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ASSESSMENT OF WATER DEMAND AND SUPPLY PROSPECTS IN KHARUN RIVER BASIN

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ABSTRACT
The assessment of disparity between water demand and supply has always been a great concern for water managers and policy makers due to unavailability of requisite hydrological information, lack of long term quality data, need of appropriate methodology and complexity of modeling techniques. The aim of this study is to assess supply status of Kharun river of Chhattisgarh state in term of its water availability using probability approach, estimation of projected water demands and its comprehensive water surplus and deficit analysis. The water from Kharun river is utilized mainly to meet domestic water demand of Raipur city, its nearby industrial area, railways and other on-stream demand water demands like Nistari. Estimated total water demand of Kharun river was 65.21 MCM in 2010-11 which will become 174.56 MCM by the year 2050-51. Kharun river has sufficient annual water yield but run dry during lean period. To meet various water demands, river is supplemented from Ravishankarsagar reservoir through canals and links. The demand supply analysis carried out using Flow Duration Curve techniques using 10-daily flow data of Pathardihi Gauge Discharge (G/d) site on Kharun gives an idea of water surplus and deficit scenario of present and future situation. It was seen that when the demand of the river in year 2030 and 2050 will increase to 133 and 175 MCM, the water deficit would becomes 73.56 and 105.33 MCM respectively. The demand deficit analysis gives an idea of variation in water deficit with respect to the variation in water demand and dependability level of the river flow. On comparison of total water demand to be fulfilled from river and water deficit periods, it was observed that, as the water demand increases, the deficit period also increases, the river experiences the deficit earlier when the demands is very high.

Key Words: *water demand, demand supply, surplus deficit, flow duration curve, domestic and industrial water supply, Kharun river.*

INTRODUCTION
Supply and demand is perhaps one of the most fundamental concepts of economics, which is equally important in water sector too. Water has demands, sources and supplies; it has economic, social, and political values which make it a unique and challenging natural resource to manage. The assessment of disparity between water demand and supply has always been a great concern for water managers and policy makers due to unavailability of requisite hydrological information, lack of long term quality data, need of appropriate methodology and complexity of modeling techniques. Numbers of researchers have worked to address water demand and supply

issues on the river basin or administrative unit scale using hydrological models or water planning tools. An attempt has been made to assess India's food and water future in 2025 and 2050 and water availability assessment at temporal scale like annual or seasonal and spatial scale like rural, urban or basin using PODIUSIM model (Amarasinghe et al. 2007). Water balance model can also be applied to find out solutions of supply-demand problem to meet future demands under average and stress conditions (David et al. 1982, Hendricks et al. 2007). Analysis of water demand-supply systems in large spatial areas based on the hydrological processes of evapotranspiration and runoff can be employed to meet future water demand (Toshisuke Maruyama, 2007). Other important aspect of demand supply scenarios is water demand management policy that stresses making better use of existing supplies, rather than developing new ones (Winpenny, 1997 and Brooks, 2006). Assessment of water demand and supply prospects for its management coupled with effective policy, awareness, efficient structures, institutional strengthening and professional skills is vital to enhance the sustainability of the system (Bhatti, 2010).

The aim of this study is to assess supply status of Kharun river in term of its water availability using probability approach, estimation of projected water demands and its comprehensive water surplus and deficit analysis. Kharun is one of the important river in Chhattisgarh state which is tributary of Seonath river traversing through Durg, Raipur and Dhamtari districts having catchment area 4112 km^2. The major part of Kharun river basin comes under command area of Ravishankarsagar reservoir and small part under Tandula reservoir. The water from Kharun river is being utilized to meet the domestic water demand, industrial water demand, water supply for railways and other water demands in the basin. In the analysis, the water available in the Kharun was considered as the "supply". The "demand" includes the amount of water needs to be supplied from Kharun river. The Kharun river is regularly supplemented from Ravishankarsagar reservoir situated on Mahanadi river to meet these water demands. The schematic of water transfer system in Kharun river and its location in Chhattisgarh has been shown in Figure 1.

