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CLIMATE CHANGE EFFECT ON THE HUNZA LAKE AND GEOMORPHOLOGIC STATUS OF THE HUNZA RIVER BASIN, GILGIT-BALTISTAN, PAKISTAN

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ABSTRACT

The study appraises the affects of climate change on both fresh and perennial water resources by integrating geomorphology of the Hunza River watershed, Gilgit-Baltistan, Pakistan. An effort has been made to investigate potential transformation in watershed river-flow and geomorphology which move forward to consequential change of climate. The Hunza River is identified a significant source of water supply for agriculture and down stream, rural villages, and potential for electricity generation. This region, up-streams significantly brought water throughout the year and during monsoon season and adding substantial sediment loads. On Jan. 4th, 2010, a sudden landslide hit at Attaabd, located about 20 km upstream of Karimabad on the right bank of Hunza River. The geomorphic status of the wiped village (Attabad) was identified as a mud mount close to the Hindu Kush Range with a slope of 60° to 70° to the ground level. Land sliding completely blocked the Hunza River by raising a barrier of maximum height of 150m and minimum 70 to 80m and formed a Hunza lake. At that time, maximum length of the lake was 21 km and depth was 109 m, while on 25th June, 2010, lake depth was noticeably extended up to 116.7m and spillway reported discharge was 352 m^3 /s. The estimated total inflow was 419 m^3 /s against outflow of about 358 m^3 /s. Moreover, the resultant landslide debris length was identified as 3000m in East-West and width 1500m in North-South direction. Latest Spot Image taken on 31st May, 2011 notified, with debris height 8796 ft. The Lake is kept spreading on, which is a big menace for the numerous other downstream villages. Though, uncertain events are nature's own enterprise for overflow management. Various natural and anthropogenic forces have critically impaired this natural activity. Finally, such lakes remain under threats and prone to multifaceted episodes by ever changing climatic conditions. Two decades of temperature and precipitation data as well as seismic data of the surrounded mountainous ranges have been evaluated by using different statistical models.

This paper analyzed groundwork key environs of a watershed at the initiation of precipitation. It is noticed that groundwork is exposed to be a role of pre-storm base-flow strengthened by consistent seismic activity in the Hindu Kush Region. The stream flow series provides facts for differences in the yearly high and low flow seasons. On these bases degree of seasonal annual flow is perceived. Geomorphic changes are interlinked with the hydrologic changes. The results emphasize the probable upcoming hazards.

This paper analyzed preliminary underlying vicinity (PUV) of a watershed has been based only on the limited data (2007-2010), which was not sufficient for establishing good results and predictions. However, the trends in rainfall corresponds the climate data as outlined in graphs. An in-depth study has been proposed by using GIS and RS techniques so that a strategy could be proposed to take proper measures to avoid the future disastrous activity.

Keywords: - climate change, sudden landslide, Hunza Lake, precipitation and temperature deviation, GIS and RS techniques

INTRODUCTION

The northern mountainous regions of Pakistan are composed of NW Himalayas, Central Karakorum and northeastern Hindu Kush While the Himalayas belong to the lndo-Pakistan Plate. The Karakorum constitutes southern part of the Asian Plate. Sandwiched in between the two plates is the Kohistan Fossil Island are, with its northern and margins sutured to respective plates by the Main Karakorum Thrust (MKT) zone and the Main Mantle Thrust (MMT) zone. The latter represents the late-Cretaceous subduction zone of the

Indo-Pakistan Plate, that was closed during mid-Tertiary (Searle, 1989) and got locked during Miocene (Zeitler et al 1985) Notably, this region had been acting as a regional depocentre of detrital sediments transported into the shrinking Tethyan Sea, mainly from northern and southern continental masses. After emergence of the Himalayas, however, the direction of sedimentation got reversed so that the region became source of sediments transported southwards by the Indus River drainage system. Among such products are the sediments of Rawlpindi and Siawalik groups. In the South of the main Himalayas that were deposited between 20 and I million years ago (Meissmer et al 1974)

While the processes of weathering and erosion initiate as soon as topographic level starts rising, these get highly intensified in the case of tectonically Active Mountain, such as those of the northern Pakistan when considered on regional scale, this problem deserves special serious notice particularly with reference to the surface water reservoir. It is essential that, erosional and sedimentation potential of a relevant drainage be assessed and evaluated as to the dynamics of regional characterization. Present study aims at assessing the erosional potentials of Hunza River as the reference drainage system.

MASS EROSION PROCESSES

The peculiarities of mass erosion processes in the Karakorum-Himalayas are rooted in their rapid rise <.2 mm to over 10 mm per year, (Zeitler, 1985) and exceptionally steep slopes (valley floors 1500m and mountain peaks 7000m and above). Consequently, weathering is intense and mass erosion formidable seen as thick valley-fills exceeding 700m or so (Goudie et al. 1984). The major processes and their effects are reviewed below as a background to the problem under study:

A. The Collisional-type Karakorum and Himalayas represent active crustal plate regimes, involving both drifting and rising components to produce crustal shortening. While the drift is adjusted through regional system of active faults, the uphill is countered by mass denudation. Fission track data on NW Himalayas over the last 10 years (Zeitler. 1985) shows uplift up to 10km or so. Similar activity has been accepted in the case of Karakorum Range as well. Even presently, the Nanga Parbat is rising at a rate of 5mm/year which is rather phenomenal. Notably, the Himalayas are at least six times lower than it should have been. This has been attributed to its phased uplift and the high rate of erosion. For instance, the total volume of sediment shed into the Indian Ocean over the last 40 million years through the agency of Himalayan drainage systems is estimated to be about 85 x 10^6 km^2, giving an annual erosion rate of 0.2 mm/year (Schroder, 1989). Remarkably, the present rate of denudation of about I mm/year shows at least five times increase over the historical rate. Even higher rates of denudation have been calculated for the upper Hunza basin of the Karakorum Range. However surface lowering rate of nearly 118mm/year represents among the highest rate of denudation in the world (Ferguson. 1984).

