Case History

Attabad Landslide- Dam Disaster in Pakistan 2010

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ABSTRACT
On January 4, 2010, in the remote Hunza Valley of Northern Pakistan a massive landslide buried the village of Attabad, destroyed 26 houses and killed 20 people. The landslide dammed Hunza River and formed an extensive lake of 100m depth. Until the end of July 2010, 381 houses were ruined; out of which 141 were directly affected by Attabad landslide, others were submerged due to expansion of the lake. By the end of May 2010 local authorities excavated a spillway to guide the flow of impounding lake over the natural dam. Until August, 2010, the spillway is performing well but internal response of the loosely deposited debris is unknown.

INTRODUCTION

Attabad village is situated in the extremes of Northern Pakistan. It is located at a distance of 760km from Islamabad, the capital of Pakistan.

Karakoram highway connects Islamabad to Gilgit and further passes through Hunza valley up to Khunjrab Pass. The Karakoram Range of Himalayas passes through the Hunza valley in NW-SE direction. High snow-covered mountains with steep cliffs and narrow valleys are topographic characteristics. The difference of elevation between the valleys and the peaks ranges from 2200 m to 2700 m. Hunza and Hispar Rivers control the drainage of the area. A very high mountain of Rakaposhi (7788m) lies to the South-West and the Pasu Glacier lies in North of Attabad landslide area. Hunza valley rises from 1850 m to the peak of Rakaposhi at 7788 m over a distance of 11 km which is the most contrasting relief in the world.

The highest areas of the valley have pyramidal peaks and sharp ridges without plateau features. Weathering due to frost action is the cause of slope failures and mass movements. High peaks covered with snow are common along with rock and scree slopes, and mud flows are present throughout Hunza valley. The moraines have irregular topography. Attabad area have extreme climate in winter in which temperature falls below 0°C; however, spring and summer are pleasant with an average temperature of 30°C. The area receives about 1 m of snow in winter; January is the coldest and snow melting causes mudflows and rock falls during summer.

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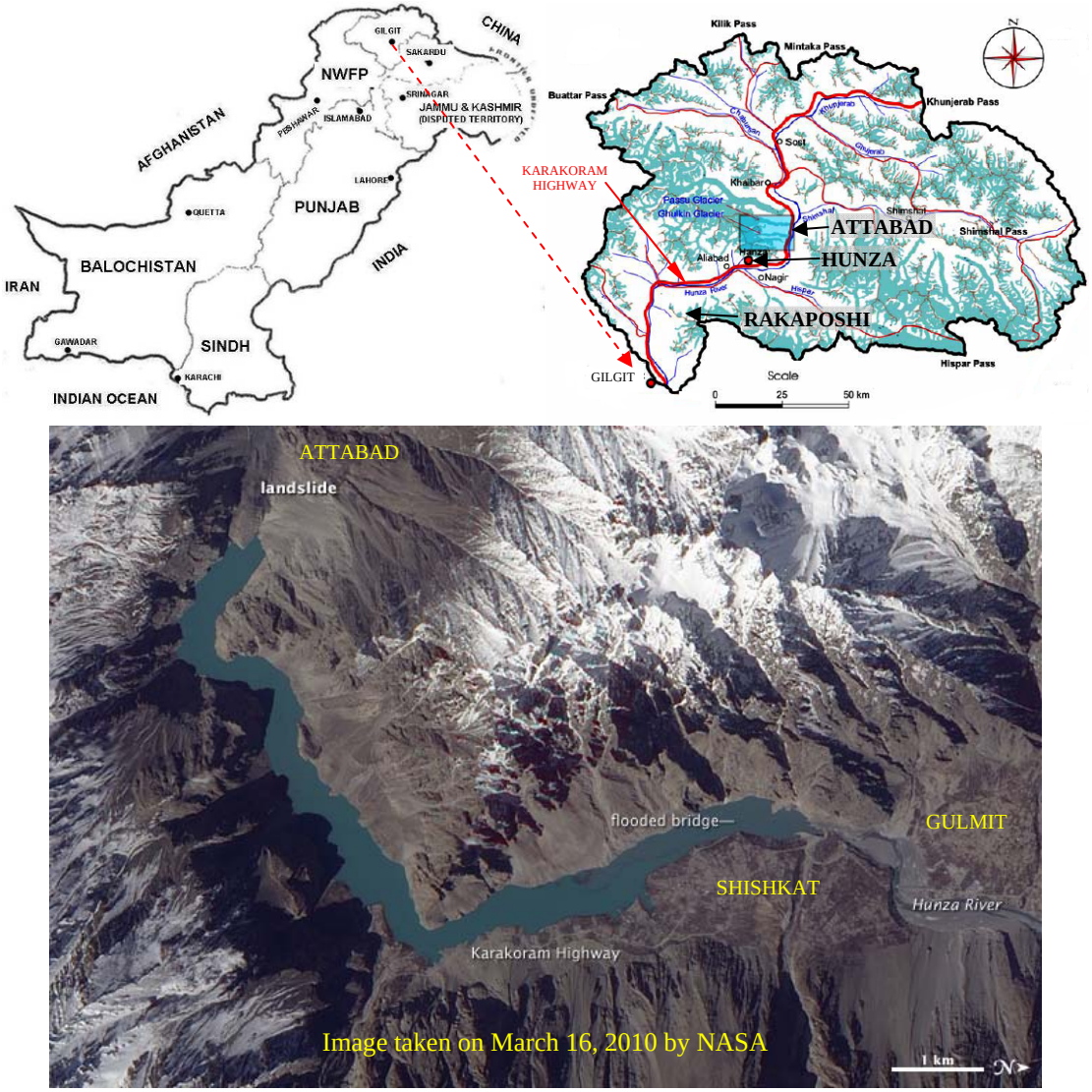