METHODOLOGY

The demand supply analysis has been carried out for Kharun river using observed flow data at Patherdihi G/d site. It includes the assessment of present and future water demands, water availability in river and surplus deficit scenario at various probability levels.

Water Demands

The Kharun river water is being used to meet domestic and industrial water demand, water supply for railways and other small on-stream demands like Nistari. The Kharun water is not being used for irrigation purpose hence it is not accounted in analysis. The Kharun river water is being supplied to Raipur city through Bhatagaon and Ghugwa anicuts to meet domestic water demand of Raipur city. The existing water supply arrangements of Raipur city are designed to meet water demand of 10.28 lakhs population at rate of 110 lpcd, which is lower than the water supply norms of National Building Code (NBC) and Indian Standards suggesting 135 lpcd and Urban Development Plan Formulation and Implementation (UDPFI) Guidelines suggesting 170 lpcd.

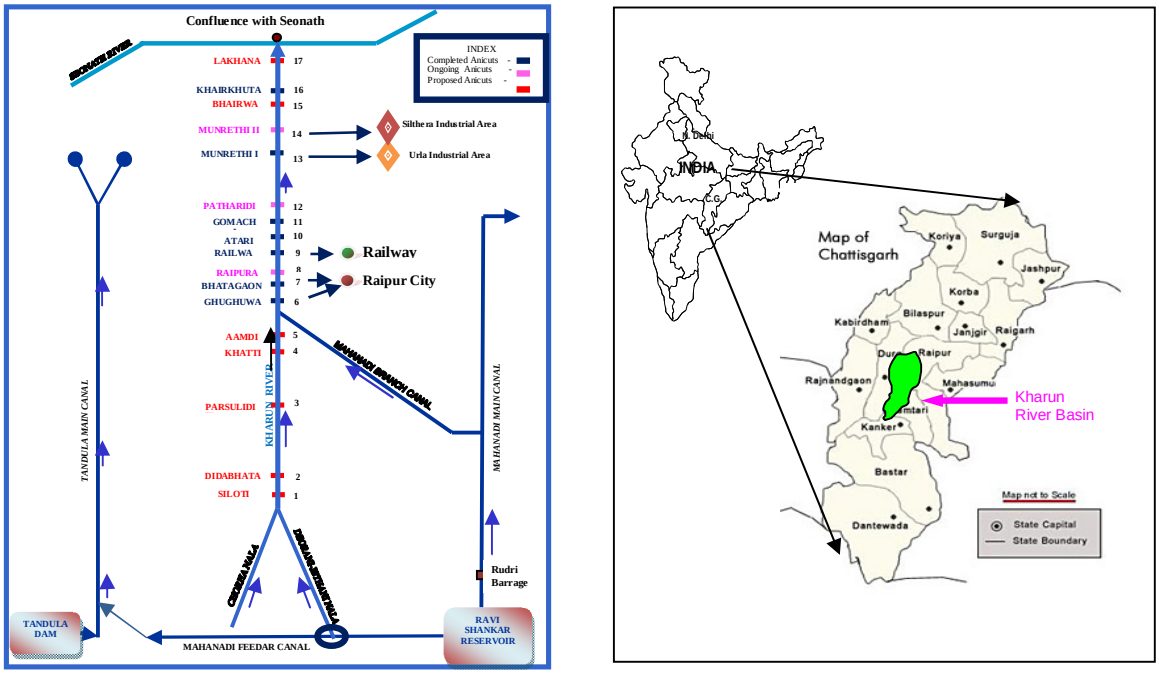


Figure 1: Schematics of water transfer system in Kharun river and its location in Chhattisgarh