B. In addition to water transport of eroded material, glaciers also play a very effective role in mass movement in the Karakorum-Himalayas region. Remarkably, Karakorum glaciers are also among the longest, the Siachin glacier alone being more than 75 km long (Shams & Khan, 1987). These valley glaciers are infact the remnant of last Ice sheet that covered northern Pakistan till about 10,000 years ago (Mason 1930, Derbyshire et al 1984; Desio, 1974). The past glaciations periods had created hundreds of meters thick moraines and tillite deposit widespread in northern Pakistan. The studies on the 59 km long Batura glacier, Hunza, Karakorum, shows the great volumes of debris and imbedded rock material that is continuously transported down-slope (Batura Glacier Investigation Group, 1980). The snow avalanches are also a powerful vehicle of debris transport to valley beds. For instance, a single Kapan snow avalanche in the Kaghan Valley transported about 103 m^3 of rock debris (de Scally, 1986; Bell et al 1990). Hewitt (1982, 1988) has described a catastrophic deposition of about 20x 10^6 m^3 debris on the Baultar glacier in the Karakorum during July, 1986. Flash floods, glacier-lake outburst, landslides and mud flows are also responsible for voluminous transport of weathered material. For instance, the notorious Shishkit event of 1974, originating from Balt Bar Valley of upper Hunza, involved pouring down of nearly 5 million m^3 of mud-rock slurry at a speed of 6300m/second (Wenying et al.1984).

C. LANDSLIDES

Landslides, debris-slides, flow slide and related phenomena are notoriously widespread in the Karakorum-Himalayas region. Goudie et al (1984) and Owen (1991) has given comprehensive descriptions, supported with location examples of scare slopes, debris-fans and huge alluvial terraces. Occasionally depositing huge volumes of debris flow into the River Indus, and historical event of temporary damming of their river and later catastrophic flooding is recorded (Abbot. 1848)

D. Wind is yet another powerful agent of erosion, although it is not given its due: importance. Considering the huge loss of soil from great loess plains of China and the smaller plain of Potwar, Punjab, the role of wind erosion is evident For example; Goudie et al (I984) experienced many server dust storms in the upper Hunza Valley during the single month of July, 1980. The erosion created by valley channeling of winds is spectacular. Notably, the dust falling in the drainage system cannot be ignored, although not easy to estimate quantitatively. Besides, silt to clay sized material; wind can move even large stones and generally destabilizes rock projections

E. Man has also become a powerful agent of erosion in order to meet the demands of his fast expanding population. His activity is now considerably strengthened with the power of modern science and technology. Beside earth- moving operations, concerned with mining, engineering works and human settlements man is also responsible for high rate of deforestation and overgrazing of mountain pastures. Consequently, landscapes are exposed to erosion excessively, resulting into greater yield of sediment-load to the drainage systems. Estimates on the Kunhar River, show that annually about 1.38 million tonnes of soils is removed through erosion (Khan, 2009). Deforestation and overgrazing of Alpine pastures in the upper reaches of the valley is well known. The same applies to other parts of the mountainous terrains of northern Pakistan.

The glaciers melt and feed rivers around which over one billion inhabitants live. The Hindu Kush-Karakoram-Himalayas (HKH) region, which has worlds longest rivers (Indus, Brahmaputra, Ganges, Yamnas, Mekong and Yangtze) region has been dramatically affected by retreating glaciers causing serious threat to the old civilizations of the region. The global warming has ensued series of natural hazards. According to the Disaster Management Authority of Pakistan (DMA) “The number of people affected by floods from 1990 to 2010 in Pakistan is reported to be around 44 million”. The number of affectees has been increasing as may be obvious from the Table1 (State News, 2010). There appears to be 5–7 yearly cycles of natural calamities in the forms of flood, earthquake, draught and storm. The HKH region is tectonically very active and is characterized by steeps slopes and high rate of erosion. The intensive pattern of this region triggers a variety of natural hazards in the form of glacier advancements, avalanches, headways, landslide occurrences and flash flood follow-ups.

Table: 1 – Shows series of previous disasters along with affectees No. and financial damages

Disaster	Date	Affected	Cost (US$ X 1,000)
Flood	2010	20,102,327	9,500,000
Flood	2005	7,000,450	5,200,000
Flood	1992	6,655,450	1,620,000
Flood	1992	6,184,418	1,000,000
Earthquake *	2005	5,128,309	327,118
Drought	1999	2,200,000	247,000
Strom	2007	1,650,000	246,000
Flood	1996	1,300,000	103,000
Flood	2003	1,266,223	92,000
Flood	1995	1,255,000	30,000

The glaciers all over the world are under going substantial thinning. The European Alps have lost major part of their ice volume since mid 19th century. The glaciers in the Himalayas are no exception and are showing visible deterioration and degradation. The region is facing several challenges, creating social problems and economic difficulties. The Indus River, originates from western Tibet and 202 glaciers varying in sizes contribute to the water of this life line of Pakistan. Gilgit–Baltistan (GB) region is getting water mainly from stream flow resulting from snow and ice melt. Its mean monthly and annual rainfall varies between 125 mm to 500mm.The climate of the area is cold in winter and hot in summer at low elevations, while it is pleasant in summer and cold in winter in valleys at higher elevations.

There is a long history of earthquakes in the northern Pakistan. Prior to the earthquake disaster of October 8, 2005, Pakistan has experienced 66 earthquakes, majority of them were in 1966. The earthquake of October 8, 2005 was exceptionally catastrophic in terms of heavy loss of human lives, apart from dislocation of millions. The overall damages rose to more than 6 billion dollars. Pakistan including Gilgit-Baltistan has also experienced 607 earthquakes (4-5 on Richter scale) between October 8, 2005 and March 5, 2006. There have been earthquake shocks and after shocks in Gilgit–Baltistan during 2002, which persisted for more than a month. The epicenter of these seismic activities was just in the north of Naga-Parbat, which is the cause of great concern to the inhabitants of the northern Pakistan.

