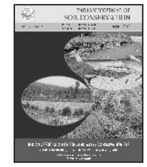
Vol. 46, No. 2, pp 146-150, 2018
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Assessment of base flow and base flow index of Ramganga river catchment

Rajesh Kumar[1,3], P.R. Ojasvi[2], V.K. Chandola[1] and A.K. Nema[1]

[1]*Department of Farm Engineering, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh;* [2]*ICAR-Indian Institute of Soil and Water Conservation, Dehradun-248 195, Uttarakhand.*

[3]*E-mail: rajeshyadav04@yahoo.co.in*

ARTICLE INFO

Article history:
Received : February, 2017
Revised : May, 2018
Accepted : June, 2018

Key words:
Base flow,
Base flow index,
Discharge,
Ramganga catchment

ABSTRACT

A study was conducted for assessment of base flow and base flow index in the Ramganga catchment area, a sub catchment of river Ganga, in Uttarakhand, India. The discharge data of three gauging stations *viz.*, Kedar, Naula and Sarpdully were collected and base flow and base flow index (BFI) were estimated from daily discharge record by Untied Kindom Institute of Hydrology method. This method performs a separation of the base flow from the total discharge to calculate the BFI. The mean BFI for total period of available daily record for the three gauging sites of Kedar, Naula and Sarpdully were 0.620, 0.676 and 0.800, respectively. The mean base flows of all gauging sites were estimated for daily stream gauge data series and the annual mean base flow was calculated. The highest base flow of 45.087 m^3s^{-1} was obtained at Sarpdully in 2012 followed by 42.679 m^3s^{-1} at Naula during 1973 and 7.573 m^3/s at Kedar gauging site in 1973. From the analysis it was concluded that the base flow contribution from the aquifer draining into Sarpdully gauging site has been maximum which indicated a perennial stream with porous aquifer whereas Naula and Kedar sites too have perennial streams but the aquifer of that area seems to be less porous or may have some obstructions.

1. INTRODUCTION

Increasing water demand poses new challenges for water resources planners and managers. The world population is increasing rapidly and expected to touch the 9.30 billion mark by 2050 from the 7 billion in 2011 (United Nations, 2010). Agricultural production needs to be increased in order to provide food and fiber for the burgeoning global population (Singh and Panda, 2012). To keep pace with the increasing population, agricultural production needs to be increased along with irrigation. Increases in agricultural production will depend heavily on existing water resources (Mishra *et al*., 2016). This is possible through development of new water resources projects including ground water or efficient water management of both available surface and groundwater resources (Panigrahi *et al.*, 1990; Panigrahi *et al.*, 1995; Mishra *et al*., 2015; Pande *et al.*, 2015; Dahiphale and Singh, 2017; Singh *et al.*, 2017).

Groundwater is the major source of drinking water in urban and rural India. Besides, it is an important source of water for agricultural and industrial sector. In many areas of India surface water is not available in sufficient quantity for irrigation and other purpose that case groundwater (base flow) is used as source of water. Base flow is a deciding factor the availability of water in a perennial stream of river. Groundwater is also help full to balance the use of surface water and groundwater (conjunctive use) exploration in agriculture and other sector. Knowledge about base flow is useful in assessing water quality, forecasting discharge, allocating water supply and designing hydropower plant under low-flow condition (Tallaksen, 1995). Knowledge of discharge regimes is one way to understand the stream flow process in a catchment (Bruskova, 2008).

