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GROUND WATER ASSESSMENT USING REMOTE SENSING DATA

- A *case study of Bhadra River Basin.*

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ABSTRACT

An attempt was made to assess the groundwater balance using the water table fluctuation method in which all the components in the water balance equation are known, and the only component which is considered unknown is the rainfall recharge. Most of the inputs were derived from the satellite remote sensing data. Seventeen rain gauge stations and observation wells falling within and outside the periphery of the basin were considered for groundwater assessment. The total annual recharge includes recharge from (i) monsoon rainfall, (ii) non-monsoon rainfall, (iii) hilly areas, (iv) surface water-bodies, (v) groundwater irrigation, (vi) seepage from canals and (vii) canal irrigation. The total annual draft consists of water applied to the crops and water consumed for domestic and industrial use. Difference in the net annual draft and the net annual recharge will yield groundwater balance. This method though tedious gives reliable and accurate results compared to the other methods.

1. INTRODUCTION

Keeping in view the experience of erratic rainfall, frequent events of droughts and over-exploitation of groundwater, a detailed study was undertaken to assess the groundwater resources using inputs from remote sensing data for Bhadra river basin. As regards the norms to be followed in the evaluation of groundwater resources, it is recommended by the Central Groundwater Estimation Committee Report (1997), that the groundwater recharge should be estimated based on groundwater level fluctuations. This method though tedious, gives precise and accurate results. The fluctuations so measured from the water table levels were used along with the specific yield (S_y) to compute groundwater recharge. As a guide, the S_y values for different geological formations in the zone of water level fluctuation as adopted by Raju (1987) also endorsed by CGWEC (1997) have been used.

2. STUDY AREA AND DATA USED

The Bhadra river basin covering an area of 3435 km^2 falls in two districts, viz., Chikmagalur and Shimoga of Karnataka State, South India as shown in Fig.1. The terrain is hilly and steeply sloping. Soils of the basin area fall under two agro-climatic zones viz - South Transition Zone and Hilly zone. The basin has its geological significance with vast representations of Sargurs, Peninsular Gneisses, Bababudan and Chitradurga groups of Dharwar Super Group. Various thematic maps like landuse/cover, landforms, geological, hydrological soils and slope were prepared on 1:50,000 scale using Indian Remote Sensing (IRS)-1D LISS-III satellite data along with conventional data. The drainage network and sub-basin maps were prepared using Survey of India (SOI) topographic maps on 1:50,000 scale. Rainfall data and water table fluctuation data of 30 years (1973-2002) were utilised for the study.

3. METHODOLOGY

For the present study, the methodology recommended by the Central Groundwater Estimation Committee (CGEC, 1997) has been used, which is based on water balance approach in which all the components in the water balance equation are known, and the only component which is unknown is the rainfall recharge (Rajagopalan et al., 1997). Seventeen rain gauge stations and seventeen observation wells falling within and outside the periphery of the basin were considered for groundwater quantity assessment analysis.

Preparation of Thematic Maps

The thematic maps like landuse/landcover, geology, soil, slope and drainage network maps were prepared using the satellite data and conventional data on 1:50,000 scale. The areal extent of built-up areas, areas under rabi and kharif crops, rock outcrops and surface water-bodies were obtained from the landuse/cover map, while the areas with slopes greater than 20% were realised from the slope map. Based on the geology/rock type/soil, the specific yield value S_y of 0.03 was used in the recharge calculations.

Recharge Assessment

The recharge values from (i) monsoon rainfall, (ii) non-monsoon rainfall, (iii) hilly areas, (iv) surface water-bodies, (v) groundwater irrigation, (vi) seepage from canals, and (vii) canal irrigation were calculated.

Monsoon Rainfall Recharge, MRR (ha m)

MRR = {(A_1 x Sy x WLF) +(GKD)}x {Long term monsoon rainfall /Avg. monsoon rainfall},

where, A_1 is the area of the aquifer after deducting the area falling under rock outcrops and built-up area, MRF is the long term monsoon rainfall (mm), RF is the average monsoon rainfall in (mm), WLF is the difference in the water table fluctuation between the lowest pre-monsoon and highest post- monsoon (m) and GKD is the Gross Kharif Draft which is the total irrigation water applied during kharif season.

