Significance of Morphometric analysis in the Evaluation of Landslide Incidences with Special Reference to Neotectonic Activity of The Suel *Nala* Watershed, Chamba District, Himachal Pradesh

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Abstract

The paper discusses the significance of drainage morphometry in evaluating the landslide hazard in the Suel Nala watershed/sub-basin Chamba district, Himachal Pradesh. The area comprises Recent Alluvium to Lower Proterozoic Group of rocks. The bedrocks are folded in NW-SE direction forming the Chamba syncline.

The basin has high drainage density, high bifurcation ratio and high ruggedness number demonstrating the structural control over it and its 'tectonically active' status. Low circulatory ratio, length of overland flow and constant channel maintenance indicate that the basin is high disturbed, has low permeability, steep to very steep slopes and high surface runoff. 19 landslide incidences are marked on left flank of the watershed while only 9 are marked on the right. The Asymmetry Factor of the watershed is 36% with higher length of tributaries on the left side (east side), which shows that the downward tectonic tilting is towards the west side. The landslide incidences are more on the up-lifted side of the basin.

Introduction

Landslide incidences map, in parts of Ravi basin (Fig. 1), Himachal Pradesh covering an area of approxlmate 213.22 sq. km with a perimeter of 68.89 km. The area lies in between Latitude 32°30'-32°55'N and Longitude 75°45'-76°E. The basin is characterized by undulating to highly dissected topography with hill ranges in the North-Easternly part of the area and valleys and plain are found in the south-western part. The basin is underlined by granite, gneissic rock, sedimentary sequence of rocks i.e. shale, slate, sandstone, limestone and intrusives of volcanics and exhibits dendritic drainage pattern. 19 landslide incidences marked on the left flank of the river basin and 9 in the right flank of the river basin. The morphological studies provide information of lithology, structure, relative infiltration, runoff, erosional aspects, stage of the maturity of the basin, basin upliftment, neotectonic activity and landslide studies of the basin.

The morphometric characteristics are directly related to fluvial characteristic of the basin (Horton, 1945) and detect tectonic tilting of drainage basin (Hare and Gardner, 1985; Keller, Edward A. and Pinter Nicolas, 1996). The following morphometric attributes i.e. bifurcation ratio, stream length, drainage density, stream frequency, constant channel maintenance, elongation ratio, ruggedness number and asymmetric factor of the Suel Nala basin were computed, analyzed with special reference to landslide incidences and related to the hydrogeological condition as well as neotectonic activity of the basin.

Geology and structure

Geologically the study area comprising the Chamba Formation, Manjir Formation, Katarigali Formation, Basantpur Formation, Dalhousie Granite, Panjal Volcanics and Upper Siwalik. The bed rock consisting of sandstone, boulder conglomerate, slate quartzite, granite intrusive, micaceous

sandstone, calcareous siltstone, limestone, polymictic diamictite and shale. The major tend of the beds are NNW-SSE. Dip of the bed varies from 45°-55°. The above formations are folded into a major syncline i.e Chamba syncline along NW-SE direction. There is pronounced development of Quarternary deposits in the area, which is represented by valley fill deposits such as fluvial terraces, debris cone and fans and glacial drift deposits.

Methodology

The drainage map of the basin has been prepared based on SOI toposheets of 1:50,000 scale. The drainage map (Fig.1) is prepared digitally by digitizing each order of stream on separate layer and all are assigned separate ID. Landslide incidences map has also been prepared by the same method with another layer i.e. point layer and overlain using ArcGIS software. Each stream order has been represented by the different colors and landslide incidences are represented by symbol. The salient features of the basin are represented in Table No. 1. The morphometric attributes are computed using Microsoft Excel and analyzed to study their influence on neotectonic activity with special reference to the landslide incidences.

