Geological feasibility report from Nauni Chowk (Kolaka to Dareota Village-Pkg IIA, Dareota to Daseharan Village-Pkg IIB & Daseharan Village to Nauni Chowk- Pkg IIC)

Submitted to

National Highway Authority of India

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1 INTRODUCTION

The development of a geological model for a tunnel project is an evolving process. It is reasonable to expect that with each phase of the project, the model's accuracy will improve. As new investigations are conducted, the overall knowledge base grows, provided that previous investigations are accurately documented and accessible. Base tunnels, in particular, require more extensive effort to refine the geological model. Typically, for a tunnel project, the geologist conducts a desktop study, compiles a geological map and sections, and then initiates drilling campaigns. In addition, geophysical investigations, field and laboratory tests, and water monitoring programs are sometimes carried out. **Rehabilitation and Upgrading of Existing Road to 4 Lane with Paved Shoulder from Kolaka village to Nauni Chowk (Kolaka to Dareota Village-Pkg IIA, Dareota to Daseharan Village-Pkg IIB & Daseharan Village to Nauni Chowk-Pkg IIC) of NH 205 [Design Chainage – Km 28+800 to Km 58+450, Design Length – 29.65 Km.** The project is currently in the DPR stage, and surface geological investigations have been completed. The geologist has conducted surface geological mapping through geo-profiling, and based on this study, an anticipated geological model has been developed. The desk study serves as a crucial initial step in any site investigation program. Its aim is to review published information and other relevant records concerning the region, area, and surroundings of the project site. This includes examining geology, geomorphology, aerial photographs, and other archival data.

The preliminary model was developed following geological field mapping, which involved identifying the distribution of ground types and classifying the main structures, such as folds, faults, and other discontinuities. As a result, the uncertainty of the geological model at the tunnel level will be significantly reduced. During construction, the geologist must regularly conduct face mapping.

Deep tunnels differ significantly from shallow ones, and creating a geological model for them requires a considerably greater amount of time and effort. Detailed engineering geological field mapping, including structural and hydro-geological analysis, is crucial. With each design step, the prediction of ground behavior becomes more accurate, providing greater benefits for construction.

2 STUDY DESK

A geological desk study is a crucial preliminary investigation typically conducted during the pre-feasibility phase of a construction project. It involves reviewing existing data on the site's geology, hydrology, and soil conditions to assess the project's feasibility and identify potential risks.

The key reasons for conducting a geological desk study include:

- Identifying potential hazards: It helps uncover geological risks, such as landslides or ground instability that may impact construction, allowing for risk mitigation planning.

- Assessing soil conditions: The study provides insight into soil type, depth, and composition, essential for evaluating foundation suitability and excavation needs.
- Estimating costs: It offers early cost estimates for site preparation and construction, aiding in project budgeting and feasibility assessments.
- Ensuring regulatory compliance: The study helps ensure the project meets local geological and geotechnical regulations, including environmental impact assessments.

For the project area, geological information was gathered from various sources, including Geological Survey of India (GSI) papers and maps, and the area was examined on Google Earth to understand its geological features.

3 PURPOSE

The purpose of this Geological Report is to summarize the site and surface data collected during the surface study and reconnaissance survey investigations conducted as part of the preliminary engineering efforts for Tunnel T-1, located at the Shimla-Mataur Project under Package-IIA, IIB, and IIC in India.

The surface geological investigation was carried out along the planned alignment, with NHAI conducting the preliminary engineering investigation. This involves the Rehabilitation and Upgrading of Existing Road to 4 Lane with Paved Shoulder from **Kolaka village to Nauni Chowk (Kolaka to Dareota Village-Pkg IIA, Dareota to Daseharan Village-Pkg IIB & Daseharan Village to Nauni Chowk-Pkg IIC) of NH 205 [Design Chainage – Km 28+800 to Km 58+450, Design Length – 29.65 Km**.

The findings of this investigation are detailed in the "Geological Evaluation & Assessment Report" for Preliminary Engineering. This document serves as the foundational reference for the current project, compiled into the Geological Report. The expert conducted the surface data collection and reconnaissance survey, which forms the basis of the geotechnical investigation and has been integrated into this matrix report.

This report aims to summarize the conclusions of the consultants' work and compile all surface data, including geomorphic and lithological information. The data from this surface exploration, along with existing studies, was used to define the geological matrix and anticipated geology along the tunnel alignment. The geological details will guide the establishment of geotechnical parameters essential for preliminary engineering.

4 PROJECT OVERVIEW

Rehabilitation and Upgrading of Existing Road to 4 Lane with Paved Shoulder from Kolaka village to Nauni Chowk (Kolaka to Dareota Village-Pkg IIA, Dareota to Daseharan Village-Pkg IIB & Daseharan Village to Nauni Chowk-Pkg IIC) of NH 205 [Design Chainage – Km 28+800 to Km 58+450, Design Length – 29.65 Km] are indicated in Fig. 1.1 and fig. 1.2 below

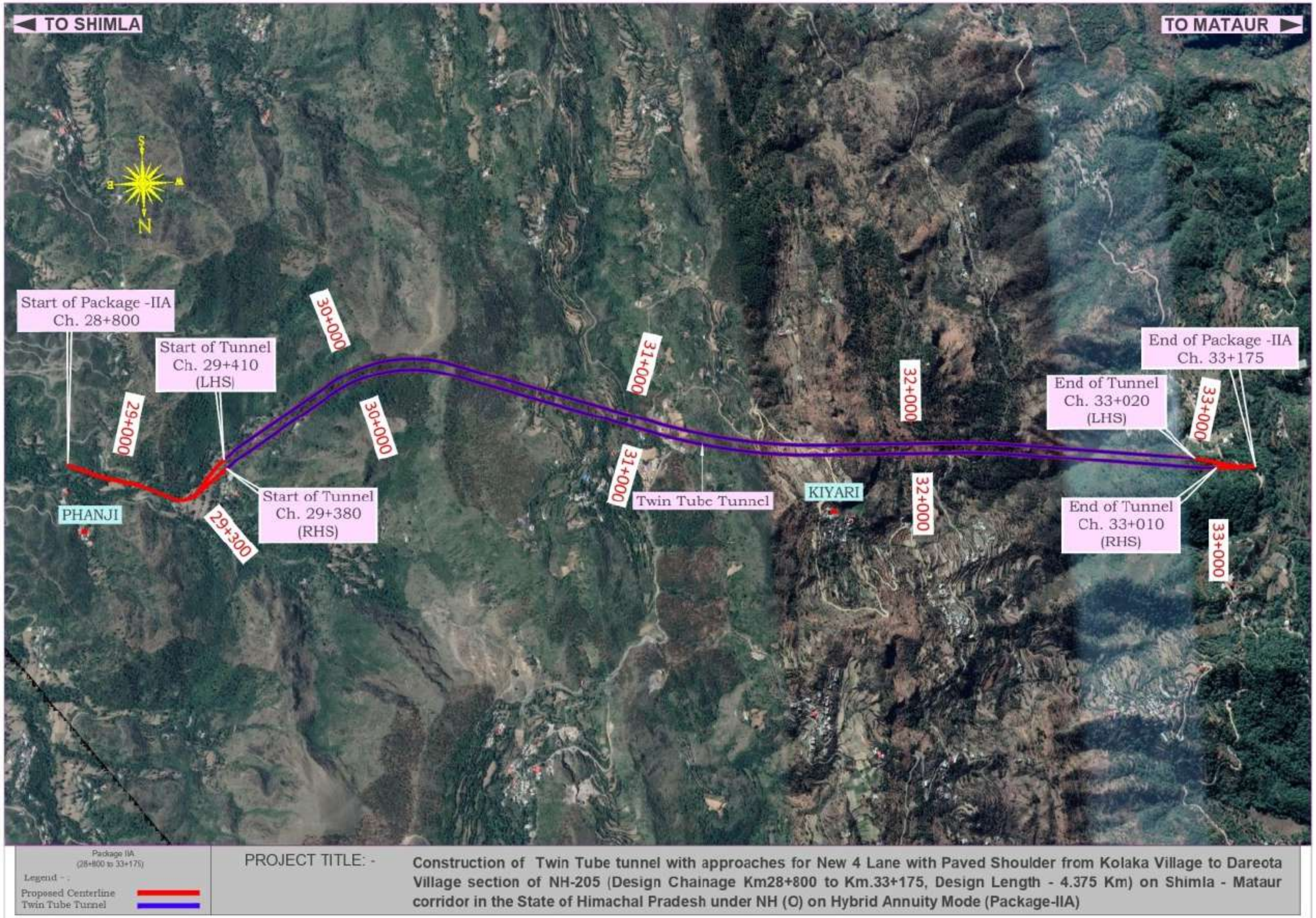


Figure 1.1: Plan Showing the Salient Characteristics of the Package IIA.

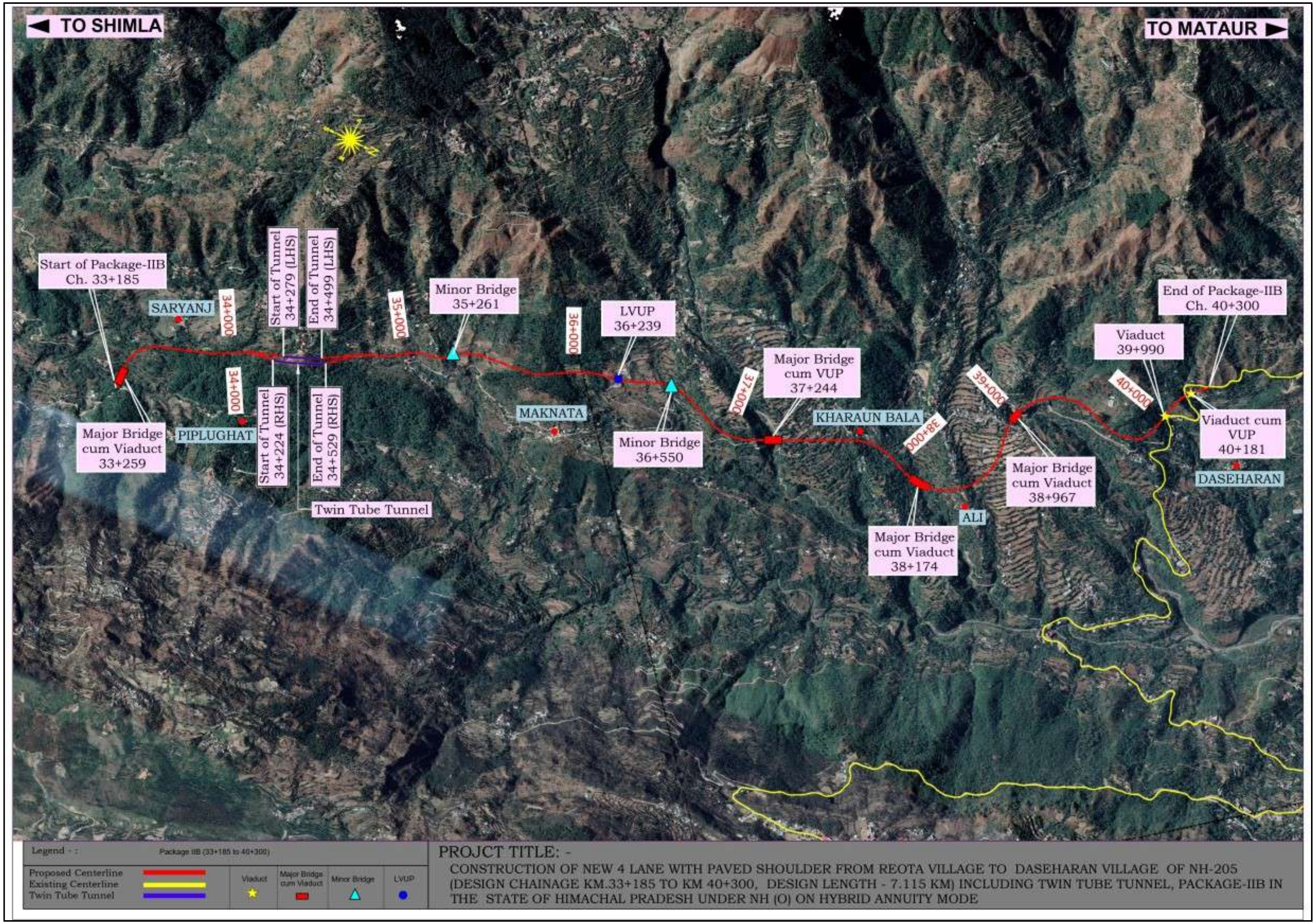


Figure 1.2: Plan Showing the Salient Characteristics of the Package IIB

5 GEOMORPHOLOGY

The area is part of the Siwalik foothills and Lesser Himalayas, with the western and eastern sections respectively characterized by low to moderate relief. It features a complex landscape of high mountain ranges, hills, and valleys, with elevations ranging from 358 meters at Rautanwala to 2069 meters at Baridevi (Fig. 1.3). The northern region has higher hill ranges, while the south-western part of the district consists of lower, eroded hill ranges of the Siwalik. In the regions with high Himalayan hill ranges, the valleys are narrow, deep, and have steep slopes that trend north-south in the eastern part, gradually shifting to a northwest/north-northwest to southeast/south-southeast orientation in the western part. Approximately 89% of the terrain is moderately to highly dissected, with steep slopes ranging from 0° to 58°. The badland topography is especially prominent in the hill ranges underlain by Upper Siwalik rocks. Major physiographic features include longitudinal and transverse V-shaped valleys, linear denudational hills, and mounds. Key geomorphic features of fluvial origin in the area include fluvial terraces, channel bars, lateral bars, active flood plains, and piedmont alluvial plains. These landforms have developed through the normal progression of geomorphic cycles.

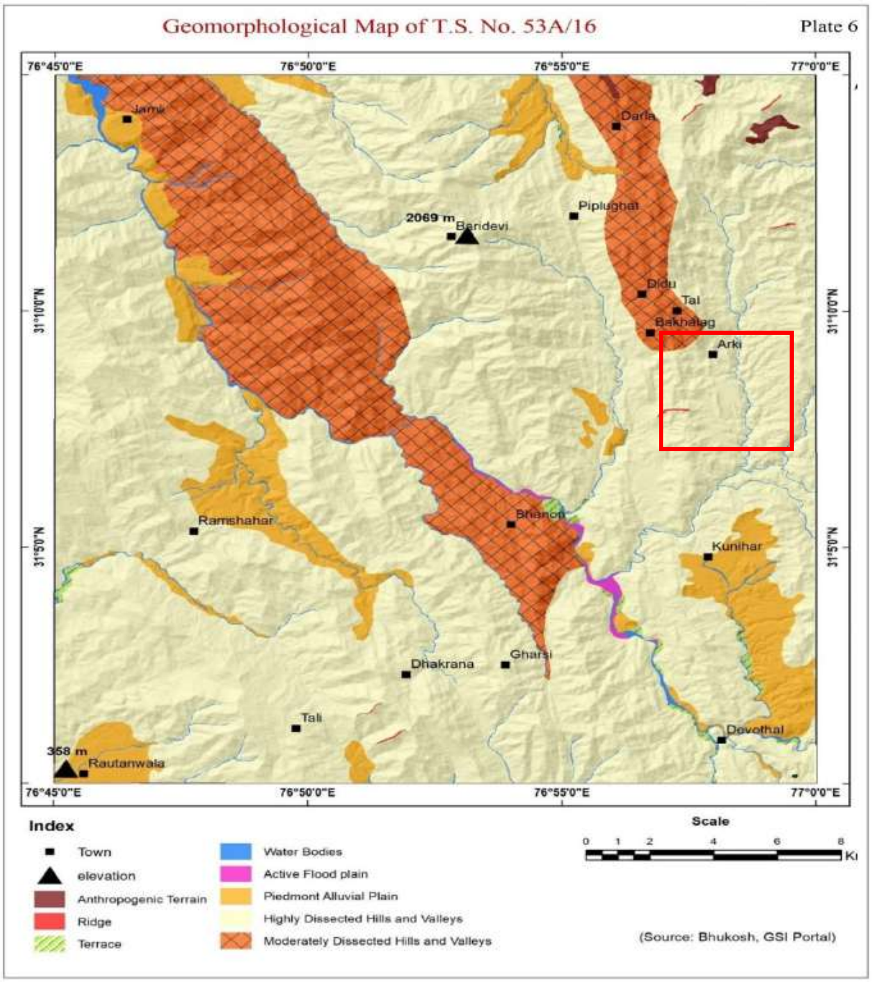


Figure 1.3: Geomorphological Map of Project Area Marked in Red (Source: Bhukosh GSI)

Solan district is situated on the Siwalik ranges and is part of the Lesser Himalayas, featuring a varied landscape of hills, valleys, and a piedmont zone. The hill system comprises seven main ranges: Naina Devi, Kot, Jhanjiar, Tiun, Bandla, Bahaurpur, and Ratanpur. The lowest point in the district is around 290 meters above mean sea level (AMSL), while the highest peak, Bhadurpur Hill, reaches an elevation of 1980 meters (AMSL). The elevation of the PKG-IIA and PKG-IIB Tunnels ranges from 1259 to 1823 meters.

The Sutlej River flows through the center of the district from east to west, entering near Kasol in the northwest and exiting near Naila to the southwest, after covering a distance of 90 km. The Sutlej is fed by several tributaries, with the three main ones being Ali Khad, Gamrola Khad, and Seer Khad. Ali Khad, about 26 km long, originates in Shimla district, flows through Bahadurpur Dhar, and joins the Sutlej at Bilaspur. Gamrola Khad also originates in Shimla district, draining the Rattanpur Dhar, and meets the Sutlej approximately 5 km downstream of Bilaspur. Seer Khad, the third tributary, begins at Wah Devi, 10 km from Sarkaghat in Mandi district, flows through Kot-Ki-Dhar and much of Ghumarwin Tehsil, and joins the Sutlej at Serimatla Village, about 15 km downstream from Bilaspur.

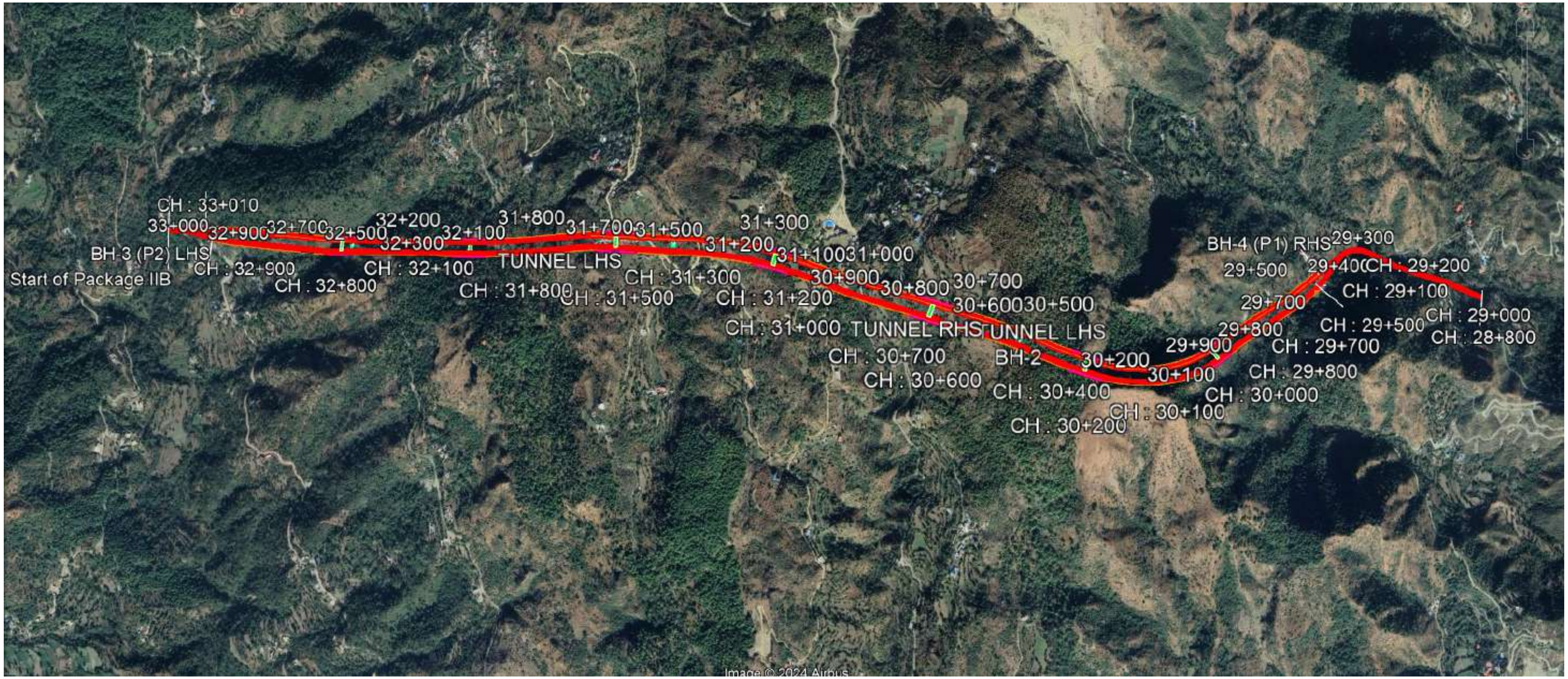


Figure 1.4: Project Location (Google Earth) PKG-IIA

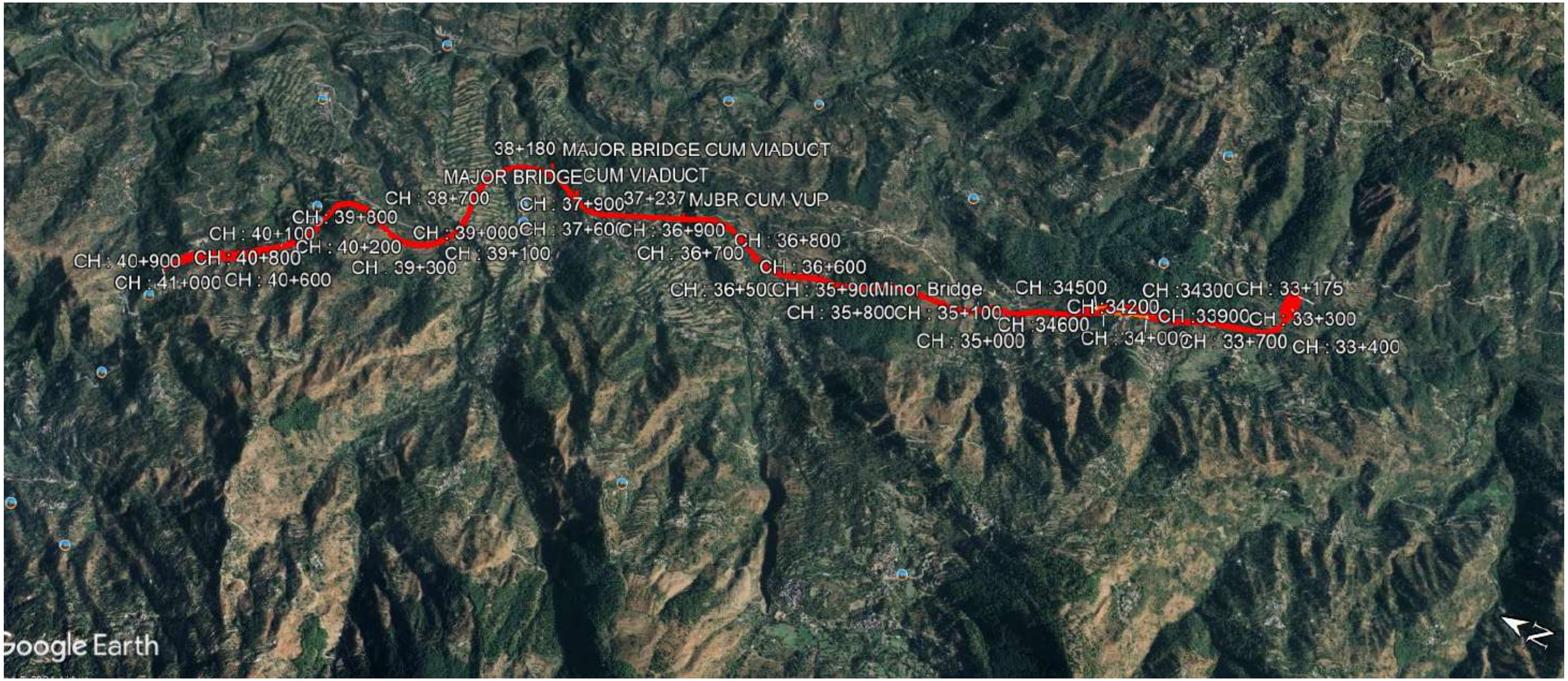


Figure 1.5: Project Location (Google Earth) PKG-IIB

6 REGIONAL GEOLOGICAL SETTING

PKG-IIA includes twin tunnels, approximately 3610 meters (LHS) and 3630 meters (RHS) in length, for the highway tunnel between Shimla and Mataur. The tunnel section of Package-IIA begins at Kolaka Village and ends at Dareota Village, located about 35 kilometers from Shimla, Himachal Pradesh.

Figure 1.6: Project Location Marked in Red

The first authoritative geological work in the Himachal Himalaya was carried out by Medlicott in 1864 followed by *McMohan (1882, 1883 and 1885)*. *Gansser (1964)* gave the integrated approach towards stratigraphy and structure of this great Himalayan mountain range (Fig. 1.7). Himachal Himalaya can broadly be divided into two major geo-tectonic zones namely Lesser Himalayan Tectogen in the south and the Tethys Himalayan Tectogen in the north respectively (*Srikantia and Bhargava, 1998*). Himalayan belt is divided into a number of tectonic units from south to north based on the presence of major thrusts and predominant lithologies extending through the entire longitudinal range of the orogen (*Gansser, 1964*) (Fig.1.7). At present, the Himalayas are divided into five widely accepted lithotectonic units namely Sub or Outer Himalaya, Lesser or Lower Himalaya, Great or Higher Himalaya, Tethys Himalaya and Trans-Himalaya or Indus-Tsangpo suture zone from south to north successively (*Sharma, 1998*). Larji, Shali and Deoban, the three tectono-stratigraphic domains of Proterozoic age, are identified in the Lesser Himalayan Tectogen of the Himachal Pradesh. The term Tethys Himalayan Tectogen refers to the thick sedimentary sequence ranging from Late Precambrian (>600 million years) to the Cretaceous and Eocene (95-45 million years) extended to further northeast after Greater/Higher Himalaya *(Valdiya 1980, 2016)*. The Central Crystalline Zone of the Himalaya represents a geanticline along the axis of the Great Himalaya Range, a zone of progressive regional metamorphism and the principal Himalayan orographic axis. It represents a tectonised basement which has undergone multiphase deformation including high grade regional metamorphism, deformation, migmatisation and intrusion of remobilised granite (*Srikantia and Bhargava, 1998*). The Vaikrita, Jutogh and Kulu are the principal Proterozoic crystalline belts of the Tethys Himalayan Tectogen.

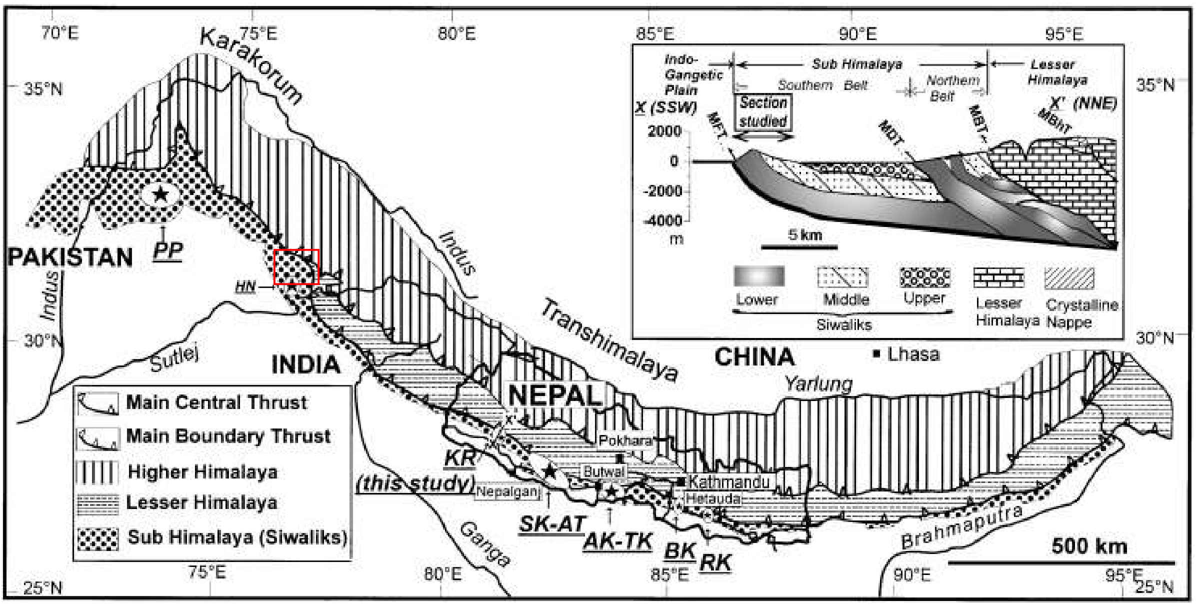


Figure 1.7: Map Showing Tectonic Divisions of Himalaya and the Foreland Basin on South of Main Central Thrust (MCT) and the Siwaliks (After Gansser, 1964).

In the Lesser Himalayan Tectogen Paleogene rocks were developed. These are Sirmur Group of rocks. The Sirmur Group is closely associated with the Mandi volcanics of Sundernagar Group. The Mandi volcanics are tholeiitic lava flows interstratified with minor quartz arenite and shale (*Srikantia & Bhargava, 1998*). These volcanics are hard, massive with the development of vesicles and amygdules. The amygdules are filled with quartz, epidote and minor calcite. The volcanics occur as discontinuous exposures for a long distance (*Ahmad and Bhat, 1987*). The general trend of the flows is NW-SE with 50-60° northeasterly dip. Mandi volcanic rocks occur in the Para-autochthonous zone of the Lesser Himalayas and comprise of olivine-free basalts with sub-calcic plagioclase and subordinate andesites. The variation diagrams clearly show that these volcanics are derivative from the parental magma of Alkali Basalt lineage (*Kanwar and Singh, 1986*).

Rapa and Nagal, 1984 have carried large scale mapping on 1:25,000 on the right bank of the Beas River between Pandoh and Nahogi sections. They have established the continuity of the Chamba, Manjir and Salooni formations into Nahogi Area, where they brought out the synclinal core of the basinal closure of the Chamba basin. An entirely new classification and nomenclature was proposed by *Des Raj & Inder Singh, 1990* for Vaikrita Group of rocks along with overlying Manjir and Katarigali Formation during mapping of FS 1988-89 in parts of toposheet nos. 53E/1&2.

Group	**Formation**	**Lithology**	**Age**
Quaternary	Older & Newer Alluvium	Unconsolidated to semi-consolidated gravel, sand, silt, clay.	Holocene
Siwalik	Lower, Middle & Upper	Sandstone, shale, conglomerate	Pleistocene to Miocene
Sirmur	Kasauli	Grey sandstone, siltstone, shale	Eocene to Miocene
	Dagshai	Maroon sandstone, siltstone	
Mandi-Dalhousie Granitoid		Biotite-muscovite granite, tourmaline granite, Granite gneiss	Palaeozoic
	Katarigali	Carbonaceous phyllite, slate and quartzite	Neoproterozoic
	Manjir	Diamictite with sandstone and intercalated argillites	
Simla	Basantpur	Argillite and siltstone with bands of limestone and dolomite	
	Guma Formation	Shale, salt, grit and dolomite	
Shali	Sorgharwari	Limestone	Mesoproterozoic
	Khatpul	Dolomite, quartzarenite and shale	
Sundernagar	Maloh	Purple quartz arenite, shale, slate phyllite	Palaeoproterozoic

Mandi volcanics		Basaltic and Andesitic flows	Palaeoproterozoic
Kullu	Khokhan	Phyllite, quartzite	Undifferentiated Proterozoic (?)
	Gahr	Gneisses, phyllite	
	Khamrada	Carbonaceous phyllite, quartzite	
Vaikrita	Chamba	Phyllite, slate	
	Morang	Schist, quartzite	

Table 1.1: Generalised regional stratigraphy of the area (Ref: Geology and Mineral Resources of Himachal Pradesh, Misc. Pub. 30, Part XVII, 2nd Revised Ed., 2012)

Himachal Pradesh is located in the Western Himalayas and is primarily composed of Precambrian rocks that were formed and deformed during the collision between the Indian and Asian plates, followed by the orogenic processes that created the Himalayas. The region has a rugged terrain with elevations ranging from 320 m to 6,975 m. Around 60-60 million years ago, the Indian craton collided with Asia, causing massive folding and pushing of rock sections. The landscape has since been shaped by focused orographic precipitation, glaciation, and rapid erosion.

The elevation of Himachal Pradesh increases from southwest to northeast, with the orogenic materials also varying in this direction. The region is divided into five major tectonic units, represented by fault-bounded NW-SE trending belts (Figure 1.7). These units, from southwest to northeast, include the Indo-Gangetic Plain, Sub-Himalayan Sequence, Lesser Himalayan Sequence, Greater Himalayan Crystalline Complex, and Tethyan Himalayan Sequence.

The Indo-Gangetic Plain is a recent, active foreland basin made up of alluvial sediments from the Himalayas. The Sub-Himalayan Sequence consists of sediments deposited during the Miocene in the foreland basin. The Lesser Himalayan Sequence was emplaced before the mountain-building processes began. The Greater Himalayan Crystalline Complex represents a high-grade unit that moved southwest from the hinterland, while the Tethyan Himalayan Sequence consists of strata formed on the former passive margin of the northern Indian plate.

Himachal Pradesh is situated at the northeastern end of India, within the Himalayan Mountain range. It is bordered by Pakistan to the west, China to the north, and the Indian states of Haryana, Punjab, and Uttarakhand to the south.

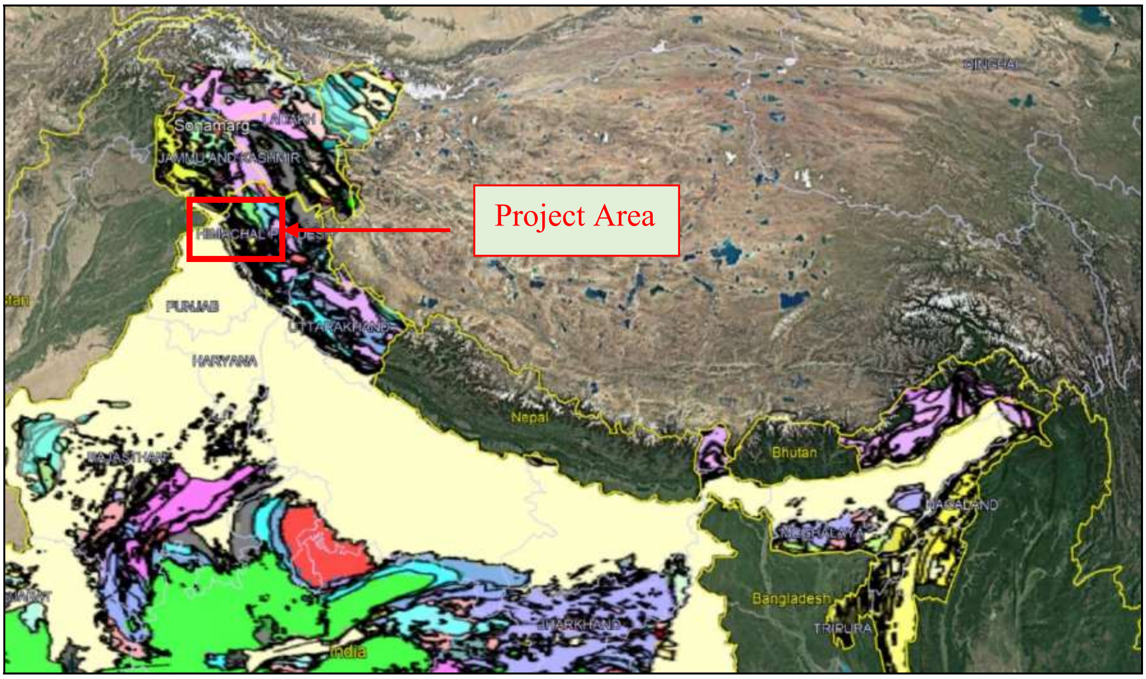


Figure 1.8: Geological Map of India Project Area Marked in Red (Geological Survey of India (1998). Geological Map of India, & 7th edition. Ministry of Mines, Government of India)

The Himalayan Mountain range was formed as a result of the collision between the Indian and Eurasian plates, leading to the closure of the Tethys Sea. This mountain range is composed of litho-tectonic zones, which are divided by thrust and normal faults (Gansser, 1964).