Figure 1 Location plan of Attabad landslide disaster

GEOLOGY & 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 are composed of igneous and metamorphic rocks of various types. On the basis of regional tectonic set up, the Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT) are the major tectonic features and these mega-shears may affect the Attabad area during any seismic activity

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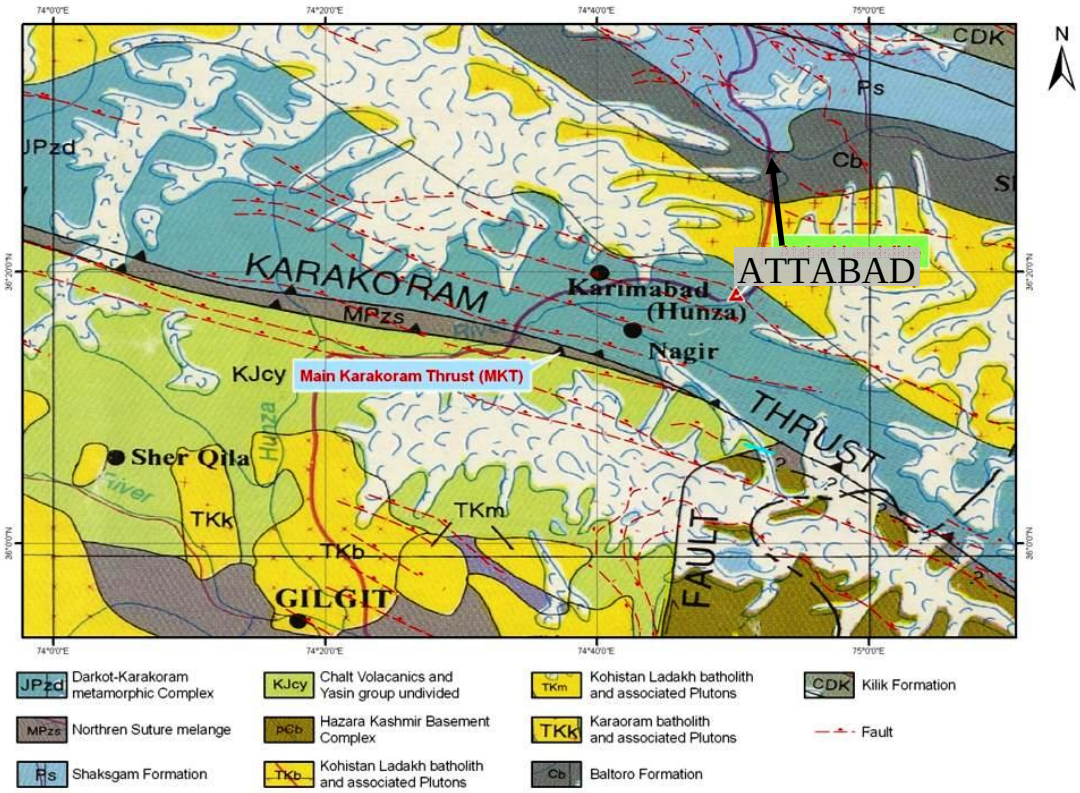

