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Estimation of snow melts contributionin runoff using ϕ index method for Manali and Pandoh catchment

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Abstract:Precipitation falls on the earth via various means such as Drizzle, Rain, snow, etc. out of this snowfall is the most important form for hilly catchment areas. In winter snow covers the hilly tracks and which contributes to the water in stream in the form of snow melts. This snow melts needs to be calculated by scientific methods in order to use it wisely. In this method ϕ index method is adopted and daily rainfall runoff data is used for 10 years (1991 to2000) to calculate the snow melts contribution in runoff for Manali and Pandoh catchment in Himachal Pradesh, After the analysis of data & statistical techniques it is used to determine % snow melts contribution, for Manali catchment the estimated snow melts contribution is about 48 to 52% and for Pandoh it is about 32 to 36%.

Index terms: Rainfall-runoff modelling, snow melts contribution, ϕ index method, rainfall, runoff

I. INTRODUCTION

"Water is the elixir of life. Without it life is not possible" (Fetter, 2000).A huge mass of water is stored in the snow and glaciers form on basins which are situated at very high elevation or at very high hilly areas. Many rivers, distributaries, tributaries and lakes are served by the fresh water which comes into it due to the melting of snow and glaciers. The total estimated area ofGlaciers in the world is about 14.9×10^6 km^2, means the 10% area of land is covered by glaciers which are the ultimate source of fresh water. At Pandoh the maximum and minimum snow covered area is 51% (2700 km^2)and 14% (780 km^2) respectively.

In India about 35% of the topographical area is concealed by the highlands and about 58% of this area is a part of Himalayas in which more than 5000 glaciers covers about 38000 km^2area (Dr. S.K. Jain et al.,2014). Dueto such high amount of runoff Himalayas contribute about 78% of the total hydropower generated which is 26% of total power generated. The snow melts contribution is also essential to determine because before constructing any hydraulic structure, it is necessary to determine the amount of water, for which hydraulic structure is designed so for designing or constructing hydropower project, it is essential to determine the total runoff i.e. runoff due to rainfall plus runoff due to snow melts contribution.

Basin	Site	Total area (Km^2)	Max. snow cover area (Km^2)	Min. Snow cover area(Km^2)
Beas basin	Pandoh	5,278	2700 (51%)	780 (14%)
Ganga basin	Devprayag	19,700	9080 (46%)	3800 (19%)
Satluj basin (Indian part)	Bhakra dam	22,275	14498 (65%)	4528 (20%)
Chenab basin	Akhnoor	22,200	15590 (70%)	5400 (24%)

Table 1: Various basins and their max. and min. snow cover areas

Pandoh site is a basin of Beas river in winters its snow cover is maximum upto 51%, i.e. 2700 $Km^2$and in summers its snow cover is minimum upto 14%, i.e. 780 Km^2. The elevation of the Pandoh site varies from 900 above mean sea level to 5000 above mean sea level. A number of the essential tributaries which are a part of the BeasRiver upstream of Pandoh dam are the Parvati River close to bhuntar; the tirthan and Sainj Rivers near larji; the sabari nala close to kulu; and the bakhlikhad near Pandoh dam. A chief portion of the catchment lies beneath degraded forests and cultivated land. Steep slopes are very common place, but are terraced for agricultural purposes at several places within the decrease ranges.

II. STUDY AREA

Manali & Pandoh are the two catchments of Beas river. Pandoh is located in Mandi Tehsil of Mandi district in Himachal Pradesh, India. It is situated 18km away from Mandi, which is both districts& sub-district headquarter of Pandoh.The catchment of the Beas basin upstream of Pandoh Dam is 5278 km^2, of which approximately 780 km^2 is under everlasting snow and ice. The altitude of the examine location varies from about 900 m to above 5000 m a.M.S.L. The Beas move starts at an associate elevation of 3900 m (a.M.S.L.) from Beas Kund (a tiny ice body) at the Japanese slopes of Rohtang Pass of the mountain range accomplice flows in a very nearly north–south direction to Larji, anyplace it takes a flip closer to the west and flows within the identical direction to Pandoh in Himachal Pradesh.