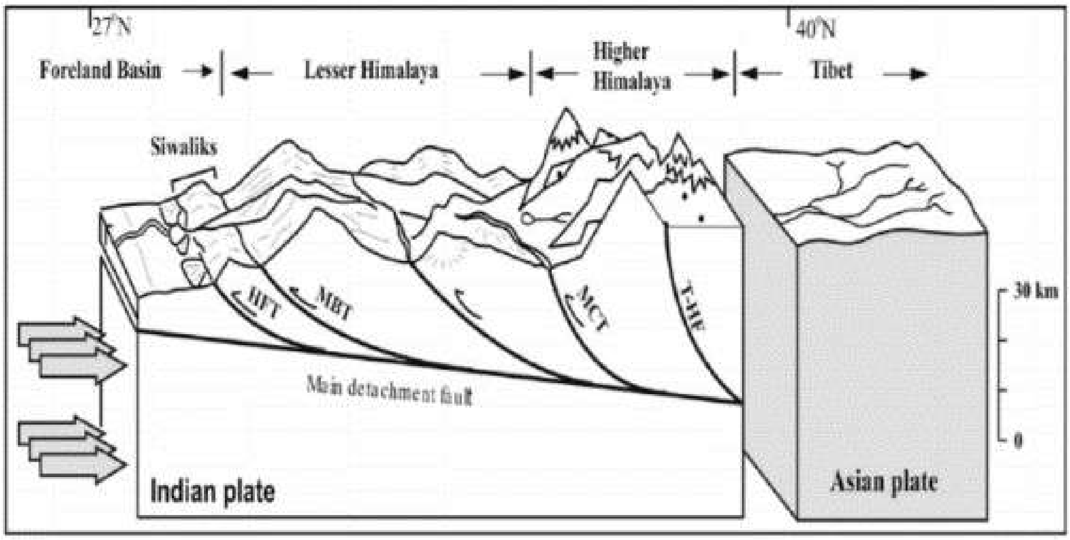
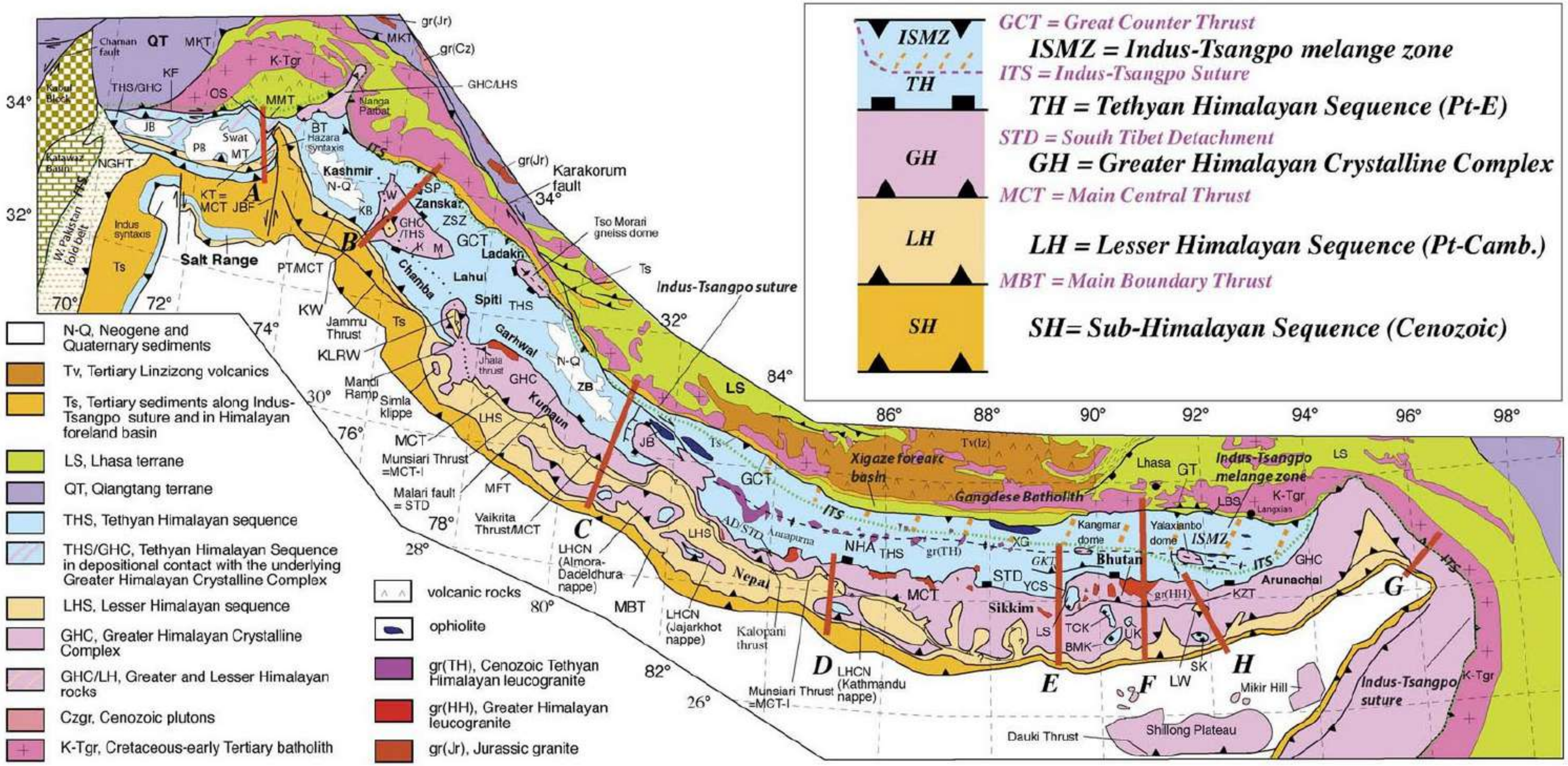


Figure 1.9: General Scheme of Compresive Forces Himalayan Range



Faults
AD, Annapurna Detachment
BT, Batal thrust
GCT, Great Counter Thrust
GT, Gangdese Thrust
JBF, Jhelum-Balakot fault
K, Kilar shear zone
KZT, Kakhtang-Zimithang thrust
KF, Kohistan fault
KT, Khairabad thrust
LHCN, Lesser Himalayan Crystalline Nappes
M, Miyar thrust
MBT, Main Boundary Thrust
MCT, Main Central Thrust
MFT, Main Frontal Thrust
MKT, Main Karakorum Thrust
MMT, Main Mantle Thrust
MT, Mansehra thrust
NGHT, Nathia Gali-Hissartang thurst
NHA, North Himalayan antiform.
OS, Oghi shear zone
PT, Panjal Thrust = MCT
W, Warwan thrust
STD, South Tibet Detachment
YCS, Yadong cross-structure
ZSZ, Zanskar shear zone

Ophiolites
SP, Spongtang ophiolite
JB, Jungbwa ophiolite
XG, Xigaze ophioite
LBS, Luobusha ophiolite

STD Klippe
TC, Tang Chu klippe
UK, Ura klippe
SK, Sakteng klippe
LS, Linshi klippe

MCT windows
KLRW, Kullu-Larji-Rampur window (NW India)
KW, Kishtwar window (NW India)
LW, Lumpla Window (NE India)

Himalayan Basins
ZB, Zada Basin (SW Tibet)
KB, Kashmir Basin (Pakistan/India)
PB, Peshawar Basin (Pakistan)
JB, Jalalabad Basin (Pakistan)

Figure 1.10: Regional Geological Plan (Yin, 2006)

Himachal Pradesh is located in the Western Himalayas and is primarily composed of Precambrian rocks that were deposited and deformed during the collision between India and Asia, along with the subsequent orogenic processes that formed the Himalayas. The region features rugged terrain with elevations ranging from 320 m to 6975 m. Around 60 million years ago, the Indian craton collided with Asia, causing the massive pushing and folding of rock sections. The landscape has since been shaped by focused orographic precipitation, glaciation, and rapid erosion.

The elevation of Himachal Pradesh increases from southwest to northeast, with the orogenic materials also varying in that direction. The region is divided into five major tectonic units, forming fault-bounded NW-SE trending belts. From southwest to northeast, these are the Indo-Gangetic Plain, Sub-Himalayan Sequence, Lesser Himalayan Sequence, Greater Himalayan Crystalline Complex, and Tethyan Himalayan Sequence. The Indo-Gangetic Plain is an active foreland basin composed of alluvial sediments derived from the Himalayas. The Sub-Himalayan Sequence consists of sediments deposited in the foreland basin during the Miocene. The Lesser Himalayan Sequence represents materials that were emplaced before the mountain-building process. The Greater Himalayan Crystalline Complex is a high-grade unit that has been moved southwestward from the hinterland. Finally, the Tethyan Himalayan Sequence consists of strata deposited along the former passive margin of the northern Indian plate.

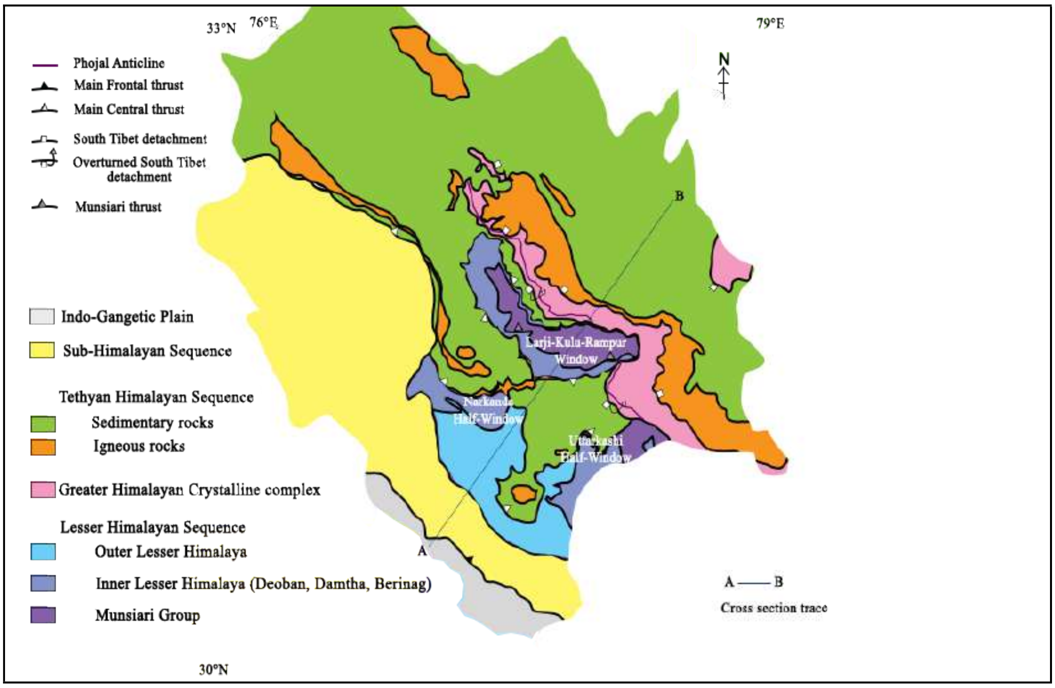


Figure 1.11: Geological Map of Himachal Pradesh.

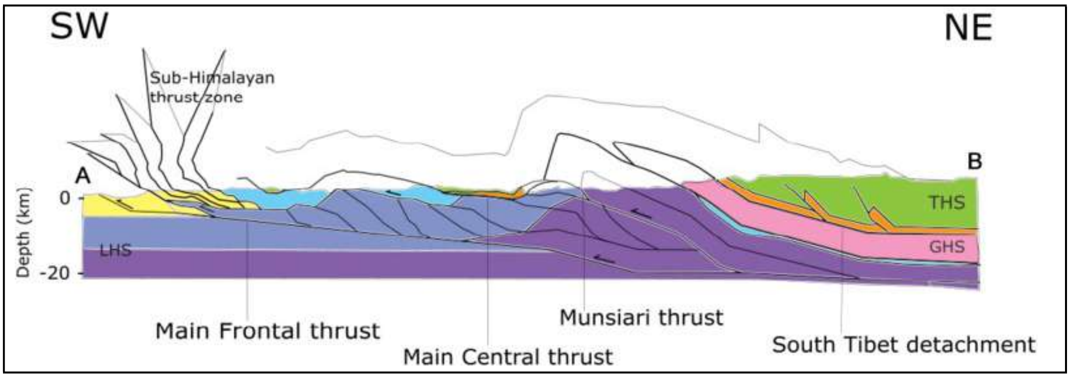


Figure 1.12: Cross Section of Himachal Pradesh, Tectonic Units in the Region Are Arranged Generally in the NE-SW Direction. Large Scale Folds and Faults are Present.

6.1 Indo-Gangetic Plain

The Indo-Gangetic Plain (IGP), situated at the southwestern edge of the state, is an alluvial plain made up of sediments eroded from the Himalayan rocks. This area serves as an active depocenter, receiving a significant sediment influx from major nearby rivers. For example, the frontal Sutlej's Himalayan catchment has a high average erosion rate of 1.8 mm/year, which contributes to a substantial sediment load. Beneath the Indo-Gangetic Plain lie the generally undeformed strata of the Indian Craton. These regions are all bounded on the northeast by the Main Frontal Thrust (MFT).

6.2 Sub-Himalayan Sequence

The Sub-Himalayan Sequence, also known as the Siwalik Group, primarily consists of sedimentary layers dating from the Paleocene to the Pliocene. These sediments share a similar origin to those found in the Indo-Gangetic Plain. However, sedimentation began before the India-Asia collision and persisted until the late Miocene. During this period, the depositional environment transitioned from shallow marine to continental.

Age	**Lithology**	**Unit**	**Deposition Environment**
Pleistocene-Miocene (11-7Ma)	Siwalik Formation	Sandstone, Conglomerate, Siltstone	Continent
Miocene (20-13Ma)	Dharamsala Formation	Gray Sandstone, Siltstone, Shale, Caliche	Continent
Latest Paleocene-Middle Eocene	Subathu Formation	Limestone, Shale, Minor Fine-Grained Sandstone	Shallow marine
Late Cretaceous-Paleocene	Singtali Formation	Limestone, Minor Quartz Arenite	Shallow marine

Table 1.2: Stratigraphy (SHS)

Two sub-groups have been recognized within the Sub-Himalayan Sequence: the Paleocene to Eocene shallow-marine deposits and the Miocene to Pliocene continental deposits. The older sub-group is represented by the Singtali and Subathu Formations, while the younger sub-group is composed of the Dharamsala and Siwalik Formations. These two sub-groups are separated by an Oligocene unconformity, which suggests a period of non-deposition during the Oligocene, possibly due to a temporary uplift of the Indian continent. During this time, the region may have risen above sea level, possibly triggered by mantle upwelling from the detachment of the Indian oceanic slab or the development of a forebulge due to downward slab-pull.

The Sub-Himalayan Sequence has been thrust southwestward at a rate of 10±6 mm/yr along the Main Frontal Thrust during the Quaternary. Within this sequence, rocks have been extensively thrust and accreted, forming the Sub-Himalayan Thrust Zone in southwest Himachal Pradesh (Fig. 1.11). The unit is capped by the Krol Thrust and the Tons Thrust.

6.3 Lesser Himalayan Sequence (LHS)

The Lesser Himalayan Sequence is primarily composed of metasedimentary rocks, metavolcanic rocks, and augen gneiss. These strata were initially deposited as detrital sediments during the Paleoproterozoic to Cambrian periods and were later metamorphosed into rocks of greenschist and amphibolite facies. This sequence is bounded at the top by the Main Central Thrust and can be divided into four distinct units.

Age	Unit	Formation	Lithology	Note
Neoproterozoic-Lower Cambrian	Outer Lesser Himalaya	Tal Formation Krol Group Shimla Group Basantpur Formation (Mandhali)	Sandstone, Siltstone, Dolomite, Limestone and Shale	Exposed at the South, Southeast Part of the State
Paleoproterozoic -Neoproterozoic	Parautochthon	Deoba Group Damtha Group	Siliciclastic And Carbonate Rocks	• Exposed at the Uttarkashi and Narkanda Half-Windows • Part of the Inner Lesser Himalaya
Paleoproterozoic	Berinag			• Rocks Were

	Group		Sericitic Quartz-Arenite With Metabasalt Intrusion	Metamorphosed Under A Greenschist Facies Condition • Part of the Inner Lesser Himalaya
Paleoproterozoic	Munsiari Group	Wangtu Jeori	Granitic Augen Gneiss Paragneiss, Mica Schist	• The Munsiari Group is also Named Lesser Himalayan Crystalline Sequence (LHCS) • Experienced Amphibolite Facies Metamorphism Between 11 And 6 Ma (Miocene)

Table 1.3: Stratigraphy (LHS)

6.4 Greater Himalayan Crystalline Complex (GHC)

The Greater Himalayan Crystalline Complex, also called the High Himalayan Crystalline Sequence, consists of high-grade metamorphic rocks dating from the Paleoproterozoic to Ordovician. This complex, 4.5 to 8 km thick, includes Paragneiss, schist, and orthogenesis, with leucogranites concentrated at the top. The metamorphic grade increases upwards, showing staurolite, kyanite, sillimanite, and migmatite zones. Peak metamorphism occurred around 23 million years ago, with temperatures reaching 750°C and pressures of 8 kba.

6.5 Tethyan Himalayan Sequence (THS)

The Tethyan Himalayan Sequence comprises Neoproterozoic to Cretaceous, fossiliferous sedimentary strata interlayered with Paleoproterozoic to Ordovician igneous rocks. At the base of this unit, Baragaon granitic gneiss having an age of 1840 Ma has been identified.

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Unit	Formation	Note
Sedimentary Rocks	Giumal-Chikkim succession Tandi Group Thaple-Muth-Lipak succession Parahio Formation Haimanta Group	• Consists Of Sedimentary and Low-Grade Metasedimantary Rocks • Deposited at the Northern Boundary of the Indian Continent
Igneous Rocks	Early Paleozoic granitoids	• emplaced in Cambrian-

	Neoproterozoic granite Baragaon granitic gneiss	Ordovician, peraluminous wit h mafic enclaves[12] • ca. 830Ma • ca. 1850Ma

Table 1.4: Stratigraphy (THS)

7 PROJECT GEOLOGY

The rock formations occupying the district range in age from pre-Cambrian to Quaternary period. The generalized geological succession in the district is given below: -

GROUP	FORMATION	LITHOLOGY	AGE
Newer Alluvium	Channel Alluvium	Grey micaceous sand, silt and gravel	Holocene
	Undifferentiated Quaternary Deposits	Sand, gravel, silt and clay	
Older Alluvium		Brown silt, sand, laminated clay with concrete nodules or beds	Middle to Late Pleistocene
Upper Siwalik		Soft sandstone, sand rock, clay and boulder conglomerate	Middle to Early Pleistocene
Middle Siwalik		Sandstone, clay and gravel bed	
Lower Siwalik		Sandstone and sandy clay	
Sirmur	Kasauli	Green micaceous sandstone and interbedded greenish purple shale	Late Plaeocene to Early Miocene
	Dagshai	Red to purple clay, siltstone and intraformational conglomerate	
	Subathu	Olive green shale, limestone and quartzite	
	Kakra	Variegated shale, intercalated limestone with basal laterite	Plaeocene
Baliana	Infrakrol	Dark grey pyritous shale and subordinate quartzarenite	Neo-Proterozoic Vendian
Simla	Sanjauli	Shale, siltstone, greywacke and conglomerate	Neo-Proterozoic
	Chhaosa	**Shale, siltstone, greywacke and orthoquartzite**	
	Kunihar	**Shale, siltstone and stromatolitic limestone**	
	Basantpur	Platy to massive limestone, fissile shale, siltstone and quartzite	
UNCONFORMITY			

GROUP	FORMATION	LITHOLOGY	AGE
	Darla Tattapani Volacanics	Massive to schistose metabasic flows with occasional beds of quartzarenite and phyllite	Meso-Proterozoic
UNCONFORMITY			
Shali	Parnali	Cherty stromatolitic dolomite, quartzite, limestone	Meso-Proterozoic
	Makri	Purple and green slate, quartzite and cherty dolomite	
	Tattapani	Pink grey cherty dolomite (stromatolitic) and shale	

Table 1.5: Stratigraphic Succession of the Project Area (Highlighted in Red Colour).

Geologically, the region is primarily composed of Proterozoic and Tertiary-aged rocks, including the Shali Group, Darla-Tattapani volcanics, Simla, Baliana, Sirmur, Siwalik, and both Older and Newer Alluvium groups (Fig. 1.13). In the northern part of the area, the Shali Group and Darla-Tattapani volcanics are folded into a significant NW-SE trending syncline. The region is crossed by three major thrusts: the Bakhalag, Dehar, and Gambhar thrusts, which run from southwest to northeast.

Simla Group

The Simla Group in this area includes the Basantpur, Kunihar, Chhaosa, and Sanjauli formations (Table 1.5). The Basantpur Formation unconformably rests over the Darla-Tattapani volcanics and is in tectonic contact with the Shali Group. In the southeastern part, the Simla Group is thrust over the Infra-Krol Formation. The Simla Group is in gradational contact and unconformably overlain by the Baliana Group.

Chhaosa Formation

The Chhaosa Formation, which overlies the Basantpur Formation, consists of thinly laminated shale, siltstone, wacke, and orthoquartzite. This formation is a thick, rhythmic sequence of shale, siltstone, and greywacke, which transitions upward into a coarser clastic sequence found in the Sanjauli Formation. Exposed east of Arki ki Khad, the sandstones in this formation are fine- to medium-grained, parallel-laminated, and occasionally show low-angle cross-lamination. Features such as flute casts, load casts, and current ripples are common, indicating rapid deposition by traction currents.

The Kunihar Formation is characterized by a sequence of shale, siltstone, and stromatolitic limestone.

7.1 Geology along the Alignment

The geological map of toposheet no. 53A/16, at a scale of 1:50,000, was obtained from the Geological Survey of India, Chandigarh. This map was compiled during the

50K GMS series and later updated with data from the 1:25,000 scale Siwalik map created during the 2016-17. The map provides a detailed geological overview (Fig. 1.14). To better understand the lithological exposures, the geological map was overlaid with a grid reference map, dividing the area into 2km x 2km cells for site selection.

In areas where conglomerates are present, the region is highly prone to landslides. However, areas with shale, slate, sandstone, dolomite, limestone, quartzite, and phyllite are controlled by discontinuity orientations and can fall between stable and unstable zones depending upon orientation of slopes and joints. Sections along the alignment where Quartzite rocks, sandstone, and dolomite occur are relatively stable, but joint orientations form wedges, causing rock falls on the highway. The Slopes with high angle and unfavorable joint orientation may cause landslides which can be prevented while using proper remedial measures. Slope protection will be necessary along the cutting sections.

The Solan region, part of the Lesser Himalayas, experiences landslides due to its geologically brittle terrain, compounded by heavy rainfall and other natural and human-induced factors. Mountain roads, which are vital infrastructure, suffer significantly from landslides, disrupting regular traffic, particularly during the monsoon season. These events have a negative impact on road networks, communications, and economic or development activities. Landslide occurrences in the project area have been increasing, with most incidents happening during extended periods of rainfall.

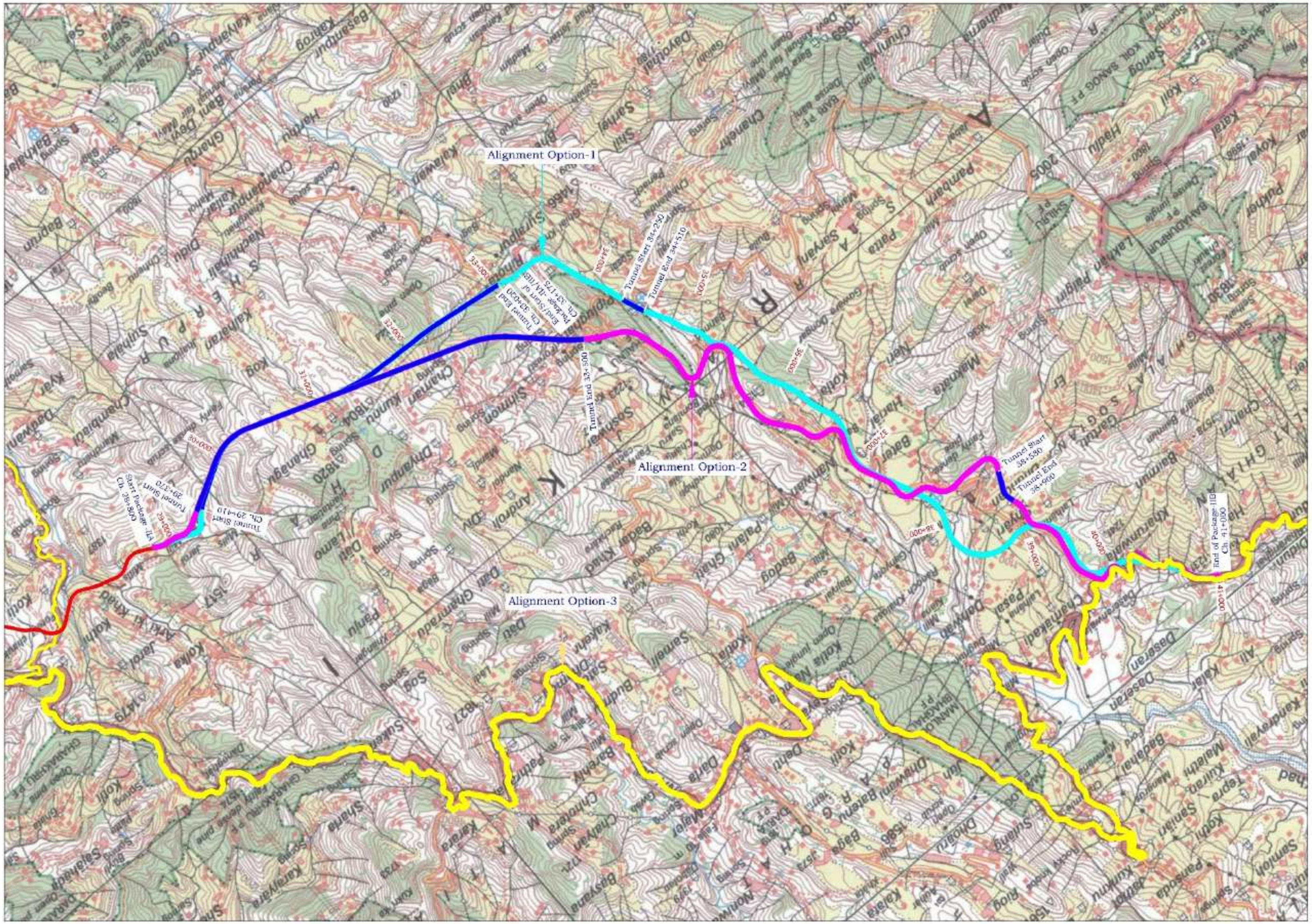

Figure 1.13: Topographic Map of Project Area

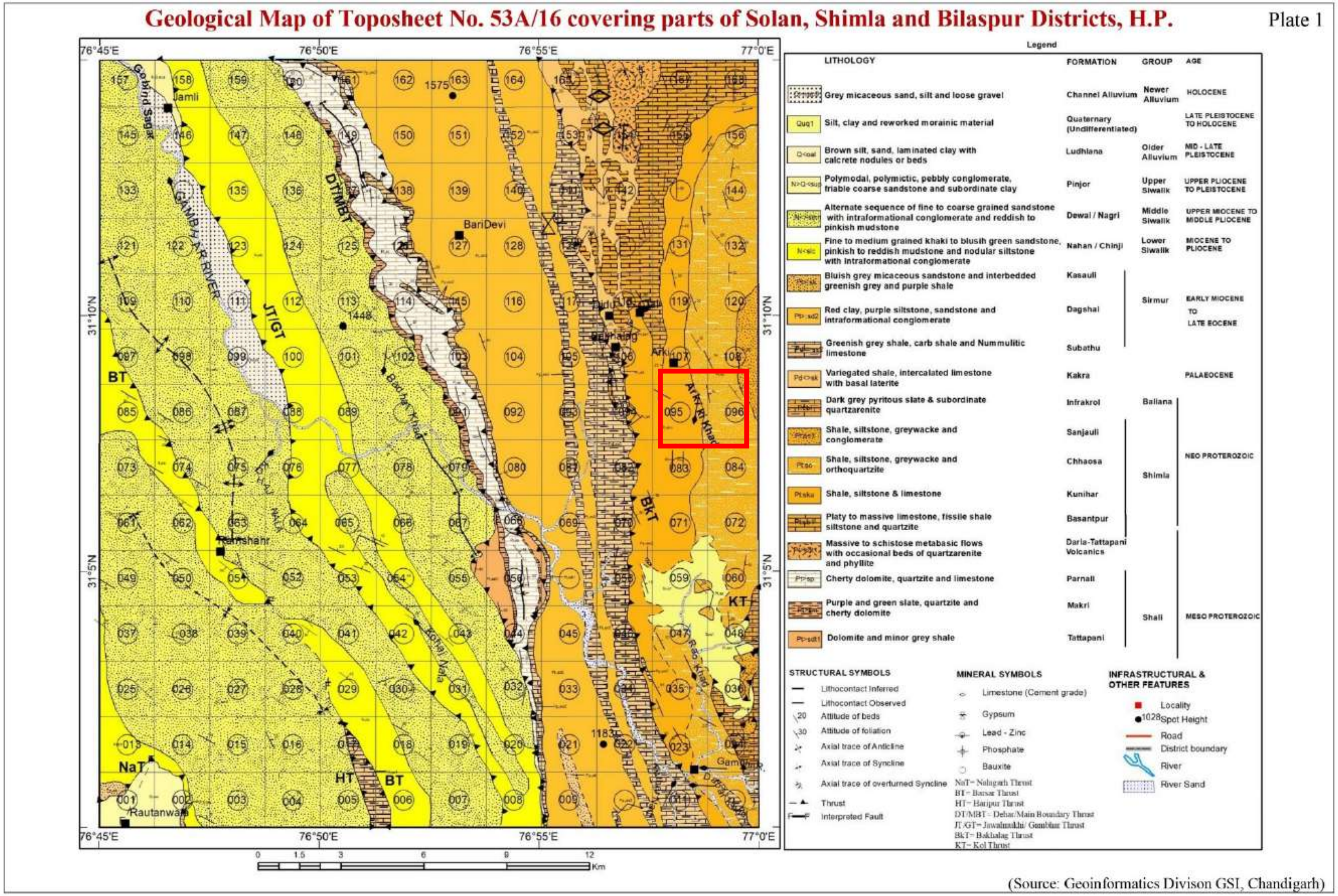

Figure 1.14: Geological Map of Solan Shimla and Bilaspur Districts, H.P. Project Area Marked in Red (Source: GSI, Chandigarh)

- **Drainage Map**

The drainage map was created by digitizing the streams from the base map (toposheet 53A/16) of the area at a scale of 1:50,000. The map is further divided into 2km x 2km grid intervals to identify potential sample collection locations. Points for stream sediment, slope wash, soil, and water samples, obtained using a GPS device, were plotted on the drainage map using ArcGIS software. This map is essential for planning and selecting sites for stream sediment sampling.

The area is part of the Sutlej River drainage basin, with the Gambhar River being its primary tributary, flowing from southeast to northwest. The Gambhar River is joined by several smaller streams, including Kuthar Nadi, Dabar Khad, Kuni Khad, and Kohaj Nala (Fig. 1.14). The drainage pattern is predominantly dendritic to trellis in shape. The Gambhar River follows the Gambhar Thrust in its lower reaches, indicating structural control of the drainage system. On the drainage map, the catchment area is outlined, and water sample collection points are marked on a 5' x 5' grid, with each grid representing a specific water collection point within the basin area (Fig. 1.16).

