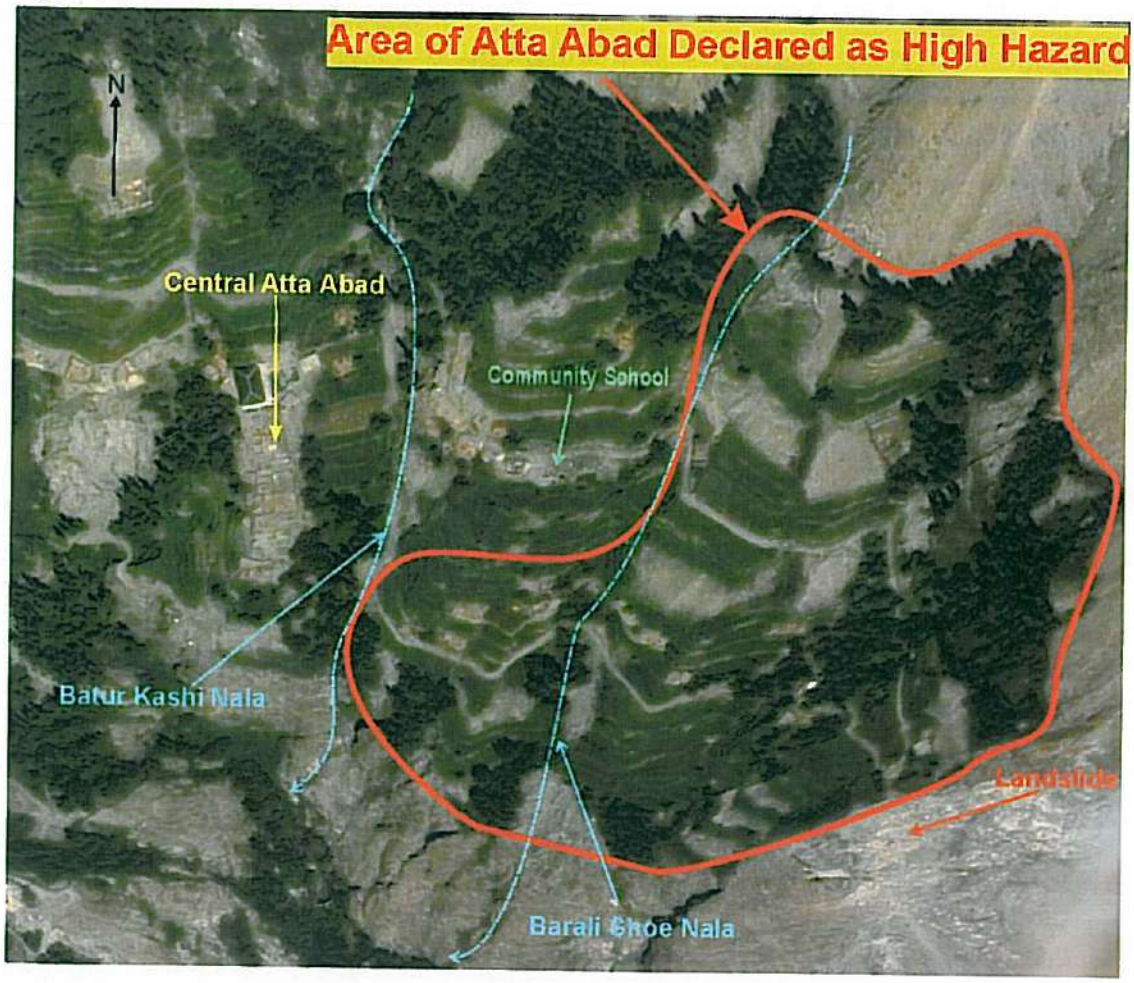
GOVERNMENT OF PAKISTAN
MINISTRY OF PETROLEUM & NATURAL RESOURCES
GEOLOGICAL SURVEY OF PAKISTAN

