WATER AVAILABILITY ASSESSMENT IN KHARUN RIVER UNDER REGULATED AND VIRGIN FLOW CONDITIONS USING MIKE BASIN

Ravi Galkate[1], Palak Mehta[2], R.K. Jaiswal[1], T. Thomas[1]

[1] : Scientist, National Institute of Hydrology, Regional Centre, Sagar
[2] : JRF, National Institute of Hydrology, Regional Centre, Sagar

Abstract

The water availability study of Kharun river in Chhattisgarh state has been carried out to estimate dependable flow in the river basin at various probability levels at different time periods and to analyze the flow regime under virgin and regulated condition using MIKE BASIN software and Flow Duration Curve technique. The assessment of water availability is important for the planning of water allocation scheme in Kharun river basin to meet its on-stream demands. From the study it was observed that the flow regime in Kharun river has been strongly influenced by regulation operations associated with water transfer from Ravishankarsagar reservoir to Kharun river and its supply for various usages through the series of anicuts. The study indicated that the Kharun river is originally a intermittent river having flow during monsoon season and 2-3 months thereafter. To meet the various demands in Kharun basin, the water is being released in to the river from Ravishankarsagar reservoir, thus river experiences flow throughout the year under regulated flow condition.

Key Words: *water availability, virgin flow, regulated flow, flow duration curve, MIKE BASIN model.*

1.0 Introduction

Chhattisgarh, a newly born state is exploiting its water resources mainly for domestic, industrial water supply and developing irrigation schemes. However, the state is facing the problem of water scarcity in rural as well as in urban areas to meet various water demands. In such circumstances, understanding the complex system of hydrological processes and the water availability in the river basins, sub-basins are important for the sustainable water resources development of an area. Present study deals with the water availability study in Kharun river basin which is a tributary of Seonath basin in Chhattisgarh state. The area under Kharun river basin is characterized by water scarcity, increasing water demand and over exploitation of the available water resources. Lack of suitable water management measures in Kharun river leads to most of the precious water being drained down the rivers without being tapped causes more dependence on groundwater resources (Galkate et. al. 2010)

Water availability study of a Kharun river is an important component of hydrological planning, on the basis of which development of water resources of a river for various beneficial uses is thought of. The flow regime in Kharun river is strongly influenced by regulation operations associated with water transfer from Ravishankarsagar reservoir to Kharun and its supply for various usages through the series of anicuts. The study of water availability scenario in the Kharun basin has been carried out to analyze the present flow regime under regulated condition. The analysis has also been carried out under virgin flow condition to understand the nature of the river. The virgin flow of the Kharun river was simulated from observed regulated

flow by preparing Kharun River Basin Model in MIKE BASIN software. The present paper is a part of outcome of World Bank sponsored Purpose Driven Study (PDS) under HP-II programme.

2.0 Study Area

The Chhattisgarh region in India is characterized by dense forests at some regions, severe soil erosion and increasing water demands for industries and irrigation. The average annual rainfall in the region is about 1022 mm. Kharun is one of the important tributary of Seonath river. Seonath sub-basin is one of the important sub-basins of Mahanadi river. Kharun river basin falls in Durg, Raipur and Dhamtari districts. The Kharun river basin is situated between 20^{o} 38' N to 21^{o}36'N Latitude and 81^{o} 20' to 81^{o}55'E Longtitude. Kharun river originates from Petechua in the south-east of the Durg district and after flowing 129 km joins Seonath river near Somnath in Raipur district. The index map showing location of Kharun river in Chhatisgarh is shown in Figure 1.

The catchment area of Kharun river basin is 4112 km^2. It flows to the west of Raipur town and supply water to Raipur city through small storages Bhatagaon and Ghugwa anicuts. The major part of Kharun river basin comes under command area of Ravishankarsagar reservoir and small part under Tandula reservoir. The industries like steel plant, cement plant and Raipur industrial area falls in the catchment of Kharun river. It is supplemented from Ravishankarsagar reservoir situated at Dhamtari on Mahanadi river to meet the domestic water demand of Raipur city and railways and industrial water demand of Urla and Silthara industrial area. The main types of land use and land cover are agriculture, forest, settlements, barren, etc. and main crops are paddy, oilseeds, wheat, gram and vegetable. This region generally has a dry tropical weather which is moderate but on a warmer side in summer season. The peak temperatures are usually reached in May or June and can be as high as 45^{0}C. The onset of monsoon is usually from July and the season extends up to September, with monsoon peaking during July and August.