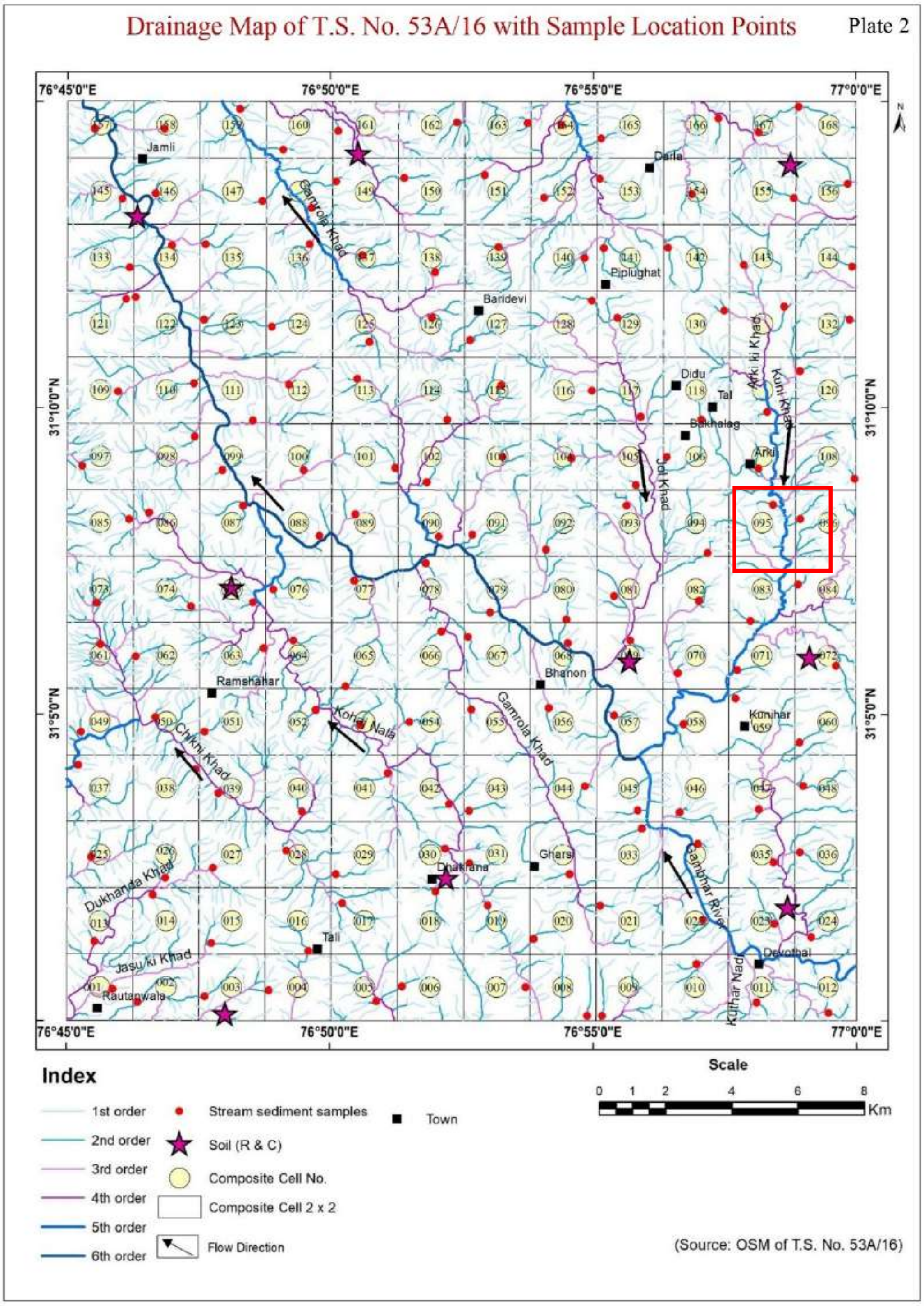

Figure 1.15: Drainage Map of Solan Shimla and Bilaspur Districts, H.P. (Project Area Marked in Red) (Source: GSI)

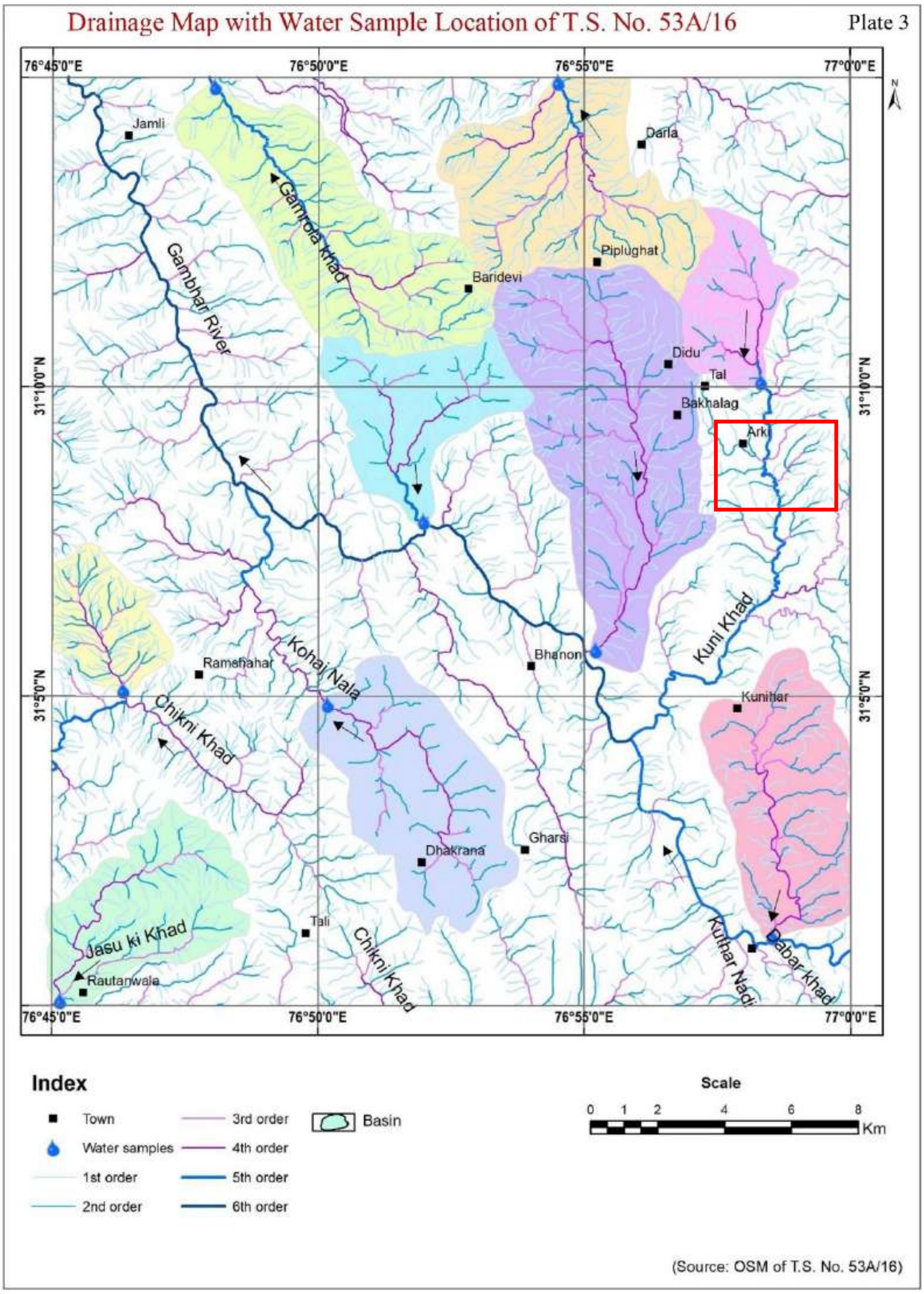

Figure 1.16: Drainage Map of Solan Shimla and Bilaspur Districts, H.P. (Project Area Marked in Red) (Source: GSI)

Digital Elevation Model Map

A Digital Elevation Model (DEM) is a specialized dataset that represents the terrain relief by showing elevation variations across a surface, essentially providing a 3D representation of the terrain. The DEM for the area was created using ArcGIS software with data from the Shuttle Radar Topography Mission (SRTM), which was downloaded from the Bhuvan store, NRSC (Fig. 1.17). The elevation in the region ranges from a minimum of 358 meters above mean sea level in the southwestern part to a maximum of 2069 meters above mean sea level at the northern peak. Tectonic contacts, including thrusts, as well as antiformal and synformal axes, are also marked on the map.

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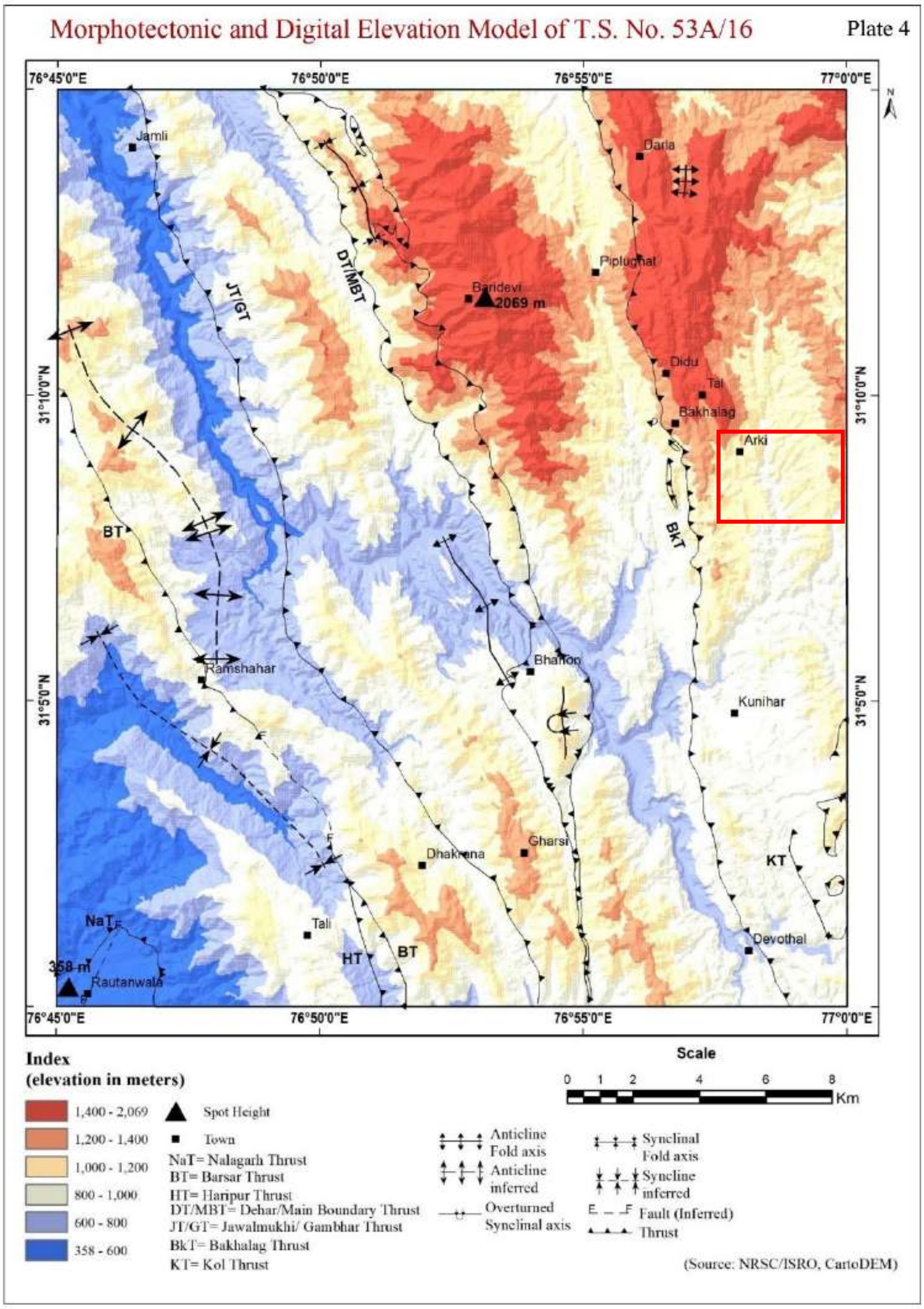


Figure 1.17: Digital Elevation Model (Project Area Marked in Red) (Source: GSI)

During the field investigation along the tunnel alignment, the primary rock types encountered were shale/slate and dolomite/limestone, with quartzite and sandstone also present. The identification of these rock types was based on visual inspection, and geotechnical investigations are still ongoing. The rocks in the portal area are categorized as poor to fair quality, requiring special treatment in the tunnel design. Throughout the alignment, no rocks of very poor quality were observed, but caution is needed during tunnel construction, as the rock classes range from poor to fair.

The Geological Strength Index (GSI) has been applied for rock mass classification along the proposed tunnel, as it is an effective system based on rock mass observations. It combines two key parameters of geological processes: (i) blockiness of the rock mass, and (ii) the condition of discontinuity surfaces.

Based on the current rock mass conditions, the classification corresponds to disintegrated rock mass in Hoek's GSI chart, characterized by highly interlocked, fractured shale and slate, mixed with dolomitic/limestone and quartzite rocks. The discontinuity surfaces range from slightly rough to smooth and are moderately to highly weathered. Combining both the structure and surface condition, the GSI is estimated to range between 20 and 50.

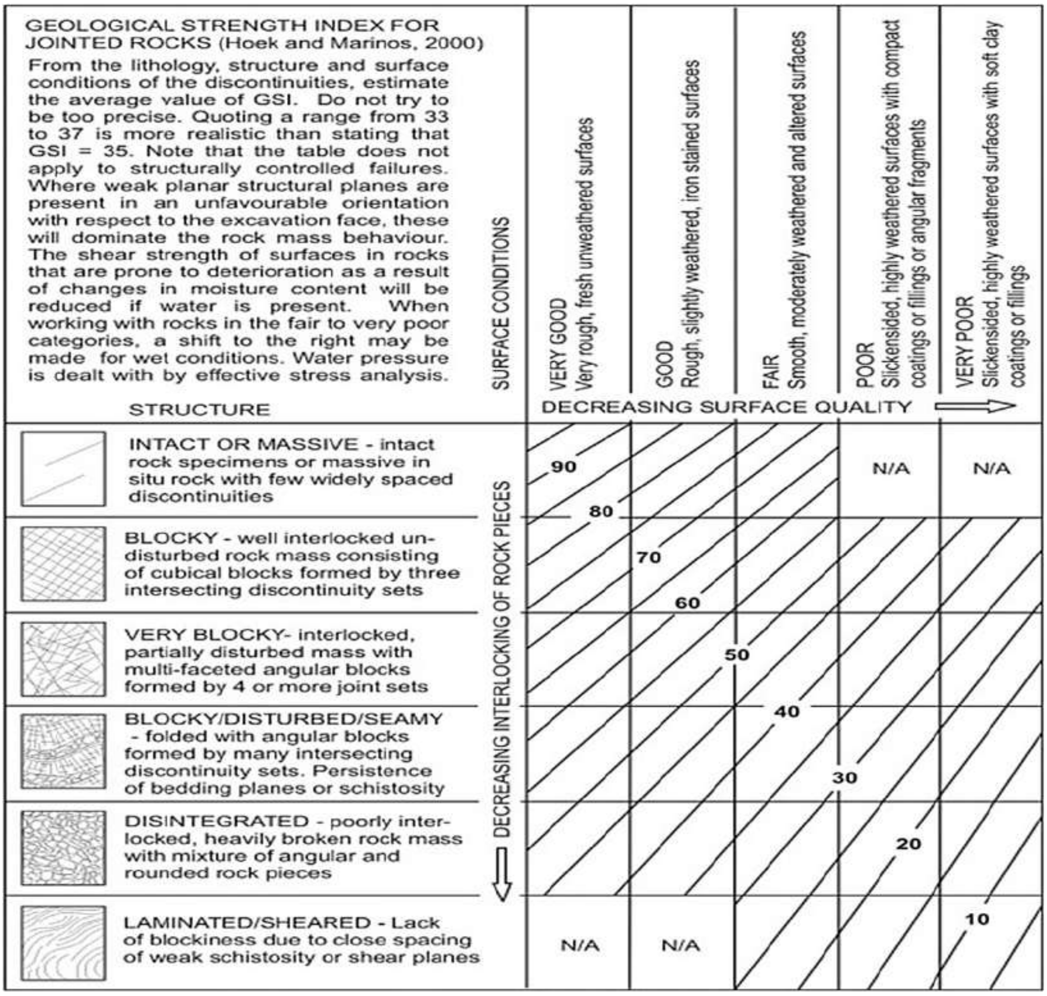


Figure 1.18: Geological Strength Index for Jointed Rocks.

8 Seismicity

The Seismicity Map of India reveals a higher concentration of earthquake epicenters along the Himalayan arc and the adjacent Indo-Gangetic plain. This region stands out globally, as other areas do not exhibit such a pronounced concentration of seismic activity.

The figure below shows the Seismic Zoning Map of India, highlighting the location of the project area.

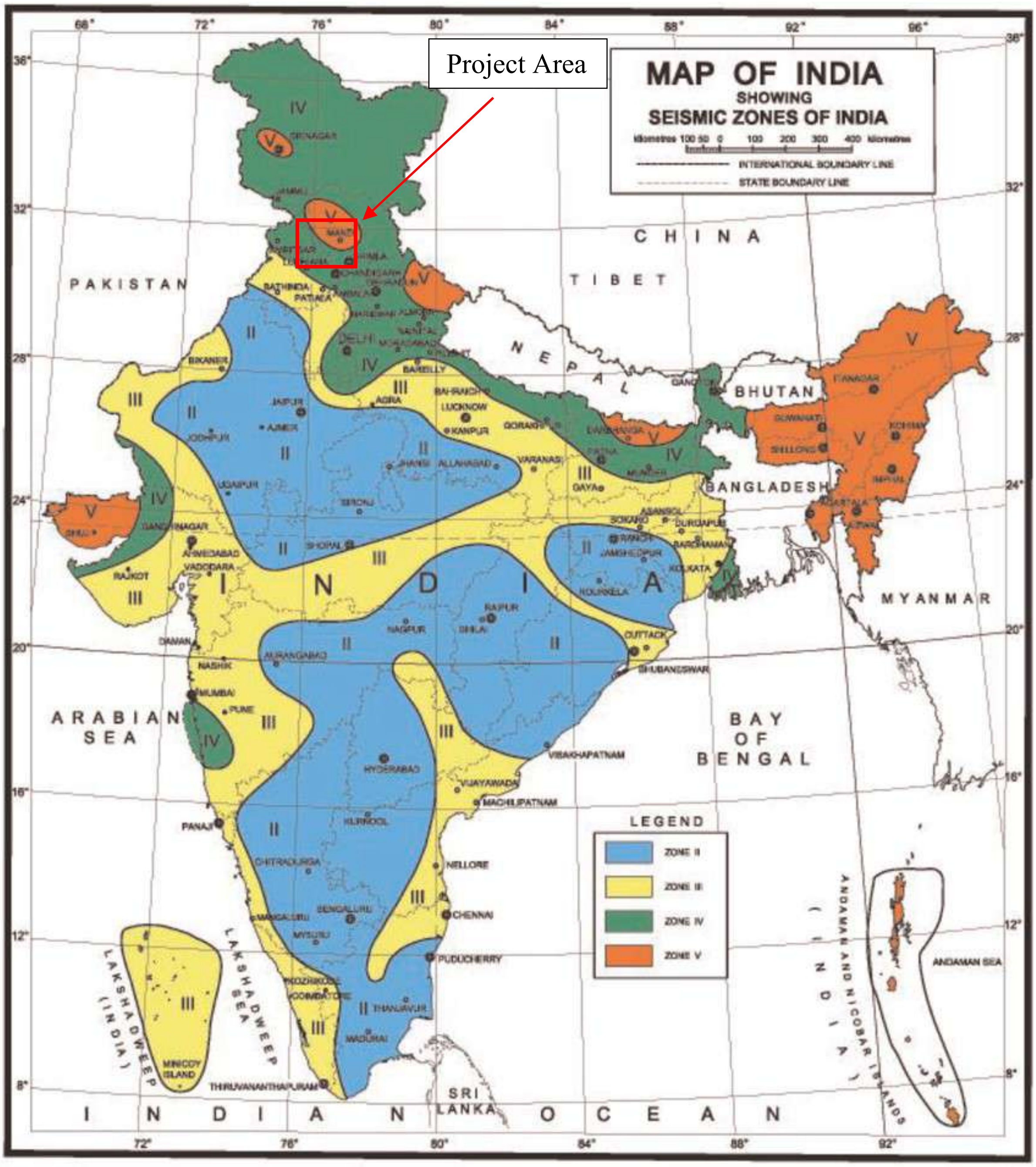


Figure 1.19: Seismic Zoning Map of India (Project Area Marked in Red)

Each Seismic Zone has been characterized by a Basic Horizontal Seismic Coefficient and a Seismic Zone Factor, table 1.6.

Seismic Zone	Basic Horizontal Coefficient	Seismic Zone Factor
I	0.08	0.40
II	0.05	0.25
III	0.04	0.20
IV	0.02	0.10
V	0.01	0.05

Table 1.6: Basic Horizontal Seismic Coefficients Values and Seismic Zone Factors in Different Zones

According to the Amateur Seismic Centre (ASC), Himachal Pradesh is predominantly situated in the Himalayan mountains, specifically in the Punjab Himalayas. Due to its location, the region experiences numerous mild earthquakes annually. Significant earthquakes have occurred throughout the state, with the largest being the 1905 Kangra Earthquake. Major geological features such as the Himalayan Frontal Thrust, the Main Boundary Thrust, and several other thrusts, including the Krol, Giri, Jutogh, and Nahan thrusts, are found in this area. Additionally, there are several smaller faults, such as the Kaurik Fault, which triggered the 1975 earthquake. However, it is important to note that being near faults does not necessarily equate to a higher seismic hazard, as earthquake damage is influenced by various factors, including subsurface geology and adherence to building codes.

The Seismic Zoning Map of Himachal Pradesh, along with the location of the project area, is shown in Figure 1.20. As depicted, the PKG-IIA site is situated in Zone IV. The Seismicity Map for Himachal Pradesh highlights the significant concentration of earthquake epicenters in this region.

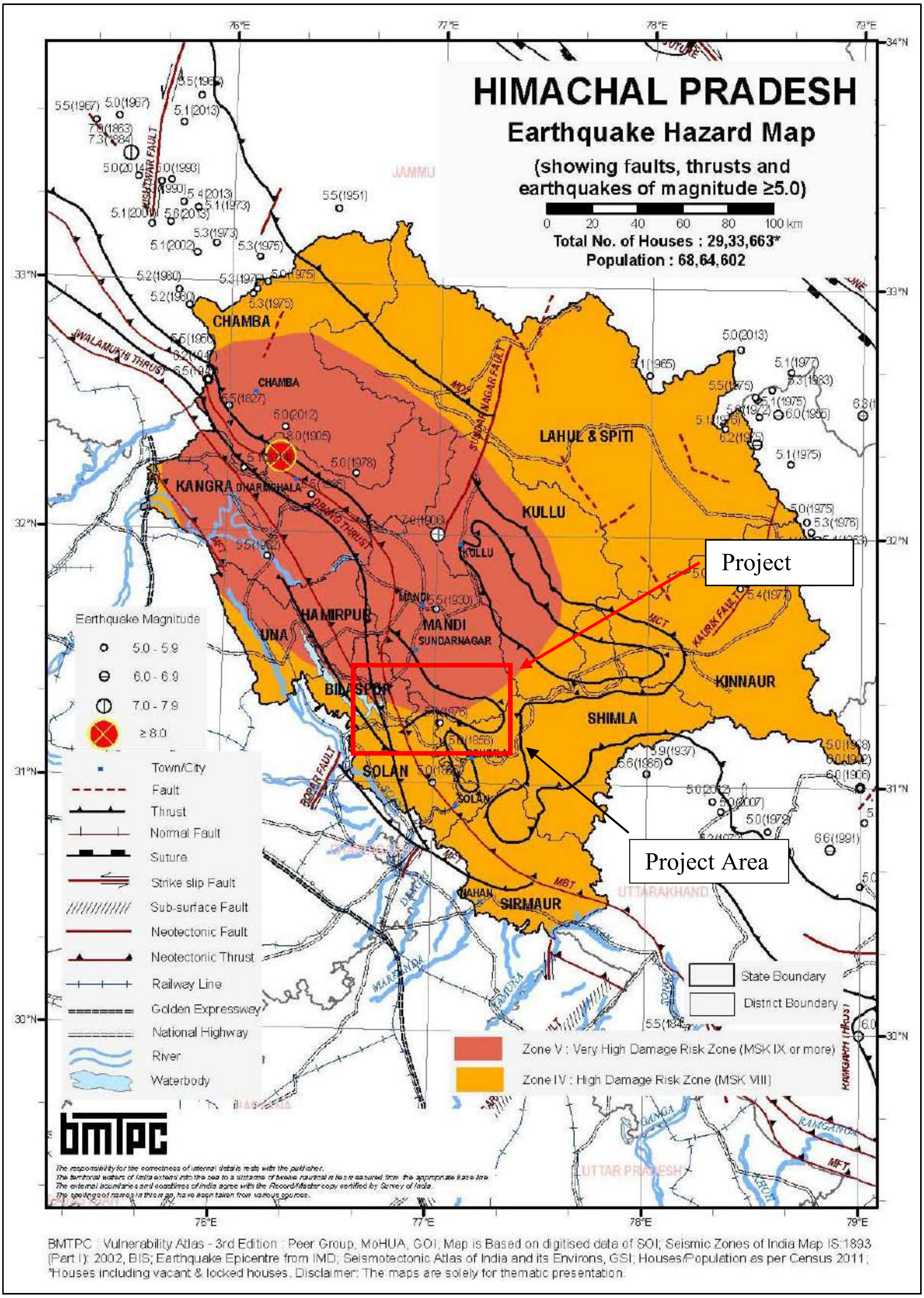


Figure 1.20: Earthquake Hazard Map Showing Fault & Thrust of Himachal Pradesh (Project Area Marked in Red).

S. No.	Name of District	Seismic Zones	Intensity MSK IX or more % Area	MSK VIII % Area
1	Kangra	V/IV	98.6	1.4
2	Mandi	V/IV	97.4	2.6
3	Hamirpur	V/IV	90.9	9.1
4	Chamba	V/IV	63.2	36.8
5	Kullu	V/IV	53.1	46.9
6	Una	V/IV	37.0	63.0
7	**Bilaspur**	**V/IV**	**25.3**	**74.7**
8	**Solan**	**V/IV**	**2.4**	**97.6**
9	Lahaul & Spiti	V/IV	1.1	98.9
10	Bilaspur	V/IV	---	100
11	**Shimla**	**V/IV**	**---**	**100**
12	Sirmour	V/IV	---	100

Table 1.7: Districts of Himachal Pradesh with Seismic Intensities

From the above information, it is evident that the region experiences frequent earthquakes and is highly susceptible to seismic events. Over the past two centuries, major earthquakes in the Himalayas have occurred at an average interval of approximately every 30 years. The area under investigation, located within the sub-Himalayan belt, has been the site of one of the four largest earthquakes of the past century.

9 GEOMECHANICAL OBSERVATION POINTS

Geomechanical observation points are used to characterize the lithology and fracturing in specific areas. At each observation point, in addition to describing the land mass, parameters such as joint distribution and other structural features are recorded. This information allows for:

- Generating family orientation charts for wedge calculations, either on slopes (using the Rocscience Swedge program) or in tunnels (using the Rocscience Unwedge software).
- Determining the Geomechanical classification index (RMR, Q) for the observed area.

A total of 20 Geomechanical observation points have been established at accessible outcrops along the project area. During site visits on September 18, 2024, and September 19, 2024, 11 and 9 Geomechanical observation points were recorded, respectively, along the tunnel alignment (PKG-IIA) to assess the lithology and structural measurements. The photographs taken at these locations were positioned using high-resolution aerial imagery with GPS and compass data, marking the rock outcrops. The locations of these observation points are indicated with ‘G, GOP’ symbols in the images, with red symbols representing the locations from September 18, 2024, and blue symbols from September 19, 2024. These locations are shown in Figures 1.21 to 1.24.

