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SPRINGS OF MID WESTERN HIMALAYAN (UTTARAKHAND) AND THEIR RESPONSE

1. Since early times, the population of sub-humid regions in Mid Western Himalayan hills has their homes clustered around natural water resources primarily springs. The population settlement in hills is therefore distributed forming clusters depending on availability of springs. These water resources are so low discharging that most of them fall under the lowest flow category between 0.82 to 6.55 m^3/day classified as seventh or eighth category of Meinzer's (1918) spring classification. Behaviour of a spring can only be administrated and forecasted by studying their temporal discharge variation or commonly known as the spring hydrograph (Vashishth and Sharma, 2007).The numbers and magnitude of spring perhaps limits the population sustainable and over above have to migrate. Especially, during summer followed by a low rainfall year, when evaporation is high the flow of the springs is much decreased or even cease. The importance of mountains springs can be considered very high as these are the main water resources for drinking and other household purposes for the habitat of the high land (Agarwal *et al.*, 2012). The discharge from these sources has decreased drastically due to human activities (Nagi and Joshi, 2002; Valdiya and Bartarya, 1989 and 1991). It has been emphasized; that climatic change such as rise of rainfall intensity, reduction in winter rain could be reasons for a decrease in spring discharge (Tambe Sandeep *et al.*, 2012). Yonghong Hao *et al.* (2006 and 2009) studied the response of karst springs to climate change and anthropogenic activities for the Niangziguan Springs, China and found that discharge has been declining since the 1950s. (Negi and Joshi, 1996; Negi and Joshi, 2004) found that the spring yield during rainy and non rainy seasons is affected by rainfall and recharge area characteristics. Recession of seasonal springs is much more rapid than the perennial springs. Valdiya and Bartarya (1991) explained that in Central Himalayas around eight types of springs are recognized on the basis of the geology, nature of water bearing formations and the conditions related to their formation. The highest yielding spring (Negi and Joshi, 2004) are obtained from fluvial originating springs and the rate is about 405 × 10^3 l/d whereas the colluviums originating springs are at the lowest rate and producing 7.2 × 10^3 l/d. The variation in mean annual spring water yield was found to be 0.72 × 10^3 l/d to 56.0 × 10^3 l/d in Himalayan region (Rai *et al*., 1998). Variations in spring yield are very much marked and noticeable those are followed by rainfall and indicate rapid infiltration of rain water and recharge the colluviums originating springs.

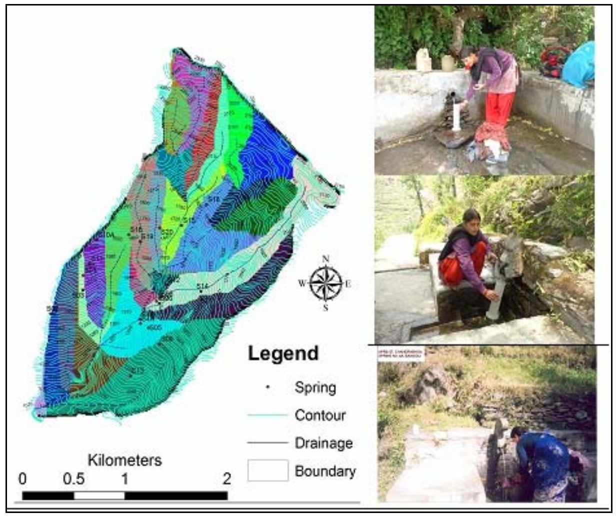

Fig. 1. Few springs of Chandrabhaga and their location in watershed

2. The selected watershed 'Chandrabhaga' is a sub-watershed of river *Alaknanda* forming river Ganga downstream at Devprayag (Uttrakhand), the confluence point of river Alaknanda and Bhagrithi. Chandrabhaga lies in 'Mid Western Himalaya' agro-ecological region and the location of area and watersheds is shown in Fig. 1 along with the few selected springs of the area. The lithology of the study area is mainly phyllites and schists rocks of Chandpur formation (Lesser Himalaya). Valdiya (1980) describes the rocks of Chandpur formation as "the olive green and grey phyllite inter-bedded and finely inter-banded with meta-silt stone and a very fine grained wackes with local metavolcanics" to act as filter that regulates the groundwater paths for the spring as conduit or diffused or a combination of both (Waltham, 1972; Tambe *et al*., 2012).