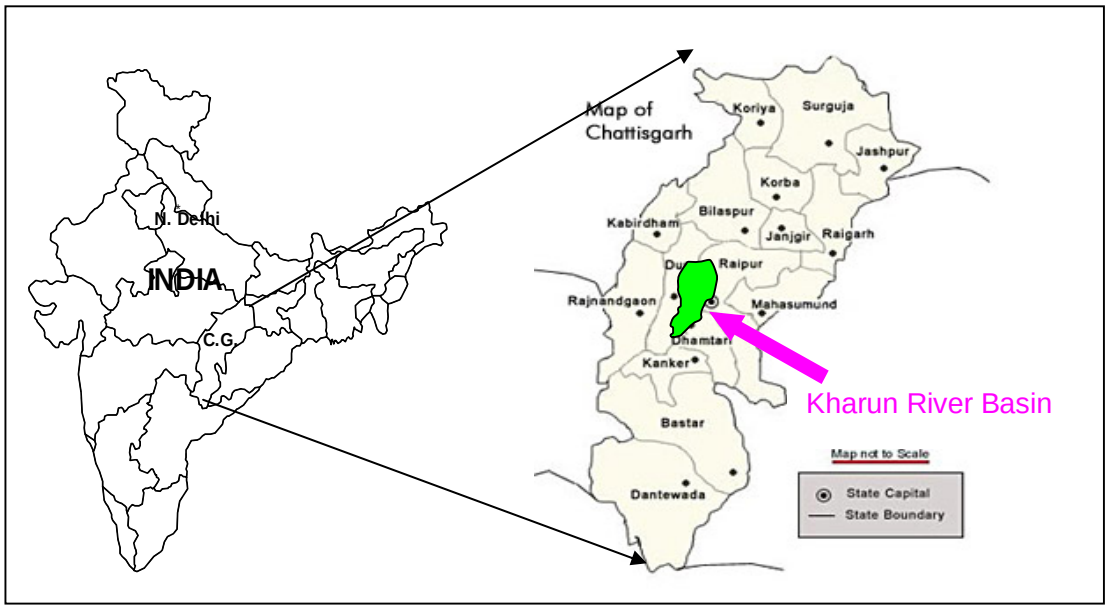

Figure 1: Index map showing location of Kharun river in Chhattisgarh

3.0 Estimation of Virgin Flow and Regulated Flow at Kharun Outlet

Runoff representing the response of a catchment to precipitation reflects the integrated effect of a wide range of catchment, climate and precipitation characteristics. True runoff is therefore stream flow in the natural condition that is without human intervention. Such as a stream flow unaffected by works of man, such as structure for storage and diversion works on a stream is called virgin flow. When there exists the inter basin transfer, storage or diversion works on a stream, the flow in the downstream channel is affected by structures and hence does not represent the true runoff unless corrected for water transfer effects, storage effects and the diversion of flow and return flow. The Kharun river flow is affected due to addition of water from Ravishankarsagar reservoir and diversion of water from series of anicuts which are shown in schematic in Figure 2.

