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Avalanche from Gangapurna Himal in Manang.

Fostering Knowledge on Disaster
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4.4 Seti Flash Flood: Technical Analysis and DRR Interventions

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Before the Seti River Flood Disaster After the Seti River Flood Disaster on 5 May 2012

1 Integrated Mountain Development (ICIMOD)
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ABSTRACT

The Seti Flash Flood of 5 May 2012 exemplifies some of the challenges the Himalayan countries faced with due to inherent geological, topographical, and climatological complexities. This flash flood which came out of a blue took many lives and damaged livelihood of many who survived. Cause of the event remained mystery for long and baffled many researchers looking for cause of the event until satellite data, air borne survey, and interaction with local people started to unveil the mystery. The cause and the subsequent processes that resulted in catastrophic flood revealed sequence of cascading events. The event however complex it may seem is a natural process, which went to become a disaster due to lack of preparedness. This article apart from putting in perspective the sequence of events that resulted in flood based on published article, reviewed DRR interventions in pre and post event. The review showed some positive development in improving preparedness but issue of sustainability question the effectiveness of the effort. Finally this article puts forth some way forward to sustain these interventions so that it can contribute in averting another disaster that no one knows when it will befall.

KEYWORDS: Seti river, flash flood, Pokhara, disaster, DRR.

1. Introduction

On 5th of May 2012 flash flood along the Seti River of Kaski District of Nepal (Figure 1) swept away infrastructures and settlements, killing about 72 people and damaging bridges and house [1]. It is one of the many such events Nepal and countries[6] across the Hindu Kush Himalaya (HKH) has witnessed and will continue to do so. Between 1900 and 2012 these countries witnessed 1912 major hydro-meteorological hazard and earthquake events out of which 40% of the total is flooding events (EmDAT). Similarly 74.7% of the people killed and 54.8% of the economic loss is attributed to flooding events. Historical disaster loss database spanning from 2000 to 2014 (April) managed by Ministry of Home Affairs (MoHA), Government of Nepal (GoN) has 12141 recorded events of 18 different disaster types[7] of which 38.5% (4674 events) pertains to flood and landslide events, which accounts for 55.91% of people killed and 48% of economic loss.

Seti flash flood of 5th May 2012 unlike rainfall induced flooding events was shrouded with mystery in terms of genesis of the event in the immediate days after the event. Initial unfounded rumor was of Glacial Lake Outburst Flood (GLOF), understandably so due to the source being in the high mountains. National and international scientists pondered hard to put pieces together and connect the dots to reveal actual happening and understand the phenomenon, thus giving way to many hypothesis. The strongest of all the hypothesis are [2] and [3] based on remote sensing analysis and air survey. Review of these hypothesis is presented in following heading. Understanding of the process in completeness and retrospect prepares us to better manage similar events if encountered in future. This article looks back in time, 3 years after the event and attempts to gain better understanding of the event based on analysis done by different scientists, and looks to the future mainly focusing on preparedness alternatives to minimize death and destruction.

6 Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan

7 Air crash, avalanche, boat capsize, bridge collapse, cold wave, drought, earthquake, epidemic, fire, flood, flood & landslide, landslide, forest fire, hailstorm, rainfall, thunder bold, wind storm, and others.

2. Geo-Physical Setting

The Seti River catchment, upstream of Dobhanghat is 1473 km2 (Figure 1) with elevation ranging from 750m to 7555m asl (Figure 2). North to south the Seti basin transcends from Tethys Himalayan Sequence (THS), Higher Himalayan Crystalline (HHC), and Lesser Himalayan Sequence(LHS) [4]. The THS contains a sequence of Cambro-Ordivician to Cretaceous marine sedimentary rocks that represent a large carbonate shelf sequence formed along the northern passive margin of the Indian plate [5]. South of THS is HHC, referred as Upper Greater Himalayan Sequence (Upper GHS) by [5]. Upper GHS consists of quartzite, schist, gneiss, migmatites and leucogranites. Further south is LHS mainly consisting of shale, slate, siltstone, sandstone, graphitic schist, phyllite, and amphibolite [4].

The Seti River starts at the base of Annapurna about 2500m asl and traverse south to an elevation of 1100m asl at Seti Dam, a drop of 1400m in longitudinal distance of 26 km (Figure 2). Longitudinal

Figure 1. Elevation map (top) and geology map (bottom) of Pokhara area. Geology map is sourced from [4].

