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**Short Communication**

# Mapping of Vulnerable Landslide Zones by Large Scale Mapping in and around Devprayag Area along National Highway 58, Uttarakhand, India

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**Abstract**

Landslide is one of the most common disaster of mountainous region of Uttarakhand during monsoon season which results in loss of life, property and transportation communication. Present study aims to investigate vulnerable landslides zones and their causative factors in and around Devpraag town, Uttarakhand along National Highway (NH) 58. NH 58 is the life line for residents of the district Tehri, Uttarkashi, Chamoli, Rudraprayag and Pauri Garhwal. Satellite imagery, toposheet (53J/12) and GPS on GIS platform used to analyze the data. Large scale mapping carried out in the study area along National Highway 58 to identify the slope instability. Sandstone, quartzite of Chakrata Formation and phyllites of Chandpur Formation of this area displays different types of discontinuities and shuttering of rocks. Debris slide, rock fall and creeping are most prominent mass movement observed in the study area. Present road widening under Char Dham Yojana project along NH 58 necessitates simultaneous suitable mitigation and treatment of potential landslide zones. There are 9 vulnerable landslides observed in and around study area. Based on the information, landslide inventory and landslide location map prepared. The paper discusses about the causative factors of triggering of landslide such as higher degree of fracturing and joints in the phyllitic terrain coupled with developmental activities, reoccurring rainfall and enormous stream power at the base. The bioengineering, retaining wall, wire mesh, anchoring, rock bolting, shotcrete and culvert pipe are the suggested mitigation measures which will be very helpful for slope stability and smooth operation of vehicular traffic in the future.

## Introduction

The landslide describes a number of processes that contribute to the downward and outward movement of slope-forming various materials like rock, soil, man-made fillings or a

combination of these that are radically different types of mass-waste processes occurring on the surface of the soil (Varnes, 1958, 1978, 1984; Hutchinson, 1968; Cruden and Varnes, 1996; Dahal *et al.,* 2009; Hungr *et al.,* 2014; Siddque and Pradhan, 2018) . It is a gravitational movement that causes immediate and visible earth surface modifications (Thonbury, 1954). Cruden (1991) defined landslides as movement of a mass of rock, debris, or earth down a slope that encompasses various kinds of nature-related slope failure processes.

In India, hazards due to landslide are very frequent in the tectonically disturbed areas of the mountainous region i.e. Himalaya. The ongoing high tectonic deformations and discontinuities in the Himalayas results into higher vulnerability for various natural hazards. The landslides in hilly region are generally confined along the hill-cut slope or road section which are frequent during monsoon but may also be triggered in dry season by rock blasting done of road widening (Singh *et al*., 2008). The National Highway 58 connecting Rishikesh town to China Border (i.e. Badrinath-Manna border) is a strategic road. The Devprayag town also connects to Char Dham yatra.

Among the all-natural disaster occurred worldwide from 1990 to 2005, the landslide alone constituted 4.89 % (Kumar *et al*., 2008). Globally landslide causes loss of mass approximately 1000 deaths per annum and property worth US $ 4 billion (Lee, 2007). But in the context of damage caused by landslide in Himalayan region, it is around 200 deaths per year with property loss of more than US $ 1 billion, which is of 30 % global loss (Sarkar and Kanungo, 2004). This trend is an alarming stage in Himalayan region because of diverse contributing factors for landslide such as shearing, adversely oriented structural discontinuity (fault, unconformity, contact etc), adversely oriented mass discontinuity (Bedding, schistosity etc) (Cruden and Varnes, 1996). During the monsoon period of 2004, deaths of around 78 people were reported in various incidences caused by inherent and extrinsic factors (Pande, 2006).

