ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

Life line: The Springs of Uttarakhand, India

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Abstract: Springs of *Uttarakhand* hills, derived from seepage water are turning from perennial to seasonal and have been highly ignored, even though the springs are secure source behind domestic water availability. A study was initiated in the middle mountainous region of *Devprayag, Uttarakhand* for the *Danda* watersheds with area around 3 km^2. Automated hydro meteorological data were collected. Regular (daily) spring flow measurements were taken on almost all springs that are used by the habitat of the area. Spring flow availability is evaluated along with the average low flow duration curve for the springs of the watershed. The spring flow variability is related with spring rainfall lag. Relationship between total rainfall and total springflow are also developed.
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Keywords: Himalayan, Springs, Watershed, Rainfall, Flow

I. Introduction

Western Himalayan watersheds are rich in natural resources and provides fundamental basis for the existence of life at mountain and also provides water to millions at down stream through its perennial river system. Even than some times the availability of natural resources at hills goes to acute shortage due to its uneven distribution in space and time. Especially, during summer and low flow years, the people face acute shortage of water. It is, therefore, important to study the existing water availability, uses and its impacts on watershed hydrology. Research on small watershed is important in generating understanding of physical processes that affect the quantity of water from small watersheds. Study area Danda lies in 'Western Himalaya' agro-ecological region and the location of area and watersheds is shown on cover page. The lithology of the study area is mainly phyllites and schists rocks of Chandpur formation (Lesser Himalaya). Valdiya (1980) has described 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 Sandeep et al., 2012).

II. STUDY AREA

Danda watershed of around 1.34 km^2 is sub-humid, located geographically between latitude N30° 14' to N30° 16' and longitude E 78° 37' to E 78° 39' at an altitude of 780 m to 1800 m above mean sea level with average annual rainfall in this region of the order of 900 mm. The study area, locally known as Khas Patti and is located in the Hindolakhal Block (Devprayag Tehsil) of Tehri-Garhwal district. The area is known for scarcity of drinking water. The salient features of the watershed are given in *table 1*. The area has many springs and the location of springs is shown in *figure* 1 with its prospective springshed and topographic information and an spring of watershed on cover page as well as in *figure 2*.

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Table 1: Salient Features of Danda Watershed

Population, Yr 1991	Human: 1732, Cattle: 839
Population, Yr 2009	Human: 1276, Cattle: 367
Major crops	Rice, Wheat, Koda, Rajma, Tor, Masoor, Soyabean, Mustard, Uardh, Gaith
Forest Produce	Timber, fuel wood, grass, fodder leaves, resin, honey, wax
Rainfall, mm	Monsoon: 575 mm Non-monsoon: 325 mm
Elevation, m	780-1800
Air temperature, ^{0}C	Max: 35 Min: 4
R. Humidity, %	Max: 92 Min: 40
Evaporation, mm/day	Max: 6 Min: 1.4

The domestic water source in the area is mainly springs. The springs are gravitational fracture springs of perennial or seasonal in nature. The highly weathered and immensely fractured geological system allows a rapid transit of water through the aquifer. Springs dries up with early summer as the soil which has water retaining capacity are being degraded due to deforestation and thinning of forest cover and or due to rainfall pattern with increasing high intensity storms with longer dry spells.

III. SPRING FLOW RESPONSE

The monthly average discharge of a particular high yielding spring of Danda watersheds is shown in *figure 3* along with the rainfall of the watershed. The spring response to rainfall can easily be identified through the sudden peaks in spring flow.

