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GEOLOGY AND SLOPE STABILITY STUDIES ALONG THE GILGIT-SKARDU ROAD NORTHERN AREAS, PAKISTAN

By

Arshad Fayaz
Mohammad Latif
Kanwar Sabir Ali Khan

Issued by the Director General, Geological Survey of Pakistan, Quetta.
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GOVERNMENT OF PAKISTAN
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ABSTRACT

Engineering Geological investigations were carried out during 1987-88, along the Gilgit - Skardu Road. These studies included preparation of geological road log map, identification of landslide areas and evaluation of the suitability of various bridge sites under consideration. Contour plans already available were utilized as the base maps for further geological details of the proposed sites. In all 21 bridge sites and 6 landslide affected areas were studied and are described in this report.

Gilgit - Skardu road was started after the completion of Karakoram Highway, and the experiences gained at the KKH were effectively utilized during the construction of this road. It has greatly helped in limiting the landslide and slope stability problems on this road as compared to the KKH.

The recommendations proposed in this report may help a great deal in stabilizing the slopes and construction of safer bridges on the Gilgit - Skardu Road.

ACKNOWLEDGEMENT

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INTRODUCTION

1.1 Purpose and Scope

The construction of Karakoram Highway (KKH) has added new dimensions to the importance of the Northern Areas. The accessible and hitherto far flung areas have been opened up and linked with rest of the country.

Whereas, the KKH has miraculously played an important role in the socio-economic uplift of the people of the Northern Areas, much larger and no less important areas are still cutoff with outside world and needs to be opened up and linked to the KKH. The most important of these areas is the district of Baltistan in the southeast, with Skardu as its capital and Chitral in the Northwest of Gilgit.

Keeping in view, the strategic importance of these places, a project was initiated in 1987-88 to carry out geological and engineering geological studies along the Gilgit - Skardu road.

The Geological Survey of Pakistan has previously carried out road alignment studies and bridge site investigations along the Gilgit-Skardu road and the present construction activities by the Frontier Works Organization (FWO) is based upon these studies (Sabir, 1974). In May 1987 and Feb-March 1988, the previous study was followed by engineering geological investigations. The study has been done to prepare a geological road log map on 1:250,000 scale and to give a brief description of the regional geology and structure in the Gilgit-Haramosh Range. Emphasis has also been given to the engineering geological problems which includes landslide study at a few selected places and foundation study for 21 major bridge sites falling on this road.

1.2 Location and Accessibility

Gilgit-Skardu road starts from Alam bridge located 52 km, south of Gilgit on the Gilgit river. This road strip is 170 km long upto Skardu, and passes through Survey of Pakistan toposheets No. 43-I and 43-M on 1:250,000 (Fig. 1) Gilgit-Skardu road after crossing the Gilgit river at Alam bridge (a few kilometre upstream of the junction of the Gilgit River with the

Figure 1. Location map of the Gilgit - Skardu Road.

Indus River) follows the Indus river on the right bank upto the Ayub (Sapper) bridge. The road thus crosses over to the left bank of the Indus River in the Skardu valley upto the Skardu town.

1.3 Relief and Topography

The Skardu Road is 170 km long and passes through deeply incised valleys, narrow gorges and rugged topography. The road height at Alam bridge - the starting point of this road is 1,250 m amsl and becomes 2,347 at Skardu, characterized by rugged topography.

The relief is very high and the areas between Astor and Indus River on the left bank are largely inaccessible. At places, Indus River passes through narrow gorges of hardly 30 metres width. All the major side valleys are crossed by perennial streams, which are fed by snow melt water from the high peaks.

The road passes through the Trans-Himalayan region which falls in the arid climatic zone with scanty rainfall during the summer. The weather is dry and precipitation is mainly in the form of snow fall on the higher reaches of the hills.

1.4 Method of Investigations

The investigation included preparation of a geological road log map, schematic cross-section and sketches of the landslide affected areas and of the major bridge sites. At each landslide locality, the rocks/material involved in the slides were noted. Rock texture and structural elements such as faults, folds, joints and other discontinuities were also noted to determine the probable reason for particular landslide. These studies helped in determining the best possible treatment for the slope stability work.

In studying the bridges, the rock type exposed on the flanks and their abutment sites were given due consideration. These were classified and mapped on detailed drawings available for the bridge sites. It also included study of scouring depth of water and the high and low flood levels for the safe designing of the bridge.

1.5 Previous Work

Preliminary road alignment studies along Gilgit-Skardu road and bridge site investigations were carried out by Geological Survey of Pakistan during 1973-74.

GEOLOGY

Rocks exposed along the road section are mostly metamorphic comprising quartzite, phyllite, schists, gneisses and amphibolite with some marble bands. These are intruded by diorite, granodiorite and granite. The stratigraphic sequence of the area is tabulated below :-

Quaternary.	Unconsolidated deposits : Moraine deposits, terrace deposits, River deposits and sand dunes.
Creto-Tertiary.	Kohistan Batholith: Diorite, granodiorite, granite, pegmatite and aplites.
Upper Cretaceous.	Chilas Complex: Pyroxene quartz diorite, gabbronorite, gabbro - layered, gabbro, ultramafics.
Early Cretaceous.	Katzarah formation: Gneisses, phyllite, schists and slate.
Jurassic-Early Cretaceous.	Kamila amphibolites: Banded and massive amphibolite.
Pre-Cambrian.	Nanga Parbat gneisses: Granitic gneisses, leucocratic biotite - muscovite gneisses with minor amphibolites.

2.1 Nanga Parbat Gneisses

The name Nanga Parbat gneisses has been given by Tahirkheli (1979) to the sequence of gneisses of different varieties exposed in the area of Nanga Parbat Haramosh loop. The earlier workers such as Wadia (1932) has assigned Salkhala series of a sequence of gneisses schist, phyllite, quartzite and carbonaceous material. Along Gilgit Skardu Road this formation is exposed about 35 km in length forming an anticline. A wide belt of amphibolites and intrusive rocks wrapped round the Nanga Parbat gneisses.

In the area of Sasi and Shengus following major lithologic units of this formation are exposed.

Leucocratic biotite - muscovite gneiss:

It is the unit which is mostly found in the area, especially in Shengus area. This unit occurs interlayered with quartzite and has been intensively dissected by stringers and veins of pegmatite. Augen structure and segregation banding of mica and feldspar are common features. Pegmatites in this unit have a random occurrence.

Biotite Gneiss:

It is intensively deformed and foliated, pale grey, weathering to yellowish grey, fine grained, hard and compact. It contains layers of feldspar and mica. Garnet, tourmaline and augens of quartz and feldspar are also present. In places it is graphitic and contains layers, lenses and sills of amphibolites and other basic rocks.

Granite Gneiss:

It is pale grey, fine grained, hard, compact and massive. It is well jointed and fractured and has been intruded by mafic sills and granite pegmatite bodies. The granite gneiss is mainly composed of feldspar, quartz and biotite with trace amounts of muscovite and garnet.

The marble bands are conformably interlayered with schists and amphibolite in Shahbatot area. The marble bands are white to grey in colour.

Amphibolites:

These are mostly para - amphibolites and occur as thick, interfoliated with gneiss. They are dark grey, medium grained, compact hard and garnetiferous. These amphibolites form extensive out crops near Shengus.

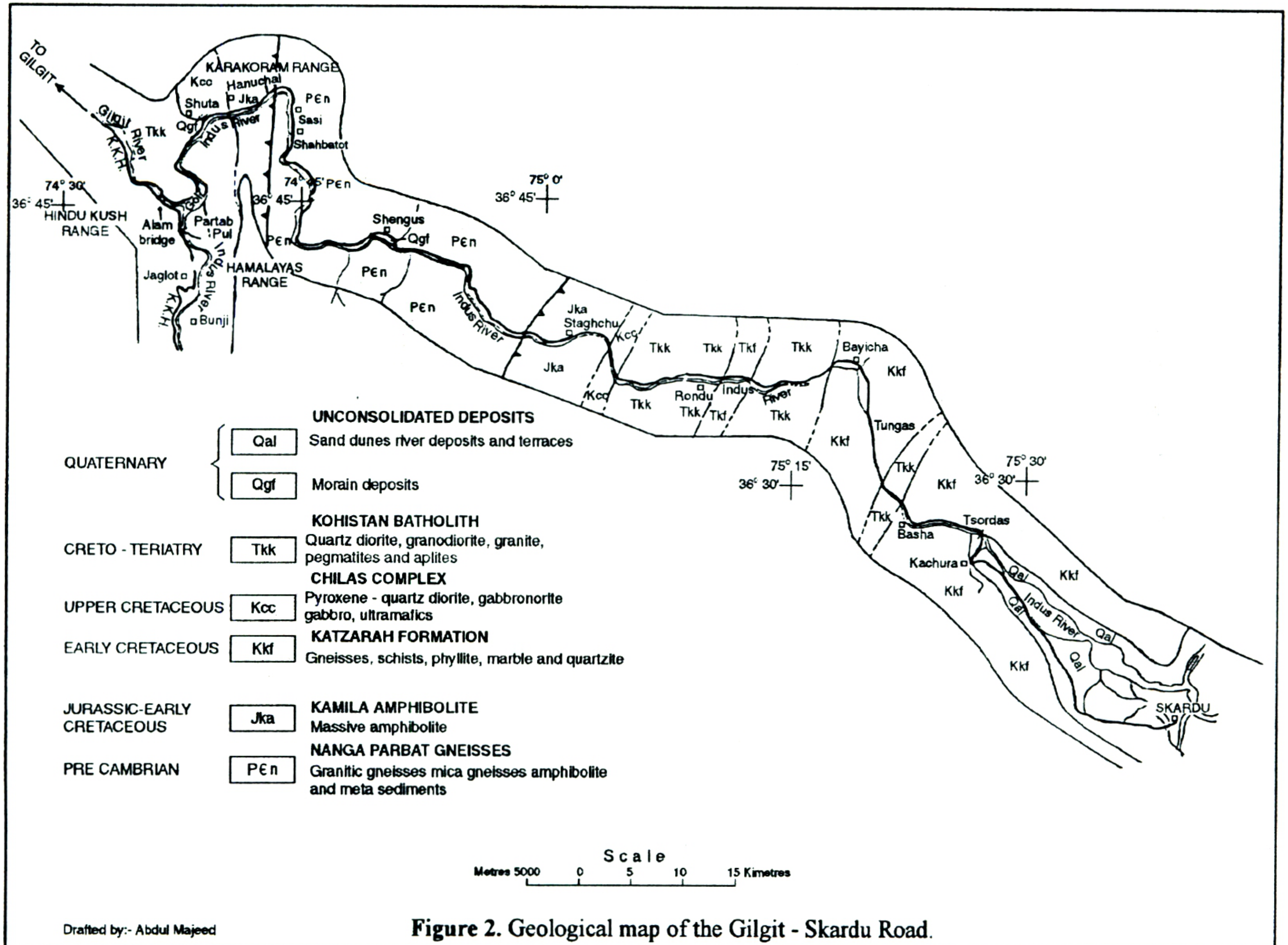


Figure 2. Geological map of the Gilgit - Skardu Road.

2.2 Kamila amphibolite

The name Kamila amphibolite has been given by Jan (1977), and Tahirkheli, (1979) to the part of the Precambrian Salkhalas of earlier workers (Wadia, 1932, and Gansser 1964), described these metasediments which are highly metamorphosed and gradually granitized to granite gneiss in the neighboring Nanga Parbat area. Kamila amphibolite is the subduction of the Swat hornblendic group of Martin, et al., 1962, which occupy a large part of Kohistan and extend westwards into Dir; while towards east of Nanga Parbat after looping around the Nanga Parbat.

According to Tahirkheli (1982), the Kamila amphibolites constitute part of an oceanic crust which is the product of an intra-oceanic subduction in the fore - arc basin of the Kohistan island arc, thus it forms base of this arc. He described three main types of the amphibolites viz. I) massive and homogeneous, ii) banded and shared and iii) a banded variety. These are the products of prograde metamorphism of the basic and intermediate plutonic and volcanic rocks which are associated with the oceanic sediments and tuffs. Along Gilgit - Skardu road rocks of Kamila amphibolite are exposed in Hanuchal and Stagh Chu areas.

These amphibolites are massive, medium grained. They are composed of feldspar and hornblende predominantly with minor quartz and biotite.

The Kamila amphibolite has been assigned Jurassic-early Cretaceous Age (Tahirkheli, 1982).

2.3 Katzarah formation

The meta sedimentary rocks exposed in the vicinity of Katzarah was first assigned as Katzarah schist by Desio (1963). Katzarah area lies in the north - west of Skardu. Later on, Tahirkheli (1982), named it as Katzarah formation. This formation consists of siltstone, shale, slate, quartz - micaceous phyllitic schist, gneisses with intercalations of quartzitic sandstone. Moreover, the highly meta morphosed metasediments viz. migmatised gneiss, sillimanite gneiss along slightly low grade amphibole mica schist, exposed in the surrounding areas of Skardu, Tungas and Bayicha are also considered to be a part of the Katzarah formation. The rocks of the Katzarah formation grade from epi to kata - zone facies of metamorphism. Along Skardu - Gilgit road mostly the gneisses of different varieties are exposed with minor phyllite and schists. Biotite gneiss predominates with garnet - biotite sillimanite gneiss, two mica - plagioclase - garnetiferous gneiss. These rocks are grey to dark grey in colour weathering to greyish brown, commonly medium grained, foliated and at places thinly laminated. Quartz veinlets, pockets and ellipsoidal lenses parallel to foliation are common. Ptygmatic folding is prominent within these metasediments. Lineation on the foliation plane develop occasionally. Tahirkheli (1982) assigned an early Cretaceous age to the Katzarah formation.

2.4 Chilas Complex

Chilas Complex formerly called Bahrine granulite by Jan (1979) is composed of feldspathic gabbro norite and pyroxene - quartz diorite with subordinate gabbro - layered - gabbro, ultramafic rocks and mafic to ultramafic pegmatites.

The rocks of Chilas Complex are exposed in Shuta nala area, along Skardu road. In Shuta area the rocks exposed is pyroxene quartz diorite which is light grey to brownish grey, medium grained nearly equigranuler compact, hard and commonly massive. It is gneissic in appearance in eastern margins. It consists of feldspar, hornblende, biotite with minor quartz. Thin biotite bearing pegmatite veins also intersect the diorite.

The age assigned to Chilas complex is upper Cretaceous by Mikoshiba, et al., (115 ± 39 Ma; Sr-Rb dating, 1996).

2.5 Kohistan Batholith

The Ladakh granitoid (Ivanac et. al., 1956), Kailas granitoid (Bakr, 1965), has been renamed as the Ladakh - Kohistan granitic belt (Jan et al., 1981) and the Kohistan batholith (Patterson and Windley, 1985).

Patterson and Windley (1985) have also divided the Kohistan batholith into stage -I, stage -II and stage -III plutons. The stage -I plutons comprise deformed gabbro, diorite and tonalite (102 ± 12 Ma) The stage-II plutons are Andean type which range from hornblende gabbro to diorite, granodiorite and granite and are partly deformed. The stage-III plutons consist of acid sheets (Leucogranites, aplites and pegmatites (34 ± 14 Ma to 29 ± 8 Ma), So the age assigned is Creto-Tertiary.

Rocks of Kohistan batholith are exposed in the areas of junction of Gilgit and Indus Rivers upto Ansar camp and Dasu - Murdo and Rondu areas along Skardu road.

In the area between Alam bridge and Ansar camp the granodiorite is richer in mafic minerals and is associated with a complex assortment of hybrid diorites and syenites, and includes irregular masses of hornblendite, derived from the metamorphism of basic xenoliths. The lit-par-lit injections of pegmatite and aplite veins, veinlets are note worthy in this area.

Three phases of magmatism have been observed along the road in Dasu, Murdo area. The oldest intrusion is fine to medium grained diorite and middle is coarse grained granodiorite and the younger one is very coarse grained granite. Dolerite dykes, small quartz veins and a few pegmatite veins also intersected these acidic intrusions, xenolith of amphibolite are abundantly found in the area of contact. All the rocks are equigranular and show hypidiomorphic texture.

2.6 Quaternary Deposits

The Indus valley road from Skardu to Alam bridge passes through mostly deep gorge made by Indus river. Quaternary deposits are present at certain places.

Moraine deposits:

A few moraine deposits along the road are found which create problems on the road. They are in Shuta, Barumdoir, near Shengus and Dambudas areas. The moraine deposits are buff coloured, slightly greenish at places, and vary from loose to semi-consolidated. They are mostly composed of clay to sand material with minor gravel, cobbles, pebbles and boulders. The thickness of the moraine deposits varies from place to place.