METHODOLOGY

The detailed literature review of the Karakorum-Himalaya and Hidu-kush region of Pakistan provided the Preliminary understandings of gradual deformation of sudden Attaabad landslide hazard (Hunza Lake) and its corresponding effects on River Hunza, which have been examined and correlated with the recent incident and its present status. Two field visits during May, 2010 and June, 2011 were conducted and data of the Attabad and surrounding areas was obtained to substantiate the historical deformation. During these visits, photographs were taken and a questioner was developed to collect reliable information on the basis of personal interviews of the local community. SPSS software was used to compute data. Based on these findings comments and suggestions have been proposed to keep the new cold water lake functional and sustainable.

Formation of New Cold Water Hunza Lake (Attabad Lake), an Immediate Consequence

Attabad Hunza (Lat 36. 354130° Lon 74.807098°) lake created by a landslide dam in the Hunza Valley of Gilgit-Baltistan (Fig. 1), initially formed due to the massive landslide at Attabad Village 20 km upstream (east) of Karimabad that blocked the flow of Hunza River for five months. Landslides involve movement of earthen materials and generate catastrophic situations of varying degrees quite frequently in Gilgit-Baltisan. The recent landslide of January 4, 2010 at Attaabad, has been a very serious episode in the Karakorm region which affected village (Attabad) and was completely wiped out. This historical landslide blocked communication not only between Hunza and northern parts of the country, but also became an immediate barrier between Pakistan and China. After short period it was noticed that level of lake decreased by inches and the the Attabad Lake, at Gojal valley, was opened on January 28th 2010. At that time the water flow into the Hunza River was about 22,000 cusecs. The level of the lake stood around 370ft during peak hours.

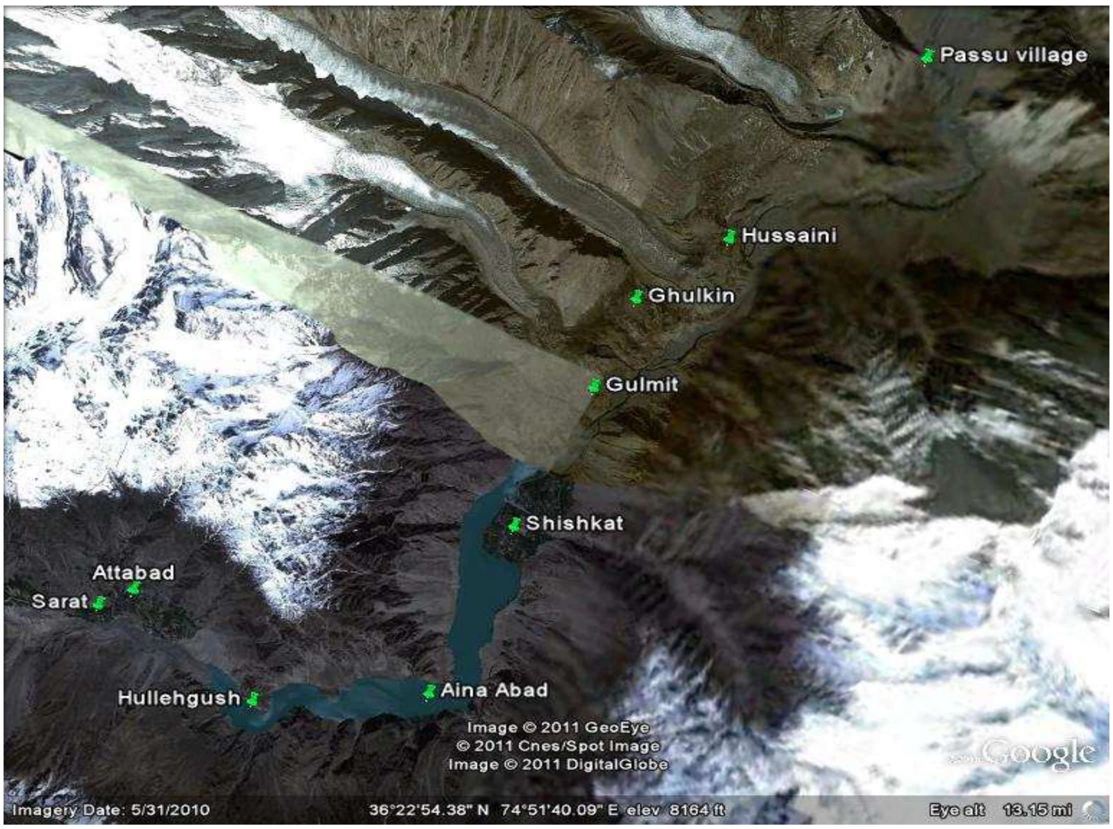


Figure 1 Attabad Lake in Hunza, a location map (Lat 36. 354130° Lon 74.807098°) on 4th of Jan.2010, a huge landslide created an artificial dam which impeded the course of the Hunza River.

Initially 47 homes were completely destroyed and 19 people suffered death in addition to the other losses involving livestock, crops etc. The 6000 inhabitants of Sarat and Salmanabad were displaced and a further 25,000 were trapped upstream in the upper Hunza valley. The upstream water lake further increased and drowned the Shishkat Bridge and the low lands. The people sadly saw submerging of village Shishket. The national media covered the whole Incident of the formation of this New Cold Water Lake.

The lake formed under went extension to 25 km which additionally affected 173 families, 1,773 men, women and children. The barrier created by massive segments of huge rocky portions and earthly debris almost completely blocked the Hunza River for five months. Yet barrier is nature's own enterprise at flood control but at present, significance of this event is badly messed up due to various natural and artificial reasons.

PERILS PROBLEMS AND MISERIES

The research area covers metamorphic rocks of intermediate and high-grade. These rocks counteract by the Main Karakoram Thrust (MKT) which incline South East across the region. In the K2 region, only to the northeast of the study zone, dipping exhumation during the last 3–5 Ma was extremely quickly i.e. 3–6 mm/A with = 6 km of exhumation was on a height of the 6000 m asl taken place documented by Foster et al. (1994).