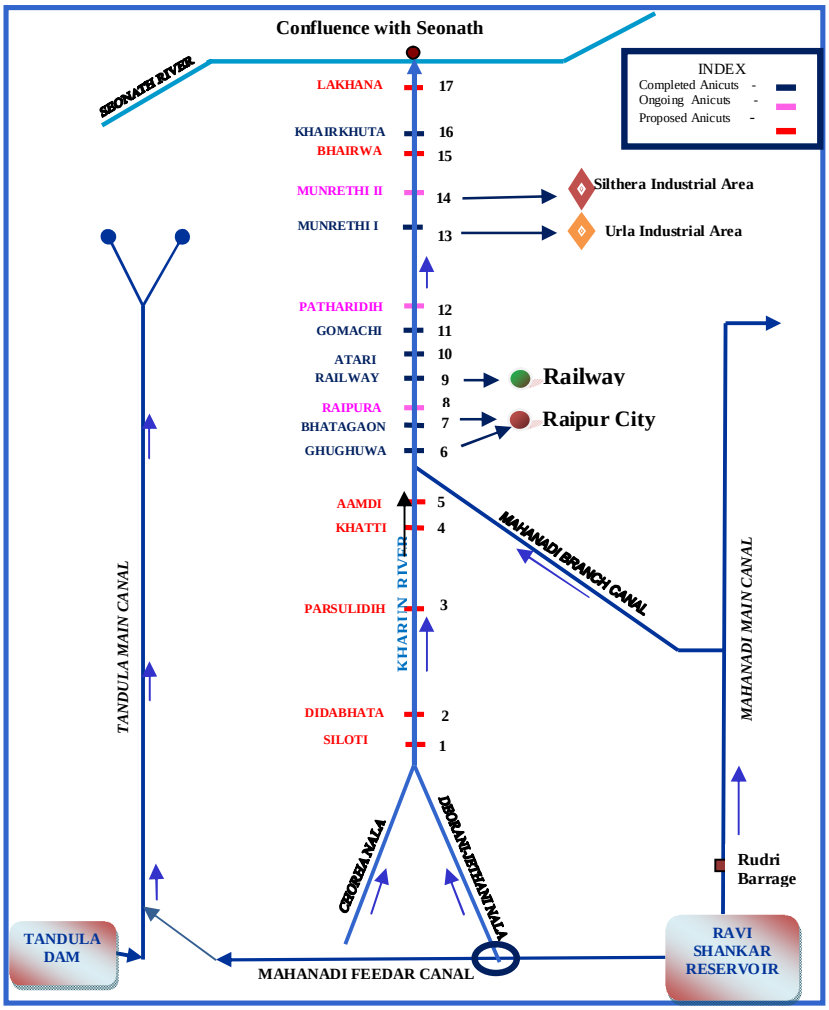

Figure 2: Schematic of Kharun rivers water transfer system

The water from Ravishankarsagar reservoir is being released into Kharun river from Mahanadi Feeder Canal (*MFC*) through Deorani Jethani Nala. The Mandhar Branch Canal (*MBC*) a major distributor of Mahanadi Main Canal (*MMC*) directly releases water into Kharun river. The water transferred into Kharun river is utilized to meet various water demands like domestic

water demand of Raipur city, industrial water demand, water supply for railways and other water demands. The irrigation water supplied through Mahanadi Main Canal (*MMC*) and Tandula Main Canal (*TMC*) in Kharun catchment area also joins the river in the form return flow and has significant contribution to the river flow. In present study the observed flow data of Patherdihi G/d site of CWC has been used for the analysis. The flow in Kharun at Patherdihi is highly regulated and influenced due to various regulation operations like water transfer, addition and diversions associated with it. The virgin flow time series at Patherdihi has been estimated from the regulated observed flow using MIKE BASIN Model. The data of water releases and diversions at all locations were collected from Water Resources Department, Govt. of Chhattisgarh, Raipur and used in the model. The existing water transfer setup of Kharun river basin is depicted through MIKE BASIN Model and is shown in Figure 3. MIKE BASIN is a network model in which the river and their tributaries are represented by network of branches and nodes. The river system is represented in model by digitized river network which can be generated directly in Arc Map 9.1 (DHI. 2003). Wubet, et. al. (2009) used MIKE BASIN model to gain an insight in to the potential downstream consequences of the development of physical infrastructure and water abstraction in a number of future development scenario in Abbay river basin in Ethiopia.