Results and discussiona

Drainage pattern

The area represented dendritic to sub-dendritic pattern and is most common in hard rock terrains especially in granitic and gneissic areas (Clearland, 1916). This pattern

Table 1: Salient Feature of Suel Nal watershed

Origin	:Kila ri Dhar, west of
Elevation	Padri forest
Area of the basin	: 1795 km
Basin order	: 213.22 sq. km.
Total no of stream	: 6th
Total length of stream	: 2092
Maximum basin length	: 841.32 km
Perimeter of basin	: 33.66 km
	: 68.89 km

developed where rocks offer uniform resistance in horizontal direction and devoid of marked structural control suggesting uniform lithology.

Stream order and stream number: The study area is of 6th order basin with total number of 2092. Stream order and stream number is represented in the table 2.

Bifurcation ratio

The bifurcation ratio of 1st order is 2.33, 2nd order is 1.88, 3rd order is 0.68, 4th order is 3.75 , 5th order is 1.83 and the mean

Table 2: Number of stream in each order

Stream order	No of stream	$\log^{N}_{10}$
1	981	2.99
2	421	2.62
3	224	2.35
4	330	2.52
5	88	1.94
6	44	1.64

bifurcation ratio is 2.09 (table 3.). High bifurcation ratio indicates high structural complexity and low permeability of the area.

Table 3: Bifurcation ratio of different stream order

Stream order	No of stream	Bifurcation Ratio
1	981	2.33
2	421	1.88
3	224	0.68
4	330	3.75
5	88	1.83
6	44	-

Stream length ratio

The stream lengths (Table 4) ranges from 12.75 km to 465.33 km while the stream length ratio ranges from 0.496 to 1.636 with an average 0.993. The high number of streams and greater length suggest low permeable strata of the area.

Circulatory ratio

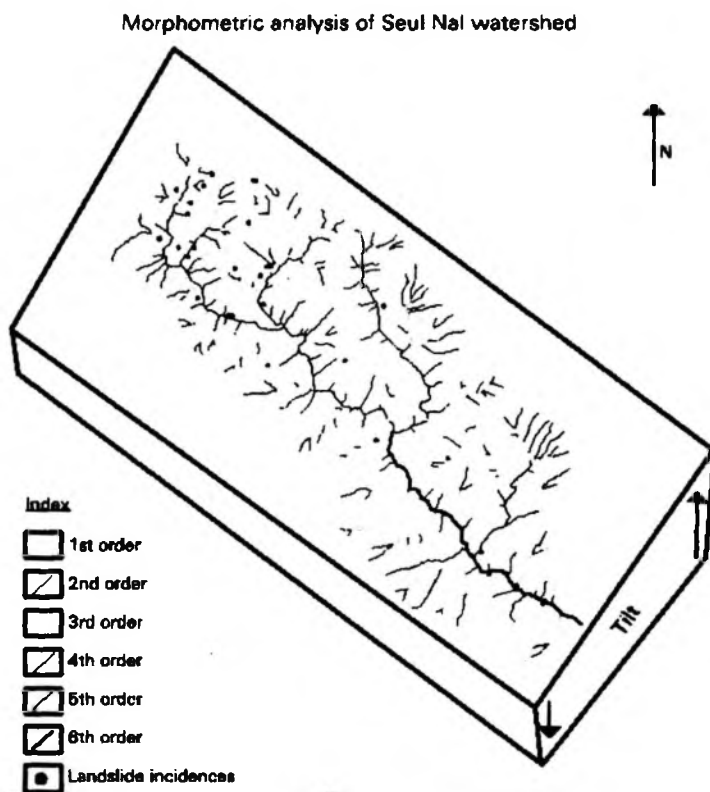The circulatory ratio of the basin is 0.56, which indicate that the watershed is

Morphometric analysis of Seul Nal watershed

Fig.1: Suel Nala river basin with landslide incidences representing tilting of the basin

Table 4: Stream length ratio of stream order

Stream order	No of stream in each order	Stream length In Km	Mean length	Length ratio	Average
1	981	465.33	0.474	-	
2	421	135.93	0.323	0.681	
3	224	60.87	0.272	0.842	0.994
4	330	147.01	0.445	1.636	
5	88	19.44	0.221	0.497	
6	44	12.74	0.290	1.312	

elongated in nature and characterized by high relief (Miller, 1953). It is also suggested that the area is not prone to floods.

