Executive summary on Attabad landslide survey in Hunza
7-17 April 2010

Short introduction

This report provides a summary of the key findings of a short field visit (10-13 April, 2010) to the Attabad landslide and damming site in the Hunza Valley. This report provides some risk/hazard management recommendations regarding Saret and Gogal villages, upstream and downstream of the Hunza river, elaborated based on our field observations.

An international group of geologists and researchers were involved in the survey:

Dr. Chiara Calligaris – Geosciences Departement (DIGEO) - Trieste University (Italy)
Mr. Michele Comi – Ev-K2-CNR (Italy)
Dr. Shahina Tariq – Baharia University (Islamabad – Pakistan)
Mr. Furrukh Bashir – Pakistan Meteorological Department
Mr. Deear Karim – FOCUS Humanitarian Assistance
Mr. Hawas Khan – KIU University (Gilgit – Pakistan)

Some documentation on the landslide is already available (Petley, 2010) and we begin our report based on Petley's findings so as to avoid repeating previously made considerations.

Background of potential glacial lake outburst floods in the Hunza Valley

Sixty historical damburst events have been reported in the northern part of Pakistan. This gives an average recurrence frequency of about one event every 3 year. For ice-dam failures with floods exceeding 20,000 cumecs (9 events in 100 yrs), the apparent frequency is one event every 11 years. For floods exceeding 11,000 cumecs (17 events in 100 yrs) the apparent frequency is one event every 6 years (POE, 1988). The majority of recorded damburst flood events over the last 200 years have been glacial lake outburst floods. A few events have resulted from the failure of landslide dams, the most well known being those of June 1841 and August 1858. Much smaller landslide dam failures took place on the Gilgit river in 1911, and in Hunza valley in 1977. In recent years there have also been some minor flood events due to the sudden drainage of supra glacial lakes. Damburst events were relatively common during the period from 1833 to 1933. The most critical glacial lake outburst floods occurred in August 1929, June 1841, August 1885 (landslide), when the massive flood waves resulted in a significant rise in water levels.

About sixteen potentially glacial lake outburst floods, damaging life and property occurred in Hunza valley (1830-1993), and approximately two smaller landslide dam failures are reported, one at Gilgit in 1911 and the other in Hunza valley in 1977. More than five glacial lake outburst flood events occurred in less than one year (2007-08) in Gojal Teshil, Hunza river basin.