Terrace deposits:

Terrace deposits mostly consist of loose and unsorted debris. The width of these deposits varies according to the width of the valley. The terraces have thickness ranging from 30 to 80 metres. Nearly all the villages along the road are situated on terraces for example, Sussi, Shengus, Hanuchill, Dambudas, Baghicha, Tungas.

River deposits:

They are composed of stratified, buff coloured very fine grained clay, grey silt, sand, grit and subrounded pebbles of various compositions. At places, stratification is much disturb, showing different compositional bands in inclined and vertical position. These deposits are found near Skardu city and Gulcha area.

Sand dunes:

Vast sand dunes are exposed around the Skardu airport, west of Skardu Town, Koyo and in area near the confluence of Gilgit and Indus rivers. It is composed of coarse grained sand and is derived from the flood plain areas of the Indus River. The dunes are barkhan type and indicative of strong wind action in the area.

3. ENGINEERING GEOLOGY

3.1 Landslide Areas

3.1.1 Shuta Nullah Slide: This slide is located near Shuta Nullah 16.4 km from the Alam bridge on Gilgit-Skardu road. It lies on Survey of Pakistan toposheet No. 43-I (Fig. 3).

After crossing the Shuta Nullah, towards Skardu, moraine deposits are exposed in the form of vertical cliffs. These deposits are about one kilometre long and about 200 m high. These deposits are composed of mainly gravels to boulders with sand, silt and clay. Cementing material is mostly sand, silt with minor clay which are loosely packed.

In the snow melting period and during the rainy season, moraine deposits start falling and create problems of blocking the road. The road is badly damaged due to falling of the heavy boulders.

Recommendations:

1. Efficient catch water drains in the upper reaches of the moraine deposits may be provided to prevent the rain water from infiltrating into the loose material.

2. Plantation may be done in the area of moraine deposits as some bushes are already grown along the slopes. Water for the required plantation can be achieved from nearby Shuta Nullah.

3. Side drains may be provided along the road to divert the rain water into river without damaging the road.

3.1.2 Barum Area Slide : This slide is located 13 km short of Shengus 37 km from Alam bridge on Gilgit - Skardu road. It lies on Survey of Pakistan toposheet No. 43-I (Fig. 3).

The road has been washed away for about 1,300 metres due to sliding in this area.

Moraine deposits are lying vertically in this area. These deposits mostly comprise about 80 % finer materials, with clay and upto 20% is coarse sand and pebbles with occasional boulders. About 9 to 10 small gullies have formed across these morainic deposits along the road. The field investigations have shown that the following factors have played their role in the development of sliding in this section of the road.

i) Heterogenous composition of morainic deposits.

ii) Critical angle of repose of the material on the side slopes.

iii) Active gullying of the morainic deposits.

iv) Effect of rain water in the destabilizing of the road.

Recommendations:

The following steps are suggested for the control and minimization of slides :-

1. Construction of catchwater drains along the sides of the road.

2. Plantation along the hill slopes to provide anchoring support to the loose deposits.

3.1.3 Brum Bridge Slide: This slide is located near Brum bridge, 42 km from Alam bridge on Gilgit-Skardu road. It lies on Survey of Pakistan toposheet No. 43-I (Fig. 3).

This nullah is passing through the morainic material, which are making cliffs along the banks of the nullah. Barum Nullah has a perennial flow. Snow covered peaks can be seen on the catchment area of the nullah. This nullah passes through high gradients making many falls along its course. During heavy burst of rains, water with high currents cut the material along the turnings of the nullah thus originating mudflow.

The same type of out burst of mudflow broke the concrete bridge at this spot. At present a temporary Baley bridge of class 30 is launched and traffic is passing on it. Both the abutments of the bridge are safe. The remnants of the mudflow can be seen on both the banks of nullah. No scouring effect is seen and a new bridge may be constructed on the same abutments.

Recommendations:

1. To safe guard the bridge from the mudflow in future, an arch type bridge is proposed making the road 5 metres higher than the present road level.

2. With these two measures i.e. an arch type structure and increased deck level of the bridge, the maximum of mudflow will pass underneath the bridge in future.

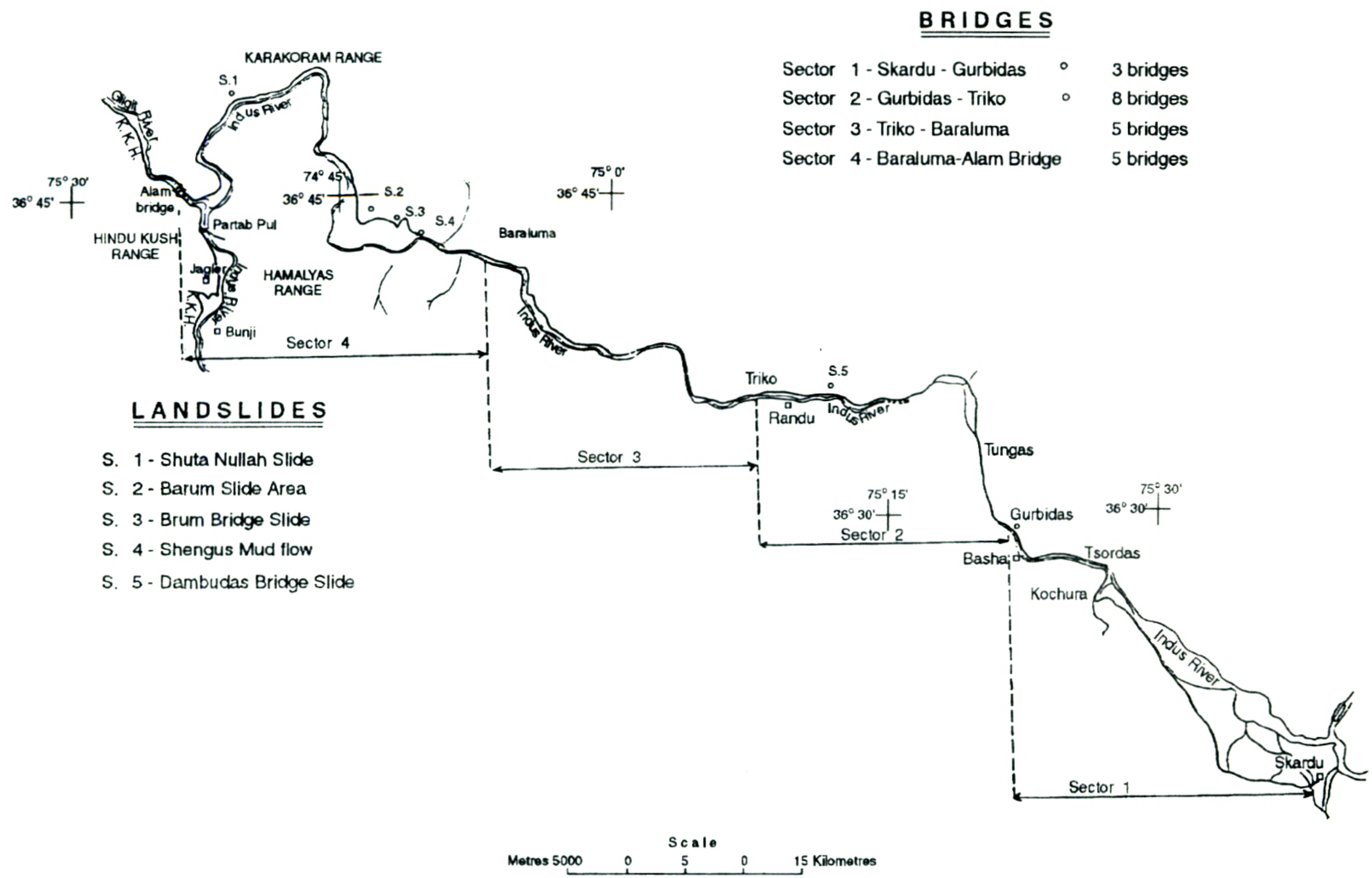


Figure 3. Map showing the landslides and bridges on the Gilgit - Skardu Road.

3.1.4 Shengus Mudflow: This mudflow is located 51 km from Alam bridge on Gilgit-Skardu road. It lies on Survey of Pakistan toposheet No. 43-I (Fig. 3).

The debris material is deposited on the side sloping top of the hill which has been deeply incised by the Mudflow follows the nullah path.

Rocks are exposed at river level and upto half way between the road and river, however at road level the rocks are not exposed but may be encountered at a shallow depth of 2 to 3 metres from the surface. Schistosity planes dip at 60 degrees.

Recommendations:

1. Construct check dams in the nullah course to confine the moving material into narrow channels and the protective walls may be built on side rocks.

2. Upto a reasonable length from the bridge site, nullah path required protective works.

3.1.5. Dambudas bridge Slide: This slide is located near Dambudas bridge, 98 km from Alam bridge on Gilgit Skardu road. It lies on Survey of Pakistan toposheet No. 43-I (Fig. 3).

On the right side of the bridge, diorite rocks are exposed which are highly jointed, fractured and crushed due to local faults. These rocks are highly tectonized. Slope angle is very high.

On the western side, at the left bank of the nullah, moraine deposits are lying vertically at a critical angle of repose. Rain water makes its passage in the shape of gullies in the moraine material. Most of the debris material move down upto the road and block it during rainy days.

Recommendations:

1. Breast walls and catch water drains are recommended in this area.

2. Gabion walls are already constructed to safeguard the bridge, which require more strengthening.

3.2 Bridge Site Investigations

Bridge site investigations were carried out along the Gilgit -Skardu road to examine the suitability of various sites under consideration from the engineering geology point of view. The area has already been surveyed for the road alignment and contour plans of various bridge sites along the road were available. The contour plans were utilized as the base maps for noting geological details of the proposed sites, the foundation condition, their suitability, and the precautionary measures to be adopted. Whenever necessary alternate sites were suggested based on a comparative study of the geological and engineering aspects, of the sites. The following sites were examined:-

3.2.1 Skardu - Gurbidas Sector

Katzarah Nullah Bridge
Khoso Nullah Bridge
Skardu Nullah Bridge

3.2.2 Gurbidas - Triko Sector

Boram Nullah Bridge
Tungus Nullah Bridge
Gun Nullah Bridge
Bayicha Nullah Bridge
Dasu Nullah Bridge
Skoyo Nullah Bridge
Thowar Nullah Bridge
Keksho Nullah Bridge

3.2.3 Triko - Baraluma Sector

Askor Nullah Bridge
Staghchu Nullah Bridge
Janwye Nullah Bridge
Mile 69 Nullah Bridge
Baraluma Nullah Bridge

3.2.4 Baraluma Alam Bridge Sector

Barumdoir Nullah Bridge
Ishkapal Nullah Bridge
Dache Nullah Bridge
Khaltaro Nullah Bridge
Hanuchal Nullah Bridge

3.2.1 Skardu - Gurbidas Sector

Katzarah Nullah Bridge

GEOLOGY : The stream is full of glacial boulders. The present bridge is located on Rounded Boulder Gravel (RBG) and abutments rest on big erratic boulders. The left abutment has developed cracks but probably not due to the movement of boulders. It may be due to defective masonry work or passing of higher load than permissible. The nullah has considerable flow which increases during the melting period.

The present site may be utilised for a permanent bridge. Abutment site may be excavated at least 15 feet deep for encountering good foundation rock/material. Isolated boulders should be avoided for foundation because of expected scouring at the base and probable tilting of boulders due to removal of interstitial sand and silt. Protective works to be done at the toe and upstream of the bridge (Fig. 4).

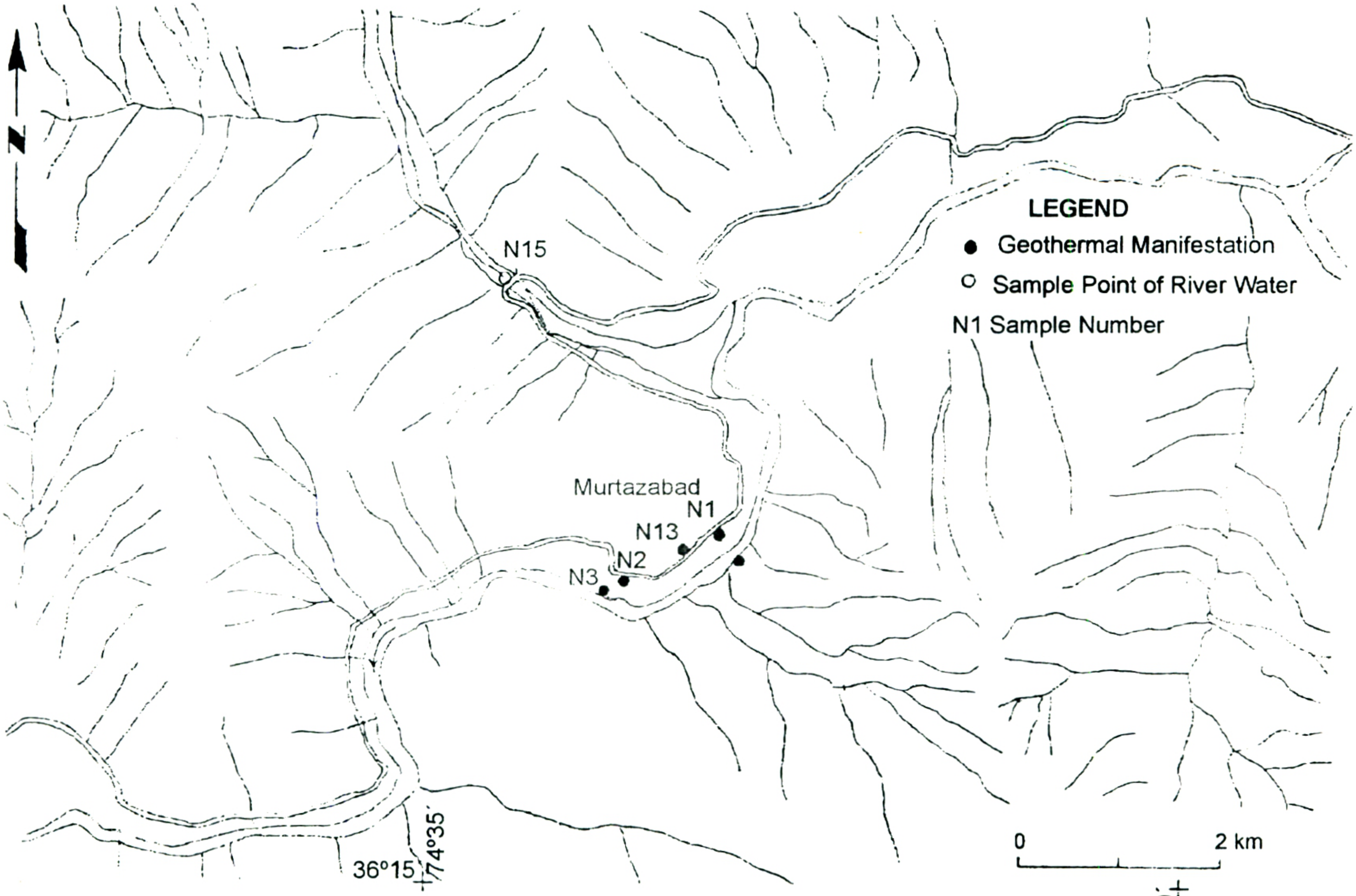


Figure N-7. Map showing sampling points at Murtazabad (toposheet 42-L).