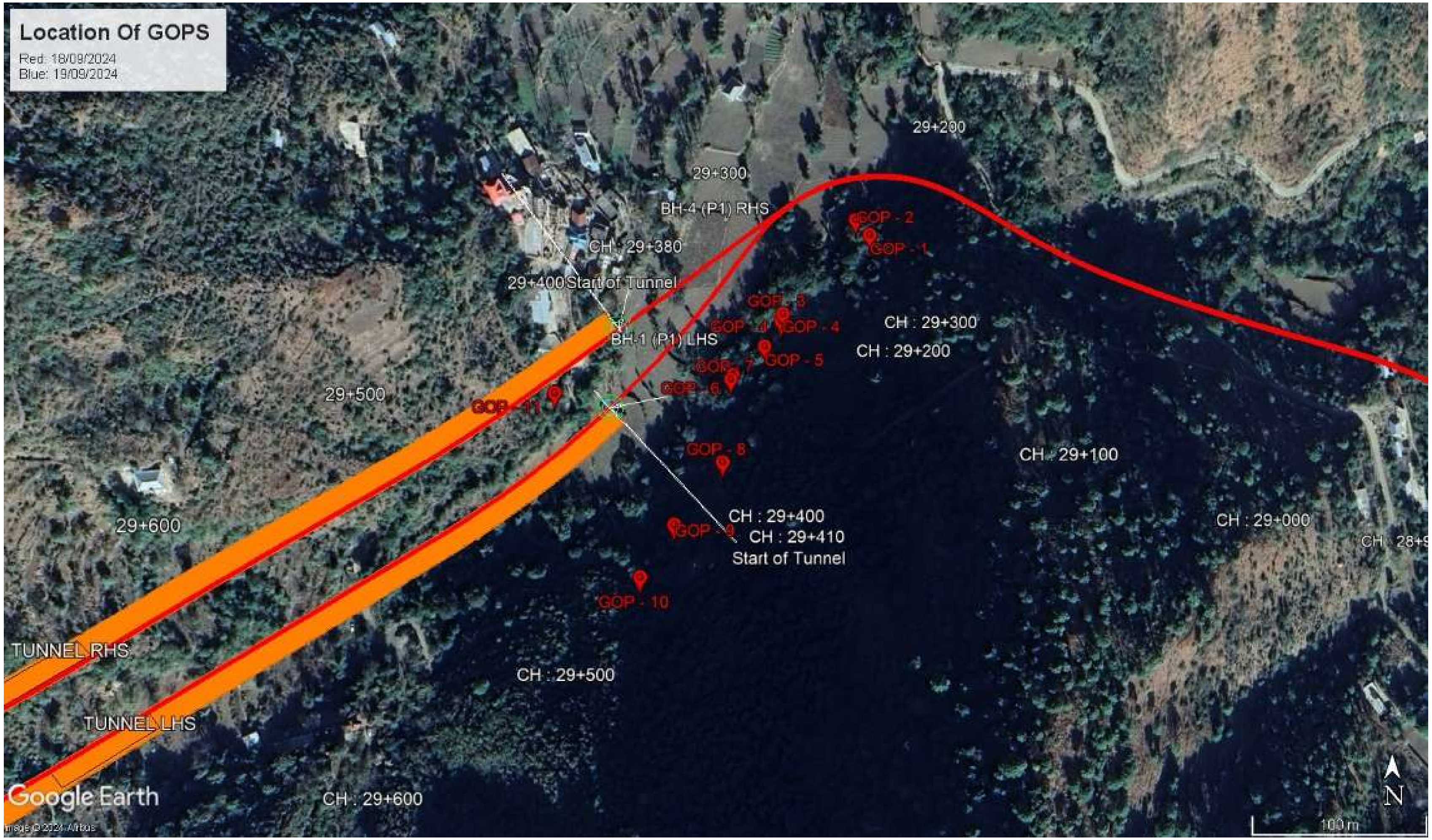


Figure 1.21: Location of GOPS

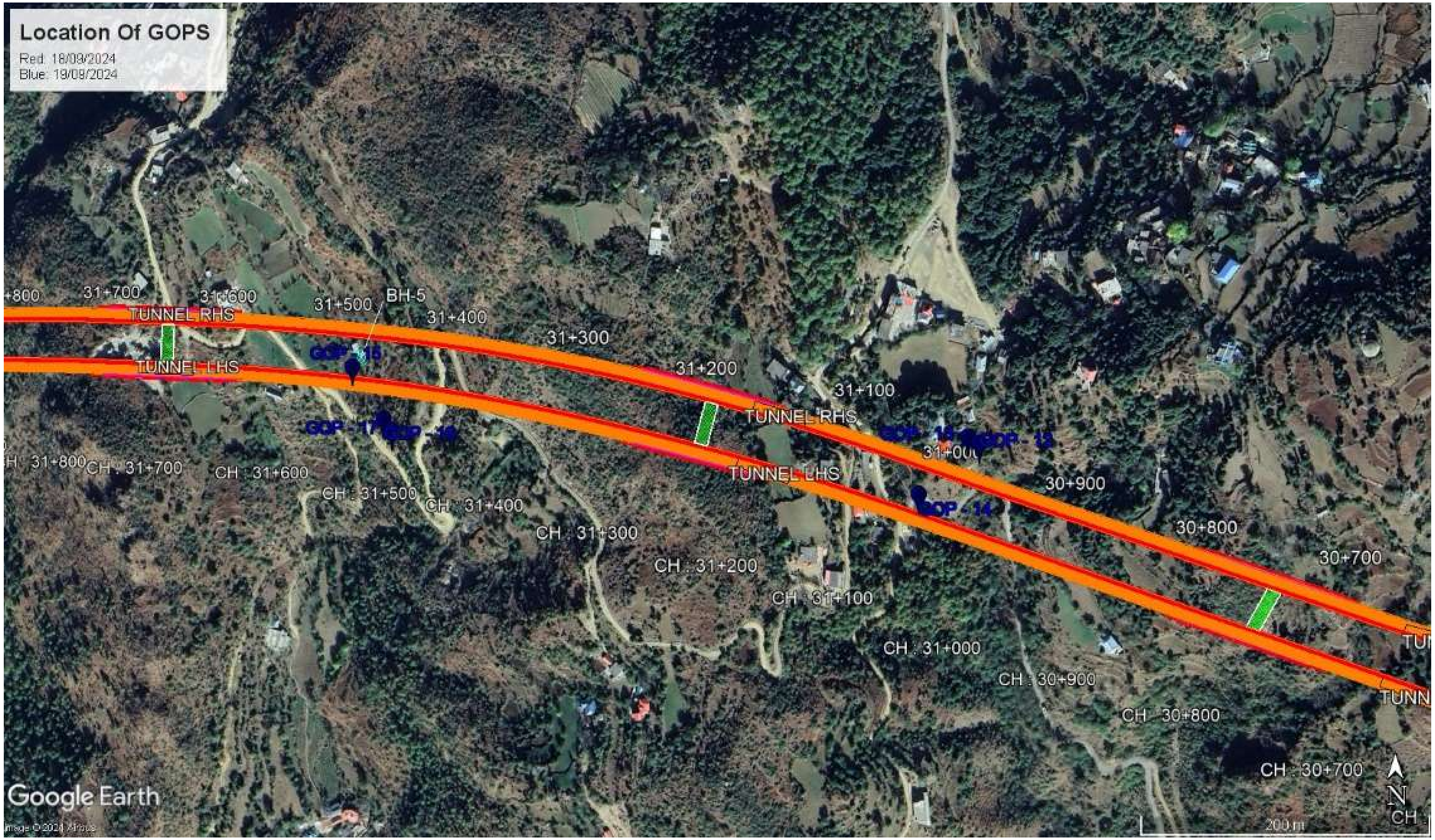


Figure 1.22: Location of GOPS

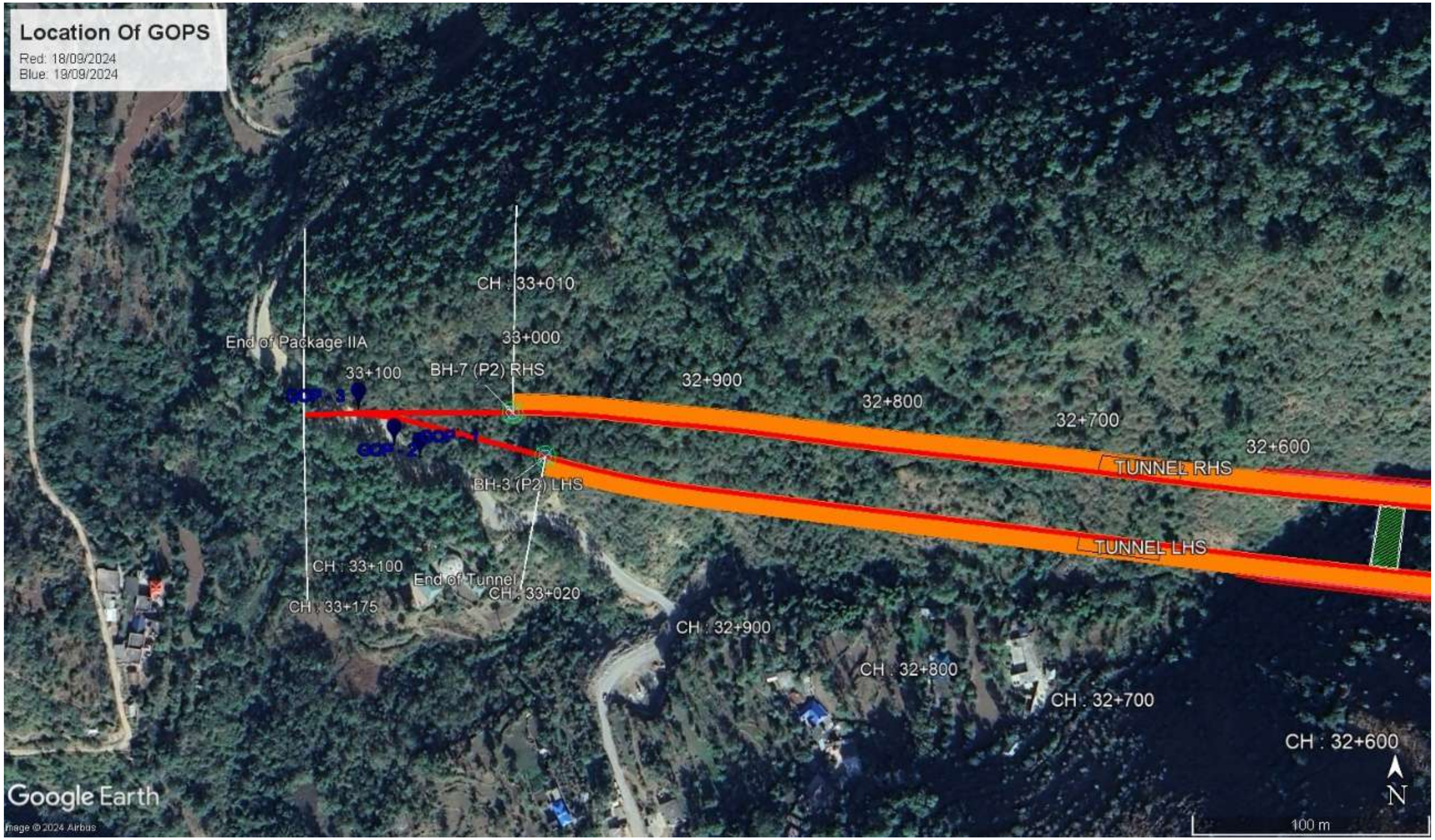


Figure 1.23: Location of GOPS

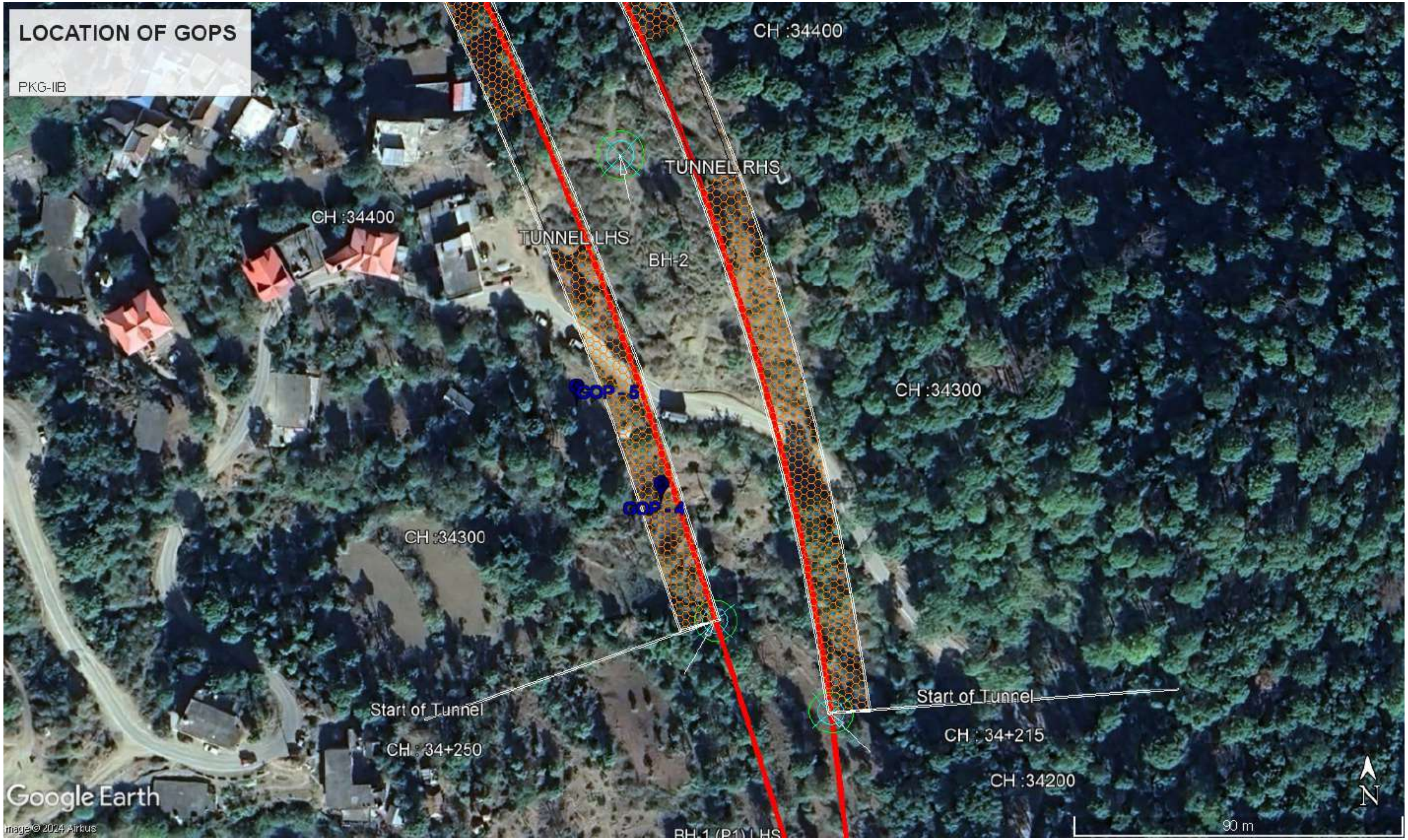


Figure 1.24: Location of GOPS

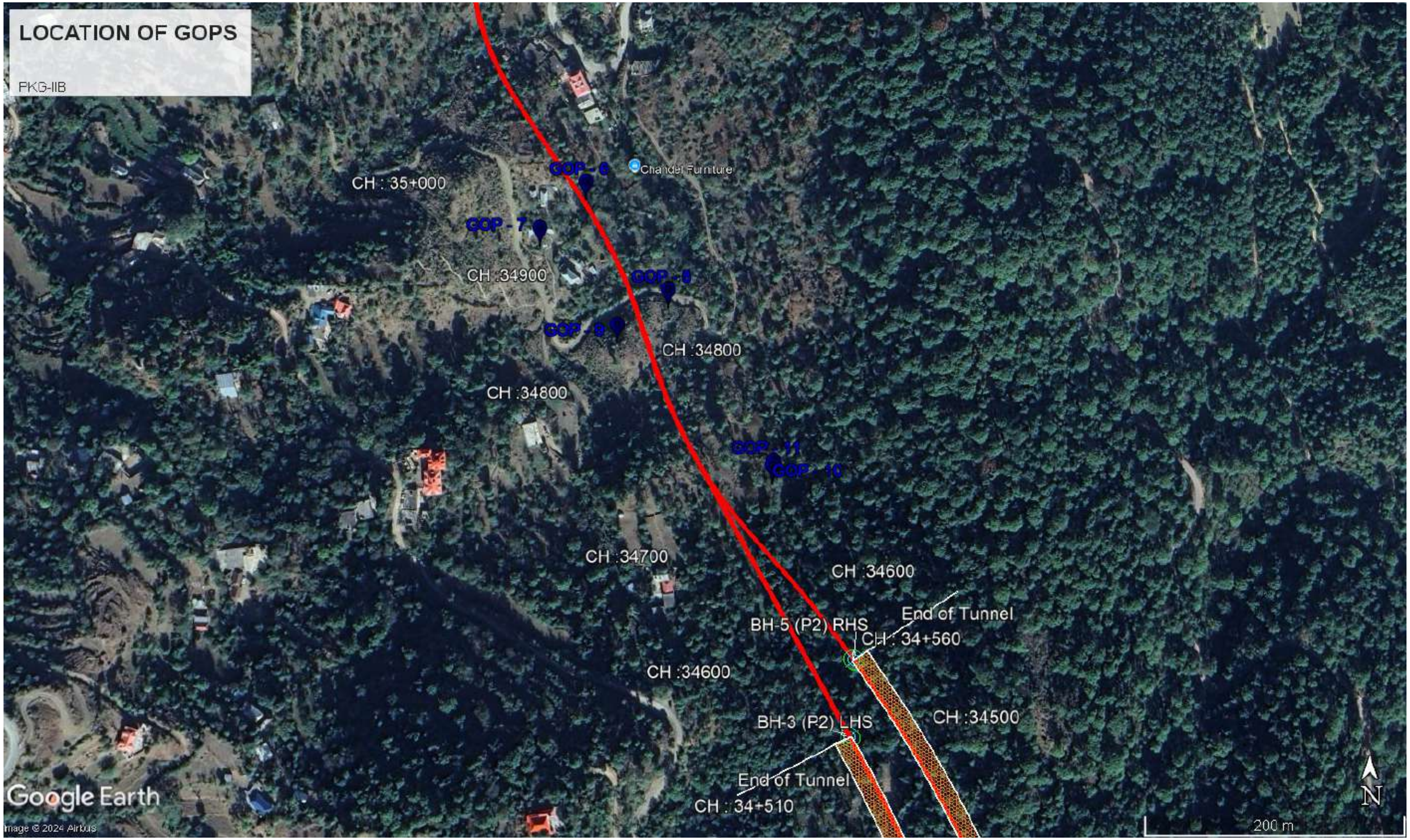


Figure 1.25: Location of GOPS

Location of GOPS (1 to 3).

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: **18.09.2024**	Rock Mass Description	Light brownish colour weak Shale with highly fractured.	**GOP NO.: 1**
			Mapped by
	Ground Water Conditions	Dry To Damp	MF

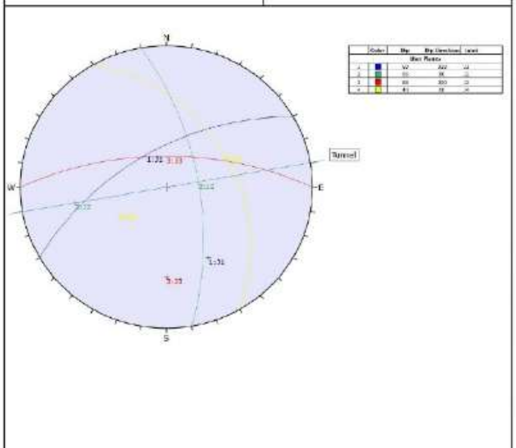
ROCK MASS JOINT CONDITIONS

	Orientation			1	2	3	4					5		
							Condition of Discontinuities							
GOP /Point	Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	Ground Water Codition	Lithology	Remarks & Water Conditions
1	60	330	J1	5 to 25	<25	0.06 - 0.2 m	3 to10	1-5 mm	Sl. R- Sr	<5	MW-HW	Damp-Dry	Shale	Wet to Dry water condition have been observed at the exposed out crop
	65	80	J2											
	65	360	J3				1 to 3							
	40	60	J4											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**
Correlations		
GSI = (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**
Correlation		
RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



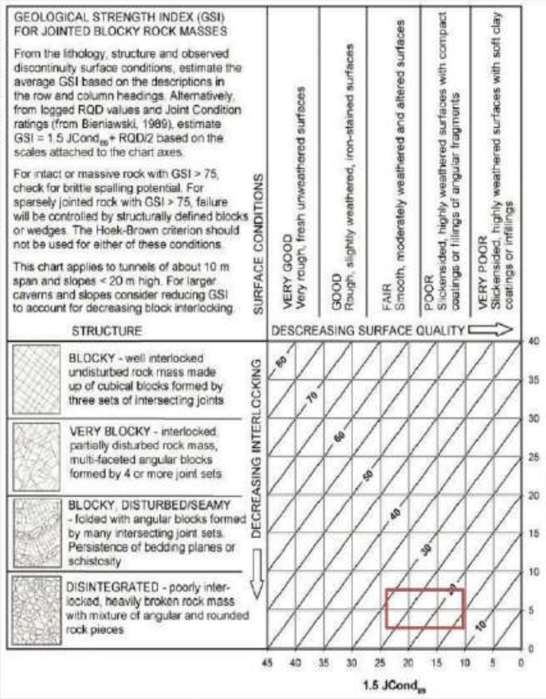


Figure 1.26: GOP No. 01

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Darcota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: **18.09.2024**	Rock Mass Description	Light brownish colour Sandstone fine to medium grained fractured sandstone.	**GOP NO.: 2**
	Ground Water Conditions	Dry To Damp	Mapped by MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
2	65	310	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R- R	<5	MW-HW	Damp-Dry	Sandstone	Wet to Dry water condition have been observed at the exposed out crop.
	80-85	360	J2											
	85	100	J3											
	25-35	135	J4											

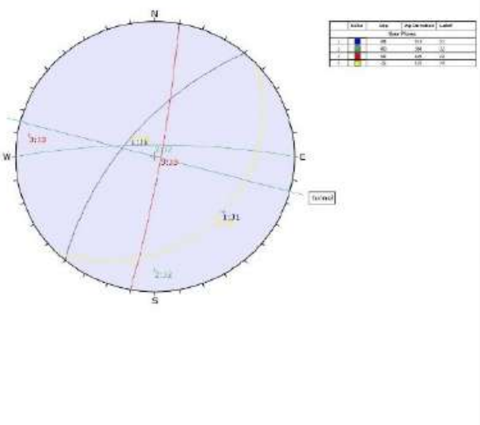
ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlations		
GSI ≈ (Dry RMR_{L})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Correlation		
RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



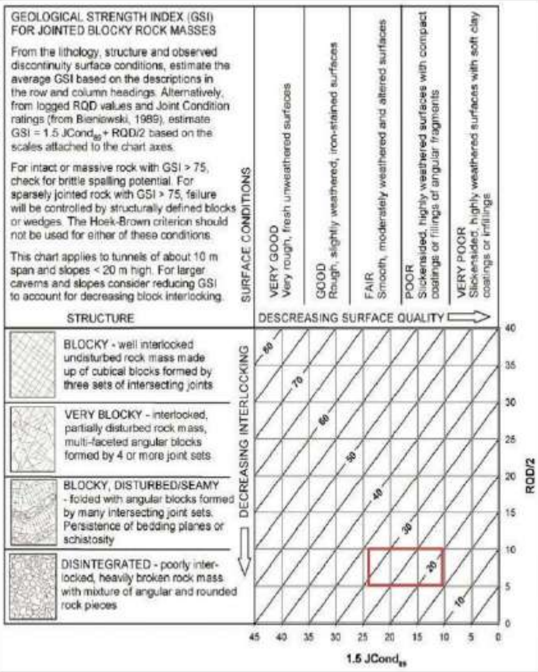


Figure 1.27: GOP No. 02

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 18.09.2024	Rock Mass Description	Light brownish colour week shale/Slate with highly fractured.	GOP NO.: 3 Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
3	75-80	270	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	SL R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate	Wet to Dry water condition have been observed at the exposed out crop.
	80-85	360	J2											
	40	350-360	J3											

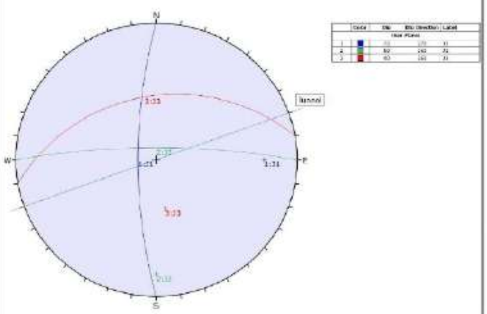
ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	5
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**31**

Q-value (NGI, 2013)		
RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**

Correlations		
GSI ≈ (Dry RMR_L)-5 =	14	28
Q-value (Barton95) =	0.005	0.054
Q-value (Bieniawski89) =	0.04	0.24

Correlation		
RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



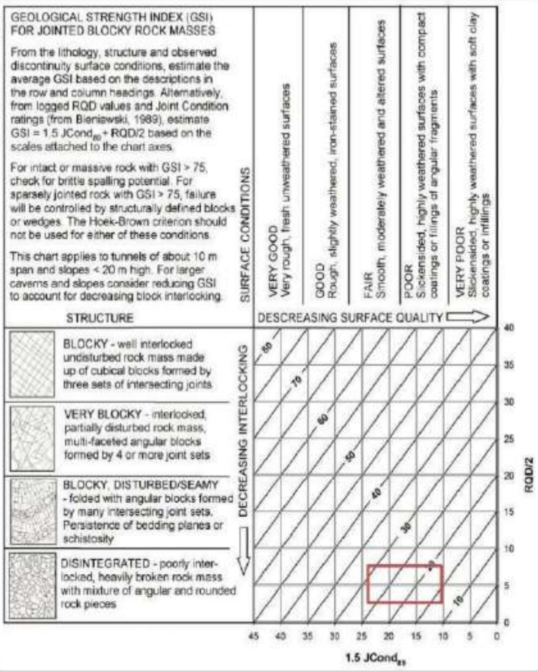


Figure 1.28: GOP No. 03

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 18.09.2024	Rock Mass Description	Light brownish colour week Shale/Slate with highly fractured. Folds have been observed.	**GOP NO.: 4**
	Ground Water Conditions	Dry To Damp	Mapped by MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
4	70	90	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate	Wet to Dry water condition have been observed at the exposed out crop. Folds have been observed at the exposed rock mass.
	65	315	J2											
	75-80	360	J3											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	5
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**31**

Correlations

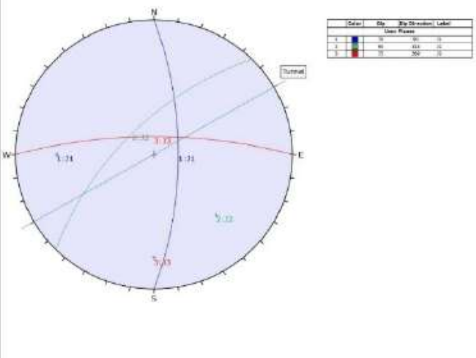
GSI = (Dry RMR_{s})-5 =	14	28
Q-value (Barton95) =	0.005	0.054
Q-value (Bieniawski89) =	0.04	0.24

Q-value (NGI, 2013)

RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**

Correlation

RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



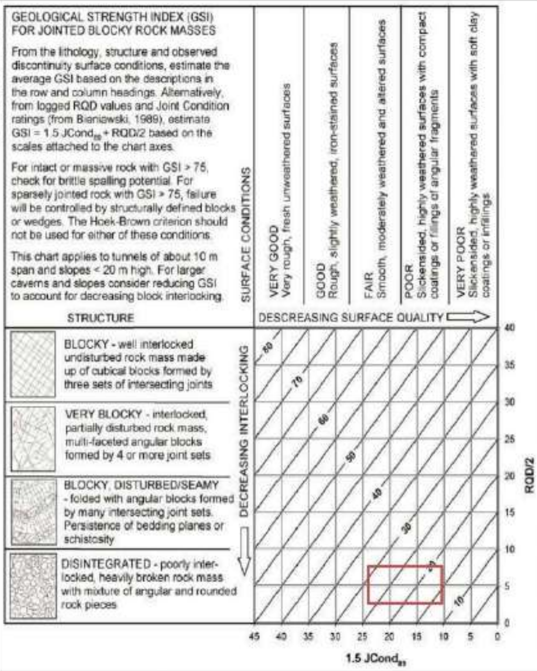


Figure 1.29: GOP No. 04

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 18.09.2024	Rock Mass Description	Light brownish colour week shale/Slate with highly fractured. Having Staining and rusting along joint planes, Folds have been observed.	GOP NO.: 5 Mapped by MF
	Ground Water Conditions	Dry To Damp	

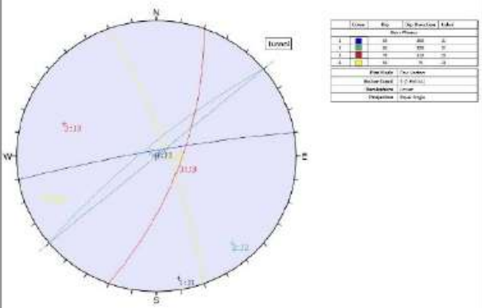
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
5	85	350-360	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate Folds have been observed.	Exposed rock mass is Wet to Dry Water Condition. Folds Have Been Observed.
	80	320	J2											
	70	110	J3											
	80	70	J4				1 to 3							

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	5	15
RQD:	5	5	Jn:	15	12
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**31**	**Q:**	**0.06**	**0.50**

Correlations			Correlation		
GSI = (Dry RMR_b)-5 =	14	28			
Q-value (Barton95) =	0.005	0.054	RMR (Barton95) =	32	45
Q-value (Bieniawski89) =	0.04	0.24	RMR (Bieniawski89) =	18	38



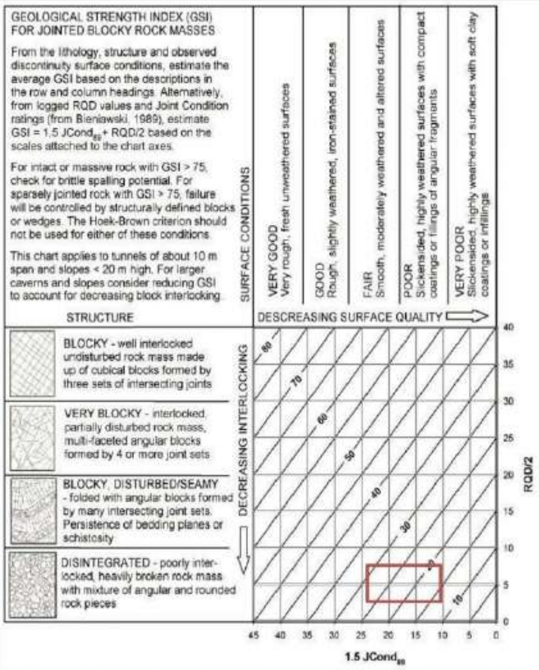


Figure 1.30: GOP No. 05

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: 18.09.2024	Rock Mass Description	Light Brownish Colour Weak Shale/Slate with Highly Fractured. Having Staining and Rusting Along Joint Planes, Folds Have Been Observed.	**GOP NO.: 6** Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
6	85	240	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate	Exposed rock mass is Wet to Dry Water Condition. Folds Have Been Observed.
	70	325	J2											
	20	65-70	J3				1 to 3							

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	5
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**31**

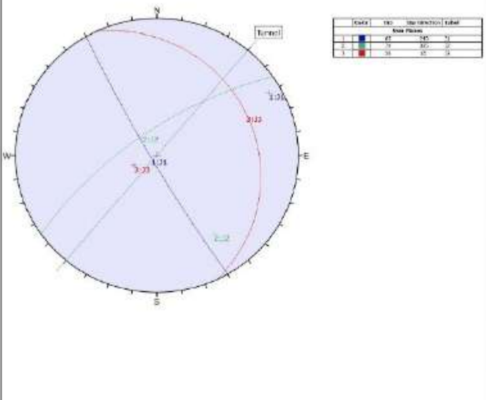
Q-value (NGI, 2013)		
RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**

Correlations

GSI ≈ (Dry RMR_b)-5 =	14	28
Q-value (Barton95) =	0.005	0.054
Q-value (Bieniawski89) =	0.04	0.24

Correlation

RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



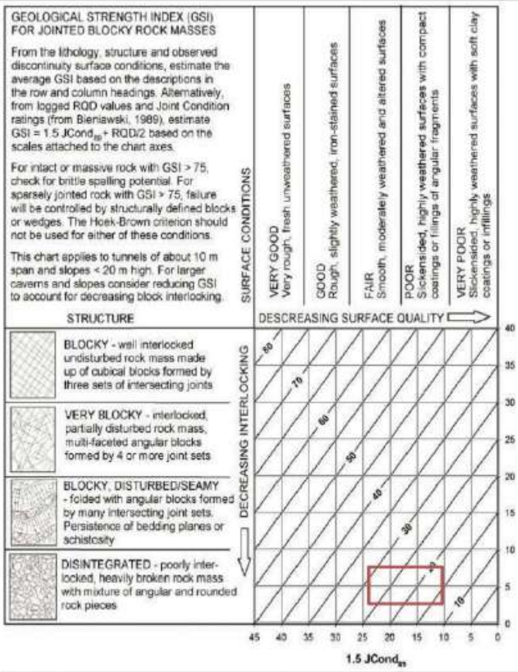
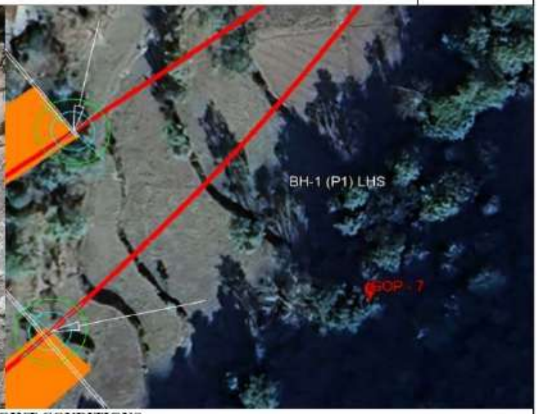


Figure 1.31: GOP No. 06

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: **18.09.2024**	Rock Mass Description	Light brownish colour weak Shale/Slate with highly fractured. Having Staining and rusting along joint planes.	**GOP NO.: 7** Mapped by
	Ground Water Conditions	Dry To Damp	MF



ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
7	80	240-260	J1	5 to 25	<25	0.06 - 0.2 m	3 to10	1-5 mm	Sl. R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate	Exposed rock mass is Wet to Dry Water Condition. Folds Have Been Observed.
	65-70	290	J2											
	30	50	J3				1 to 3							

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	5
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**31**

Correlations

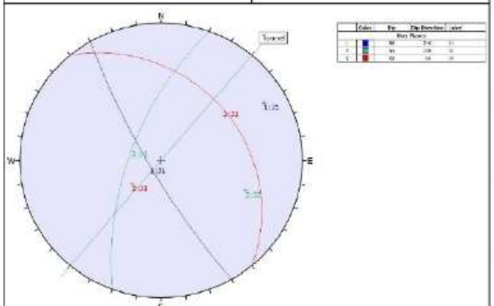
GSI ≈ (Dry RMR_{b})-5 =	14	28
Q-value (Barton95) =	0.005	0.054
Q-value (Bieniawski89) =	0.04	0.24

Q-value (NGI, 2013)

RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**

Correlation

RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



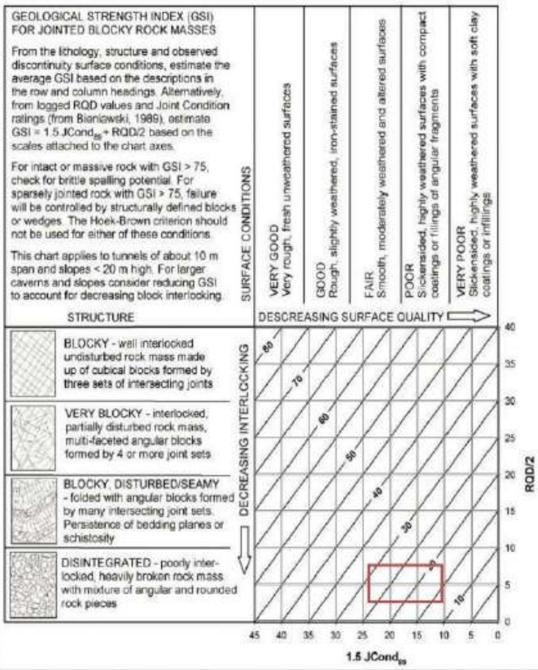
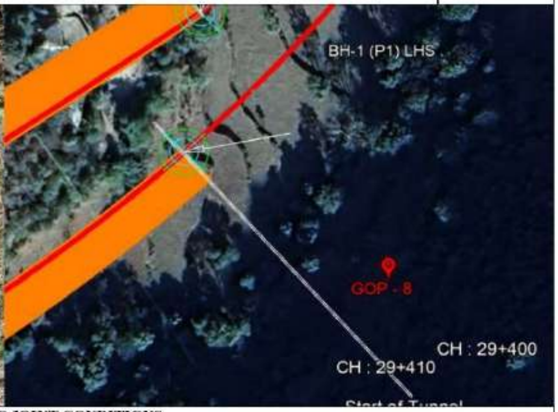


Figure 1.32: GOP No. 07

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: 18.09.2024	Rock Mass Description	Light brownish colour weak Shale/Slate with highly fractured. Having Staining and rusting along joint planes.	GOP NO.: 8 Mapped by
	Ground Water Conditions	Dry To Damp	MF

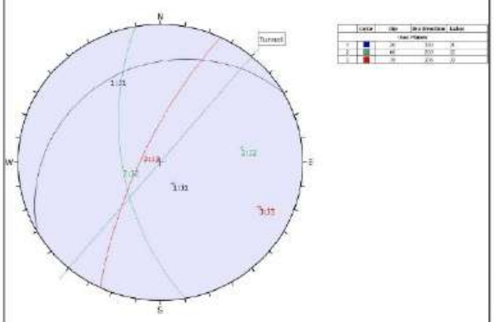


ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
8	20	330	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R-Sm	<5	MW-HW	Damp-Dry	Shale/Slate	Exposed rock mass is Wet to Dry Water Condition.
	60-70	260	J2											
	60-75	295	J3				1 to 3							

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	5	15
RQD:	5	5	Jn:	15	12
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**31**	**Q:**	**0.06**	**0.50**
Correlations			Correlation		
GSI ≈ (Dry RMR_{b})-5 =	14	28	RMR (Barton95) =	32	45
Q-value (Barton95) =	0.005	0.054	RMR (Bieniawski89) =	18	38
Q-value (Bieniawski89) =	0.04	0.24			



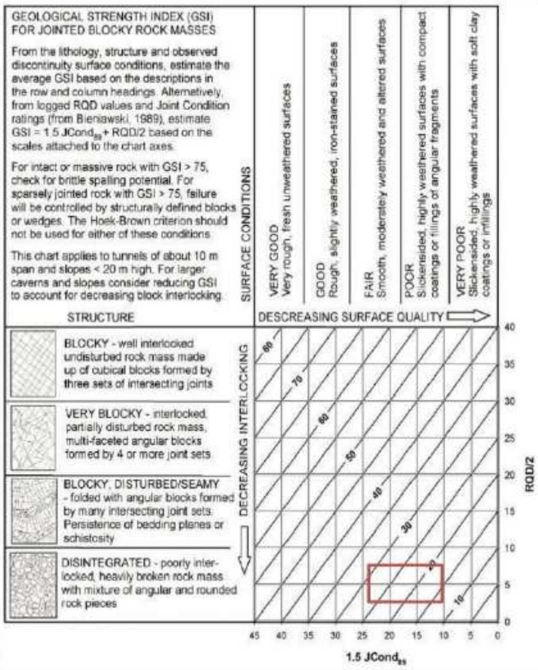
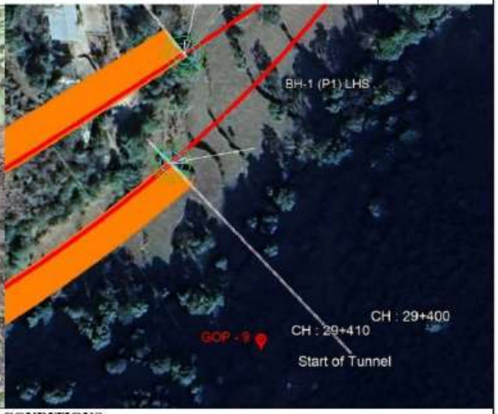


Figure 1.33: GOP No. 08

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 18.09.2024	Rock Mass Description	Light Brownish Colour Weak Shale/Slate with Highly Fractured. Having Staining and Rusting Along Joint Planes	**GOP NO.: 9**
	Ground Water Conditions	Dry To Damp	Mapped by MF



ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
9	55	240-260	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R-R	<5	MW-HW	Damp-Dry	Shale/Slate	Exposed Rock Mass is Wet to Dry Water Condition.
	80	180	J2				1 to 3							
	70	350	J3											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	5
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**31**

Correlations

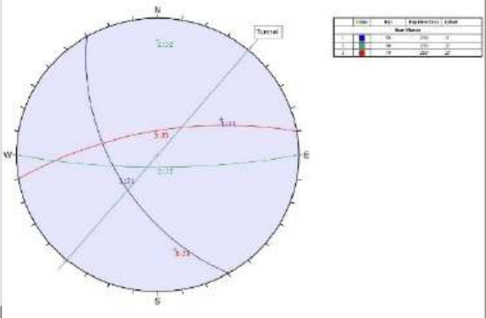
GSI ≈ (Dry RMR_s)-5 =	14	28
Q-value (Barton95) =	0.005	0.054
Q-value (Bieniawski89) =	0.04	0.24

Q-value (NGI, 2013)

RQD:	5	15
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.06**	**0.50**

Correlation

RMR (Barton95) =	32	45
RMR (Bieniawski89) =	18	38



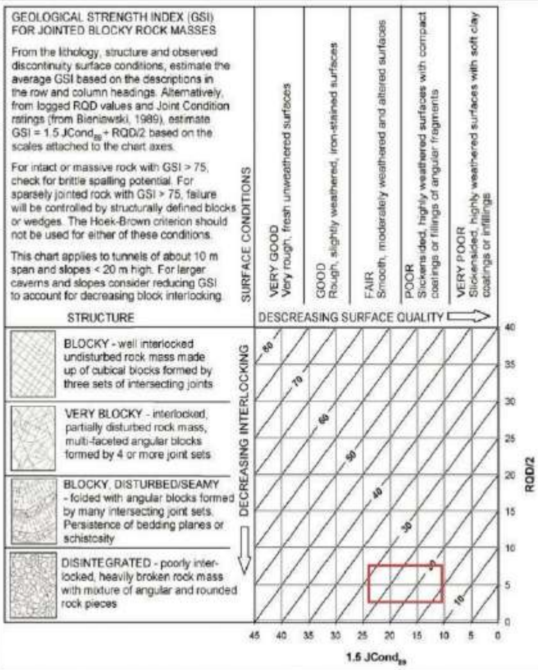
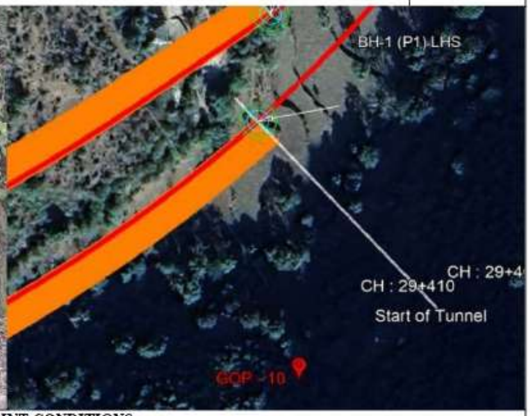


Figure 1.34: GOP No. 09

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 18.09.2024	Rock Mass Description	Light Brownish to Greyish Colour Weak Shale/Slate with Highly Fractured. Having Staining and Rusting Along Joint Planes.	**GOP NO.: 10** Mapped by
	Ground Water Conditions	Dry To Damp	MF



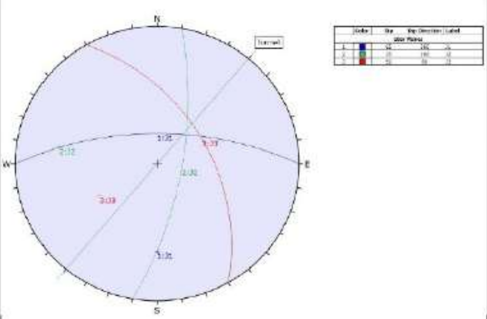
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation		Discontinuity Type	1	2	3	4					5	Lithology	Remarks & Water Conditions
							Condition of Discontinuities							
	Dip	Dip Direction		UCS	RQD (%)	Spacing (m)	Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	Ground Water Codition		
10	65-70	360	J1	5 to 25	<25	0.06 - 0.2 m	3 to 10	1-5 mm	Sl. R- R	<5	MW-HW	Damp-Dry	Greyish Colour Weak Shale/Slate	Exposed Rock Mass is Wet to Dry Water Condition.
	70-80	100	J2											
	50	60	J3				1 to 3							

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	5	15
RQD:	5	5	Jn:	15	12
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**31**	**Q:**	**0.06**	**0.50**

Correlations			Correlation		
GSI ≈ (Dry RMR_b)-5 =	14	28			
Q-value (Barton95) =	0.005	0.054	RMR (Barton95) =	32	45
Q-value (Bieniawski89) =	0.04	0.24	RMR (Bieniawski89) =	18	38