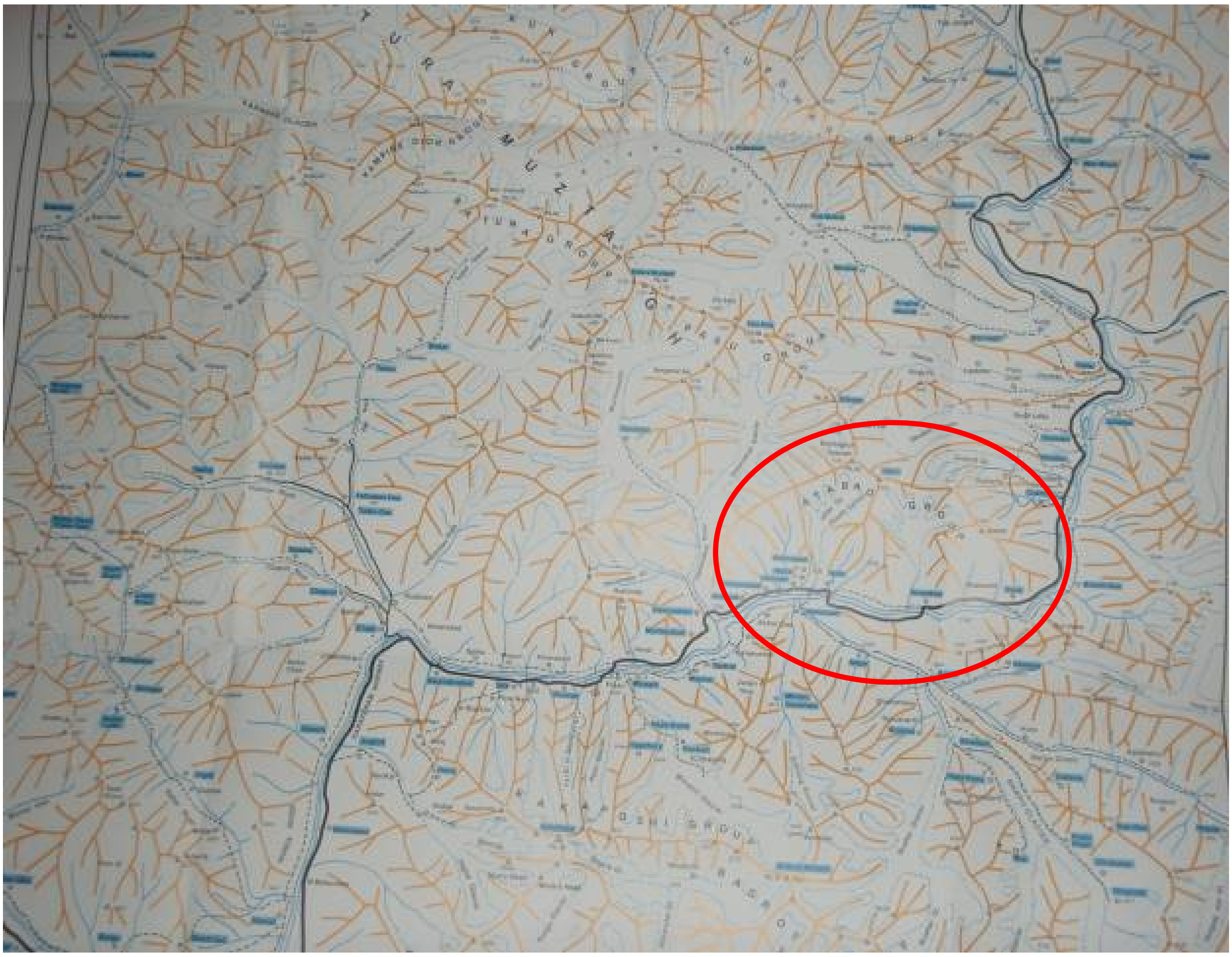

Figure 1: Approximate localization of the area of interest (in red) – Karakoram Maps: sheet 1 (1:200,000).