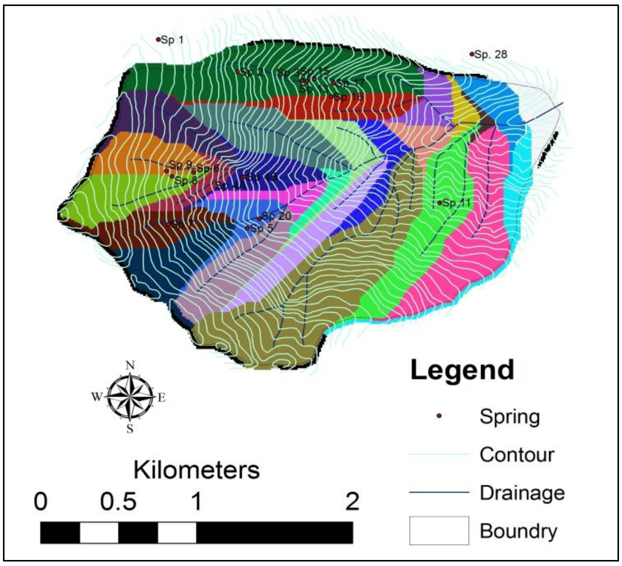

Figure 1: Springs of Danda on its Sub-Watershed

ISSN: 2319-8753

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Figure 2: One springs of Danda watershed

The quick response of rainfall on springs suggests that the recharge area of spring is in close vicinity of spring with in the watershed and is due to only rainfall. The cumulative spring flow and cumulative rainfall for five selected springs of Danda watershed is presented in *figur 4.*

Overall the cumulative spring flow indicated exponential/power or second order polynomial response to cumulative rainfall for the yearly period (June to May). A sudden rise of cumulative spring flow in the months of October to January can well recognize the impact of winter rains in sustaining the spring flow for forthcoming summer (*figure 4).*

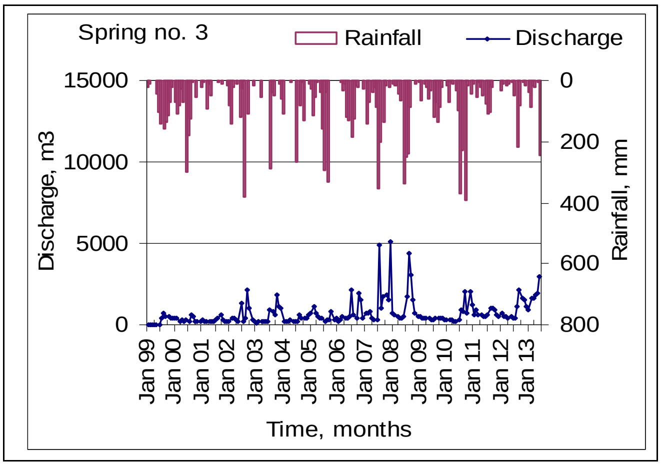

Figure 3: Monthly average discharge of a spring

ISSN: 2319-8753

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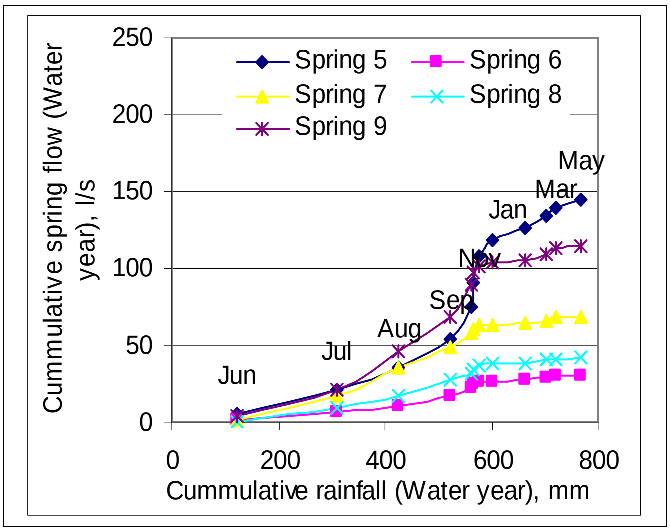

Figure 4: Cumulative spring flow for water year for few selected springs

The slope of ten day flow duration curve (*figure 5*) is almost flat for higher ten daily average discharge but increases at low discharge, indicates that the limitation of available base flow to the springs. A sudden drop of flow duration curve is an indication of required recharging activates in the watershed in order to increase the base flow as to continue the flow in springs.