4. N13 Alteration Zone

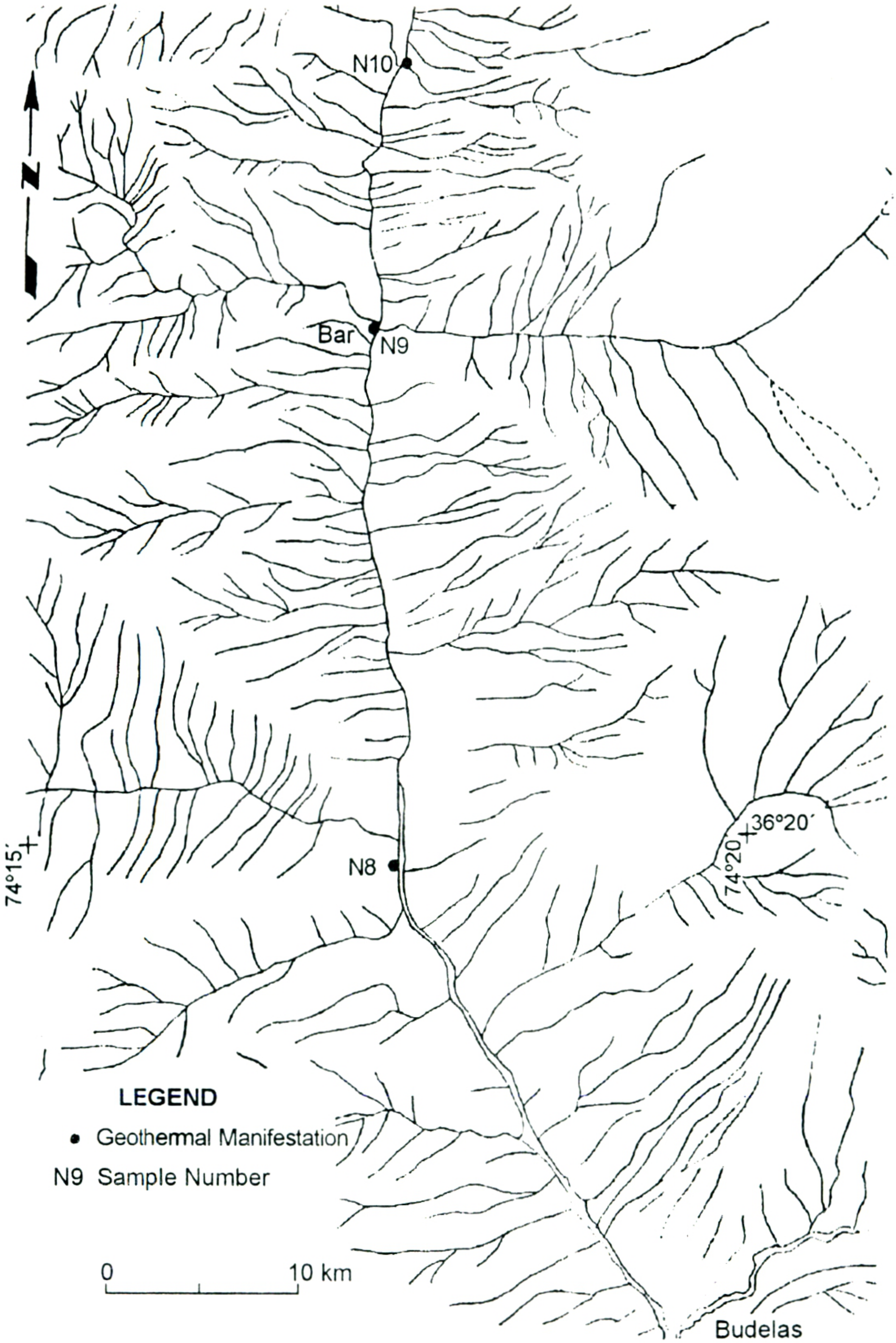
This geothermal manifestation is the largest alteration zone in this area (Plate 3). The approximate length and height are 50m and 20m, respectively. The alteration zone mainly consists of white clay and some sublimated sulphur with trace of mud pots. The country rock is talus. Some cracks whose direction is N 45°W are observed in the zone. The vapor bearing temperature of 89.8°C is issuing from the cracks. Its pH is between 3 and 4 by pH test paper.

It appears that the geothermal fluid from the Murtazabad manifestation is brought up through fractures and open cracks in the metamorphic rocks of the Baltit Group and is discharged through the Quaternary deposits.

2.4.2. Budelas Hot Springs

Three geothermal manifestations (N8, N9, and N10) were studied in the Buledas areas falling in Toposheet 42 L/7. These manifestations are located NW of Chalt on the bank of the Bola Das river or its tributary locally called Garamsal (Figs. N-6 and N-8). Approach to these hot springs is by an unmetaled road which branches off towards NW from Gilgit-Hunza road near Sikandarabad locality. The nearest thermal spring is N8, around 12 km from the main road. It is located just on the right bank of the Bola Das river. The spring issues from talus. Other manifestations, i.e. N9 and N10, are located 7 km and 10 km further north on the right and left banks of the river, respectively. These manifestations are located between the Main Karakoram Thrust and the Karakoram Granodiorite. The rocks exposed around N10 belong to the Baltit Group and comprise magmatite gneisses and schistose rocks. The physical features of these manifestations are as follows:-

1. N8 Hot Spring	Temperature	46.0° C (Ambient temperature: 32.0° C)
	Flow rate	100 l/min (Visual estimate)
	pH	7.85
	Electric conductivity	1,540µs/cm
	Feature of hot water	Colourless, H_2 smell, and salty taste
	Geology	Talus/Garnet mica schist (Baltit Group)
	Other	Use: bathing
2. N9 Hot Spring	Temperature	36.0° C (Ambient temperature: 17.0° C)
	Flow rate	100 K l/hr (Visual estimate)
	pH	7.49
	Electric conductivity	776 µs/cm
	Feature of hot water	Colourless, H_2 smell.
	Geology	Talus Garnet -staurolite Schist (Baltit Group)
	Other	Junction of two rivers.



.**Figure N-8.** Map showing sampling points atBudelas (toposheet 42-L/7).

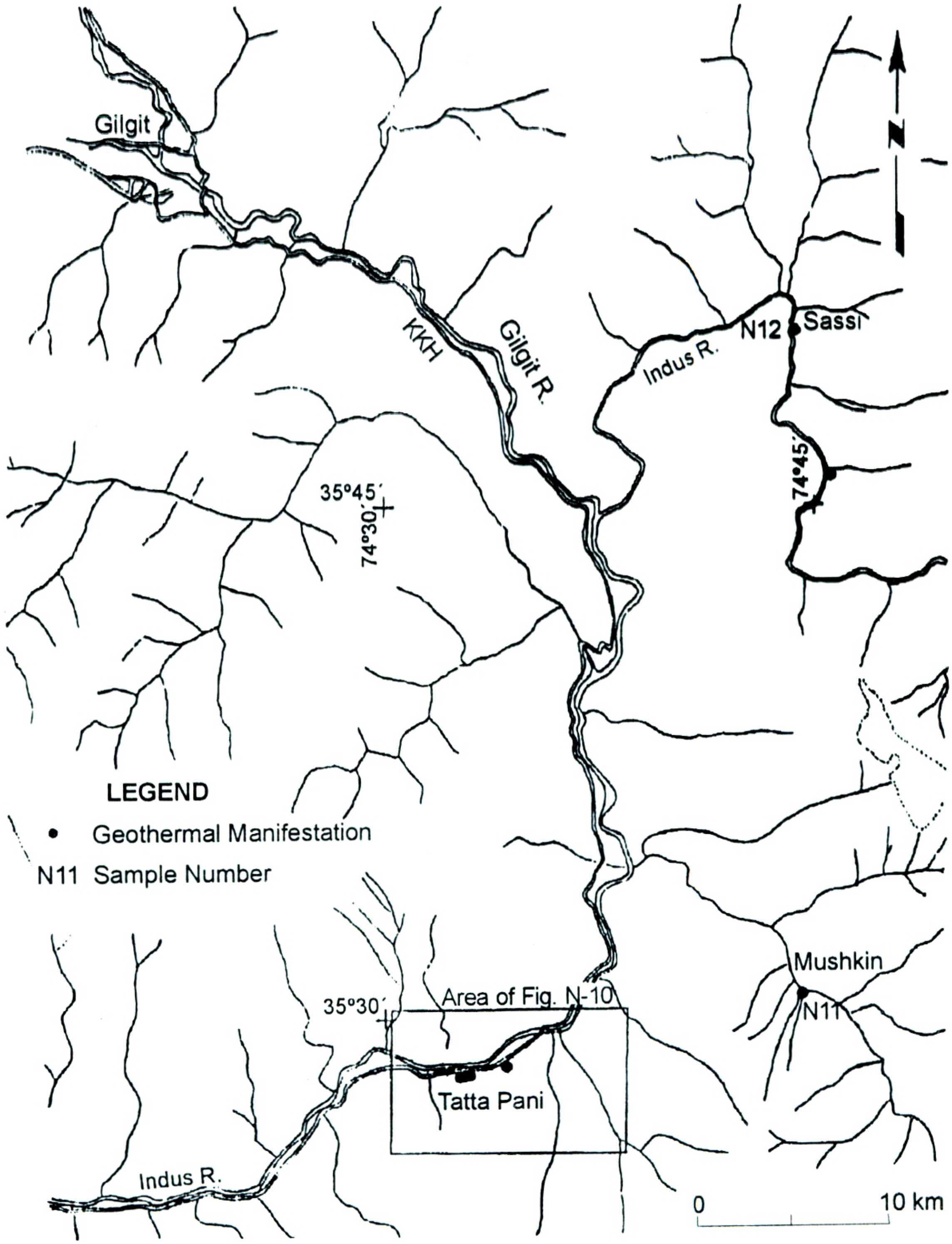


Figure N-9. Map showing distribution of geothermal manifestations at Tatta Pani, Mushkin, and Sassi (toposheet 43-I).

3. N10 Hot Spring	Temperature	Near boiling temperature (91.0^0 C)
	Flow rate	Unknown
	pH	7.64
	Electric conductivity	1,160 µs/cm
	Feature of hot water	Colourless, H_2 S smell.
	Geology	Talus/Migmatic gneiss (Baltit Group)
	Other	Junction of two rivers. Silicified zone is present.

2.4.3. Tatta Pani Hot Springs

Tatta Pani geothermal manifestations are located on the right bank of the Indus River along the Karakoram highway aligned along a straight line. The springs and seepages are numerous and stretch along a 2-3 kilometres wide zone located approximately 33 km SW of Gilgit town. Rakhiot Bridge is in the vicinity of these springs (Toposheet 43 I/11). The springs emanate from unconsolidated to semi-consolidated fluvial deposits or talus. Observations were made at four manifestations namely N4, N5, N6, and N7 (Figs. N-9 and N-10). Amphibolites which are fractured by the Main Mantle Thrust constitute the hard rocks exposed around these geothermal manifestations. The springs are located at an altitude of 1,200 m. A brief description of thc physical features of the springs as noted in the field, follows:-

1. N4 Hot Spring	Temperature	83.0°C (Ambient temperature: 17.0° C)
	Flow rate	More than 62 l/min
	pH	8.83
	Electric conductivity	1,060 µs/cm
	Feature of hot water	Colourless, H_2 smell, salty taste
	Geology	Terrace deposits/Fractured amphibolite (Kamila Amphibolites) .
2. N5 Hot Spring	Temperature	65.5° C (Ambient temperature: 36.5° C)
	Flow rate	800 l/min
	pH	8.57
	Electric conductivity	1,540 µs/cm
	Feature of hot water	Colourless, H_2 smell, salty taste
	Geology	Talus/Fractured amphibolite (Kamila Amphibolites)
3. N6 Hot Spring	Temperature	78.0° C (Ambient temperature: 36.5° C)
	Flow rate	More than 100 l/min
	pH	7-8 (by pH test paper)
	Feature of hot water	Colourless, H_2 smell, salty taste
	Geology	Talus/Fractured amphiobolite (Kamila Amphibolites) .

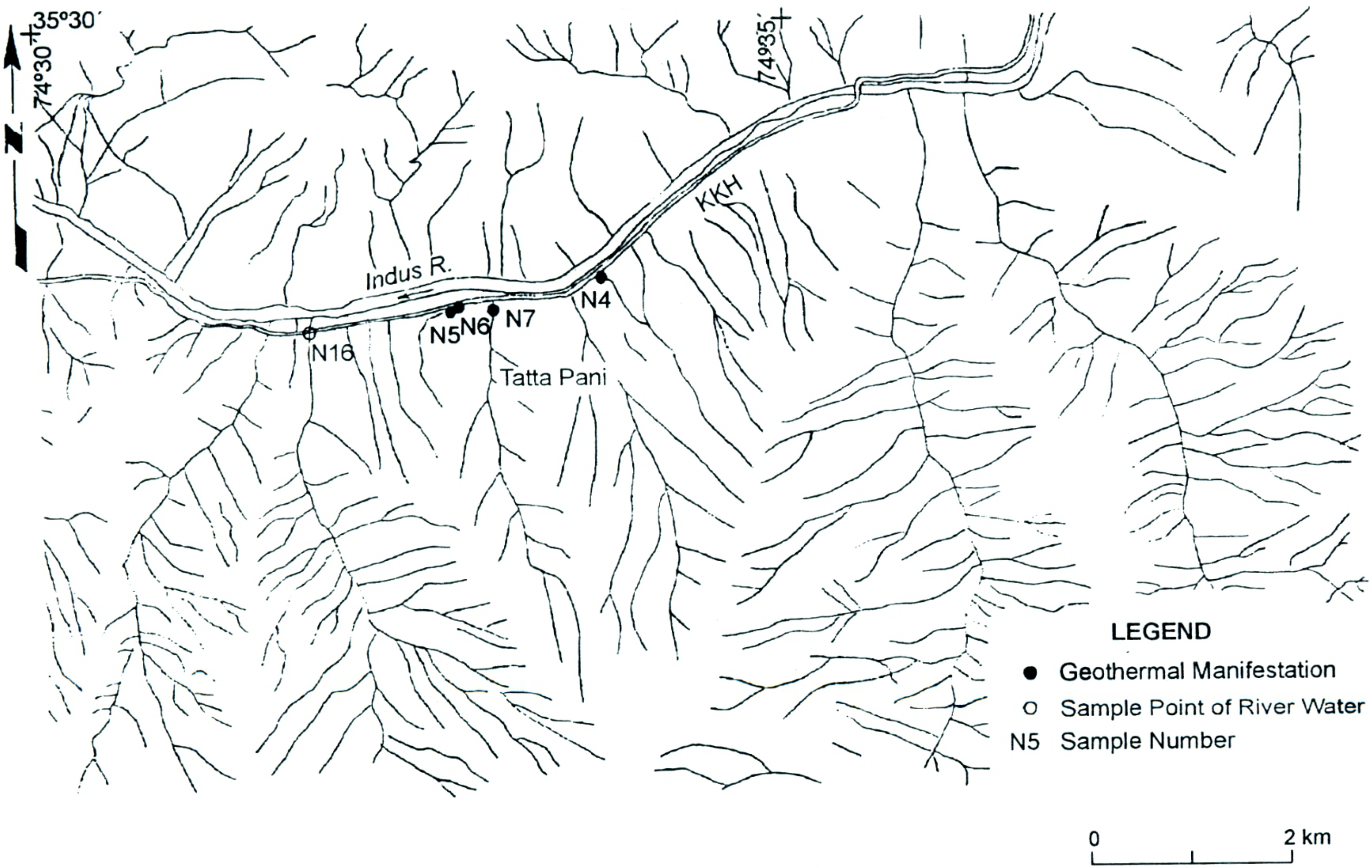


Figure N-10. Map showing sampling points at Tatta Pani(toposheet 43-I/11).

4. N7 Hot Spring	Temperature	80.0°C (Ambient temperature: 37.4° C)
	Flow rate	34 l/min
	pH	8 (by pH test paper)
	Feature of hot water	Colourless, H_2 smell, salty taste
	Geology	Talus/Fractured amphiobolite (Kamila Amphibolites)

As compared with other hot springs, the hot spring water at Tatta Pani has salty taste. These hot springs have a definite linear arrangement.

2.4.4. Mashkin Hot Spring

This geothermal manifestation is located in Toposheet 43 I/11 on an unmetalled road off he Karakoram highway, leading to Astore (Fig. N-9). The manifestation is located on the left bank of the Astore river at an altitude of 2,135 m. The valley is very narrow with steep sides, the peak on the right bank rises to 4,617 m and one on the left is 4,323 m high. The spring water oozes out and accumulates in wooden tub installed for the purpose. The exposed rocks around the spring are the Nanga Parbat Gneisses. The features of the hot spring (N11) are as under:-

Temperature	57.0° C (Ambient temperature: 34.4° C)
Flow rate	1 l/min (Visual estimate)
pH	7.87
Electric conductivity	1,070 µs/cm
Feature of hot water	Colourless, H_2 smell.
Geology	Surface soil /Gneiss (Nanga Parbat Gneisses)
Other	Use: Clothe washing.

2.4.5. Sassi Hot Spring

The Sassi thermal spring is located in toposheet 43 I/9 near the Sassi village on the left bank of the Indus river, at an altitude of 1460 m (Fig. N-9). The valley is appreciably narrow. Around the manifestation the slopes are steep and rise to altitudes of 5,325 m on the right bank and 3716 m on the left bank. The spring issues from he Quaternary deposits and the hard rocks exposed in the vicinity of the thermal spring largely comprise gneisses. The physical parametres of the hot spring (n12) observed are summarised below:-

	Temperature	54.0° C (Ambient temperature: 33.0° C)
pH	7.87	
	Electric conductivity	1,310 µs/cm
	Feature of hot water	Colourless, odorless.
	Geology	Talus/Gneiss (Kohistan Island Arc Sequence)
	Other	$CaCO_3$ deposition.