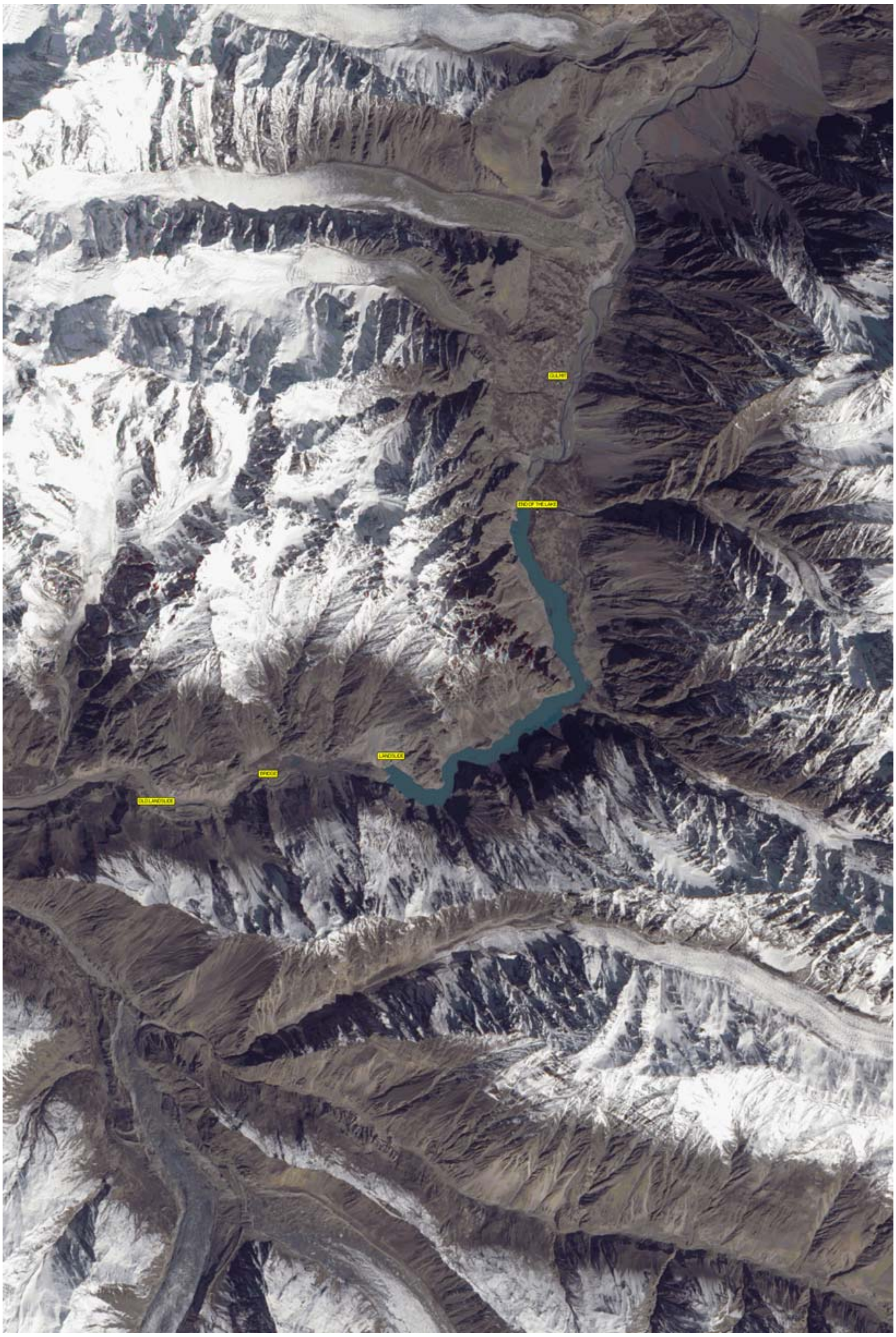

Figure 2: Satellite image with reference pionts (web source).

Attabad Landslide 4 January, 2010

Focus Humanitarian Assistance, Pakistan produced the first reconnaissance field assessment reports on the Active Landslide at Attabad in 2002, and subsequently in 2006, 2007. The 1974 Hunza earthquake and the 2002 Astor valley earthquake (6.5 Richter scale) produced some tensional cracks and displacements at points of contact between a rocky and overburdened slope (scree slope) and material of colluvial nature comprised of sub-angular to sub-rounded boulders, cobbles and gravel with sand and silt matrix at Attabad. These tensional cracks and ruptures in a vulnerable area remained unchanged for a long period of time. The downward movement along the main scarp observed were about 6 to 260 cm in 2002 (Karim, 2002). These cracks became wider (1- 80 cm) when the earthquake on October 8, 2005 hit the entire region. With distant aftershocks, potential amplification effects, and thunder storm rains, a slope mass began moving downward in the form of slump and debris flow two years ago. However, due to lateral movement of slope, lateral gaps in tensional cracks and wedge failure, a strong downward movement of this vulnerable, threatened area was triggered, putting locals at high potential disaster risk on 4 January 2010, at Sarat, Attabad. The Hunza river formed a landslide-dammed lake of about 10 km upstream of Sarat-Gogal Gulmit. The daily water level in this lake is continuously rising. In 1858 historically important landslides also dammed the Hunza river 35 kilometres upstream, from Salmanabad to Khabar in the Hunza region.

The slide debris mass in Attabad on 4 January 2010 fell for about 1.5 kilometres (Figure 1). The movement can be divided essentially into four different phases:

1. Rock fall of large boulders from the right hydrographic side which occluded part of the riverbed, squeezing the clay deposits derived from the lake created downstream by the event of 1858.
2. The squeezed materials invested the opposite banks reaching an elevation of 2,460 m and collapsed over the previously deposited rocky material, covering it all.
3. Another rock fall, again from the right side, submerged the previous one, running through it and giving the actual shape to the deposit (Figure 1).
4. The material squeezed through a mud flow reached 0.8 km upstream and 1.2 km downstream to the dam that had been created. The colossal amount of clay deposit is due to sedimentation caused by the blockage of the Hunza river by the ancient landslide. When the dam formed, a new lake was created.

Figure 3: View of the landslide from the southern side; in red the main scarp.

Figure 4: Clay deposits squeezed in a mud flow due to the rocky landslide.