3. Chandrabhaga watershed of around 3 km^2 is sub- humid, located geographically between latitude N 30° 18′ to N 30° 19′ and longitude E 78° 35′ to 78° 36′ at an altitude 1070 m to 2350 m above mean sea level with the average annual rainfall in this region of the order of 1200 mm. The area falls under the Jakhnidhar block of Tehri-Garhwal district (Uttarakhand). The area has many springs and the location of springs is shown in Fig. 1 with its prospective springshed and topographic information.

4. The data collection is automatic as well as manual. The rainfall measurements are based on four to five automatic rain-gauges installed in the watershed. The spring flow measurements are manually recorded by measuring the time taken for a specific amount of water coming out of the spring. During high flow season in monsoon months, the specific quantity was 5.0 liter and in non-monsoon months it was reduced to 1.0 liter. Since, the springs are throughout distributed in watersheds

(Fig. 1), the measurements are taken on alternate days or maximum in three days interval in both the watersheds. The data collection started in year 1999 and continued to June 2010. As for as possible all springs of the watersheds were considered for observation leaving one or two that fall under deep forest and are not in easy approach. **A** total of around twenty springs were under observation in the watershed. Monthly average values of the rainfall and spring flow are estimated using daily data. The methodology adopted for the low flow analysis is as per the procedure of Institute of Hydrology (1980). Dally and monthly rainfall- spring lag was estimated using full length available data and adopting correlation analysis between rainfall and spring flow.

5(a). *Spring flow response* - The monthly average discharge of a particular high yielding spring of Chandrabhaga watershed is shown in Fig. 2 along with the weighted rainfall over the watershed. The quick spring response to rainfall can easily be identified by the sudden raise and fall of the flow and suggests that the recharge area of spring is in close vicinity of spring may be within the watershed and is due to only rainfall. The cumulative spring flow and cumulative rainfall for five selected springs of Chandrabhaga watershed is presented in Fig. 3. Overall the accumulative spring flow indicates an exponential/power or second order polynomial response to accumulative rainfall for the yearly period (June to May). Impact of monsoon is well recognized from Fig. 3.

5(b). *Spring flow duration curves* - Ten daily flow duration curves for the springs of watershed are shown in Fig. 4 along with the average flow curve for the watershed springs. The slope of ten day flow duration curve is very mild to mild for discharges higher than average ten daily discharges but sharply increases for discharges below average ten daily. It indicates the limitation of available base flow to the springs. A sudden drop of flow duration curve is an indication for required recharging activates in the watershed in order to increase the base flow as to continue the flow from springs during lean periods.

5(c). *Rainfall - Spring flow lag characteristics* - Time lag between rainfall and spring flow has been identified considering daily data and to converted monthly average data. Different springs of Chandrabhaga watershed indicated a lag of 9 to 30 days and 0 to 1 months (Table 1). A low value of rainfall-spring lag in days again suggests the springs of watershed are as fast responding springs and the springshed of the springs is in the close vicinity within the watershed.

Here the spring variability is defined by the ratio of minimum to maximum correlation between rainfall and spring flow. The spring flow variability is related to