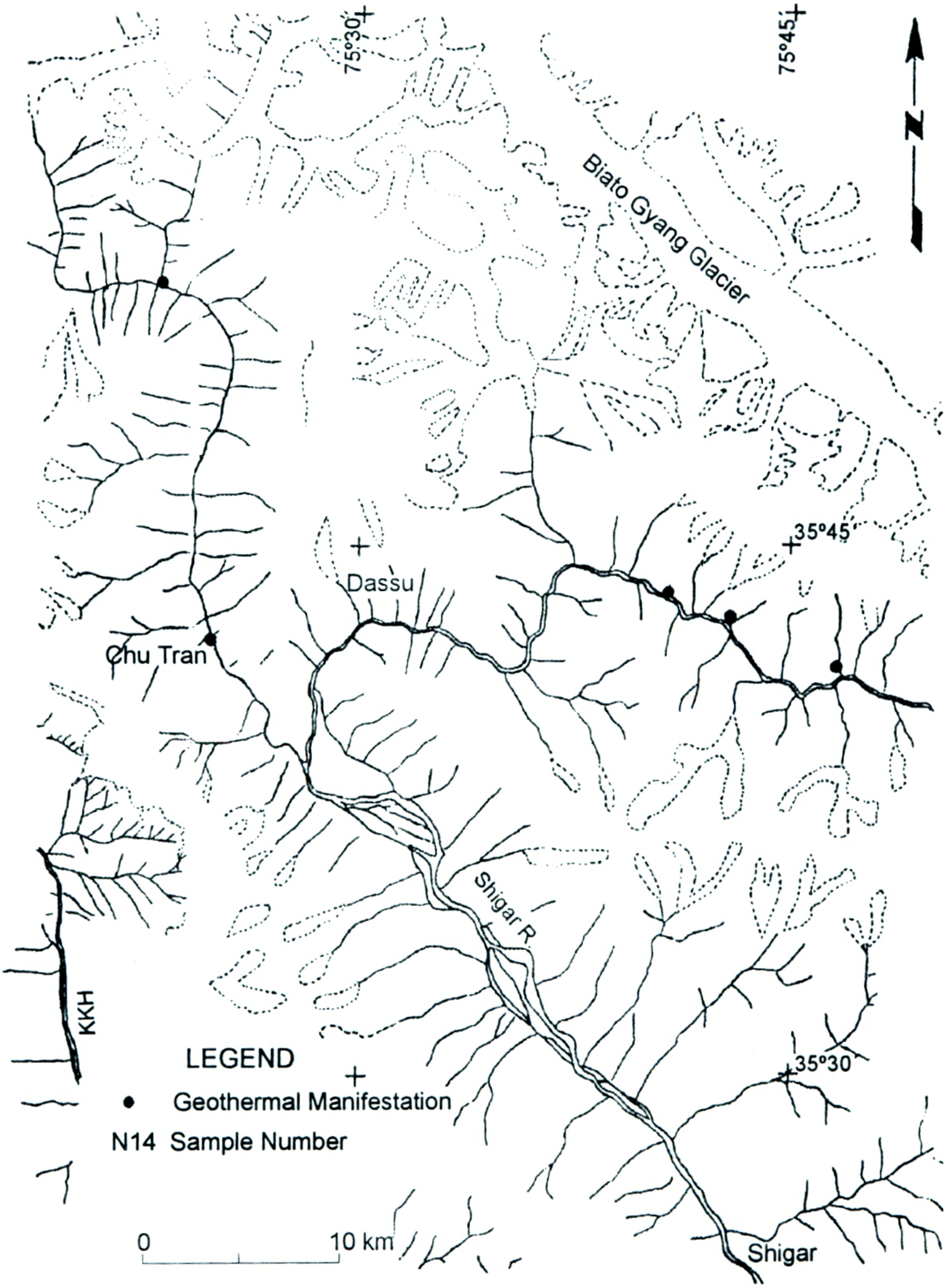


Figure N-11. Map showing distribution of geothermal manifestations in Dassu toposheet 43-M).

There are seven hot seepages spread over a length of 100 metres, which have a definite linear arrangement.

2.4.6 Chu Tran Hot Spring

Chu Tran hot spring is located in the Basha valley on the right bank of the Basha River which feeds the Shiggar River and falls in toposheet 43-M/6 (Fig. N-11). The manifestation is situated 6.4 km NW of the confluence of the Basha and Braldu rivers. This valley around the hot spring is moderately broad. The spring issues from the semi-consolidated Quaternary deposits. The hard rocks exposed around the spring are limestones. Observations made at the spring (N-14) are as follows:-

Temperature Flow	43.9° C (Ambient temperature: 32.0° C)
Flow rate	200 k l/hr (Visual estimate)
pH	7.74
Electric conductivity	5,090 µs/cm
Feature of hot water	Colourless, Odorless.
Geology	Talus/Limestone(Eurasian Mass) $CaCO_3$ deposition.
Other	Spring located not far from the junction of two rivers. Used for bathing,

2.5 Chemical Analysis of Waters

2.5.1 Characteristics of water and its classification

Twelve water samples from various springs in the Northern Areas were collected and analysed at the Karachi laboratory of the Geological Survey of Pakistan. Water samples collected from various localities of the Northern Areas are listed below:-

Locality	Water Sample No
1. Murtazabad	N1, N3, N15
2. Buledas	N8, N9, N10
3. Tatta Pani	N4, N5, N16
4. Mushkin	N11
5. Sassi	N12
6. Chu Tran	N14

Table N-1. Chemical composition of waters from Northern areas.

Sample No.	N1	N3	N4	N5	N8	N9	N10	N11	N12	N14	N15	N16
Sampling Data	10.7.88	27.7.88	23.7.88	23.7.88	26-7-1988			27-7-88	28-7-88	6-8-88	10-8-88	
pH	7.50	9.21	8.83	8.57	7.85	7.49	7.64	7.87	7.86	7.74	8.34	7.41
EC(us/cm)	1720	2470	1060	900	1540	776	1160	1070	1310	509	131	276
TSM(mg/l)	1430	1860	740	680	1102	526	940	860	940	350	100	212
Na(mg/l)	170	470	180	150	212	45	120	180	200	7	1	6
K(mg/l)	39	52	6	8	20	10	17	15	14	3	4	2
Ca(mg/l)	108	0	0	0	60	80	32	0	0	68	0	0
Mg(mg/l)	53	14	5	0	12	22	41	6	74	17	13	27
Cl(mg/l)	20	37	48	39	17	13	19	66	25	10	8	13
SO_4 (mg/l)	374	475	173	185	247	116	308	63	213	86	16	76
HCO_3 (mg/l	600	551	162	129	407	162	291	356	356	52	32	48
Co_3(mg/l)	16	191	64	32	48	64	0	32	32	32	0	0
SiO_2(mg/l)	37	50	45	14	38	<10	32	35	10	<10	<10	<10
Water Temp. At Field (^oC)	42.3	90.0	83.0	65.0	46.0	36.0	(91)	57.0	54.0	43.9	3.4	20.0

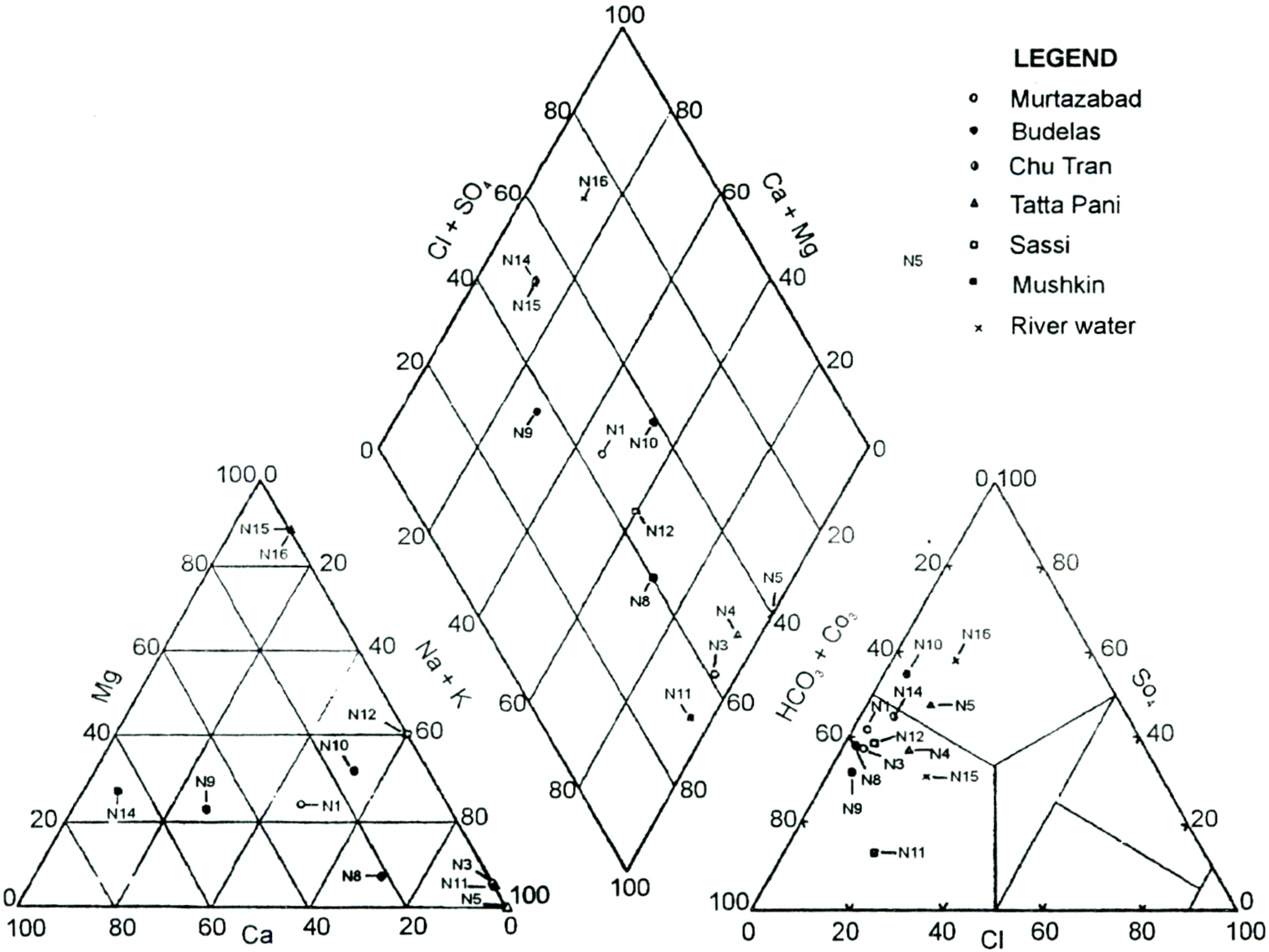


Figure N-12. Key diagram for classification of waters from Northern Areas.

Of these waters, the N15 and N16 samples are river waters from Hasanabad and Batchaloi Gah, respectively (Figs. N-7 and N-10). The water temperatures are 3.4°C and 20.0°C, respectively.

Figures N-6 to N-11 and Table N-1 show the locations of water samples and results of analyses. The ion charge balances range from 0.7 to 14.0% and its average is 6.85%. The reliable data are only N-1.

Fluid types of hot water were classified on the basis of characteristics of main dissolved anions as shown in the key diagram (Fig. N-12). In addition, a hexadiagram based on equivalent of main dissolved in each spring water is shown in figure N-13.

The hot spring waters from the Northern areas are classified as HCO_3 or SO_4 type. These waters fall around the boundary of the HCO_3 and SO_4 types in key diagram (Fig. N-12). On the other hand, the main cation is Na except the N9 and N14 samples. TSM, EC, and temperature of the N9 and N14 waters are low compared with the others. It is suggested that these hot spring waters are mixed with nonthermal water such as river water or surface water.

2.5.2 Reservoir Temperature

A list of temperature by the silica and the Na-K-Ca geothermometres is shown in Table N-1 At Murtazabad, the silica and Na-K-Ca geothermometers (Na-K geothermometers in the N-3 sample) indicate 88° C and 102° C and 198° C and 212° C at Buledas, 51° C and 97° C and 172° C and 189° C, respectively. The estimated temperature of N9 at Buledas is excluded because the effect of mixing with nonthermal water is assumed to be too much. These temperatures show little difference from the results of Shuja and Iqbal (1983). The temperature by the silica geothermometers is generally lower than the temperature by the Na-K-Ca geothermometer in both the areas. It is considered to be subject to the influence of the mixing of nonthermal water as mentioned later in detailed discussion.

The Na-K-Ca geothermometer of the other area is not applicable because Ca is not detected in their samples and the ion charge balance is not good (17.4-14.0%). However, when trying to estimate the temperature by the Na-K geothermometer (Truesdell, 1975), they are 93° and 128°C at Tatta Pani, 169°C at Mushkin. On the other hand, the silica geothermometer indicates from 51° C to 97°C at Tatta Pani, 86°C at Mushkin, 40°C at Sassi and less than 40°C at Chu Tran. Most of them are considered to be mixed with nonthermal waters.

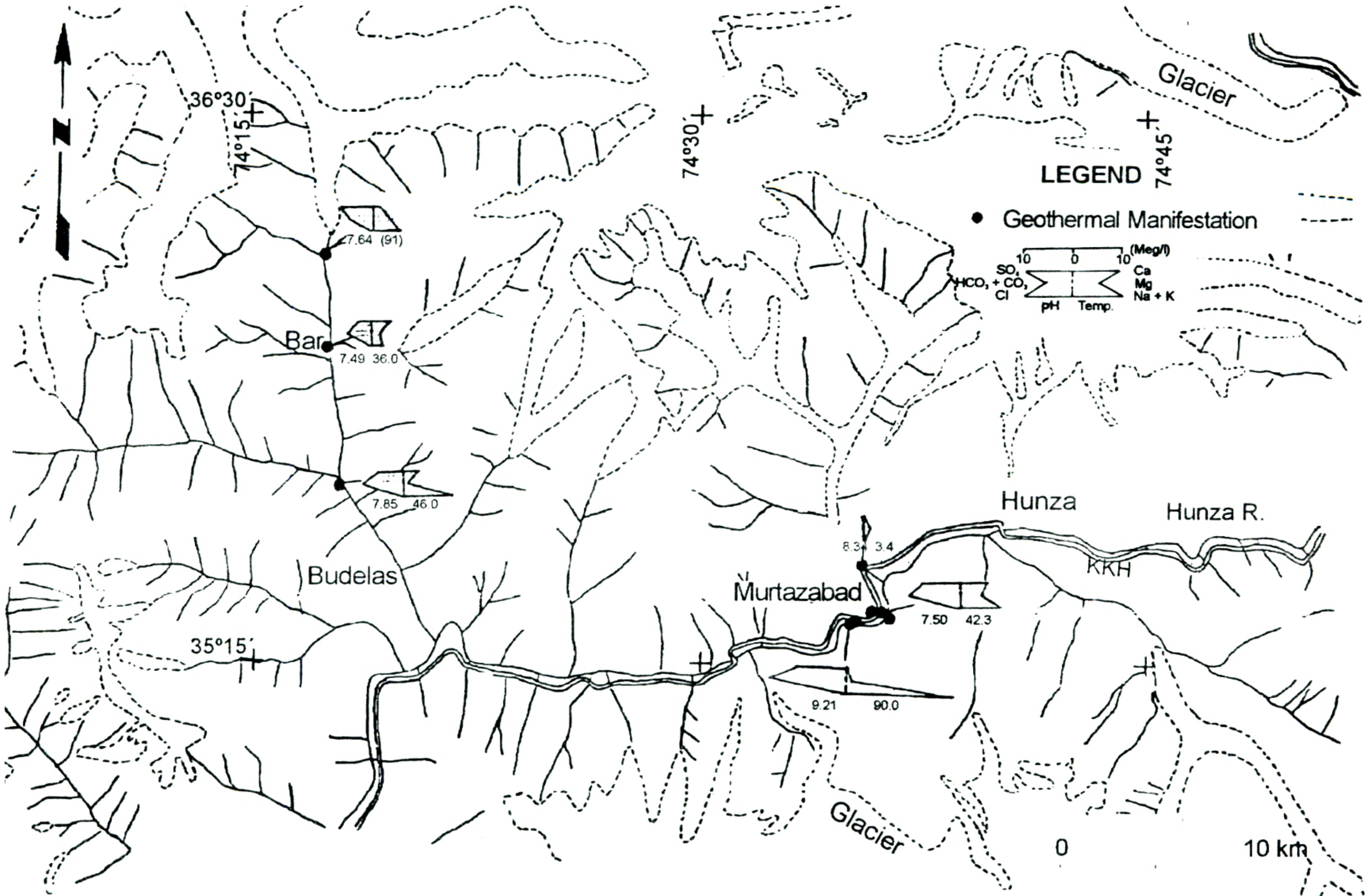


Figure N-13. Hexadiagram showing chemical composition of waters from Northern Areas (3-1)