India's population is increasing and causing rapid urbanization, slightly over half of India's population will live in urban areas by 2050 (Mahmood and Kundu, 2006, Kundu, 2006 and UN, 2004). City Development Plan, Raipur City Municipal Infrastructure report pointed out the 3.5% per year urban population growth of Raipur city. Considering the rate of increase, projected population and domestic water demands during next decades in the Raipur city have been estimated. Based on the field information it was understood that, around 50% domestic water demand of the Raipur city is fulfilled from Kharun and remaining demand is fulfilled from groundwater and other local sources. Kharun water is also being supplied to Urla and Siltara industrial area located near Raipur city through Murethi-I and Murethi-II anicuts. Railway has also been extracting water from river for its uses. Water from river is also being utilized for Nistari purpose (village tank supply) and recreational activities. Various agricultural, commercial activities like Brick Kiln Furnaces, small scale industrial units, etc are directly extracting or lifting water from Kharun river, which are accounted and considered in other demands. The water demands on Kharun are expected to be boost up in next few decades due to rapid population and industrial growth. Thus the total water demands in the Kharun basin and projected water demands were estimated in proportion to the population and industrial growth.

Water Supply

Kharun river has series of anicuts along the river which are main sources of supply to meet various water demands. Despite having sufficient annual water yield, Kharun river has no flow during lean season due to its intermittent nature and unavailability of water storage structure at the upstream locations (Galkate et al. 2012). To overcome this situation an arrangement has been made to supplement Kharun river from Ravishankarsagar Reservoir, which helps to maintain regular flow in river to meet various demands.

Demand Supply Analysis

The demand supply analysis has been carried out by estimating the surplus or deficit volumes in Kharun river on 10-daily basis at various probability levels using flow data of Patherdihi G/d site with the help of Flow Duration Curve technique.

Generation of Flow Data using MIKE BASIN

All important water users are mainly located 20 to 25 km at upstream and downstream side of Patherdihi G/d site. The anicuts supplying water to Raipur city and railways are located at the upstream and the anicuts supplying water to industrial area are located at the downstream of Patherdihi G/d site. Though the water is being supplied from various locations but for the analysis purpose it is assumed that the water is supplied to all the water users from single point i.e. Patherdihi. A new flow time series at Patherdihi was generated using equation MIKE BASIN software which was then used for demand supply analysis. The MIKE BASIN Model setup for generation of new flow time series is shown in Figure 2. Mike Basin is an Arc Map based engineering software package developed by Danish Hydraulic Institute, Denmark which has been accepted worldwide especially for water resource planning and management applications (DHI, 2003).

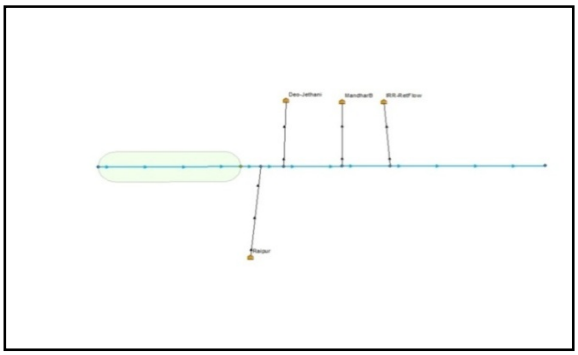


Figure 2: MIKE BASIN Model setup for generation of new flow time series at Patherdihi

As the water is being diverted from upstream location of Patherdihi for Raipur city and Railways, new discharge time series at Patherdihi was generated by adding diverted water to the observed flow using Equation 1.

$$Qp = Qobs + Q_{RC} + Q_{RL} \quad \ldots (1)$$

Where, Qp = Generated Flow at Patherdihi (m^3/s)
$Qobs$ = Observed Flow at Patherdihi (m^3/s)
Q_{RC} = Flow diverted for Raipur City (m^3/s)
Q_{RL} = Flow diverted for Railways(m^3/s)

The new generated flow time series was then used further for assessing the supply scenario of Kharun river in terms of water availability at various probability levels. As it was assumed that all the demands on Kharun river are to be fulfilled from one location Patherdihi, the annual demand time series were lumped and compared with the newly generated discharge data.