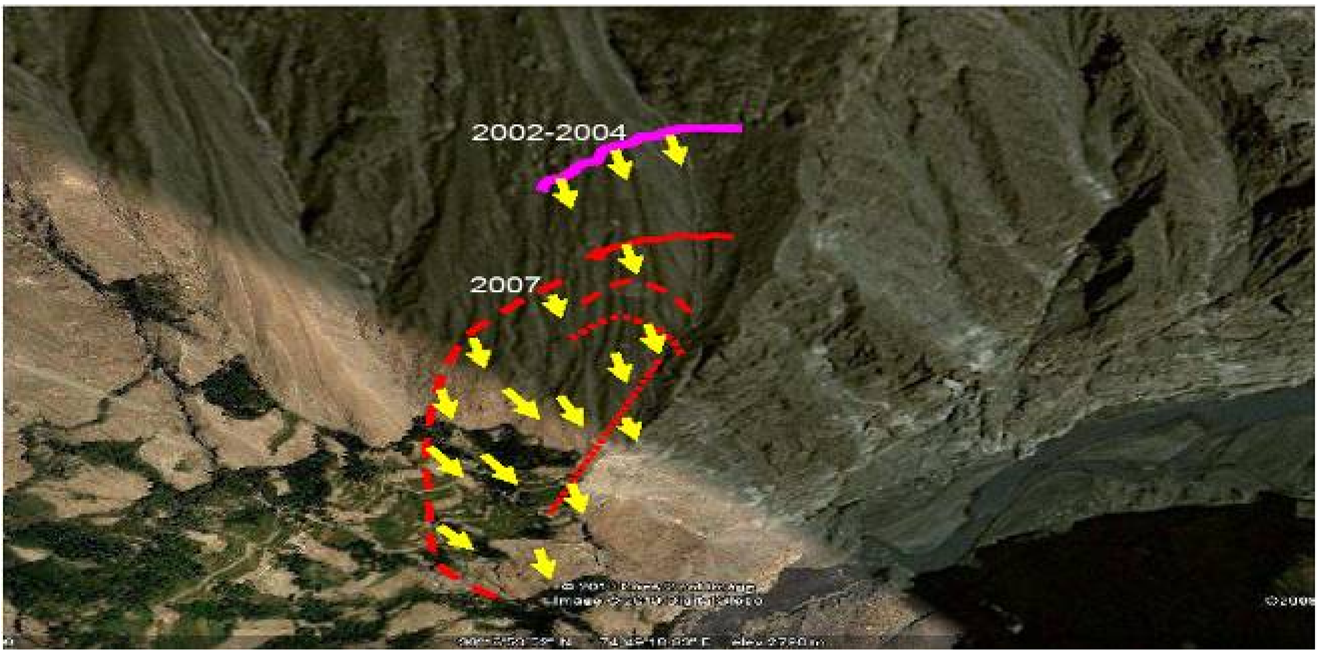

Figure 5: The main scarp of debris on the slope in 2002-2004 and 2007 at Attabad (Karim. E, 2002 Focus Humanitarian Assistance).

Figure 6: The main scarp of the slope in 2002 at Attabad (Karim. E 2007 - Focus Humanitarian Assistance).

