NEPAL ELECTRICITY AUTHORITY

TEKU – RATANPARK 132 KV DOUBLE CIRCUIT UNDERGROUND TRANSMISSION LINE FOR KATHMANDU VALLEY TRANSMISSION SYSTEM EXPANSION PROJECT PACKAGE A

Desk Study Report
Teku - Ratnapark 132 kV UG Transmission Line

Client:

Kathmandu Valley Transmission System
Reinforcement Project – Package A
Nepal Electricity Authority
Durbar Marga, Kathmandu, Nepal

Consultant:

NEA Engineering Company Limited
Trade Tower, Kathmandu-10
Nepal

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General Information

Project	Teku – Ratnapark 132 kV UG Transmission Line for Kathmandu Valley Transmission System Expansion Project, Package A
Client	Kathmandu Valley Transmission System Expansion Project - Package A, Transmission Directorate, Nepal Electricity Authority
Consultant	NEA Engineering Company Limited
Report	Desk Study Report

Preparation, Review and Authorization

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Project	Teku – Ratnapark 132 kV UG Transmission Line for Kathmandu Valley Transmission System Expansion Project, Package A
Project Location	Bagmati Province, Nepal
Districts	Kathmandu
Municipalities along the route	Kathmandu Metropolitan City
T/L Starting Point	Teku Substation
End Point	Ratnapark Substation
System Voltage	132 kV
Type of Line	Double Circuit Underground Transmission Line
Length of Line	Approximately 3.22 km
Type of Conductor	XLPE Cable, Copper Conductor with Single Core
Conductor size	800 sq.mm.

Abbreviations

Abbreviation	Definition
A	Ampere
D/C	Double Circuit
E	East
GoN	Government of Nepal
HV	High Voltage
km	kilo meter
kV	kilo Volt
L	Inductance
m	metre
mm	millimeter
mH	milli Henry
MC	Metropolitan city
MVA	Mega Volt Amperes
MW	Mega Watt
N	North
nF	Nano Farad
SS	Substation
TL	Transmission Line
UM	Urban Municipality
UTM	Universal Transverse Mercator
Veco	Economic Voltage Level
X	Reactance
Y	Admittance
Z	Impedance
NEA	Nepal Electricity Authority
NEC	NEA Engineering Company Limited
UG	Underground Cabling
XLPE	Cross-linked Polyethylene

1 INTRODUCTION AND PROJECT INFORMATION

1.1 INTRODUCTION

Consumption of Electrical energy is increasing in Nepal lately. It is primarily due to increase in availability of consumable electrical energy. NEA Annual Report of 2019, states that the increment was around 13.89% than that of the previous year. Increase in GDP and increase in electrification indicates that, the energy demand is bound to increase further. However, the increase in demand is not uniform in all parts of the countries. With residential load having highest share in electricity consumers, the load is concentrated in urban areas. To add to that, urban areas often comprise a handful of industrial areas that contribute to power demand. It is essential to increase the energy consumption, as number of generating plants are connecting to national grid in few years. Use of electric vehicles and electric cooking shall play a major role in demand increase in coming years.

The increase in demand poses a problem for the power delivery system. The infrastructure should be able to withstand the peak demand of the system. This may not be possible with regular increase in electric demand every year. The situation is more adverse in the Kathmandu valley with years old infrastructure and already overloaded lines. The peak load of Kathmandu valley grew at the rate of 11% annually in the last three years.

For providing quality electricity for the consumers, power distribution system must be as effective to supply power to the consumers with utmost reliability. The peak demand of around 377.6 MW in last fiscal year overloaded several distribution lines of Kathmandu Valley. This figure of peak demand may not resemble the actual situation as there was a period of lock down due to Covid 19 pandemic. Demand of Kathmandu Valley shall reach around 800 MW in next five year with business as usual. The existing infrastructure is not in a condition to withstand this demand. Construction of new transmission lines and substations is inevitable.

The existing transmission lines and substations at 132kV and 66 kV feeding the Kathmandu Valley needs to be upgraded, however possible. New substation needs to be constructed and the part of loads of existing substations needs to be shifted there.

Constructing a new transmission line within Kathmandu Valley is a challenging task. Densely populated areas of Kathmandu provide no room for Right of Way required for overhead transmission lines. In such scenario, first emphasis should be given to upgrading existing lines.

NEA has completed a project to reconductor the 66 kV transmission line all the way from Bhaktapur to Ratnapark by equivalent HTLS conductor. This has increased the power delivery capacity of the valley, but it shall be merely sufficient to withstand the demand in near future let alone the contingency condition. This leaves no option but to build new transmission lines and substations.

To increase the reliability of the power delivery system, the reinforced high voltage transmission infrastructure must be able to withstand the contingency condition. It is thus, with the combination of new river corridor lines and substations, upgradation of existing lines, the high voltage transmission system of Kathmandu Valley can be reinforced to withstand 2000 MW of peak load demand. The reliability of transmission network shall improve significantly, and the loss incurred due to energy not served can be reduced.

1.2 Project Description

NEA has envisaged a Transmission System Network Expansion Project for the improved and reliable Integrated Nepal Power System Network in the valley.

Under Package A of the project, the project package comprises of following components:

1. Construction of 132 kV Double Circuit Underground Transmission Line from proposed New Patan Substation to proposed Harisiddhi Substation (5.66 km approx.)
2. Construction of 132 kV Double Circuit Underground Transmission Line from proposed Harisiddhi Substation upto proposed Sirutar Substation (6.32 km approx.)
3. Construction of 132 kV Double Circuit Underground Transmission Line from existingTeku Substation up to proposed Ratnapark Substation (3.22 km approx.)

The report presents the Desk Study of 132 kV Double Circuit Underground Transmission Line from existing Teku Substation to proposed Ratnapark Substation.

1.3 Location and Accessibility

The underground transmission line project is located in Kathmandu Metropolitan City, Kathmandu District, capital of Nepal. The underground transmission line is routed such that it is accessible from construction, operation and maintenance point of view. The map showing project location is presented in Figure 1-1.