Estimation of Dependable Flow Volumes

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 new generated daily flow data of 18 years from 1990 to 2007 was grouped in 36 Ten-Daily periods of the year. The Ten-Daily dependable flow rates and flow volumes at 70%, 90% and 95% probability of exceedance were estimated using Flow Duration Curve technique. The water demands time series at Patherdihi for same 36 Ten-Daily periods of the year was estimated from the total annual water demands.

Surplus Deficit Analysis

The surplus and deficit volumes were estimated on every Ten-Daily bases within the year by subtracting Ten-Daily water demand from the Ten-Daily flow volume. The calculations and analysis of estimation of surplus or deficit for each Ten-Daily period was carried out using the following logic.

If Supply > Demand then Supply – Demand = Surplus
If Demand > Supply then Demand – Supply = Deficit

Thus the water surplus and deficits were estimated for dependable flow volumes at various probability levels. Similar analysis was carried out for all the present and future projected water demands. From the above analysis the surplus or deficit flow was estimated on a Ten-daily basis. Once the water surplus volume becomes zero it could be considered as beginning of deficit vice-versa. Thus the 'beginning' and 'termination' period of water deficit were identified and are used to study the demand supply scenario. Further it also envisages the estimate of additional amount of water required to meet the desired demands. The scenario of water demands and corresponding water deficit volumes in Kharun river are estimated and demand deficit curves showing water deficit to its corresponding demand were compared.

RESULTS AND DISCUSSION

Assessment of Water Demand

From the analysis of demographic information, it was observed that the population of Raipur city in year 2010-11 was 10.28 lakhs and it will become 23.57 lakhs by the year 2050-51. If the domestic water supply is planned as per UDPFI guidelines, 73.16 MCM water will be needed from Kharun river to fulfill water demand of the Raipur city in year 2050. The annual industrial water demand was estimated 52.54 MCM however around 38.29 MCM of water was being supplied from Kharun river. Railway was assumed to be consuming water at the rate of 0.2 m^3/sec i.e. 4.5 MCM throughout the year and projected accordingly for future estimation. The information of other petty demands was not available hence it was assumed as 1.5 MCM per annum and projected accordingly for future estimation. From the analysis of data, it was observed that, the total water demand to be fulfilled from Kharun river in 2010-11 was 65.21 MCM which will become 174.56 MCM by the year 2050-51.

Estimation of Dependable Flow Volumes

From the analysis of Ten-Daily Period flow volumes at various probability levels at Patherdihi it was observed that, the water availability in Kharun river becomes very low (0.74 MCM) during

the period from 1st January to 31st March at 90% and 95% probability and it became highest during 3rd and 2nd Ten-Daily period of August i.e. 29.27 MCM and 21.97 MCM respectively.

Demand Supply Analysis

The results of surplus deficit analysis for present and future scenario and the dates of 'beginning' and 'termination' of water deficit period were identified and are given in Table 1. The graph showing the dates of 'beginning' and 'termination' of water deficit period at Patherdihi at 75%, 90% and 95% are shown in Figure 3. The demand deficit curves showing water deficit to its corresponding demand are given in Figure 4. The graph illustrating amount of additional water required to meet various demand in Kharun river is shown in Figure 5.