The aim of this paper is to study the hydro-geological behavior of the Himalayan watershed and their aquifer system by separating the base flow from total discharge. Many methods have been developed to characterize the base flow of catchments, which can be conveniently categorized in to four basic approaches as (i) Graphical base flow separation (Linsley *et al.*, 1975; Frohlich *et al.*, 1994; Szilagyi and Parlange, 1998) (ii) Filtering algorithms (Nathan and McMahon, 1990; Eckhardt, 2005), (iii) Frequency analysis (Smakhtin, 2001) and (iv) Recession analysis (Welderufael and Woyessa, 2010). Graphical methods are used only for small catchment area and where data should not be too much longer period. Large catchments have large time of concentration which results in more error in base flow estimation by hydrograph method. This method is also very time consuming. This problem could be resolved by adopting BFI method for separation of base flow. BFI method is easy, less time consuming and gives more accurate result compared to hydrograph separation method. Groundwater system is a complex dynamic system characterized by non-stationary input (recharge), output (base flow), and response (groundwater levels) (Bruskova, 2008). Base flow is a discharge component which reacts slowly to rainfall and is usually associated with water discharged from groundwater storage (Eckhardt, 2008). It should be noted that watersheds covered principally by coarse materials and natural vegetation tend to contribute high proportions of groundwater to streams, while low percentages of groundwater discharge are associated with watersheds having large proportions of imperviousness (Zhang *et al.*, 2013).

2. MATERIALS AND METHODS

Study Area

The present study is confined to Ramganga river catchment which has 29^0 30'44" to 30^0 06'11"N latitude and $78^0$46'13" to $79^0$34'20"E longitude covering an area of 2519.95 km$^{2.}$ Ramganga river catchment is situated in Nainital and Almora districts of Uttrakhand state. It supports Ramganga reservoir project at Kalagarh for irrigation and hydroelectric generation under river valley project (RVP) scheme. River Ramganga originates from Doodhatoli ranges in the district of Pauri Garhwal in the Uttarakhand state of India. It flows towards south west in the Kumaun Himalaya. The gauging sites are located at three locations *viz.*, Kedar, Naula and Sarpdully, at a fairly stable cross-section of the river (Fig. 1). Data was collected from soil conservation division of Forest Department, Uttarakahand. Discharge data from 1973 to 2012 for Kedar and Naula sites, respectively and from 1986 to 2012 for Surpdully sites was collected. The catchment area of Kedar, Naula and Sarpdully sites is 704.94, 1108.94 and 2519.95 km^2, respectively (Fig. 1). The flow in this river is perennial and the catchment provides almost 8 months of base flow which includes the non-rainy season of almost 4 months. Base flow is generally influenced by watershed characteristics such as watershed physiographic features, distribution of water storage, evapotranspiration, geomorphology, land use and soil type (Price, 2011).

Estimation of Base Flow Index (BFI)

The BFI method developed during a low-flow study in the UK Institute of Hydrology (UKIH, 1980) was used for the proposed study. BFI is the index ratio of the base flow to the total flow which is calculated from a hydrographic smoothing and separation procedure using daily discharge. The

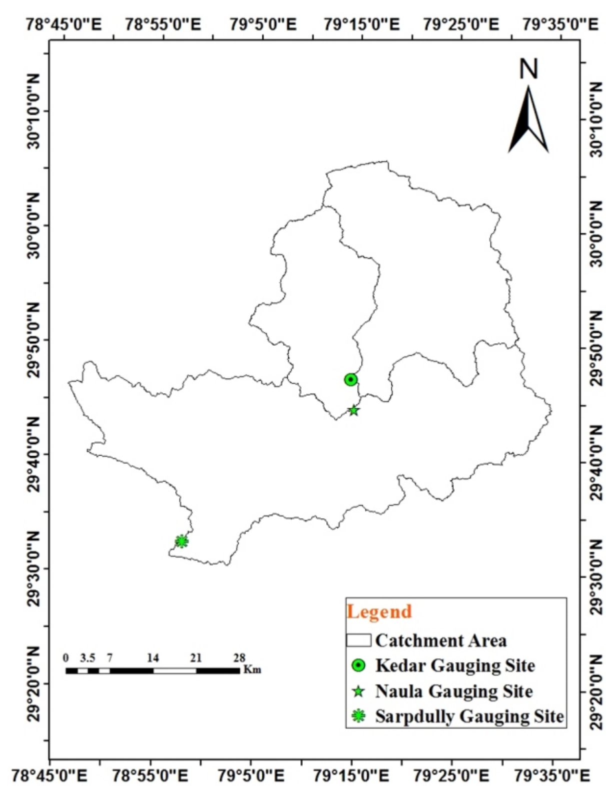


Fig. 1. Catchment area and gauging sites map of study area

program developed for UKIH method calculates the minima of five-day non-overlapping consecutive periods and subsequently searches for turning points in this sequence of minima. The turning points are then connected to obtain the base flow hydrograph, which is constrained to equal the observed hydrograph ordinate on any day when the separated hydrograph exceeds the observed. The procedure for calculating the index is as follows (UKIH, 1980):