REPORT FOR NATIONAL DISASTER MANAGEMENT AUTHORITY

ON

CAUSATIVE MECHANISMS OF TERRAIN MOVEMENT IN HUNZA VALLEY



by
S. HAMID HUSSAIN
ADNAN ALAM AWAN
ENVIRONMENTAL AND ENGINEERING GEOLOGY DIVISION

Issued by Dr. Imran Khan, Director General, Geological Survey of Pakistan
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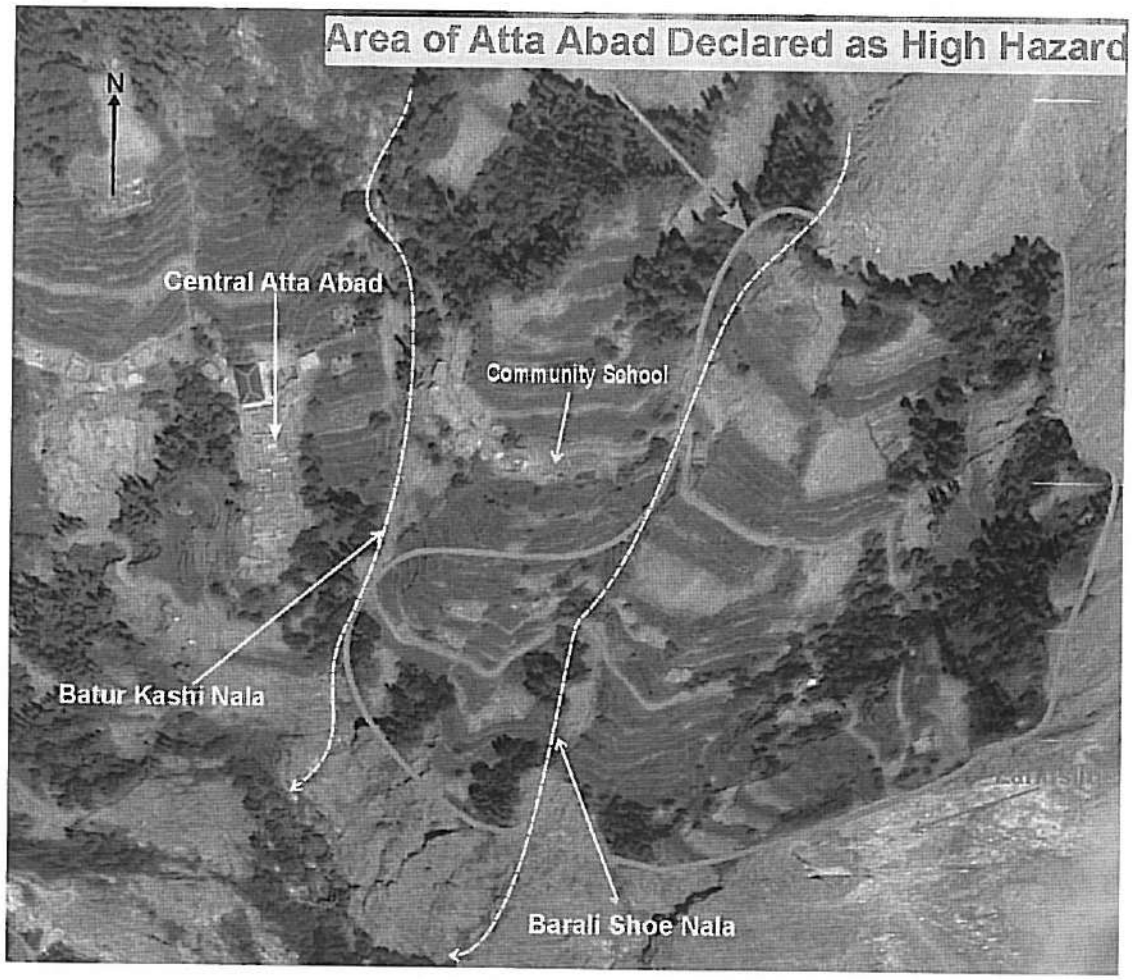

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1. INTRODUCTON

1.1 Purpose & Scope:

On the request of National Disaster Management Authority Islamabad, the study of Movement Terrain / ground causing cracks in the houses pitched on the mountain slope in the village Atta Abad, Hunza valley, District Gilgit was carried out from 9th August to 15th August 2009 by GSP personnel. According to Atta Abad community & local people, cracks appeared in houses of Atta Abad village at the crown for the first time in 2002 when Astore earthquake waves hit Atta Abad village. Crown of slope is almost 1000 feet above the settlement. The movement in the upper overburden slope started in 2003 and with the passage of time, these cracks began to widen which caused large scale slumping in the area. This slide badly affected 24 families and 66 family's agricultural land. Kashmir earthquake of 2005 expedited the movement and cracks destroyed some houses and damaged several residences.

The Geological Survey of Pakistan was requested to investigate the causes for development of these cracks and to suggest some remedial measures for the control and minimization of the slide effects.

1.2 Methods of investigation:

The investigation included preparation of generalized location map, marking of High hazard areas and inventory of major cracks. Emphasis is given to the causes of slope failure, type of material involved in the sliding and recommendation for the safety of the people and their agricultural land at Atta Abad village.

1.3 Location and Accessibility

Atta Abad village is situated in the extremes north of Pakistan. It is located at a distance of the 760 km from Islamabad, 130 km from Gilgit, 30 kms (North East) of Aliabad and 5.5 km from Karakarum Highway (KKH) near Sarat on steep valley slopes in Hunza valley. All weather metaled road passes through the

Hunza valley connecting Islamabad with Gilgit and further to Khunjrab pass. Crossing Hunza river by suspension bridge near Sarat from KKH very narrow, steep, rough and unmetaled road leads to Atta Abad village.

It lies in Survey of Pakistan topographic sheet No. 42 L/15 between coordinates.

Upper Left	36°19'08.50" N 74°47'58.14" E	Lower Right	36° 18'35.36" N 74° 49'02.45" E

1.4 Topography, Geomorphology & Climate

The Karakorum Range of Himalyas passes through the Hunza valley in NW-SE direction. High snow bound mountains with steep cliffs and narrow valleys are topographic characteristics.

The difference between valleys and peaks ranges from 2200 m to 2700 m. Hunza and Hispar rivers control the drainage of the area. The world's 11th highest peak Rakaposhi (7788 m) lies to the south of investigated area. Pasu Glacier is in the North of the said area.