Varnes (1984) and Hutchinson (1995) have enlisted major factors which influence the landslide movement such ason bedrock geology, geomorphology, soil, land use/land cover and hydrogeological conditions as inherent factors. Kumar and Anbalagan (2015) had discussed influence of rainfall, seismic activity, cloudburst and unplanned blasting and drilling as the extrinsic factors. Joshi *et al.* (1998); Joshi and Naithani. (2002), Pham *et al.,* 2017 elaborated the various causative factors such as change in natural drainage basin, loss of vegetation, disturbances caused by geological setting of the area along with the effect of river basin silting and also discussed the different strategies for the management of instability and landslide in Garhwal Himalaya.

## Materials and Methods

### Study Area

The study area (Figure 1) of the present research includes the Bhagirathi Bridge – Devprayag bus stand area, Pauri- Devprayag bifurcation road and areas upto Devprayag 4 km milestone along National Highway 58. Devprayag (N $30.146315^0$ ; E $78.578291^0$) is a municipal town of Tehri Garhwal district of Uttarakhand where the two sacred rives namely the Alaknanda and the Bhagirathi confluence to form the Ganga river. This region experiences heavy precipitation during the month of July to September and bears average temperature of $18^0$C. The

average elevation of Devprayag is 830 meters and has a total of population of 94441 as per census of 2011.

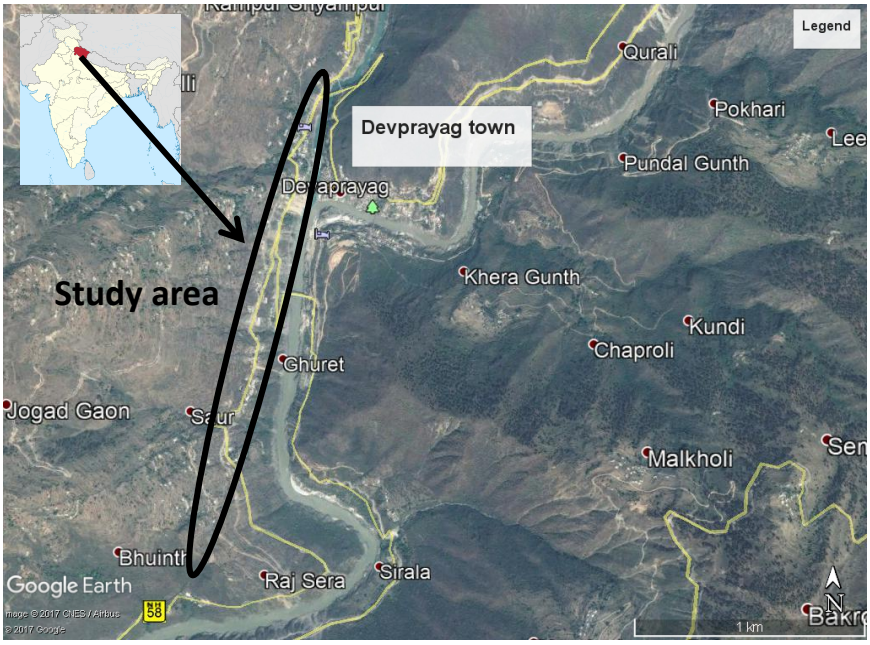


Figure 1. Satellite imagery (Google, 2019) of study area just upstream side of Devprayag township.

Stratigraphically this area is associated with Dudatoli Group and Saknidhar formation of Kumaun Supergroup which is of Precambrian age (Kumar *et al*., 1974) Table 1. The lithology of these areas mainly comprises of Chandpur phyllite with thin bands of greywacke and quartzite (Bist and Paul, 2008). The most common sedimentary structure present in Saknidhar formation is flute and load casts which indicate its normal sequence. The greywacke and sandstone rocks of Saknidhar formation dips northerly and is overlained by by phyllite of Chandpur formation. The exposed outcrop of Chandpur formation along Alaknanda and Bhagirathi river is also known as Pauri-Phyllite (Bist and Paul,2008).