Figure 2 Geological map of Hunza valley and adjoining areas

The destroyed Attabad village was located on valley slope of glacio-fluvial deposits underlain by Gneissic rocks (orthogenesis and Para-gneisses of Baltit Group); Baltit group consists of gneisses, schist, quartzite, dolomite limestone and marble. Glacio fluvial deposits forming the site of Attabad village consist of boulders, cobbles and gravels with some silt and sand as cementing materials. The rocks exposed at crown and toe are highly fractured, sheared, jointed and weathered. A fault on the eastern side of the village is passing through Hunza River trending almost North-South.

PRE-DISASTER PERIOD

Attabad village has been affected by very complex slope instability conditions due to denudation process, effect of seismic activity, high slope angle, river cutting, lithological conditions, snow melt, rains and irrigation for agriculture, and heavy overburden on bed rock in the form of glacio-fluvial deposits. In 2002 Astore earthquake of magnitude 6.3 was recorded as one of the major triggering factor, and cracks appeared at the back-slopes of Attabad. The second major displacement was observed in 2004, when the cracks extended longitudinally and transverse into the cultivated fields and populated areas of Attabad and surface failure features appeared at the toe of the affected area. The 2005 Kashmir earthquake of magnitude 7.6 accelerated the slope movement and networks of cracks destroyed several houses.

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(a) Right bank (b) Left bank

Figure 3 Site of Attabad landslide in pre-disaster period (August 2009)

Geological survey of Pakistan conducted a hazard analysis of the area in August 2009 and reported their viewpoint as follows;

1. Unconsolidated overburden lies on the bed rock in the form of glacio-fluvial deposits ranging in thickness from 3 to 12m. These deposits form the terraces and back-slopes of the affected area. Clay and silt constitute major proportions of the overburden at the back-slope 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 (Fig. 3(b)). 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.
3. High slope angle is the major triggering factor of the eastern Attabad. A slope angle at terraces is ranging from 30° to 40°, at the back-slope from 35° to 55° and toe of terraces is nearly vertical (Fig.3 (a)).
4. The bed rock is highly fractured, sheared and jointed due to the tectonic activity in the area. Blocks of rocks started to slide down in the form of wedge failure, while rockfalls and toppling are observed at some places. The 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 infiltering into the cracks and fissures, i.e. rain, snow melt and irrigation. At many places water is directly infiltrating into the cracks and fissures and damaging the mechanical behavior of failure planes, accelerating the underground movement that appears as surface failures.

Based on those studies Attabad was declared as high hazard zone. Local authorities were suggested by Geological Survey of Pakistan to take necessary action for the evacuation of dwellings from vulnerable area. A suggestion was given to monitor the hazardous area during the winter and snow melt season.

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SALIENT FEATURES

On January 4, 2010 a huge mass failed, destroying the village of Attabad and damming the Hunza River. Fig.4 shows the secondary landslide taking place at the site. The blocked length of the river was about 2 kilometers with the width of 500m. The landslide itself blocked 1.3km of Karakoram Highway. Till the end of May 2010, the lake stretched to a length of 22km. The estimated potential storage of the lake, if it impounds up to the maximum height of the dam, is 305 million m^3.

Figure 4 Secondary landslide on January 22, 2010 at Attabad (image courtesy PAMIRTIMES)

The distribution of deposited debris is shown in Fig. 5. A longitudinal profile through the flow path of Hunza River is shown in Fig.6. Deposited mass is mainly composed of non-cohesive rock flour (fine dust, silt, silt gravels and cobbles) at the toe of the failed slope. Large boulders of granodioritic rocks with intrusions of granite, pegmatite and apatite were deposited close to the left bank of Hunza River. The deposit on the downstream side is composed of black clay with high plasticity and organic content.