1. Divide the mean daily flow data into non-overlapping blocks of five days and calculate the minima for each of these blocks, and let them be called Q_1, Q_2, Q_3...Q_n.
2. Consider in turn (Q_1, Q_2, Q_3,), (Q_2, Q_3, Q_4),...(Q_{i-1}, Q_i, Q_{i+1}) etc. In each case, if 0.9 x central value < outer values, then the central value is an ordinate for the base flow line. Continue this procedure until all the data have been analyzed to provide a derived set of base flow ordinates QB_1, QB_2, QB_3,...QB_n which will have different time periods between them.
3. By linear interpolation between each QB_i value, estimate each daily value of QB_1...QB_n.
4. If $QB_i > Q_i$ then set $QB_i = Q_i$.
5. Calculate the water volume (V_B) beneath base flow hydrograph between the first and last date of interest QB_1... Qb_n.
6. Calculate V_A the volume beneath the recorded mean daily flows Q_n for the period QB_1 ... Qb_n.
7. The base flow index is then V_B/V_A.

Base flow separation cannot start on the first day of the data record and similarly will not finish on the last day of record. It is important therefore to recognize that when the dates of the beginning and end of the base flow line have been established, then these same dates must be used in calculating the total volume of flow beneath the hydrograph as well as in calculating the volume of flow beneath the base flow line.

***Mean of annual BFIs*:** This field displays the mean of the annual BFIs, which are displayed under "Result: Annual values".

$$\text{Mean of the annual BFIs } = \frac{\sum_a BFI_a}{n}$$

Where, *BFIa* – Annual or seasonal BFI where *a* denotes the year / season, *n* - Total number of years / seasons (Morawietz, 2004).

All above steps for the estimation of BFI and base flow are analyzed by a program written in the Visual Basic.

3. RESULTS AND DISCUSSION

Base flow analysis was carried out for the Ramganga river catchment of three gauging sites *viz.*, Kedar, Naula and Sarpdully by using long term daily data of discharge.

Base flow and BFI at Kedar

For Kedar gauging site, base flow separation was performed for 40 years of available long term daily discharge data. It was estimated from daily discharge time series data for the whole period and mean annual base flow was calculated. This site has a fairly high base flow response with a maximum base flow 7.573 m^3s^{-1} in the year of 1973. The minimum base flow of 1.265 m^3s^{-1} was obtained during 2009 (Table 1). The mean daily base flow of this catchment is 3.040 m^3s^{-1} and indicated 62% contribution of base flow to the total discharge. The mean base flow and mean discharge of Naula site shown in Fig. 2 which clearly indicates the pattern and relationship of discharge and base flow. It was found that base flow was directly proportional to discharge of river in maximum period.

The BFI was estimated after separation of base flow from total discharge. It is the ratio of base flow to total discharge. The maximum BFI of 0.845 was observed in the year 1991 (Table 1) indicating 85% contribution of base flow to the total discharge. Minimum BFI value of 0.406 was obtained in the year 1984.

Base flow and BFI at Naula

Naula gauging site is located just below Kedar site at the Ramganga river. For Naula gauging site, base flow separation was performed for 40 years of available long term daily discharge data. It was estimated from daily discharge time series data for