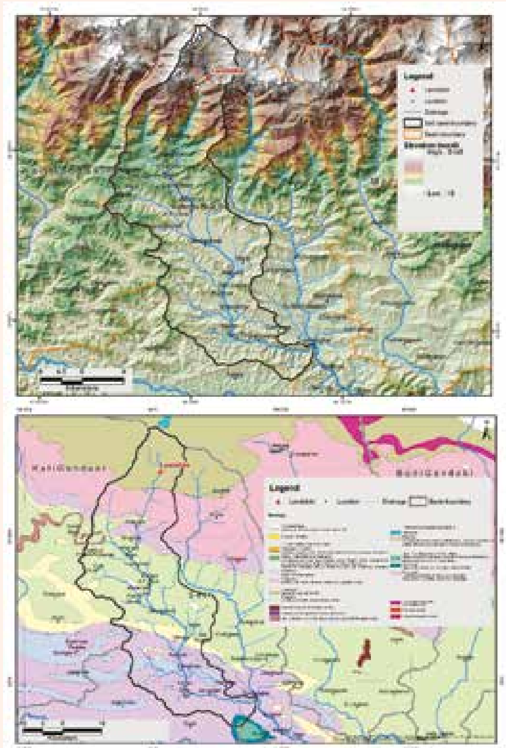
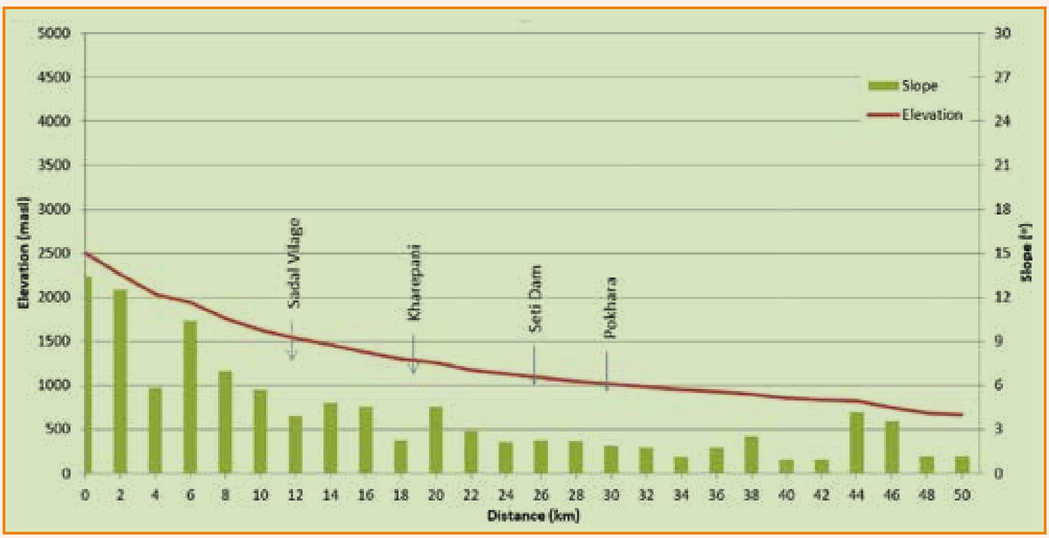


Figure 2. Longitudinal profile of Seti River from the source.



river profile as mapped using 90m SRTM DEM show higher gradient in the north as compared to south. Upper reaches of the Seti River is topographically challenging due to steep and narrow gorge, due to which it is devoid of human settlements.

3. Cause of the Seti Flash flood

There were many speculation about cause of the flood in immediate days after the event, including GLOF and Landslide Lake Outburst Flood (LDOF). As satellite data of post event became available and airborne survey possible, the cause of the flood was ascertained to be sequence of events as organized below in the order of occurrence.