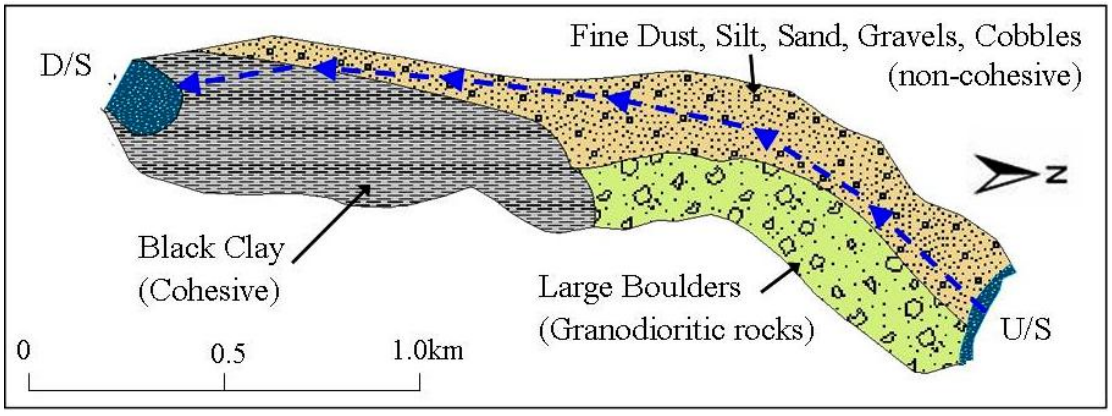

Figure 5 Distribution of debris material

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The longitudinal profile (Fig.6) indicates that the upstream shoulder of the natural dam has mild slope, however downstream slope is quite steep. With such length (2 km) of the dam there are rare chances of piping failure. Fig.7 shows drowned villages of Shishkat and Gulmit along with the stretches of Karakoram Highway.

