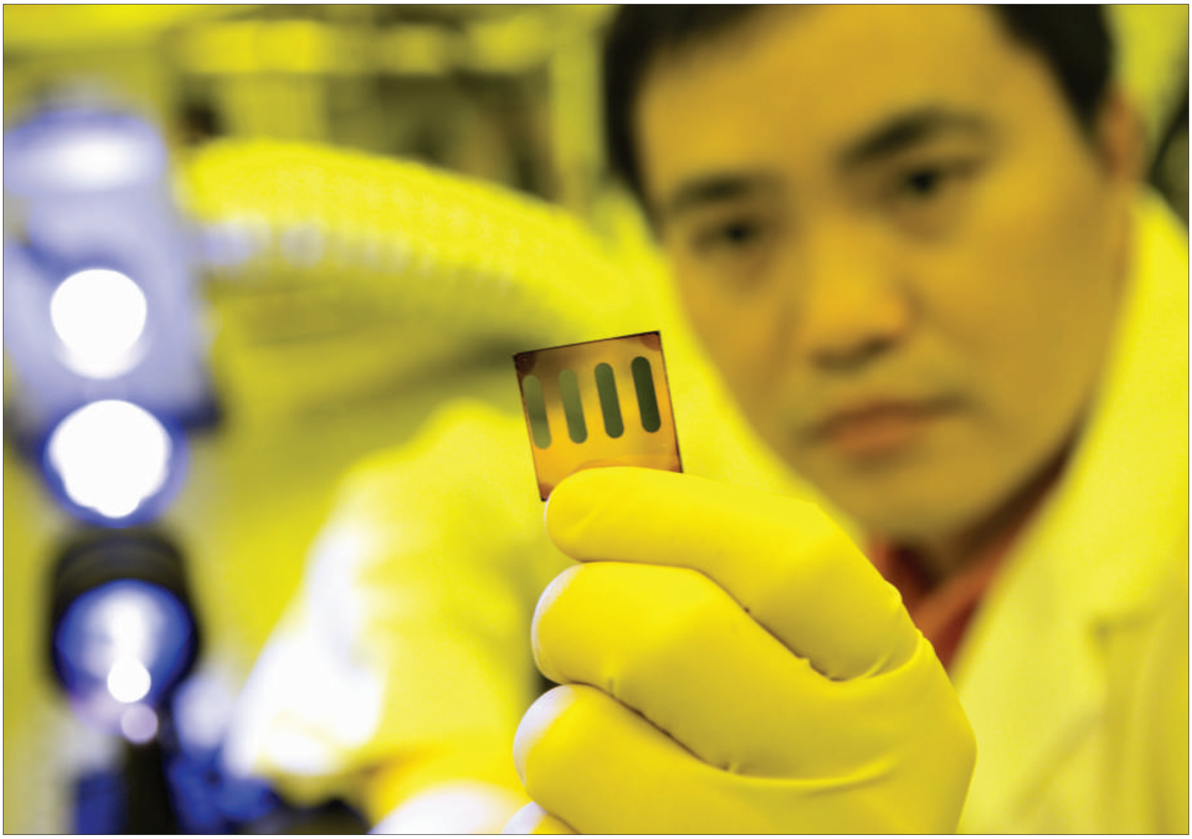

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Geomorphological Fearures of Tons River of Uttarakhand State, India

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ABSTRACT
The present study was undertaken to assess the geomorphological parameters of Tons river of Uttarakhand State, India which is largest tributary of the Yamuna river and flows through Garhwal region in Uttarakhand, touching Himachal Pradesh. A total of 500 m of area was selected for estimation of various geomorphological features which includes river width, river depth, width-depth ratio, entrenchment ratio, water-current velocity, substrate type and channel type. Width of the river was reported maximum while depth was minimum at site-II. Width-depth ratio was reported maximum at site-II. The maximum mean value of entrenchment ratio was also observed at site-II thus according to the Rosgen system of river/stream classification, the river under report is slightly entrenched. Site-I was reported with boulders, site-II with large and small boulders cobbles, pebbles, sand, silt and clay and site-III with cobbles, pebbles, silt, sand and clay as dominating substrate along with other organic and inorganic matters.