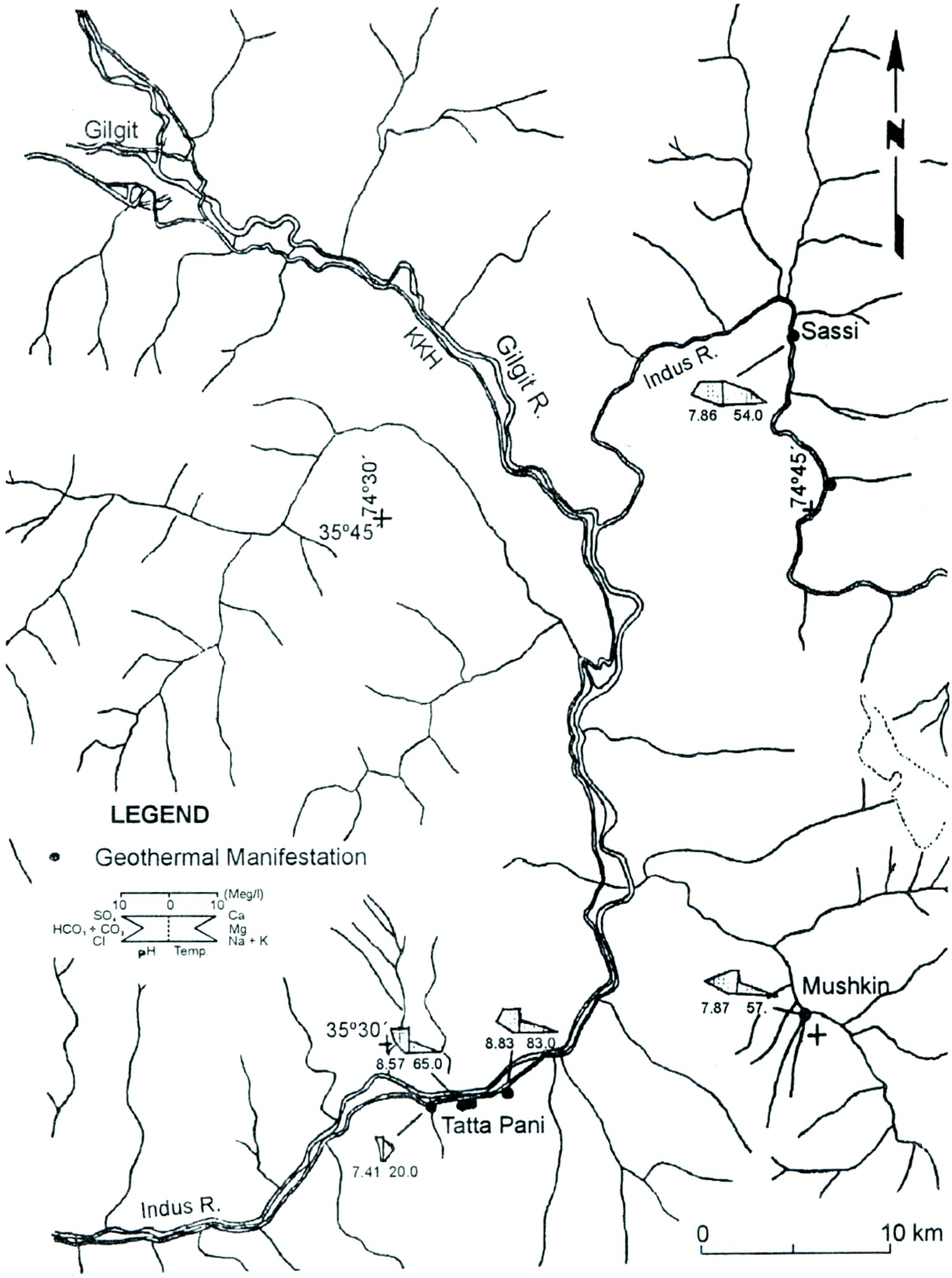


Figure N-13. Hexadiagram showing chemical composition of waters from Northern Areas (3-2).

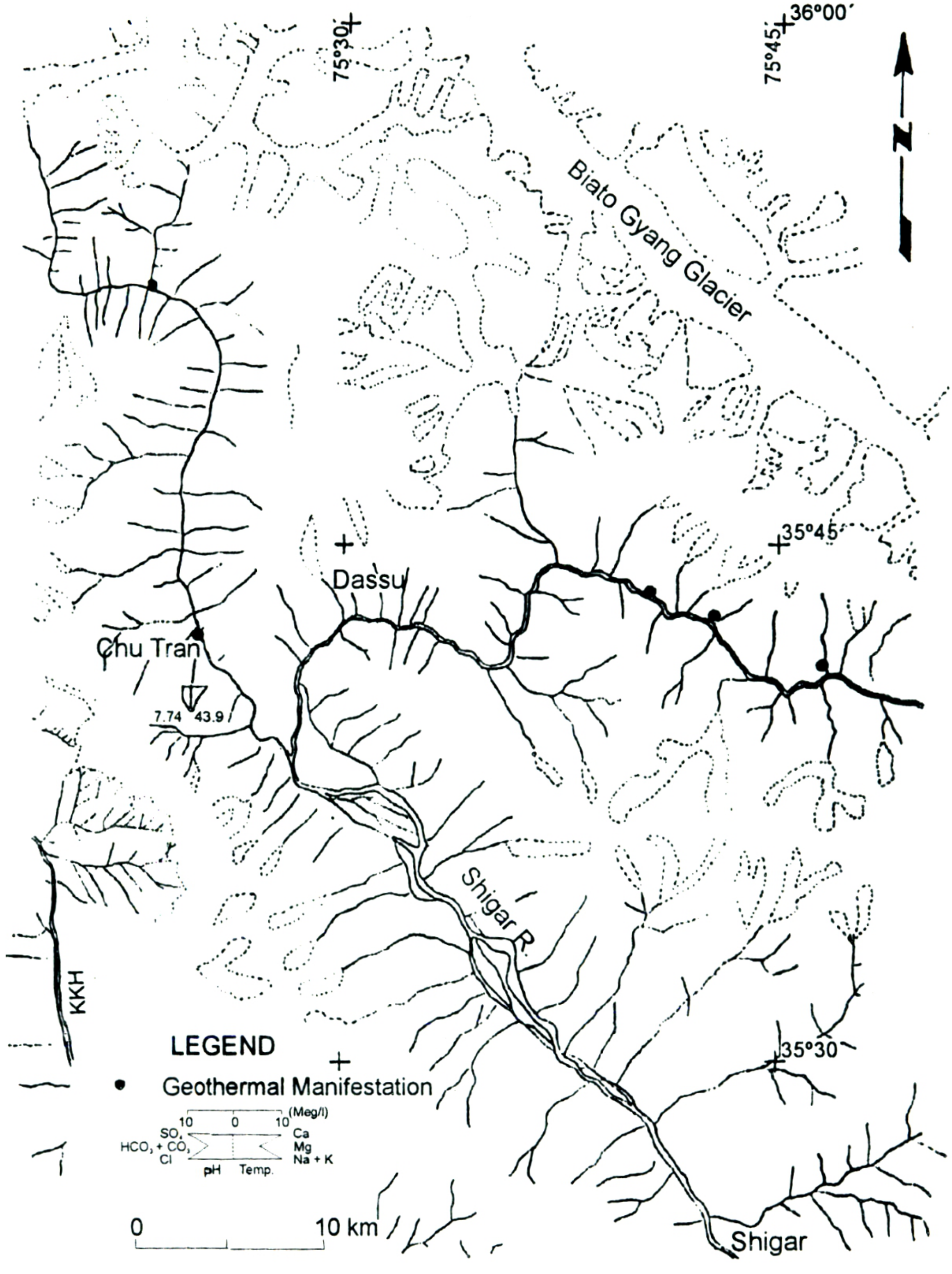


Figure N-13. Hexadiagram showing chemical composition of waters from Northern Areas (3-3)

2.6. Geothermal System

2.6.1 Geothermal System Related to Main Karakoram Thrust

The geothermal manifestations at Murtazabad and Buledas lie north of the Main Karakoram Thrust (MKT) as shown in Figure N-2. The distance between the geothermal manifestations and the MKT ranges from 6 to 17 km. The hot spring water is discharged, not from the foot wall of the MKT but from the hanging side which is made up of the Eurasian Mass comprising the Baltit Group and the Karakoram Granodiorite. The permeability of the Baltit Group which mainly consists of gneisses and schists is generally low. The open cracks, however, have a tendency to develop in the hanging side of the thrust. The open cracks are typically observed at Murtazabad. Not only the strike of the cracks but also that of the lineaments (Fig. N-3) are consistent with that of the MKT.

At Buledas, the hot springs emerge at junctions of two rivers whose direction is N-S and E-W. These rivers are accepted as the predominant lineaments. It is assumed that the E-W lineaments which are associated with the manifestations are related to the Main Karakoram Thrust. From these facts, it may be concluded that the permeability of the zone bearing the open cracks and the faults is relatively high and that they play an important role of transmitting the geothermal fluid as shown in Figure N-14.

As to the heat sources, the obvious evidence such as the existence of a young volcano is not found in this area. However, the heat generated due to friction along the MKT and the that due to the radioactive decay of the Karakoram Granodiorite is likely source of heat giving rise to the thermal springs. At Buledas, three hot springs are distributed along the Bola Das river which runs in N-S direction. These hot springs are located between the MKT and the Karakoram Granodiorite (Fig. N-2). These hot springs are aligned perpendicular to the Karakoram Granodiorite Belt. The hot spring water of the manifestation nearest to the Karakoram Granodiorite Belt (Loc. N10) bears the highest temperature which is near the boiling temperature (91° C). However, the hot spring water of the middle manifestation (Loc. N9) at the Bar village has low temperature (36° C). It is assumed that the hot spring water is mixed with river water and/or surface water because it is located at the riverside and discharges fairly large volume of water, and has low electric conductivity (776 μs/cm) and low TSM (526 mg/l). The actual temperature is expected to be higher than the recorded temperature. Consequently, a marked increase in temperature is noted as we draw closer to the Karkoram Granodiorite. The relation between the Karakoram Granodiorite and the heat source is suggested.

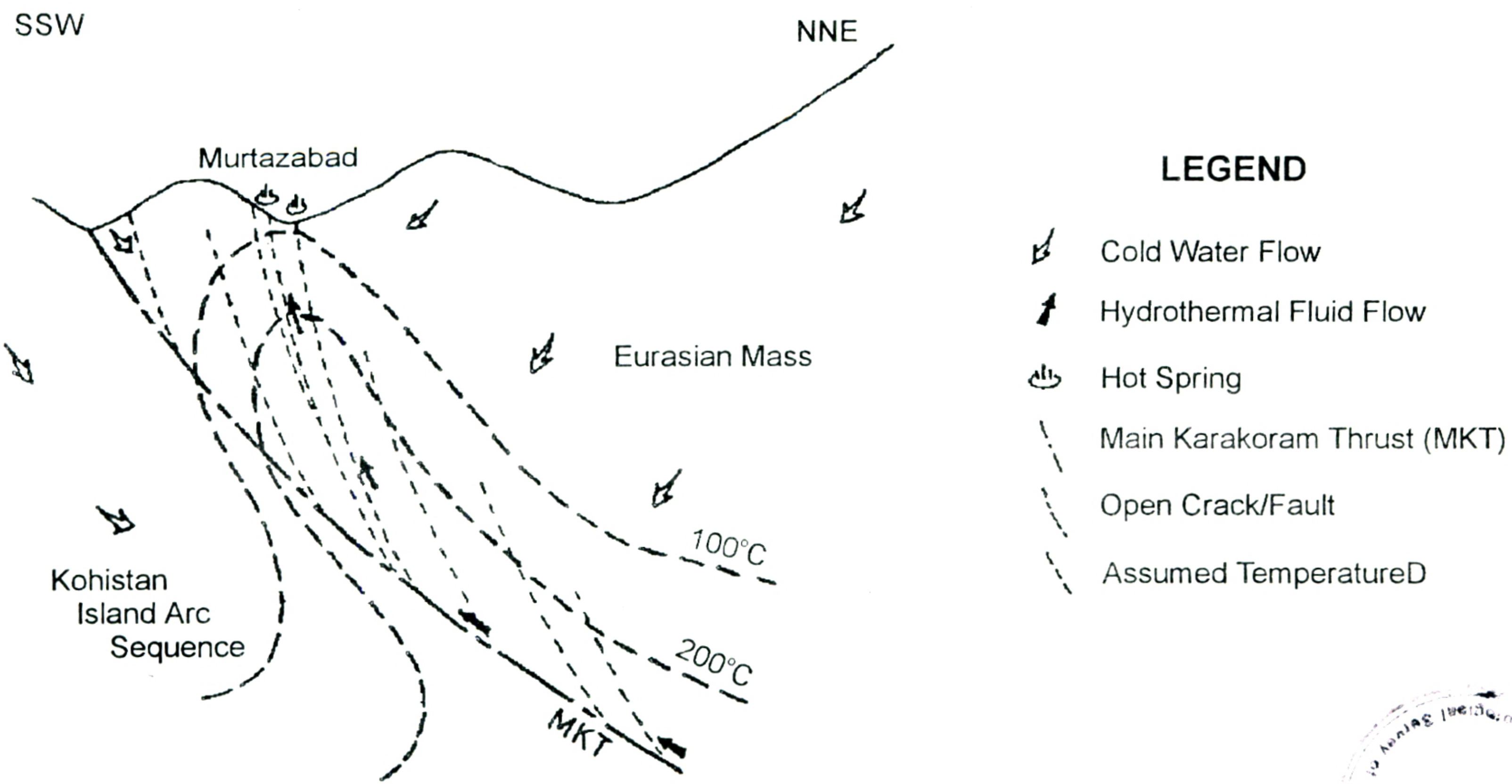


Figure N-14. Profile showing Murtazabad geothermal manifestations in relation to Main Karakoram Thrust.

Table N-2. Estimated geochemical temperature of waters from Northern Areas.

Samle No.	Water Temp. At Field	TSiO2		T Na-K-Ca	Remarks
		adia	cond		
	°C	°C	°C	°C	
N1	42.3	92	88	212	1 Mg = 34°C
N3	90.0	104	102	-	T Na-K = 198°C
N4	83.0	100	97	-	T Na-K = 93°C
N5	65.0	59	51	-	T Na-K = 128°C
N8	46.0	93	90	172	T Mg = 79°C
N9	36.0	<48	<40	61	
N10	(91)	87	82	189	
N11	57 0	90	86	-	T Na-K = 169°C
N12	54.0	48	40		T Na-K = 152°C
N14	43.9	<48	<40	17	

It appears that the thermal springs are mainly fed by the glacial-melt as is indicated by the prevalent dryness of the area. However, the isotopic analysis of the waters will shed a conclusive light on the origin of the thermal waters. The geothermal system is visualised as follows:-

The water from the glacier penetrates the deep zone and is heated by the heat sources as mentioned earlier. The heated water rises along the open cracks and the geothermal manifestations are formed on the surface.

The silica geothermometer and the Na-K-Ca geothermometer (the N3 sample is calculated by the Na-K-geothermometer) indicate that reservoir\temperature ranges from 88° to 102° C and 198° to 212° C at Murtazabad and from 51° to 97° C and from 172° to 189° C at Buledas, respectively. These temperature are similar to that of Shuja and Iqbal (1983). The temperature estimated by the silica gothermeter is lower than that estimated by the Na-K-Ca geothermometer in both the areas. The Na-K-Ca geothermometer is not appreciably effected by the mixing of the water. On the other hand, the silica geothermometer is effected by mixing process and thereby indicates lower temperature. As these hot springs appear on the riverside. It is possible that the hot spring water is diluted by groundwater in the shallow zone and that the Na-K-Ca geothermometer indicates closer to reservoir temperature in the deep zone. The C9 sample apparently indicates mixing with cold water as evidenced by the discharge temperature and volume, chemical composition, and the vicinity of river. The river water was sampled during the present exploration to study the mixing model (Fournier, 1977) applying the silica geothermometer to verify the above hypothesis.

