	0.12m ～ 0.42m
TP14-2	43.75	Dontalat	Flood Plane	Banking	Clayey Sand with Laterite	0.00m ～ 0.25m
TP14-3	33.05	Vatlouang-Kao	Flood Plane	Banking	Sandy Clay with Laterite	0.00m ～ 0.17m
TP14-4	14.25	No Name	Flood Plane	Nature	Stiff Clay	0.20m ～ 0.55m
TP14-5	6.75	Nonghoy	Alluvial Cone	Nature	Medium Sand	0.20m ～ 0.45m
TP16-1	5.8	No Name	Hill Top	Cutting	Clay with Laterite	0.00m ～ 0.23m
TP16-2	20.0	No Name	Hill Slope	Cutting	Clay with Traces of Laterite	0.35m ～ 0.65m
TP16-3	35.1	Nong-1-oy	Hill Top	Nature	Stiff Clay	0.30m ～ 0.55m
TP16-4	53.5	Katamtok	Talus	Cutting	Stiff Clay	0.20m ～ 0.50m
TP16-5	60.6	Phatao Namho	Talus	Cutting	Stiff Sandy Clay	0.20m ～ 0.50m
TP16-6	67.6	Kagnongtang	Alluvial Fan	Banking	Stiff Clay with Laterite	0.35m ～ 0.70m

Note: Km Post shows the distance via existing road.

Table 2.4.2 Result of Laboratory Test for Test Pit Samples

Result of Laboratory Test for Test Pit Samples (1)

Route No.	Number of Sample	Particle Size			Specific Gravity	Moisture Content(%)	Dry Density (g/cm^3)	Atterberg Limit			Soil Classification
		Gravel(%)	Sand(%)	Silt･Clay(%)				LL(%)	PL(%)	PI	
R14A(i)	5	23.4	20.8	55.8	2.65	11.2	1.76	25.4	16.8	8.6	CL,SM,GM
R16A	6	14.1	29.6	56.3	2.75	19.1	1.35	43.8	26.4	17.4	CL,SC,GC

LL = Liquid Limited, PL = Plastic Limited, PI = Plasticity Index

Result of Laboratory Test for Test Pit Samples (2)

Route No.	Number of Sample	Compaction			Swell(%)	CBR at Percent of MDD		
		MDD(g/cm^3)	OMC(%)	Cd(%)		100(%)	98(%)	95%
R14A(i)	5	2.05	10.7	85	0.42	43	39	28
R16A	6	1.77	17.5	77	0.68	39	34	25

MDD = Maximum Dry Density, OMC = Optimum Moisture Content, Cd = Compaction Ratio

2.4.3 Materials for Embankment and Sub-grade (Borrow Pit)

Several samples of embankment material were taken from existing borrow pits to confirm the quality for the materials for embankment. The results are shown in Table 2.4.3 and the borrow pit logs are shown in ANNEX F-5.

Table 2.4.3 Existing Borrow Pits alongside the Route 14A and the Route 16A

Borrow Pit	Km Post	Village Name	Land Use	Land Form	Soil Type
BP14-1	56.45+0.7	No Name	Existing Pit	Flood Plain	Clayey Sand with Laterite
BP14-2	52.45	Bak	Natural Surface	Flood Plain	Sandy Clay with Laterite
BP14-3	47.35	Chikthangngo	Natural Surface	Flood Plain	Sandy Clay with Laterite
BP14-4	37.65+3.5	Muang-Kang	Existing Pit	Flood Plain	Clayey Sand with Laterite
BP14-5	18.75	Khangnen	Natural Surface	Natural Levee	Clayey Sand with Laterite
BP14-6	7.55	Nonghoy	Natural Surface	Mountain Slope	Weathered Sand Stone
BP16-1	7.6	No Name	Natural Surface	Hill Top	Clay with Laterite
BP16-2	17.0+2.0	Vanchansavang	Existing Pit	Hill Slope	Clay with Laterite
BP16-3	34.5	Nong-1-oy	Existing Pit	Hill Slope	Clay with Laterite
BP16-4	45.3	No Name	Existing Pit	Hill Slope	Clay with Laterite
BP16-5	43.5	Tagnuksua	Existing Pit	Hill Slope	Clay with Laterite
BP16-6	67.3	Kagnongtang	Existing Pit	Alluvial Cone	Clay with Laterite

Note: Km Post shows the distance via existing road.