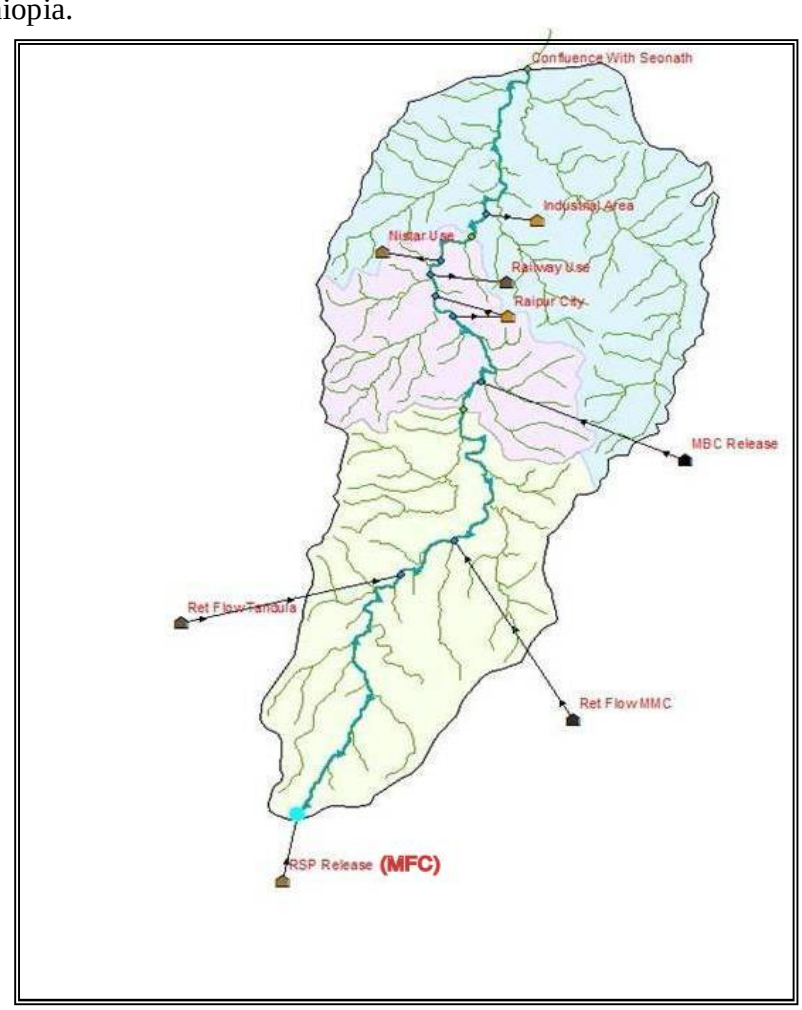

Figure 3: Kharun River Basin Model in MIKE BASIN for the estimation of virgin flow

The virgin flow time series at Patherdihi has been estimated from the regulated observed flow at Patherdihi using the following equations developed after critically observing the field conditions and existing setup of the Kharun river basin. The equations were developed and applied in the MIKE BASIN Model and the virgin flow time series at Patherdihi was obtained which was then used to simulate runoff at Kharun oulet. Virgin flow is calculated by accounting the water diverted and added into the Kharun river basin as shown in equation no 1, 2 and 3.
The equations developed for estimation of virgin flow are as given below:

$$Q_{Obs\ virgin} = Q_{Obs\ reguleted} - Q_{Added} + Q_{Diverted} \quad \ldots\ldots\ldots (1)$$

$$Q_{Added} = Q_{MFC} + Q_{MBC} + RF_{TMC} + RF_{MMC} \quad \ldots\ldots\ldots (2)$$

$$Q_{Diverted} = Q_{TO\ Raipur+Railway+Nistar} \quad \ldots\ldots\ldots (3)$$

Where

$Q_{obs\ virgin}$ = Virgin flow at Patherdihi G/D site
$Q_{obs\ regulated}$ = Actual observed flow at Patherdihi G/D site
Q_{MFC} = Flow from Mahanadi Feeder Canal through Deorani Jethani Nala
Q_{MBC} = Flow from Mandhar Branch Canal
RF_{TMC} = Return flow from Tandula Canal System
RF_{MMC} = Return flow from Mahanadi Main Canal System.
$Q_{Diverted}$ = Water diverted from Raipur city supply, railway and for the purpose of nistari

The regulated and virgin flows were then simulated for the whole Kharun basin using the same MIKE BASIN setup. To simulate the runoff at the river outlet, the virgin flow time series (in m^3/sec) thus generated at Patherdihi was converted in the form of specific runoff time series (in l/sec/km^2). This specific runoff time series was then applied in MIKE BASIN model to catchment properties of all sub-catchments of the model and model was run to simulate the runoff at all its nodes, sub catchment outlets and at the main outlet of the Kharun river. The runoff time series thus obtained as a virgin flow time series at Kharun river outlet. The observed regulated flow data at Patherdihi was routed in similar way to get regulated flow time series of Kharun river. The virgin and regulated flow time series of Kharun basin thus obtained using MIKE BASIN Model as described above were used for the water availability analysis using flow duration curve technique.