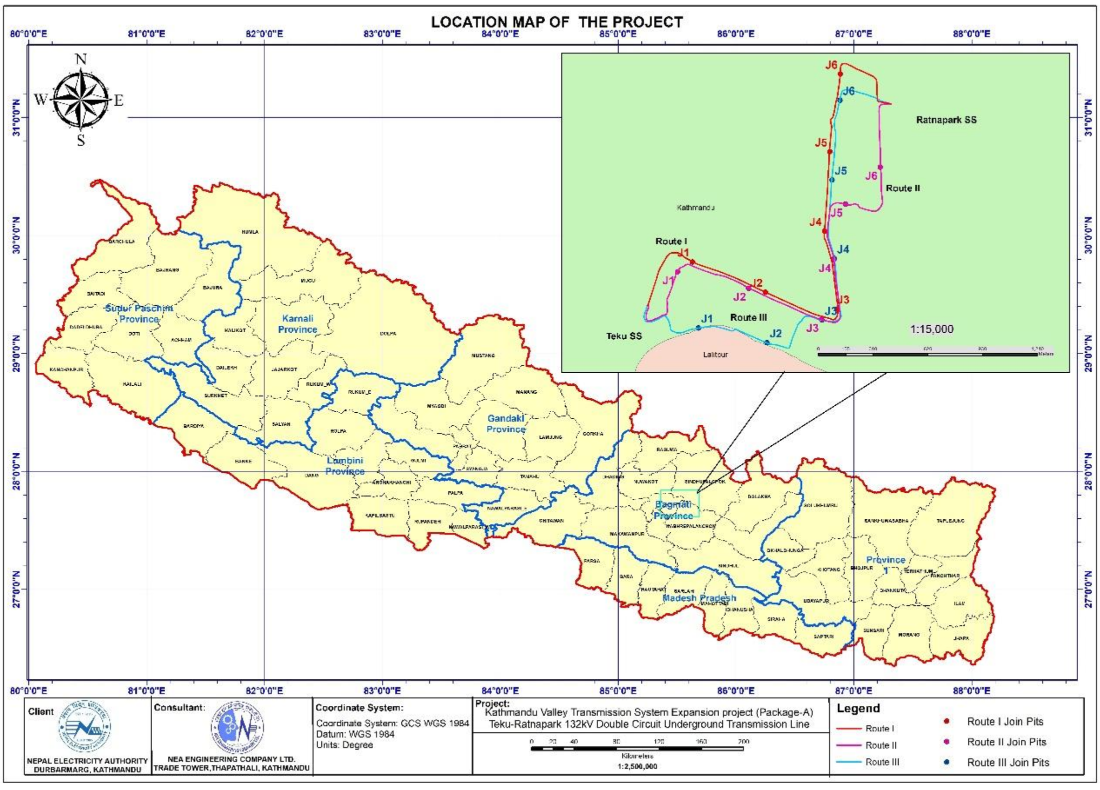


Figure 1-1: Map of Nepal Showing Project Location.

2 OBJECTIVES AND SCOPE OF WORK

The primary goal and scope of this study are to identify three alternative routes, assess their viability, and recommend the most feasible option (considering both technical and economic factors) for construction of a 132 kV Double Circuit (D/C) Underground Transmission Line from existing Teku Substation to Ratnapark Substation.

This report shall provide the information about the underground transmission Line routes along with total line length, major Joint Pits, crossings, etc. and selection of the most feasible route for reconnaissance survey and detail survey.

3 METHODOLOGY

In order to identify potential alternative routes for the underground transmission line, a comprehensive study of the underground transmission line corridor using recent topographical maps, satellite images on Google Earth, land use maps, etc. was conducted. Three alternative underground transmission line alignments were identified taking into consideration the topography, route lengths and other basic technical requirements. This desk study report provides the description of general topography of routes, line length and other features. The location and number of joint pits selected during the desk study can be changed after the reconnaissance survey and/or detail survey.

3.1 Route Selection Criteria

While selecting the routes for the underground transmission lines, a basic set of criteria is employed while selecting the preliminary route alignments. The main criteria employed are:

a. The route alignment shall be kept straight or short to the extent possible and practicable so that the number of joint pits can be kept minimum.
b. The cable turnings/deviation and crossings were determined keeping in mind the bending radius of underground cable to be laid.
c. The lateral crossings from one side to other, major highway/road crossings were kept to minimum.
d. Sites and places with social, cultural and archaeological significance were avoided to the extent possible.
e. The cable route alignment was routed along the geologically suitable terrain.
f. Ease of accessibility and convenience for construction, operation and maintenance work.
g. The grading / profile of the UG cable alignment is also considered.

The selected underground route alignment shall be a trade-off between these idealized criteria and the actual site conditions with due consideration for technical and economic aspects.

3.2 Other Considerations

The underground transmission line through high voltage cables requires less right of way when compared to the overhead transmission lines. The depth of laying shall be normally at 1.5 to 2 meters below the ground surface, depending upon the configuration and laying requirements of high voltage cables. Provisions of communication, condition monitoring and control signals shall be provided by means of optical fibers/control cables in addition to the power cables.

HDPE pipes shall be placed in every section of the underground transmission line and flexible HDPE pipes shall be laid at the bends. In places such as road crossing, the cables shall be placed inside the GI Pipes for the protection of cables from stress damage. Additional extra spare duct with spare cable shall be laid for contingency condition of failure the cable. In places like river/khola crossings, cable bridges with pillars or metal structures supporting the cables are provided. The structures shall be capable of withstanding the most severe force action upon it e.g., the wind force. The bending radius of the cable shall be no less than 16 D, where D is the outer diameter of the cable.

Link boxes (Joint Pits) shall be usually required in every 450 to 500 meters with a tolerable range of ±5%, which is usually the approximate length of the cable in the drum. Additional cable link boxes may be required based on the site conditions. The pre-moulded type straight through joints for XLPE cable which is impervious to the entry of water, confirming to IEC 60840 shall be suitable for underground buried installation with incorporated back fill and chances of flooding by water.

Extensive soil study is required to accurately plan the most appropriate cable laying arrangements along the alignment. In addition, a detail study of the physical structures below ground such as sewage system, communication lines etc. is also required.

3.3 Identification of Route Alignments

Required topographical maps of appropriate scale were obtained from Department of Survey, Government of Nepal.

The location of sending and receiving end substations were marked and connected with a straight line in the topographical sheet and in the Google earth. The physical, geographical and demographical features along the line were studied and analyzed for the suitability of transmission line. The line was adjusted in various sections considering the route selection criteria mentioned above which subsequently produced three distinct route alignments.

The alignments are pictorially shown in the image below:

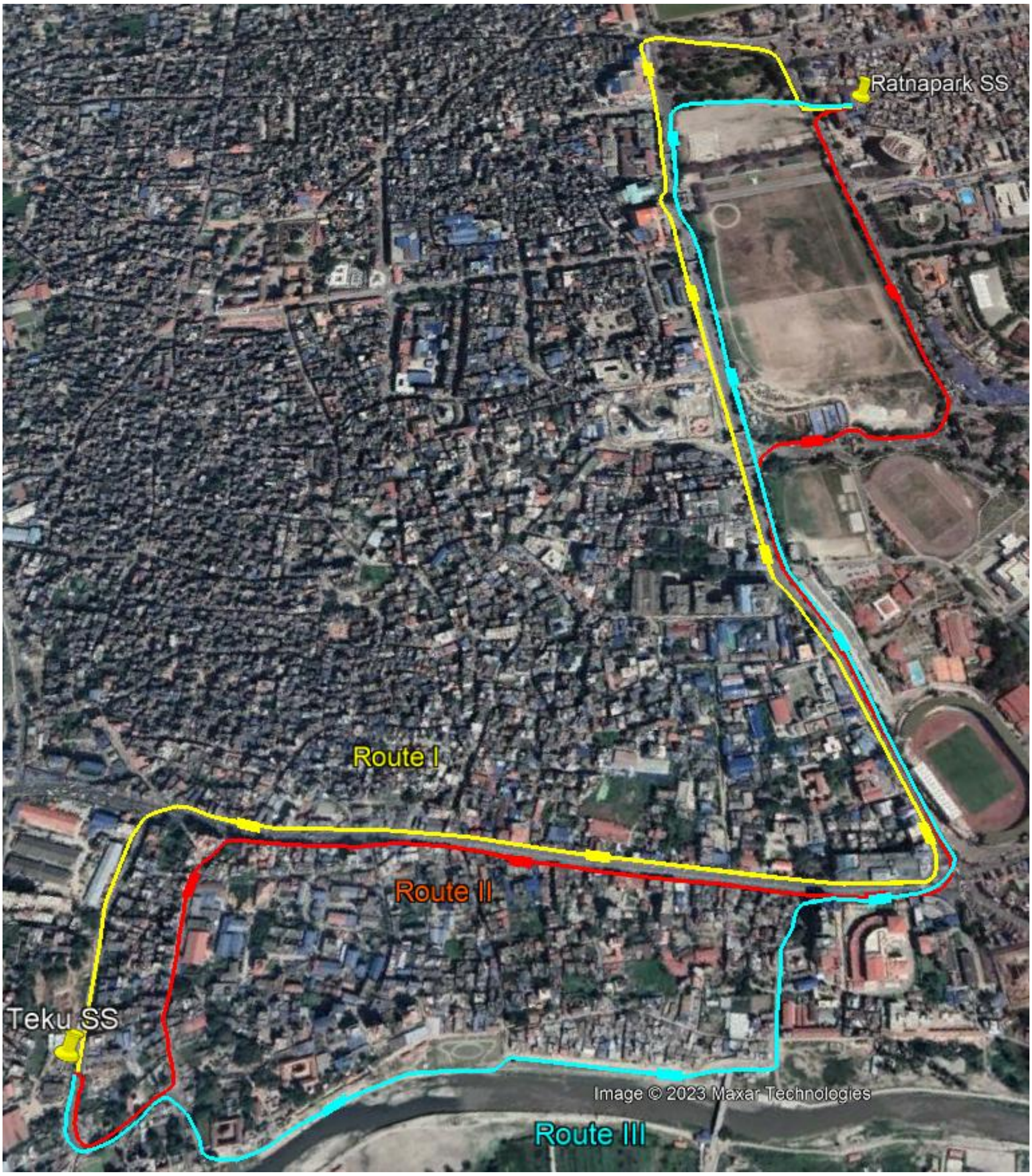


Figure 3-1: Alternative Route Alignments (Teku – Ratnapark)

4 DESK STUDY

This chapter elucidates the features of the three alternative transmission line alignments and the comparison between the alignments.

4.1.1 Evaluation of Alignments

The study team defined a basic set of criteria for the selection of an optimum route for the underground transmission line. Using this set of criteria as guidelines, routes were produced, compared and three of them were selected for rigorous evaluation. The salient features and comparative analysis of selected routes are briefly discussed in the succeeding sections.

The length of the underground transmission line is about 3.22 km. The cable alignment initiates at the existing Teku Substation located at Kathmandu Metropolitan City and ends at the existing Ratnapark Substation. Detail and careful study of the possible routes were plotted on the map. On the basis of map studies, three different routes were selected. These routes are listed in Table 4.1.

Table 4.1: Alternative Route Selected During Desk Study

S.N.	Route	Urban Municipalities/Metropolitan Cities along the route	Length (km)
1	Route I	Kathmandu Metropolitan City and Kathmandu Metropolitan City	3.22
2	Route II	Kathmandu Metropolitan City and Kathmandu Metropolitan City	3.1
3	Route III	Kathmandu Metropolitan City and Kathmandu Metropolitan City	3

4.1.2 Description of Selected Routes

The desk study of the alignment for Teku - Ratnapark132 kV underground transmission line is carried out by consideration of three transmission line route alignments. The alignment commences at Teku Substation, with coordinates approximately 332664.00 m Easting and 3064523.00 m Northing, terminating at Ratnapark Substation with coordinates of about 334086.00 m Easting and 3065676.00 m Northing. It's important to note that all coordinates adhere to the Universal Transverse Mercator (UTM) system.

The descriptions of these three route alignments are presented in subsequent sections.

4.1.2.1 Route I

The Underground Cable Alternative Route I is 3.22 km long. The alignment commences from Teku Substation located at Ward Number 12 of Kathmandu Metropolitan City and ends at Ward No. 28 of Kathmandu Metropolitan City.

The cable route passes through the following places lying in Kathmandu Metropolitan City. There are six (06) joint pits along the route alignment. The proposed boundary coordinates of the joint pits of Route I are presented below in Table 4.2.

Table 4.2: Details of Joint Pit Locations along the UG Cable Alignment of Route I

SN	Joint Pit	Name	Easting (m)	Northing (m)	Location (Metropolitan City/Urban Municipality)	Ward Number
1	Joint Pit 1	J1_A	332925.7	3064763	Kathmandu Metropolitan City	12
		J1_B	332943.1	3064753	Kathmandu Metropolitan City	12
		J1_C	332941.5	3064750	Kathmandu Metropolitan City	12
		J1_D	332924.1	3064760	Kathmandu Metropolitan City	12
2	Joint Pit 2	J2_A	333338.4	3064590	Kathmandu Metropolitan City	11
		J2_B	333356.8	3064582	Kathmandu Metropolitan City	11
		J2_C	333355.5	3064579	Kathmandu Metropolitan City	11
		J2_D	333337.1	3064587	Kathmandu Metropolitan City	11
3	Joint Pit 3	J3_A	333753.2	3064481	Kathmandu Metropolitan City	11
		J3_B	333751.4	3064500	Kathmandu Metropolitan City	11
		J3_C	333754.6	3064501	Kathmandu Metropolitan City	11
		J3_D	333756.3	3064481	Kathmandu Metropolitan City	11
4	Joint Pit 4	J4_A	333679.2	3064921	Kathmandu Metropolitan City	22
		J4_B	333681	3064941	Kathmandu Metropolitan City	22
		J4_C	333684.2	3064941	Kathmandu Metropolitan City	22
		J4_D	333682.4	3064921	Kathmandu Metropolitan City	22
5	Joint Pit 5	J5_A	333709.8	3065370	Kathmandu Metropolitan City	22
		J5_B	333711	3065390	Kathmandu Metropolitan City	22
		J5_C	333714.2	3065390	Kathmandu Metropolitan City	22
		J5_D	333713	3065370	Kathmandu Metropolitan City	22
6	Joint Pit 6	J6_A	333768.4	3065810	Kathmandu Metropolitan City	22
		J6_B	333771.2	3065829	Kathmandu Metropolitan City	27
		J6_C	333774.3	3065829	Kathmandu Metropolitan City	27
		J6_D	333771.6	3065809	Kathmandu Metropolitan City	27

Note: The co-ordinates are in Universal Transverse Mercator (UTM) system.

4.1.2.2 Route II

The Underground Cable Alternative Route I is 3.1 km long. The alignment commences from Teku Substation located at Ward Number 12 of Kathmandu Metropolitan City and ends at Ward No. 28 of Kathmandu Metropolitan City

The cable route entirely passes through Kathmandu Metropolitan City. There are six (06) joint pits along the route alignment. The proposed boundary coordinates of the joint pits of Route II are presented below in Table 4.3.

