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# Geomorphological Evolution and Disaster Dynamics in Pokhara Valley: Insights from the 2012 Seti River Flood

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**Abstract**
*Pokhara Valley, located between the Himalayas and Mahabharat range, is a geologically active region formed through long-term tectonic uplift and fluvial processes. The Seti Gandaki River, originating from the southern slopes of the Annapurna Himalayan range, has played a central role in shaping the valley's flat terrain. Over thousands of years, the river has eroded materials from the high Himalayas and deposited them in layers across the valley floor. Although historical records of flood events are limited, radiocarbon analysis of sediment layers indicates that much of the valley's current structure developed between 600 and 1,100 years ago. On May 5, 2012 (Baisakh 23, 2069 B.S.), an unexpected and off-season flood struck the Seti River. Triggered by a massive rock and snow avalanche from Annapurna IV, the flood carried high volumes of debris and caused extensive destruction claiming 72 lives and damaging infrastructure, ecosystems, and settlements downstream. The event is considered a natural continuation of the valley's geomorphological evolution. It highlighted the risks posed by fragile geology, narrow gorges, and rapid urban expansion near the riverbanks.*
*The ongoing erosion by the Seti River and the elevation gap between the Annapurna range and Pokhara, similar flood events remain a significant threat. The Seti River, while vital to Pokhara's formation and development, continues to present both opportunities and dangers that must be managed with urgency and foresight.*

**Kewords:** Seti River, Pokhara valley, sedimentation, flashflood, landslide, vulnerability

## Background

Pokhara is one of the most beautiful places in the world, known for its unmatched natural beauty and unique geomorphological formation (Gurung, 1970). Located almost in the middle of Nepal, this city lies at the foothills of the Annapurna Mountain range. The Seti Gandaki River flows the almost center of Pokhara. It originates from the southeastern slopes of Machhapuchhre mountain and the southwestern part of Annapurna IV.

Pokhara Valley is believed to have been formed through a combination of geological activity and continuous sediment deposition carried by the Seti River (Yamanaka, 1982; Singh, 1990). These processes have played a central role in forming the flat terrain seen in the present.

The region is not only naturally stunning but also culturally rich, attracting people from all over the world due to its blend of landscape and heritage (Shrestha, 2004).

This geological behavior allows the river to alternately deposit sediments or cause powerful erosion, contributing to both land formation and transformation (Selby, 1985).

The flat areas from Bharabhari near Pokhara to Bhimad in Tanahun district are mainly composed of the sediment deposits brought by the Seti River (Koirala, 1998). The river appears milky white because it carries fine limestone and calcareous sediments along its course hence the name Seti, which means "white" (Shrestha & Kshetri, 2008). This ongoing geomorphological evolution makes the valley highly susceptible to natural hazards such as landslides, debris flows, and flash floods (Koirala et al., 2013). Although under normal conditions the river deposits material slowly, during flooding it becomes a highly destructive force, capable of reshaping entire landscapes. The 2012 flood, in particular, serves as a striking reminder of the geological power of the Seti River which force that both formed and continues to transform the Pokhara Valley. This study tries to describe significant importance as it investigates the geological dynamics of the Seti River and its critical role in shaping the formation and structure of the Pokhara Valley. It emphasizes how natural geomorphic processesvlike including glacial melt, erosion, and sediment deposition etc. have historically contributed to the development of Pokhara's landscape, while also revealing the destructive potential of the same processes when intensified, as seen during the 2012 flood.

The primary objective of this research is to analyze the interrelationship between the Seti River and the geomorphological formation of Pokhara Valley. It specifically aims to assess the causes, origin, and impacts of the Seti River flood, with focus to search supporting evadance of Pokhara Formation

## Methods and metrials

The information gathered primary and secondaru surces for this study. Secondary data was collected from previous research papers, seminar presentations, and published materials that discussed the causes and effects of the flood. Geographic data (secondary spatial data) was also used, including topographic maps published by the Survey Department. These maps were digitized using GIS software and mapped using the Transverse Mercator Projection based on the D_Everest_1830 datum. Since the flood's origin point was not easily accessible, tools like Google Earth and available photographs were also used. Based on all these sources, the study analyzes various aspects of Pokhara's geological structure and the behavior of the Seti River flood.