Drainage density

The drainage density of the area is 3.95 and it affects the runoff. The high drainage density indicates that the runoff will be more in this area. It also indicates that the presence of low permeable strata in the area (Smith, 1950).

Table 5: Different morphometric parameters of Suel Nal watershed

Circulatory ratio	Drainage density	Length of overlan d flow	Constant channel maintenanc e	Ruggedness number
0.56	3.95	0.127	0.253	7.09

Length of overland flow

The length of overland flow of the study area is found to be 0.127 km, which indicates that the rain water has to run over this distance before getting concentrated in the stream channel. It also suggests that the basin has less scope for ground water recharge (Nautiyal, M.D. 1994). (Table5).

Constant channel maintenance

Inverse of the drainage density is Constant channel maintenance and represented in the table 5. The constant channel maintenance of the Suel Nala is 0.253 which indicates that the basin has been under the influence of high

structural disturbance, low permeability, steep to very steep slopes and high surface runoff.

Ruggedness number

Ruggedness number of the area is 7.09 which indicate high structural complexity (Strahler, 1964) of the area.

Asymmetric factor

Asymmetric factor has been developed to detect the tectonic tilting at the drainage basin scale (Keller, Edward A. and Pinter Nicolas, 1996).

The asymmetric factor (AF) is defined as

$AF=100(Ar/At)$

Where Ar= Area of the right (facing down stream) of the trunk stream

And At=total area of the drainage basin

Here $Af=100\times(83.52/213.22)=36$

It indicate that the tectonic rotation is down to the west i.e. right flank of the drainage basin and the tributary of this side of the main streams are short comparative to the left flank (east side) Fig.1.

Landslide Incidences

28 landslide incidences have been recorded, represented in Fig. 1. In the right flank of the main stream there are 9 landslide incidences and in the left flank there are 21 incidences. So, the numbers of the landslide incidences are more in upward tilting side, than in the downward rotational side. Maximum landslide incidences are recorded in the 1st order streams, which are more prone to landslide hazard.

Conclusions

Conclusions that emerge from the study are-

- The area, drained by river Ravi and its tributaries, features a hilly terrain with ruggedly youthful topography in the northern and western parts and a relatively mild and mature topography in the remaining parts.

- The area exposes rocks ranging in age from Lower Proterozoic to Recent. The major formations are Chamba Formation, Manzir Formation, Katarigali Formation and Khalel Formation. The major tend of the beds are NNW-SSE. The above formations are folded into a major syncline—Chamba syncline along NW-SE direction. There is pronounced development of Quarternary deposits in the area, which is represented by valley fill deposits such as fluvial terraces, debris cone and fans and glacial drift deposits.

- The study area is of 6th order basin with total number of 2092 and represent dendritic to subdendritic drainage pattern.

- High bifurcation ratio (2.09) indicates high structural complexity and low permeability of the area.

- The stream length ranges from 12.75 km to 465.33 km while the stream length ratio ranges from 0.496 to 1.636 with an average 0.993. The high number of streams and greater length suggest low permeable strata of the area.

- The circulatory ratio of the basin indicates that the watershed is elongated in nature, characterized by high relief and the area is not prone to floods.

- The high drainage density indicates that the runoff will be more in this area.

- The length of overland flow of the study area indicates that the basin has less scope for ground water recharge.

- Constant channel maintenance indicates that the basin has been under the influence of high structural disturbance, low permeability, steep to very steep slopes and high surface runoff.

- Ruggedness number of the area indicates the high structural complexity of the area.

- Asymmetric factor indicates that the

tectonic rotation is down to the west i.e. right flank of the drainage basin and the tributaries of this side of the main stream are short, comparative to the left flank (east side)

- Numbers of landslide incidences are more in upward tilting side, than the downward rotational side.

- Maximum landslide incidences are recorded in the 1st order stream or other way we can say, those 1st order streams are much more prone to landslide.

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