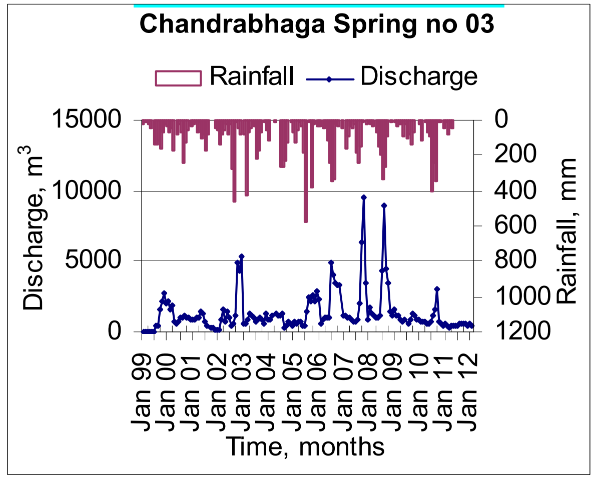

Fig. 2. Monthly average discharge of a spring of Chandrabhaga watershed

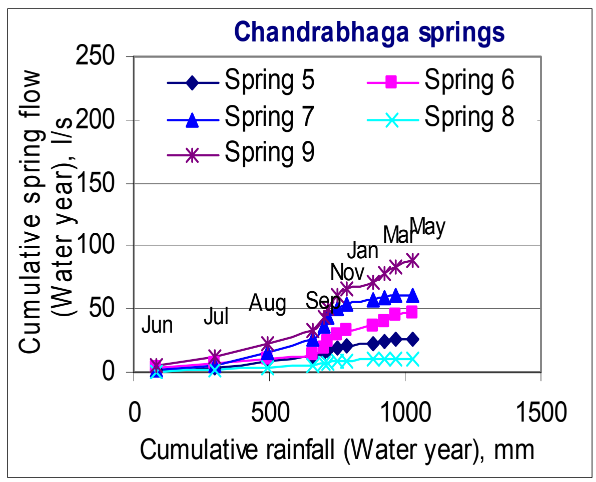

Fig. 3. Accumulative spring flow for water year for few selected springs of watershed

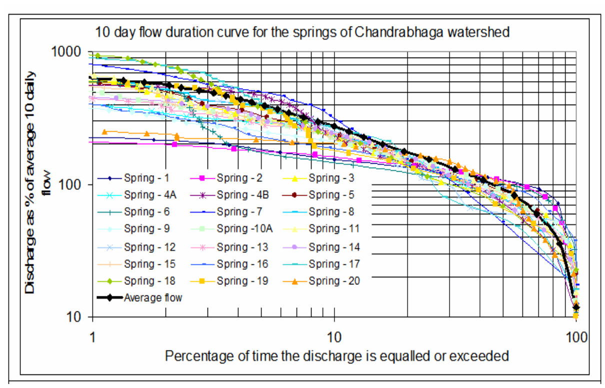

Fig. 4. Ten daily flow duration curves for the flow of the springs of watershed

TABLE 1

Spring to rainfall lag for Chandrabhaga springs

S. No.	Sp. No.	Data length	Lag, days	Lag, months	Min./max. corr. ratio
1	1	Jul 99 - Jun 10	13	1	0.713
2	2	Jul 99 - Jun 10	13	1	0.723
3	3	Jul 99 - Jun 10	27	1	0.427
4	4A	Jul 99 - Jun 10	13	1	0.614
5	4B	Jul 99 - Jun 10	25	1	0.609
6	5	Jul 99 - Jun 10	27	1	0.623
7	6	Jul 99 - Jun 10	29	1	0.298
8	7	Jul 99 - Jun 10	28	1	0.361
9	8	Jul 99 - Jun 10	30	1	0.472
10	9	Jul 99 - Jun 10	29	1	0.489
11	10A	Jul 99 - Jun 10	17	1	0.480
12	11	Jul 99 - Jun 10	21	1	0.524
13	12	Jul 00 - Jun 02	30	NA	0.422
14	13	Jul 03 - Jun 10	28	1	0.597
15	14	Jul 00 - Jun 06	16	1	0.560
16	15	Jul 00 - Jun 10	14	1	0.546
17	16	Jul 00 - Jun 10	14	1	0.717
18	17	Jul 05 - Jun 10	11	1	0.748
19	18	Jul 03 - Jun 09	9	0 or 1	0.669

rainfall-spring lag in days (Fig. 5). It can be seen that the spring variability decreases with increase in rainfall-spring lag in days. The exponential decay function exists between the spring variability and rainfall-spring lag. The obtained equation with correlation (r^2) is below as;

$$y_{(Chand)}=0.8891*e-0.0237\,x \quad (r^2 = .502)$$

In above equation, $y_{(Chand)}$ is the minimum to maximum rainfall-spring lag correlation ratio and x is the rainfall-spring lag in days. Since the spring variability defined by the correlation ratio which decreases with an increase in rainfall-spring lag, the rainfall-spring lag could be used as an indicator for relative classification of springs.