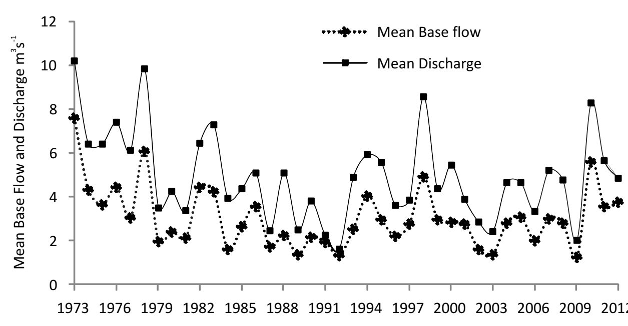


Fig. 2. Mean base flow and discharge of Kedar gauging site

Table: 1
Result of annual values BFI and Base Flow of different Sites

Year	Kedar site		Naula site		Sarpadully site	
	BFI	Base flow ($m^3 s^{-1}$)	BFI	Base flow ($m^3 s^{-1}$)	BFI	Base flow ($m^3 s^{-1}$)
1973	0.735	7.573	0.730	42.679	-	-
1974	0.675	4.310	0.786	19.326	-	-
1975	0.568	3.627	0.671	17.544	-	-
1976	0.599	4.428	0.608	14.688	-	-
1977	0.497	3.035	0.727	24.576	-	-
1978	0.617	6.076	0.648	29.971	-	-
1979	0.568	1.981	0.689	14.070	-	-
1980	0.569	2.425	0.540	12.612	-	-
1981	0.625	2.108	0.692	9.859	-	-
1982	0.687	4.423	0.705	15.245	-	-
1983	0.582	4.245	0.656	19.205	-	-
1984	0.406	1.591	0.596	12.059	-	-
1985	0.608	2.653	0.616	8.182	-	-
1986	0.704	3.574	0.765	17.424	0.630	17.390
1987	0.701	1.728	0.684	13.893	0.689	10.463
1988	0.445	2.260	0.686	17.205	0.543	12.141
1989	0.549	1.355	0.667	12.902	0.863	12.459
1990	0.570	2.172	0.679	19.900	0.747	12.530
1991	0.845	1.912	0.695	12.806	0.817	12.865
1992	0.823	1.319	0.703	10.756	0.874	12.539
1993	0.515	2.518	0.712	17.816	0.863	11.549
1994	0.687	4.057	0.678	22.442	0.876	9.686
1995	0.532	2.953	0.698	27.015	0.896	9.599
1996	0.608	2.188	0.758	10.309	0.892	7.921
1997	0.713	2.753	0.708	14.038	0.879	9.145
1998	0.572	4.901	0.592	15.385	0.648	12.464
1999	0.683	2.978	0.701	9.378	0.771	12.361
2000	0.519	2.830	0.559	12.722	0.618	16.544
2001	0.719	2.781	0.744	14.342	0.836	16.023
2002	0.561	1.591	0.637	6.155	0.711	14.834
2003	0.571	1.371	0.658	9.296	0.706	17.179
2004	0.603	2.793	0.534	8.213	0.898	19.146
2005	0.668	3.087	0.599	7.663	0.802	17.070
2006	0.606	2.025	0.777	10.926	0.894	15.738
2007	0.576	3.005	0.596	7.919	0.763	22.364
2008	0.591	2.803	0.636	6.833	0.914	19.186
2009	0.629	1.265	0.777	10.496	0.884	13.444
2010	0.677	5.598	0.748	6.759	0.811	17.115
2011	0.634	3.582	0.667	13.038	0.828	33.588
2012	0.775	3.743	0.717	20.157	0.924	45.087
Mean data	0.620	3.040	0.676	14.895	0.799	15.942

the whole period and mean annual base flow was calculated. This site has a fairly high base flow response with a maximum base flow 42.679 m^3s^{-1} in the year of 1973. The minimum base flow of 6.155 m^3s^{-1} was obtained during 2002 (Table 1). The mean daily base flow of this catchment is 14.895 m^3s^{-1} and indicated 68% contribution of base flow to the total discharge. The mean base flow and mean discharge of Naula site shown in Fig. 3. But in some years less base flow was produced with respect to discharge, it may be affected by change of the rainfall pattern and catchment properties.

The maximum BFI of 0.786 was observed in the year 1974 (Table 1) indicating 79% contribution of base flow to the total discharge. Minimum BFI value of 0.534 was obtained in the year 2004.