Key words: Morphology, Tons, entrenchment ratio, Yamuna, UK

INTRODUCTION
Rivers and streams are characterized by flowing waters and are called lotic systems having four dimensions: A longitudinal dimension with a pronounced zonation of chemical, physical and biological factors; a lateral dimension involving exchanges of organic matter, nutrients and biota between the stream channel and the adjacent floodplain; a vertical dimension consisting of a hydraulic connection linking the river channel with groundwater and a fourth dimension of time which pertains to the velocity of the water flow. They are critical components of the hydrological cycle, acting as drainage channels for surface water providing habitat, nourishment and means of transport to countless organisms and leaving valuable deposits of sediments, such as sand and gravel. Rivers are natural watercourses, flowing over the surface in extended hollow formations (i.e., channels), which drain discrete areas of mainland with a natural gradient, thus existence of a river depends on three things: The availability of surface water, a channel in the ground and an inclined surface. Channel morphology is a function of the balance between sediment transport and resistance of bed and bank material to transport. The latter is influenced by size of the bed material, nature of bank material and presence of riparian vegetation. The morphology of river channel influences the distribution and typology of flow hydraulic habitat, these in turn provide, along with the substrate composition, basin physical habitat element of the channel that is available for stream biota.

Tons is the largest tributary of the Yamuna river and flows through Garhwal region in Uttarakhand, touching Himachal Pradesh. The Tons thrust is named after this river. Its source lies in the 20,720 ft (6,315 m) high Bandarpunch mountain and is one of the most major perennial Indian Himalayan rivers. In fact, it carries more water than the Yamuna itself, which it meets below Kalsi near Dehradun, Uttarakhand. The environmental changes were brought about by various anthropogenic activities that lead to degradation of not only environment but also affected the floral and faunal diversity of Tons river. Species diversity is declining due to over exploitation, habitat degradation, anthropogenic activities and exotic introduction. Keeping in view the above points present study was undertaken to assess the morphological parameters of Tons river of Uttarakhand State, India

MATERIALS AND METHODS

For the assessment of river morphology a total area of 500 m was taken into consideration for each site. For the study of river morphology, various morphological parameters have been taken in consideration. Width of the channel was measured with the help of simple inch tape measuring the width across the river, the depth of the channel was measured at each site (average 5-6 points) to the nearest 0.1 mm with the help of a graduation iron rod, width-depth ratio was estimated as the typical bankful width divided by depth at each site, Entrenchment ratio is the flood-prone width divided by the bankfull width and is calculated by the given equation:

$$E.R = \frac{\text{Total flood plain area}}{\text{River bank full area}}$$

The water current velocity of the river was calculated in the field by simple float method and the time was noted between the known distances covered by the float. Following formula was used for calculation of water current velocity:

$$V = \frac{D}{T}$$

where, V is the velocity, D is the distance covered by the float, T is the time taken by the float to cover total distance.

Substrate and channel types were analyzed by visual observations and were classified after Armantrout (1999) as Table 1.

Altitude, longitude and latitude were measured on the spot with the help of Magellan Trailblazer XL GPS system. For the study of river morphology the standard methods of Rosgen (1996) and Armantrout (1998) were followed.

Table 1: Classification of particles

Name of particles	Size (mm)
Large boulder	Over 1024
Small boulder	256-1024
Cobble	64-128
Coarse gravel	32-64
Fine gravel	2-34
Sand particle	0.062-2.0

RESULTS

The present observations are based on the monthly data collected from the selected sites of the Tons River and are presented in Table 2. The river under report is perennial and receives water throughout the year although the volume of water increases during rainy season. During present investigation, a total of 500 m of area was selected for estimation of various geomorphological features which includes river width, river depth, width-depth ratio, entrenchment ratio, water-current velocity, substrate type and channel type. Graphical representations of various geomorphological parameters are shown in Fig. 1-3 and types of substrates and habitats at three selected sites were also documented. The mean and standard deviation are shown in Table 2.