3.1 Rockfall and daming of Seti river

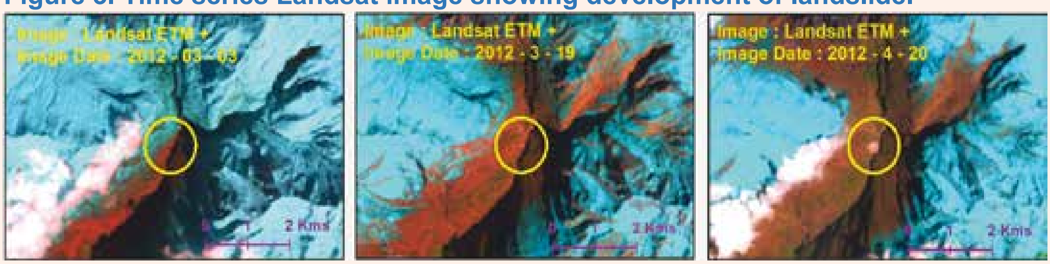
From the very beginning the issue of contention was source of the flood water which is estimated to be 7,480,000m3 [6] with estimated peak discharge varying from 10 m3/s [7] and 8,400m3/s [6], at Kharapani. This actually made locals speculate the event to be either GLOF or LDOF. Rapid assessment by a team in International Centre for Integrated Mountain Development (ICIMOD) based on satellite data (Landsat) mapped a fresh land/rock slide scar (Figure 3) and indicated likelihood of a role in the flood generation process to explain large volume of flood water, which was refuted by [2]. The Landsat ETM+ images of 2012 (3rd and 19th March, and 20 April) used by ICIMOD team clearly showed progression of rockslide in months preceding to the event. Rockslide which was non-existence in image dated 3rd March grew from 0.01 km2 to 0.06 km2 between 19 March and 20 April, over a period of one month.

The role of the rockslide has now been ascertained after image analysis, air borne survey and field investigation by a team comprising of international and national experts. The rockslide "affected a knick point in the Seti River gorge and impounded glacial meltwater and spring snowmelt" which got breached by a process triggered by an avalanche in southwest flank of the Annapurna IV (Figure 4).

3.2 Snow, ice and rock avalanche

Snow, ice and rock avalanche [2],[7],[8] with estimated volume of 32,725,000m [6] occurred in southwest flank of the Annapurna IV (Figure 4) at about 09:00 AM local time on 5 May 2012, as inferred from the amateur video clip captured by Captain Alexander Maximov of the Aviaclub Nepal (https://www.youtube.com/watch?v=Uk82ggshSKs). The impact of the avalanche is said to have created seismic waves which was picked up by global seismic network which was analyzed by S.G.Eksrom, a Columbia University geoscientists, according to which time of avalanche is estimated as 09:09:56 AM [9]. So the avalanche is expected to have occurred between 9:00 AM and 9.09 AM.

Figure 3. Time series Landsat image showing development of landslide.



Dimension of the failure that initiated the avalanche is summarized in Table 1. The avalanche made near vertical fall of about 1,500m from 6,700 m asl to 5,200m asl [7] which generated high potential energy enough to pulverize unconsolidated rock debris (glacial moraines and ancient glacial lake silts and gravels) resting unstably in the deep bowl of the Sabche Cirque [8]. The volume of material that fell on the base of the Sabche Cirque is estimated as 14,500,000m3, while the volume of debris which flowed into the Seti River was calculated at around 18,230,000m3 [6]. Estimate velocity of the avalanche was 200km/hr [6] and the high energy fall caused the failed rock mass to disintegrate into pieces producing a large amount of dust clouds, and frictional heat produced due to debris movement melted ice and snow which formed hyperconcentrated slurry flows leading to even accelerated movement of the debris towards the Seti gorge [6]. The high speed avalanche created air blast strong enough to fell tress along the right flank of the upper part of Seti gorge (Photo 1).

3.3 Breaching of rockslide dam

Energy of the avalanche was so that transported material were made into high-speed debris which fell into Seti gorge. The average slope of the base of the Sabche Cirque where dislodged materials made an impact and inlet of the gorge is 14° [6], which played a role in generating high speed avalanche. This high speed avalanche consisting of ice and rock made into impoundment reservoir, and aided by

Figure 4. Process flow to illustrate sequence of event that led to Seti flash flood.

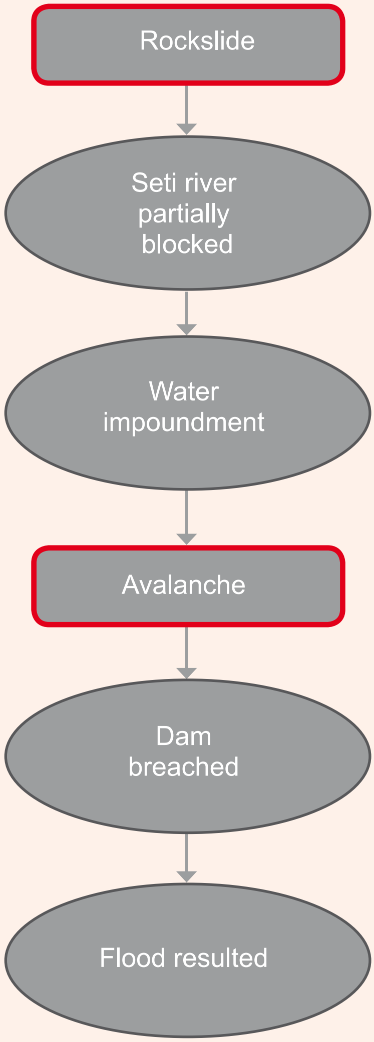


Table 1. Summary of detachment block that induced avalanche (Source: [7]).