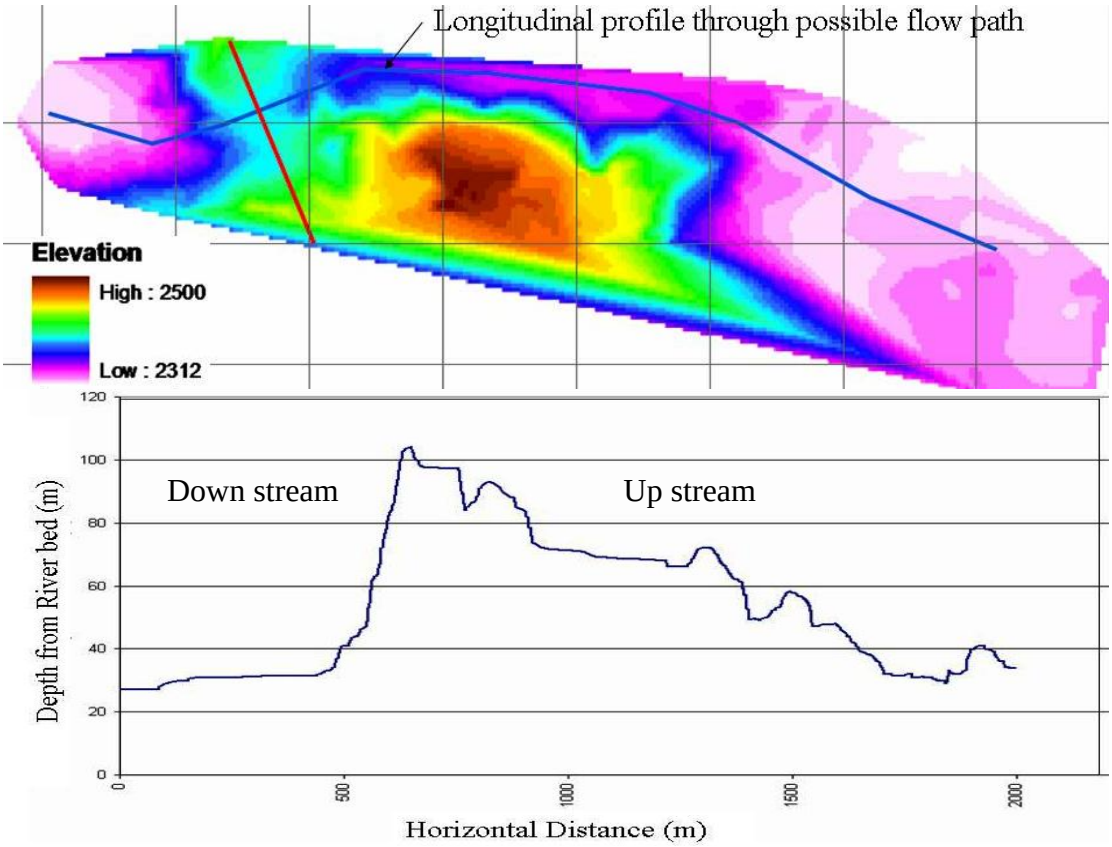

Figure 6 Topography and Longitudinal profile of failed deposited material

TIME HISTORY OF LAKE EXPANSION

NASA monitored the expansion of lake by taking satellite imageries as shown in Fig. 8. It was believed that the lake expansion has direct relation with the increase in temperature which is the cause of snowmelt and increased inflows. Timely evacuation of the inhabitants was carried out from the drowning villages of Shishkat and Gulmit.

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Figure 7 Drowning of villages due to expanding lake (image courtesy PAMIRTIMES)

CONTROLLED DRAINAGE FROM LAKE

A Dam breach study was conducted by NESPAK (National Consulting Firm). They reported the study in March 2010 to National Disaster Mitigation Authority (NDMA) and proposed the excavation of spillway as a safe way to drain the water. The recommended spillway was 24 m deep and 45 m wide. The excavation works for the spillway were finished in the mid of May. As anticipated the overflow began on May 29, 2010. Time histories of stage over spillway crest and discharge that was measured downstream at the Ganish Bridge (down stream of Attabad) show the performance of the spillway (Fig. 9). The consistency of stage and discharge curves contradicts because the measured discharge also includes the seepage allowance. However, inflow depends on the snowmelt which is directly related to the rising temperature in summer. Data shown in Fig. 10 was reproduced from the daily pager reports given by NDMA. Fig. 10 shows the situations before and after over spilling of the downstream slope. The marks of erosion are quite visible in Fig. 10(b). NASA satellite image shows the overflowing spillway in Fig.11.