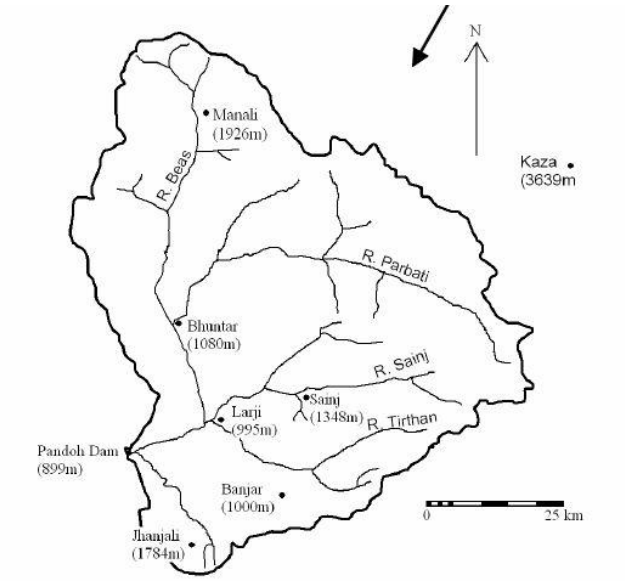

Figure 1: Pandoh dam site with raingauge network (Source: Vijay Kumar et al., 2010)

Manali Sub-basin, the look at region is ready at the north face ofKula district among 32.230 N- 32.420 N and 77.050 -77.280 E, Himachal Pradesh (HP) in the Republic of India. The most sites of location unit the globe, the world rectangular measure Manali (2000 m), Palchan (2320 m) and Solang (2480 m), Dhundi (2800 m), Beas Kund (3690 m) and distinctive stations location unit Kothi (2530 m), Marhi (3340 m), Rohtang Pass (3980 m), Bashist (2050 m), and Bhrigu Lake (4250 m). The sub-basinis also an area of the Beas flow mainly because of the Depression, one in each of the tributaries of watercourse system. It's an area of 350 Km^2 might be a part a place of "Valley of Gods" due to its non-secular and scenic locations.

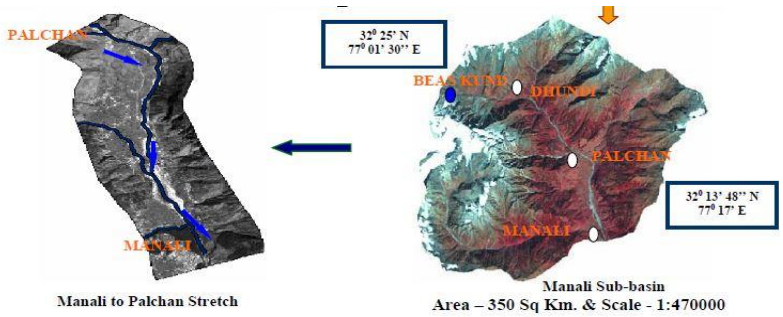

Figure 2: Manali Sub-basin at scale of 1:470000 (Source: D.K. Maity et al., 2009)

III. Data used

For Estimating the snow cover at Manali and Pandoh the daily rainfall and runoff data of 10 years is used,i.e. 1991-2000 and this data is used to estimate the runoff using ϕ index method and this estimated runoff is again used to determine snow melts contribution by comparing this estimated runoff with actual runoff since this actual runoff contains runoff due to precipitation and runoff due to snow melts hence the excess runoff in actual runoff is due to snow melting.

IV. METHODOLOGY

Φ –Index

The φ-index is that rainfall below which all the rainfall contribute to losses, hence no runoff occurs below this value or it is that value of rainfall after that the excess rainfall gives a contribution to the runoff.The φ-index is derived from thehyetograph of rainfall with the information of the subsequent runoff volume. The preliminary loss is also considered as infiltration. The value of φ-index is found by treating it as a constant infiltration volume. If the rainfall intensity is less than φ, then the infiltration rate is equal to the precipitation intensity; however, if the precipitation intensity is larger than φ the difference between the rainfall and infiltration in an interval of time represents the runoff volume.

Consider a rainfall hyetograph of event duration D hours and having N pulses of time interval Δt such that

$N .\Delta t = D$

Let Ii be the intensity of rainfall in the pulse and Rd = total direct runoff

Total Rainfall P = P $= \sum_1^N$ Ii .Δt

If φ is φ-index, then P – φ .te = Rd

Where te = duration of rainfall excess

If the rainfall hyetograph and total runoff depth Rd are given, the φ-index of the storm can be determined by trial and error procedure

a) In the first step we find the value of φ-index using formula P – φ . te = Rd
b) After finding the value of φ-index this value is considered as constant for the entire calculation.
c) Now subtract this value for φ-index from each daily rainfall data (te =1) the value which we get after subtracting is direct runoff value.
d) Compare this direct runoff value with actual runoff value,the value which we get after subtracting direct runoff value from actual runoff (direct runoff plus snow melts) is snow melts contribution.
e) To separate base flow exploitation by straight line methodology, the days in which the direct runoff begins and ends should be determined by observing the stream flow hydrograph.