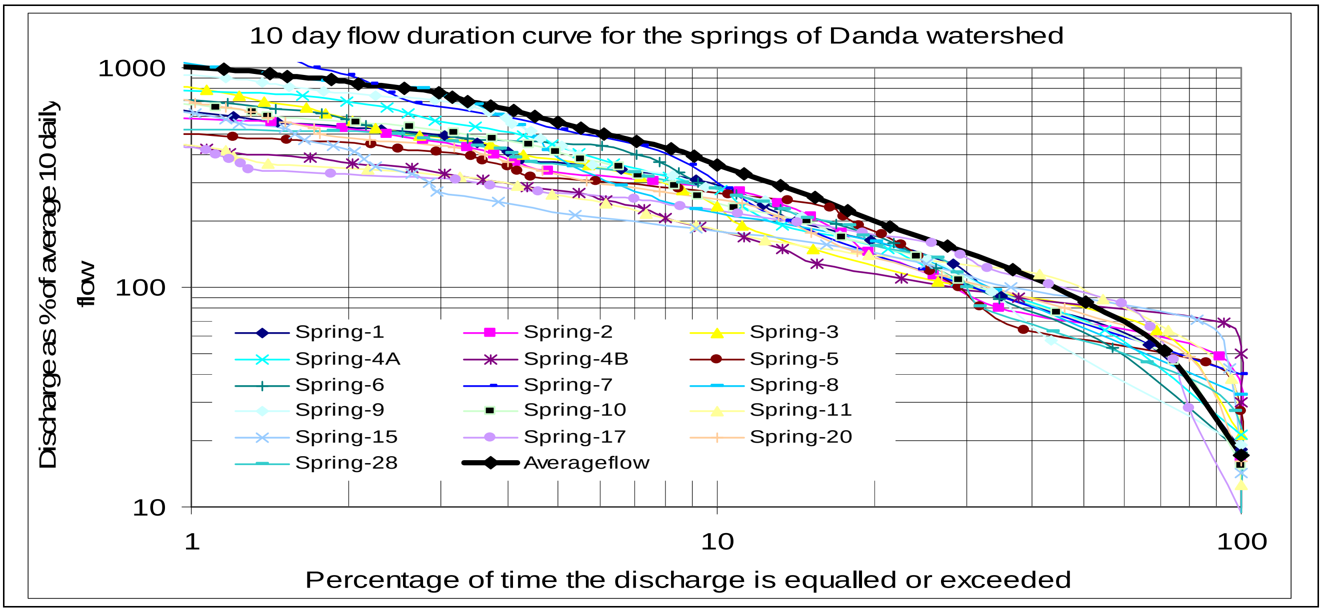

Figure 5: Ten daily flow duration curves for the flow of the springs of watershed

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IV. SPRING-RAINFALL LAG CHARACTERISTICS

The spring-rainfall lag characteristics have been identified considering daily data and to converted monthly data. Different springs of Danda watershed indicated a lag of 9 to 30 days and 0 to 1 months (*table 2*). A low value of spring-rainfall lag again suggests the springs of watershed as fast responding springs and the springshed in the close vicinity of the spring.

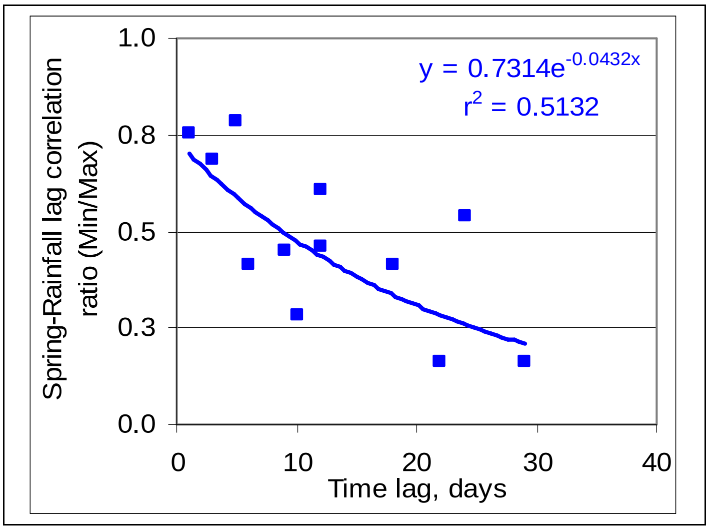

Figure 6: Relationship between spring–rainfall lag correlation ratio and spring-rainfall time lag