Table 1: Stratigraphy of the Saknidhar- Devprayag area

| Age | Stratigraphy | Tectonic Unit |
|---|---|---|
| Tertiary | Siwaliks(lower Siwalik)<br>----------Krol Thrust---------- | Siwalik |
| Permian | Infra Krol Formation | Krol |
| carboniferous | Bialni Formation | |
| | ---------Unconformity---------- | |
| Precambrian | Kumaon Supergroup { Dudatoli Group<br>Saknidhar Formation | Dodatoli-Almora |

Source: Kumar *et al*., 1974

Gaur and Dave (1979) designated rocks of this area under Jaunsar Group which consist of Nagthat and Chanpur formations. The Chandpur formation of Jaunsar Group has phyllite-quartzite association with upto 5mm thick band of phyllite and upto 3m thick bands of quartzite. The sub rounded to subangular grains of quartz reflects coarse grained texture of quartzite (Gaur and Dave, 1979) Table 2.

Table 2: Stratigraphic Sequence in the Garhwal Syncline, Rishikesh-Devprayag area

| Group | Formation | Lithology |
|---|---|---|
| Blaini Group | Infra Krol Formation | Thinly laminated slate quartzite association |
| | Blaini Formation | Tillites, limestone, shales and siltsones and sandstones |
| ---------Unconformity---------- | | |
| Jaunsar Group | Nagthat Formation | Purple sandstones, greywackes, grit |
| | Chandpur Formation | Phillite-Quartzite association |

Source: Gaur and Dave, 1979

Bist and Paul (2008) reported sandstones of Saknidhar formation are interbanded with bands of shale and the presence of turbidite sedimentary structure shows depositional environment as a flyschoid (Table 3).

Table 3: Lithotectonic succession of Saknidhar-Devprayag area along Alaknanda valley

| Group/Litho Unit | Lithology |
|---|---|
| ----------North Almora/Srinagar Thrust------- | |
| Pauri/Jaunsar Phyllite<br>(late Proterozoic) | Phyllites inter bedded with meta siltstone |
| ------- Tectonic Contact------- | |
| Saknidhar/ Damta<br>(Rephaean) | Greywacks and slats with terbidites |
| ----------Nayar Fault---------- | |
| Krol Nappe | Shale with felspathic nodules, limestone, dolomite, quartzite and Blani conglomerates |
| ---------Main Boundary Thrust | |
| Siwaliks<br>(Mid Miocene to Pliestocene) | Sandstone, shale and conglomerate |

Source: Bist and Paul, 2008

The methodology undertaken in the present study includes the generation of geodata base using the Toposheet no. 53J/12 (1:50000 Scale), Survey of India map, Google Earth Imagery, and GPS locations of the study area in which the relevant data was digitised to generate various useful vector layers such as river, road, and landslide locations in GIS framework. Then geological mapping carried out by observing the lithology (rock type), attributes of the bedding plane and other relevant geological related properties. Furthermore landslides (critical zone) were delineated and recorded during field work using GPS along the National Highway NH 58. Coordinates of all critical zones recorded from field using GPS incorporated in maps in GIS framework. Finally, integration of field and gis data helped in preparing landslide inventory (Table 4) and landslide location map (Figure 2).

## Results and Discussion

An old landslide zone observed near Bhagirathi bridge area, which may probably reactivate in future due to road widening and subsequent rainfall. This slide zone looks very vulnerable and extended towards crown posing risks to local residents and the electric poles (Plate 1). Higher degree of fracturing and joints with quartz veins observed (Plate 2). 300 m ahead from the Bhagirathi bridge along NH 58, near the confluence of the two rivers, the interaction of water i.e. by precipitation, seepage and surface water with clay minerals of phyllitic rocks results into the swelling which causes instability to the in-situ rocks and makes these areas vulnerable to landslide (Plate 3).