Aspect	Unit (m)	Basis
Width	Approx. 550	Based on the satellite image
Depth	Max approx. 100, Average approx. 70	Based on the satellite image
Length	850	Based on photo taken from helicopter

Photo 1. Narrow and deep gorge in the upper reaches of Seti River. Also visible are fallen trees due to air blast the avalanche in ensuing processes generated (Source: [2]).

"violent ground-surge event, plus possibly an air blast caused by a violent gravity flow of airborne debris then burst the rockfall dam" [8]. Sudden release of the impounded water is source of enormous volume of flood water which is estimated to be 7,480,000 m^3 [6] at Kharapani village, about 20 km downstream of impounded reservoir.

This subsequent breach of rockslide dammed reservoir resulted in flood with estimated volume of 7,480,000 m3 [6] of water at Kharapani, and estimated peak discharge ranging from 10 m3/s [7] to 8,400m3/s [6]. The flow was mainly muddy mix of fine silt similar to glacial flour found at the source [2].

On the large question of if climate change had any role in causing Seti Flash Flood, report prepared by a team of scientists including National Aeronautics and Space Administration (NASA) of the United States refutes the role and attributes it to be "geological changes" [10]

4. Impact

The impact of the event was felt further downstream as the physical challenging topography was devoid of human settlement and infrastructure in the immediate vicinity of the source. Sardikhola Village Development Committee (VDC) and Sadal village in Machhapuchhre VDC are worst hit by the powerful outburst [10]. Kharapani settlement (also known as Tatopani) in Sardikhola VDC and Sadal village in Machhapuchhre VDC (Figure 1) were hit hard [11].

In total 71 people (including 40 missing) loss their life and estimated property loss of worth of Rs. 49.25 million reported according to the report made by DDRC [11]. [8] reported loss of lives to be 72. In total 4 houses, 2 local temples, 16 temporarily erected sheds, 2 suspended trail bridges, 7 tractors, 3 mini trucks, and 1 van were swept away by the flood [7]. In the same article [7] accounted for 52 goats and 17 cow and buffaloes killed based on the data provided by the rescue team. Most of the people killed were picnickers, locals, tourists and laborers working on sand/ stone quarry in the river bank [10]. The wash out also destroyed two water supply system supplying 80% of the drinking water to Pokhara valley.

It is praiseworthy that alert sounded by Captain Alexander Maximov of the Aviaclub Nepal about the avalanche, radioed to aviation tower in Pokhara airport saved from taking more lives and inflicting greater loss from the event. This message was immediately disseminated by the tower to concerned agencies and local FM radio stations.

5. DRR Interventions

5.1 DRR interventions implemented

Disaster risk reduction interventions can be well spread across time and space, from early warning to post disaster reconstruction. In this case alert sounded by Captain Alexander Maximov and disseminated through other communication channels (FM, mobiles) forewarned the downstream communities, and gained time in preparing state mechanism to respond to the inevitable. Humanitarian and national agencies responded immediately, as a result of adequate preparedness put in place by state and non-state players [11]. The response was led by District Disaster Relief Committee (DDRC) in coordination with the security forces (Nepal Army, Nepal Police and Armed Police Force), the Nepal Red Cross Society (NRCS) and other humanitarian agencies. The coordination was reported to have been of highest level and OCHA report dated 8 May [11] reports of distribution of immediate cash and NFI support to the flood affected families and the families of the deceased by DDRC and NRCS. Unlike other disaster, flood can render entire affected area useless by turning into field of debris obliterating whatever potential and promise it had once, and government had relocated affected families to safer ground.

Apart from the immediate response a 2 year (April 2012-March 2014) project titled "Building Disaster Resilience Community" (BDRC) in Pokhara was implemented by ActionAid Nepal, and Practical Action Nepal, along with Siddhartha Club (a local partner) [12]. The project put in place structural and non-structural flood risk management measures. Non-structural measures included formation of Disaster Management Committees (DMC) and Task Force at different levels: Wards (18 Wards[8] of Pokhara Sub-metropolitan City), VDC[9] (7 VDCs) and Municipality (Pokhara). Task

Photo 2. Display board at District Administrative Office, Pokhara displaying river water level.