The spring-rainfall lag correlation ratio (minimum to maximum) defines the variability of spring flow and has been related to spring-rainfall lag in days (*figure 6*). It can be seen that the ratio decreases with increase in time lag in days. The exponential decay function exists between the variables and the obtained relationship is below as;

$$y_{(Danda)} = 0.7314e\text{-}0.0432x \qquad r^2 = .51$$

In above equation, y is the minimum to maximum spring-rainfall lag correlation ratio and x is the lag in days**.** This correlation ratio could be an indicator for classification of springs of watershed.

V. SPRING FLOW DEMAND AND USES

Springs are main dependable source of water for adequacy of water to the people of the watershed, especially for their domestic requirements. Through a human and animal population survey in 1991 the spring wise domestic water consumption of each family was estimated.

The domestic water demand in Danda watershed, which has a population of 427 man, 377 women, 472 minors and 367 animals is 40570 l/d compared to actual domestic use as 12670 l/d. This is only around one third of the theoretical domestic water requirements. This reflects the population's living condition and difficulty in acquiring water. A similar trend of water use was observed for almost all springs of Danda. The minimum monthly flow availability of all springs in use was 38364 l/d and that is around twice of actual water use as 12670 l/d but less than domestic water demand. It indicates that water availability even under lowest condition of flow can meet the uses but not the demand and is indication a very self restricted water consumption practices.

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The average maximum spring flow from Danda springs is found varying 5460 l/d to 60868 l/d and the minimum is form 102 l/d to 7000 l/d indicating the spring flow is highly variable (*table 2*). The average maximum and average minimum flow form the springs of watershed is 358874 l/d and 38364l/d. A high variation between average and minimum flow suggest that almost all the springs of the area drain to a lowest flow level towards to its end and are fast responding springs.

Table 2: Rainfall-spring lag, available flow and dement on Danda springs

Sl. no.	Sp. no.	Data length	Spring Lag days	Spring Lag months	Average available spring flow l/day	Minimum available spring flow l/day	Domestic water demand l/day	Domestic water use l/day
1	1	Jul 99 - Jun 10	22	2	26086	807	11055	4530
2	2	Jul 99 - Jun 10	12	2	33414	7000	4430	1015
3	3	Jul 99 - Jun 10	2	0 to1	20097	4462	1130	270
4	4A	Jul 99 - Jun 10	24	1	39916	3664	4775	1105
5	4B	Apr 05 - Jun 10	22	0	5460	3011	1160	340
6	5	Jan 03 - Jun 10	9	1 to 2	33964	8286	5395	1430
7	6	Jul 99 - Jun 10	12	1 to 2	7686	102	375	125
8	7	Jul 99 - Jun 10	10	1 to 2	14434	440	1025	310
9	8	Jan 03 - Jun 10	6	0	11148	783	635	185
10	9	Jul 99 - Jun 10	18	1	27898	297	Not in use	Not in use
11	11	Jun 00 - Jun 10	29	3	11545	1401	4135	1265
12	13	Nov 99 - Jun 10	5	1	13939	1527	2395	705
13	15	Nov 99 - Jun 10	1	0	8739	1223	2295	670
14	16	Jul 02 - Jun 10	17	0 to 1	5729	475	870	395
15	17	Nov 99 - Jun 08	25	1	8053	730	Not in use	Not in use
16	20	Nov 99 - Jun 10	25	1	29898	3020	895	325
17	28	Jul 01 - Jun 10	25	1	60868	1136	Not in use	Not in use

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VI. RAINFALL SPRING FLOW RELATIONSHIP