Figure N-15 shows the dissolved silica enthalpy graph. Most of the samples except the N1, N8, and N11 samples are plotted along the quartz solubility curve. It means that the estimated temperature by the silica geothermometer is close to the discharge temperature. It appears that silica reached a state of equilibrium after the hot water mixed with cold water in the shallow zone before being discharged from the spring. Results of application of the mixing model is as follows:

Intersection of the solubility curve and the straight line joining N8 and N15 indicates a temperature of 210° C. These temperatures are consistent with temperature estimated by the Na-K-Ca geothermometer (172° to 189° C). Similarly, the temperature indicated by the N1 and N15 line is about 150° C. However, the possibility of the silica geothermometer indicating closer to real reservoir temperature compared with the Na-K-Ca geothermometer cannot altogether be ruled out.

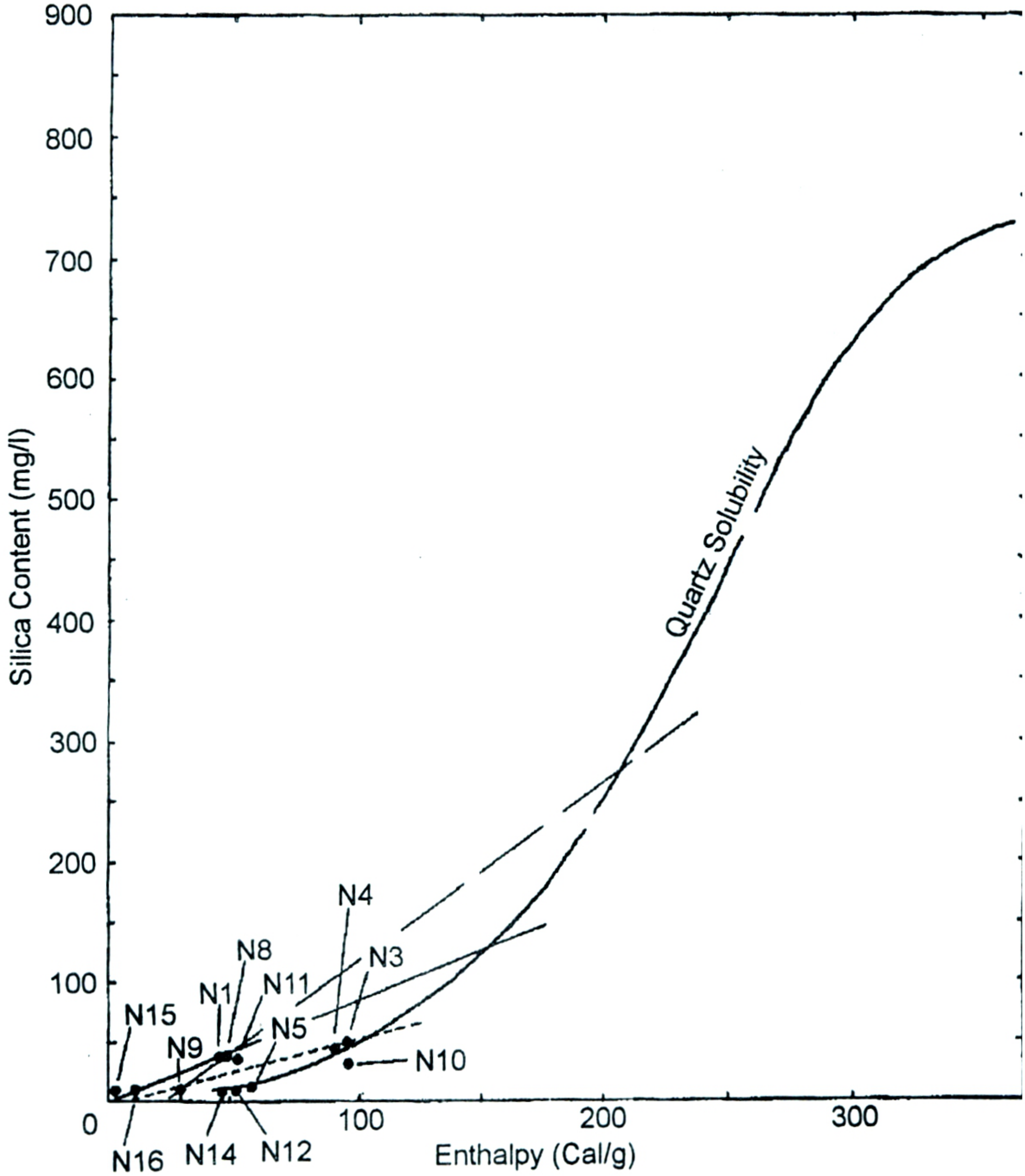


Figure N-15. Dissolved silica-enthalpy graph from determining the temperature of hot water component mixed with cold water.

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KEKSHO NULLAH BRIDGE

Map sheet No. 43/M Skardu
Grid Ref: NH -078995
SVY STAS 90 - 91
Hor. Scale: 1 Inch = 50 Ft.
Contour interval 5 Ft.

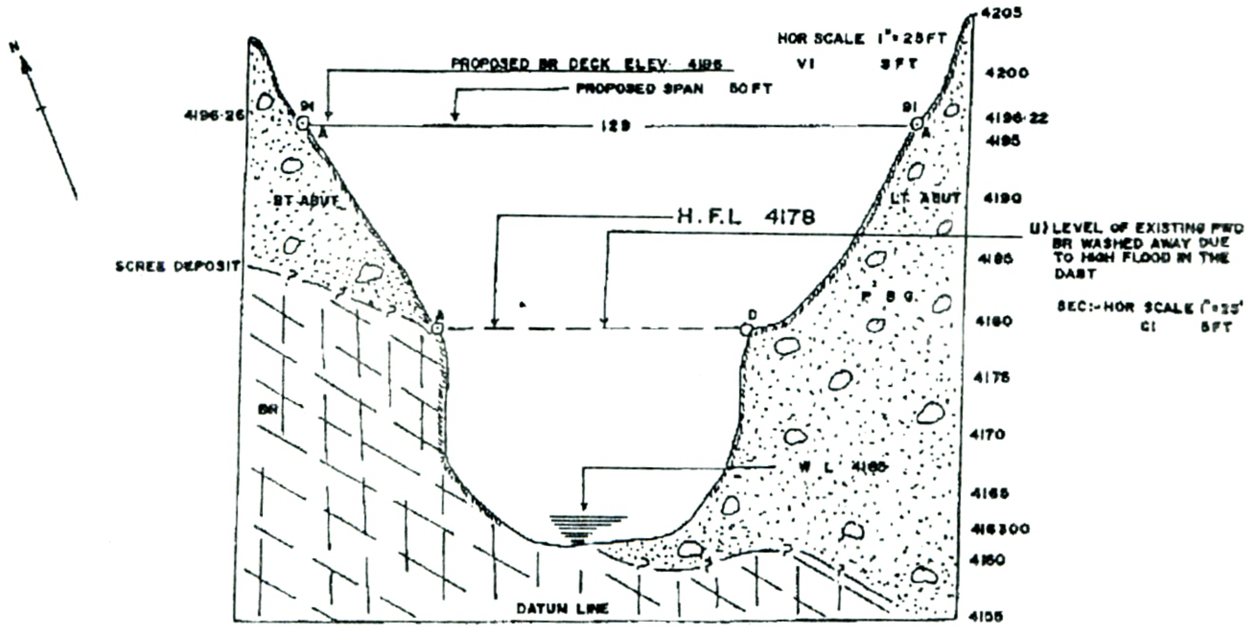

Figure 14. Geologic cross section at the proposed Keksho Nullah bridge.

3.2.3 Triko Baraluma Sector

Askor Nullah Bridge

1. PROPOSED DECK LEVEL	:	5,135.00 Feet.
2. PROPOSED BR SPAN	:	50 Feet
3. HIGH FLOOD LEVEL	:	5,120 Feet.
4. HYDROLOGY	:	The nullah has a perennial flow Bed is underlain by big boulders. Slope of the nullah bed is 1 in 16. High floods occur in summer. Has a large catchment area and its source is located in glaciers. Water course remains shifting on either side.
5. SITE CONDITIONS	:	The present bridge is located on big glacial boulders embedded in silty sandy soil. Nullah banks have gradual slope. Bedrock is not encountered. However, if move about 200 feet upstream bedrock may be encountered at right abutment and scree and superficial deposits on the left side. But rock at the left abutment may be encountered at shallow depth. The level of the bridge at the present site is very low and within the H.F.L. It requires for high abutment walls, deep foundation and protective works upstream and at the toe of the bridge. The upstream site is better. Problem of approach and grade may be negotiated. Protection against HFL and scouring is to be taken care of (Fig. 15).

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ASKOR NULLAH BRIDGE

Map sheet No. 43/M Skardu

Grid Ref: NH - 928095

SVY STAS 405 to 406

Hor. Scale: 1 Inch = 50 Ft.

Contour interval 5 Ft.

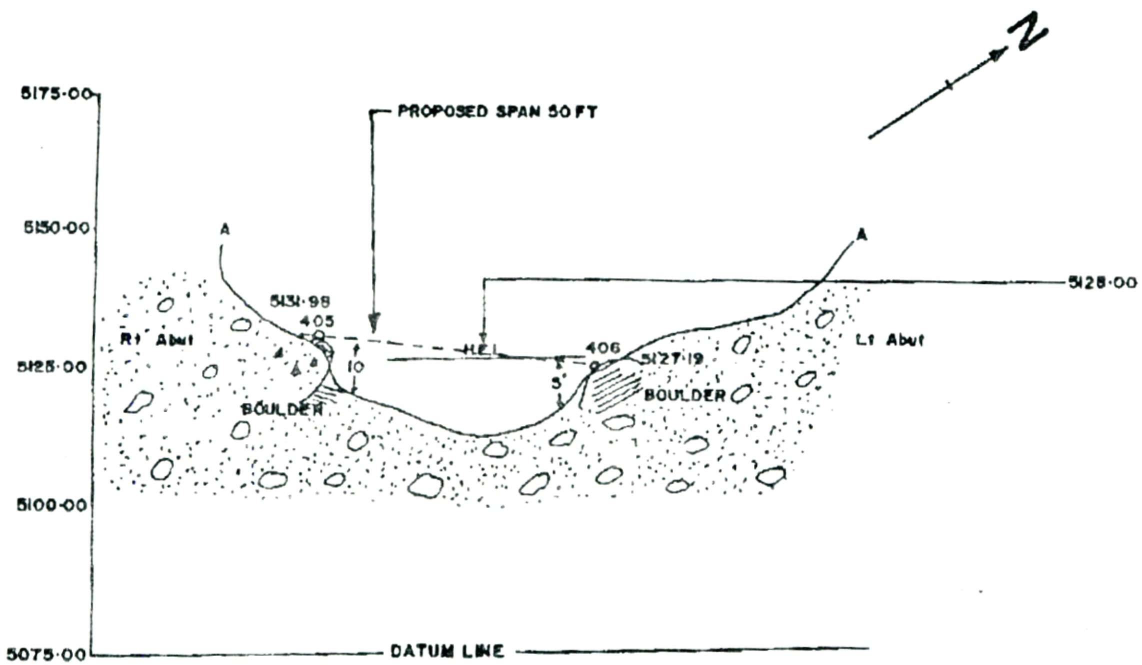

Figure 15. Geologic cross section at the proposed Askor Nullah bridge.

Staghchu Nullah Bridge

1. PROPOSED SPAN	:	30 Feet.
2. HIGH FLOOD LEVEL	:	5,067 Feet
3. HYDROLOGY	:	Perennial flow, slope of bed 1 in 20.
4. SITE CONDITIONS	:	The present bridge is located on boulders and heterogenous soil. It is a low level bridge and abutments rest on boulders. The deck level is also low. The present site is not suitable for a bridge. For a better site move about 250 feet upstream Bedrock is available on both sites. Overburden on left side to be removed for the foundation and vertical steep slopes to be cut for approach and bridge site. Rock is good for any load (Fig. 16).

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STAGHCHU NULLAH BRIDGE

Map sheet No. 43/M Skardu
Grid Ref: GR - 955029
SVY STAS 345 to 346
Hor. Scale: 1 Inch = 25 Ft.
Contour interval 5 Ft.

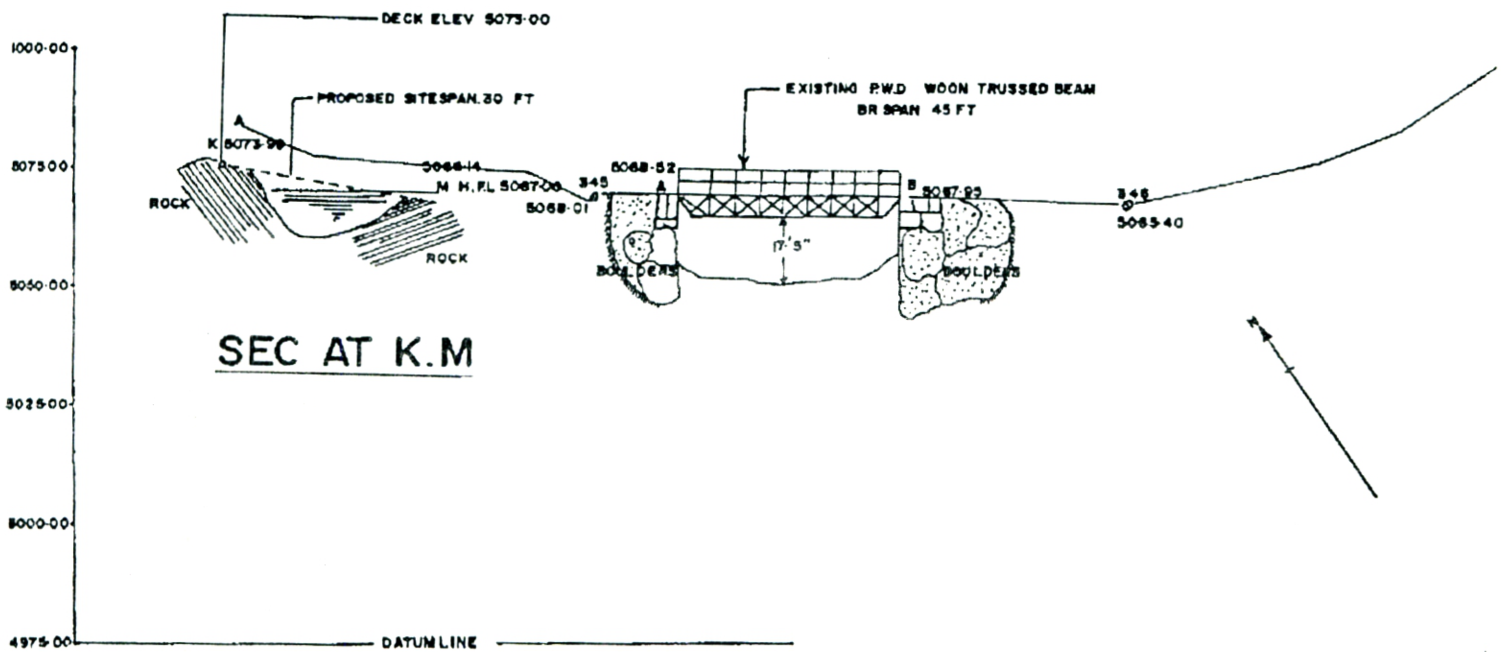

Figure 16. Geologic cross section at the proposed Staghchu Nullah bridge.

Janwye Nullah Bridge

1. PROPOSED BR SPAN	:	59 Feet
2. PROPOSED DECK LEVEL	:	4,787 Feet
3. HIGH FLOOD LEVEL	:	4,711 Feet.
4. CLASS OF EXISTING PWD BRIDGE	:	Wooden trussed beam.
5. HYDROLOGY	:	Perennial flow. Steep bed slope 1: 5.
6. SITE CONDITIONS	:	The present bridge is located on hard granitic rock which is massive and jointed. The left abutment is good and can hold bridge of required specification Right abutment rock is sheared and badly jointed. The right abutment rock is to be cushion-blaster for platform. The present platform is subject to sliding two joint sets are clearly indicated (i) N 85 E, vertical. (ii) N-S dip 70 E. Some problem of approach may be encountered. High gravelly fills on one side to be tackled and approach made. Hanging boulders on right side may fall down and damage the bridge structure. These boulders are to be pulled down. Some protective measures against sliding to be adopted. Site is suitable for permanent bridge (Fig. 17).

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JANWYE NULLAH BRIDGE

Map sheet No. 43/M Skardu

Grid Ref: NB - 8833046

SVY STAS 105 to 106

Hor. Scale: 1 Inch = 25 Ft.

Contour interval 5 Ft.