V. RESULT AND DISCUSSION

A. Runoff at Manali

Runoff output for 10 years (1991-2000) of the period at Manali catchment is estimated using φ-index method and according to the data available the maximum rainfall at Manali occurred was 2479.6 mm in 1995 and the minimum rainfall at Manali was 1715.8 mm in 19992. The maximum rainfall in monsoon season occurs in July and August and minimum in monsoon in September and October. The value of runoff estimated using φ-index method, for the Manali sub-basin and the main point of results, in the year 1992 the rainfall, Estimated runoff and actual runoff was1715.8, 1344.1 mm and 2656.95 mm similarly for the year 1995 it was 2479.6 mm, 1967.75 mm and 4052.89 mm respectively and for the year 1996 it was 1847.8 mm, 1400.84 mm and 2779.85 mm respectively , for the year 1997 it was 1894.21 mm, 1583.69 mm and 2271.48 mm respectively, for the year 1999 it was 2263.2 mm, 1901.88 mm and 3704.3 mm respectively.

B. Runoff at Pandoh

The runoff is estimated for Pandoh site for Pandoh catchment the maximum rainfall was 1284.90 mm in 1997 and the minimum rainfall was 950.94 mm in 1996. The main point of results are in 1992 the rainfall, estimated runoff and actual runoff was 1047.16mm, 981.42 mm and 1492.45mm respectively, for the year 1995 it was 1211.32mm, 1134mm and 1654.72mm respectively, for the year 1996 the rainfall was 950.94 mm and estimated runoff 871.69 mm and the actual runoff is 1422.64 mm, for the year 1997 it was 1284.90mm, 1226.41mm, and 1377.36mm respectively, for the year 1999 it was 981.13 mm, 920.75 mm and 1311.32 mm respectively, for the year 2000 the rainfall was 1001.86 mm, estimated runoff 935.84 mm and the actual runoff 1339.62mm.

C. Snow melts contribution in runoff

The snow melts contribution for the Pandoh site for the year 1991 to 2000 is as follows

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Snow melts contribution (%)	44.47	34.47	32.83	38.25	31.43	38.51	10.96	33.91	26.15	30.48

Table 2: snow melts contribution (%) for Pandoh site from the year 1991-2000

From the above table, it is observed that the maximum snow melts contribution in runoff is in the year 1991 i.e. 44.47% and minimum snow melts contribution in runoff is in the year 1997 i.e. 10.96% and the average snowmelts contribution from year 1991 to 2000 is 32.15%. The snow melts contribution trend is almost similar for every year except in the year 1997, in this year the snow melts contribution is very less i.e. 10.96%,i.e. 150.6 mm and this contribution is very low as compare to average snow melts contribution

The snow melts contribution for the Manali site for the year 1991 to 2000 is as follows

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Snow melts contribution (%)	32.63	49.41	67.58	71.45	51.44	49.67	43.42	7.63	61.22	34.63

Table 3: Snow melts contribution (%) for Manali sub-basin from year 1991 to 2000

From the above table, it is observed that the maximum snow melts contribution is occurring in the year 1994 i.e. 71.45% and the minimum snow melts contribution occurred in the year 1998 i.e. 7.63%. The average snow melts contribution for the Manali sub-basin from year 1991 to 2000 is 46.91%. For every year the trend of snow melts contribution is similar except in 1998, in that year the snow melts contribution is very low as compared to the average value.

VI. VALIDATION OF RESULTS

On Manali sub-basins and Pandoh site there are manyresearches taking place by research scholars and they find the various factors for these sites. The (Vijay Kumar et al., 2007) runoff is estimated on Pandoh site using 15 years of data of yearly rainfall and snow melts contribution is estimated which is 35.1% and the snow cover area is estimated by two (Jain et al., 2009, Thomas et al.,1999) S.K. Jain mapped the snow coverage area for the maximum rainfall month (July, August) and S.K. Jain has also done research on Manali catchment using 15 years of rainfall runoff datafrom (1991-2004) and estimate the average snow melts contribution i.e. 50-52%. The average values for snow melts contribution we determine is 32.15% for Pandoh and 46.91% for Manali sub basins which is approximately same as another scholar so our results which we determine is found within the range.

VII. CONCLUSION

We have successfully done the estimation of snow melts contribution in runoff at Manali and Pandoh site the average snow melts contribution is 32.15% of the Pandoh site from 1991 to 2000 and the average snow melts contribution at Manali site is 46.91% from 1991 to 2000, these results are verified with research result and the result is found satisfactory. The results have some variation than actual results because of so many reasons such as they adopt the 15 year of data to estimate snow melts contribution while we use only 10 years of data to estimate snow melts contribution, In the (Vijay Kumar et al., 2007) Pandoh site the snow melts contribution in the year 2001, 2002, 2003 is more than 40% due to which the average contribution of 1990-2004 is approximately 35.61% these reason are same for the Manali sub basin for variations.

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