The Hunza valleys have most contrasting relief than any other place in the world which cuts the Karakorum mountains and has comparably great vertical height difference over a short horizontal distance. Hunza valley rises from 1850 m to the peak of Rakaposhi at 7788 m, a vertical distance of over 11 km. The highest areas of the valley have pyramidal peaks, sharp ridges and without plateau features. Mass movement activity is great due to slope failure weathered by frost action in the area. The slope morphology of Hunza valley is of several types. Snow covered high peaks are common alongwith rock slopes. scree slopes, mud flows are present throughout Hunza valley. The morains have irregular topography.

Hunza and investigated areas are very cold with extreme climate during winter. But spring & summer are quite pleasant. The area usually receives two to three feet of snow in winter. January is coldest month of the winter. March &

April are the dangerous months due to melting of snow causing mud flow & rock falls. Rain is very scanty.

Although important fruits of Hunza valleys are apricots, walnets, almonds, apples, peaches, peares and grapes but people of Atta Abad village rely on apricot and patoto as major cash crop.

1.5 Acknowledgement

The authors gratefully acknowledge the active participation and guidance provided by Dr. Imran Khan, Director General, Geological Survey of Paksitan, during writing of this report. We are also thankful to Director Incharge, Geological Survey of Pakistan, Islamabad for his cooperation to make arrangements on emergency basis for the field work.

We are thankful to the Administration of District Gilgit, specially to Mr. Assad Zamin, Additional Deputy Commissioner, Gilgit, Mr. Zameer Abbas, Assistant Commissioner, Hunza and Mr. Tikka Khan, Secretary, Ismaili Regional Council, Hunza for their cooperation and hospitality during our stay at Hunza.