## Study area

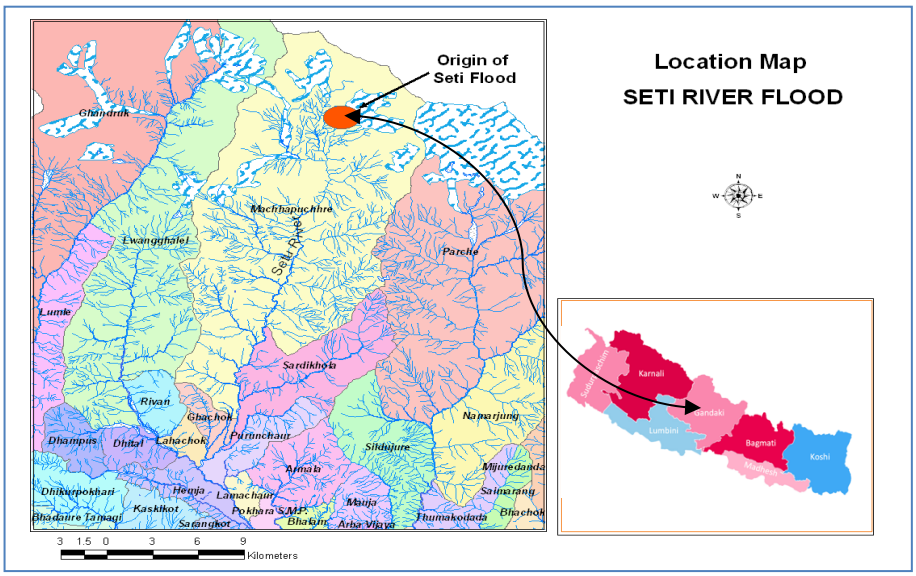
The study area lies in central Nepal, mainly covering parts of Kaski District, along with the southern borders of Manang and Mustang districts. The Seti River, which flows through

this region, passes directly through the Pokhara Valley. Geographically, Kaski District stretches from 28º06' to 28º36' North latitude and from 83º40' to 84º12' East longitude

The Seti River originates from the Machhapuchhre Ruaal Municipality, specifically from a place called Gyamirbari where the first settlements began. From there, the river flows through Sardikhola, Ghachok, Purunchaur, Hemja, and Lamachaur, eventually passing through the heart of the Pokhara Valley. The land shaped by the Seti River stretches for approximately 50 kilometers, from Machhapuchhre Kaski to Bhimad in Tanahun District.The elevation of Pokhara Valley ranges from around 500 meters above sea level at Kotr. The elevation gradually increases upstream along the river. The overall area of the valley spans approximately 850 square kilometers. This study focuses on the landslide origin points, the areas affected by those landslides, the location where the flood began, and the flood-impacted regions near the and Pokhara valley foirmation. it is examining that reflection of 2012 flood and its sediment diposition, assume that Pokhara valley formed by previous disaster dynamic I the geohraphicha histriy.

**Figure 1**

***Location map showing the course of the Seti River***




Source: Topographical survey map-1997 & field verification 2069

**The Role of the Seti River in the Formation of Pokhara's Geology**

The geological structure of Pokhara Valley is the result of complex tectonic activity over millions of years, particularly the collision between the Indian and Eurasian plates. This process began during the Cenozoic era, around 70 million years ago, when the land that is now Nepal lay beneath the Tethys Sea (Singh, 219). As the Indian plate continued to move northward beneath the Eurasian plate at a rate of approximately 20 cm per year (Selvy, 92), massive pressure caused crustal shortening and the formation of the Himalayan range between 30 and 2 million years ago. The Seti River, originating from the southern slopes of the

Annapurna range, especially near Machhapuchhre previous study shows that it is played a central role in shaping the Pokhara basin. Similarly, Kali, Yamdi, Fusre, and Bijayapur streams also further shaped the valley. It carried glacial meltwater and sediments from high altitudes and deposited them across the valley, forming flat plains and layered geological structures (Gurung, 1970).