The runoff time series data of virgin and regulated flow was then converted in the form of annual yield from the Kharun catchment. The average annual rainfall, virgin flow, water added and regulated flow in Kharun river are given in Table 1. From the analysis of the results given in Table 1, it was observed that the average annual rainfall in Kharun basin is 1147.57 mm which produces 1802.88 MCM average annual runoff. The river has sufficient annual water yield but due to lack of big storage structures on river which is due to prevailing flat topographic conditions, the water demands in the basin cannot be fulfilled by the river. The Ravishankarsagar reservoir and other sources add around average 116.22 MCM water in the river which is supplied to Raipur city, railways and industrial area through the series of anicuts and the average annual regulated flow in Kharun river becomes 1919.1 MCM.

Table 1: Annual rainfall, virgin flow, water added and regulated flow in Kharun river

Year	Rainfall (mm)	Virgin Flow (MCM)	Water Added to river (MCM)	Regulated Flow (MCM)
1993	1182.9	1620.12	112.85	1732.97
1994	1640.8	3688.99	99.60	3788.60
1995	1166.6	2084.71	117.56	2202.27
1996	1129.3	1648.02	93.85	1741.88
1997	1177.1	1564.40	109.91	1674.31
1998	1097.8	1163.47	80.82	1244.29
1999	1074.7	1544.13	110.79	1654.91
2000	698.5	484.38	114.62	599.00
2001	1065.7	1529.47	134.48	1663.95
2002	811.9	993.54	127.20	1120.73
2003	1384.4	2642.12	125.31	2767.44
2004	1023.9	1452.38	139.54	1591.91
2005	1425.1	2794.48	118.08	2912.55
2006	1110.3	1681.78	138.34	1820.12
2007	1224.5	2151.22	120.33	2271.54
Average	**1147.57**	**1802.88**	**116.22**	**1919.10**

4.0 Water Availability Analysis

Water availability analysis in Kharun basin has been carried out by estimation of dependable flow volumes at various probability levels using Flow Duration Curve technique. Assessment of dependable flows along with their distribution in time is essential for planning and development of water supply schemes. Especially the study of the lean season flow characteristics is important to determine the probability of the river system to provide adequate and assured water supply for meeting the expected demands (Pandey and Ramasastry, 2003). It is generally observed that the flow characteristics of the streams are highly dependent upon watershed topography, climate and land use. The flow duration depends on natural conditions as well as man-made effects and may reflect some specific water use practices (Chang and Boyer, 1977 and Clausen and Pearson, 1995). The time periods usually considered in flow duration analyses are 1 day, 7 days, 10 days or 30 days. The present study aims to assess the availability of dependable flows volumes in the Kharun river on monthly basis within a year at 60, 70, 80 and 90% probability of exceedance. The virgin and regulated daily flow data of 15 years from 1993 to 2007 was grouped under twelve months periods. The monthly Flow Duration Curves (FDC) for the month of December under virgin and regulated flow condition are shown in Figure 4. The dependable flow available in Kharun river under virgin condition (m^3/s) at various probability levels is given in Table 2. The dependable flow available in Kharun river under regulated condition (m^3/s) at various probability levels is given in Table 3. The graph showing water

availability in Kharun river under virgin and regulated flow condition at 90% probability is given in Figure 5.

Table 2: Dependable flow available in Kharun river under virgin condition (m^3/s) at various probability levels

Prob.(%)	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
60	0.00	0.00	0.00	0.00	0.00	3.500	36.715	102.867	33.332	0.624	0.127	0.069
70	0.00	0.00	0.00	0.00	0.00	2.230	17.819	72.327	17.380	0.279	0.067	0.042
80	0.00	0.00	0.00	0.00	0.00	1.830	12.296	47.180	7.898	0.052	0.040	0.035
90	0.00	0.00	0.00	0.00	0.00	1.032	8.107	19.035	1.540	0.030	0.022	0.000

Table 3: Dependable flow available in Kharun river under regulated condition (m^3/s) at various probability levels