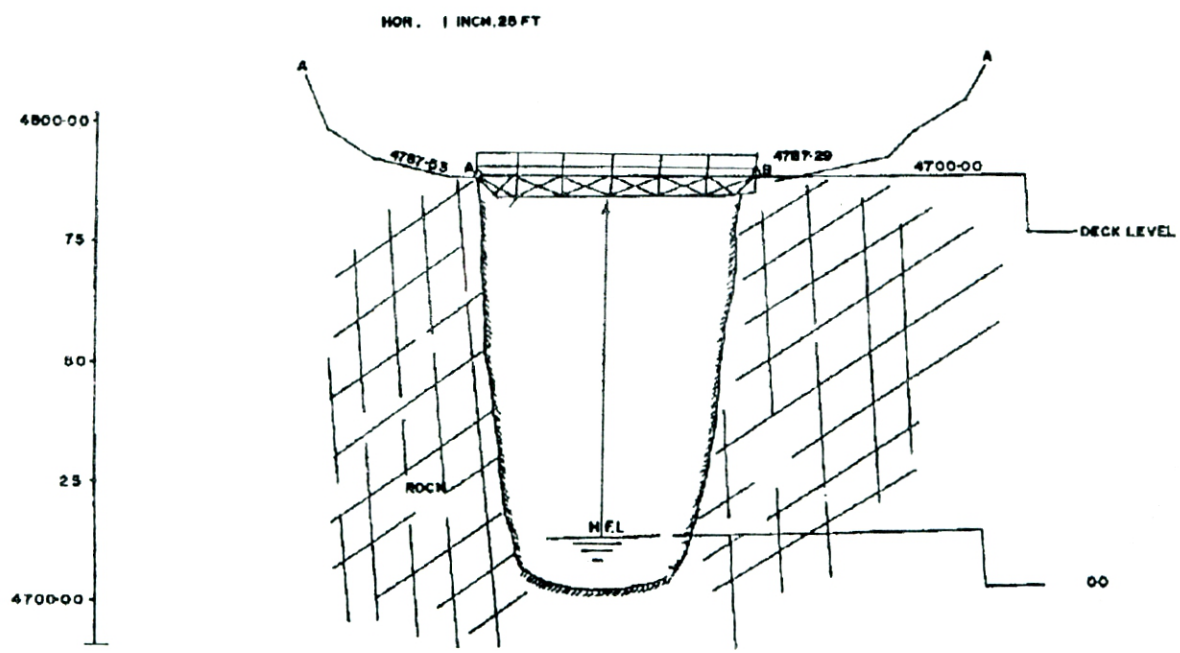

Figure 17. Geologic cross section at the proposed Janwye Nullah bridge.

Mile 69 Nullah Bridge

1. PROPOSED SPAN	:	31 Feet.
2. PROPOSED DECK LEVEL	:	4,942.00 Feet
3. HIGH FLOOD LEVEL	:	4,930.00 Feet.
4. TYPE AND CLASS OF EXISTING PWD BRIDGE	:	Wooden trussed class 3 bridge. Span 31 feet Abutments on rock.
5. HYDROLOGY	:	Flow is seasonal contributed by glacier. Maximum discharge during July August.
6. SITE CONDITIONS	:	Good hard granitic rock is exposed on both sides. Rock is jointed and massive with no adverse joint of importance. Formation is suitable for the construction of permanent bridge of required classification (Fig. 18).

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MILE 69 NULLAH BRIDGE

Map sheet No. 43/M Skardu

Grid Ref: NB - 841094

SVY STAS 80 to 81

Hor. Scale: 1′′ = 25′

Contour interval 5′

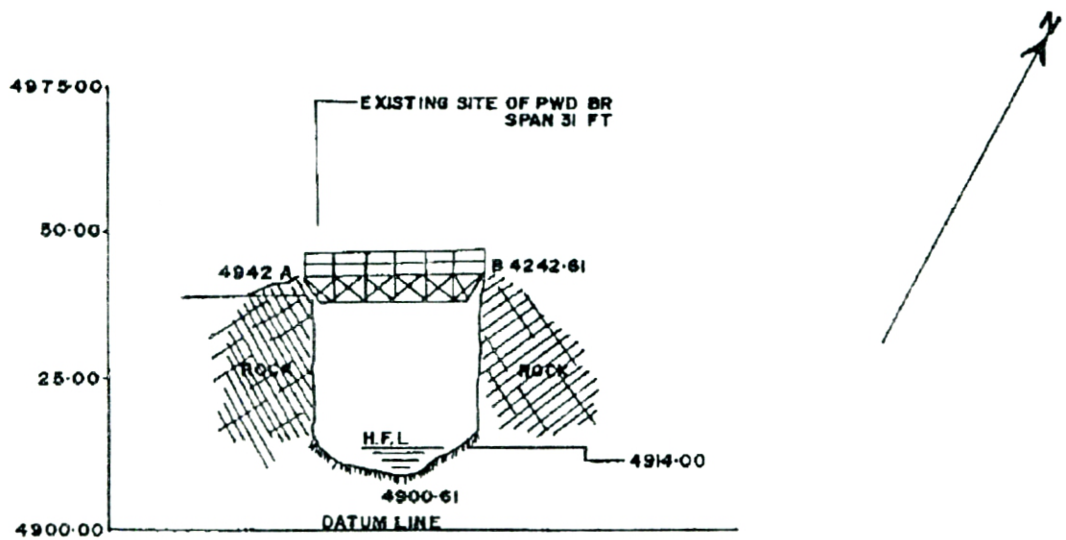

Figure 18. Geologic cross section at the proposed Mile 69 Nullah bridge.

Baraluma Nullah Bridge

1. PROPOSED SPAN	:	152 Feet
2. PROPOSED DECK LEVEL	:	4,600.00 Feet.
3. HIGH FLOOD LEVEL	:	4,520.0 Feet.
4. TYPE AND CLASS OF EXISTING PWD BRIDGE	:	Class-3, Wooden suspension bridge. Span 151 ft. Deck level 4,600.00 feet. Both abutments made on rock foundation.
5. HYDROLOGY	:	Perennial flow in the nullah. Source located is glaciers. Bed slope 1 in 30 approx.
6. SITE CONDITIONS	:	Rock available on both ends, foliated and jointed, foliation dip upstream. Nullah has steep vertical faces at the present site. The rock above the bridge at a height of about 20 feet from the deck level is underlain by loose scree and alluvial deposits consisting of mixed. ABG and silt, sand and boulders. Excavation is involved on each side for approach and curvature and protective work, against falling stones from above. Upstream or downstream shifting of the site is possible according to the suitability of approach and grade (Fig. 19).

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BARALUMA NULLAH BRIDGE

Map sheet No. 43/I Gilgit

Grid Ref: NB - 769115

SVY STAS 0 to 1

Hor. Scale: 1 Inch = 25 Ft.

Contour interval 5 Ft.

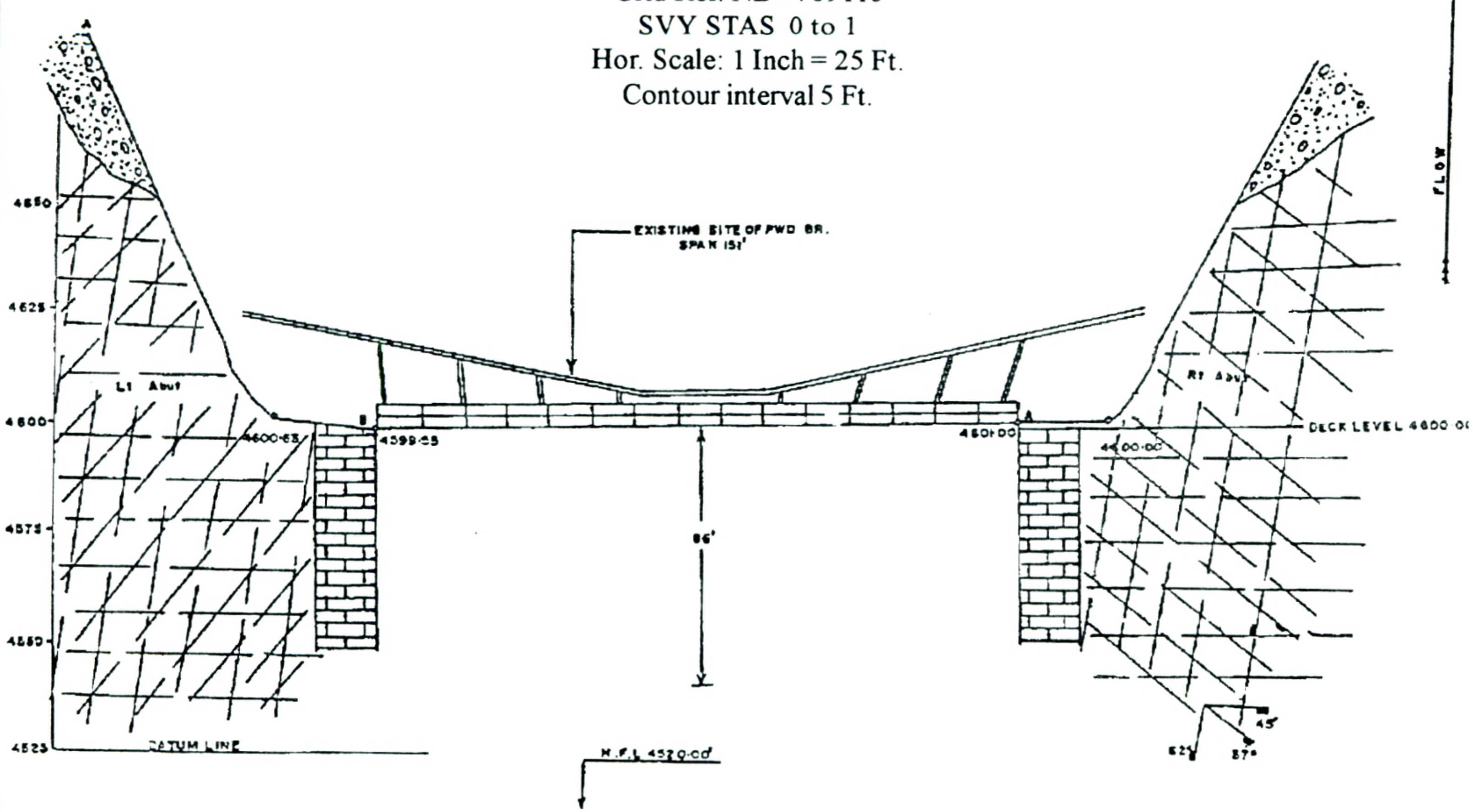

Figure 19. Geologic cross section at the proposed Baraluma Nullah bridge.

3.2.4 Baraluma - Alam Bridge Sector:

Barumdoir Nullah Bridge

1. PROPOSED BR DECK LEVEL	:	4,722.00 Feet.
2. PROPOSED BR SPAN	:	50 Feet
3. HIGH FLOOD LEVEL	:	4697.50 Feet.
4. TYPE AND CLASS OF EXISTING PWD BRIDGE	:	Wooden trussed beam class 3, bridge. Span 45 feet. Abutments merely skin wall 6 feet high in 1:6 cement mortar.
5. HYDROLOGY	:	The flow in the nullah is seasonal which is maximum during the melting period and dries up in winter.
6. SITE CONDITIONS	:	Bedrock not exposed. Alluvial silt, boulder and gravel are encountered. Nullah has cut deeply into the formation and formed a narrow gorge with steep sides. The foundation material is loose with little cementation and is liable to extensive amount of erosion and undercutting at the base during the floods. Since no alternative sites available the present site is to be considered. Foundation should be taken deep for the abutments and strong anchoring structure to be made (Fig. 20).

Gilgit - Skardu Road

BARUMDOIR NULLAH BRIDGE

Map sheet No. 43/I Gilgit
Grid Ref: NB - 686172
SVY STAS 80 to 81
Hor. Scale: 1 Inch = 25 Ft.
Contour interval 5 Ft.

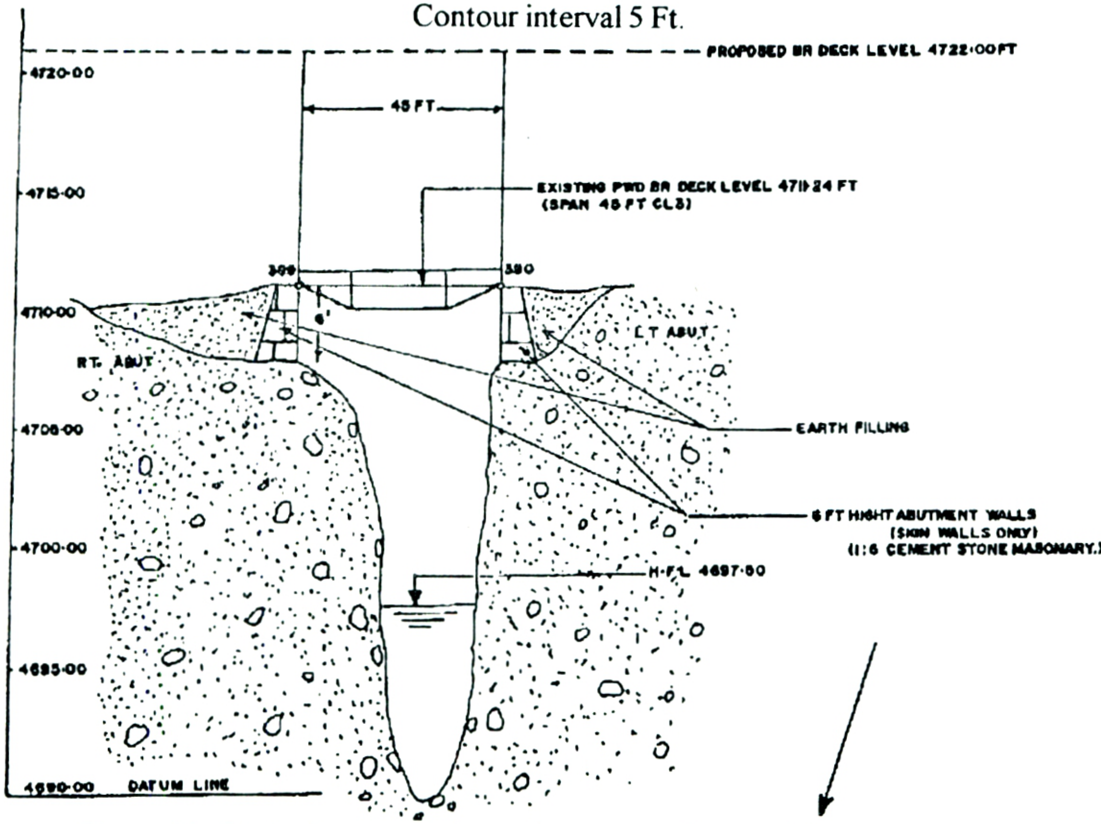

Figure 20. Geologic cross section at the proposed Barumdoir Nullah bridge.

Ishakpal Nullah Bridge

1. PROPOSED BR DECK LEVEL	:	4,516.00 Feet.
2. PROPOSED BR SPAN	:	50 Feet
3. HIGH FLOOD LEVEL	:	4,500 Feet.
4. HYDROLOGY	:	Nullah has a perennial flow. Maximum flow during the melting period. Slope of bed 1:8.
5. SITE CONDITIONS	:	Bedrock not available RBG embedded in a silt sandy matrix is encountered. Formation partly compact and cemented. The rocky exposure at the base is likely to be a big erratic boulder. As bedrock is not available, foundation may be placed in RBG. But in view of high velocity of water due to a waterfall about 500 feet upstream, of the bridge site and floods during the melting period, the rate of scouring and undercutting is expected to be high. Therefore, proper protective measures to be adopted at the foot and upstream of the bridge (Fig. 21).

Gilgit - Skardu Road

ISHAKPAL NULLAH BRIDGE

Map sheet No. 43/I Gilgit
Grid Ref: 661218
SVY STAS 321 to 325
Hor. Scale: 1 Inch = 25 Ft.
Contour interval 5 Ft.