Base flow and BFI at Sarpdully

Sarpdully gauging site is located in the Jim Corbett National Park, Ramnagar district of Nainital below Kedar and Naula site at the Ramganga river. For Sarpdully gauging site, base flow separation was performed for 27 years of available long term daily discharge data. This site has a very high base flow response with a maximum base flow 45.087 m^3s^{-1} in the year of 2012. The minimum base flow of 7.921 m^3s^{-1} was obtained during 1996 (Table 1). The mean daily base flow of this catchment is 15.942 m^3s^{-1} and indicated 80% contribution of base flow to the total discharge. Fig. 4 showed that the total discharge and base flow having a close relationship that means the maximum part of total discharge contributed through the base flow. This site mostly found that the total discharge and base flow nearly overlapped in

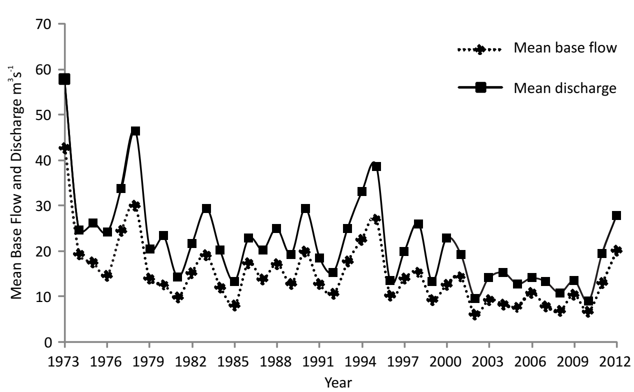


Fig. 3. Mean base flow and discharge of Naula gauging site

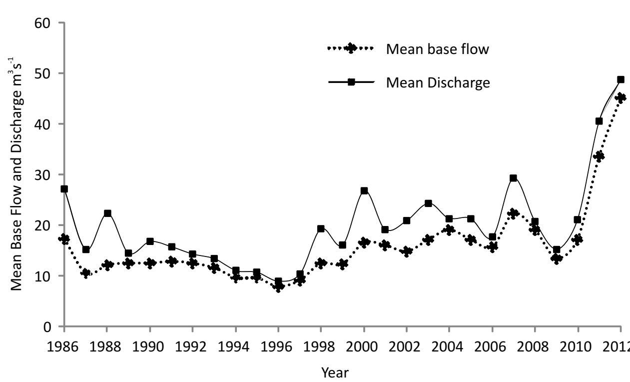


Fig. 4. Mean base flow and discharge of Sarpdully gauging site

maximum observations. There is no obstruction are available in the aquifers and it is more porous.

The maximum BFI of 0.924 was observed in the year 2012 (Table 1) indicating 92% contribution of base flow to the total discharge. Minimum BFI value of 0.543 was obtained in the year 1988.

4. CONCLUSIONS

From the present study it is concluded that Sarpdully site has maximum base flow and BFI as compared to Kedar and Naula gauging sites. Sarpdully has a mean daily BFI of 0.8 which clearly indicates that the catchment contributing surface runoff to the stream and recharging the groundwater is porous with perennial streams. The physiographic features of the site itself indicate that it is located in the reserve forest area where the aquifer is more porous. Naula and Kedar sites too have perennial streams but the aquifer of that area seems to be less porous or may have some obstructions. The average BFI value is 0.696 for all three gauging site of Ramganga river catchment which shows that in Ramganga basin about 69.6% discharge in the studied catchment is derived from groundwater discharge.

REFERENCES

Bruskova, V. 2008. Assesment of the base flow in the upper part of Torysa river catchment. *Slovak J. Civil Eng.*, 2: 8-14.

Dahiphale, Pravin and Singh, P.K. 2017. Identification of groundwater potential zones and artificial recharge sites in Jaisamand catchment using remote sensing and Geographical Information System. *Indian J. Soil Cons.*, 45(3): 244-254.

Eckhardt, K. 2005. How to construct recursive digital filters for base flow separation. *Hydrolo. Proces.*, 19: 507-515.