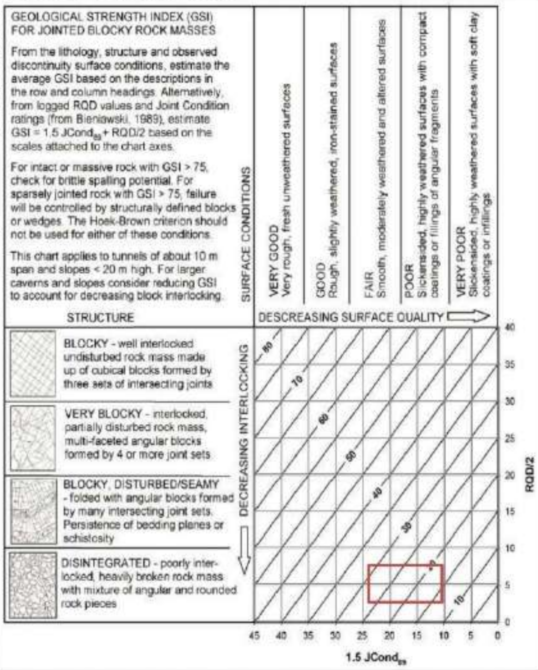


Figure 1.35: GOP No. 10

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: **18.09.2024**	Rock Mass Description	Light Greyish to Whitish Colour Medium to Strong, Medium Grained Dolomite.	**GOP NO.: 11** Mapped by
	Ground Water Conditions	Dry To Damp	MF

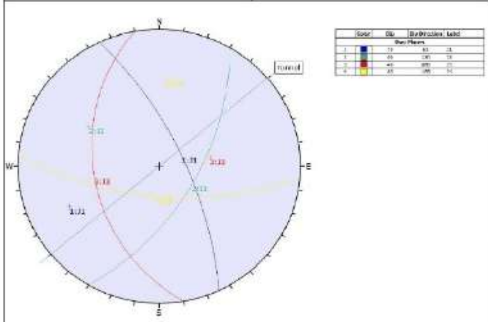
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1 UCS	2 RQD (%)	3 Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	4: Sepration (mm)	4: Roughness	4: Infilling	4: Weathering	5 Ground Water Codition	Lithology	Remarks & Water Conditions
11	70	65	J1	100 to 250	25 to 50	0.06 - 0.2	3 to 10	1-5 mm	R- Sl. R	<5	Sl- MW	Damp-Dry	Dolomite	Exposed Rock Mass is Wet to Dry Water Condition.
	60	120	J2											
	40	260	J3		50 - 75	0.2 to 0.6	1 to 3							
	65	185	J4											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	7	12	RQD:	50	75
RQD:	8	13	Jn:	12	9
J-Spacing:	8	10	Jr:	2	3
J-Conditions:	9	18	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**29**	**51**	**Q:**	**0.73**	**3.30**

Correlations			Correlation		
GSI ≈ (Dry RMR_c)-5 =	27	48			
Q-value (Barton95) =	0.040	1.166	RMR (Barton95) =	48	58
Q-value (Bieniawski89) =	0.19	2.18	RMR (Bieniawski89) =	41	55



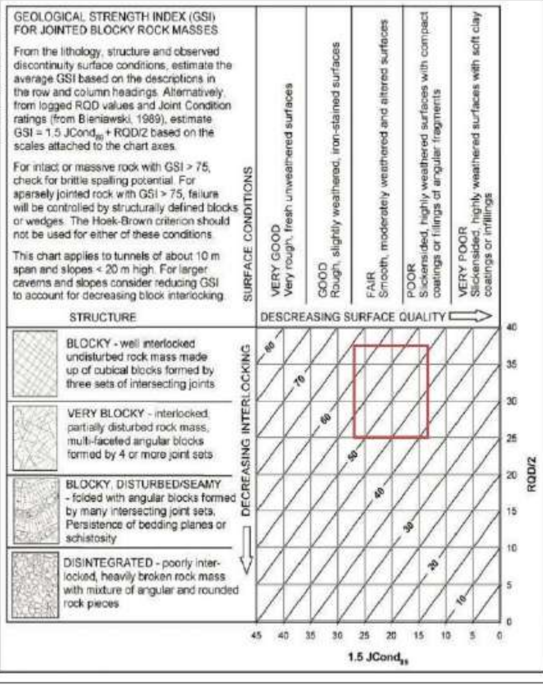
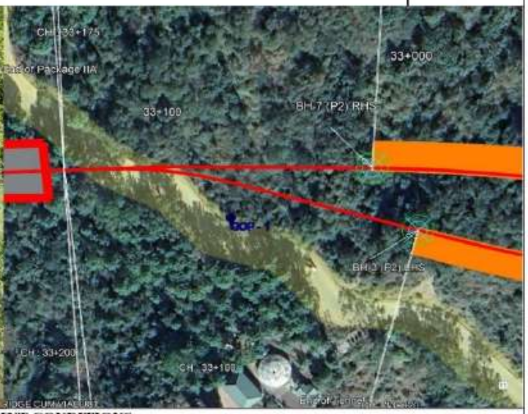


Figure 1.36: GOP No. 11

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.: 1** Mapped by
	Ground Water Conditions	Dry To Damp	MF



ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
1	50	160-150	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Dry to water condition have been observed at the exposed out crop.
	60	210	J2				1 to 3							
	45	10	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Correlations

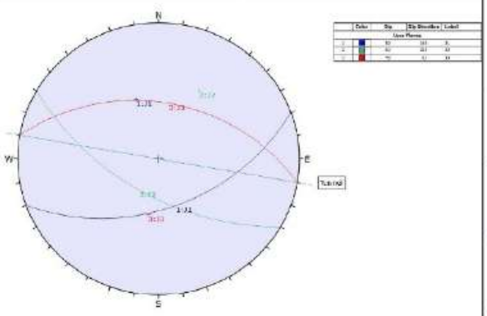
GSI ≈ (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)

RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



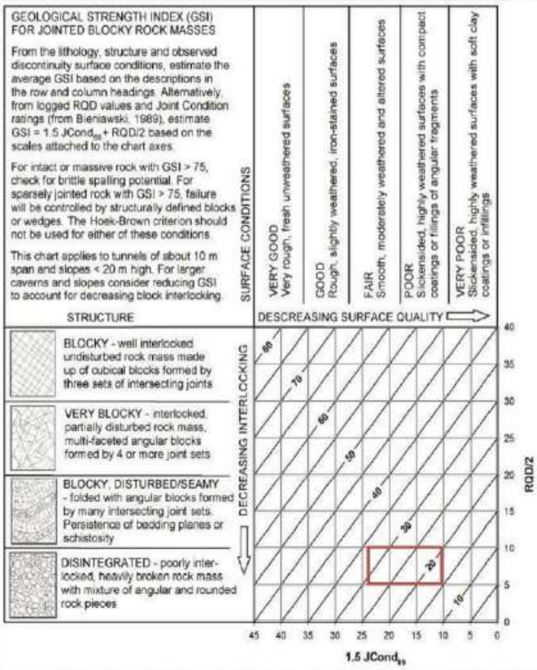


Figure 1.37: GOP No. 01

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	GOP NO.: 2 Mapped by
	Ground Water Conditions	Dry To Damp	MF

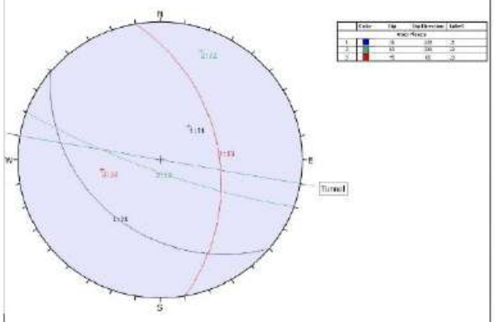
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation		Discontinuity Type	1	2	3	4					5	Lithology	Remarks & Water Conditions
							Condition of Discontinuities							
	Dip	Dip Direction		UCS	RQD (%)	Spacing (m)	Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	Ground Water Codition		
2	35	220	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Dry to water condition have been observed at the exposed out crop.
	80	200	J2				1 to 3							
	45	80	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**
Correlations		
GSI ≈ (Dry RMR_{6})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**
Correlation		
RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



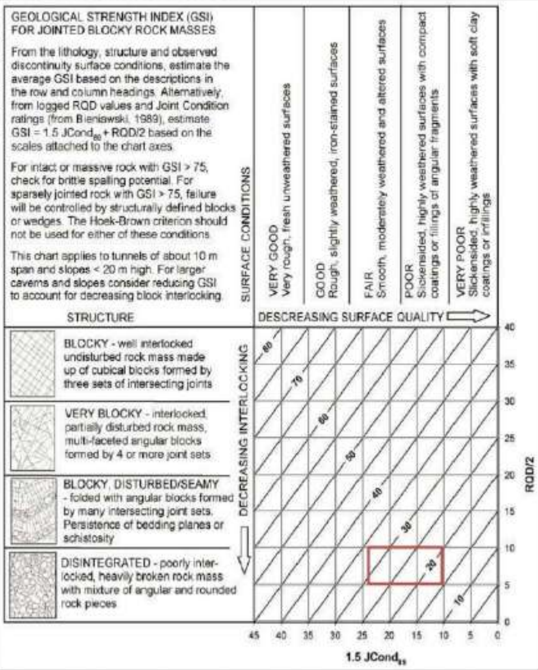
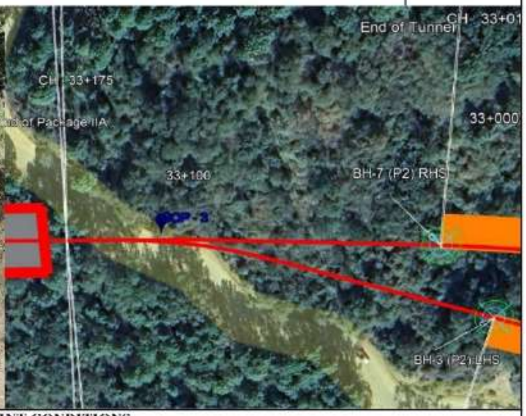


Figure 1.38: GOP No. 02

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	GOP NO.: 3
	Ground Water Conditions	Dry To Damp	Mapped by MF



ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
3	70	120	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Dry to water condition have been observed at the exposed out crop.
	65	210	J2				1 to 3							
	70	320	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Correlations

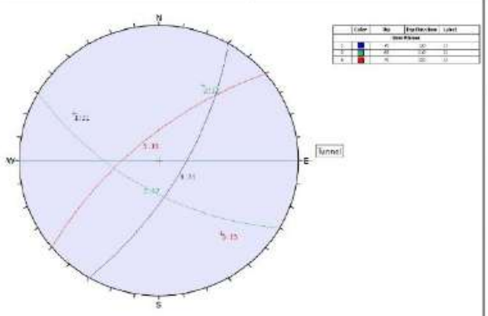
GSI = (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)

RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



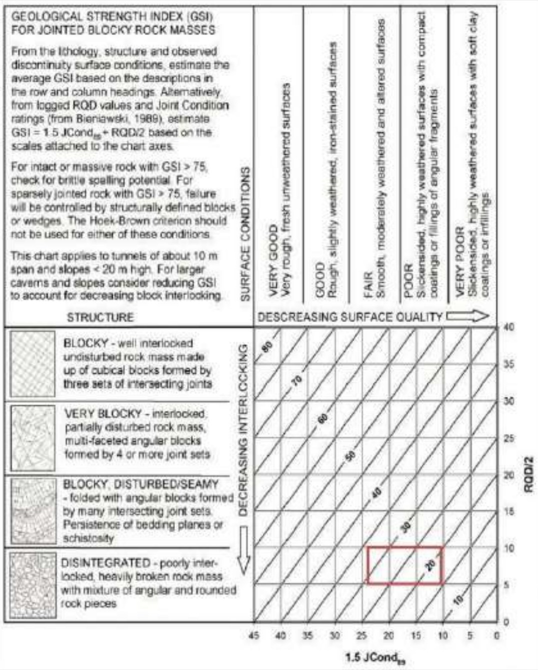


Figure 1.39: GOP No. 03

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: **19.09.2024**	Rock Mass Description	Light Greyish to Light Browaish Colour, Dolimite with Share Bands / Share Zones of Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. Open joint have been observed.	**GOP NO.: 12** Mapped by
	Ground Water Conditions	Dry To Damp	MF

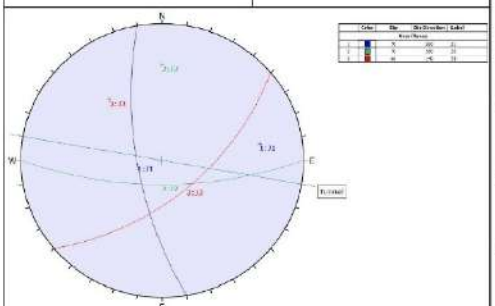
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
12	70	260	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Dolomite with Shale Bands	Wet to Dry water condition have been observed at the exposed out crop
	70	180	J2				1 to 3							
	60	140	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	10	20
RQD:	5	8	Jn:	15	12
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**34**	**Q:**	**0.12**	**0.66**

Correlations			Correlation		
GSI ≈ (Dry RMR_u)-5 =	14	31	RMR (Barton95) =	36	47
Q-value (Barton95) =	0.005	0.086	RMR (Bieniawski89) =	25	40
Q-value (Bieniawski89) =	0.04	0.33			



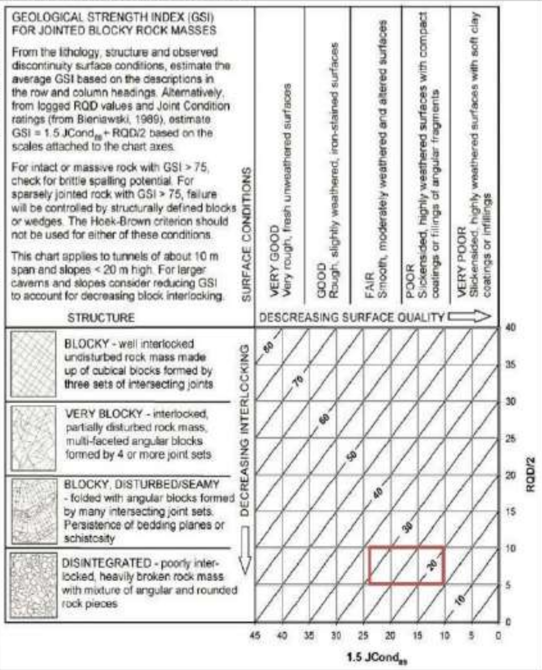


Figure 1.40: GOP No. 12

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

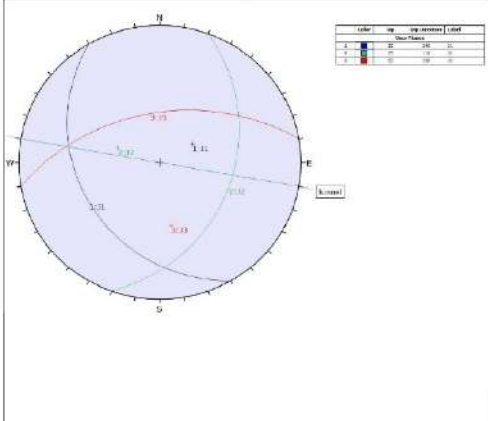
Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Dolimite with Share Bands / Share Zones of Weak, Fractured Shale Having Staining and Rusting Along Joint Planes.	GOP NO.: 13 Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
13	30	240	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Dolomite with Shale Bands	Wet to Dry water condition have been observed at the exposed out crop
	35	110	J2				1 to 3							
	50	350	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	10	20
RQD:	5	8	Jn:	15	12
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**34**	**Q:**	**0.12**	**0.66**
Correlations			Correlation		
GSI ≈ (Dry RMR_b)-5 =	14	31	RMR (Barton95) =	36	47
Q-value (Barton95) =	0.005	0.086	RMR (Bieniawski89) =	25	40
Q-value (Bieniawski89) =	0.04	0.33			



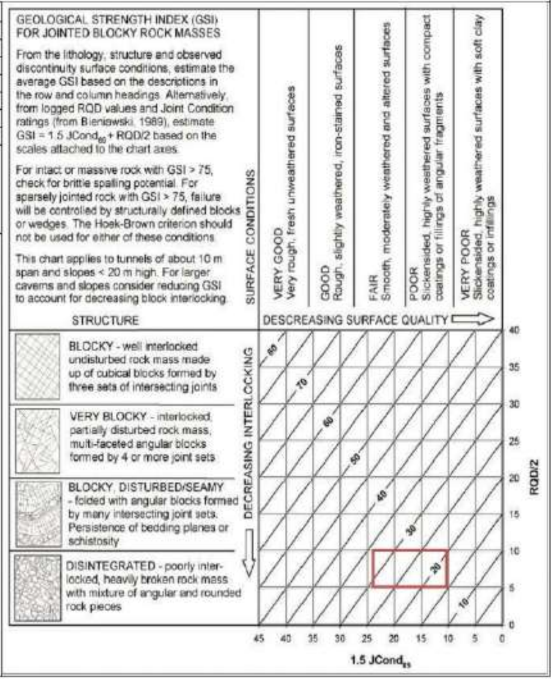


Figure 1.41: GOP No. 13

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak to medium strong, Moderately Fractured Shale Having Staining and Rusting Along Joint Planes.	**GOP NO.: 14** Mapped by
	Ground Water Conditions	Dry To Damp	MF

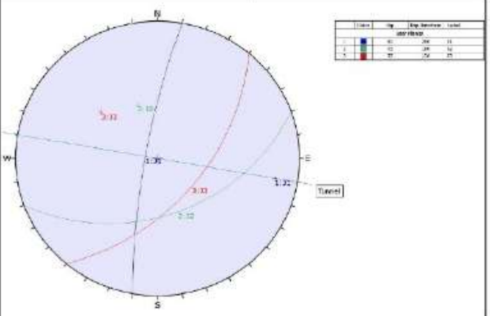
ROCK MASS JOINT CONDITIONS

	Orientation			1	2	3	4					5		
							Condition of Discontinuities							
GOP /Point	Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	Ground Water Codition	Lithology	Remarks & Water Conditions
14	80	280	J1	50-100	25-50	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	45	160	J2			0.06 - 0.2 m	1 to 3							
	55	130	J3					0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	2	4	RQD:	10	20
RQD:	5	8	Jn:	15	12
J-Spacing:	5	8	**Jr:**	2	3
J-Conditions:	7	16	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-10	-12	SRF:	2.5	2.5
RMR_{89}:	**16**	**34**	**Q:**	**0.12**	**0.66**

Correlations			Correlation		
GSI ≈ (Dry RMR_{b})-5 =	14	31			
Q-value (Barton95) =	0.005	0.086	RMR (Barton95) =	36	47
Q-value (Bieniawski89) =	0.04	0.33	RMR (Bieniawski89) =	25	40



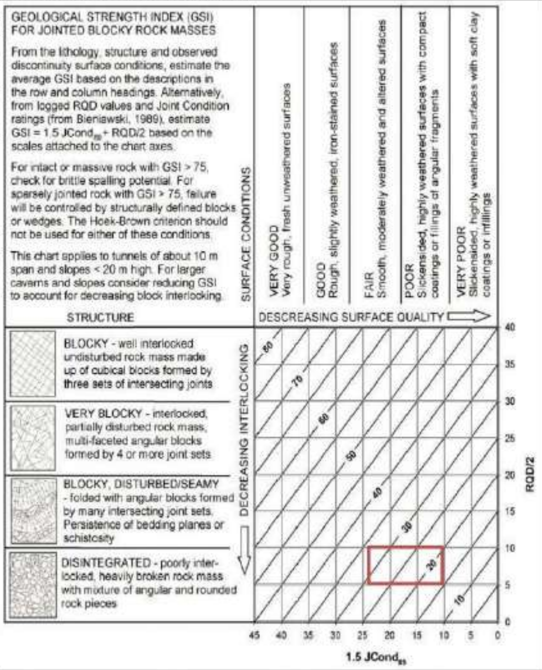


Figure 1.42: GOP No. 14

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Whitish Colour, Medium Strong, Medium Grained Dolomite. Open Joints have been observed.	**GOP NO.: 15** Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4: Condition of Discontinuities: Length / Persistance (m)	4: Separation (mm)	4: Roughness	4: Infilling	4: Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
15	85	180	J1	50-100	20 to 30	0.06 - 0.2 m	3 to 10	0.1 - 1	Sl. R	hard > 5 mm	Sl. W to MW	Dry to Wet	Dolomite	Wet to Dry water condition have been observed at the exposed out crop
	45	200	J2				1 to 3							
	80	260	J3											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	4	7
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	14	19
GW-Conditions:	7	10
J-Orientation:	-5	-12
RMR_{89}:	**30**	**40**

Correlations

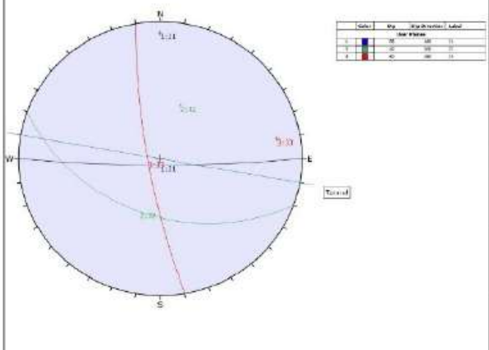
GSI ≈ (Dry RMR_b)-5 =	23	37
Q-value (Barton95) =	0.046	0.215
Q-value (Bieniawski89) =	0.21	0.64

Q-value (NGI, 2013)

RQD:	20	30
Jn:	12	9
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.29**	**1.32**

Correlation

RMR (Barton95) =	42	52
RMR (Bieniawski89) =	33	46



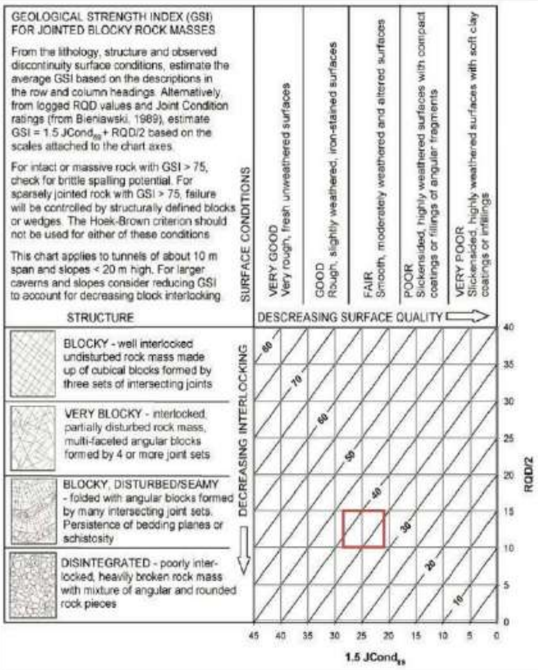


Figure 1.43: GOP No. 15

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)			
Date: 19.09.2024	Rock Mass Description	Light Greyish to Whitish Colour, Medium Strong, Medium Grained Dolomite. Open Joints have been observed.	GOP NO.: 16 Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
16	80	190	J1	50-100	25-50	0.06 - 0.2 m	3 to 10	0.1 - 1	Sl. R	hard > 5 mm	Sl. W to MW	Dry to Wet	Dolomite	Wet to Dry water condition have been observed at the exposed out crop
	85	80	J2				1 to 3							
	25	180	J3											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	4	7
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	14	19
GW-Conditions:	7	10
J-Orientation:	-5	-12
RMR_{89}:	**30**	**40**

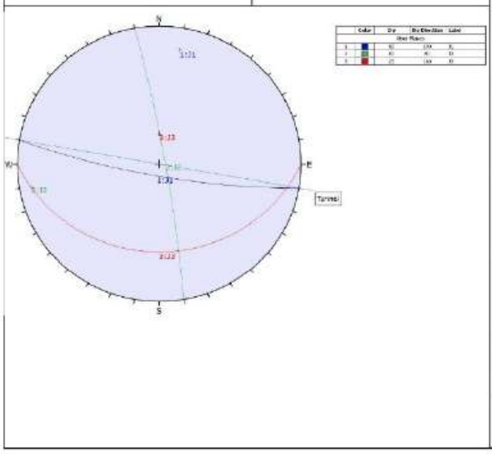
Q-value (NGI, 2013)		
RQD:	25	50
Jn:	12	9
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.37**	**2.20**

Correlations

GSI ≈ (Dry RMR_{β})-5 =	23	37
Q-value (Barton95) =	0.046	0.215
Q-value (Bieniawski89) =	0.21	0.64

Correlation

RMR (Barton95) =	43	55
RMR (Bieniawski89) =	35	51



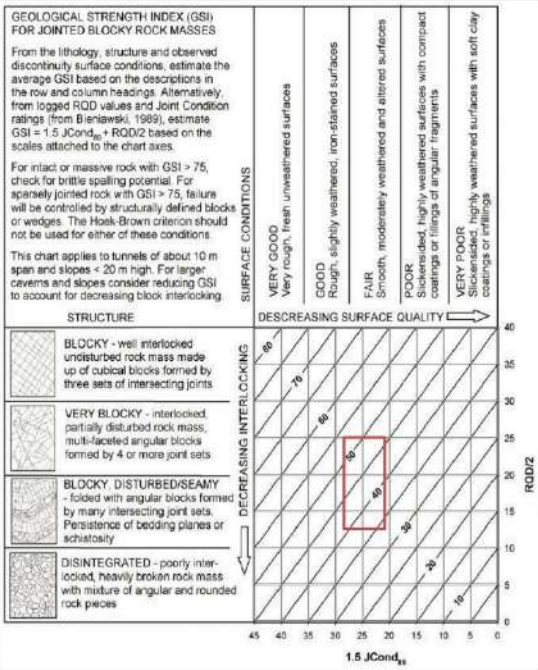


Figure 1.44: GOP No. 16

Construction of Twin Tube tunnel with approaches for New 4 Lane with Paved Shoulder from Kolaka Village to Dareota Village section of NH-205 (Design Chainage Km28+800 to Km.33+175, Design Length - 4.375 Km) on Shimla - Mataur corridor in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode (Package-IIA)

Date: 19.09.2024	Rock Mass Description	Light Greyish to Whitish Colour, Medium Strong, Medium Grained Dolomite. Open Joints have been observed.	GOP NO.: 17 Mapped by
	Ground Water Conditions	Dry To Damp	MF

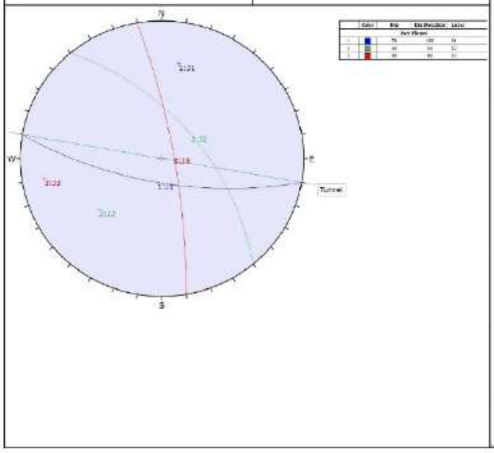
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
17	70	190	J1	50-100	25-50	0.06 - 0.2 m	3 to 10	0.1 - 1	Sl. R	hard > 5 mm	Sl. W to MW	Dry to Wet	Dolomite	Wet to Dry water condition have been observed at the exposed out crop
	60	50	J2				1 to 3							
	80	80	J3											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)			Q-value (NGI, 2013)		
UCS:	4	7	RQD:	25	50
RQD:	5	8	Jn:	12	9
J-Spacing:	5	8	Jr:	2	3
J-Conditions:	14	19	Ja:	3	2
GW-Conditions:	7	10	Jw:	0.66	0.66
J-Orientation:	-5	-12	SRF:	2.5	2.5
RMR_{89}:	**30**	**40**	**Q:**	**0.37**	**2.20**

Correlations			Correlation		
GSI ≈ (Dry RMR_c)-5 =	23	37			
Q-value (Barton95) =	0.046	0.215	RMR (Barton95) =	43	55
Q-value (Bieniawski89) =	0.21	0.64	RMR (Bieniawski89) =	35	51



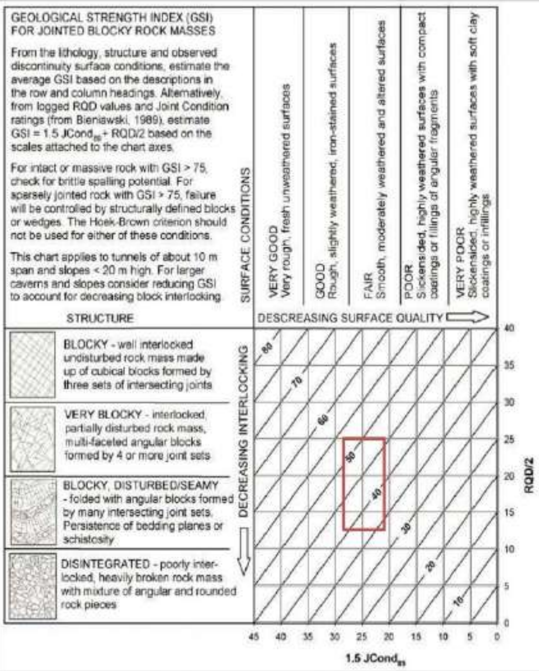


Figure 1.45: GOP No. 17

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode			
Date: **19.09.2024**	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.: 4** Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1 UCS	2 RQD (%)	3 Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5 Ground Water Codition	Lithology	Remarks & Water Conditions
4	70	260	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Dry to water condition have been observed at the exposed out crop.
	65	180-170	J2				1 to 3							
	70	350	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

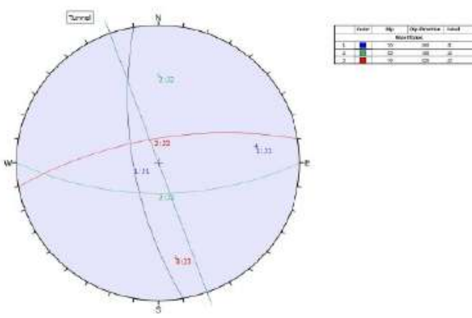
Correlations

GSI ≈ (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



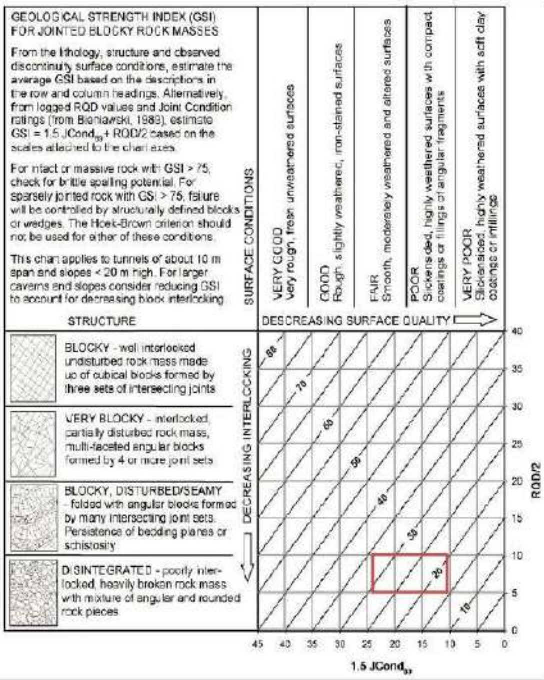


Figure 1.46: GOPS 4

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Dasecharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode

Date: **19.09.2024**	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.: 5** Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1 UCS	2 RQD (%)	3 Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	4: Sepration (mm)	4: Roughness	4: Infilling	4: Weathering	5 Ground Water Codition	Lithology	Remarks & Water Conditions
5	75	280	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Dry to water condition have been observed at the exposed out crop.
	55	145	J2											
	80	190	J3			0.06 - 0.2 m	2 to 3	0.1 - 1						
	65	210-220	J4											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

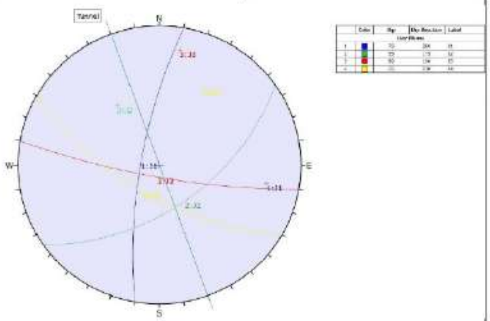
Correlations

GSI ≈ (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



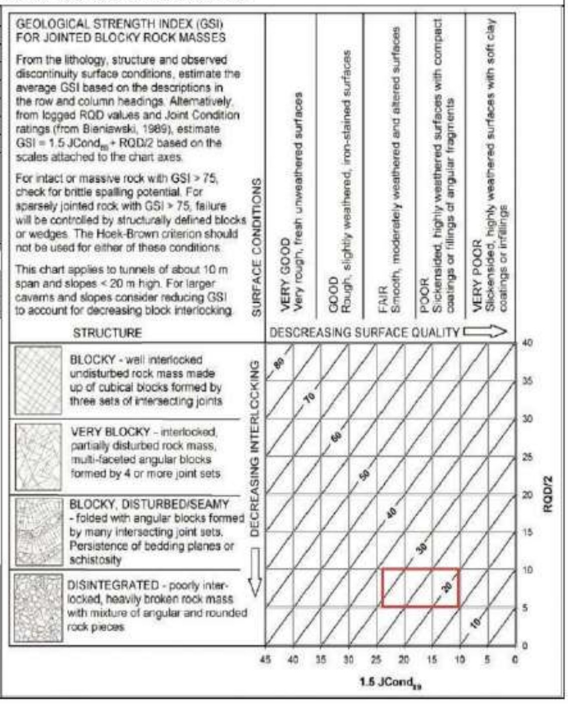


Figure 1.47: GOPS 5

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	GOP NO.: 6
			Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

	Orientation			1	2	3	4					5		
					R(		Condition of Discontinuities							
GOP/Point	Dip	Dip Direction	Discontinuity Type	UCS		Spacing (m)	Length / Persistence (m)	Separation (mm)	Roughness	Infilling	Weathering	Ground Water Codition	Lithology	Remarks & Water Conditions
6	45	200	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop.
	70	80	J2				1 to 3							
	70	140	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

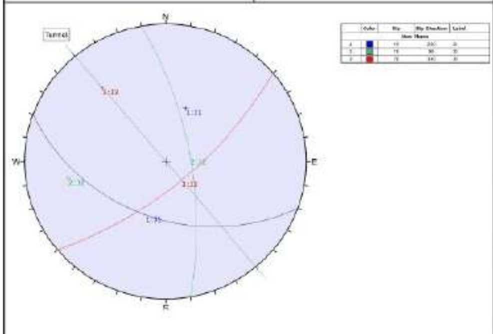
Correlations

GSI = (Dry RMR_{89})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	0.66

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



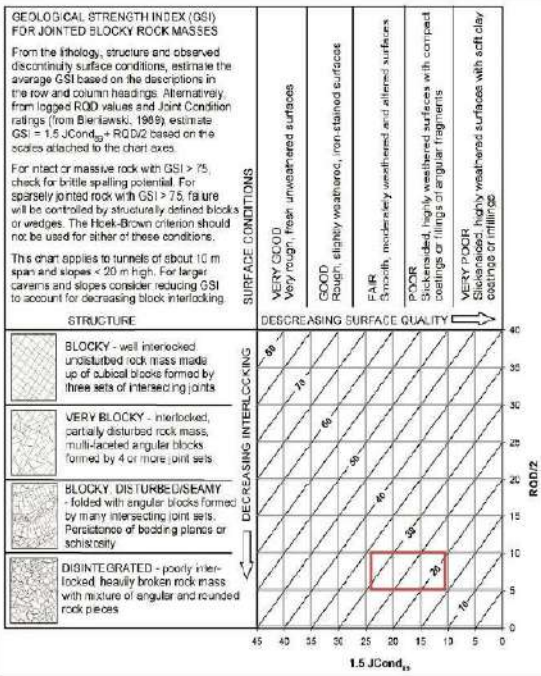


Figure 1.48: GOPS 6

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode

Date: **19.09.2024**	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.:** 7 Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Separation (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
7	60	250	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	40	65	J2				1 to 10							
	80	350	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Correlations