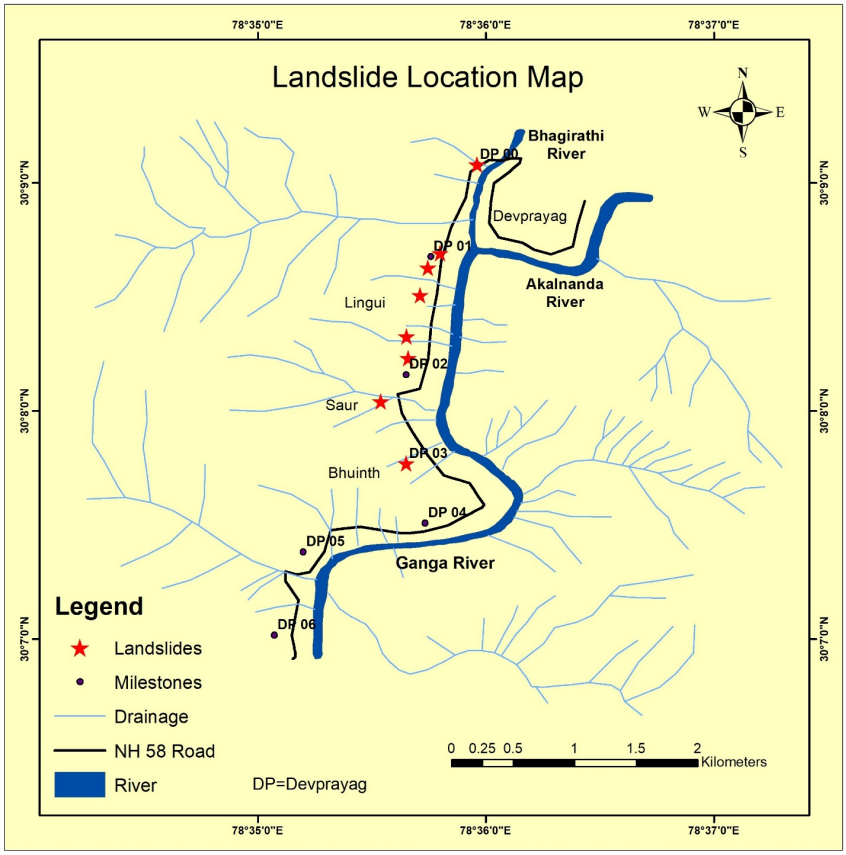


Figure 2. Landslide location map (Toposheet no. 53 J/12, 1965)

Table 4: Landslide inventory of the area of investigation.

| S. N. | Name of Landslide | Coordinates | Lithology | Major causative factor | Slope | Dimension (height/ Length) (m) | Types of failure | Affected area |
|---|---|---|---|---|---|---|---|---|
| 1. | Bhagirathi landslide | N 30.15136 E 78.59935 | Phyllitic rocks | Overburden pressure, steep slopes, fractured. | $240/70^0$ →150 | 40/155 | Debris slide | Settlement areas and road |
| 2. | Devprayag 1 landslide | N 30.14486 E 78.59665 | Phyllitic rocks | Water interaction with clay minerals | $220/80^0$ →130 | 40/60 | Debris slide and debris flow | Settlement areas and road |
| 3. | Devprayag 2 landslide | N 30.14381 E 78.59575 | Phyllitic rocks | Sinking and subsidence zone, instable | $180/40^0$ →90 | 42/70 | Debris slide and debris fall | Settlement areas and road |
| 4. | Lingui 1 landslide | N 30.14181 E 78.5952 | Phyllitic rocks | Rainfall and structural discontinuity | $180/40^0$ →90 | 42/130 | Debris slide | Settlement areas and road |
| 5. | Lingui 2 landslide | N 30.13879 E 78.59421 | Phyllitic rocks | Weathered, fractured and precipitation | $180/80^o$ →090 | 60/90 | Debris slide | Nirikshan bhawan, settlement area and road |
| 6. | Lingui 3 landslide | N 30.13719 E 78.59433 | Phyllitic rocks | High Precipitation | $180/75^0$ →90 | 65/50 | Debris slide | H.P. Petrol pump |
| 7. | Saur landslide | N 30.13403 E 78.59231 | Phyllitic rocks | Road section cutting | $160/35^0$ →250 | 40/80 | Debris fall | Road |
| 8. | Buint 1 landslide | N 30.12950 E 78.59418 | Phyllitic rocks | Stream and rainfall | $180/45^0$ →90 | 35/30 | Debris flow | Road |
| 9. | Buint 2 landslide | N 30.12868 E 78.59452 | Phyllitic rocks | Rainfall | $110/80^0$ →020 | 35/28 | Debris slide | Road and retaining walls |