Table 4.3: Details of Joint Pit Locations along the UG Cable Alignment of Route II

SN	Joint Pit	Name	Easting (m)	Northing (m)	Location (Metropolitan City/Urban Municipality)	Ward Number
2	Joint Pit 1	J1_A	332843.3	3064693	Kathmandu Metropolitan City	12
		J1_B	332853.5	3064710	Kathmandu Metropolitan City	12
		J1_C	332856.3	3064709	Kathmandu Metropolitan City	12
		J1_D	332846.1	3064691	Kathmandu Metropolitan City	12
2	Joint Pit 2	J2_A	333243.5	3064613	Kathmandu Metropolitan City	11
		J2_B	333261.9	3064605	Kathmandu Metropolitan City	11
		J2_C	333260.7	3064602	Kathmandu Metropolitan City	11
		J2_D	333242.3	3064610	Kathmandu Metropolitan City	11
3	Joint Pit 3	J3_A	333655.1	3064435	Kathmandu Metropolitan City	11
		J3_B	333674.6	3064430	Kathmandu Metropolitan City	11
		J3_C	333673.8	3064427	Kathmandu Metropolitan City	11
		J3_D	333654.4	3064432	Kathmandu Metropolitan City	11
4	Joint Pit 4	J4_A	333734.6	3064759	Kathmandu Metropolitan City	11
		J4_B	333732.8	3064779	Kathmandu Metropolitan City	11
		J4_C	333736	3064779	Kathmandu Metropolitan City	11
		J4_D	333737.7	3064760	Kathmandu Metropolitan City	11
5	Joint Pit 5	J5_A	333809.7	3065080	Kathmandu Metropolitan City	28
		J5_B	333790.1	3065084	Kathmandu Metropolitan City	28
		J5_C	333790.7	3065087	Kathmandu Metropolitan City	28
		J5_D	333810.3	3065083	Kathmandu Metropolitan City	28
6	Joint Pit 6	J6_A	333996.5	3065283	Kathmandu Metropolitan City	28
		J6_B	333994.7	3065303	Kathmandu Metropolitan City	28
		J6_C	333997.9	3065303	Kathmandu Metropolitan City	28
		J6_D	333999.7	3065283	Kathmandu Metropolitan City	28

Note: The co-ordinates are in Universal Transverse Mercator (UTM) system.

4.1.2.3 Route III

The Underground Cable Alternative Route III is 3 km long. The alignment commences from Teku Substation located at Ward Number 12 of Kathmandu Metropolitan City and ends at Ward No. 28 of Kathmandu Metropolitan City

The cable route passes through the following points throughout Kathmandu Metropolitan City. There are six (06) joint pits along the route alignment. The proposed boundary coordinates of the joint pits of Route III are presented below in Table 4.4.

Table 4.4: Details of Joint Pit Locations along the UG Cable Alignment of Route III

SN	Joint Pit	Name	Easting (m)	Northing (m)	Location (Metropolitan City/Urban Municipality)	Ward Number
1	Joint Pit 1	J1_A	332958.1	3064382	Kathmandu Metropolitan City	12
		J1_B	332977.3	3064388	Kathmandu Metropolitan City	12
		J1_C	332978.2	3064385	Kathmandu Metropolitan City	12
		J1_D	332959	3064379	Kathmandu Metropolitan City	12
2	Joint Pit 2	J2_A	333347.1	3064305	Kathmandu Metropolitan City	11
		J2_B	333365.5	3064297	Kathmandu Metropolitan City	11
		J2_C	333364.2	3064294	Kathmandu Metropolitan City	11
		J2_D	333345.8	3064302	Kathmandu Metropolitan City	11
3	Joint Pit 3	J3_A	333657.8	3064430	Kathmandu Metropolitan City	11
		J3_B	333677.6	3064427	Kathmandu Metropolitan City	11
		J3_C	333677.1	3064424	Kathmandu Metropolitan City	11
		J3_D	333657.4	3064427	Kathmandu Metropolitan City	11
4	Joint Pit 4	J4_A	333737.2	3064766	Kathmandu Metropolitan City	11
		J4_B	333734.1	3064786	Kathmandu Metropolitan City	11
		J4_C	333737.3	3064786	Kathmandu Metropolitan City	11
		J4_D	333740.4	3064767	Kathmandu Metropolitan City	11
5	Joint Pit 5	J5_A	333721.6	3065211	Kathmandu Metropolitan City	22
		J5_B	333723.9	3065230	Kathmandu Metropolitan City	22
		J5_C	333727.1	3065230	Kathmandu Metropolitan City	22
		J5_D	333724.8	3065210	Kathmandu Metropolitan City	22
6	Joint Pit 6	J6_A	333765.4	3065662	Kathmandu Metropolitan City	22
		J6_B	333769.6	3065681	Kathmandu Metropolitan City	22
		J6_C	333772.7	3065681	Kathmandu Metropolitan City	22

SN	Joint Pit	Name	Easting (m)	Northing (m)	Location (Metropolitan City/Urban Municipality)	Ward Number
		J6_D	333768.5	3065661	Kathmandu Metropolitan City	22

Note: The co-ordinates are in Universal Transverse Mercator (UTM) system.

4.2 Comparison of Different Routes

To give a better insight of the identified routes, a comparison table has been made with the data prepared from desk study as follows:

Table 4.5: Comparison of Different Routes

SN	Items	Route I	Route II	Route III
1	Total length (km)	3.22	3.1	3
2	Number of Joint Pits	06	06	06
3	Major khola/bridge crossing	1	1	1
4	Road crossings	Yes	Yes	Yes
5	Order of Priority	1	2	3

After examining the comparison table, it is evident that Route I is lengthier. However, the alignment is comparatively easier for construction because of bigger road section/width, lesser houses nearby therefore lesser social issues etc. in comparison to other routes. So, we prefer Route I because of these reasons.

The alignments shall be further optimized after a reconnaissance survey is conducted. This survey shall incorporate all the data and observations recorded at the site, allowing the Consultants to refine the proposed alignments and address any potential issues in close coordination with the NEA. By doing so, the final route alignment selected shall be the most suitable and practical option, taking into account all relevant factors and considerations.

4.3 Conclusion

The reconnaissance survey shall be carried out for all the three route alignments and any of the above or the combination of the above alignments shall be considered as the feasible route alignment and shall be selected for carrying out the detail survey of the route alignment. The selection of the alignment shall be conducted to verify the suitability of the alignment from construction and maintenance perspectives.

During the detail design stage, the Consultant shall conduct a comprehensive survey and design of the underground transmission line alignment, including the Geophysical Penetrative Radar (GPR) and Geotechnical Investigation. Several factors, such as cable bonding methods, the suitability of the location of cable joint pits, soil types identified, and underground geophysical features of the alignment etc. shall be considered. These factors significantly impact the route alignment, and adjustments may be made during later stages of the project.

It is important to note that this desk study report is based solely on preliminary route alignments identified from the Desk Study without any field investigation. Its purpose is only to acquire the Survey License from the authorized Authority.