Pokhara is dominated by coarse gravel and rocky materials, supporting the theory that flooding and glacial action, rather than long-standing lakes, shaped its terrain (Gurung, 1970). Rapid sedimentation is believed to have occurred within the last few centuries (Yamanaka, 2007), with radiocarbon studies dating key formations such as Ghachok and Tallakot to between 600–1,100 years ago. The flood event of May 5, 2012 (Baisakh 23, 2069 B.S.) is seen as a continuation of these natural geological processes. The Seti River and its tributaries Sandhu and Batase merge at "Teensira" and flow through a geologically fragile zone composed of limestone-rich, soft soils. Thus, the Seti River has been both a creator and destroyer in

**Figure 2**

*Geomorphological Features of the Seti River*

Geological history over times, but occasionally unleashing devastating floods, reminding us of its dual nature (Nepali proverb: The same fire that burns also gives warmth). The Pokhara Valley's flat landscape is a product of long-term geomorphological evolution shaped by glacial activity and the sediment-carrying Seti River. Originating from the southern slopes of Annapurna IV and Machhapuchhre, the Seti and its tributaries (Sandhu and Batase Khola) transported debris and deposited layers of sediment over thousands of years, forming stratified landforms in the basin (Gurung, 1970; Yamanaka, 2007). During the last Ice Age, glacial meltwater carried moraines into the valley, creating the present flat terrain. Natural lakes like Phewa, Begnas, and Dipang remain in areas where flood deposits did not fully reach. Radio-

carbon dating suggests that much of the valley's present structure formed between 600 and 1,100 years ago (Yamanaka, 2007). The devastating Seti flood on May 5, 2012, triggered by a massive rock and snow avalanche from Annapurna IV, exemplifies the valley's ongoing geological transformation.

**Disaster dynamics**

The Seti River originates from the snow-covered Annapurna IV (7,525 meters), Annapurna III (7,555 meters), and Machhapuchhre (6,998 meters) ranges. Seasonal snowmelt and shifting snowlines destabilize the terrain, especially in the periglacial zones, where thawing permafrost loosens soil and rock. This leads to landslides and avalanches, which increase the river's flow and erosive power. A major flood in 2012 was triggered by such a mix of rockslide, avalanche, and rapid snowmelt. The river's milky white color comes from dissolved limestone it carries through fragile, erosion-prone terrain. Even without local rain, snowmelt and geological instability in its headwaters can cause sudden floods in downstream areas like Pokhara.

**Landslide as a Cause of the Seti River Flood**

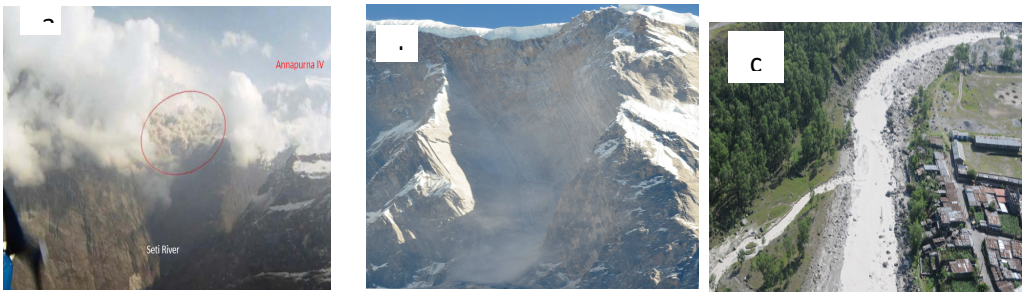
The landslide originated from Annapurna IV, where a rock mass approximately 300 meters wide, 1,300 meters tall, and 30 meters thick collapsed. This massive fall is also supported by aerial photographs taken by Avia Ckobe pilots who captured the event as it occurred.


Source: Field Study 2069 B.S., Department of Mines and Geology

According to the Himalayan Disaster Report (Kartik 26, 2069 B.S.) photos show dust clouds rising from the rockfall, and the path of the landslide clearly indicates that a large volume of debris was dislodged. NASA satellite imagery taken after the incident confirms that the landslide originated from the glacial area above. As the rock mass fell, it applied pressure to the loose and unstable materials below, displacing and pushing them into the river. The sudden increase in volume caused the Seti to flood downstream.

As the flood moved downhill, the speed of the river increased due to the volume and steep terrain. The fast-moving water, combined with heavy sediment and debris, acted like a cutting tool and eroding riverbanks, removing trees, and scouring away soil and rocks. The force of the flood also deposited large amounts of debris in low-lying and flat areas where the river spread out.it is assumed that, Pokhara vlley formed different time phases in the past therefore, Ghacok formation, Tallakot formation, Pokhara formation oceured different disaster dynamics stage which can prove tha last Seti flood disaster.