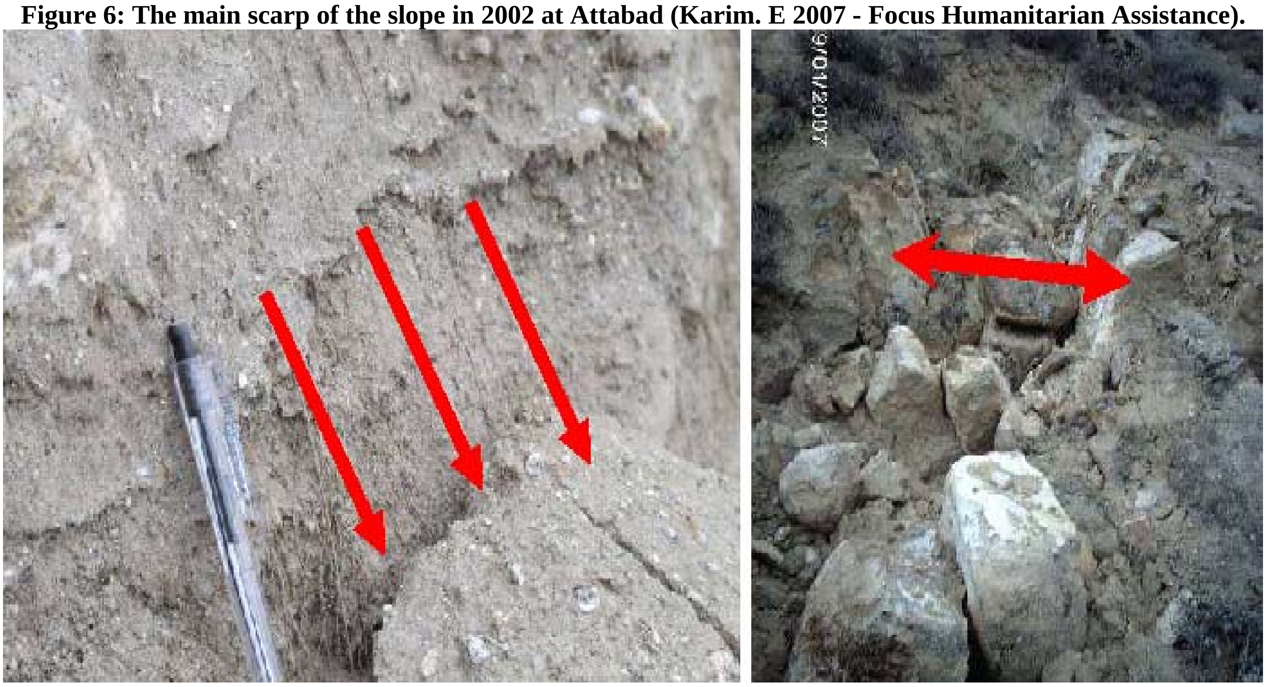

Figura 7: Later slope movement in unconsolidated material at Attabad (Karim. E, 2007 – Focus Humanitarian Assistance).-

Figure 8: 4 January 2010 - Landslide along the main scarp downslope at Attabad (web source).

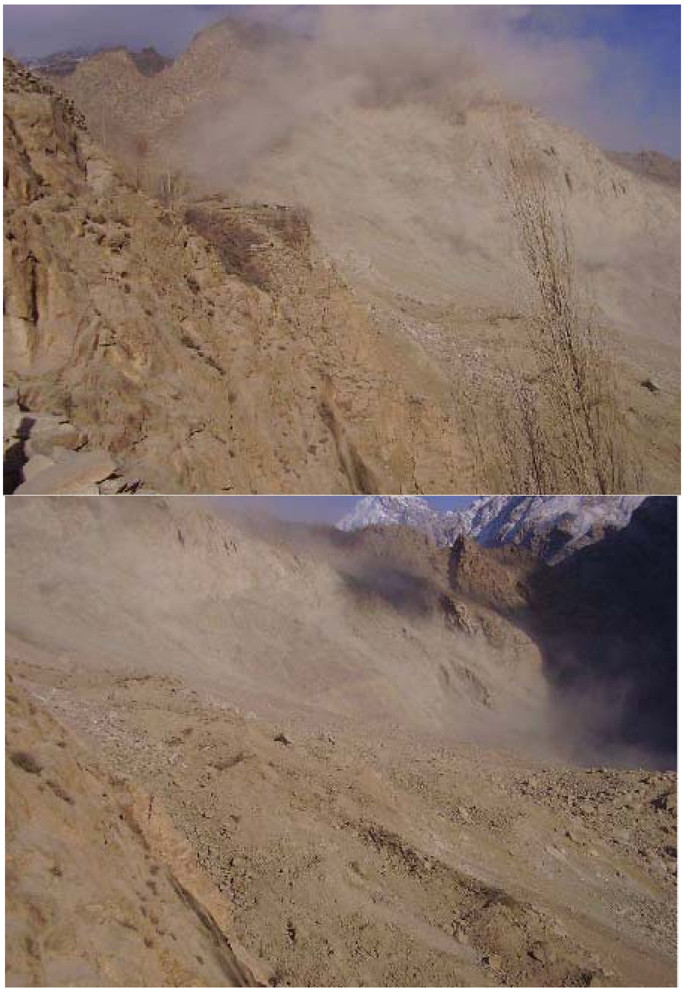

Figure 9: Debris along downward slope in the Hunza river channel on 4 January 2010 (FOCUS Humanitarian Assistance, 2010).

Figure 10: Moments of life just after the event (FOCUS Humanitarian Assistance, 2010).

The disaster affected several small settlements, mainly Sarat, Salmanabad, Attabad Bala, Payeen and Ayeenabad. Burial of villages under the debris flows and rock avalanches was followed by the lost of at least nineteen lives, with numerous persons injured or missing. Attabad, comprised of about forty-three houses, numerous cattle and thousands of fruit and timber trees, is completely buried under the landslided rubble. The Sarat and Salmanabad villages, however, had relocated due continuous landslides in the area.

The material involved consists of clay and silt size particles with some rounded fluvially-transported pebbles and cobbles (Petley, 2010). These materials have a very low permeability. The surface appears quite dry and resistant with a thickness, in the dam area, of about 20 cm, underlain by material with a high water content. The behaviour of this material is peculiar, as it deforms readily when loaded without any break in the surface. The people working in the area often walk on it, moving almost as if on a mattress.

Due to blockage of Karakorum Highway (KKH), the upper Hunza valley has been completely cut off from the southern, downstream valley. Different sources have reported that approximately 20,000 people are at a risk of facing severe food, medicine, and fuel shortages. Needs are currently being met using helicopter and boats travelling back and forth across the dammed water upstream.