5 LINE DESIGN CALCULATIONS

This chapter consists of technical specifications of the underground transmission line alignment and calculation of the efficiency and voltage regulation of the transmission line.

Considering the 132kV underground transmission line between the Teku SS and Ratnapark SS, we have,

Length of the transmission line = 3.22 km approx.

Conductor = XLPE Cable (Cu, 800 sqmm)

Number of Circuits = 2

We shall be calculating the voltage selection, conductor selection, efficiency and voltage regulation at parameters specified above

5.1 Cable Selection

P = Power to be transmitted = 340 MW

V = Voltage Level for given Power Transmission =132 kV

Current (I) = P/(√3 x V x I x pf)

= (170 x (10)^6)/(√3 x 132 x (10)^3 x 0.85) = 874.77 A

The derating factor is calculated by considering the correction factors as indicated below in Table 5.1.

Table 5.1: Correction factors for underground cabling system

SN	Description	Correction Factors
1	Laying Depth (1.5 metre)	0.98
2	Thermal resistivity of ground (1.2 K.m/W)	0.93
3	Ground temperature (20°C)	1
4	Air temperature (30°C)	1
5	Equivalent Derating Factor	0.9114

After taking the consideration of derating factor, the current in the conductor is 797.27 A.

Power after deration = 2 x √3 x V x I x pf

= 309.87 MW

Comparing this value of current with current carrying capacity from standard conductor table, standard practice and manufacturer’s datasheet, XLPE Conductor of cross - sectional area of 800 sq.mm. is selected.

As per Standard and from Standard Manufacturer's Catalogue,

Effective Resistance of XLPE (Cu, 800 sqmm) at 90 ^oC	= 0.057 ohm/km
Ampacity at 90 ^oC	= 875 A
Sectional Area of Copper Conductor	= 800 sqmm
Overall Diameter of Cable (Outer), D	= 101 mm
Recommended Bending Radius	= 20 D

5.2 Voltage Selection

The transmission voltage of a line is determined by the amount of power to be transmitted, transmission distance, future expansion plan of the system, the national standard system voltage etc.

The most economical voltage is given by the following empirical formula as per American Practice and Cable Research Handbook for determination of optimum voltage for lines and hence the most economical voltage is given by the following empirical formula:

$$\text{Economical Voltage } (V_{eco}) = 5.5 \text{ x} \sqrt{\left(\frac{Lt}{1.6}\right) + \left(\frac{P*1000}{Nc*150*PF}\right)}$$

where,
Lt = length of transmission line ~= 3.22 km
PF= Power Factor = 0.85
The power transmitted shall be 309.87 MW.
Then, using the above values:

$$Veco = 5.5 \text{ x} \sqrt{\frac{3.22}{1.6} + \frac{309.87*1000}{2*150*.85}}$$

$$= 191.88 \text{ kV for Nc} = 2$$

For a transmission power of 309.87 MW, transmission distance of 3.22 km and power factor of 0.85, the transmission line voltage is around 191.88 kV for Double Circuit Configuration. Due to the existing switchgear facility at Teku Substation, 132 kV line is reasonable as well as economical. Therefore, we choose 132 kV voltage level to connect Teku SS and Ratnapark SS.

In the case of a single circuit, the system possesses the capability to facilitate the power flow of approximately 154.93 megawatts (MW). Additionally, a redundancy measure has been implemented through the provision of spare cabling. This redundancy is designed to mitigate the impact of a single conductor failure, thereby ensuring the uninterrupted continuity of power flow between the two substations.

So, the brief summary of the technical parameters for the selection of Economic Voltage level are presented below:

Voltage Level for given Power Transmission	=132 kV
Number of Circuit	= 2
Power Factor (cos Ø)	= 0.85

Length of Transmission Line (L) = 3.22 km (approx.)

5.3 Efficiency and Loss Calculation

Line Parameters

Power to be transmitted = 309.87 MW
Transmission Voltage = 132 kV
No. of Circuits = 2
Power Factor = 0.85
Conductor = Copper
Line Length = 3.22 km

For XLPE Cable;

Effective Resistance of XLPE (Cu, 800 sqmm) at 90 ºC (R) = 0.057 ohm/km

Current Carrying Capacity (I_L) = 797.27 A

The power loss in the line is given by,

$$P_{L1} = 3 \text{ x } {I_L}^2 R$$
$$= 3 \text{ x } I_L^2 \text{ x } R_{ac} \text{ x } L$$
$$= 3 \text{ x } 797.27^2 \text{ x } 0.057 \text{ x } 3.22$$
$$= 0.6999 \text{ MW}$$

The efficiency in the line is given by,

$$\eta = 1 - \frac{\text{Ploss}}{\text{P}}$$
$$= 1 - \frac{0.6999}{309.87}$$
$$= 0.9977$$
$$= 99.77 \%$$

5.4 Voltage Regulation Criterion

For 132 kV XLPE (Cu, 800 sq mm), the following line parameters were obtained:

Inductance of cable (L) = 0.55 mH/km

Inductive Reactance (X_L) = 2π x f x L

= $2*\pi*50*0.55*10^{-3}$ Ω/km

= 0.1727 Ω/km

Impedance of the line (Z) = R + j X
= R + j (2π x f x L)
= 0.057 + j0.1727 Ω/km

= 0.1835 + j0.5560 Ω

Capacitance of the cable (C) = 250 nF/km

Admittance of the line (Y) = jwC = j*2*π*50*250*10^{-9} S/km

= j0.0003783 S

Calculation of ABCD parameters;

Where,

$V_S = AV_R + BI_R$

$I_S = CV_R + DI_R$

The transmission line can be modelled by;

$\mathrm{A} = \mathrm{D} = 1 + \frac{\mathrm{YZ}}{2}$ = 0.9999+j0.000023

$\mathrm{B} = \mathrm{Z}$ = 0.1835 + j0.5560 Ω

C = ($1 + \frac{\mathrm{YZ}}{4}$)Y = -2.93*10^{-9} + j0.00025

The magnitude of receiving end current at full load is calculated as:

∴$|\mathbf{I_R}|$ @ full load = 0.79 $\angle(-\cos^{-1} 0.85)$ kA (lag)

= 0.79 ∠ -31.78

The power factor (cos Φ) = 0.85 (lag)

The receiving end voltage per phase at full load is given by:

V_R per phase @ full load = $\frac{132}{\sqrt{3}}\angle 0° = (76.21\angle 0°)$ kV

Therefore, sending end voltage per phase at full load is given by:

V_S (per phase) @ full load = $AV_R + B\,I_R$

= (0.9999+j0.000023) $(76.21\angle 0°)$ + (0.1835 + j0.5560 Ω) 0.79 ∠ -31.78

$= 76.56 + \mathrm{j}0.3015$

The receiving end voltage at no load is given by:

$|V_R|$ per phase @ No load = $\left|\frac{\mathrm{Vs\ @\ full\ load}}{\mathrm{A}}\right| = \left|\frac{76.56+\mathrm{j}0.3015}{0.9999+\mathrm{j}0.000023}\right|$ = 76.56 kV

The voltage regulation is calculated as shown below:

Voltage Regulation (V.R.)