Table 1: Beginning and end of water deficit period at various probability levels

Projected Period	Demand (MCM)	AT 75%		AT 90%		AT 95%	
		Deficit Starts	Deficit Ends	Deficit Starts	Deficit Ends	Deficit Starts	Deficit Ends
2010-11 @ 110 lpcd	65	01-Dec	20-Jun	21-Nov	20-Jul	01-Oct	31-Jul
2010-11 @ 135 lpcd	70	01-Dec	20-Jun	21-Nov	20-Jul	01-Oct	31-Jul
2010-11 @ 170 lpcd	92	21-Nov	20-Jun	11-Nov	20-Jul	21-Sep	31-Jul
2020-21	111	11-Nov	20-Jun	01-Nov	20-Jul	21-Sep	31-Jul
2030-31	133	11-Nov	10-Jul	01-Nov	20-Jul	21-Sep	31-Jul
2040-41	154	11-Nov	10-Jul	01-Nov	20-Jul	21-Sep	10-Aug
2050-51	175	11-Nov	10-Jul	01-Nov	20-Jul	11-Sep	10-Aug
When demand becomes 200 MCM	200	01-Nov	20-Jul	01-Nov	20-Jul	11-Sep	10-Aug
When demand becomes 250 MCM	250	01-Nov	20-Jul	21-Oct	20-Jul	11-Sep	10-Aug

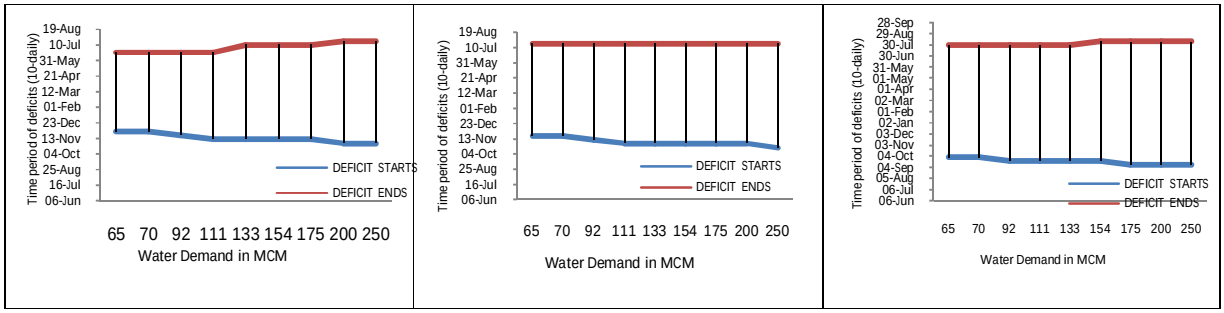


Figure 3: Beginning and end of deficit for 75, 90 and 95% dependability

From the Table 1 and Figures 3 it was observed that, when the water supply from river was planned to meet annual water demand of 65 MCM at 75% dependability, the deficit period was 233 days which begins on 1st December and terminates on 20th June. Whereas if water supply was planned at 95% dependability, the deficit period would be of 305 days which would begin much earlier i.e. on 1st October and terminates on 31st July. Form this analysis, it was concluded that, the period of water deficit prolonged when assured water availability was planned at higher probability level. When the water supply from the river was planned at 90% dependability to meet the water demand of 65 MCM, the deficit period would start from 21st November, for the

demand of 111 MCM the deficit period would start from 1st November and for the demand of 250 MCM the deficit period would start from 21st October. All the deficit periods were coming to an end on 20th July in monsoon season. Thus on comparison of water demand on river and deficit periods, it was observed that, as the water demand increased the deficit period also increased, the river experienced the deficit much earlier when demands were increased.