This area is lying over active fault known as Main Karakoram Thrust (MKT) fault (GSP, 2011). According to Thingbaijam *et al. (*2009) the affected area is evaluated as being coupled with high levels of seismic hazard, aggravated by the probable setting of a big seismic gap. The slope had glacial deposits which were loose and lacked consolidation. All this led to the formation of a new lake and created a lot of debris. Episode of mass movements caused wide disturbance and resulted in numerous failures. The left over debris was about 200 meters from river bed level. The debris was estimated to occupy 10 million cubic meters. A three kilometer long strip of KKH was totally destroyed. The debris took the shape a dam and its upstream water level was rising at the rate of four meter per day

A number of villages plunged while a vast segment of the Karakorum Highway had gone for ever under the expanding lake water. This landslide presented a tail of mythical paradise of Shangri-La. Apart from the reported deaths, the debris obstructed about 2 km of the fast flowing river Hunza and a longer stretch of highway that cutting through stunning snow capped peaks. People stranded in Upper Hunza were relying on relief supplies mainly by helicopter. Hundreds of peoples were displaced and were forced to live in relief camps. The lake formed by the landslide was about 7 miles long and 215ft deep and set to be rising at 1.5 feet a day reported by Tribune Daily (July 2010). One major newly constructed bridge also got submerged (Fig.2). Volunteers painfully removed 130000 cubic yards of debris in order to create a spillway for the water to pour through. It was expected that the spillway will be opened by mid April 2010. Clearing up the KKH was considered a tedious work according to National Disaster Management Authority (NDMA). The authorities were pessimistic that water might rise enough to over flow by June 2010.

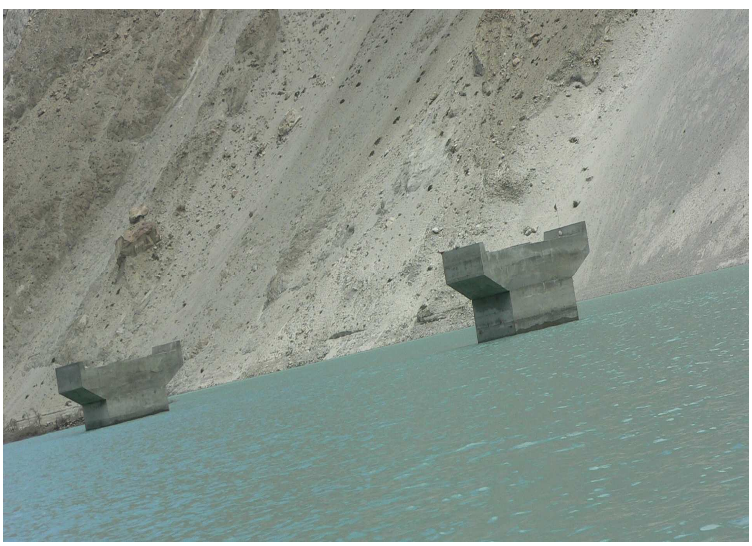


Figure 2 The lake formed by the landslide is now about 25km long 358ft deep and rising gradually. Newly under construction bridge by the Chinese Engineers also went under water.

Water flow from the spillway (111.41 metres above the valley floor) was opened on 29th May 2010. Leonard et al. (2010) stated that at that time projected lake capacity was 520-640 million m^3. Due to this unfortunate lake formation incident a number of villages, their crops, agriculture and more than 195 residential properties had swamped (Fig 4). The out flow (376 cusecs) of water was more than the inflow suggesting that the water bursting its banks were not eminent.

The level of lake stood around 370ft. The water level was lowering by several inches in the early days.

Figure 3 Author witnessed on 6th of June, 2011, a productive part of Gulmit, Shishkat, Shishkat Bridge Ayyain abad Attabad (almost wiped out). Communities are still waiting for support.

Water level went down to around 3.5 feet after about 5 days. It resulted in the formation of the lake, the water started rising day by day in the remote part of Gilgit-Baltistan posing a threat to thousands who were likely to lose their crops, their homes and even there lives. It was anticipated that a flash flood could threaten down stream villages too. The vital trade link to China in the form of Karakorum Highway buried under lake water and thousands of isolated people in the upper Hunza valley confronted untold miseries. People also sadly saw submerging of village of Shiskut. It was estimated that the water level would be lowered by an additional 30 meters by May 2011 and 15 km of the KKH which currently underwater would re-emerge. According to a Canadian Prof. Hewitt, such landslides rarely occurred in Northern Pakistan before. Evidently, there was an eminent requirement of proper evacuation plan for communities down the river. Potato growers in Hunza Area were very worried of this development, feeling that their access to the region would be curtailed and means of earrings reduced. It would aggravate the situation because no seeds and fertilizers would be available to promote their crops. The Gilgit-Baltistan students were greatly concerned as well about the continuation of their studies.

The Chinese experts visited Attabad Lake a few months before it started swelling and put forward proposals to avoid flooding and control blasting. Unfortunately the local experts disagreed with the Chinese experts and were relying on some long term measures. In the meanwhile the lake inundated nearby villages that were forced to vacate their homes. The Chinese government was ready to help Pakistan in the rehabilitation work. They put forward two options, one to make a bye-pass and two, lower the level of the water by 30 meters. Finally it was decided to resort to controlled blasting to lower the water level in the lake and undertake rehabilitation work and restoration of normal life in this suffering area (Abbas Zaidi et.al., 2010). Unfortunate residents of Hunza Valley were subjected to severe sufferings due to Attabad Lake. It undoubtedly disrupted international trade between Pakistan and China. Small traders and residents of Hunza Valley had reservations about the relief work around the site of new lake. The traders who were using boats were without life jackets which were jeopardizing their crossing. The service remained suspended for quite a long time and has not been restored fully yet.