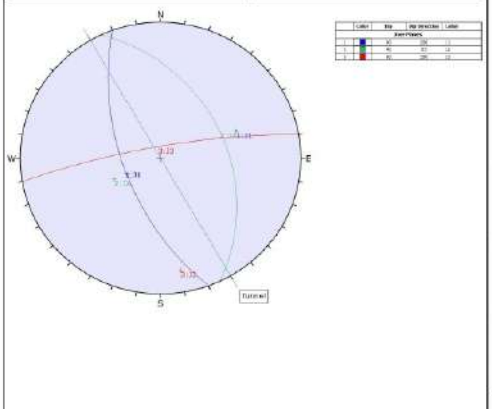
GSI = (Dry RMR_{89})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)

RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



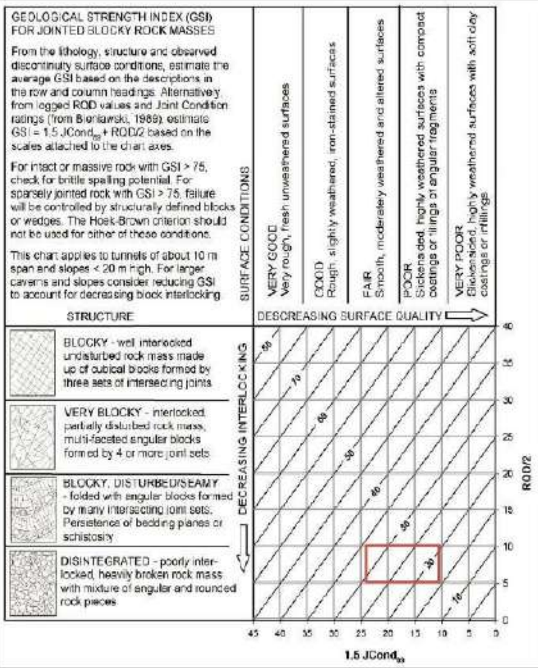


Figure 1.49: GOPS 7

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode

Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.: 8** Mapped by MF
	Ground Water Conditions	Dry To Damp	

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1 UCS	2 RQD (%)	3 Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5 Ground Water Codition	Lithology	Remarks & Water Conditions
8	60	70	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	50	180	J2											
	40	10	J3			0.06 - 0.2 m	1 to 3	0.1 - 1						
	65	240	J4											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)

UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Correlations

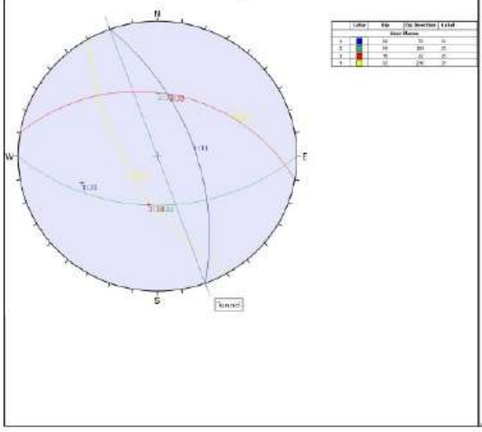
GSI = (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)

RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



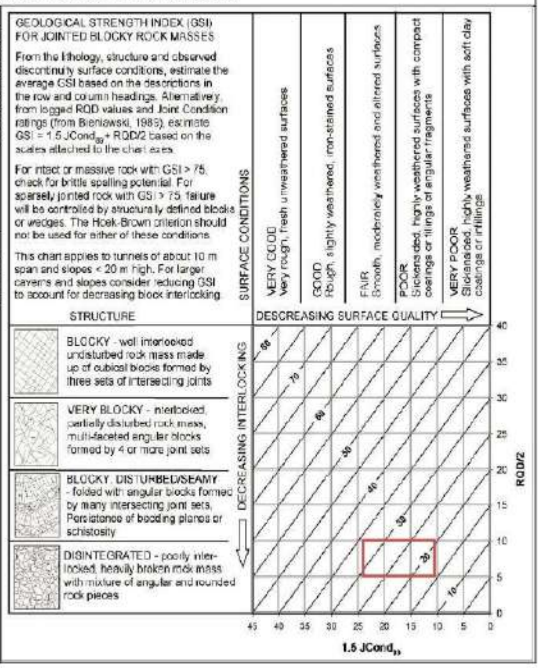


Figure 1.50: GOPS 8

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode			
Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	GOP NO.: 9
	Ground Water Conditions	Dry To Damp	Mapped by MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
9	80	80	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	35	260	J2				1 to 3							
	40	180	J3			0.06 - 0.2 m		0.1 - 1						

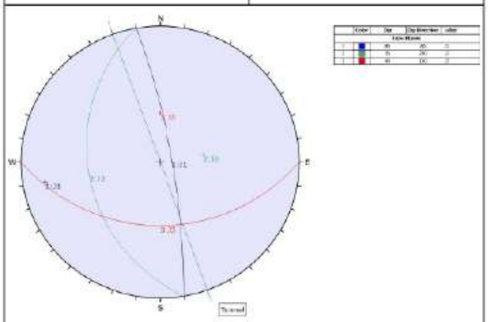
ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

Correlations		
GSI = (Dry RMR_b)-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlation		
RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



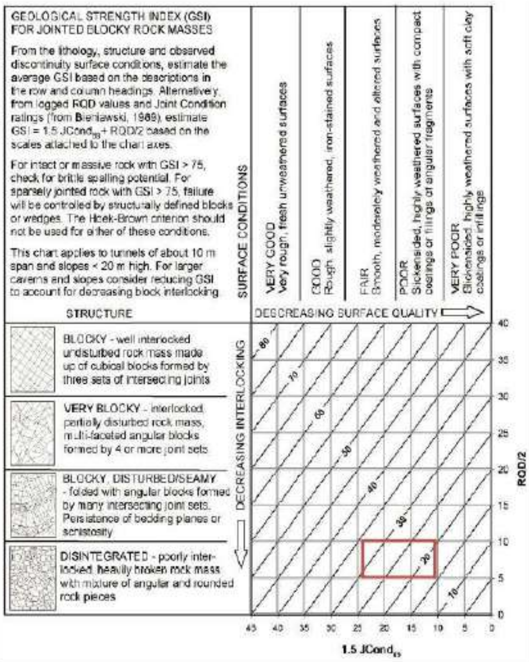


Figure 1.51: GOPS 9

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode			
Date: 19.09.2024	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	GOP NO.: 10 Mapped by
	Ground Water Conditions	Dry To Damp	MF

ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
10	65	260	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	60	180	J2											
	35	340	J3			0.06 - 0.2 m	1 to 3	0.1 - 1						
	70	50	J4											

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**

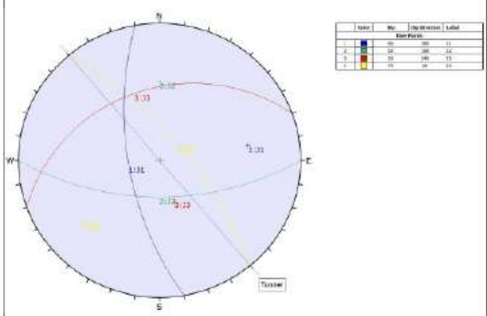
Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**

Correlations

GSI = (Dry RMR_{89})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Correlation

RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



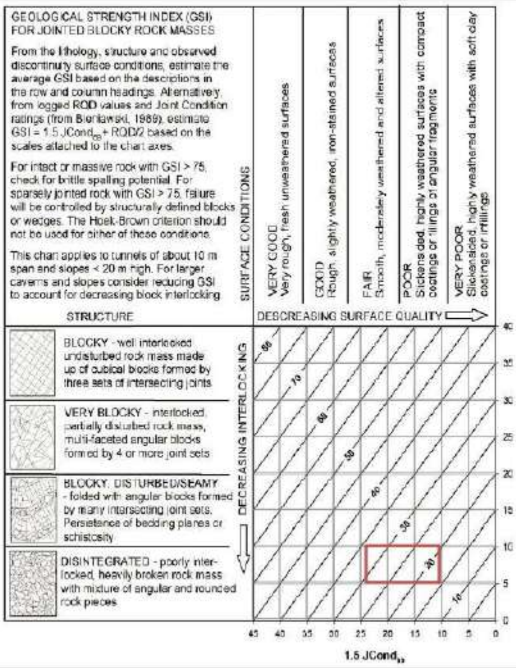


Figure 1.52: GOPS 10

Construction of New 4 Lane with Paved Shoulder from Dareota Village to Daseharan Village of NH-205 (Design Chainage Km.33+175 to Km 41+000, Design Length – 7.825 Km) including twin tube tunnel, Package-IIB in the State of Himachal Pradesh under NH (O) on Hybrid Annuity Mode			
Date: **19.09.2024**	Rock Mass Description	Light Greyish to Light Brownish Colour, Weak, Fractured Shale Having Staining and Rusting Along Joint Planes. With share Zone / Bands.	**GOP NO.: 11** Mapped by
	Ground Water Conditions	Dry To Damp	MF

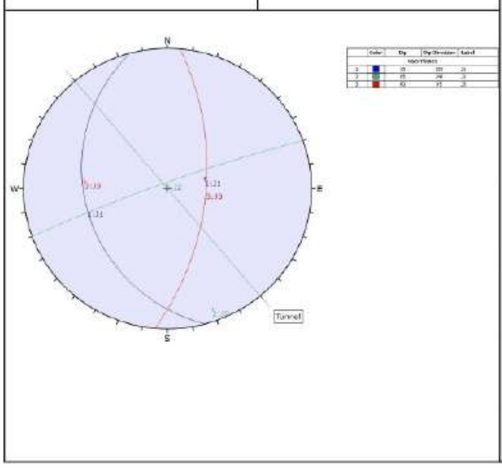
ROCK MASS JOINT CONDITIONS

GOP /Point	Orientation: Dip	Orientation: Dip Direction	Discontinuity Type	1: UCS	2: RQD (%)	3: Spacing (m)	4 Condition of Discontinuities: Length / Persistance (m)	Sepration (mm)	Roughness	Infilling	Weathering	5: Ground Water Codition	Lithology	Remarks & Water Conditions
11	30	255	J1	5 to 25	<25	0.06 m	3 to 10	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale	Wet to Dry water condition have been observed at the exposed out crop
	85	340	J2				1 to 3							
	60	95	J3			0.06 - 0.2 m		0.1 - 1						

ROCK MASS CLASSIFICATION & JOINTS ORIENTATION

Rock Mass Rating (Bieniawski, 1989)		
UCS:	2	4
RQD:	5	8
J-Spacing:	5	8
J-Conditions:	7	16
GW-Conditions:	7	10
J-Orientation:	-10	-12
RMR_{89}:	**16**	**34**
Correlations		
GSI ≈ (Dry RMR_{89})-5 =	14	31
Q-value (Barton95) =	0.005	0.086
Q-value (Bieniawski89) =	0.04	0.33

Q-value (NGI, 2013)		
RQD:	10	20
Jn:	15	12
Jr:	2	3
Ja:	3	2
Jw:	0.66	0.66
SRF:	2.5	2.5
Q:	**0.12**	**0.66**
Correlation		
RMR (Barton95) =	36	47
RMR (Bieniawski89) =	25	40



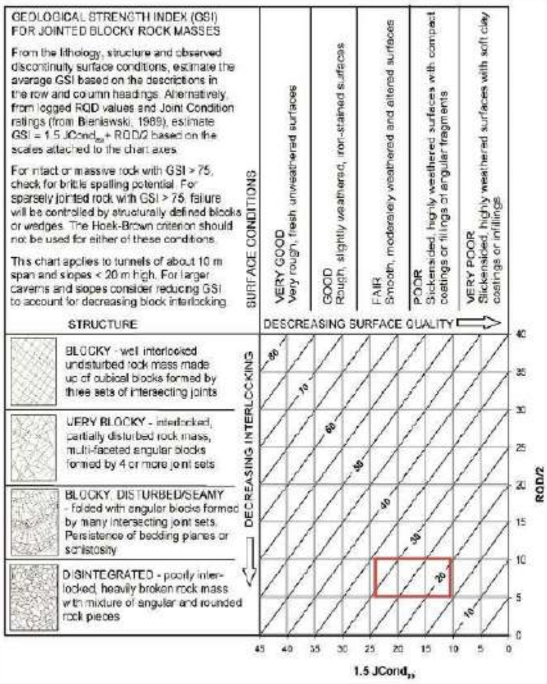


Figure 1.53: GOPS 11

10 SLOPE STABILITY

The slope stability map was created using Shuttle Radar Topographic Mission (SRTM) data from the Bhuvan Store, NRSC, and processed with ArcGIS software to illustrate the gradient of the target area. The slope in the area ranges from 0° to 58° (Fig. 1.54). The steepest slopes are found along the ridges, while the valley areas and the stretch along the Gambhar River exhibit lower slopes. The majority of the area has slope angles between 21° and 40°. The northern and northeastern parts of the toposheet show steeper slopes, while the southern and southwestern areas have gentler to moderate slopes.

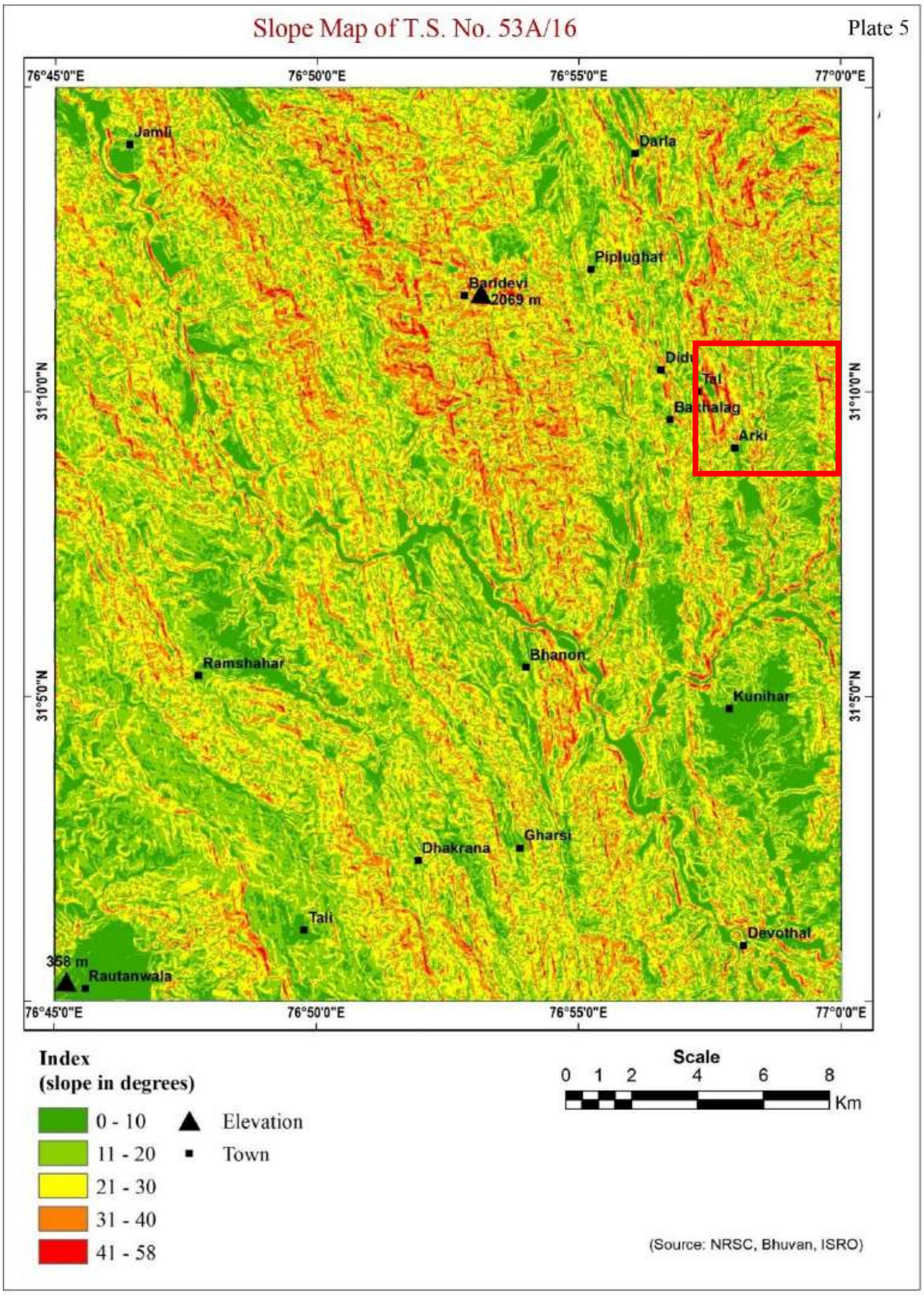


Figure 1.54: Slope Map (Project Area Marked in Red)

The entire project area, where shale and slate are present, is highly prone to landslides. In contrast, regions with Dolomite, Limestone, Sandstone, and Quartzite are relatively more stable, though they are affected by structurally controlled, fragile topography, sensitive rock conditions, heavy rainfall, and occasional earthquakes. Although the areas with Quartzite, Sandstone, and Dolomite along the alignment are generally stable, the joint orientations create wedges, leading to rockfall on the highway. Therefore, slope protection will be necessary along the cutting sections.

The Solan region, located in the Lesser Himalayas, faces significant landslide risks due to its geologically brittle terrain, combined with heavy rainfall and other natural and human factors. Mountain roads and highways are critical infrastructure in this area, but they are often disrupted by landslides, impacting regular traffic, especially during the monsoon season. These events cause significant challenges for transportation and communication, negatively affecting economic, commercial, and developmental activities. Landslides in the project area are increasing, with most occurring during extended rainfall periods.

11 Geotechnical Hazard Identification

Rockfall are common along transportation routes where deep cuts have been made into rock slopes. These events can cause significant damage to roads and infrastructure, potentially leading to route closures and costing millions of rupees per incident. Similarly, landslides are frequently triggered near areas that have been altered by human activities, such as land development or soil excavation. Given the frequency and potential severity of these hazards, it is clear that both rockfall and landslides must be carefully assessed and managed.

Rockfall generally occur in rock-cut slopes when rock blocks become dislodged due to weathering, flowing water, or erosion of surrounding rocks and soil.

- Rockfall: This hazard typically arises along rock slopes but can also occur in mixed areas (rock slopes with debris). The occurrence of rockfall is strongly linked to the degree of fracturing within the rock mass. The impact of such instability depends largely on the size of the unstable rock blocks.
- Shallow landslides: These are commonly found along existing national highways and potential new alignment routes. These landslides typically involve several meters of debris, including gravel, sand, cobbles, and pebbles.

The risk of these geotechnical hazards was observed during the mapping campaign at all portals and potential cut locations. It is essential to consider the effects of these hazards and implement appropriate countermeasures during the construction of portals, cuts, and roads throughout the project.

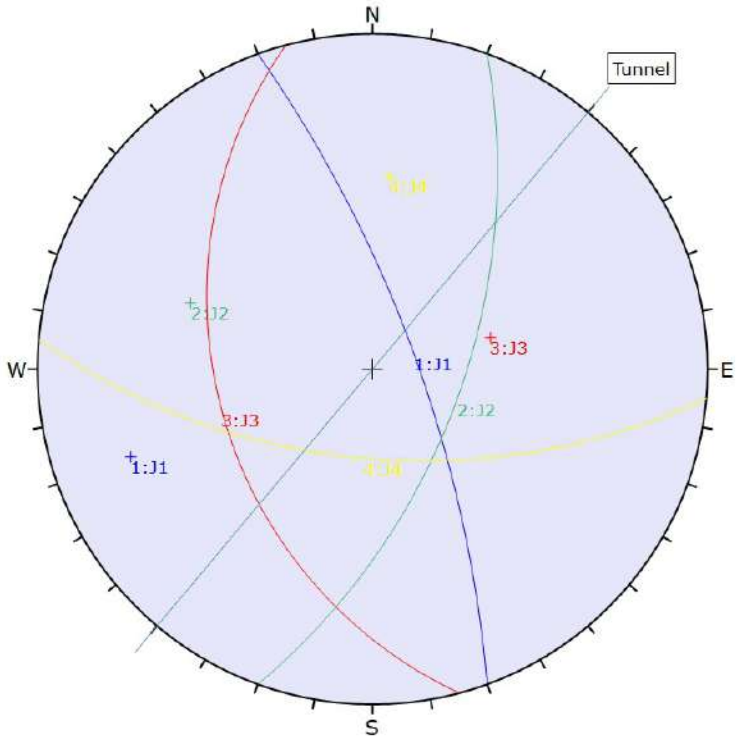
12 TOPOGRAPHY / HYDROLOGY TUNNEL T-1, P1

12.1 Portal areas of Tunnels T-1 Ch. 29+410

Geology of the Area: The proposed twin-tube tunnels for the four-lane configuration maintain a horizontal distance of 30 meters between the two tubes, with little variation in geology or joint orientation. The general bedding plane, J1, of the rock mass is oriented at 75º/070-080º (near the P-1 portal location). The tunnel alignment runs obliquely to the strike of the rock mass. The rock mass exhibits three or more random joint sets, with the bedding joint and the N-S trending joint sets being the most prominent. The various joint sets observed in the area are summarized in the table below:

ROCK MASS JOINT CONDITIONS												
Orientation			1	2	3	4 Condition of Discontinuities					5	Description
Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length/Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Weathering	Ground Water	Lithology
75	70-80	J1	100 to 250	25 to 50	0.06 - 0.2	3 to10	1-5 mm	R	<5	Sl- MW	Damp-Dry	Dolomite
60	110	J2		50 to 75	0.2 to 0.6	1 to 3						
40	255	J3										
60	185	J4										

Table 1.8: Main Joint Sets T-1 at 29+410



	Color	Dip	Dip Direction	Label
User Planes				
1		75	70	J1
2		60	110	J2
3		40	255	J3
4		60	185	J4

Figure 1.55: Main Joint Sets T-1 at 29+410

At the proposed location of Portal-1 for Tunnel T-1, the cutting section along the National Highway reveals a different rock composition compared to the portal area. The cutting section consists of moderately to highly weathered Dolomite/Limestone, while the portal area is characterized by Dolomite with a high quartz content. The slopes in this area are moderately steep, and excavation activities are likely to destabilize the area, necessitating proper protective measures. The portal location is in close proximity to the existing highway and falls within Package-IIA of the Shimla-Mataur section.

Photo 1: Hard Compact Dolomite Rock Exposure at T1P1 near the Portal

Photo 2: Portal-1 Location

Photo 3: Meter from Portal-1 Towards Road Side Rock Around the Portal Areas

Traversing along the Tunnel Alignment

During the site visit, we observed alternating bands of Dolomite and some Sandstone along the entire tunnel alignment. The tunnel engineers will face challenges during both the design and construction phases. The likelihood of water ingress into the tunnel in this project is high. The primary stratum along the tunnel path consists of moderately strong Dolomitic rock and alternating Sandstone bands. Comprehensive rock mass characterization using various classification systems has shown that, due to the moderately strong properties of the Dolomite rock, the tunnel sections will remain stable for more than 48 hours.

Based on surface field geological investigations, the Solan and Bilaspur Formation Dolomite, along with some Sandstone layers, is predominantly inclined. There is significant mechanical separation between the different layers in the Dolomite rock and weathered Limestone, with bedding rocks appearing to be moderately strong or strong. Field testing of rock strength using simple methods (Hoek and Brown classification) revealed that the rock material cannot be crumbled with a firm blow from a geological hammer; it requires at least 10-15 blows to break the rock. Based on field observations, the rock material near the tunnel area, consisting of Dolomite and some phyllitic rock along with weathered Sandstone, is classified as moderately strong. Additionally, minor folding near the portal area indicates that this zone has experienced compression.

Photo 4: Moderately weathered Dolomite with Soil cover

12.2 Topography of Tunnel T-1 at 30+500

The geology of the area at chainage 30+500 is exposed along the road cutting section, which is characterized by shrubs and trees. The alignment passes beneath the Ghanghughat Gram Panchayat Building, and the vertical alignment of the trees indicates that the ground mass is stable. However, the ground mass in this region is weak, with a mixed geological composition, primarily consisting of schist/shale beds interspersed with some hard Dolomite beds.

While three joint sets and the stratification generally maintain consistent orientation along the tunnel, the heterogeneity of the rock mass made them difficult to distinguish across all mapped fronts. The joint orientation was also affected by the fact that mapping was done along the road, as tunnel traversing was not possible due to steep cliffs. In this zone, the tunnel faces will likely encounter heterogeneous conditions during construction, including very hard, compact Dolomite layers interspersed with moderately to weak shale/Schist bands. Specific blasting techniques will be required for different rock classes to break up the hardest Quartzitic and Dolomite rocks, as well as the moderately strong sandstone materials. The rock mass, composed of moderately strong fresh rock, will likely have a UCS value of 25-30 MPa. Engineering geology front maps and facelogs must be prepared by the contractor's geologist. The average RMR value is expected to range from 20 to 25. Due to the heterogeneity of the rock fronts and overburden, proper 3D monitoring and instrumentation will be necessary during tunnel construction.

The three joint sets encountered in this zone, along with their orientation and other details, are summarized in the table below:

<table>
<tr><th colspan="13">ROCK MASS JOINT CONDITIONS</th></tr>
<tr><th colspan="2">Orientation</th><th rowspan="2">Discontinuity Type</th><th>1</th><th>2</th><th>3</th><th colspan="5">4 Condition of Discontinuities</th><th>5</th><th>Description</th></tr>
<tr><th>Dip</th><th>Dip Direction</th><th>UCS</th><th>RQD (%)</th><th>Spacing (m)</th><th>Length/Persistence (m)</th><th>Separation (mm)</th><th>Roughness</th><th>Infilling (mm)</th><th>Weathering</th><th>Ground Water</th><th>Lithology</th></tr>
<tr><td>50</td><td>210</td><td>J1</td><td>5 to 25</td><td rowspan="3"><25</td><td rowspan="2">0.06 - 0.2</td><td rowspan="2">3 to 10</td><td rowspan="2">1-5 mm</td><td rowspan="3">Sl. R- Sm</td><td rowspan="3"><5</td><td rowspan="3">MW-HW</td><td rowspan="3">Damp-Dry</td><td rowspan="3">Shale/Slate With Dolomite</td></tr>
<tr><td>60</td><td>120</td><td>J2</td><td rowspan="2">25 to 30</td></tr>
<tr><td>55</td><td>85</td><td>J3</td><td></td><td></td><td></td></tr>
</table>

Table 1.9: Main Joint Sets T-1 at 30+500

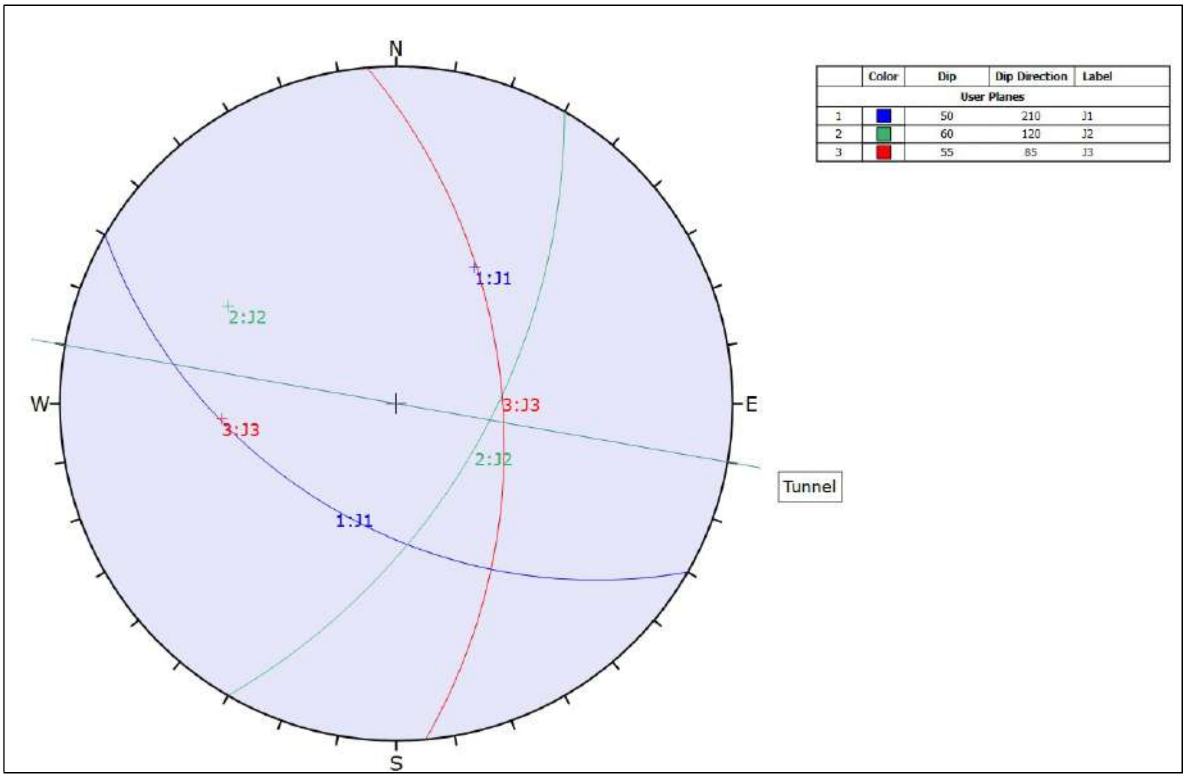


Figure 1.56: Main Joint Sets T-1 at 30+500

Photo 5: Dolomitic Rock at 30+500

Photo 6: Moderately Strong to Strong Dolomite Rock

Photo 7: Moderately Strong to Strong Quartzitic Dolomite Rock

12.3 Topography of Tunnel T-1 at 30+900

The surface geology at chainage 30+900 indicates that the tunnel lithounits consist of a uniformly dipping alternating sequence of quartzitic dolomite rock and slightly weathered sandstone, with intermixed quartzite and dolomite. The bedding plane generally trends at 35º/245º and is accompanied by three prominent joint planes and one random joint plane. Quartzite and dolomitic rock samples were observed at km 30+900, along with weathered sandstone and shale along the tunnel alignment.

Quartzitic Dolomite Rock: This rock exhibits an equigranular texture and is primarily composed of quartz and other minerals. Schistosity is well-developed, and occasional quartz veins are present. The rock is harder compared to the weathered sandstone.

All the rock units along the tunnel alignment have been classified using the RMR system developed by Bieniawski (1989). The different rock units along the alignment are categorized as having poor to fair rock quality. The presence of shear zones and weak soil bands in the rock mass could be encountered during construction, with a higher probability of rockfall due to wedge formation. In this area, conditions classified as Class IV and V may be encountered.

The general orientation and other geological conditions for this area are summarized in the table below:

ROCK MASS JOINT CONDITIONS												
Orientation			1	2	3	4 Condition of Discontinuities					5	Description
Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length/Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Weathering	Ground Water	Lithology
35	245	J1	5 to 25	<25	0.06 m	3 - 10 m	1 - 5 mm	Sl. R to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale & Dolomite
30	100	J2				1 - 3 m						
56	340	J3			0.06 - 0.2 m		0.1 - 1					

Table 1.10: Main Joint Sets Tunnel T-1 at 30+900

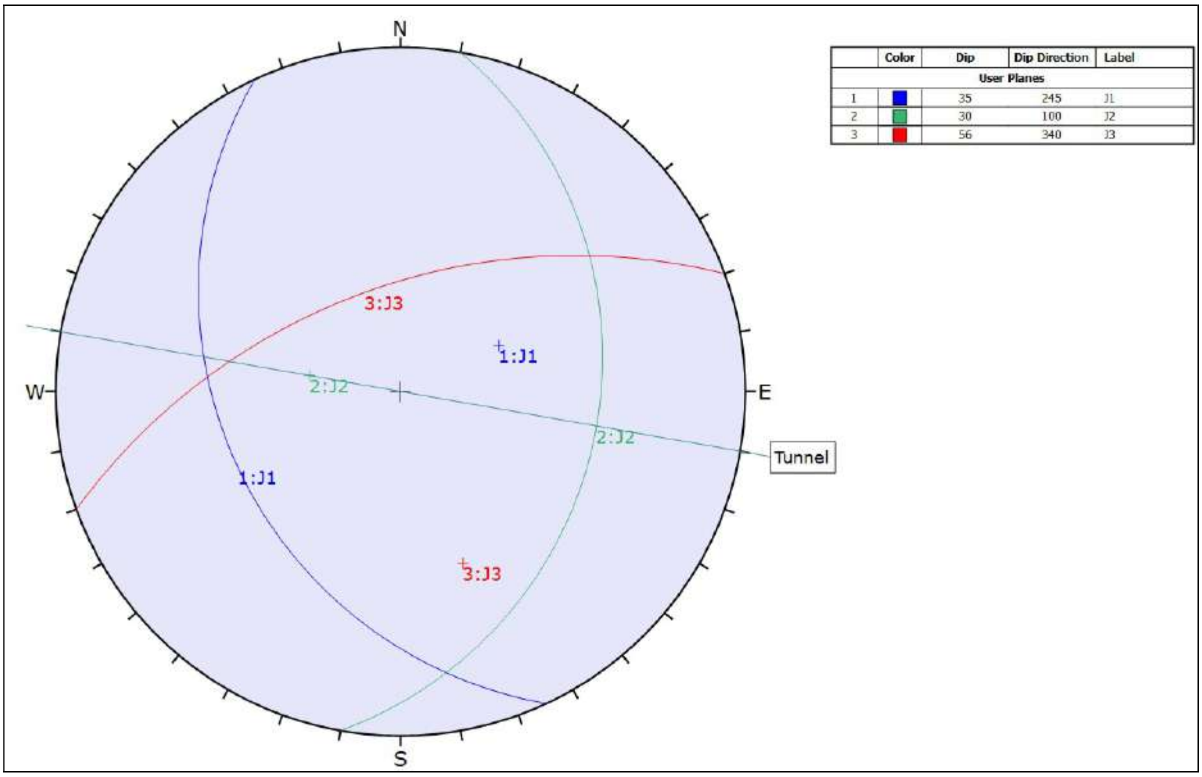


Figure 1.57: Main Joint Sets Tunnel T-1 at 30+900

12.4 Topography of Tunnel T-1 at 31+100

The proposed location along the tunnel alignment for Package-IIA features slopes that range from gentle to steep, with medium vegetation covering the surface and denser shrubs present in certain patches. The drains in the area are steep, narrow, and typically seasonal. The height of the mountains above the road is approximately 50-80 meters, with the road following a zigzag pattern and varying elevations.

Due to the steep slopes, the soil cover is minimal, and during rainfall, the degree of water infiltration into the ground is expected to be low because of the presence of joints. Geological mapping of the portal area, along with general geological observations and RMR calculations, has been carried out. The soil cover at this location is thin, ranging from about 0.5 to 2 meters. The area is composed of weathered, fractured, and highly jointed Dolomite/Limestone and shale rock. These weathered rocks exhibit three sets of random joints with soft to hard infillings.

The rock mass in this area has three sets of joints, ranging from slightly open to partially open, with high persistence. The bedding joints are more prominent, and the rock mass shows minor folding structures. The random joints form wedge structures, which are present throughout much of the area.

The slopes are covered by vertical trees and shrubs, and in some places, road cuts expose the rock types and joints. Above the alignment, there are paddy fields, and the potential ingress of water may be encountered during construction.