(1) Borrow Pit Logs

At R14A, BP1, BP2, BP3 and BP4 are located on natural levee in the flood plain. Here, Laterites are distributed. Their thickness show between 0.5 meters and 2.0 meters. BP5 is located on natural levee along the Mekong river. Upper materials of this site consist of loose sand. So, useful soil is only lower part of materials. BP6 is located in a mountain slope and silty residual soils are distributed.

R16A is located in the Boloven Plateau. Here, thick laterites are distributed on the surface of plateau and the mountain slope. At from BP1 to BP5, laterites being from 1 meter to 3 meters in thickness are useful except topsoil. Bp6 is located on the alluvial fan at east end of plateau. Here, laterites being from 1.4 meters to 1.4 meters are useful.

(2) Laboratory Test Results

Laboratory test results are shown in Table 2.4.4. The result of laboratory test for the R14A shows as average values for 7 samples. By the soil classification, these soils are divided into GC. By particle size analysis, content of sand and gravel shows 79 %. Average value of liquid limit shows 26.4 % and plastic limit shows 16.3 %. Average CBR value shows 65.

Result of laboratory test for the R16A shows as average values for 12 samples. . By the soil classification, these soils are divided into GC. By particle size analysis, content of sand and

gravel shows 78.4 %. Average value of liquid limit shows 46.8 % and plastic limit shows 33.2 %. Average CBR value shows 83.

The soil classified as GC has enough bearing capacity as sub-grade material and it has stability as embankment material. But this soil has no permeability. And this soil is unsuitable for base course material.

Table 2.4.4 Result of Laboratory Test for Borrow Pit Samples

Result of Laboratory Test for Borrow Pit Samples (1)

Route No.	Number of Sample	Particle Size			Specific Gravity	Moisture Content(%)	Dry Density (g/cm3)	Atterberg Limit			Soil Classification
		Gravel(%)	Sand(%)	Silt･Clay(%)				LL(%)	PL(%)	PI	
R14A(i)	7	69.8	9.2	21	2.72	7.8	-	26.4	16.3	10.1	GC
R16A	12	60.6	17.8	21.6	2.95	17.8	-	46.8	33.2	13.6	GC

LL = Liquid Limited, PL = Plastic Limited, PI = Plasticity Index

Result of Laboratory Test for Borrow Pit Samples(2)

Route No.	Number of Sample	Compaction			Swell(%)	CBR at Percent of MDD		
		MDD(g/cm3)	OMC(%)	Cd(%)		100(%)	98(%)	95%
R14A(i)	7	2.21	9.3	-	0.72	65	61	48
R16A	12	1.84	17.9	-	0.11	82	80	67

MDD = Maximum Dry Density, OMC = Optimum Moisture Content, Cd = Compaction Ratio

2.4.4. CBR Applied for Design

(1) Formula for Design CBR

Design CBR is decided by the following formula for sub-grade material.

Design CBR = Average Value － (Max, Value－Min, Value)/C

C = Coefficient of CBR

Note：Except unusual values among the measuring values.

Coefficient of CBR

Number of Samples (n)	2	3	4	5	6	7	8	9	> 10
C	1.41	1.91	2.24	2.48	2.67	2.83	2.96	3.08	3.18

(2) R14A Site

Measuring value

TP1	TP2	TP3	TP4	TP5
45	99	39	9	25

n = 3

Max, Value = 45

Min, Value = 25

Av, Value = (45 + 39 + 25)/3 = 36

C = 1.91

Design CBR = 36－(45－25)/1.91 = 26

(3) R16A Site

Measuring Value

TP1	TP2	TP3	TP4	TP5	TP6
92	35	30	33	40	5

n = 4

Max, Value = 40

Min, Value = 30

Av, Value = (35 + 30 + 33 + 40)/4 = 35

C = 2.24

Design CBR = 35－(40－30)/2.24 = 31

(4) Modified CBR of Filling Material (Borrow Pit Material)

Standard of modified CBR for filled up ground material and sub-grade material is as follows.

- Lower Filled Up Ground —
- Upper Filled Up Ground CBR > 2.5
- Subgrade CBR > 10 or 8

Material having following conditions at the same time is unsuitable as upper sub-grade.

- PI ≧10 (PI = plasticity Index)
- Weight percentage of sieve less than 75 μm ≧ 25%

Modified CBR values of borrow pit material, weight percentage of sieve less than 75 μm and plasticity index are shown in next tables.