Eckhardt, K. 2008. A comparison of base flow indices, which were calculated with seven different base flow separation methods. *J. Hydrol.*, 352: 168-173.

Frohlich, K., Frohlich, W. and Wittenberg, H. 1994. Determination of groundwater recharge by base flow separation: regional analysis in northeast China. FRIEND: Flow Regimes from International Experimental and Network Data. *Proc. of Braunschweig Conference*, October 1993. IAHS Publ. No 221.

Linsley, R.K., Kohler, M.A., Paulhus, J.L.H. and Wallace, J.S. 1975. *Hydrology for Engineers*. McGraw Hill, New York.

Mishra, C.D., Tiwari, Y.K., Nema, A.K., Singh, G., Nema, R.K. and Kumar, R. 2015. Impact of conjunctive use of water resources on crop production in canal command area- A case study. *Indian J. Dryland Agric. Res. Dev*., 30(2): 37-43.

Mishra, C.D., Tiwari, Y.K., Nema, A.K., Singh, G., Nema, R.K. and Kumar, R. 2016. Water resources characterization in canal command area for Jhansi minor (left bank canal of Bargi dam) of Rani Avanti Bai Sagar irrigation project- A case study. *J. Soil Water Cons.*, 15(1): 58-63.

Morawietz, M. 2004. User's guide to BFI, In Tallaksen, Van Lanen (eds.), *Hydrological Drought: Processes and Estimation Methods for Stream Flow and Groundwater*, Elsevier, Amsterdam, 579 p.

Nathan, R.J. and McMahon, T.A. 1990. Evaluation of automated techniques for base flow and recession analyses. *Water Resour. Res.*, 26(7): 1465-1473.

Panigrahi, B., Paul, J.C. and Senapati, P.C. 1990. Management of groundwater- its development and utilisation aspects in Orissa. *Indian J. Power River Valley Devel.*, 11(1): 14-19.

Panigrahi, B., Nayak, A.K. and Sharma, S.D. 1995. Application of remote sensing technology for evaluation of groundwater potential. *Water Resour. Manage.*, 9: 161-173.

Pande, V.C., Kuroshe, R.S., Sena, D.R. and Kumar, G. 2015. Implication of optimal groundwater extraction for sustainable groundwater use in India Semi-arid tropical watershed. *Indian J. Soil Cons.*, 43(1): 1-8.

Price, K. 2011. Effects of watershed topography, soils, land use, and climate on base flow hydrology in humid regions: A review. *Prog. Phys. Geog.*, *35*: 465-492.

Singh, A. and Panda, S.N. 2012. Effect of saline irrigation water on mustard (Brassica Juncea) crop yield and soil salinity in a semi-arid area of North India. *Experi. Agri.*, 48(1): 99-110.

Singh, G., Singh, S., Singh, R.M., Kumar, R. and Mishra, C.D. 2017. Assessment of natural ground water recharge in Sonar sub-basin using HELP-3 model: A case study. *Indian J. Soil Cons.*, 45(2): 176-182.

Smakhtin, V.U. 2001. Low flow hydrology: a review. *J. Hydrol.*, 240: 147-186.

Szilagyi, J. and Parlange, M.B. 1998. Base flow separation based on analytical solutions of the Boussinesq equation. *J. Hydrol.*, 204: 251-260.

Tallaksen, L.M. 1995. A review of base flow recession analysis. *J. Hydrol.*, 165: 349–370.

United Nations. 2010. World Population Prospects. Revision Population Database. *http://www.un.org/esa/population/unpop.htm*.

UK Institute of Hydrology 1980. *Low flow studies report, 3 volumes.* Institute of Hydrology, Wallingford, UK.

Welderufael, W.A. and Woyessa, Y.E. 2010. Stream flow analysis and comparison of base flow separation methods, Case study of the Modder river in Central South Africa. *European Water*, 31: 3-12.

Zhang, Y., Ahiablame, L., Engel, B. and Liu, J. 2013. Regression modeling of base flow and base flow index for Michigan USA. *Water,* 5:1797-1815.