Figure 4 During field study on 8th June, spillway photograph of the Attabad Lake and the surrounding area shows morphology

A spillway was also built by army engineers who diverted water to its old route winding into the Gilgit River. Up till now the Lake has not been drained successfully as recently witnessed by the authors (Fig.4). A recent field study witnesses and photographs advocate that calamity of Jan. 2010 is still a great challenge for the upstream and downstream communities, even for reaching the boat. Areas downstream from the lake remained on alert. Many peoples were evacuated to 195 relief camps. Two hospitals downstream evacuated both their staff and equipments. The Dawn News reported on 14th June 2010 that the water level continued to rise and 242 houses, 135 shops, 4 hotels, two school, 4 factories and several hundreds acres of agriculture land were further flooded. The villagers were still receiving foods and school fee subsides. They reiterated that 25km of the KKH and 6 bridges were destroyed. A special documentary was aired by Express News. The victims of the landslide and those affected by the expansion of the lake staged a sit in protest for the lack of government action and compensation payments to the affectees. The Punjab Government offered Rs. one hundred million for the aid to the victims and Rs.0.5 million for the relatives of those lost their lives in this calamity. Different authorities met communities, who suffered at the hands of the disaster. A UK based NGO set up a dispensary in Danyour for Hunza Landslide stricken people. They dispatched essential life saving drugs to the affected area. They were taking care of people's suffering from malnutrition, anemia, scabies, eczema and typhoid. 80-100 patients were provided free of cost life saving drugs. The charity organization was also providing access to clean drinking water in different camps.The Chinese's Embassy in Islamabad worked with Pakistani authorities and provided equipment and machinery along with engineering consultation. The misfortunate peoples were unsure of their future since they lost much of their fertile and wooded land in Sarat Village. The relief camps were never regarded as a source of satisfaction by the displaced communities. The affected displaced persons were getting 200 bags of flour daily to meet their food needs apart from medicines and other items of daily use (RCS, 2011). The role of the government and other agencies in this calamity has not been satisfactory. Presently, no relief work is being done in the area which is causing trouble to the residents. The building of an alternate road link of the KKH is estimated to cost Rs 80 million. The to and fro boat service currently available to the effectees demands heavy charges which the visitors of this unfortunate hazard can not afford on regular basis. Author interviewed various people of the area while traveling by the boat (during almost one and a half hour). They told that traveling was awfully tough with the family in the lake because young children, older and other family members were nervous and got scared while traveling by a boat.

FLUCTUATIONS IN WATER FLOW AND DISCHARGES IN HUNZA RIVER

Prior to the creation of a New Lake at Attabad, the fluctuations in the flow rate of Hunza River depended upon mainly seasonal effects The birth of a new lake at Attabad brought forth times testing challenges for the community around this area and beyond.

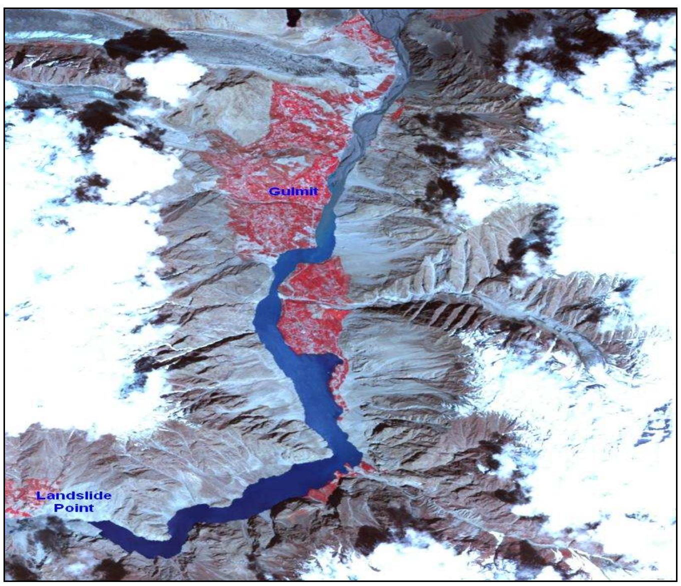


Figure 5 Latest satellite spot image of Attabad lake, Hunza Nagar, Gigit-Baltistan supports figure 3

During the initial period of winter the nature of problem was different than these on the onset of summer. Primary inflow on 26th May 2010 was 2,800 cu ft/s while Hunza River overflowing landslide dam was 3, 700 cu ft/s (100m^3/s) on 4th of June, 2010. On 26th May 2010 water volume was 330,000 acre feet (410, 000,000 m^3). At that time maximum length of the lake was 21km and depth 358 feet

(109m), while on 25th June, lake depth was visibly extended up to 116.7m and spillway reported discharge was 352 m^3 /s. The estimated total inflow was 419 m^3 /s against outflow of about 358 m^3 /s. Spot Image taken on 31st May, 2011 with debris height 8796 ft. At Attabad, landslide developed lake is keeping on spreading on, which is a big menace for the numerous other downstream villages (Fig. 5).

Initially, the discharge rate of flow was increasing up to 6th June, 2010 and remained almost stationary till 11th June then it again started rising up till 18th of June 2010. Due to rise in temperature, the channel widening continued which would be evident from the recently taken photograph of this channel on 4th of June, 2011 (Fig.3).

RESULTS AND DISCUSSION

Various scientists such as Burbank et al., (1996); Leland et al., (1998); Shroder et al., (1999); Barnard et al., (2001, 2004a, b, 2006) and Vance et al., (2003) designed the range of fluvial incision rates for the lower and upper reaches for Himalayan regions, that fluctuate from about 0.3 to 15.9 mm/a, commonly the rates difference between 2 and 6mm/a. According to Schumm, (1986 ;). the evolutionary process of a fluvial drainage system is extremely susceptible to active tectonic processes. Moreover, the streams have a conventional and calculable reaction to the neotectonic tilting, folding, and faulting of the land surface.

Results showed that, precipitation revealed a decreasing trend while the temperature exposed increasing trend. However, rainfall data has designated its steady trend. Water flow changes and groundwater are to be considered the key dynamics that has been carefully accounted for while assessing hydrological impacts of climate change.

Geomorphic changes are interlinked with the hydrologic changes.

SEDIMENTATION POTENTIAL

The Upper Indus Drainage Basin (152, 680 km2) includes catchments area of River Shyok in the East and of rivers Hunza and Gilgit in the North. Every drainage sub-system in northern Pakistan has its distinct dynamics of water discharge and sediment load and therefore demand specific attention (Khan 1992) In the present study estimation was made of the Hunza River drainage System. The water discharge and sediment data for 14 years periods (I990-2004) of the Hunza River taken at Dainyor gauging station is shown in (Fig. 6 and 7). Some interesting inferences can be drawn out of the acquired data of the Hunza River.