$= \frac{|\mathrm{Vr@\ no\ load}|-|\mathrm{Vr\ @\ full\ load}|}{|\mathrm{Vr\ @\ full\ load}|} * 100\%$

$= \frac{76.56-76.21}{76.21} * 100\%$

= 0.47 %

Since calculated voltage regulation < 10 %, the selected cable satisfies the voltage regulation criterion.

According to Department of Electricity Development, Guidelines for Operation and Maintenance of Hydropower Plants, Substations and Transmission Lines, clause 4.4.3, voltage fluctuations should not be more than 10 % for 33 kV to 400 kV Transmission lines. From the above analysis it is seen that voltage regulation doesn’t exceed 10%. Hence, voltage regulation criterion is satisfied.

6 COST ESTIMATE AND WORK SCHEDULE

This chapter consists of the cost estimate that consists of both the study cost and construction cost, and the work schedule for carrying out the study of the project.

6.1 Study Cost

The cost estimation for feasibility study of Teku - Ratnapark 132 kV Underground Transmission Line is shown in Table 6.1.

Table 6.1: Study Cost of 132 kV Transmission Line Alignment

SN	Title	Cost (NRs.)
1	Pre-feasibility Study (Desk Study, Reconnaissance Survey, Preliminary Design Works)	xx
2	Feasibility Study (Detail Survey, Feasibility Design Works)	xx
3	Environment Study	xx
	Total	**xx**

6.2 Construction Cost

The construction cost per km of Teku - Ratnapark 132 kV double circuit underground transmission line is approximately about NRs xx /- per km. The total cost for about 3.22 km length of the line (underground cabling section) is around NRs xx /- (In Words –).

The work schedule is attached herewith.

7 CONCLUSION

The reconnaissance survey shall be carried out for all the three alternative route alignments and any of the above or the combination of the above alignments shall be considered as the feasible route alignment and economically viable and feasible/doable route shall be finalized for carrying out the detail survey of the route alignment. In addition, the selection of the suitable alignment shall also be done from the view of construction and maintenance aspect.

The underground transmission line study shall be done using Ground Penetrating Radar (GPR) and Geotechnical Investigation. Several factors, such as cable bonding methods, the suitability of the location of cable joint pits, soil types identified, and underground geophysical features of transmission line shall be studied and adjustments may be made during later stages of the detail study of the Project.

Please note that this desk study report is based solely on preliminary route alignments identified from the Desk Study without any detail survey, reconnaissance and field investigation. The intent of this report is to comply with the requirements in order to acquire Survey License from the DoED.

8 ANNEXES

Annex 1: 132 kV XLPE Copper Cable Specifications

SN	Particulars	Specifications
	Cable	Single Core Copper Conductor, XLPE Cable
1)	Size	800 sq mm
2)	Applied Standard	IEC- 62067, Testing as per IEC- 60840.
3)	Voltage Grade	
	a) Nominal Voltage	76/132 kV
	b) Maximum Continuous Operating Voltage	145 kV
4)	System Frequency	50 Hz
5)	Permissible Criteria for Satisfactory Operations	
	a) Voltage	±5%
	b) Frequency	±2%
	c) Maximum Continuous Permissible Temperature	90 ^{0}C
	d) Maximum Permissible Temperature of Conductor in Short Circuit	250 ^{0}C
	e) Recommended Bending Radius	20D
6)	Outer Diameter of cable	101 mm
7)	Net Weight	14000 (approx.) kg/km
8)	Conductor	
	a) Material	Copper
	b) Shape and Formations	Longitudinally watertight segmental stranded and compacted copper
	c) Diameter	34 mm
9)	Conductor Screen	

	a) Material	Extruded semiconducting copolymer compound
	b) Thickness	1.5 mm
10)	Insulation	
	a) Material	Cross Linked Polyethylene
	b) Thickness	16 mm
11)	Insulation Screen	
	a) Material	Extruded semiconducting copolymer compound
	b) Thickness	0.8 mm followed by water swellable SC tapes.
12)	Metallic Sheath	
	a) Material	Corrugated Aluminium Sheath
	b) Thickness	2.2 mm
	c) Short Circuit current of metallic screen for 1 sec (kA)	>40kA (min)
13)	Outer Sheath	
	a) Material	Extruded Polyethylene
	b) Color	Black
	c) Thickness (Nominal/ Minimum)	4.5 mm
14)	Standard Drum length	450-500 m
15)	Safe Pulling Force	5 kg/mm^2
16)	Power Frequency Withstand Voltage	190 kV for 30 sec
17)	Impulse Withstand	650 kV$_p$
18)	Short-circuit Current for 1 sec	114.2 kA
19)	Resistance	
	a) Effective Resistance at 90 ^{0}C	0.057 ohm/km
	b) Maximum DC resistance	0.0211 ohm/km

20)	Inductance	0.55 mH/km
21)	Capacitance	0.25 microfarad/km

Annex 2: 132 kV XLPE Copper Cable Configuration in the Trench

The suggested cable configuration is in provisional phase. Further modification and adjustment can only be after conducting a detail survey during cable design phase. The preliminary arrangement is depicted in the figure below.