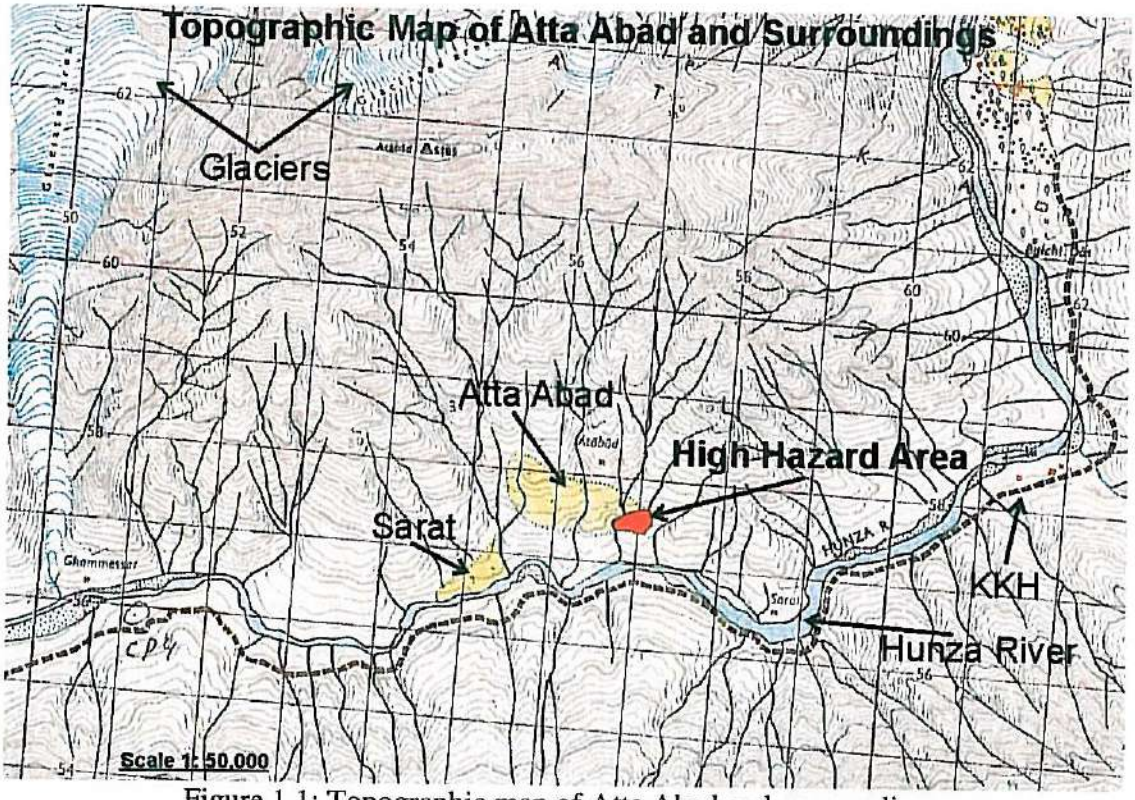

Figure 1.1: Topographic map of Atta Abad and surroundings

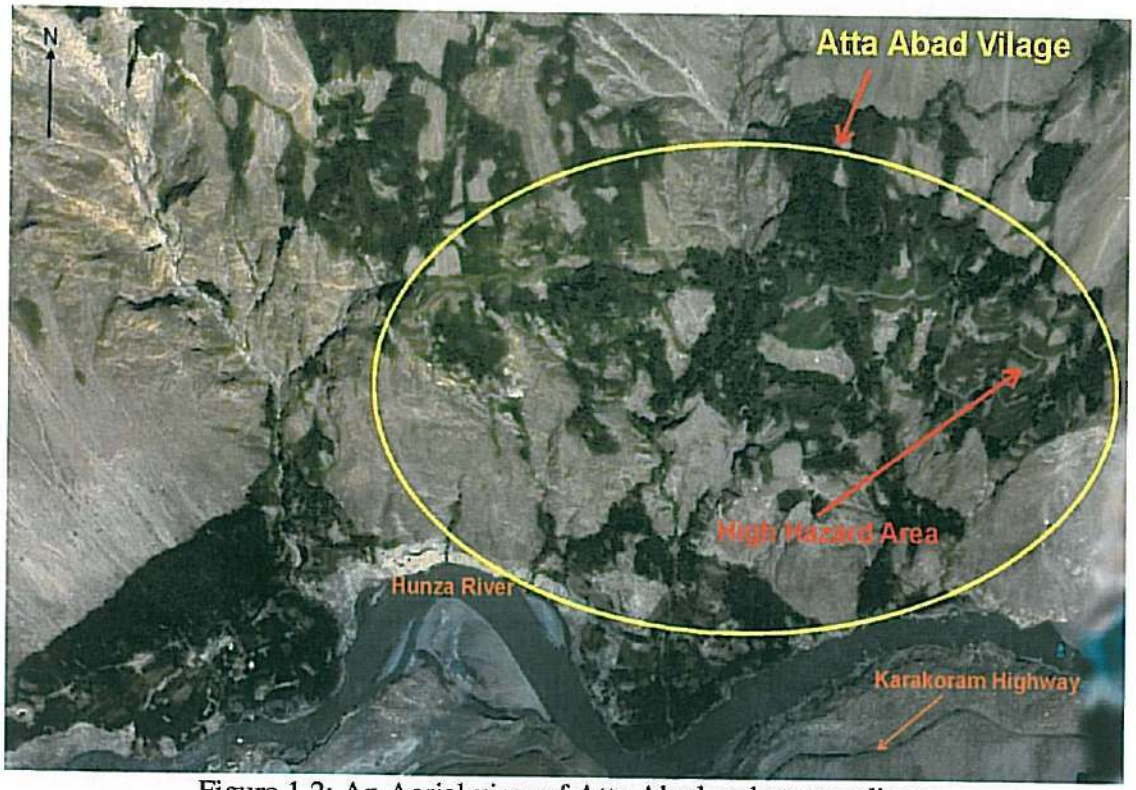

Figure 1.2: An Aerial view of Atta Abad and surroundings

2. GEOLOGY AND TECTONICS OF HUNZA VALLEY AND SURROUNDINGS

2.1 General Geology and Tectonics of the area

The Northern areas are one of the most complex and difficult terrain in the world exhibiting a great variety of rock types and structures. The exposed rocks range in age from pre-Cambrian to Recent and comprise igneous and metamorphic rocks of various types.

The rock units recognized in the Hunza valley with probable ages are as follows:

Table 1: Major Rock Units Recognized in the Hunza valley

S. No.	Group	Period	Lithology
1.	Baltit Group	Pre-cambrian-lower Paleozoic.	Gneisses, Schists, quartzite, marble and dolomitic limestone.
2.	Chalt ophiolitic mélange zone	Late cretaceous to early tertiary	Quartz-biotite schist, staurolite schist, garnet mica schist, phyllite, slate, quartzite, marble, dolomitic limestone and cherty conglomerate.
3.	Karakoram Granodiorite	Pliocene	Granodiorite
4.	Glacial Morains, Terraces, River deposits	Quaternary	Morains, Terrace deposits and stream gravel.

On the basis of regional tectonic set up, the Main Karakorum Thrust (MKT) and Main Mantle Thrust (MMT) are the major tectonic features of the northern area and these Megashears may effect the investigated area in future.

Main Karakorum Thrust

Main Karakorum Thrust or northern megashear represents the collision zone of southern margin of Eurasian plate in Asia and marks northern limit of Kohistan arc. It extends to Baltistan through Hashupa to Shigar and Shyok valleys respectively. The general trend of MKT is E and ENE shows medium to high dip

towards the N and NNW. It is high angle, seismically active thrust containing large number of epicenter of low to medium intensity.

Main Mantle Thrust

The Main Mantle Thrust or the southern megashear represents a boundary between Kohistan Island Arc and Pak-Indian plate. It spans an area about 400 sq. km through Diamir, Kohistan, Swat and is exposed on the road bend just before Jijal village. MMT has been folded on the north-south axis anticlinorium with north plunging axis.

2.2 Geology of the area

Atta Abad village is located on valley slope of Glacio-Fluvial deposits underlain by Gneissic rocks (orthogniesses & Para-gniesses of Baltit Group).

Baltit group consists of gneisses, schists, quartzite, dolomite limestone and marble. The lime silicate marble is present throughout from Sarat village to Hassanabad nala on the northern side of Hunza river. Its presence in the southern side of Hunza river has not been confirmed. The rocks in southern side of Hunza river are less metamorphosed and mostly consist of schists with quartzite.

Glacio Fluvial Deposits

Glacio fluvial deposits consist of boulders, cobbles and gravels with some silt and sand as cementing material. The rocks exposed at crown and toe or highly fractured, sheared, jointed and weathered.