LITHOLOGIC FACTORS

The lithologic framework of the area involves southern part of the Asian Plate, represented by the Karakorum Range and northern part of the Indo-Pakistan Plate, represented by the Nanga Parbat-Haramosh system. The drainage area of the Hunza River is concerned with un-metamorphosed dominantly argillaceous-carbonatic sediments, North of the Axial Batholith and slates, schists and basic volcanic in the South. Except for the acidic plutonic rocks of the Karakourm Batholith, other lithologies weather easily and contribute heavily to the mass erosion. Most of these rocks are compact, hard and comparatively resistant to weathering. Remarkably, the Hunza River contributes more detritus as compared with the Gilgit River area (Khan 1992).

TECTONIC FACTORS

Although entire region of the Indo-Pakistan and the Asian Plates is tectonically active, yet uplift components are concerned more with the NE-SW Nanga Parbat Haramosh oroganic axis that influences the Karakorum Range as well. The estimated rate of uplift varies from 2 to12 mm/year (Zeitler, 1985) which is rather phenomenal. Such a tectonic activity is strong enough to shatter rock system, destabilize hill-slopes and generates mass erosion Due to lithologic differences; the Hunza River catchments area suffers strongly and had yielded higher volumes of erodable material as compared with the Giilgit River areas.

PHYSIOGRAPHIC FACTORS

The catchment area of the Hunza River hosts large number of long valley glaciers, Hlispar (61 km). Batura (59 km). Batura-Hopar (25 km). Pasu (24 km). Gulkin (18 km), Minapin (13 km), Pisan (4 km) and Gulrnit (7 km) and a large number of smaller in length. These glaciers are of Alpine type so that their maxima of snowfall and ablation occurs in the summer half-Year (Goudie et al) 1984). Notably, although these are among the steepest in the world yet their termini are at the lowest levels, in the Range of 2070 m or so while their average flow rate varies from 100 to 1000 m/year. These glaciers create deep erosional incision, adopt rapid modification, carry large lateral and end-moraine and suffer hazardous rock avalanches, collectively discharging large volumes of eroded metreial into the Hunza River drainage system.

Besides, monsoon frequently crosses Haramosh Range to intermingle with the north-easterly, and causes widespread precipitation in the Hunza River catchment area as compared with the Gilgit River area. Notably, of the seventeen rivers or China, Pakistan and India the Hunza River is surpassed in erodability by only two Chinese rivers, the latter, however, draining the easily erodable loessic material (Goudie et al. 1984).

- In the case of the Hunza River, there is a fair degree of conformability between volume of water discharge and the amount of suspended sediments.
- There are slightly less prominent maxima peaks in the Hunza River for the year 1978,
- The sediments transported by the Hunza River are dominantly silt and clay sized (83%).

The difference in the hydrologic and sedimentation potentials of the Hunza drainage is impressive. The explanation is rooted in the lithologies, tectonic and physiographic factors influencing the drainage area. While the Hunza River drains northern part of the territory along with its E-W oriented tributaries thus, river show distinctively different drainage patterns.

ANALYSIS OF OUR SUCCESS AND FAILURE AND THE LESSON LEARNT

Undoubtedly, Attabad Landslide disaster on 4th of January 2010 is seen as the most singular landslide episode in the last two decades, in which the village of Attabad was ruthlessly demolished. The geology of the area is complex due to severe tectonicsm that has been affecting this region (Hussain and Awan, 2009). However, we are not surprised since local reports had pointed the development of a series of large cracks during an earthquake (Mw= 6.3) on 20th November 2002 (Hussain and Awan, 2009). Its epicenter was located about 75 km to the south of the concerned village, which generated some mass movement in this region. During the following six years the cracks in the slope at Attabad gradually widened and lengthened. Remarkable shaking movements were noted in 2004 and again in 2005 and during the later we had the worst earthquake in Azad Kashmir (Mw= 7.6) (Hussain and Awan, 2009). The situation worsened and the slope at Attadad developed three cracks having displacements of over 5 meters. The Attabad landslide was recognized a place that experiences progressive inclination loss some years in advance of the final breakdown event. Focus Humanitarian NGO initially recognized this event. Petley *et al. (*2005) stated that, such collapses do not require a final trigger event. The deforming component of the slope was evacuated by an NGO Focus Humanitarian Assistance, on the joint recommendations of Hussain and Awan (2009). Finally, on 4th January, 2010, the slope deformed catastrophically when atmospheric condition was cold and dry. The initial collapsing event was large and dynamical in nature. However, there were video, photographic and eye witness as evidences suggesting the possibility of retrogressive breakdown over 24 hours or so. Luckily, prior to the final collapse, the local population was safely evacuated. This may be regarded as a meaningful success in a less developed country like Pakistan.

We must keep in mind the truth which says "that coming events cast their shadow before". Apart from this apparent success, we must learn some lessons from the events that followed. The relief supplies to the displaced affectees in different camps and those stranded up streams were partially met on initial days, but we utterly failed in sustaining this humanitarian program on firm footings. The affected communities are experiencing numerous problems and facing various odds, which need our attention and support. We must evolve a well defined strategy to mitigate the sufferings posed by these natural hazards. The NDMA should gird up loin to do the needful. The scarcity of funds is obviously a barrier, but a cry for help by local NGOs would certainly bear the fruit. We are still in the midst of uncertainties regarding the fate of this lake in the days ahead. Some expected emergencies are still knocking at the doors. There is strong evidence that similar large scale progressive failure is developing in northern Pakistan at Thoi in Yasin Tehsil in Ghizar District and at Gupis Village with a major contingency plan to meet expected happening in the days ahead (David Petley, 2010).

COMMENTS/SUGGESTIONS

Presently, there are several observations regarding natural and man-made tribulations that demand persistent attention and action. In order to keep this new cold lake functional and sustainable following comments/suggestions are being highlighted:-

1. A spill way has already been built by army engineers which has diverted water to its old route winding into the Gilgit River
2. In order to reduce pressure on the new lake and avoid unnecessary widening of the channel suitable diversions are immediately required and demand early action in order to facilitate water supplies to the growers and avoid eroding tendencies of flowing water.
3. At every diversion site, suitable hydal power/electricity generating system can be conveniently installed to boost up their agriculture productivity.