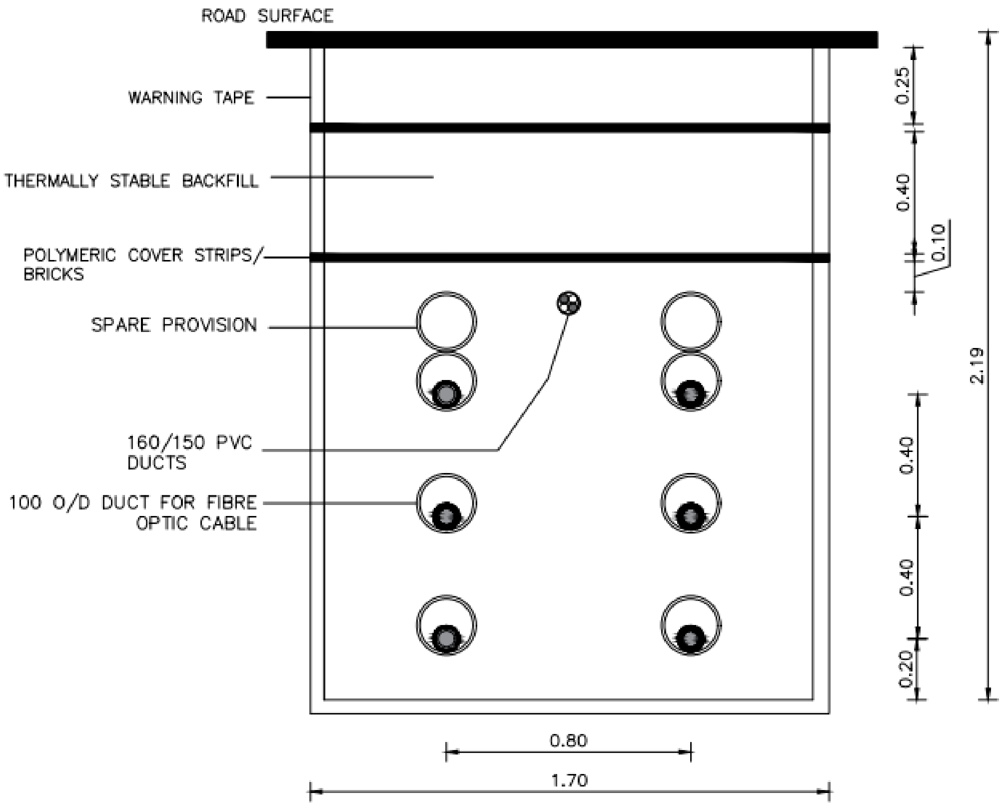


Figure 8-1: Cable Configuration

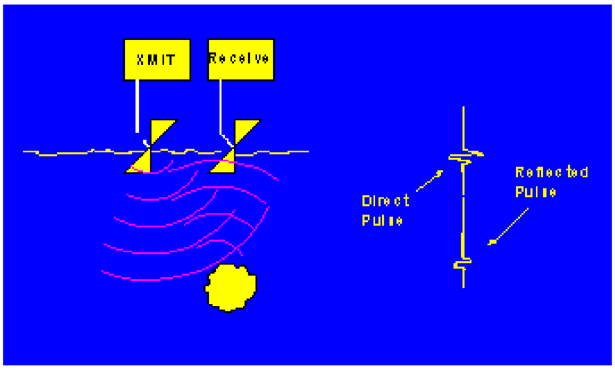
Annex 3 : Underground Utility Mapping Methodology

Ground Penetrating Radar, also known as GPR, Georadar, Subsurface Interface Radar, Geoprobing Radar, is a very non-destructive technique to produce a cross section profile of subsurface without any drilling, trenching or ground disturbances. Ground penetrating radar (GPR) profiles are used for evaluating the location and depth of buried objects and to investigate the presence and continuity of natural subsurface conditions and features.

Radio Detection and Ranging (RADAR) a system using short duration electromagnetic pulses. Ground Penetrating Radar (GPR) uses radio waves, typically in the 1 to 2000 MHz frequency range and is a non-invasive electromagnetic geophysical technique that produces profiles showing a virtual cross-section of soil, sediments, bedrock layers and other man made engineering structures beneath the ground without drilling, probing, or digging. GPR has been widely used to detect subsurface utilities like pipes, cables, archaeological objects, cavities, subsurface lithological information. It is difficult and troublesome to map these buried utilities and cavities and piping features as they are invisible to naked eyes. So, proper subsurface information is essential prior to any reconstruction activities in the area to avoid loss of life and property during construction.

GPR equipment specially consist of three components; transmitter unit, receiver unit and control unit. The GPR uses echo- principle. A mobile antenna (Transmitter) unit transmits short pulses of electromagnetic waves which pass toward the ground and gets reflected back to the surface being dependent upon the properties of the materials. When the transmitted waves encounter a buried object with different reactive indices some of the waves are reflected back. The phenomenon occurs when the electromagnetic waves sense the changes in physical properties and composition of the subsurface material like grain size, moisture, dielectric permittivity and electrical conductivity (Davis and Annan, 1989; Daniels, 2000; Jol and Bristow, 2003) and these reflected waves are received by the receiver unit.

Multiple pulses are sent into ground, and signals are displayed on screen. The radar is moved along the ground and each new echo is plotted alongside the previous ones. When enough of these signals are plotted side-by-side, the operator can see a pattern which he can interpret as an object. These waves create representative image as the object are detected. These signals are sent to control unit are further transferred to computer and these data are processed by using highly sophisticated software program. Thus, the images of the subsurface can be obtained, and then further analysis and interpretation are made.



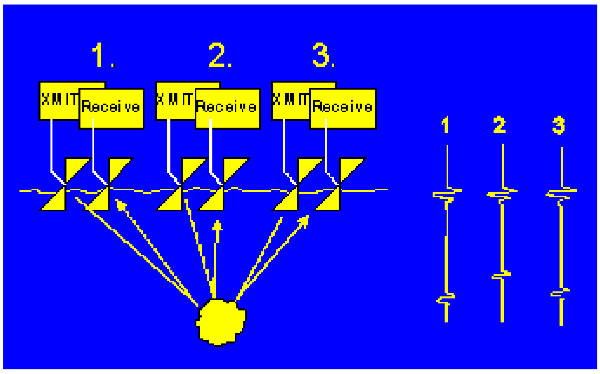


Figure 8-2: Electromagnetic Waves

When the object is ahead of the radar, it takes more time for the echo to bounce back to the antenna. As it passes over, the time grows shorter, and then longer again as it goes past the object. This effect causes the image to take the shape of a curve called a "hyperbola". Experienced users recognize that a hyperbola is actually the image of a smaller object (like a pipe) located at the center. Other patterns are produced by different structures. For example, a buried tank might have a flat image with curves down from either end. Knowledge of the dielectric constant of the local soil is an important parameter for determination of depth of the utilities accurately. Synthetic hyperbola is constructed for the determination of depth of utilities.