Prob.(%)	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
60	3.960	3.960	4.250	4.955	5.100	5.100	36.393	111.842	38.907	4.866	3.204	2.833
70	2.955	3.850	3.400	4.608	4.540	4.250	17.891	77.743	22.030	4.443	3.013	2.831
80	2.916	2.955	2.830	3.648	3.018	2.915	12.910	48.446	11.598	4.255	2.953	2.830
90	2.830	2.830	2.830	3.262	3.013	2.830	8.189	19.399	5.450	3.943	2.851	2.830

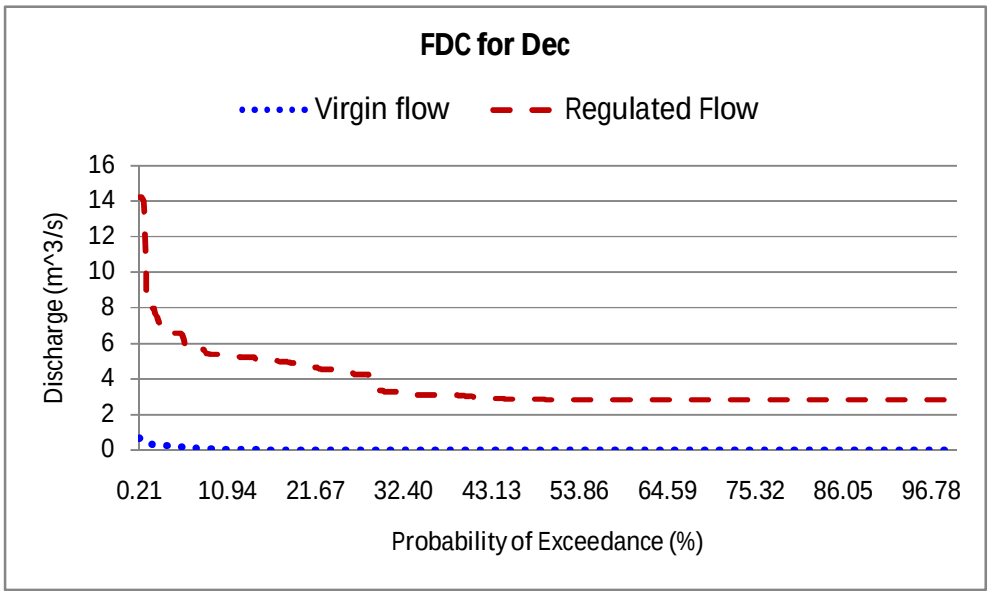

Figure 4: Flow Duration Curve for December under virgin and regulated flow condition

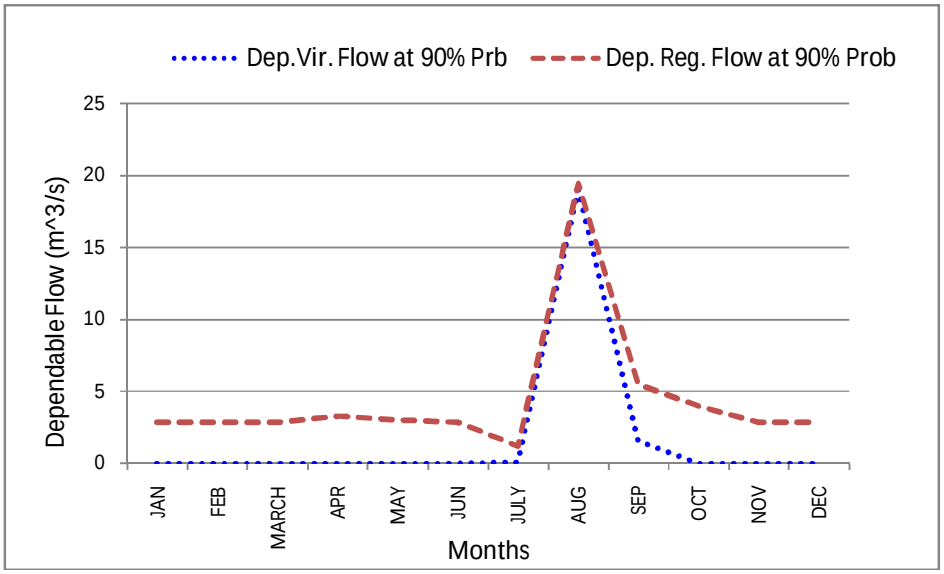

Figure 5: Water availability in Kharun river under virgin and regulated flow condition