5(d). *Rainfall spring flow relationship* - The yearly impact of total rainfall on total spring flow has been identified by combining the flow of all the springs of the watershed and is shown in figure in Fig. 6. The relationship identified between yearly rainfall and total

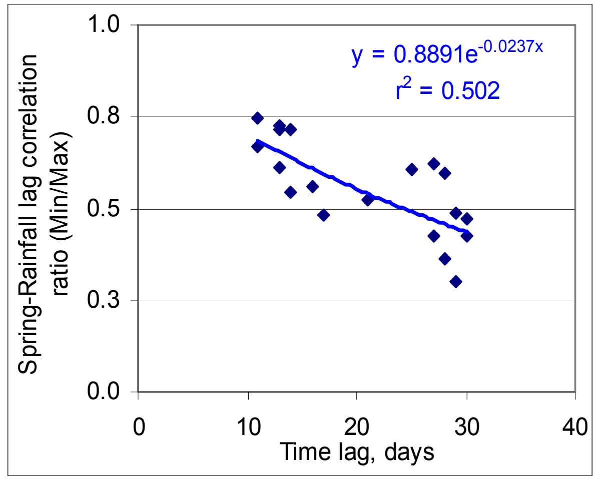

Fig. 5. Relationship between rainfall-spring lag correlation ratio and spring-rainfall time lag.

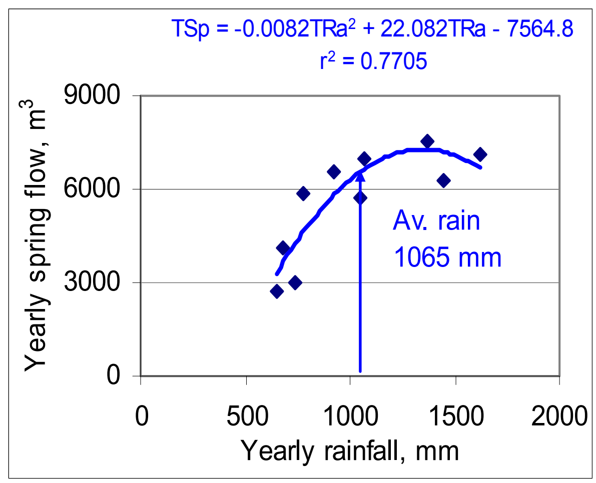

Fig. 6. Relationship between total yearly rainfall and total yearly spring flow.

yearly spring flow is in the form of second order polynomial form for the springs of watershed below as;

$$TSp = -0.0082TRa^2+22.08TRa-7564 \quad (r^2 = 0.77)$$

in which, TSp is total yearly spring flow (m^3) and TRa yearly rainfall (mm). Relationship indicates that the total spring flow increases with total amount of rainfall. Particularly the relationship supports that for an a rainfall below average the corresponding springs flow will be minimum, for average rainfall the springs flow will be average and for above average rainfall the springs flow will be maximum. The best fitted form of the polynomial equation suggests that spring flow from Chandrabhaga watershed reaches to a saturation for rainfall slightly above average rainfall. Any rainfall greater than above average is no further increasing the total spring flow.

The maximum spring flow from Chandrabhaga spring is found for spring no. 3 maximum as 315 m^3/day to a corresponding minimum 28 m^3/day. The minimum is found for spring no. 10A maximum as 2 m^3/day to corresponding minimum 1 m^3/day. The average maximum flow out of all springs is 58 m^3/day and minimum is 1 m^3/day excluding the spring no3. It suggests that most of the springs of the watershed are of the magnitude of seventh and eight group of Meinzer's (1918) classification. Only the spring no. 3 is of the magnitude of sixth group.

Overall, the springs with high discharge indicates relatively a high variability in flows. A high variability in flows suggests that almost the springs of the area drain to a lowest flow level towards to its end of the season and are fast responding springs.

6. *Proposed solutions* **-** The proposed solution to overcome the water problem is to make efficient use of the available water and at the same time increase available water resources adopting treatments in spring shed below as;

(*i*) Due to variable demand and seasonal variability of flow the water storage structures are essentially required to store spring flow of the non use periods and if required the transfer of water from "excess" areas to "shortage" areas, through gravity flow.

(*ii*) An increased infiltration is required on respective spring shed to increase storage of rainwater in monsoon months in order to increase the flow of springs.

(*iii*) Water retention power of the springshed is to be increased for delayed rainfall response and to reduce the variability of spring flow as well as to obtain high yield in summer months.

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AVINASH AGARWAL
M ARORA
R. K. NEMABISHAL GURUNG

National Institute of Hydrology (NIH), Jal Vigyan Bhavan, Roorkee Uttarakhand – 247667, (India)
(*Received 31 January 2014, Accepted 8 January 2015*)
email : avinash@nih.ernet.in