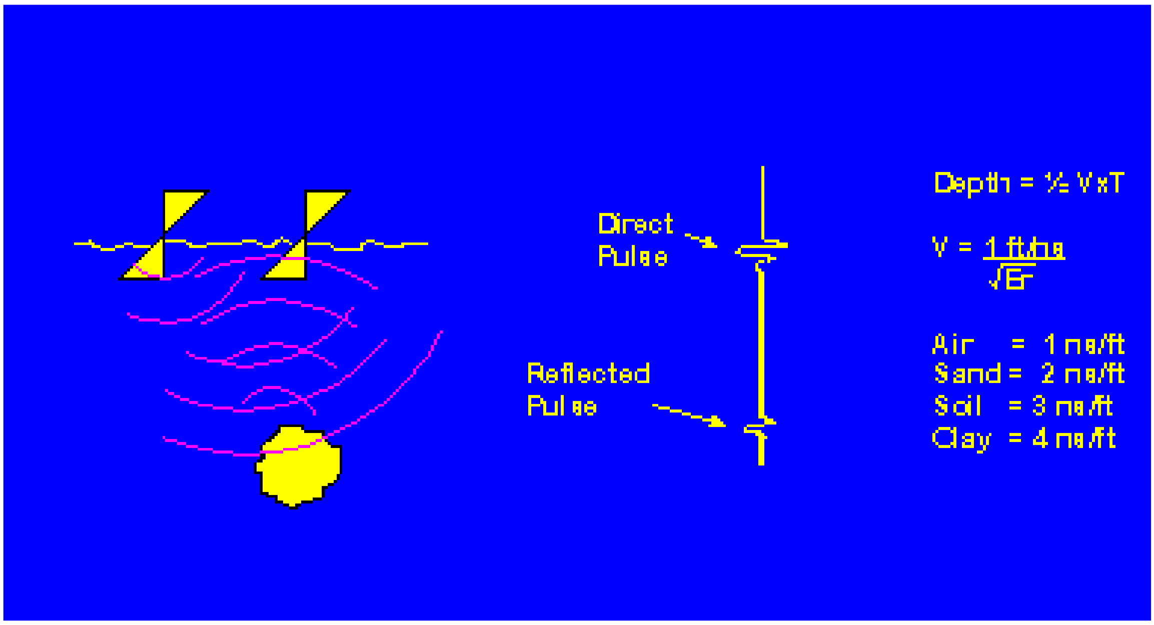


Figure 8-3: Direct and Reflected pulse

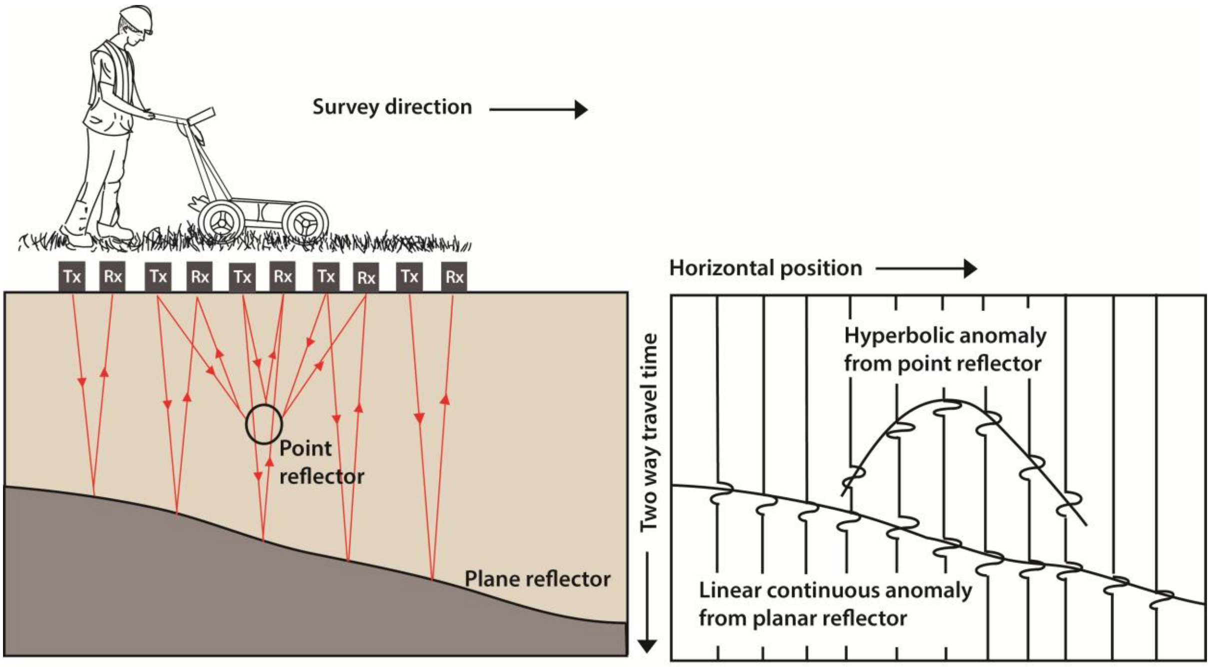


Figure 8-4: General idealized diagram of GPR data acquisition.

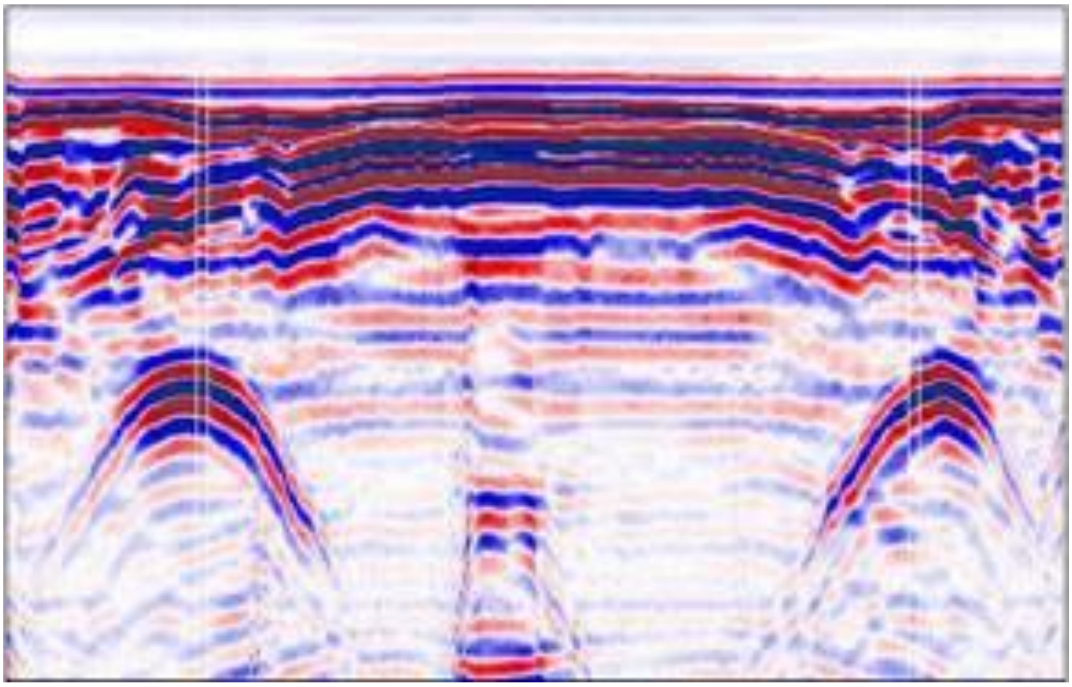


Figure 8-5: Typical signatures from underground pipes

Ground penetrating radar waves can reach depths up to 60 meters in low conductivity material such as dry sand or granite. Clays, shale and other high conductivity materials may attenuate or absorb GPR signals, greatly decreasing the depth of penetration. The moisture level in top soil is mainly responsible for conductivity, and should be carefully considered before embarking on a detailed GPR investigation plan. The depth of penetration is also determined by the GPR antenna used. Antennas with low frequency obtain reflections from deeper depths but have low resolution. These low frequency antennas are used for investigating the geology of a site, such as for locating sinkholes or fractures, and to locate large, deep buried objects. Antennas with higher frequencies (300 to 2000 MHz) obtain reflections from shallow depths (0 to 10 meters) and have a high resolution. These high frequency antennas are used to investigate surface soils and to locate small or large shallow buried objects, pipes, cables and rebar in concrete. GPR can detect objects of any material, metallic or non-metallic.

Annex 4 : Scope of Works

The scope of services shall consist of the following:

a) To carry out Desk Study of the underground transmission line routes
b) To carry out Reconnaissance Survey of the alternate route alignments.
c) Conduct Detail Survey for the finalized route alignment.
d) Carry out Geotechnical Investigation works at required locations.
e) Carry out Geophysical Investigation works along the route alignment.
f) Carry out Electrical and Civil Design Works.
g) Prepare Bidding Documents.

Annex 5: Contract Agreement and Terms of References

The contract agreement between the Kathmandu Valley Transmission System Expansion Project and NEA Engineering Company Ltd and its Terms of References have been attached herewith.