Yearly spring flow from the springs of the watershed has been shown in *figure 7* and the identified relationship between yearly rainfall and total yearly spring flow in the form of second order polynomial form for the watersheds is below as;

$$TSp = 0.0072*TRa^2-3.352*TRa-3967 \qquad r^2 = 0.83$$

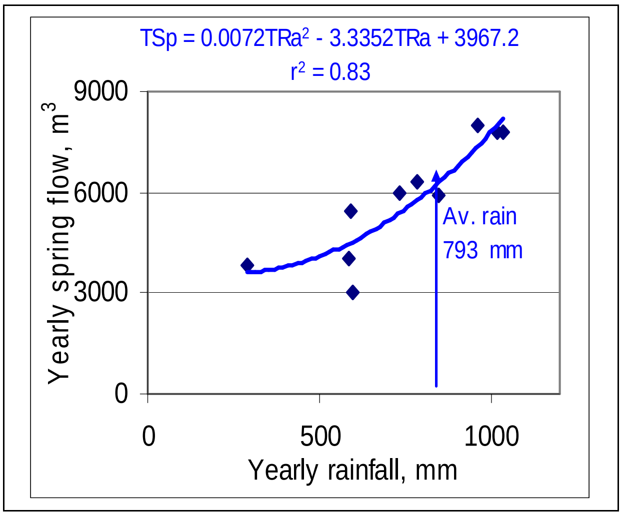

Figure 7: Relationship between total yearly rainfall and total yearly spring flow

In which, TSp is yearly spring flow (m^3) and TRa yearly rainfall (mm). Relationship indicates that the total spring flow increases with total amount of rainfall. In principal the relationship supports that for an a rainfall below average the 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 form of polynomial equation suggests that spring flow for Danda watershed has not reached to saturation for rainfall up to 1000 mm.

VII. CONCLUSIONS

The proposed solution to overcome the problem is to make efficient use of the available water and at the same time increase available water resources adopting below as;

1. Water storage structures are essentially required to store spring flow of the non use periods for domestic use during other periods. Planning is required especially for proper storage and distribution and if required the transfer of water in collaboration with the existing social laws, from “excess” areas to “shortage” areas, through gravity flow.
2. Water availability through springs under lowest condition of flow can meet the uses but not the demand and is strong indication a very self restricted water consumption practices.
3. Water harvesting structures are required over respective springshed to increase infiltration of rainwater in monsoon months in order to increase the flow of springs.
4. A decision support plan required for proper distribution and utilization of water in the watershed for domestic use.
5. Efficient drip irrigation method is highly recommended with horticulture crops as to maximize the use of limited spring water potential.

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ACKNOWLEDGEMENT

Author acknowledges the data of Department of Science & Technology (DST), project ES/11/741/2003 and an internal study of National Institute of Hydrology, Roorkee.

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BIOGRAPHY

Dr. Avinash Agarwal presently working at National Institute of Hydrology, Roorkee in the capacity of Scientist ‘F’. He was born in 1956 and earned qualifications as B.Tech. (Allahabad), M.Tech. (Pantnagar), M.S. (Guelph, Canada), Ph.D. (Pantnagar). He has served in different capacities and published more than seventy papers national and international level. He has guided a number of graduate thesis and published number of reports at official level. He has published two e-books on artificial neural network. Area of research interest is hydrological modeling, sediment transport modelling, hydrological drought analysis, regional low flow analysis, artificial neural network modeling, watershed monitoring & water management planning, springs monitoring & modelling and Dam break analysis.

Dr. Nitin Kumar Agrawal received the M.Sc. degree from M.J.P. Rohilkhand University, Bareilly, Uttar Pradesh, India in 2002 and Ph.D. degree from Gurukula Kangri University, Hardwar, India in the year 2009. Currently he is an Assistant Professor in Department of Applied Sciences and Humanities in Moradabad Institute of Technology, Moradabad, Uttar Pradesh, India. He has published Various research papers in different reputed International and National journals and also presented various research papers in National and International conferences.