A fault on the eastern side of the village is passing through Hunza river trending almost North-South.

3. GEOTECHNICAL STUDY OF ATTA ABAD

3.1 Background Analysis:

Atta Abad village has been assessed as among very complex slope instability conditions due to denudation processes, effect of seismic activity, high slope angle, river cutting, lithological conditions, snow melt, rains and water used for agriculture, heavy overburden on bed rock in the form of glaciofluvial deposits. Atta Abad has been divided into Eastern, Central and Western parts and large area of eastern part of the village has been declared as High Hazard area (Fig 4.7).

Astore earthquake of 2002 has been recorded as one of the major triggering factor, and cracks appeared at the backslopes of Atta Abad, the second major displacement was observed in 2004, when these cracks extended longitudinally and transverse into the cultivated fields and populated areas of Atta Abad and small landslide and surface failure features appeared at the toe of affected area. The 2005 Kashmir 7.6 magnitude earthquake accelerated the slope failure and network of cracks destroyed several cattle houses and damaged several residences.

3.2 Present Situation:

The eastern part of Atta Abad is creeping continuously and enlargement of cracks, edge failures, lateral and vertical displacement of terraces are the potential indicators of slope failures. Recently edge failures at the lower end destroyed popular and fruit trees. 12 houses are partially damaged due to cracks, 5 cattle houses are completely destroyed and no loss of human life and animal recorded. Some agriculture land has become completely uncultivated due to network of cracks and irregular shape of the ground surface.

3.3 Critical Geotechnical Analysis:

Slope failure in eastern Atta Abad has been induced by the effect of ground shaking caused by the earthquakes and other major triggering factors include;

1. Unconsolidated overburden on the bed rock in the form of glaciofluvail deposits ranging in thicknes from 3 to 12 meters. These deposits form the terraces and backslopes of affected area. Clay and silt constitute major proportions of the overburden at backslope and terraces.
2. A fault is passing through the affected area having a strike NS and crossing the river. A huge landslide has developed across the river and timing of slope failure at Atta Abad and landslide across the river is quite same. This landslide is associated with the fault. The movement along this fault has weakened the shearing strength of the rocks and decreased the angle of repose in the area.
3. High slope angle is a major triggering factor for eastern Atta Abad (Fig 3.1). Slope angle at terraces is ranging from 30° to 40°, at backslopes from 35° to 55° and toe of terraces is near to vertical.
4. The bedrock is highly fractured, sheared and jointed due to the tectonic activity in the area. Blocks of rocks have started to slide down in the form of wedge failures, rockfalls and at some places toppling. This mass movement has weakened the base and results in widening and vertical settlements of cracks and expanding the landslide phenomena in the areas.
5. Hydrological conditions of the affected area are further accelerating the slope failures, water from three sources are infiltrating into the cracks and fissures, i.e. rain water, snow melt and huge volumes of water being used for agricultural

purposes. At many places water is directly infiltrating into the cracks and fissures and decreasing the mechanical behavior of the failure planes, accelerating the underground movement that appears as surface failures.