4. At two appropriate river junctions bigger hydal power electricity generating systems using indigenous technology can be installed to supplement exiting power generating measures.
5. To alleviate the sufferings of the affectees a stepping path needs to be constructed by cutting, leveling and filling with rocky material at appropriate sites.
6. The boat system presently in vogue as a means of transport is extremely vulnerable, expensive, risky and unreliable. It does not offer a safe and satisfactory transport facility.
7. The boat users can be advised to use scarf as mask to save themselves from the clouds of debris floating around the lake area.
8. In consultation with the members of the community environmentally friendly measures, would be taken to safe guard against polluting agents. To make some measures on sustainable basis the competition between the communities at different sites can be arranged on regular basis. The participants can be offered small incentives/ prizes for best contributions.
9. The surrounding area of the New Lake can be turned into tourist spots by revitalizing. A program can be chalked out to create hosting facilities at suitable intervals for prospective tourists on mutually settled turn system and agreed by wiling initiators and contributors. In this connection, the Japanese concepts of Satoyama (CNN 2011) can be replicated. According to Nakao (2011), "the principal aim of the Satoyama Initiative is to examine rural areas threatened with overuse or neglect and highlight new activities which can revitalize them". In this connection the author has the opportunity to witness a Japanese model of Satoyama in Kanzawa Prefecture which is open for us to replicate
10. To reduce sedimentation, suitable lagoons can be developed, with vegetative, orchards and flowering bodies. These will act as sources of

attraction to the tourists and the children around and generate a modest means of earning for the poor dwellers.

11. To achieve the above mentioned targets a comprehensive strategy will have to be adapted such :-
    a. change detection in land-surface features using pre- and post-event images acquired from high resolution satellites (Ground detail from 1m to sub-meter/ pixel, both in panchromatic and multispectal imaging modes)
    b. Detection of Landslides, and soil analysis for the appraisal of land-slide prone areas;
    c. Conduct social reconnaissance survey for assessing the general condition of the quake-hit mountain community
    d. Geomorphic analysis for the detection of new geomorphological formation
    e. As a pre requisite satellite image datasets from Landsat Thematic Mapper and SPOT-HRV sensors offer spatial high resolution having adequate potential to portray the diversity of environmental challenges and are badly required.

Conclusion

It is very difficult to predict that the real hazard has gone away because the water stored in the lake remains vulnerable to different natural processes like erosion, flooding, land sliding and possibly some seismic events. The NDMA has yet to remain greatly careful to meet massive challenges of outflow and inflow at Attabad during summer and winter. It is obvious from that rainfall during 2007 was highest (839.8mm) while gradually decreased in 2009 (148.8mm), but slightly increased (230mm) in 2010 Similar trends can be seen from temperature (Fig.6).

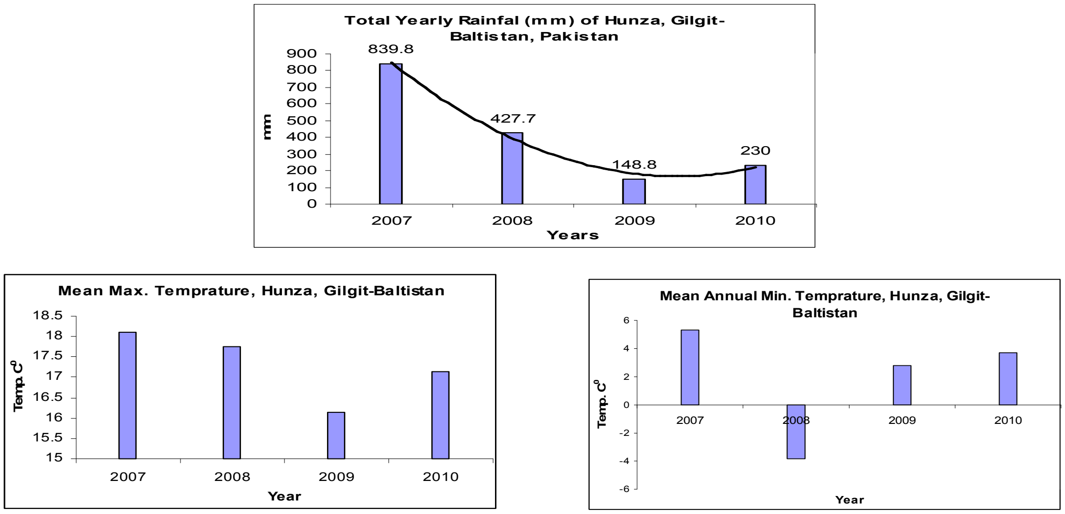
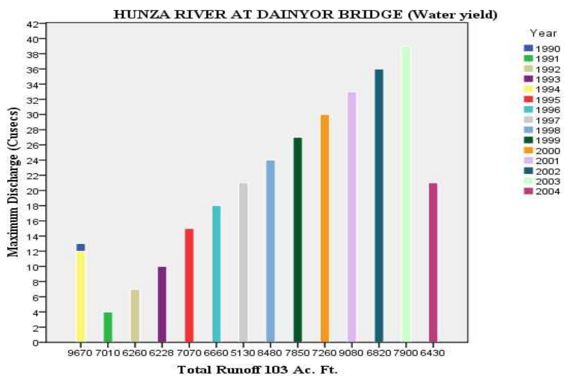
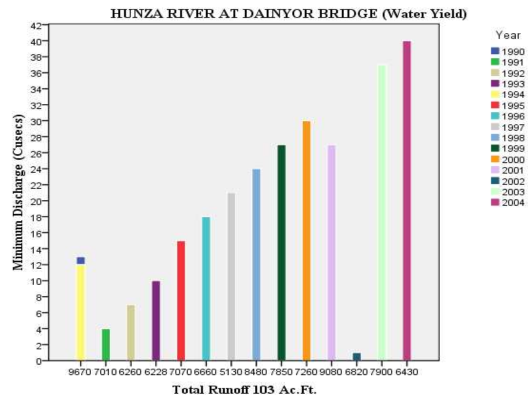
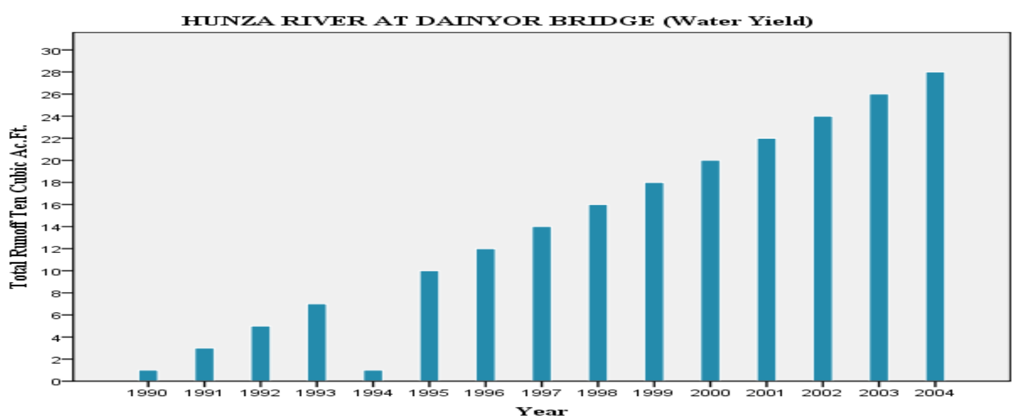