5.0 Results and Discussion

From the analysis of Table 2, dependable flow available in Kharun river under virgin condition, it was observed that the Kharun river is originally a intermittent river having flow during monsoon season and 2-3 months thereafter. Under the natural virgin condition, the river has no flow during January to May at even at 60% probability. The river has high dependable flow at during July to September and highest in the month of August. The highest dependable flow 102.8 m^3/s at 60% probability and 19.03 m^3/s at 90% probability level were observed in the month of August. The river flow has significant temporal variation in monsoon and non-monsoon season, contributing large yield during July to Septembers and low flow thereafter prevailing up to December. Thus the demands of the river cannot be fulfilled with the water availability under the virgin condition.

To tackle this situation the water from Ravishankarsagar reservoir is being released into Kahrun river from Mahanadi Feeder Cannal (MFC) through Deorani Jethani Nala and Mandhar Branch Cannal (MBC) to meet the various demands in Kharun basin and river experiences flow throughout the year under regulated flow condition. From the analysis of Table 3, dependable flow available in Kharun river under regulated condition, it was observed that the Kharun river has now considerable flow during January to May even at 90% probability. At 90% probability the dependable flow in river was observed 2.83 m^3/s in January whereas 3.01 m^3/s in May which is due to addition of more water during summer months to fulfill the demand. The highest dependable flow 111.84 m^3/sec at 60% probability and 19.39 m^3/s at 90% probability levels were observed in the month of August which is almost same as the virgin flow condition indicating no need of additional water release in to the river during monsoon season.

From the analysis of Flow Duration Curve for the month of December shown in Figure 4, it was observed that the dependable flow volume has been considerably increased under regulated flow as compared to virgin flow condition. Similarly, Figure 5 illustrate the increase of monthly dependable flow volume or water availability in Kharun river at 90% probability when water is

added to river from the external sources like Ravishankarsagar reservoir and Mandhar Branch canal to meet the various on-stream water demands in the river basin. The water has also been added to Kharun river in the form of return flows from Mahanadi Main Canal and Tandula Main Canal.

6.0 Conclusions

The MIKE BASIN is a mathematical representation of the river basin. It was found as a powerful tool for flow routing to generate flow time series at required locations. The assessment of water availability is important for planning of water allocation scheme. From the analysis it was observed that the flow regime in Kharun river has been strongly influenced by regulation operations associated with water transfer from Ravishankarsagar reservoir and its supply for various usages through the series of anicuts. The study indicated that the Kharun river is originally a intermittent river having flow during monsoon season and 2-3 months thereafter. To meet the various demands in Kharun basin, the water is being released in to the river from Ravishankarsagar reservoir, thus river experiences flow throughout the year under regulated flow condition.

REFERENCE

Chang, M. and Boyer, D.G. 1977. Estimates of low flow using watershed and climatic parameters. Water Resources Research, vol 13, no 6, 1977, 977-1001.

Clausen B and Pearson C P. 1995. Regional frequency analysis of annual maximum streamflow drought. Journal of Hydrology, vol 173, 1995, 111-130.

DHI. 2003. MIKE BASIN: MIKE BASIN Training Mannual, Danish Hydraulic Institute, Copenhagen,Denmark.

Galkate, R.V., Thomas, T., and Jaiswal, R. K. (2010). “Low flow analysis in Kharun river of Chhattisgarh State”, International Workshop on River Management (IWRM), Dec 14-16, 2010, New Delhi.

Pandey, R.P. and Ramasastri, K.S. 2003. Estimation of lean season water availability in streams with limited data. Institute of Engineers (I) Journal, Vol. 84, November 2003, 149-152.

Wubet, F.D., Seleshi, B.A. and Moges, S.A. 2009. Analysis of water use on large river basin using MIKE BASIN model – A case study of the Abbay river basin, Ethiopia. International Result Dissemination Workshop, Feb. 5-6, 2009, Addis Ababa, Ethiopia.