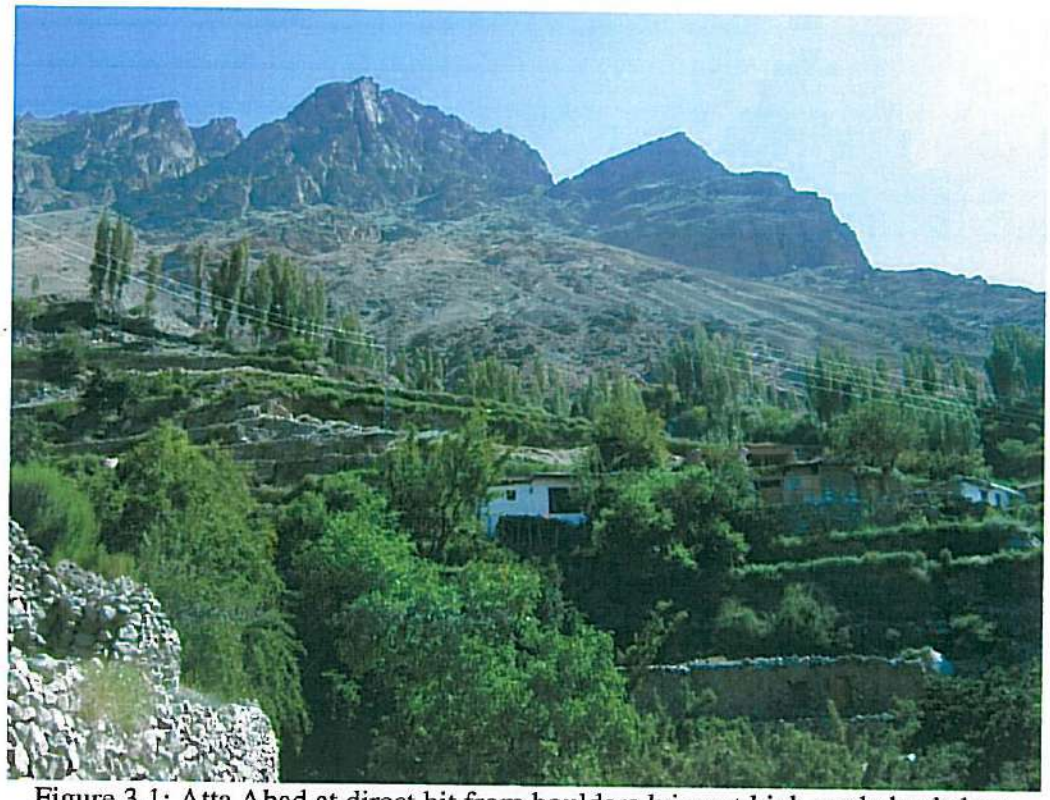

Figure 3.1: Atta Abad at direct hit from boulders lying at high angle backslope

3.4 Network of Cracks:

The network of cracks and fissures present in the area are the potential source of any future calamity and may result into loss of life and property. Three major networks of cracks (Fig 4.1) have been identified on the backslopes and one pattern of cracks has been observed at the terraces (Fig 3.4).

Crack No.01 is generating from the eastern most part of terraces and extending into the backslopes into further three branches and forming a complete slip surface. Crack No.02 is present at the middle of eastern most part of the backslopes. Crack No.03 is a semicircular crack initiating from the left margins of the backslopes, moving into upper portions of backslopes with major multidirectional displacements and finally extending downslope into the Barali

Shoe Nala and into the terraces. Movement along this crack has been observed continuously. Crack No.04 is present in the terraces and affecting the houses and cultivated areas, it is directly affecting the population of Atta Abad. There are numerous other cracks present in the area that are either small individual cracks or has some connection with the major cracks. The movement along these cracks has been recorded continuously and results into soil collapse, edge failures and settlements of terraces, particularly in the snow melt and rainy seasons (March-April).

Table 2: Inventory of Major Cracks in the affected area

	Location	Coordinates	Strike of Crack	Vertical Settlement / Depth(ft)	Horizonatl Settlement (ft)	State of Activity
Crack No.01	**lower part**	36.31337 N 74.81796 E	N70E	Nil	3.6	Active
	middle part	36.31349 N 74.81857 E	N75E	10	16	
	upper part	36.31368 N 74.81989 E	EW	5	10	
	top/end part	36.31432 N 74.82018 E	N30E	6	5	
Crack No.02	**middle part**	36.31406 N 74.82198 E	EW	8	2	Active
Crack No.03	**left margins**	36. 31502 N 74.82468 E	N50W	5	6	Very Active
	crown of crack	36.31760 N 74.82327 E	N60W	16	15	
	lower part	36.31528 N 74.81668 E	N60E	3	4	
Crack No.04	**At Terraces**	36.31475 N 74.81785 E	EW	4	3	Very Active