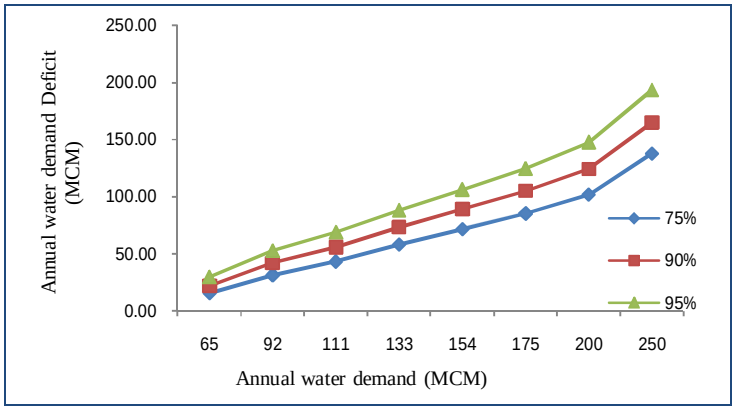
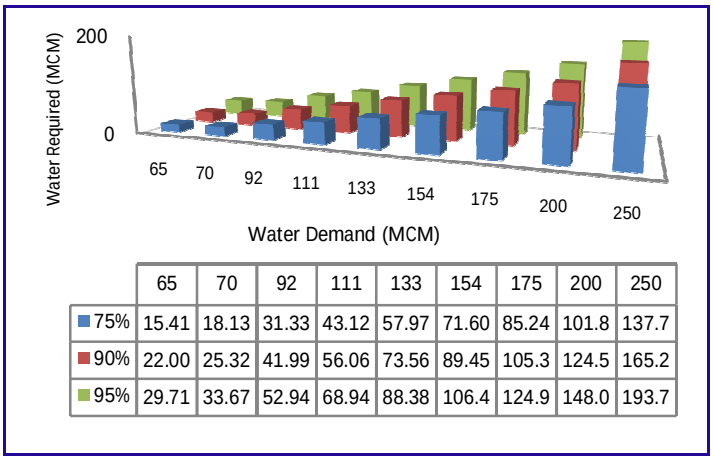


Figure 4: Demand - Deficit Curve at Various Dependable Levels



	65	70	92	111	133	154	175	200	250
75%	15.41	18.13	31.33	43.12	57.97	71.60	85.24	101.8	137.7
90%	22.00	25.32	41.99	56.06	73.56	89.45	105.3	124.5	165.2
95%	29.71	33.67	52.94	68.94	88.38	106.4	124.9	148.0	193.7

Figure 5: Additional water supply required to meet the deficit

The demand deficit curve shown in Figure 4 gives an idea about variation in water deficit with respect to the variation in total water demand and dependability of the river flow. It could be seen that, as the water demand increases, the deficit increases. The deficit also found increased with increase in probability level. From the Figure 5, it was seen that at 90% probability level, when water demand was 65 MCM the water deficit was 22 MCM. When the demand would increase to 133 MCM (in 2030-31) and 175 MCM (in 2050-51) the water deficit would becomes 73.56 MCM and 105.33 MCM respectively. In year 2050-51, the additional 105.33 MCM water would be required in Kharun river to fulfill its total demand.

CONCLUSIONS

The Kharun river has surplus water during monsoon season which flows out of basin due to non availability of storage structure and river is unable to meet water demands during lean season.

The water supplemented from Ravishankarsagar reservoir to the Kharun river helps to increase its water availability. The water demands for domestic water supply and industrial water supply are two main water demands on the Kharun river which plays important role in water resources planning strategies of the basin. The total water demand to be fulfilled from Kharun river in 2010-11 was 65.21 MCM which will become 174.56 MCM by the year 2050-51. The information of present and projected water demand will help the planners and decision makers to take appropriate action for water resources development and planning in the Kharun basin.

The Flow Duration Curve techniques can be used to assess supply deficit scenario of the river for present and future water resources planning. It could be concluded that, increases in water demand may prolong the water deficit period. The water deficit period also get prolonged when assured water supply planned at higher probability level. For Kharun it was seen that the deficit period at any probability level and even at higher demand ends in the month of July and August which is due to increased water availability in river. The supply demand analysis helps in estimating the amount of water surplus and deficit at the desired location and the also gives the idea about the beginning, termination and durations of these surplus and deficit period which assist the planners to judiciously manage the supply from river and to make possible alternate plan to manage the demands. It also provides the estimate of additional amount of water required to meet the desired demands.

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