Shishkat, Ayeenabad, and Gulmit villages (6,000 people) along the banks of the river could be affected by the dammed water upstream. If the lake outbursts, it could affect another 18,000 people downstream but engineers are trying to mitigate this potential disaster by digging a spillway to channel the river through the debris. This could, however, take a few months. About one hundred and ninety families have been affected by the disaster and they have been shifted to safer locations in relief camps at the nearby villages, Altit and Aliabad (data from survey reports). Search and rescue operations by the Pakistan Army, local administration, volunteers, residents and NGOs are still underway.

Petley. D (2010) analyzed the whole scenario based on monitoring reports (Focus) studying the various parameters of the massive landslide upstream and downstream along the Hunza river. He proposed that the level of the hazard associated with a potential outburst flood from the landslide dammed water is higher than can be considered tolerable. The downstream communities need to be protected since, although a flood is not inevitable, possibility is strong.

The four steps that define the event of 4 January 2010 created a particular sedimentary sequence that is compatible with the behaviour and positioning of the actual seepage points. It means that the water found a channel at a higher permeability compared to the clay matrix widely present in the middle part of the neoformation dam. Large boulders of granite and granodiorite compressed the lacustrine deposits and were covered by them, so the permeability of the dam is not completely compromised. This allowed multiple seepage in 4 different positions (Figure 9).

Figure 11: Seepage points at the toe of the dam (web source).

In summary, the main part of the dam is formed by colluvial material of clay and fine sand matrix that isolates rocky boulders. The shape of the blocks is generally sharp and angular, ranging in size from a few centimetres to over 10 meters.

On the two slope sides of the valley, the deposits are different. On the left side, there is a large rockslide deposit of large and very large boulders without any matrix support. On the right side, the matrix support is widely present. Over the main scarp, there is a thick glacial deposit mixed with debris deposit which could be easily remobilized. At the time of the survey, there were still several, frequent rock falls from the steep rocky slopes, which present serious danger for the persons working below.

Geological settings

The Hunza valley sits astride two major faults, the Main Mantle Thrust (MMT) and Main Karakorum Thrust (MKT). North of Chalt along the Karakorum Highway and crossing the Main Karakorum thrust (MKT) Zone, one steps on the southern edge of the Karakorum block, to which the Kohistan Island Arc was accreted during late cretaceous time as a result of the northward drift of the Indo-Pakistan plate. The Karakorum block extends from the Pakistan-Afghanistan border in the west to western Tibet in the east; its northwestern limit is marked by the Chitral Fault and the northeastern boundary is defined by the Karakorum fault. The upper Hunza fault is taken as its northern limit (Desio 1979). The Karakorum Range is over 600 km long with an average of 150 km, forming a crestent-shaped belt convex northward. The Hunza Valley zone to north of the Main Karakorum Thrust Zone is composed of rocks mainly of brittle deformation, such as syn-metamorphic mylonites, metaconglomerates and foliated carbonaceous. Between Hini and Sarat, the Hunza valley exposes a complete section of the Karakorum Axial batholith as medium-grained granodiorite.