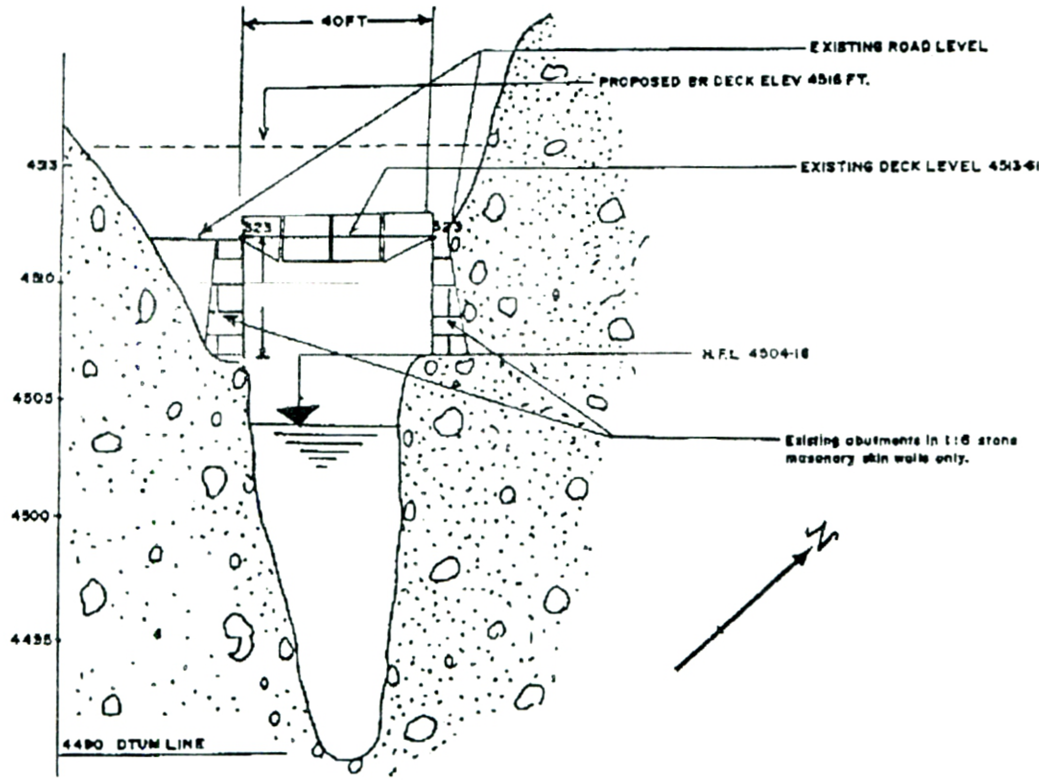

Figure 21. Geologic cross section at the proposed Ishakpal Nullah bridge.

Dache Nullah Bridge

1. PROPOSED SPAN	:	40 Feet
2. PROPOSED BR DECK ELEVATION	:	4,416.00 Feet
3. HIGH FLOOD LEVEL:	:	4,360 Feet.
4. HYDROLOGY	:	Perennially flowing nullah, slope steep 1:6.
5. SITE CONDITIONS	:	Hard rock is available at the bridge site. Rock is jointed and foliated. The foliation is along the nullah and dips steeply. Two sets of joints have developed and the 3rd is obscured. One joint follows the foliation and dips 67 to 72 degrees. The 2nd joint dips 45° SW. Some joints dip valley side but not adversely. Joints are close and cemented. Rock is hard and sound and is suitable for launching a permanent bridge. However, approach to the bridge from both ends is not straight and the gradient of the road on both sides is steep and dangerous. Rock cut from both ends will be required for easy approach and the gradient will have to be eased. The site cannot be shifted on either side of the present bridge.

Gilgit - Skardu Road

DACHE NULLAH BRIDGE

Map sheet No. 43/I Gilgit

Grid Ref: 656278

SVY STAS 233 to 235

Hor. Scale: 1 Inch = 25 Ft.

Contour interva 15 Ft.

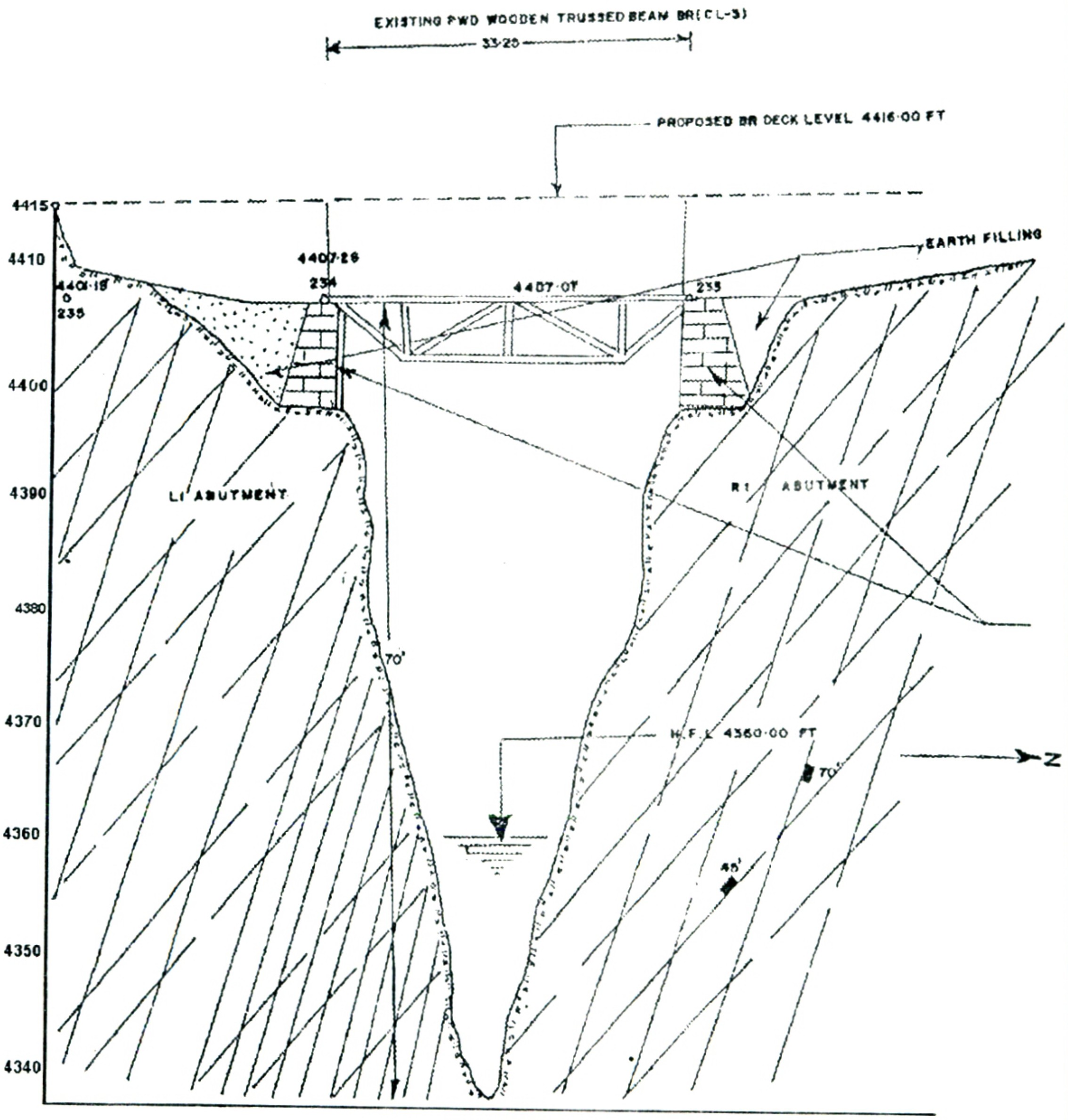

Figure 22. Geologic cross section at the proposed Dache Nullah bridge.

Khaltaro Nullah Bridge

1. PROPOSED SPAN	:	60 Feet.
2. PROPOSED DECK ELEVATION	:	4,400.00 Feet
3. HIGH FLOOD LEVEL	:	4,384.00 Feet.
4. TYPE AND CLASS OF EXISTING PWD BRIDGE	:	Wooden trussed class - 3 bridge. Present Span 44 ft. Formation exposed is RBG with silt and sand.
5. HYDROLOGY	:	Nullah has a perennial flow which is maximum during the melting period. Slope of bed 1 in 10 and is underlain by big glacial boulders.
6. SITE CONDITIONS	:	Bedrock not available. Alluvial silt and boulders encountered at the abutment site. Left abutment of the present PWD bridge rests on a big boulder. Right abutment on alluvial soil. As the present site is to be utilized for the permanent bridge, therefore, isolated boulders for foundation should be avoided, wash material to be removed and foundation placed on " in Situ" Rounded, Boulder Gravel Formation (RBG fm) at least 12 to 15 feet deep. The deck level may be raised by at least 5 ft. to protect against High Flood Level (HFL). Protective works at the base and upstream may be carried out (Fig. 23).

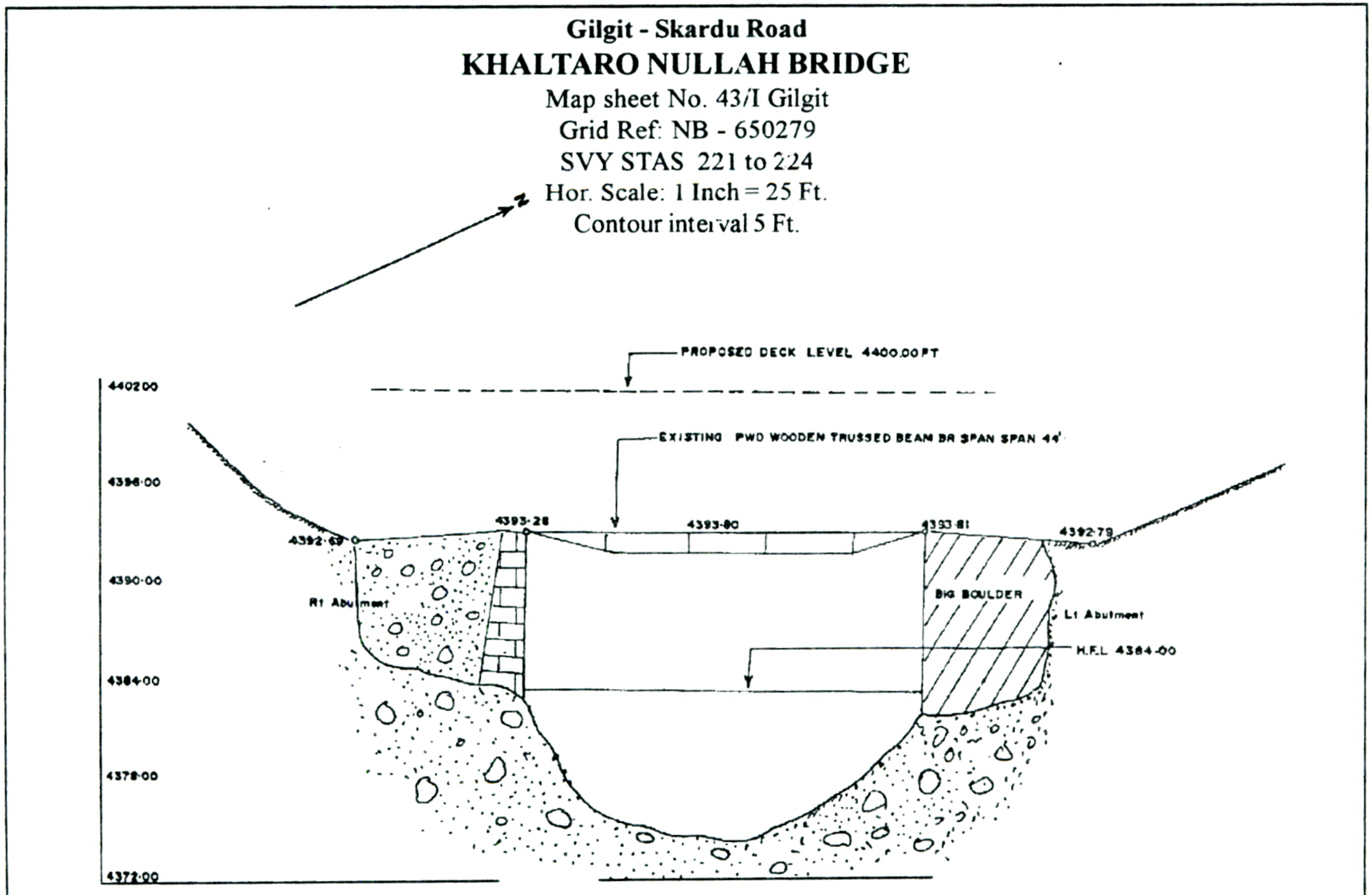

Figure 23. Geologic cross section at the proposed Khaltaro Nullah bridge.

Hanuchal Nullah Bridge

1. PROPOSED SPAN	:	50 Feet
2. PROPOSED BR DECK LEVEL	:	4,392 .00 Feet
3. HIGH FLOOD LEVEL	:	4,385.00 Feet.
4. HYDROLOGY	:	The nullah does not have a perennial flow. It is flooded during the melting period at higher altitude.
5. SITE CONDITIONS	:	The material encountered along the nullah cuttings at the proposed site consists of big boulders embedded in a silt sandy matrix. Presence of bedrock (BR) has not been confirmed. It requires some drilling. Excavation manually is not possible due to the presence of big boulders. The rock exposed at the nullah bed at the upstream of the present bridge may be a big erratic boulder. The bedrock if encountered at the proposed site, it will be at least 20 feet deep from the present deck level and within the HFL. The foundation will not be secure at that level. The proposed deck level 4,392.00 is suitable. The bedrock, if encountered at lower level of the nullah sides will resist scouring of the abutments against floods. Existing PWD bridge is located upstream of the proposed site (Fig. 24).

Gilgit - Skardu Road

HANUCHAL NULLAH BRIDGE

Map sheet No. 43/I Gilgit

Grid Ref: NB - 618255

SVY STAS 174 to 176

Hor. Scale: 1 Inch =25 Ft.

Contour interval: 5 Ft.

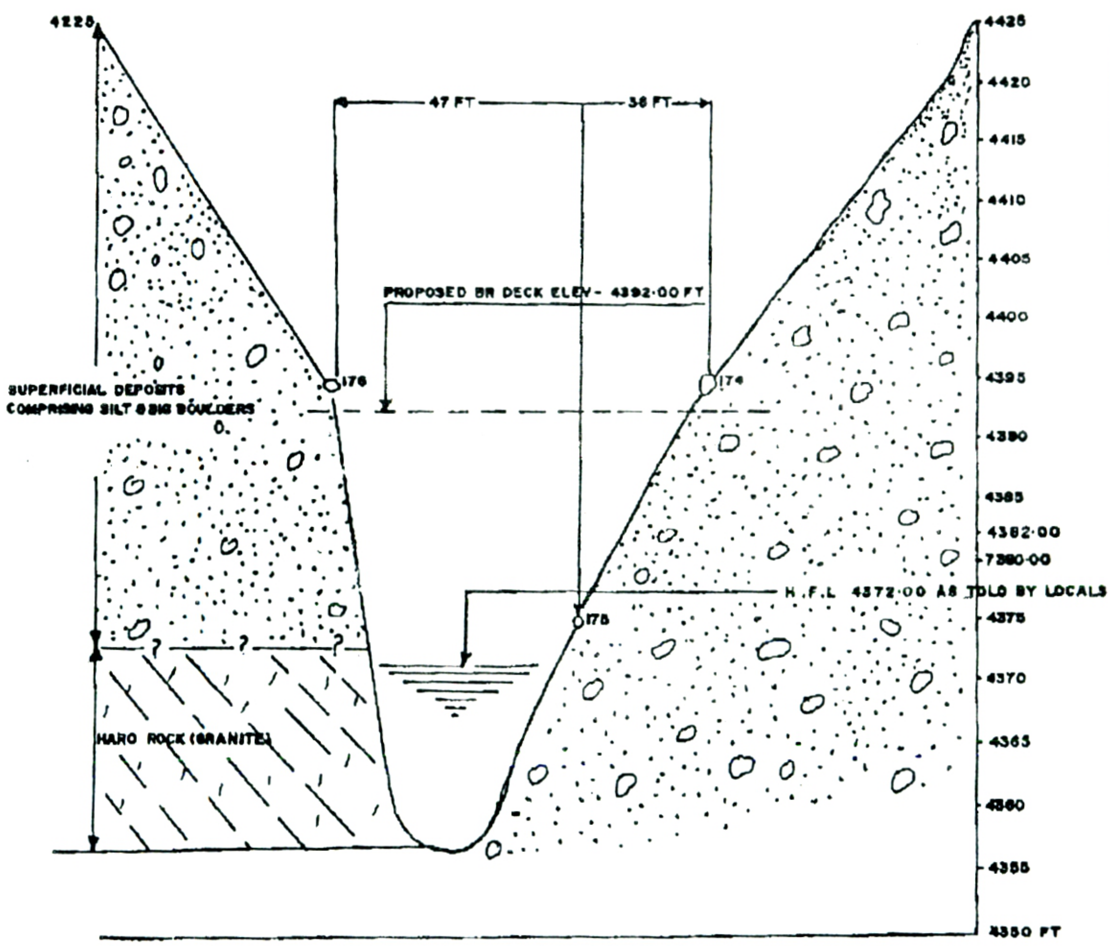

Figure 24. Geologic cross section at the proposed Hanuchal Nullah bridge.

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