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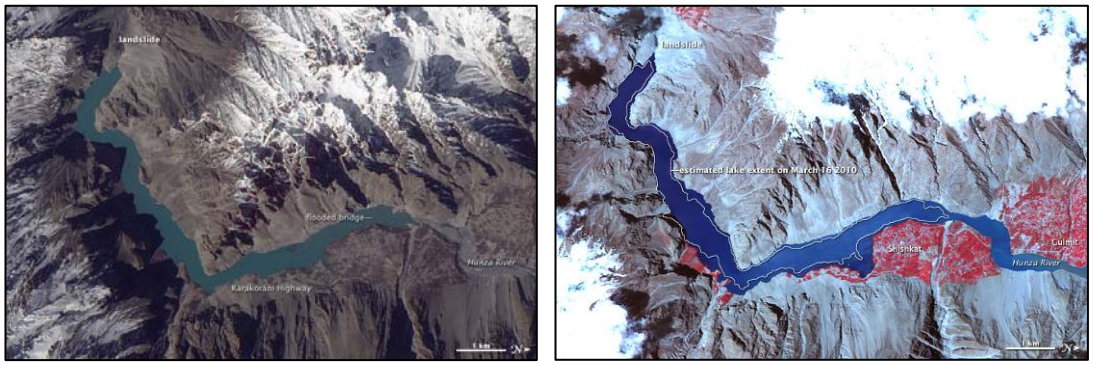
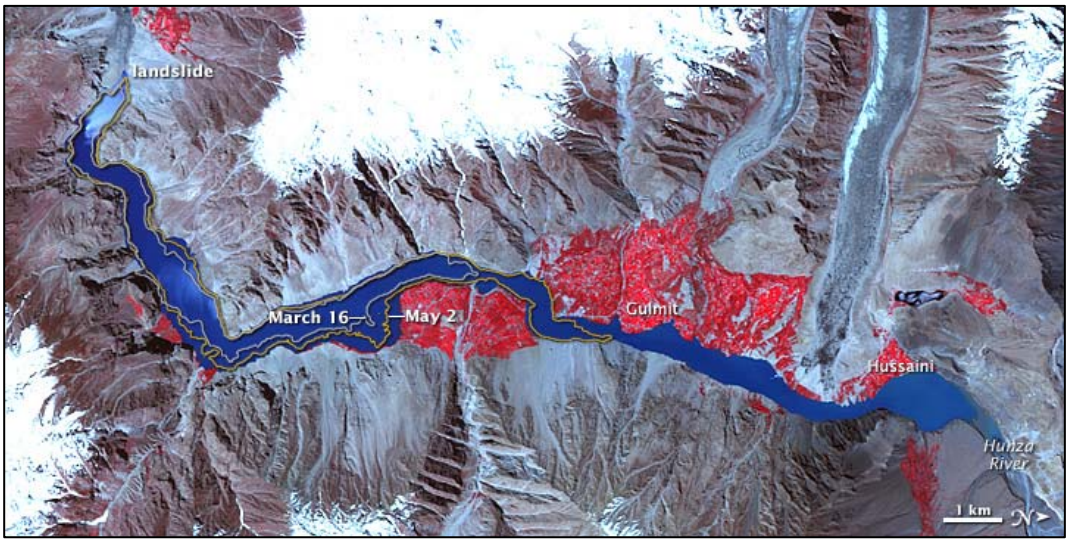
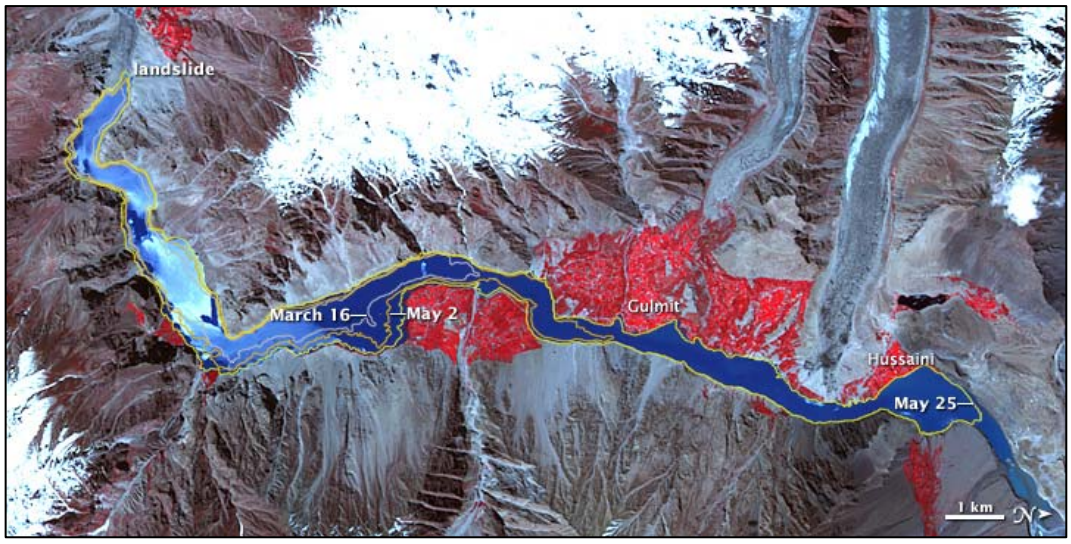