The values of the width of the river were reported maximum at site-II (11.9 m) followed by 11.2 and 11.0 m at sites III and I, respectively. The maximum mean value was reported at site-II (8.80±1.69 m) and minimum at site-III (7.60±1.22 m).

The mean depth value was observed to be maximum at site-I (1.03±0.32 m) and minimum at site-II (0.96±0.23 m) (Table 2). Width-depth ratio was reported maximum at site-II (15.3 m) and minimum at site-I (4.0 m). The mean value was reported maximum 9.53±2.19 m at site-II and minimum as 7.96±1.79 m at site-III. The values of entrenchment ratio of river ranged from 0.8-2.2 m at site I, site II and site III. Entrenchment ratio is the field measurement of channel incision. Lower entrenchment ratio indicates channel inclusion whereas large entrenchment ratio indicates well developed flood plain area. In the present investigation, at site-II

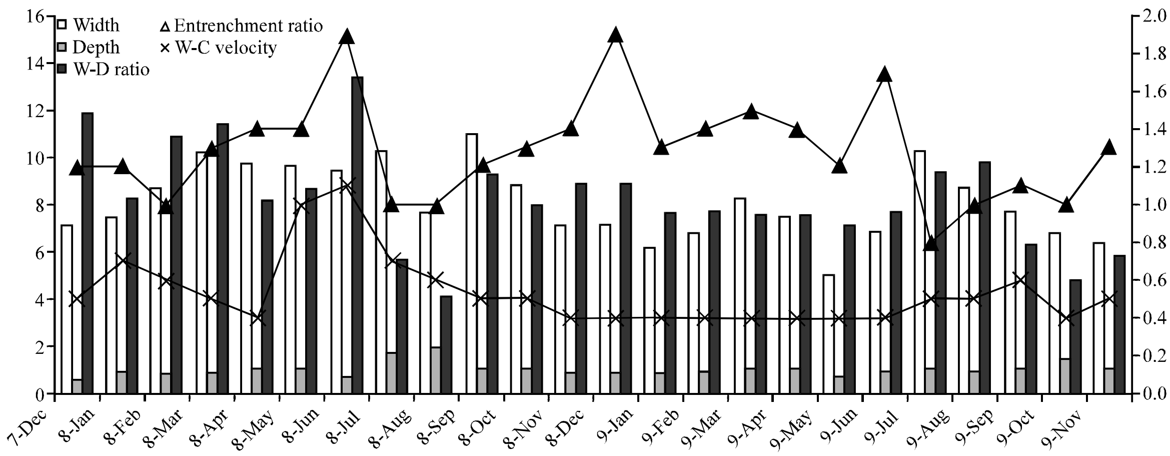

Fig. 1: Geomorphological parameters of Tons river during 2007-2009 at site-I

Table 2: Values in mean and standard deviation of geomorphological features recorded during Dec 2007 to Nov 2009 at three sites of Tons river

	Mean			SD		
Geomorphological features	S-1	S-II	S-III	S-I	S-II	S-III
River width (m)	8.070	8.80	7.60	1.55	1.69	1.22
River depth (m)	1.030	0.96	1.00	0.32	0.23	0.29
Width-depth ratio (m)	8.240	9.53	7.96	2.19	2.19	1.79
Entrenchment ratio (m)	1.280	1.44	1.38	0.28	0.34	0.31
Water-current velocity (m sec^{-1})	0.533	0.52	0.51	0.19	0.19	0.14