Figure 3.2: Huge boulders loosely lying on the baskslope

Figure 3.3: Crack widening at the left margin of upper slope

Figure 3.4: Slope failure at terraces have damaged the house

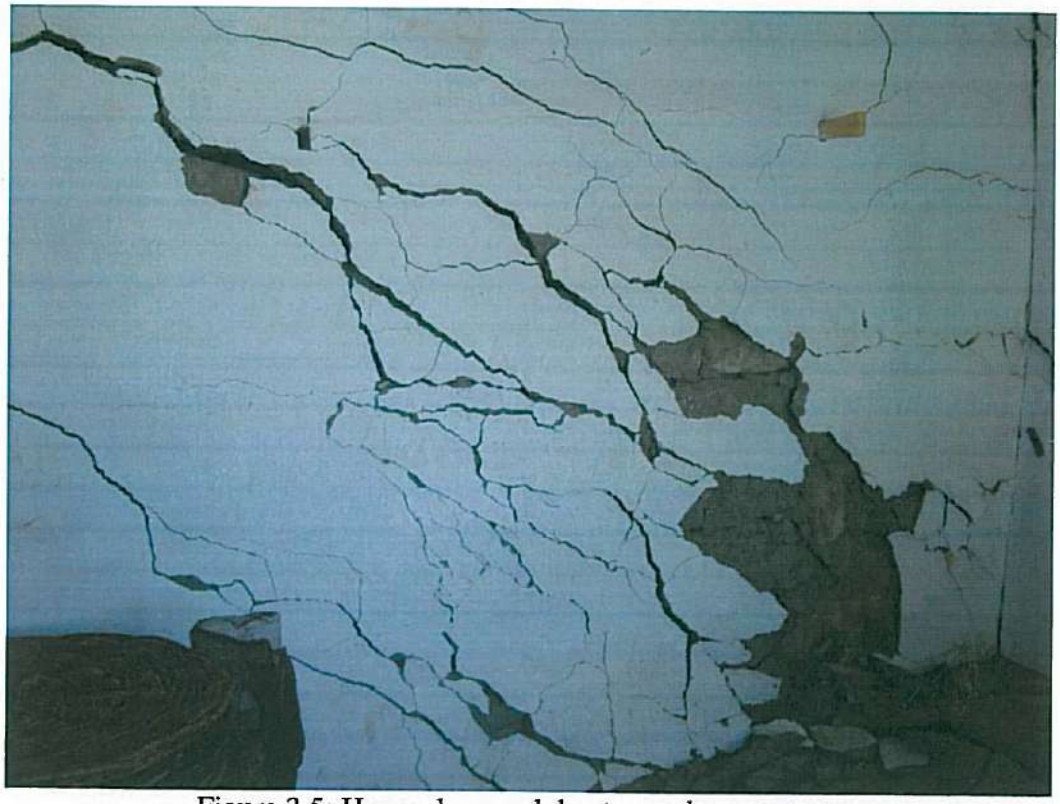

Figure 3.5: House damaged due to cracks on terraces

Figure 3.6: Very wide cracks posing a potential risk for Atta Abad village

Figure 3.7: Highly sheared and fractured bedrock forming the toe of Atta Abad

4. CONCLUSIONS & RECOMMENDATIONS

4.1 Conclusions:

Based on the detailed Geological and Geotechnical survey carried out in the area, information collected from locals and authorities, the major portion of eastern part of **Atta Abad is declared as High Hazard**. The High Hazard area starts from the eastern most margins of Atta Abad and this area is locally known as part of Ghumrat. It is bounded by the half length (at coordinates 36 18 53.50 N & 74 48 55.30 E) of Barali Shoe Nala crossing the terraces. The line of High Hazard is extended parallel of the terraces to the Batur Kashi Nala and follows the Nala downslope. (Note: Boundaries of the High Hazard area demonstrated within the red line in Fig No.4.7).

The area is at threat from multi directions. On one side huge boulders of room size (12x16x22 ft) are lying loosely at the backslops (Fig 4.1) and most of them have moved from their original location because of the slope condition, any movement in the slope or an earthquake of magnitude of 4.5 or greater on Ritcher Scale may roll down the boulders and hit the population. The toe of terraces is creeping and displacements of terraces are the result of this weak toe because the rocks are highly sheared, fractured and jointed (Fig 3.7). This part has a potential to slide down in the form of a rock avalanche and block the river. During investigation geological evidence of same kind of threatened river blockage has been identified at 1.2 km downstream at village Sarat (Fig 4.6).A landslide is present at the eastern margins of the area and material is falling into the river and it is further enhancing the triggering factors in the area (Fig 4.3).

4.2 Recommendations:

The following recommendations are proposed for Atta Abad village;

1. The High Hazard area should be evacuated from the population immediately and the affected families should be compensated in the forms of alternate lands/others.
2. The boulders loosely lying on the backslope (Fig 3.2) should be safely brought down using the techniques of control blasting.
3. Poor drainage in the terraces should be managed into proper drainage and water should be diverted from infiltrating into cracks and loose overburden.
4. It is not possible to fill all the cracks present in the area but nevertheless an effort should be made to fill and seal some cracks using the plastic sheets, starting from the terraces and moving upward into the backslopes. It will help to decrease the slope failure to some extent in the areas where the slip circle is not deep.
5. The slope conditions in the High Hazard area and surroundings should be monitored in the snow melt or rainy seasons (March-April).

5. REFERENCES

1. A report on Atta Abad crisis, 2009, "A situational study, Immediate & Long-term potential Solution" by Committee for Atta Abad Crisis, Atta Abad Community.
2. Site visit report, 2007, "Reconnaissance of Atta Abad village Landslide, Hunza valley, Northern areas" by Focus Humanitarian Assistance.