[8] Ward No. 1 to 18.

[9] Hemja, Lamachaur, Puranchaur, Machhapuchhre, Sardikhola, Lahachowk and Ghachowk.

force was also formed in Government Schools. Capacity building of stakeholders were done through training and workshops on first aid, drinking water, and sanitation under BDRC project. The project also distributed search and rescue kits, life jackets, gloves, lights, hand mike, and rope to locals of aforementioned 18 Wards and 7 VDCs and additional 6 Wards[10] situated close to the river. On structural measure the project installed Flood Early Warning System (FEWS). The FEWS comprises of a bubbler sensor in Seti River and meteorological station in Jyamibari VDC upstream of which no settlements exits. The details (rainfall, water level) from the sensors are displayed in display boards installed in Kapuche and DEOC through CDMA technology (Photo 2). One designated person has been assigned to maintain the system and communication any alarming situation develops to downstream communities. Designated focal persons assigned in the downstream settlements (eg. Santi Tole) are provided with Siren system which upon getting informed about the rising water level and heavy rainfall will be sounded out to alert locals.

In addition usual flood control measures like gabion walls are put in place regularly on need basis to deflect river water from over topping banks and minimizing flow velocity.

5.2 Gaps and needs

There seems to be complete lack of preparedness prior to the Seti Flash Flood event, also echoed by experts in different forums [13]. Things has certainly improved after the event with community based activities implemented under BDRC enhancing community resilience by EWS and more structured response mechanism in place [12]. These interventions will, if sustained will go long way in averting disaster like in past. However, what is understood from interaction with authorities (CDO office, LDO office) as existing gap is non-existence of flood hazard maps, a tool to implement land use codes for planning and implementing development activities. Disaster is a result of interaction between exposure elements like human settlements and infrastructures with hazard (flood in this case). Strict compliance to flood hazard maps as planning tool for development activities manages large part of the risk by minimizing the interaction between these two important facets of disaster triangle.

Upstream-downstream linkages bear more relevance in connection to flooding, as source for deluge is often in the high mountain setting. Despite that there is lack of high mountain monitoring instrumentation to monitor physical processes which is of high importance for many domains including disaster management. There is need for such high altitude monitoring stations if we are to understand high alpine processes, aspect critical for proper management of downstream environment.

Human memories are short and more than often our readiness to respond appropriately enhanced through capacity building interventions like training, workshops and drills decline over time. Emergency drills, workshops and training needs to be made a regular exercise so that the knowledge and experience gained is sustained. Ideally such drills will be effective if done during pre-monsoon with involvement of communities and disaster managers.

Rampant extraction of sand and boulders from Seti River has long raised concerns of various quarters [14]. The unplanned extraction has proved as counter measure

[10] Ward No. 1, 3, 9,10, 15 and 17

to some DRR interventions and thereby aggravated the risk situation. Quarrying in haphazard fashion has undermined flood protection measures (gabion walls and boxes put in place) to avert flooding thus rendering protection measures futile. The licensing for sand and boulder extraction therefore has to be more regulated with due consideration to impact particularly from flood risk.

6. Way Forward

Based on the discussions in preceding sections, there is a need to have greater role of Disaster Management Committees (DMC) to ensure better mainstreaming of DRR into development planning and implementation process. The DMCs should be empowered and given a regulatory role while licensing of activities such as mining of river materials. Flood hazard maps along the Seti River is imperative as a blue print for development if new development is to be made disaster resilient. Although it is difficult to model flash flood like the one that happened on fateful day of 5 May 2012, by and large flood hazard map with extreme situation can help minimize risk.

Ownership of DRR measures put in place by different projects by state and in particular by local government is imperative for sustenance of the measures for making communities disaster resilience. DMC should conduct drills at least once in every year at all levels so that desired response readiness is ensured. A complete drill also ensures technical FEWS is functioning, without which ensuing response measures is impacted.

Increasing high mountain monitoring stations has become matter of urgency as these alpine environment is sensitive to climate change and associated changes. One needs to understand the situation in the source if we are to effectively manage impact zones in the downstream.

7. Conclusions

The Himalayan region with complex topography and active geomorphology is hot spot of natural hazards which in most cases result in disaster. Hazard is a natural process and cannot be averted completely, while with appropriate risk reduction measures impact of natural hazard can be minimized. Therefore both hazard and risk management options need to be considered. We should accord emphasis on pro-active than reactive DRR measures, and has to include state mechanisms and communities in partnership to work closely in addressing increasing challenges faced by communities.

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