	*Photo 8: Highly sheared dolomite*

	*Photo 9: Tunnel alignment is below this paddy field*

The data was collected at different locations and the details are as follows:

<table>
<tr><th colspan="13">ROCK MASS JOINT CONDITIONS</th></tr>
<tr><th colspan="2">Orientation</th><th rowspan="2">Discontinuity Type</th><th>1</th><th>2</th><th>3</th><th colspan="5">4 Condition of Discontinuities</th><th>5</th><th>Description</th></tr>
<tr><th>Dip</th><th>Dip Direction</th><th>UCS</th><th>RQD (%)</th><th>Spacing (m)</th><th>Length/Persistence (m)</th><th>Separation (mm)</th><th>Roughness</th><th>Infilling (mm)</th><th>Weathering</th><th>Ground Water</th><th>Lithology</th></tr>
<tr><td>70</td><td>260</td><td>J1</td><td rowspan="3">5 to 25</td><td rowspan="3"><25</td><td rowspan="2">0.06 m</td><td>3 - 10 m</td><td rowspan="2">1 - 5 mm</td><td rowspan="3">Sl. R to Sm</td><td rowspan="3">soft < 5 mm</td><td rowspan="3">MW to HW</td><td rowspan="3">Dry to Wet</td><td rowspan="3">Dolomite & Shale</td></tr>
<tr><td>70</td><td>180</td><td>J2</td><td>1 - 3 m</td></tr>
<tr><td>60</td><td>140</td><td>J3</td><td>0.06 - 0.2 m</td><td></td><td>0.1 - 1</td></tr>
</table>

Table 1.11: The Various Joint Sets Recorded in the Area T-1 at 31+100)

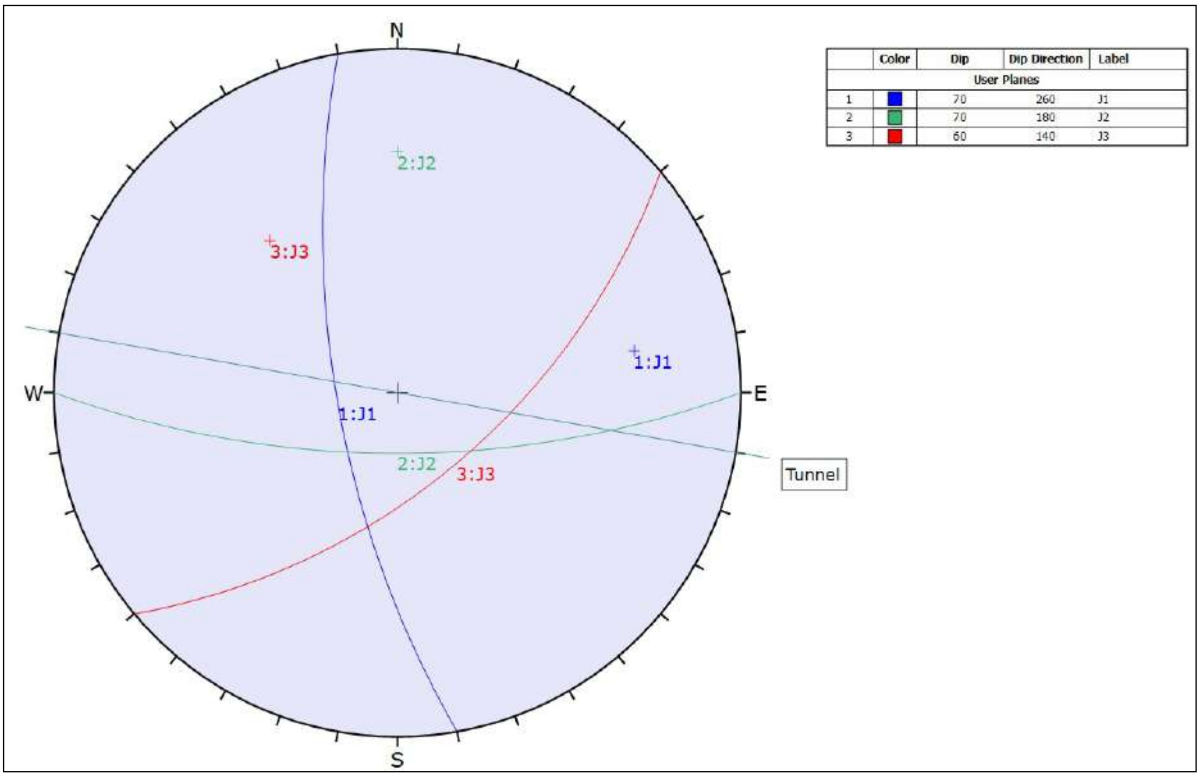


Figure 1.58: The Various Joint Sets Recorded in the Area T- 1 at 31+100)

The UCS in this zone is between 40 to 50 MPa and RMR value calculated at this area is between 35- 40.

12.5 Topography of Tunnel T-1 at 31+600

The geology at chainage 31+600 is exposed along the cutting section of the road, where the area is characterized by shrubs and trees. The ground is mixed, with the predominant rock being grey dolomite. Weathering is significant in this zone, and some sheared rock mass has been observed during traversing. The region also contains hard and compact rock, with the UCS ranging between 35 to 40 MPa and an RMR value between 25 and 30. Iron staining is visible on the outcrop, and some rock beds display quartz layering.

The orientation of the joints varies, as the mapping was carried out along the road, and traversing along the tunnel route was not possible due to steep cliffs. In this zone, the tunnel may encounter heterogeneous working faces during construction, consisting of very hard compact dolomite layers, occasionally interspersed with moderately to weak shale or schist bands. Specific blasting techniques will be required for different rock types, including the hardest quartzitic dolomite, sandstone, and moderately strong sandstone materials. Additionally, a Nalla channel flows just above the tunnel alignment, so the potential for water ingress inside the tunnel cannot be ruled out. A proper drainage system must be implemented during construction. Engineering geology front maps and face logs should be prepared by the contractor's geologist. The average RMR value in this zone is between 25 and 30.

Given the heterogeneity of the rock faces and overburden, 3D monitoring and instrumentation will be essential throughout the tunneling process.

ROCK MASS JOINT CONDITIONS												
Orientation			1	2	3	4 Condition of Discontinuities					5	Description
Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length/Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Weathering	Ground Water	Lithology
85	170	J1	30 - 40	20-30	0.06 - 0.2 m	3 - 10 m	0.1 - 1	Sl. R	hard > 5 mm	Sl. W to MW	Dry to Wet	Dolomite
40	210	J2				1 - 3 m						
75	250	J3										

Table 1.12: Main Joint Sets Tunnel T-1 at 31+600

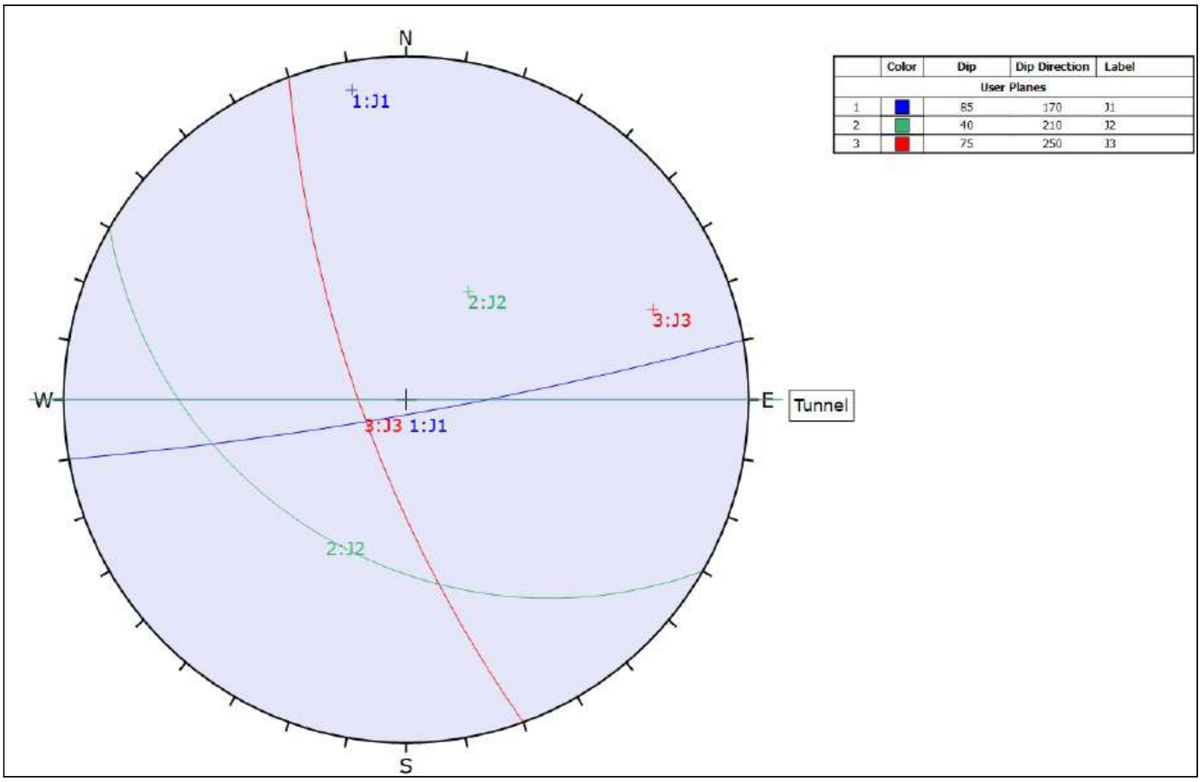


Figure 1.59: Main Joint Sets Tunnel T-1 at 31+600

12.6 Topography of Tunnel T-1 at 33+010 (Portal -2)

The surface geology at chainage 33+010 reveals that the tunnel litho-units consist of moderately to highly weathered sandstone, with intermixing of quartzitic dolomite and sandstone. The bedding plane generally trends at 55º/140-150º, with three dominant joint planes and one random joint plane. Quartzite and sandstone rock samples were observed at km 33+010, and weathered sandstone and shale are also present along the tunnel alignment. The quartzitic dolomite rock exhibits an equigranular texture, primarily composed of quartz minerals. Schistosity is well-developed, with occasional quartz veins commonly found. This rock is harder than the weathered sandstone.

	*Photo 10: Highly Sheared Sandstone With Intermixed of Soil*
	*Photo 11: Highly Sheared Rock with Schistosity*

All rock units along the tunnel alignment have been classified using the RMR system proposed by Bieniawski (1989). The rock units along the alignment, as classified by the RMR system, exhibit poor to very poor rock quality. During construction, shear zones and weak soil bands may be encountered, with a potential risk of collapse due to the soil. Conditions in this zone may correspond to Class V and VI rock classifications. The general orientation and other geological conditions for this area are provided in the table below.

<table>
<tr><th colspan="14">ROCK MASS JOINT CONDITIONS</th></tr>
<tr><th colspan="2">Orientation</th><th rowspan="2">Discontinuity Type</th><th>1</th><th>2</th><th>3</th><th colspan="5">4 Condition of Discontinuities</th><th>5</th><th>Description</th></tr>
<tr><th>Dip</th><th>Dip Direction</th><th>UCS</th><th>RQD (%)</th><th>Spacing (m)</th><th>Length/Persistence (m)</th><th>Separation (mm)</th><th>Roughness</th><th>Infilling (mm)</th><th>Weathering</th><th>Ground Water</th><th>Lithology</th></tr>
<tr><td>55</td><td>140-150</td><td>J1</td><td rowspan="3">5 to 25</td><td rowspan="3"><25</td><td rowspan="2">0.06 m</td><td>3 - 10 m</td><td rowspan="2">1 - 5 mm</td><td rowspan="3">Sl. R to Sm</td><td rowspan="3">soft < 5 mm</td><td rowspan="3">MW to HW</td><td rowspan="3">Dry to Wet</td><td rowspan="3">Dolomite, Sandstone and Shale</td></tr>
<tr><td>65</td><td>220</td><td>J2</td><td>1 - 3 m</td></tr>
<tr><td>45</td><td>10</td><td>J3</td><td>0.06 - 0.2 m</td><td></td><td>0.1 - 1</td></tr>
</table>

Table 1.13: Main Joint Sets Tunnel T-1 at 33+010 (Portal -2)

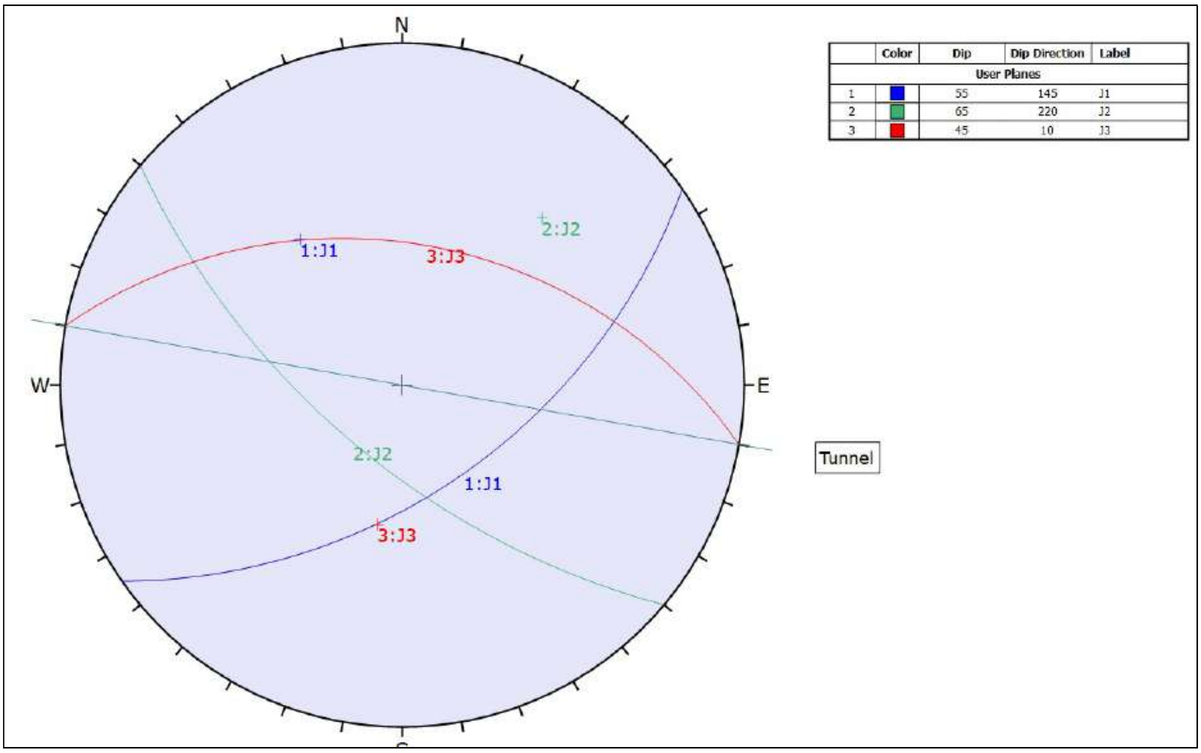


Figure 1.60: Main Joint Sets Tunnel T-1 at 33+010 (Portal -2)

Photo: 12 Quartzitic Rock having Quartz Layer

Photo 13: Moderately Strong to Strong Quartzitic Rock

12.7 Folding

The rocks in this area exhibit significant folding, particularly around Bandli Tibba, where three synclines are separated by two anticlines. To the east of Mandi, in the Chali belt, a major anticline is suspected, with the core likely composed of granites. The only evidence for this potential anticline is the repetition of green and grey phyllites on either side of the granite. In the Bandli Tibba region, the fold axes trend approximately north-south, but these have been cross-folded along a northwest-southeast axis with a shallow plunge toward the southeast. As a result, the outcrops display a sinuous pattern. The folds in this area are typically isoclinal in nature. Further north, near Maloh Nala, good exposures of Jaunsar rocks reveal several asymmetric folds, also trending north-south.

Photo 14: Visible Fold Along the Tunnel Alignment P-1

Photo 15: Visible Fold Along the Tunnel Alignment P-1

13 TOPOGRAPHY T-2, P1

13.1 Topography of Tunnel T-2 at 34+215

The geology of the Chainage 34+215 area, visible along the road's cutting section, features a landscape with shrubs and trees. The vertical orientation of the trees suggests that the ground mass is stable, though it is weak in nature. The geology in this zone is mixed, predominantly consisting of highly sheared shale/slate, along with some weathered sandstone beds. The shale is interspersed with highly weathered sandstone layers.

The three joint sets and stratification generally maintained their orientation along the tunnel; however, due to the rock mass's heterogeneity, they were not distinctly identified across all mapped fronts. The joint orientation also varied, as the mapping was carried out along the road, and access to the tunnel alignment was not possible because of steep cliffs and highly sheared ground mass.

In this zone, the tunnel is expected to encounter heterogeneous working faces composed of highly sheared shale/slate and weathered, fractured sandstone. The rock mass's unconfined compressive strength (UCS) is anticipated to range between 10-15 MPa. The contractor's geologist must prepare engineering geology front maps and facelogs. The average RMR value for this area falls between 10-15. Given the variability of the rock faces and overburden, effective 3D monitoring and instrumentation will be essential during tunnel construction.

Additionally, three joint sets were identified in this zone, and the details of their orientation and other relevant information are provided in the table below:

ROCK MASS JOINT CONDITIONS													
Orientation			1	2	3	4 Condition of Discontinuities						5	Description
Dip	Dip Direction	Discontinuity Type	UCS	RQD (%)	Spacing (m)	Length/Persistence (m)	Separation (mm)	Roughness	Infilling (mm)	Weathering	Ground Water	Lithology
50-65	220-240	J1	5 to 25	<25	0.06 m	3 - 10 m	1 - 5 mm	Sl. R. to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale /Sandstone
55	150-160	J2				1 - 3 m						
60	310	J3			0.06 - 0.2 m		0.1 - 1					

Table 1.14: Main Joint Sets PKG-II B at 34+215

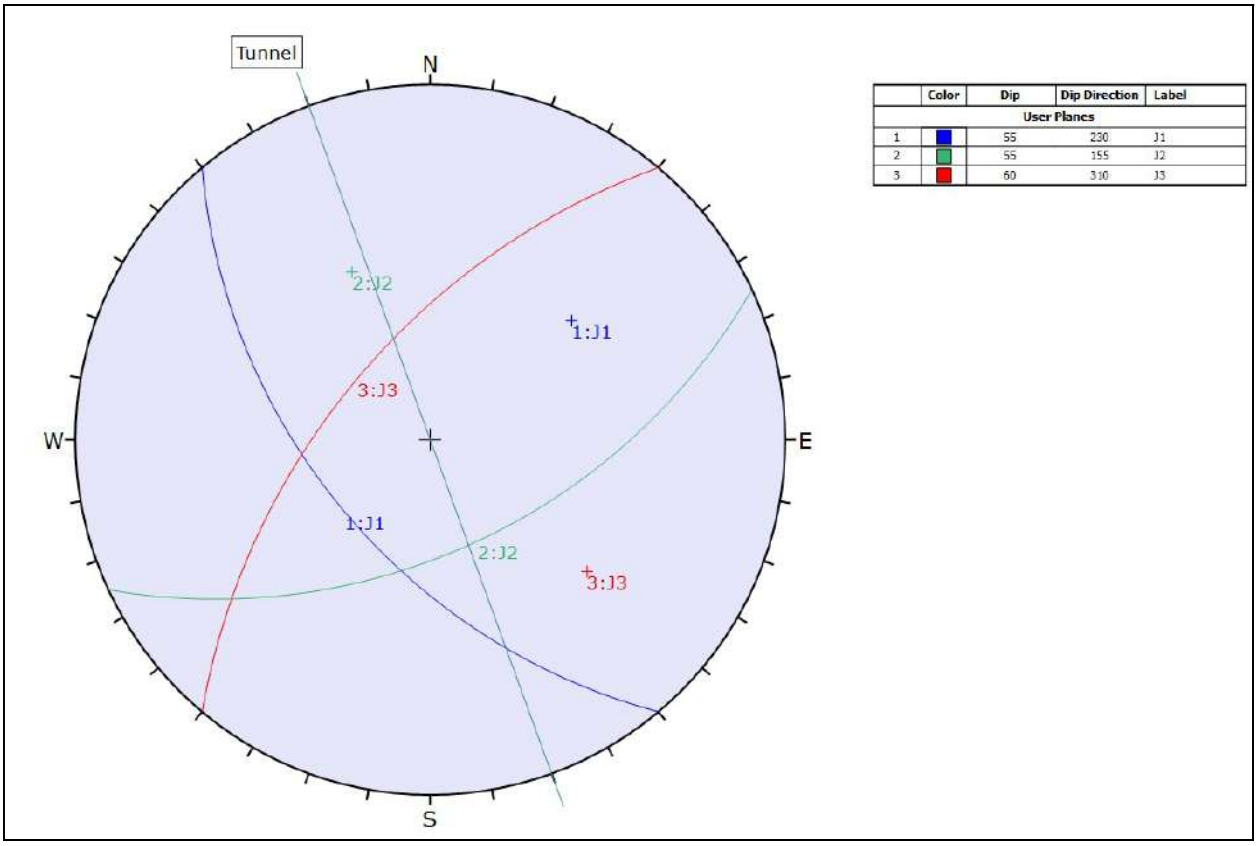


Figure 1.61: Main Joint Sets PKG-II B at 34+215

Photo 16: Highly Weathered and Fractured Ground Mass

Photo 17: Highly Sheared Rock

13.2 Topography of Tunnel T-2 at 34+560

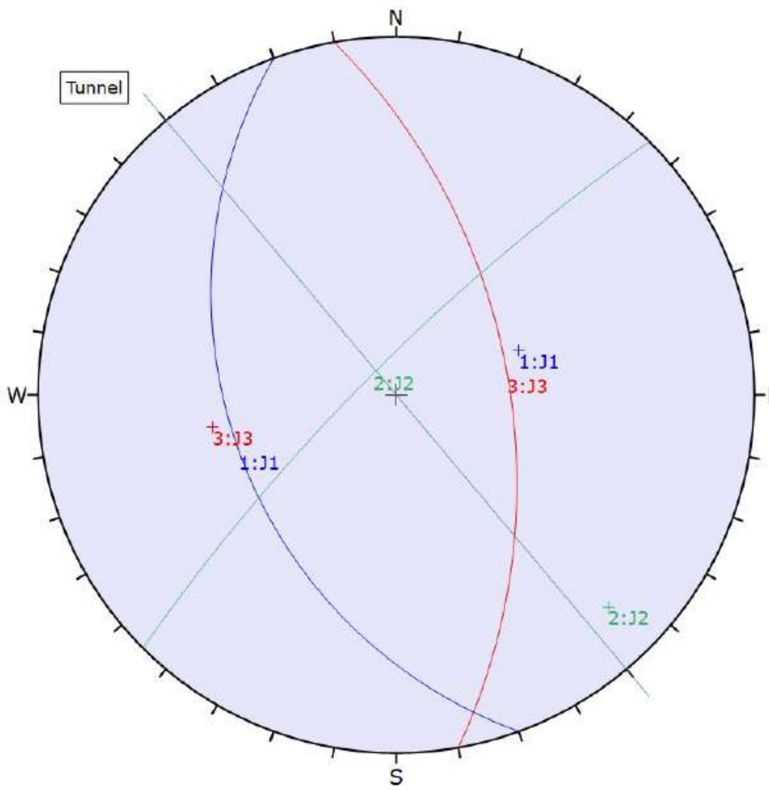
The surface geology at chainage 34+560 indicates that the rock types along the tunnel alignment consist of a uniformly dipping alternating sequence of highly sheared, highly to moderately weathered shale and slate, interspersed with bands of moderately to highly weathered, fractured sandstone. The bedding plane generally trends at 40°/245°-255°, with three dominant joint planes observed. Shale and slate rock samples were identified at km 34+560, and weathered sandstone and shale are also present in this zone along the tunnel alignment.

Photo 18: Highly Sheared Ground Mass

All the rock units along the tunnel alignment have been classified using the RMR system proposed by Bieniawski (1989). The rock units in this area are categorized as having poor to very poor rock quality. During excavation, shear zones and weak soil bands may be encountered, leading to a high probability of rockfall. In this zone, conditions corresponding to Class V and VI may be encountered. The general orientation and other geological characteristics of this area are provided in the table:

ROCK MASS JOINT CONDITIONS												
Orientation			**1**	**2**	**3**	**4 Condition of Discontinuities**					**5**	**Description**
Dip	**Dip Direction**	**Discontinuity Type**	**UCS**	**RQD (%)**	**Spacing (m)**	**Length/Persistence (m)**	**Separation (mm)**	**Roughness**	**Infilling (mm)**	**Weathering**	**Ground Water**	**Lithology**
40	245-255	J1	5 to 25	<25	0.06 m	3 - 10 m	1 - 5 mm	Sl. R. to Sm	soft < 5 mm	MW to HW	Dry to Wet	Shale
80	310-320	J2				1 - 3 m						
55	080	J3			0.06 - 0.2 m		0.1 - 1					

Table 1.15: Main Joint Sets PKG-II B at 34+560



	Color	Dip	Dip Direction	Label
		User Planes		
1		40	250	J1
2		80	315	J2
3		55	80	J3

Figure 1.62: Main Joint Sets PKG-II B at 34+560

13.3 Folding

The rocks in the project area are highly folded, with prominent folding occurring where three synclines are separated by two anticlines. To the east of Mandi, in the Chali belt, a major anticline is suspected, with granites occupying its core. The only evidence supporting the potential anticlinal nature is the repetition of green and grey phyllites on either side of the granites. In the project area, the fold axes generally trend in a north-south direction. These folds have been cross-folded along a northwest-trending axis (with a shallow plunge to the southeast), resulting in sinuous outcrop patterns. The folds are predominantly isoclinal in nature. North of Maloh Nala, where well-exposed Jaunsar formations are visible, several asymmetric folds trending in the north-south direction are observed.

	*Photo 19: Visible Fold Along the Tunnel Alignment*
	*Photo 20: Visible Fold Along the Tunnel Alignment*

Photo 21: Visible Fold Along the Project Alignment P-1

Photo 22: Visible Fold Along the Project Alignment P-1

13.4 Frequency distribution of rock-mass along tunnel alignment

On the basis of tentative geological section prepared, attempt has been made to analyze the status of anticipated rock mass conditions during execution of Tunnel-1 and Tunnel -2

The following table shows chainage-wise distribution of rock- mass conditions along alignment:

	Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
Sr. No.	From	To	Total (m)			RMR	Rock Class
1.	29+410	29+435	25	Highly weathered Limestone/dolomite	Highly weathered & fractured	20-25	Portal Class
2.	29+435	29+630	195	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately weathered & fractured	40-45	Fair
3.	29+630	29+843	213	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately to highly weathered	35-40	Poor
4.	29+843	30+123	280	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately Weathered	40-45	Fair
5.	30+123	30+522	399	Moderately to Highly weathered Shale & Slate	Moderately Weathered	35-40	Poor
6.	30+522	30+830	308	Moderately to Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor

Sr. No.	Design Chainage (Km) From	To	Total (m)	Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating: RMR	Rock Class
7.	30+830	31+180	350	Moderately to Highly weathered Shale & Slate	Moderately weathered & fractured	40-45	Fair
8.	31+180	31+565	385	Moderately weathered Shale & Slate	Moderately Weathered	30-35	Poor
9.	31+565	31+895	330	Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor
10.	31+895	32+363	468	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	42-48	Fair
11.	32+363	32+561	198	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	45-50	Fair
12.	32+561	32+900	339	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	30-35	Poor
13.	32+900	32+995	95	Highly weathered Shale & Slate with bands of sandstone	Highly weathered & fractured	15-20	V. Poor
14.	32+995	33+020	25	Highly Weathered Shale & Slate	Highly weathered & fractured	20-25	Portal Class

Table 1.16: Distribution of Rock- Mass Conditions on the Basis of RMR Classification Tunnel T-1 (LHS)

Sr. No.	Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
	From	To	Total (m)			RMR	Rock Class
1.	29+380	29+405	25	Highly weathered Limestone/dolomite	Highly weathered & fractured	20-25	Portal Class
2.	29+405	29+655	250	Moderately weathered Shale & Slate	Moderately weathered & fractured	40-45	Fair
3.	29+655	29+791	136	Moderately weathered Shale, Slate & Sandstone	Moderately to highly weathered	35-40	Poor
4.	29+791	30+041	250	Moderately weathered Shale, Slate & Sandstone	Moderately Weathered	40-45	Fair
5.	30+041	30+451	410	Moderately weathered Shale, Slate & Sandstone	Moderately Weathered	35-40	Poor
6.	30+451	30+761	310	Highly weathered Shale, Slate & Sandstone	Highly weathered & fractured	15-20	V. Poor
7.	30+761	31+071	310	Moderately weathered Shale, Slate & Sandstone	Moderately weathered & fractured	40-45	Fair
8.	31+071	31+521	450	Moderately to Highly weathered Shale & Slate	Moderately Weathered	30-35	Poor
9.	31+521	31+846	325	Highly weathered Shale & Slate With Sandstone bands	Highly weathered & fractured	15-20	V. Poor
10.	31+846	32+316	470	Moderately weathered Shale & Slate With Sandstone bands	Moderately weathered & fractured	42-48	Fair
11.	32+316	32+536	220	Moderately weathered Shale & Slate with Dolomite bands	Moderately weathered & fractured	45-50	Fair
12.	32+536	32+883	347	Moderately weathered Shale & Slate with Dolomite bands	Moderately weathered & fractured	30-35	Poor
13.	32+883	32+985	102	Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor
14.	32+985	33+010	25	Highly weathered Shale & Slate	Highly weathered & fractured	20-25	Portal Class
15.							

Table 1.17: Tunnel T-1 (RHS/Parallel Tunnel)

Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
34+250	34+444	194	Highly weathered Shale/Slate & Sandstone	Highly weathered & fractured	10-15	V. Poor
34+444	34+474	30	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	20-25	Poor
34+474	34+510	36	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	10-15	V. Poor

Table 1.18: Distribution of Rock- Mass Conditions on the Basis of Rock Mass rating Tunnel T-2 (LHS)

Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
34+215	34+389	174	Highly weathered Shale/Slate & Sandstone	Highly weathered & fractured	10-15	V. Poor
34+389	34+459	70	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	20-25	Poor
34+459	34+560	101	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	10-15	V. Poor

Table 1.19: Tunnel T-2 (RHS/Parallel Tunnel)

The area exhibits diverse geology, and the classification will be updated following a detailed geotechnical investigation. The classifications provided above are based solely on surface geological mapping. During execution, the contractor will be required to conduct a thorough geotechnical investigation, and the data gathered from this investigation will be incorporated into the detailed design.

14 CONCLUSIONS

Based on the preliminary surface geological assessment conducted during the field visit and the alignment traversing along the tunnel, it is concluded that tunneling can be anticipated. The geotechnical investigation is currently ongoing, and once completed, this report will be updated accordingly.

Rock Class	Total Length Anticipated (in meter)	% Along Tunnel Alignment
Good	0	0.00
Fair	1491	41.30
Poor	1336	37.00
Very Poor	733	20.30
Portal Class	50	1.40

Table 1.20: Preliminary Surface Geological Assessment Tunnel T-1 (LHS)

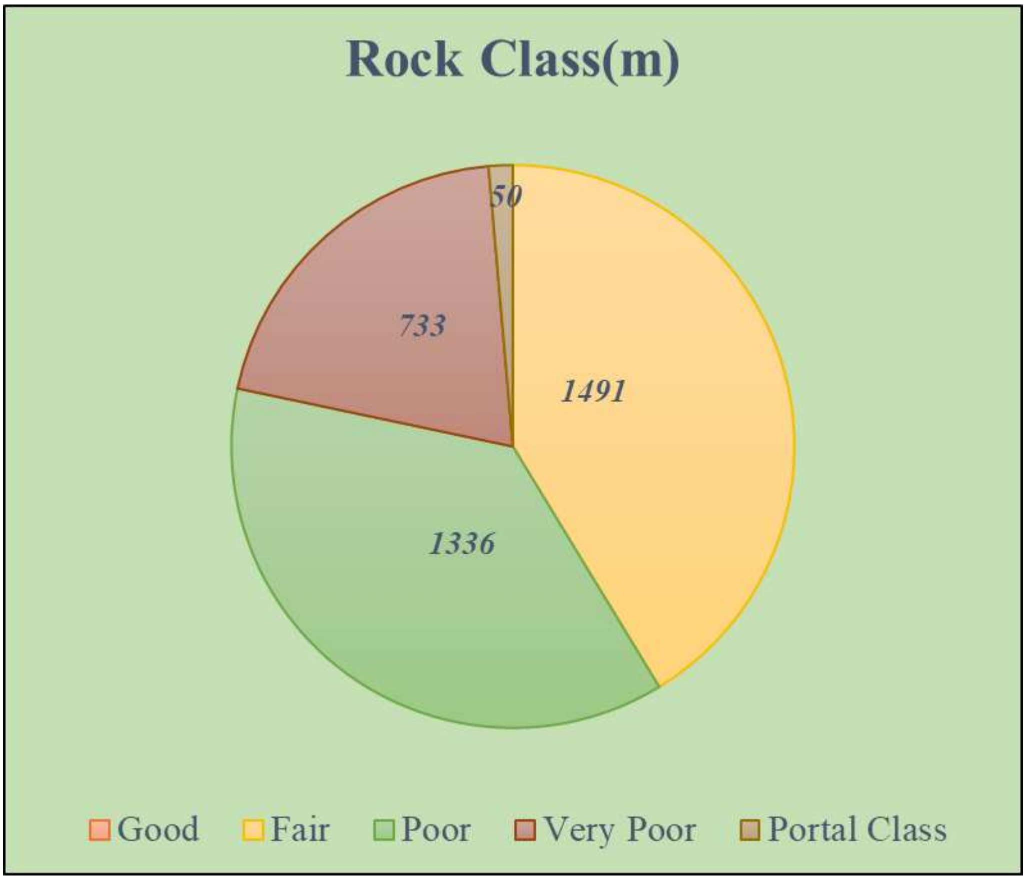


Figure 1.63: Geological Assessment Tunnel T-1 (LHS) (m)

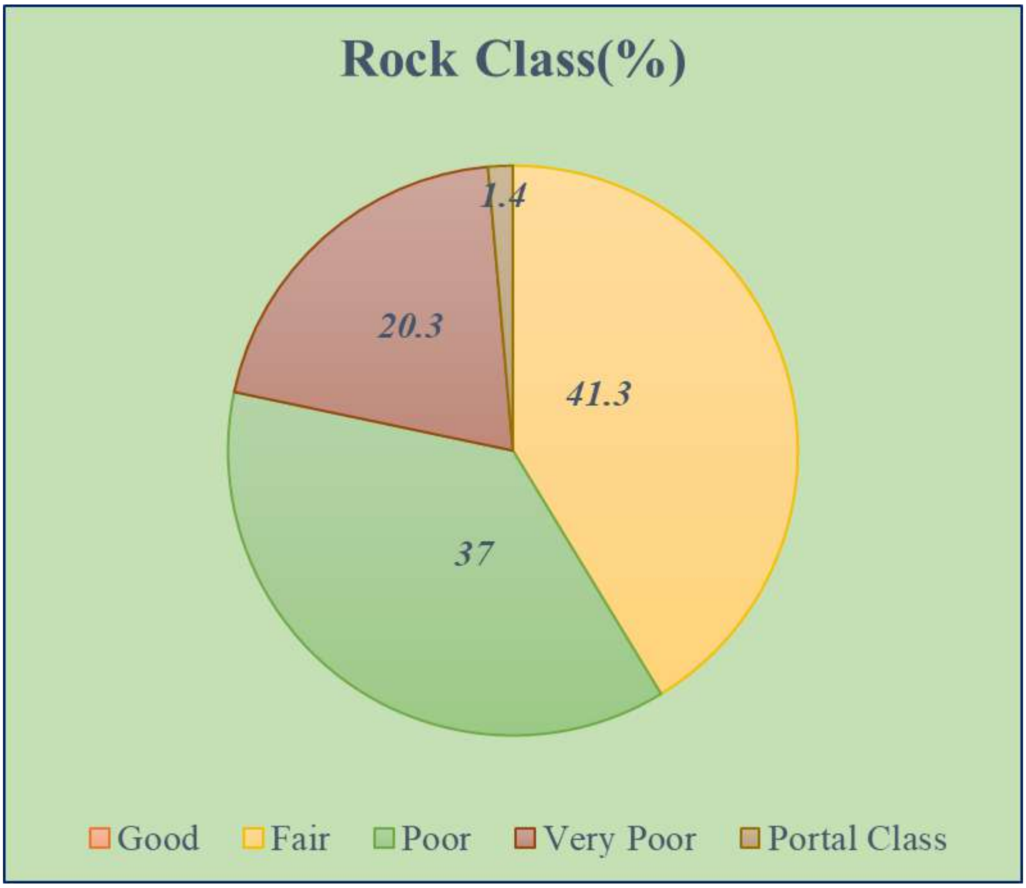


Figure 1.64: Geological Assessment Tunnel T-1 (LHS) (%)