(a) March 16, 2010 (b) May 2, 2010



(c) May 25, 2010



(d) June 1, 2010

Figure 8 Images of lake expansion by NASA before it overspills

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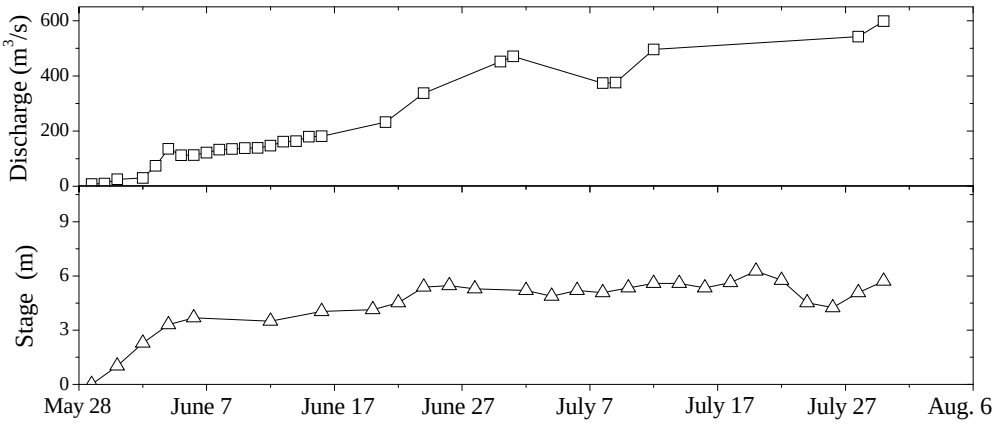

Figure 9 Time histories of discharge measured at Ganish Bridge and stage over spillway crest (drawn after daily pager report supplied by National Disaster Mitigation Authority Pakistan; NDMA)

(a) May 28, 2010 (b) June 17, 2010

Figure 10 Performance of spillway (courtesy by PAMIRTIMES)

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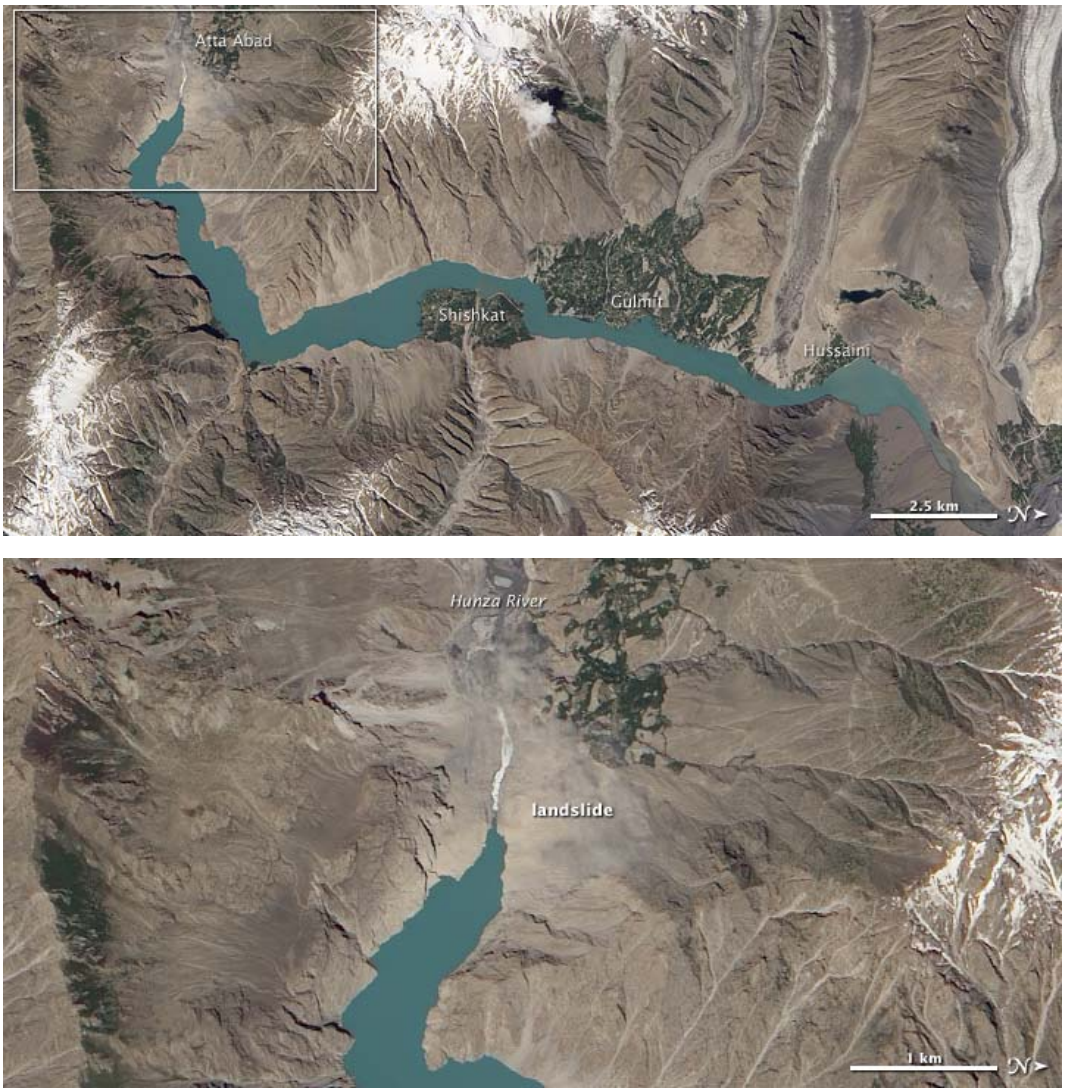