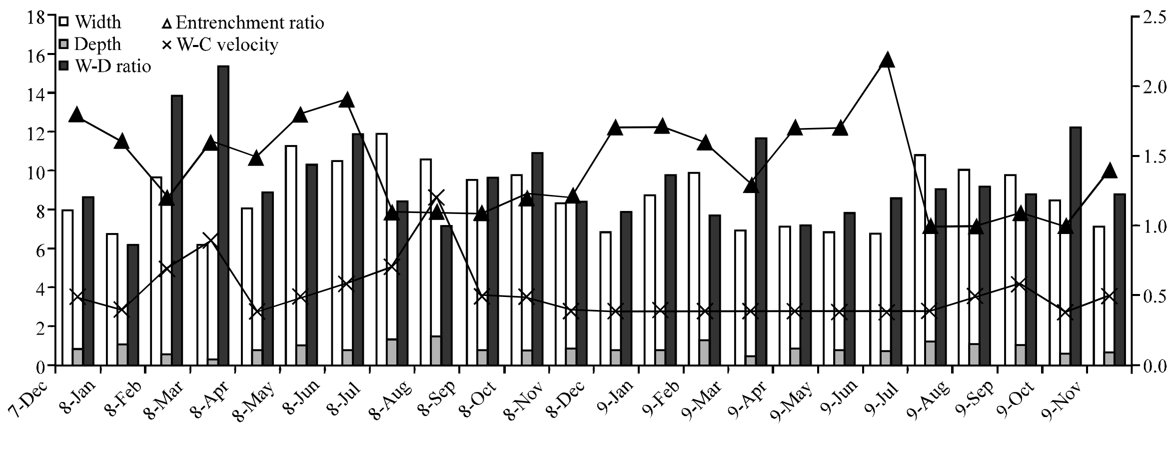

Fig. 2: Geomorphological parameters of Tons river during 2007-2009 at site-II

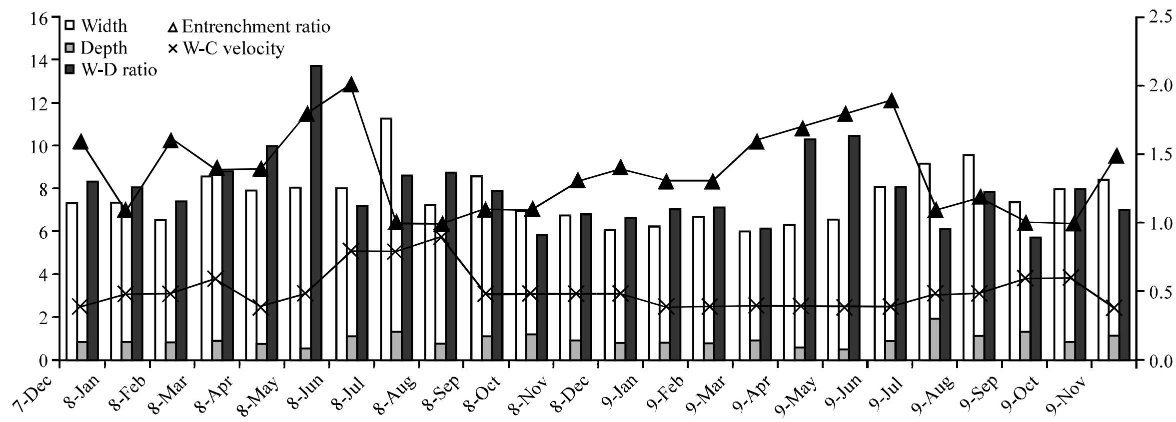

Fig. 3: Geomorphological parameters of Tons river during 2007-2009 at site-III

and site-III, maximum entrenchment ratio was observed during summer months which was found to be > = 2.0, whereas minimum value was observed during monsoon months at all the selected sites. The maximum entrenchment value was reported at site-II (2.2 m) and minimum at site-I (0.8 m). The present investigation reveals that site-II and III are moderately entrenched whereas site-I have very less flood plain area. The maximum mean value of entrenchment ratio was observed at site-II (1.44±0.34 m) and minimum at site-I (1.28±0.28 m). In the present investigation, at all the sites, mean entrenchment ratio was found to be >2.0. Thus, according to the Rosgen system of river/stream classification, the river under report is slightly entrenched.