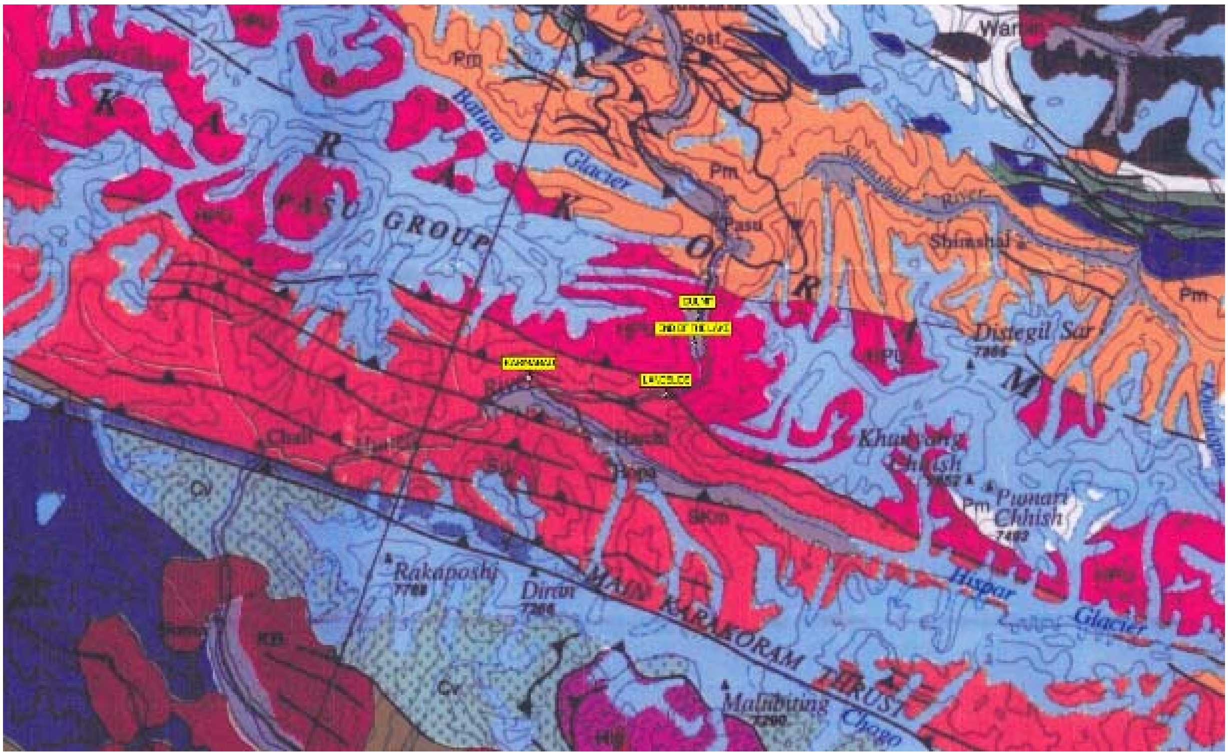

Figure 12: Location of the landslide area (yellow labels) on a geological map (original scale 1:650,000).

State of art

Data collection

On the day of survey, as shown on Table 1, the following data were collected. The majority of data is collected daily by FOCUS and NDMA technicians who are monitoring the increasing water level of the lake, the inflow rate and the outflow total seepage.

Data regarding discharges and levels at the Attabad landslide on 13 April 2010	
Length of lake	About 10 km
Rate of inflow	25.56 cubic meters per second
Total seepage (NDMA)	0.66 cubic meters per second
Total seepage (FOCUS)	0.54 cubic meters per second
Depth of lake (NDMA)	77.51 m
Depth of lake (FOCUS)	79.16 m
Freeboard	31.26 m
Direct affected population	550
Displaced population	1687
Causalities (dead)	19
Upper Hunza cut-off from the rest of the country	20000
Villages at high susceptible risk in case of dam break	20

Table 1: Data regarding the hydrological assessment in the dam area.

Figure 4 shows the hydrometric pole used to monitor the increasing water level. From the measurements already done, the level is increasing at a rate of 25-30 cm/day.

Spillway construction

The construction of the spillway is ongoing. Eight caterpillars are working to open the way for the water to flow. The expected dimensions of the spillway are about 40 m wide and about 30 m deep. During the survey, this goal had almost been reached with only about 10 m missing. The digging is quite difficult due to the nature of the colluvium forming the dam, as the excavation is primarily in lacustrine clay. Seeing that the required depth has not yet been reached, no boulder has been positioned at the base of the channel in order to prevent erosion, but this would be advisable.

Figure 13: Hydrometric pole.

Monitoring and alert system

FOCUS Humanitarian Assistance is monitoring the site 24 hours a day. They have set up a warning system for the communities downstream as far as Gilgit. The local populations have been alerted and trained for the action if or when a flood occurs.

Relocation of affected population

The populations directly affected by the landslide or by the increasing water levels have been evacuated and moved to a disaster camp near Karimabad.

Recommendations on mitigation measures

During the survey, it was possible to assess the hazard mitigation measures taken since the day the landslide occurred. The decision to dig the spillway is for sure a conscientious decision. The excavation is proceeding well, quickly and precisely, but, despite this, there is still a high level of risk at the dam site associated with a potential outburst flood.