**Figure 3:**
***Photographic evidence of rockfall and resulting dust cloud from Annapurna IV. (Slide area a and b and c High-Risk Areas Near the Seti River)***




Sources: Source: Goolge Map, May 7, 2012

**Geographical Impact of the Seti River Flood**

Floods are natural events that significantly alter the landscape, and the sudden flood in the Seti River is no exception. The disaster claimed the lives of 72 people and caused widespread destruction. It swept away Kharapani Bazaar, destroyed hot water springs near Kharapani and Sandhukhola, suspension bridges, livestock, homes, and significant amounts of property.

The flood carried a massive volume of sediment and debris from the river's origin through its narrow gorges. Because of its high velocity, the river deposited materials up to 50 meters above the normal riverbank in some areas. The force of the flood eroded the riverbanks, especially near upper Sandhukhola, while low-lying Poche farmlands were entirely covered by sediment. Similarly, farmlands and homes in Sandal were buried. The narrow areas around Poche and Lower Ewang experienced intense erosion, while Kharapani was buried under thick deposits.

The most heavily affected zones were from the confluence of Sandhukhola southward including Gyamirbari, Poche Khola junction, Sandal, Kopuche, and Kharapani where massive deposits of flood debris accumulated. In Poche, the large number of uprooted trees buried in sediment serves as visible evidence of the flood's power.

**Figure 4**
***Kharapani of Kaski, before and after the flood event***


Overall, the flood had a strong impact all the way from Sandhukhola to Ramghat. In Ramghat (Pokhara), flood debris reached up to 5 meters deep. Above Sandhukhola, the terrain is very steep, so there was less sediment deposition, and after passing through Pokhara Valley, the river deposited less material overall.

The flood also severely damaged the biological diversity along the riverbanks in the Himalayan region. The quality of sand extracted from the Seti River has since declined, and materials used from these deposits to construct infrastructure may lead to weaker structures

**Measures to Minimize the Impact Disaster**

From a geographical perspective, the structure of Pokhara and the origin of the Seti River, along with the regular flow of debris and sediment, suggest that the 2012 Seti River flood (Baisakh 23, 2069 B.S.) was part of a natural, recurring process. To reduce future flood risks in Pokhara, a multi-pronged strategy is essential. This includes establishing an early warning center in Kobuche to monitor the fragile Seti River headwaters and enforcing strict zoning laws to prevent settlements in high-risk flood zones. Natural riverbanks should be preserved and reforested, while hazard mapping and geological assessments must guide long-term planning. Public awareness campaigns are crucial for community preparedness. Additionally, infrastructure like retaining walls and vegetation should be used to stabilize erosion-prone areas. A permanent emergency response unit should be stationed in Sandal or Kobuche. Technological interventions such as widening narrow river channels and removing obstructions at chokepoints (e.g., KI Singh Bridge to Ratopahiro) will help improve floodwater flow and reduce damage during future disasters.

**Summary**

Pokhara Valley, a geologically formed flat basin nestled between the Himalayas and Mahabharat range, owes much of its landscape to the Seti Gandaki River. Originating from the

southern slopes of Annapurna IV, the river has, over millions of years, eroded high Himalayan terrain and deposited layers of sediment that shaped Pokhara's fertile plains. However, this same natural force turned catastrophic on May 5, 2012 (Baisakh 23, 2069 B.S.), when a massive rock and snow avalanche estimated at 300 meters wide, 1,300 meters high, and 30 meters thick fell from Annapurna IV, triggering a sudden flood. The disaster claimed 72 lives and devastated areas like Kharapani Bazaar, hot springs, suspension bridges, homes, and farmland. Floodwaters, loaded with debris, deposited sediment up to 50 meters above riverbanks, especially from Sandhukhola to Ramghat, where layers reached as high as 5 meters. in Ramgat. Settlements in low lying and narrow riverbank zones such as Gyamirbari, Sandal, Kopuche, and Lalrin Bazar were suffered the most, highlighting the region's vulnerability. Factors like steep terrain, unstable geology, narrow gorges, and the lack of early warning systems worsened the impact. This article examines the 2012 Seti River flood in Pokhara through an integrated lens that bridges academic research for preparedness and proactive risk reduction in Pokhara.

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