Figure 11 Image of over spilling Attabad landslide dam on July 7, 2010

SOCIAL IMPACTS

The disaster has social impacts on the daily life of community other than the displacement of residence. Karakoram Highway was the only route which connects the towns of Gulmit and Shishkat with Hunza, which has been blocked by landslide and impounded water. Now the mode of transport changed from vehicles to boat (Fig. 12). Directly or indirectly 25,000 peoples were affected by this disaster. The banks of the lake are highly vulnerable and small mass movements are frequent which restricts the boat service through the lake.

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More recently, the situation is being relaxed. Fig. 13 compares two images from NASA that were taken on July 7 and August 23. These images compare the part of upstream edge of the lake. It is therein seen that the inflow has been reduced. In the month of June and July, the temperature was high to produce more inflow due to ice melting. In contrast in August, the temperature dropped, and thus the inflow decreased.

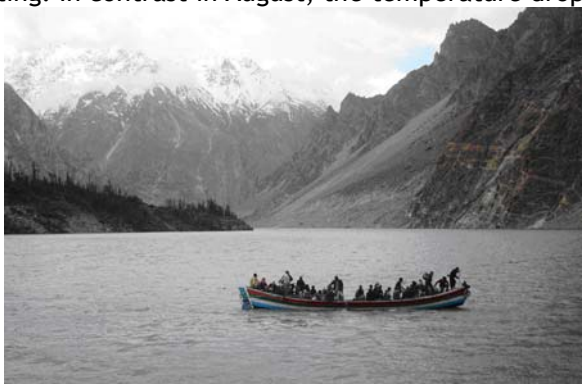

Figure 12 Modal change of transportation after the disaster from land to boat

July 7th

August 23rd

Figure 13 Decreasing inflow of water into the lake in August, 2010 (NASA images)

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National Engineering Services Pakistan (NESPAK) (2010) Dam break study of Attabad landslide, Report to *National Disaster Mitigation Authority Pakistan*, March.

S. Hamid Hussain and Adnan A. Awan (2009) Causative mechanisms of terrain movement in Hunza valley, *Geological Survey of Pakistan*, August.

Daily pager reports from January to July 2010 from the database of National Disaster Mitigation Authority Pakistan, http://ndma.gov.pk/AttaHunzaLandslide.html

Pamir Times http://pamirtimes.net/

APPENDIX. FLOODING IN AUGUST 2010

Pakistan suffered terrible flooding in August of 2010. This flooding was caused by an unprecedently heavy rain fall in the northwest part of the country. All the early warning systems for floods have been installed in the eastern rivers, and nothing has been monitored on the western and south western rivers, which are the source of the terrible flooding in 2010. A flood from these channels do not have any evidence in the recent history. Probably there will be a chance for this bulletin to report this flooding event.