- The most important thing is to check the colour of the water coming out from the seepage points and its discharge. Every change in colour or quantity means that there is an evolution in the phenomena.
- The presence of 2 sinkholes (Figure 12) formed on 14 April means that the water is flowing under the dam structure with an intense erosive power.
- The lining of the base of the channel and its banks with large boulders will be very important to prevent - as much as possible - erosion of the fine material (clay and colluvium) when the water will begin to flow.
- From the steep slopes upstream of the dam, very dangerous boulders are still falling, creating a high risk area in correspondence of the spillway and the way created and being used by the merchants attempting to carry out their business.
- On the main scarp of the landslide, there is still a significant amount of loose material, probably due to moraine deposits. This debris can easily be remobilized by an intense rainfall or an earthquake
- Along the road to Karimabad, several potential landslides can be recognized. In the eventuality of a real outburst flood, the toe of these phenomena could be eroded.
- Along the new lake, during our short survey, no large scale phenomena which could potentially trigger an outburst flood were observed, but our survey was not sufficient to exclude every type of sliding.

Figure 14: Sinkhole formed on 14 April 2010 on the dam, from the lake side.

Ev-K2-CNR could contribute to improving knowledge of the phenomena and enhancing data acquisition to support a possible stage of alert. Even considering exclusion of a potential outburst event, there will still be a long term risk. Specifically, in support of the ongoing monitoring activities (ideal for the first phases), an upgrade in the monitoring processes is possible by automation of the water level measurements to support and manage medium-term risk assessments. At the same time, an important relevance has the monitoring of the landslide site and the area around the dam trough very high resolution satellite images. Images can be compared and movement/differences can be highlighted; indeed also an accurate model of the dam site and the future possible flood event can be reconstruct.

Possible future operations:

1. positioning of 3 automatic hydrometric stations (2 upstream and 1 downstream of the dam): 2 to monitor the water level of the lake, one downstream to monitor seepage discharge.
2. one of the hydrometers could be integrated with a complete meteorological station.
3. the actual distance and elevation of the lake level can be checked using 2 GPS stations to determine with high accuracy villages and infrastructures at risk.

4. an accurate helicopter survey is recommended to monitor the areas upstream of the main scarp to identify the presence of possible open cracks and unstable volumes.
5. it would be necessary to monitor the main scarp and the downstream side of the dam using instruments such as laser scanners to define possible movements in the unstable areas.
6. Satellite images (e.g. COSMO – SkyMed) can be used to monitor the all area involved in the landslide and in the possible future flood, and to create a high resolution DEM (DTED-3 or DTED-4) useful for a new scenario of flood event.
7. a new scenario of the possible flood, with new generation data, can be recalculated (using Flo-2D software) to precisely determine the hazardous areas and the level that can be reached by the frontal wave.
8. a seismometer could be installed to determine the seismicity of the lake area.

Figure 15: Residual hazards still present in the dam area: porters, technicians and workers in rock fall danger.

Figure 16: View of the lake from the upper side of the blocking dam (porters working in a dangerous area).

CONCLUSIONS

This is only a synthesis of the possible interventions which could be carried out in the short-/medium-term. This work should not be considered exhaustive, however it hopes to summarize the main guide lines for possible future operations, should the dam not collapse in the coming weeks. This scenario remains possible and realistic based on the recent evolutions on the field.

In conclusion, all along the Hunza valley, geological and structural dynamics determine a natural predisposition to slope instability. The current phenomenon needs to be inserted in this context, where high hazards are still present. The survey along the lake did not macroscopically highlight possible failure of the slopes into the lake, but the possibility is still high due to the magnitude of the slopes involved. Given that one failure mechanism for the dam is a slide into the lake and a wave that then overtops the dam, this needs to be monitored with some urgency.

Considering the civil protection, social and commercial implications for the Hunza valley where the KKH passes, it is extremely important to further our knowledge of the area so as to reduce the residual hazards which will remain once the main event has been overcome (by collapse of the dam or outburst of the water). The monitoring is necessary also because of possible implications regarding Tarbela dam, which are not to be ruled out since solid transport and the evolution of the phenomena is evident and quick.

Gilgit, 16 April 2010

Dr. Chiara Calligaris – Geosciences Departement (DiGEO) - Trieste University (Italy)

Mr. Michele Comi – Ev-K2-CNR (Italy)

Dr. Shahina Tariq – Baharia University (Islamabad – Pakistan)

Mr. Furrukh Bashir – Pakistan Meteorological Department (PMD)

Mr. Deear Karim – FOCUS

Mr. Hawas Khan – KIU University (Gilgit – Pakistan)

Ev-K2-CNR Committee
Via San Bernardino, 145
24126 Bergamo , Italy
Tel: +39 035 3230511
Fax: +39 035 3230551
www.evk2cnr.org

Ev-K2-CNR Pakistan Representative Office
House # 3 A, Street #55
F-7/4 Islamabad, Pakistan
Tel: +92 051 2655835
Fax: +92 051 2655836