Water current velocity was reported maximum at site-II (1.2 m sec^{-1}) followed by site-I (1.1 m) and site-III (0.9 m). At all the sites the minimum water current value was observed to be 0.4 m sec^{-1}. At all the sites the mean value was almost the same as 0.53±0.19, 0.52±0.14 and 0.51±0.14 m sec^{-1} at site-I, site-II and site-III, respectively. Site-I situated at higher altitude consisted of cascading profile with boulders as dominating substrate along with other substrates like gravel, sand, silt, clay and organic inorganic matter. Site-I consists of narrow water flow area and almost no flood plain area. Site-II consisted of typical riffle-pool morphology and consists of mainly riffle dominanted channel with frequently spaced pools with stable bank and bed profile.

Site-II consists of substrate in the form of large and small boulders cobbles, pebbles, sand, silt and clay along with other organic and inorganic matters. Bar formation was noticed to be a regular feature of this site. Here the river follows a single channel type of water flow. Site-III consists of substrate in the form of cobbles, pebbles, silt, sand and clay. Presence of pools, riffles and runs shows a regular pattern of distribution. The river takes the single channel type pattern at this site too.

DISCUSSION AND CONCLUSION

Leopold and Maddock (1953) suggested that the steepness of the slope or the altitude is influenced by variation in width-depth ratio. At higher altitudes, the width-depth ratio is generally low where as at places of lower altitude the width depth ratio is usually high. Leopold (1964) observed that the pattern of river morphology is directly influenced by channel width, slope of the channel, water current velocity, discharge, roughness of channel material, amount of sediment deposition and size of sediment. According to Horwitz (1978), in the streams/channels different types of habitats i.e., pools, backwaters, riffles, run, rapids and cascades are present. These habitats are dependent on the percentage slope (gradient) of the stream and coarse substratum (i.e., sand, gravels, cobbles, boulders, bed rocks and woody logs to organic debris). Jarrett (1985) reported that high gradient streams are highly influenced by large boulders whereas lower altitude streams have roughness due to bed forms and bars. He also reported that the water current is very high in upland streams, thus the presence of substrate type breaks the high velocity of water and provides stability to the channel. Rosgen (1994) observed that the species richness of a river or the stream depends upon the morphology of the river. Various factors like depth, width, entrenchment ratio, channel type and substrate composition are an important part of any riverine system. He also pointed out that a river functions as a unified ecosystem, any change in one part of the system affects the other components of the system. Streams form fluvial processes and evolve simultaneously to operate through mutual adjustments towards self stabilization.

Rosgen (1996) classified the hill streams into six broad categories namely A, B, C, D, E and F on the basis of gradient, entrenchment ratio and width-depth ratio. Sun *et al.* (1996) observed that the formation of bars results in the migration of channel to a new direction because of a variety of causes like various local activities and geological processes for example floods and various anthropogenic activities for example collection of pebbles, sand and silt for construction purpose. Armantrout (1998) studied that in smaller water bodies, the distribution of fish is more closely related to the presence of individual habitat units whereas in larger systems features such as depth, distance from the shore/bank and bottom substrate contribute to the distribution pattern of fish. Baretto and Uieda (1998) observed that the physical habitats like depth, width, current, substrate etc forms the structure within which an organism can live. They also observed that these factors together constitute the morphology of a particular river system which determine the abundance and diversity of organism within a river or a stream.

Arunachalam (2000) after studying the stream fishes of Western Ghat concluded that various habitats like pools, riffles, rapids and cascades affect fish species distribution especially that of cyprinids and cat fishes. He also studied the macrohabitat features such as channel gradient, stream depth, stream width, riparian cover, instream cover, substrate type and concluded that high habitat diversity was associated with high species diversity and also that habitat volume was a major determining factor for species diversity and abundance. Rumana (2001) studied the streams of Western Himalayas and observed that hill stream geomorphology and fish community depends on various factors which include channel-width, depth, water-current velocity substrate type and volume of water. He also observed that fish species diversity was inversely proportional to altitude. Negi *et al.* (2007) studied the streams of Nainital district and categorized them as type-B and type-C streams on the basis of gradient which was observed to be 2.6% for Balia stream, 2% for Khichari stream and 1.8% for Nandour stream.

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