Figure 4.1: Semicircular crack with large displacements at backslope

Figure 4.2: Boulder hanging dangerously on the widened crack at eastern margins

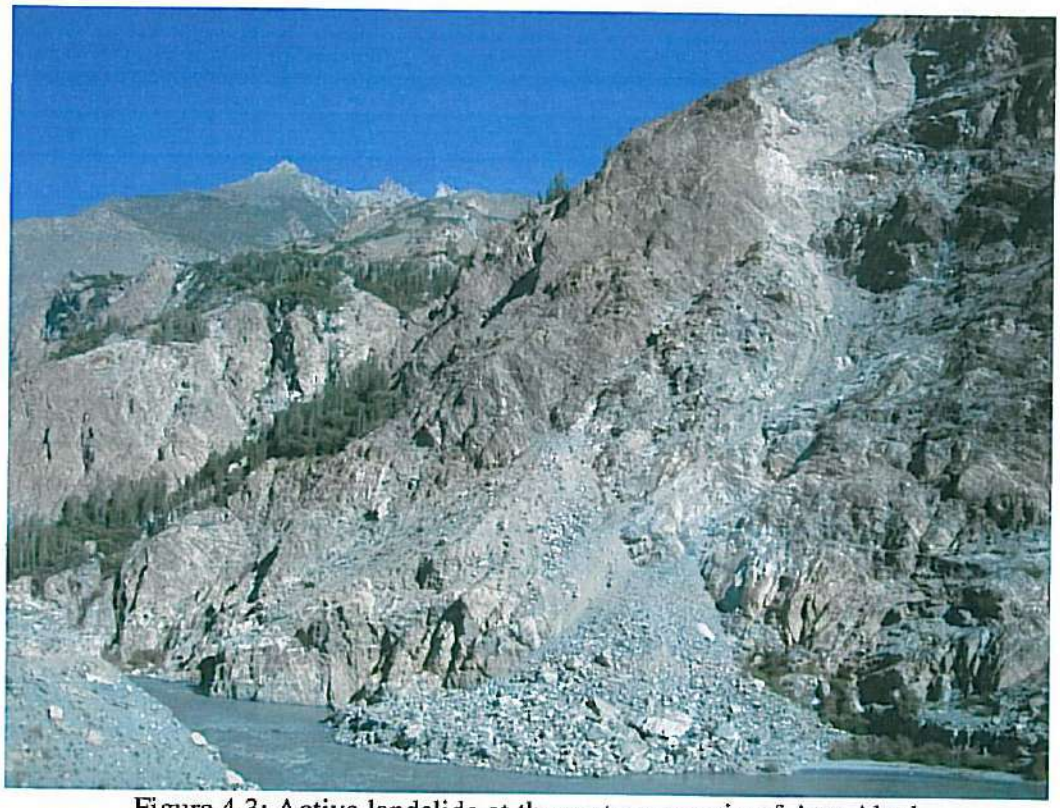

Figure 4.3: Active landslide at the eastern margin of Atta Abad

Figure 4.4: View of terraces, backslope and toe of Atta Abad village

Figure 4.5: Active landslide across Hunza River, Atta Abad

Figure 4.6: Lacustrine deposits near Atta Abad at village Sarat

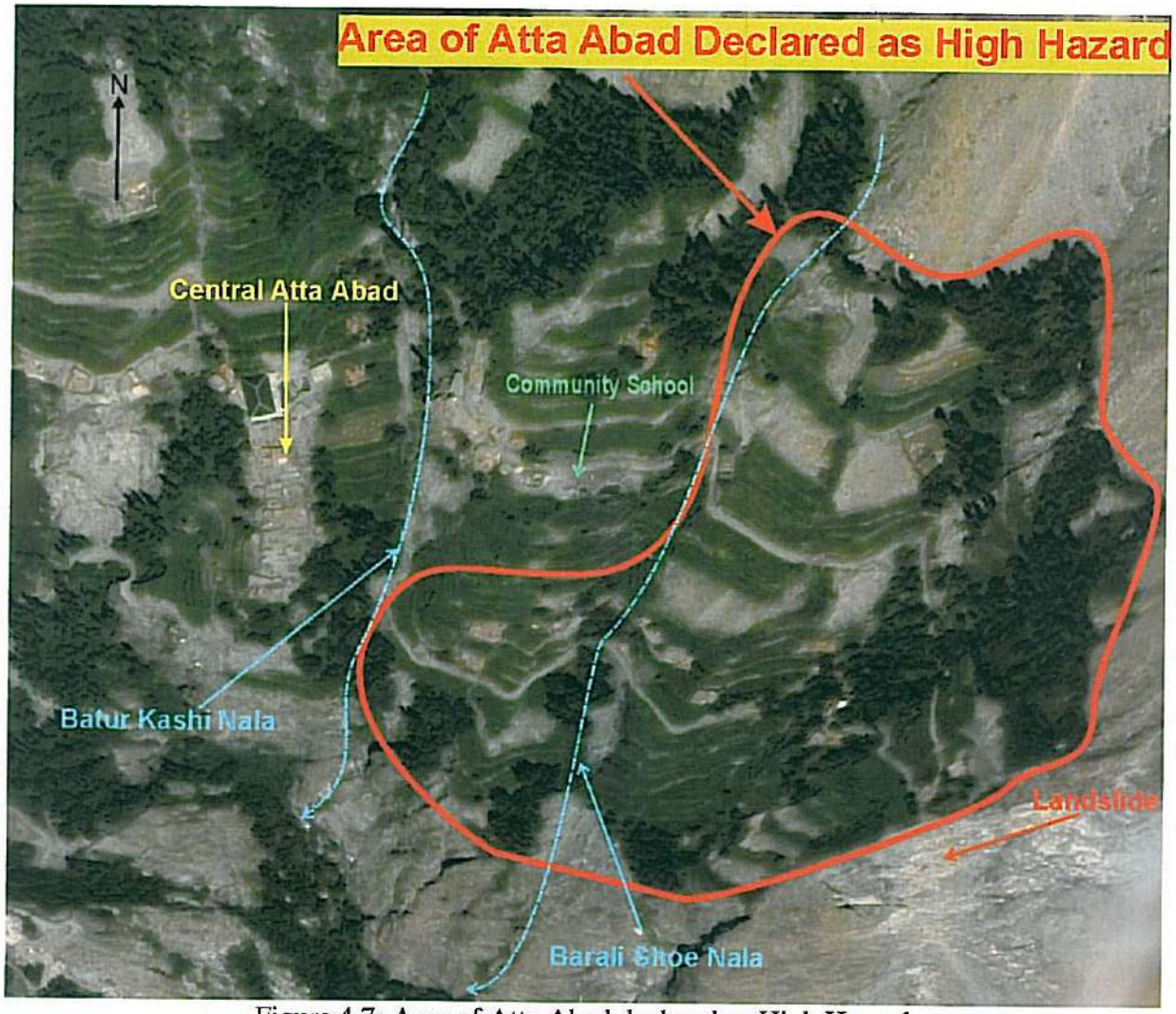

Figure 4.7: Area of Atta Abad declared as High Hazard