Rock Class	Total Length Anticipated (in meter)	% Along Tunnel Alignment
Good	0	0.00
Fair	1500	41.32
Poor	1343	37.00
Very Poor	737	20.30
Portal Class	50	1.38

Table 1.21: Preliminary Surface
Geological Assessment Tunnel T-1 (RHS/Parallel Tunnel)

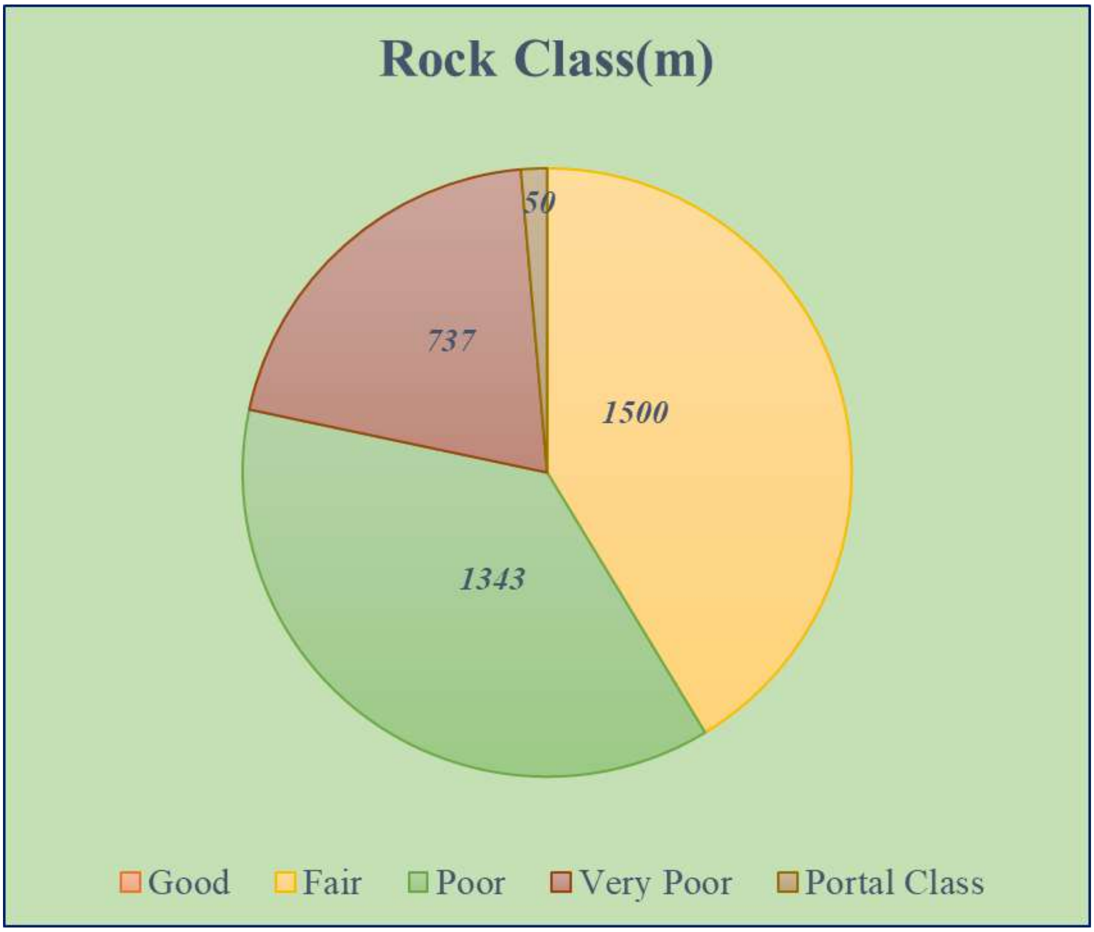


Figure 1.65: Geological Assessment Tunnel T-1 (RHS/Parallel Tunnel) (m)

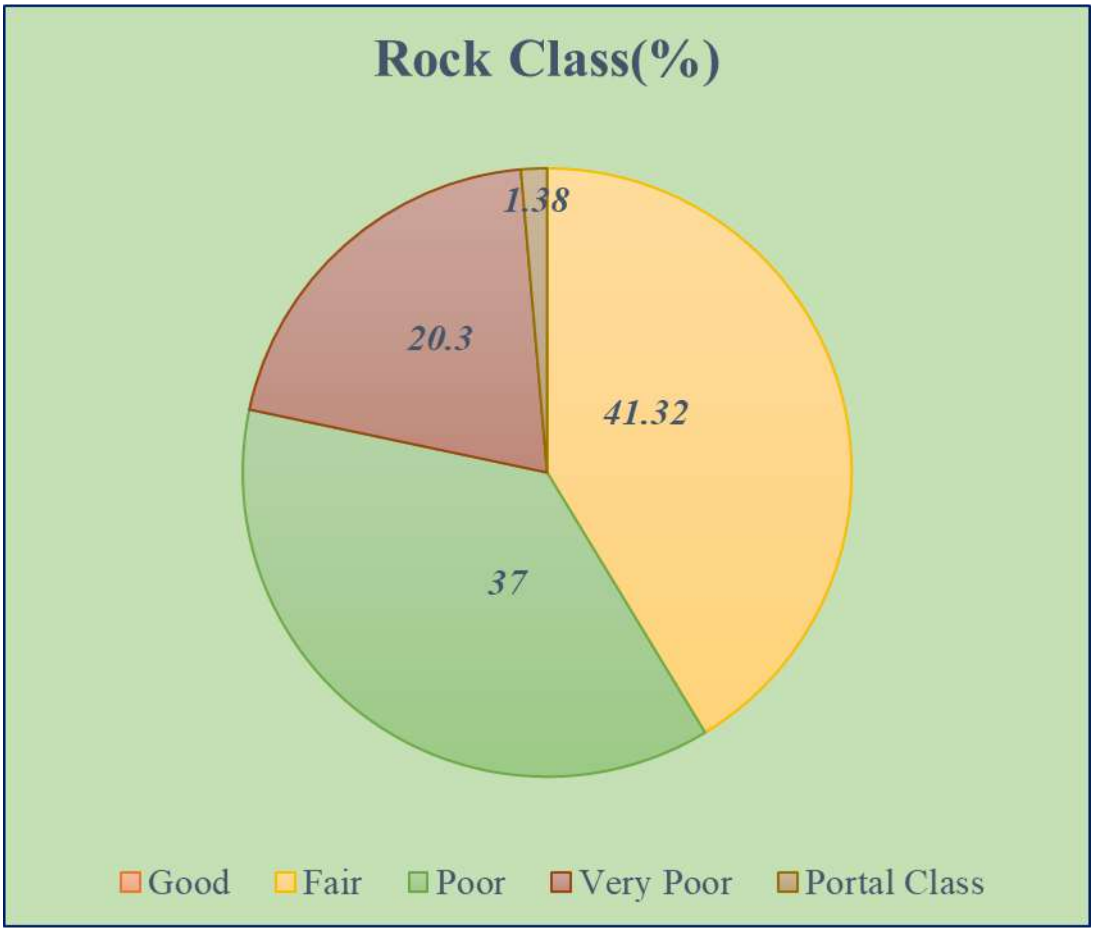


Figure 1.66: Geological Assessment Tunnel T-1 (RHS/Parallel Tunnel) (%)

Rock Class	**Total Length Anticipated (in meter)**	**% Along Tunnel Alignment**
Fair	0	0
Fair to Poor	0	0
Poor	30	11.53%
Very Poor	230	88.46%

Table 1.22: Preliminary Surface Geological Assessment of Tunnel T-2 (LHS)

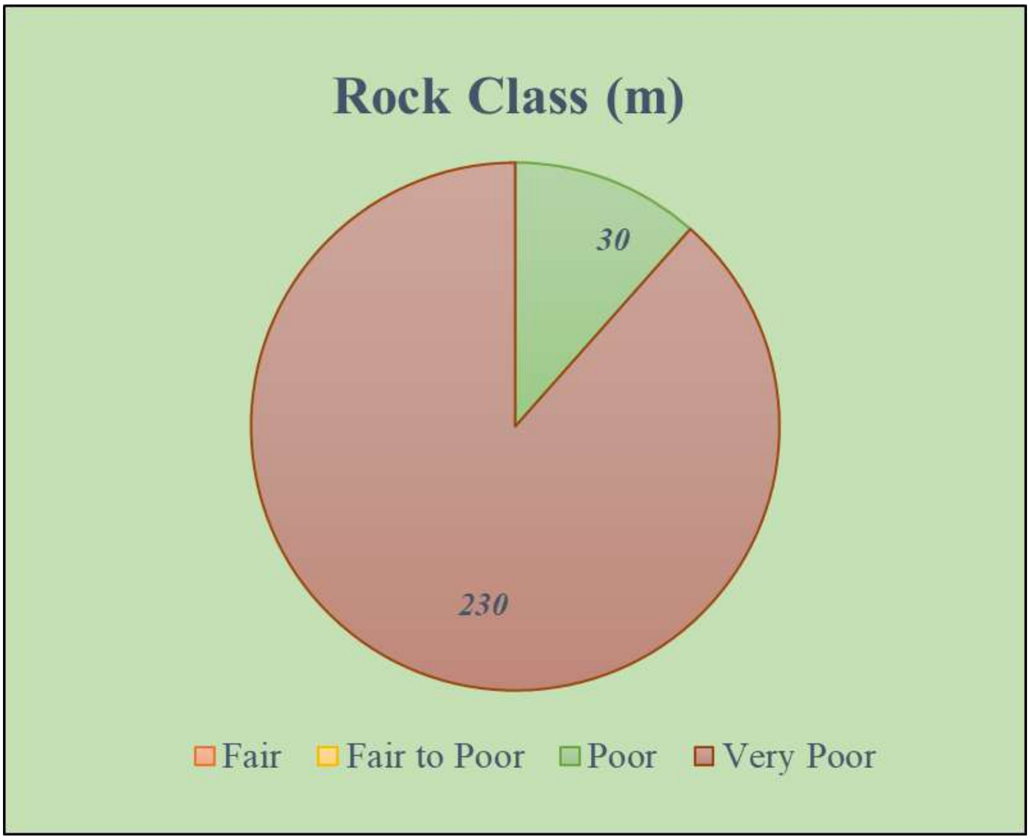


Figure 1.67: Preliminary Surface Geological Assessment of Tunnel T-2 (LHS) (m)

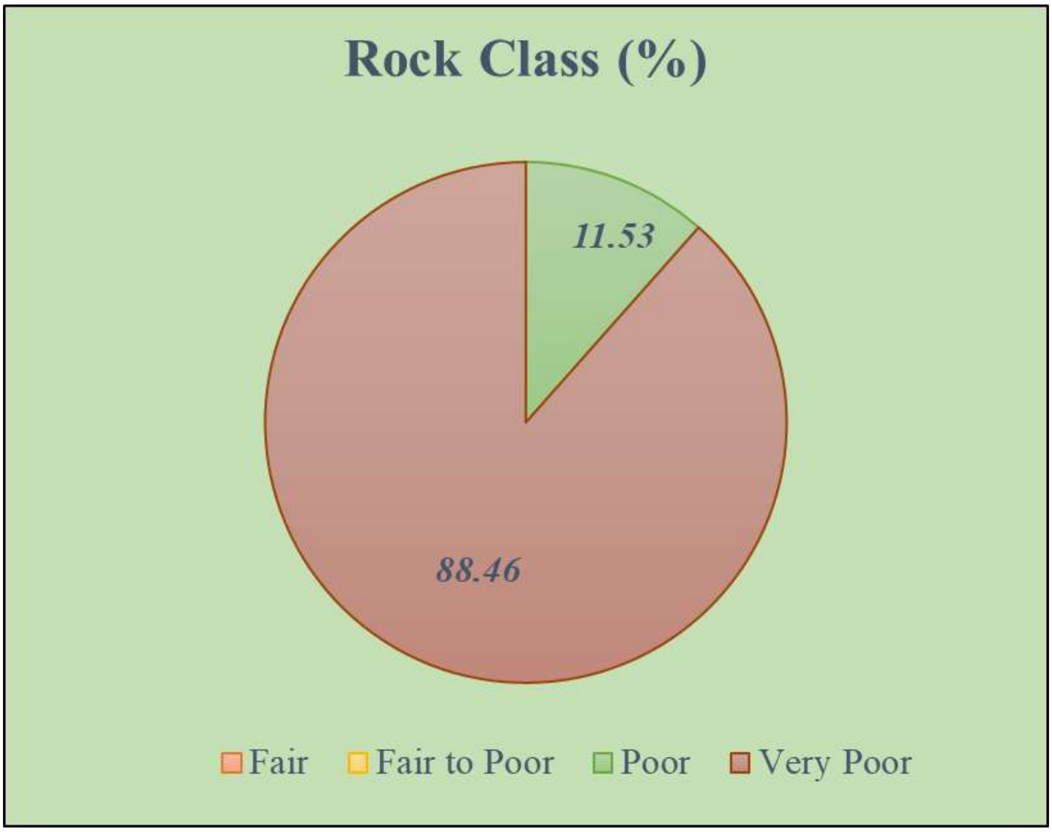


Figure 1.68: Preliminary Surface Geological Assessment of Tunnel T-2 (LHS) (%)

Rock Class	Total Length Anticipated (in meter)	% Along Tunnel Alignment
Fair	0	0
Fair to Poor	0	0
Poor	70	20.29%
Very Poor	275	79.71%

Table 1.23: Preliminary Surface Geological Assessment Tunnel T-2 (RHS/Parallel Tunnel)

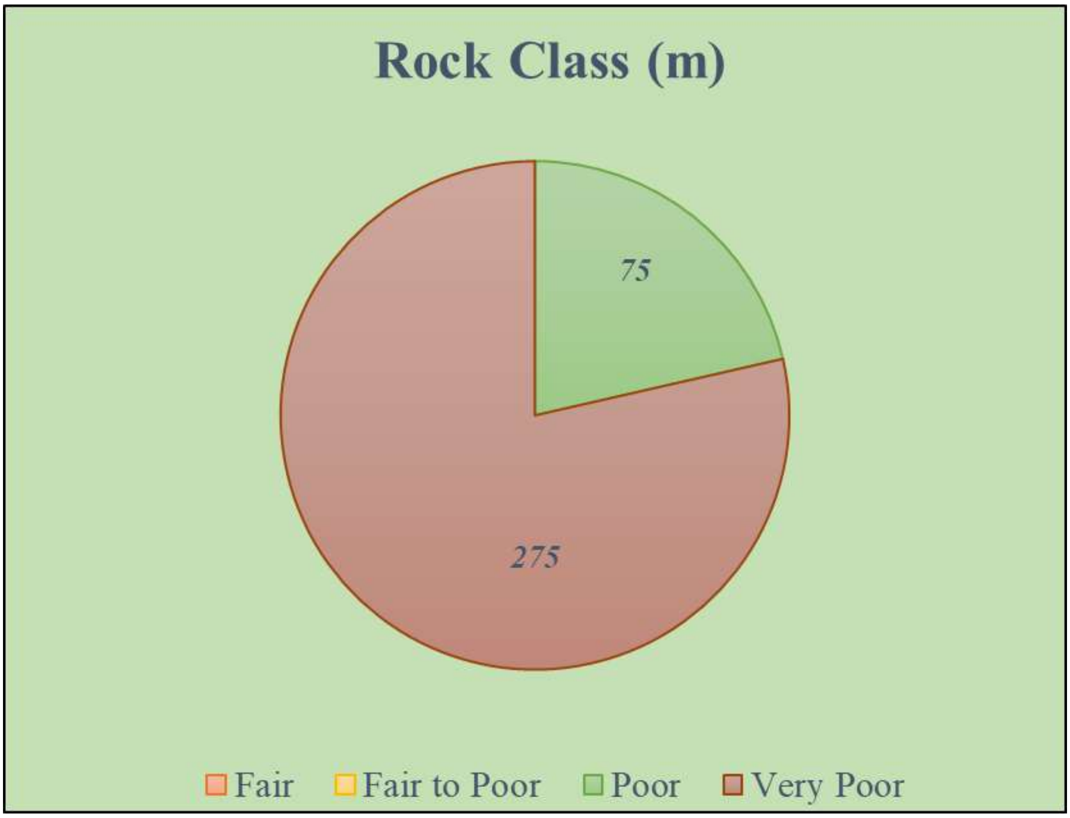


Figure 1.69: Preliminary Surface Geological Assessment of Tunnel T-2 (RHS) (m)

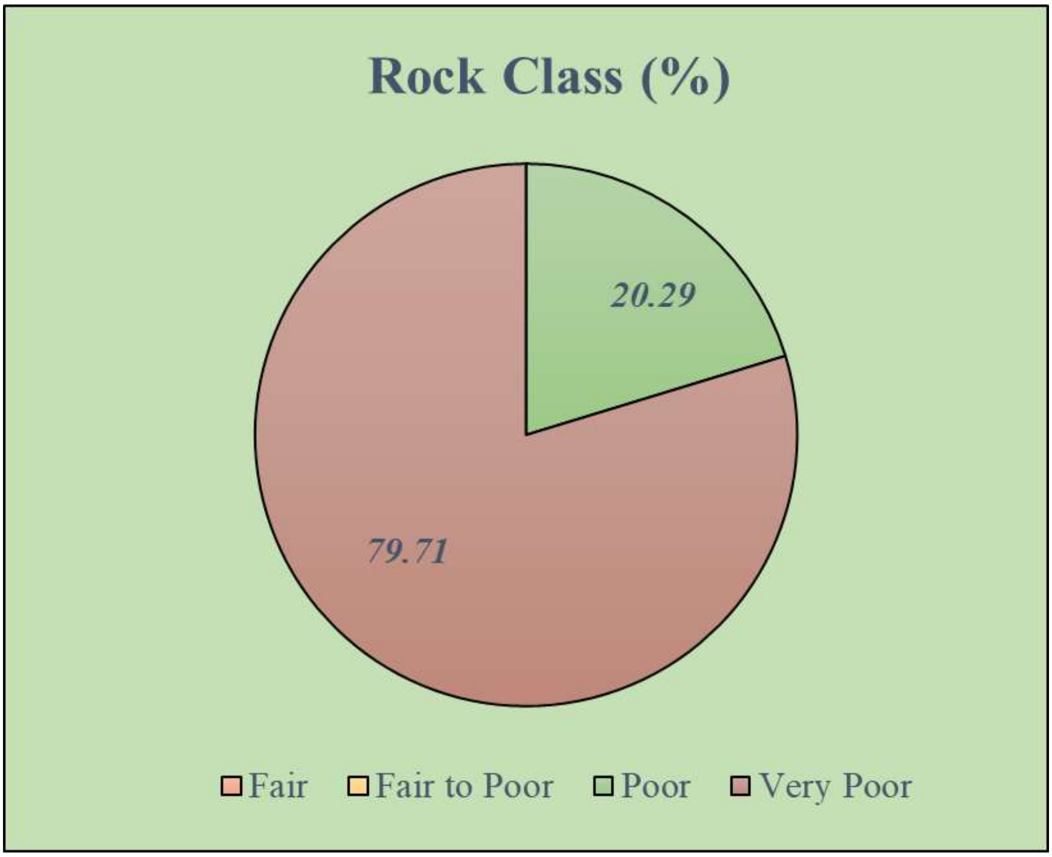


Figure 1.70: Preliminary Surface Geological Assessment of Tunnel T-2 (RHS) (%)

15 GEOLOGICAL – GEOTECHNICAL EVALUATION

A surface geological investigation was conducted along the planned alignment, with ICT carrying out a preliminary engineering assessment. The site visit for Tunnel T-1 (LHS & RHS) of the Shimla-Mataur Package-IIA project took place from 6th February 2022 to 9th February 2022, led by a Geological Expert. The results of this investigation are documented in the "Geological Evaluation & Assessment Report for Preliminary Engineering." This report serves as the foundational document for the current Tunnel T-1 geological assessment, forming the basis for the Geological Matrix Report.

The ICT Expert performed a surface data and reconnaissance survey, which was incorporated into the current matrix report. The purpose of this document is to summarize the findings and conclusions from the work carried out by the consultants, bringing together all surface data, including geomorphic and lithological information. This surface exploration and the data from existing studies were used to define the geological matrix and predict the geology along the tunnel alignment. The geological details will inform the establishment of geotechnical parameters that are essential for the preliminary engineering process.

15.1 Geological Overview

The project area is situated in the Siwalik ranges, part of the Lesser Himalayas, and features a diverse landscape with hills, valleys, and a piedmont zone. Seven major hill ranges—Naina Devi, Kot, Jhanjiar, Tiun, Bandla, Bahaurpur, and Ratanpur—make up the hill system. The lowest point in the area has an elevation of approximately 290 meters above mean sea level (AMSL), while the highest peak, Bhadurpur Hill, reaches 1,980 meters AMSL. The Sutlej River flows through the middle of the district from east to west, entering near Kasol in the northwest and exiting near Naila in the southwest, after covering a distance of 90 kilometers. The Sutlej is joined by several tributaries, with the three main ones being Ali Khad, Gamrola Khad, and Seer Khad. Ali Khad, approximately 26 kilometers long, originates in Shimla district and joins the Sutlej at Bilaspur after passing through Bahadurpur Dhar. Gamrola Khad, also originating in Shimla district, drains the Rattanpur Dhar and joins the Sutlej around 5 kilometers downstream from Bilaspur town. Seer Khad, the third tributary, originates at Wah Devi, 10 kilometers from Sarkaghat in Mandi district. After draining Kot-Ki-Dhar and a significant portion of Ghumarwin tehsil, it joins the Sutlej near Serimatla, about 15 kilometers downstream from Bilaspur.

The geological formations in the district span from the pre-Cambrian to the Quaternary period. The generalized geological succession in the district is as follows:

EON	ERA	PERIOD	GROUP FORMATION	DESCRIPTION
Phanerozoic	Cenozoic	Quaternary (Recent to sub-Recent)	Alluvium; fluvial, terrace, piedmont	Sand, silt, clay, gravel, pebble and cobble etc.
			Undifferentiated	Sand, clay, gravel, pebble, cobble and boulders
		Tertiary Pliocene to Mid. Miocene	Upper Siwalik	Soft sandstone, brownish clay, shale, poorly sorted and crudely bedded conglomerate. Boulder beds.
			Middle Siwalik	Grey sandstone, and brownish clay/ shale
			Lower Siwalik	Red and purple sandstone and shale
		Oligocene-Lower Miocene	Subathu Group	Grey sandstone, shale, Clay
			Kasauli Formation	Greenish to grayish hard sandstones
			Daghshai Formation	Dark-red and purple coloured shale
			Subathu Formation	Dark nodular clays
Proterozoic	Upper Proterozoic III Proterozoic II		Krol Formation Shali Formation	Greyish massive dolomites and Limestone Cherty Dolomite, Quartzite and Lime stone

Table 1.24: Stratigraphic Succession of the Project area

Frequency distribution of rock mass along the Tunnel-1 Alignment. (PKG-IIA)

On the basis of tentative geological section prepared, attempt has been made to analyse the status of anticipated rock mass conditions during execution of Tunnel T-1 (LHS & RHS) of Package-IIA

The following table shows Chainage-wise distribution of rock- mass conditions along alignment.

Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
29+410	29+435	25	Highly weathered Limestone/dolomite	Highly weathered & fractured	20-25	Portal Class
29+435	29+630	195	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately weathered & fractured	40-45	Fair
29+630	29+843	213	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately to highly weathered	35-40	Poor

Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
29+843	30+123	280	Moderately to Highly weathered quartzitic dolomite rock, Shale & Slate	Moderately Weathered	40-45	Fair
30+123	30+522	399	Moderately to Highly weathered Shale & Slate	Moderately Weathered	35-40	Poor
30+522	30+830	308	Moderately to Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor
30+830	31+180	350	Moderately to Highly weathered Shale & Slate	Moderately weathered & fractured	40-45	Fair
31+180	31+565	385	Moderately weathered Shale & Slate	Moderately Weathered	30-35	Poor
31+565	31+895	330	Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor
31+895	32+363	468	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	42-48	Fair
32+363	32+561	198	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	45-50	Fair
32+561	32+900	339	Moderately weathered Shale & Slate with bands of sandstone	Moderately weathered & fractured	30-35	Poor
32+900	32+995	95	Highly weathered Shale & Slate with bands of sandstone	Highly weathered & fractured	15-20	V. Poor
32+995	33+020	25	Highly Weathered Shale & Slate	Highly weathered & fractured	20-25	Portal Class

Table 1.25: Distribution of Rock- Mass Conditions on the Basis of Rock Mass Rating Tunnel T-1 (LHS)

Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
29+380	29+405	25	Highly weathered Limestone/dolomite	Highly weathered & fractured	20-25	Portal Class
29+405	29+655	250	Moderately weathered Shale & Slate	Moderately weathered & fractured	40-45	Fair
29+655	29+791	136	Moderately weathered Shale, Slate & Sandstone	Moderately to highly weathered	35-40	Poor
29+791	30+041	250	Moderately weathered Shale, Slate & Sandstone	Moderately Weathered	40-45	Fair
30+041	30+451	410	Moderately weathered Shale, Slate & Sandstone	Moderately Weathered	35-40	Poor
30+451	30+761	310	Highly weathered Shale, Slate & Sandstone	Highly weathered & fractured	15-20	V. Poor
30+761	31+071	310	Moderately weathered Shale, Slate & Sandstone	Moderately weathered & fractured	40-45	Fair
31+071	31+521	450	Moderately to Highly weathered Shale & Slate	Moderately Weathered	30-35	Poor
31+521	31+846	325	Highly weathered Shale & Slate With Sandstone bands	Highly weathered & fractured	15-20	V. Poor
31+846	32+316	470	Moderately weathered Shale & Slate With Sandstone bands	Moderately weathered & fractured	42-48	Fair
32+316	32+536	220	Moderately weathered Shale & Slate with Dolomite bands	Moderately weathered & fractured	45-50	Fair
32+536	32+883	347	Moderately weathered Shale & Slate with Dolomite bands	Moderately weathered & fractured	30-35	Poor
32+883	32+985	102	Highly weathered Shale & Slate	Highly weathered & fractured	15-20	V. Poor

Design Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
32+985	33+010	25	Highly weathered Shale & Slate	Highly weathered & fractured	20-25	Portal Class

Table 1.26: Tunnel T-1 (RHS/Parallel Tunnel)

Frequency distribution of rock mass along the tunnel-1 Alignment. (PKG-IIB)

On the basis of tentative geological section prepared, attempt has been made to analyze the status of anticipated rock mass conditions during execution of Tunnel T-1 of Package-IIB.

The following table shows chainage-wise distribution of rock- mass conditions along alignment:

Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
34+250	34+444	194	Highly weathered Shale/Slate & Sandstone	Highly weathered & fractured	10-15	V. Poor
34+444	34+474	30	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	20-25	Poor
34+474	34+510	36	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	10-15	V. Poor

Table 1.27: Distribution of Rock- Mass Conditions on the Basis of Rock Mass rating Tunnel (LHS)

Chainage (Km)			Rock Type	Rock Characteristic as per site visit	Rock Class as per RMR rating	
From	To	Total (m)			RMR	Rock Class
34+215	34+389	174	Highly weathered Shale/Slate & Sandstone	Highly weathered & fractured	10-15	V. Poor
34+389	34+459	70	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	20-25	Poor
34+459	34+560	101	Highly weathered Shale/Slate with Sandstone/Limestone	Highly weathered & fractured	10-15	V. Poor

Table 1.28: Tunnel PKG-IIB (RHS/Parallel Tunnel)

The area is having diverse geology and the classification will be revised after the detail geotechnical investigation, the above classifications is purely based on the surface geological mapping and during the execution the contractor have to carried out the detailed geotechnical investigation and after the detailed investigation the data will be utilised in the detailed design.

15.2 Determination of Ground Type (GT)

Each key parameter will be categorized, and wherever possible, numerical values such as spacing, joint opening, and strength will be used instead of descriptive data. However, due to practical constraints, some parameters may only be described qualitatively.

Using predefined criteria, the parameters will be weighted and combined to identify the appropriate Ground Types. A correlation matrix will be applied.

Field data collection will focus on gathering relevant geological and geotechnical information, as well as observing and recording the ground structure. The collected data will be documented in pre-designed forms. Based on the criteria established during the design phase, the Ground Type will be determined. In areas with heterogeneous ground conditions, the site will be divided into multiple sections, and key parameters will be collected separately for each section.

The geological and geotechnical data gathered and assessed on-site will form the basis for extrapolating and predicting ground conditions. The geological work will not be limited to documenting face conditions but will also involve predicting the ground behavior in the surrounding rock mass that affects the ground response.

●●●

Recommendations:

The project area is predominantly characterized by moderate to steep slopes, with approximately 89% of the area being moderately to highly dissected, exhibiting slopes ranging from 0° to 58°. The geological makeup of the region is complex, with the Chhaosa Formation, located above the Basantpur Formation, consisting of thinly laminated shale, siltstone, wacke, and orthoquartzite. This formation presents a rhythmic sequence of shale, siltstone, and greywacke, which transitions into a coarser clastic sequence in the Sanjauli Formation. Additionally, the Kunihar Formation is composed of shale, siltstone, and stromatolitic limestone. These geological characteristics significantly influence the area's stability and construction considerations, which must be carefully addressed in the recommendations for any development or infrastructure projects in the region.

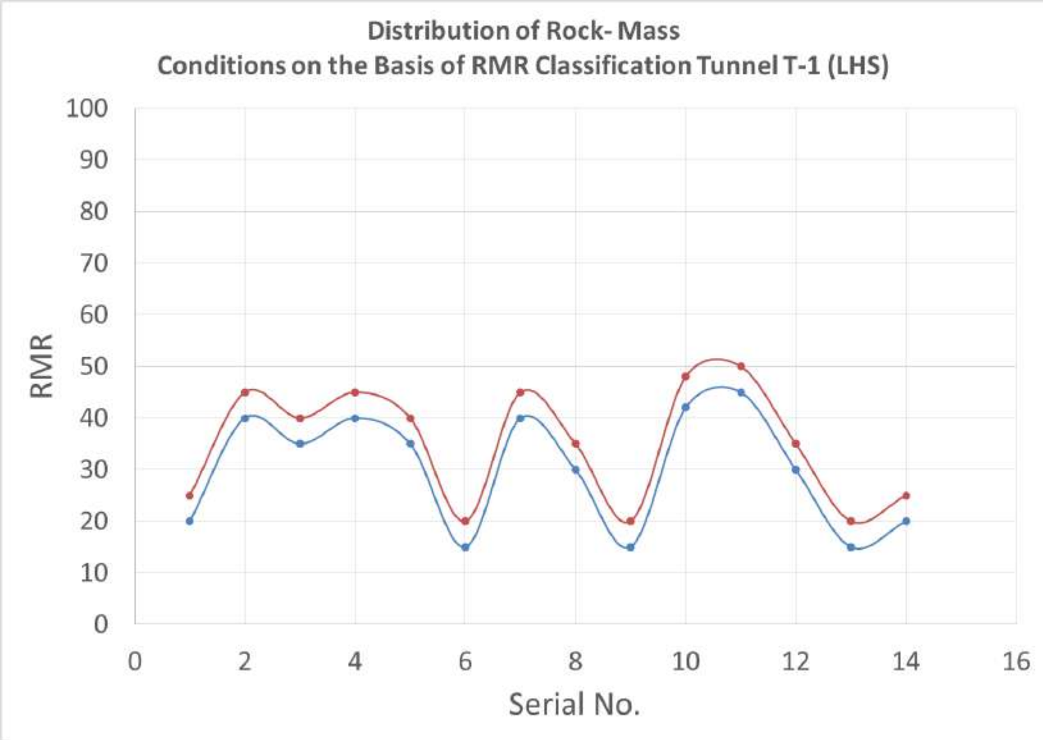


Figure 1.71: Plot of RMR for Tunnel T-1 (LHS)

As shown in Figure 1.71, the Rock Mass Rating (RMR) for Tunnel T-1 LHS indicates that the rock mass at Sr. No. 1, 6, 9, 13, and 14 falls within Rock Class V, while the remaining locations fall within Rock Classes III to IV.

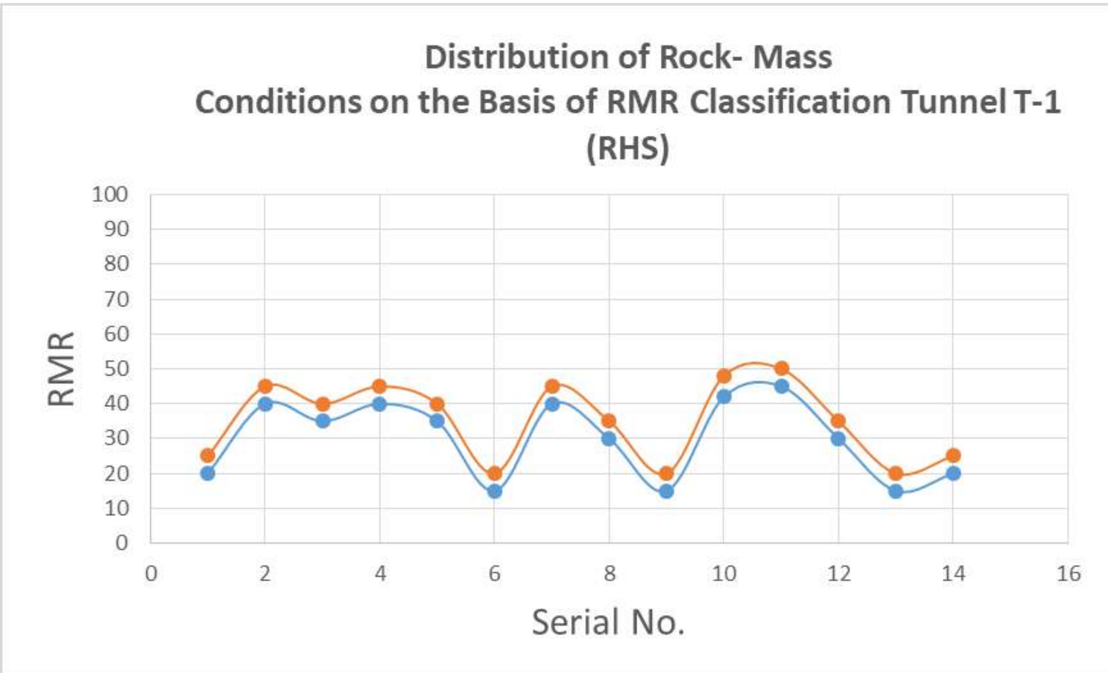


Figure 1.72: Plot of RMR for Tunnel T-1 (RHS)

As shown in Figure 1.72, the Rock Mass Rating (RMR) for Tunnel T-1 RHS indicates that the rock mass at Sr. No. 1, 6, 9, 13, and 14 falls within Rock Class V, while the remaining locations fall within Rock Classes III to IV.

The RMR for Tunnel T-2 (LHS) falls within Rock Classes IV to V, while the RMR for Tunnel T-2 (RHS) also falls within Rock Classes IV to V.

In conclusion, based on the geological and geotechnical findings, the construction of the road and tunnel along the proposed alignment appears to be feasible. Implementing an appropriate support system will be essential as per RMR data to ensure the stability of the terrain and minimize risks, thereby ensuring the safe and efficient execution of the tunnel construction while adhering to best engineering practices.