Figure 6 Graph shows the trends in rainfall corresponds the temperature parameter

This situation may be an indicator for climatic change during theses years. Based on these limited information PUV can not be reliably predicted. A graphic presentation has also made to analysis the available data (Fig.7). The sediment yield and water runoff was computed for the recorded years i.e. from 1960 to 2004 (WAPDA, 2010). The indicated sediment yield and runoff for the years of record showed the available mean annual runoff for 14 years of record (1990-2004) of 7, 438,000 Ac. Feet. Hunza River has perennial flow with a minimum of 1090 cusecs cubic acre feet during 1993. The peak flow during the period of record was 68200 cusecs 103 Ac.feet during 1994. The principal volume of runoff occurs during April through September due to melting of snow. The average annual sediment yield is expressed as 2.15 Ac.feet per sq. mile of drainage area. The average sediment concentration was 0.147% by weight. The sediment concentration depends upon flow of water. Moreover, maximum observed concentration was 27,800 ppm while minimum observed concentration was 3 ppm. The computed maximum concentration was 4240 ppm while observed maximum concentration was15800 ppm. The sediment transport computations are considered fair. The fourteen years average yield is considered to be near to average annual sediment transport and representative of the sediment characteristics of the stream although there is considerable variation from year to year. Bulk of the suspended sediment is carried during six months of year April to September. In Figure 7 graph 3 water yield shows a gradual increase in total runoff with every year except in 1994 when total runoff decreases. Similarly graph 4 shows that suspended sediment goes on increasing and decreasing randomly during same period of time. Results suggest trend of climate change but this is not sufficient data to predict future climate change scenario.







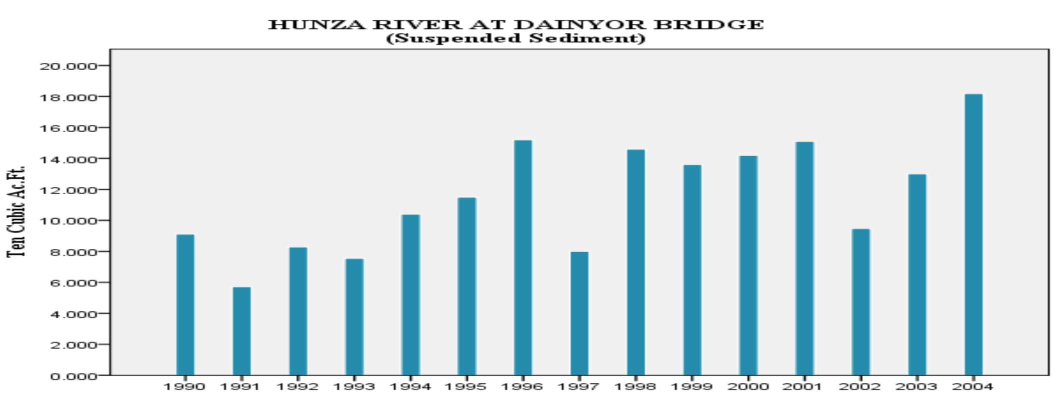


Fig. 7 Graphic presentation of water yield and suspending sediment Data of Hunza River at Dainyor Bridge, 1990-2004 (Source WAPDA)

Moreover, there is a need to adopt a visionary approach of facilitating the rehabilitation of KKH for greater national interests and catering for wellbeing of the communities. Present, boat service having vulnerable and dangerous, infrastructure is neither environmental friendly nor economically viable option. There is large prospective to considerate the interface linking surface processes and tectonic uplift. Yet, due to logistical and political inaccessibility in this region, only some geomorphic studies have been carried out.

The above study shows that each and every drainage sub-system in northern Pakistan may have its distinct dynamics of change. Therefore, for planning strategy to cop with the climate change, all sub-systems should be individually investigated and dependence should be avoided on the main drainage regime of the Indus River.

Present changing climatic scenario has made inconsistent weather parameter and therefore feeble predictable. Studies on glaciers and its relationship with climate are not up to the mark to deal with the outcome and consequences of the climate change on the highlands. The complexities to categorize long-term effects involve a time-scale of century's data, substantiation of climatic change of any area. A meticulous study is requisite for diverse regions to build up authoritative and valuable conclusion. The first round study has supply valuable understanding, though an advance in-depth research must be carried out and remedial measures formulated sequentially.

As a pre requisite satellite image datasets from Landsat Thematic Mapper and SPOT-HRV sensors offer spatial high resolution having adequate potential to portray the diversity of environmental challenges.

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