Modified CBR of R14A Borrow Pit Material

Item	BP1	BP2	BP3	BP4-1	BP4-2	BP5	BP6
Weight % (less than 75 μm)	28.2	10.2	18.2	13.1	10.4	47.1	19.5
CBR at 95 % of MDD	14	55	100	74	68	11	17
PI	9.8	8.7	8.4	9.7	7.6	16.4	9.7

Note: MDD = Maximum Dry Density, PI = Plasticity Index

Modified CBR of R16A Borrow Pit Material

Item	BP1	BP2-1	BP2-2	BP3-1	BP3-2	BP4-1	BP4-2	BP4-3	BP5-1	BP5-2	BP6-1	BP6-2
Weight % (less than 75 μm)	15.0	23.8	25.9	9.6	15.6	15.5	9.4	21.0	34.1	33.6	46.5	41.1
CBR at 95 % of MDD	62	82	18	100	100	86	38	100	70	82	28	40
PI	9.6	10.6	18.0	7.1	6.5	13.0	13.7	11.4	14.3	17.8	20.9	20.3

Note: MDD = Maximum Dry Density, PI = Plasticity Index

Regarding R14A, all modified CBR values of borrow pit materials satisfy the standard requirement for filled up ground material and lower sub-grade material. And these materials except BP5 are usable as upper sub-grade materials.

Regarding R16A, all modified CBR values of borrow pit materials satisfy the standard requirement for filled up ground material and lower sub-grade material. And BP1, BP2-1, BP3-1, BP3-2, BP4-1, BP4-2 and BP4-3 are usable as upper sub-grade materials.

2.4.5 Consideration for Design Work on Filling Materials

(1) Embankment Slope

Based on the laboratory test of borrow pit materials, they are laterite and categorized as GC (Clayey Gravel). Clayey Gravel (GC) corresponds to gravelly soil with good mechanical composition. Based on this, embankment slope employed this soil is as follows.

Clayey Gravel (GC) 1：2

(2) Moisture Content for Execution of Work

Moisture content and optimum moisture content (OMC) for borrow pit materials are as follows.

Route No.	Moisture Content (%)	OMC (%)
R14A	7.8	9.3
R16A	17.8	17.9

Moisture content during execution should be set up taking account of local weather conditions.

2.4.6 Material of Base Course

Generally, crusher material is used as material of base course. Local quarry, crusher plant could supply the material sufficiently from both rive and mountain site. Those are sand stone and basalt, and are the best materials for crusher material.

The result of rock test of the boring core sample, satisfy quality standard except vesicular basalt. Table 2.4.5 shows the quarry sites near the project area.

Table 2.4.5 List of Quarry and River Bed Materials

Site No.	Route No.	Location	Name of Company	Type of Aggregate
Q1	16	From Phonethong Town to Thailand border 4km	Phoukhongxang	Sand Stone
Q2	16	From Phonethong Town to Thailand border 4km	Ban Nasavang	Sand Stone
Q3	16	From Paksong Town to Sekong 14km	Kongtoun Mountain	Basalt
C1	13S	From Pakse to Venkham 19 km, Pathoumphone	Lak 19 Crusher Plant	Crusher Material
C2	13S	From Pakse to Venkham 25 km, Pathoumphone	SIRI Road Company	Crusher Material
SG1	13S	Huaylao Village, Pakse Dis.	Sithixay Aggregate Co.	Sand and Gravel
SG2	13S	Huaylao Village, Pakse Dis.	Keochay Aggregate Co.	Sand and Gravel
SG3	13S	Huaylao Village, Pakse Dis.	Bounhom Aggregate Co.	Sand and Gravel
SG4	13S	Kengkeung Village, Pakse Dis.	Keo Nheang Aggregate Co.	Sand and Gravel
SG5	13S	Kengkeung Village, Pakse Dis.	Souliphone Aggregate Co.	Sand and Gravel
SG6	13S	Kengkeung Village, Pakse Dis.	Sengchareun Aggregate Co.	Sand and Gravel
SG7	14A	Mophu Village, Pathoumphone Dis.	Sipaseth Aggregate Co.	Sand and Gravel
SG8	14A	Phaphine Village, Champasack Dis.	Sipaseth Aggregate Co.	Sand and Gravel