Considering the higher vulnerability to landslide, slope failure treatment was done by Bharat Contruction, Dehradun with rock-bolting and anchoring (Plate 4) and retaining walls (Plate. 5). At the bifurcation of Pauri-Srinagar road (Devprayag 1km) which is a subsidence zone and very prone to landslide which has been stabilized by retaining wall by the Border Road Organisation (Plate 6). The surrounding areas are also prone to landslide due to higher degree of weathering and fracturing in phyllitic rocks near Raghunath Palace hotel (Plate 7) and Nirikshan Bhawan (Plate 8). An old landslide at H.P. petrol pump of Devprayag town observed, the owner of pump informed that this slide caused huge loss of his property in the past (Plate 9). The unplanned excavation and road widening along the slope also increases the vulnerability of landslide (Plate 10) at Saur. The seasonal stream along the road side slope results into accumulation of debris in flow path during rainfall in every monsoon (Plate 11).

Plate 1. Bhagirathi-Bridge landslide –Local residents and Electric pole at risk

Plate 2. Fractures at outcrops of Phyllite at Bhagirathi landslide

Plate 3. Seepage causing swelling in Phyllitic rocks

Plate 4. Rock bolting and anchoring at Devprayag 1 landslide

Plate 5. Retaining wall under construction at Devprayag 1 landslide

Plate 6. Devprayag 2 landslide at Pauri- Devprayag bifurcation road

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Plate7. Lingui 1 landslide Near Raghunath Hotel

Plate8. Lingui 2 landslide near Nirikshan Bhawan way

Plate9. Lingui 3 landslide caused loss to petrol pump

Plate10. Saur landslide due to road section cutting

Plate11. Buinth 1 landslide along a seasonal stream

Plate12.Buinth 2 landslide-reactivated old landslide

An old landslide at Buinth is observed which is evident from the breakup of one side of initially constructed retaining wall (Plate 12). Total no. of 9 landslides were delineated in our present study, among which 3 landslides namely Bhagirathi landslide, Lingui 1 landslide and Lingui 3 landslide are at more risk while for the rest 6 landslides mitigations undertaken by the Border road organization and the Bharat Construction Company, Dehradun. Based on our present observations, landslide inventory (Table 4) with the landslide location map (Figure 2) prepared.

## Conclusion

The higher degree of fracturing, weathering and joints (Plate 1,2) in the phyllitic rocks of the Devprayag bus stand area near the Bhagirathi bridge results into slope instability. The subsidence zone, highly weathered outcrop, road widening and heavy rainfall coupled with very steep slopes ($80^0$) (Plate 3) at Devprayag-Pauri bifurcation road prone to reactivation of landslide. The heavy precipitation during monsoon seasons and high stream power at the base increase the pore pressure resulting into toe erosion, enhance subsidence and more frequencies of landslide incidents. The steep slope and the abundant accumulated debris materials along the hill side slope for road widening at Devprayag 2.5 km (Plate 9, Plate 10) probably increases the vulnerability to landslide Social awareness regarding landslide through camps need to be propagated in order to safeguard the lives and economical losses.The bioengineering retaining wall, wire mesh, anchoring, rock bolting, shotcrete and culvert pipe are the suggested mitigation measures which will be very helpful for slope stability and smooth operation of vehicular traffic in future. The development of early warning system and more in-depth studies of landslide in future, along a part of the National Highway 58 which is also a strategic road for the country connecting Haridwar city to China border (i.e. Badrinath-Manna border), will be very helpful for Border Road Organization, administrator, policy maker and local residents.

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