Non-Monsoon Rainfall Recharge, NMRR (ha m)

$$NMRR = \frac{A_2 \text{ x Avg. non-monsoon rainfall}}{1000} \text{ x } 11\% ,$$

where, A_2 is the area after deducting the water spread area from area A_1 and the Infiltration factor is taken as 11%.

Recharge from Tanks, RT (ha m)

Recharge from tanks is taken as 1.4 mm/day for the period in which the tank has water. Here the period is considered as 4 monsoon months, i.e., 120 days and 1.4 mm/day works out to 0.52m per year.

Recharge from Canal Irrigation, RCI (ha m) is taken as 35% of the total water applied for irrigation.

Seepage from Canals, SC (ha m)

Total seepage = L x AWP x 15

where, L is the length of the canal in m, AWP is the average wetted perimeter of the canal in m, and seepage factor is 15 ha m/day/million sq. m. Seepage from canals, SC is taken as 20% of the total seepage.

Recharge from Hilly Areas, RHA (ha m)

Land having slopes > 20% are considered hilly areas. Hence, recharge from hilly areas is taken as 2% of the average annual rainfall over the area.

Recharge from Groundwater Irrigation, RGWI (ha m)

The cropped area under kharif, rabi and summer seasons for different crops is multiplied by the respective crop water delta to get the irrigation water applied to each one of the crop types. 30% of the total water applied for irrigation during rabi and summer is taken as recharge from groundwater irrigation.

Total Annual Recharge, TAR (ha m)

Total annual recharge is the total of the monsoon rainfall recharge, non-monsoon rainfall recharge, recharge from hilly areas, recharge from tanks, recharge from groundwater irrigation, recharge from canal irrigation, and seepage from canals.

Net Annual Recharge, NAR (ha m) is taken as 95% of the total annual recharge.

Draft Assessment

Draft for Irrigation, *DI (ha-m),* is the total irrigation water applied for the crops during kharif, rabi and summer.

Draft for Domestic and Industrial use, DDI (ha m)

(P x C x 365) / 10,000,000

where, P is the population density in units of thousands per km^2 and, C is the per capita consumption, assumed as 60 litres per day per head.

Total Annual Draft, TAD (ha m) is the total draft for irrigation and draft for domestic and industrial use

Net Annual Draft, NAD (ha m) is taken as equal to total annual draft.

Total Groundwater Balance, TGWB (ha-m)

Total groundwater balance, TGB (ha m) is the difference in the net annual recharge and the net annual draft.

Present Stage of Groundwater Development

The present stage of groundwater development is taken as the ratio of the net annual draft and the net annual recharge.

Stage of Groundwater Development Five Years Hence

Yearly increment rate of groundwater development for future years is taken as 2%. Hence stage of development after 5 years will be {(present stage of development) + 5 (yearly rate)}.

For purposes of clearance of schemes by the financial institutions, categorization of areas on the stage of groundwater development using the water table fluctuation method is recommended as follows: (i) Less than 70% is Safe, (ii) 70 – 90 % is Semi-critical, (iii) 90 – 100 % is Critical and > 100% is Over-exploited. In over-exploited areas, micro-level surveys are required to be taken up for evaluating groundwater resources more precisely, for taking up further groundwater developmental schemes. Intensive monitoring, evaluation and future groundwater development should be linked with water conservation measures in these areas.

4. RESULTS AND DISCUSSION

The results of groundwater quantity assessment analysis for the entire Bhadra river basin are as follows:

Monsoon rainfall recharge = 4342.20 ha m.

Non-monsoon rainfall recharge =802.21 ha m.

Recharge from hilly areas = 5,961.89 ha m.

Recharge from tanks = 2,160.72 ha m.

Recharge from groundwater irrigation = 564.95 ha m.

Recharge from canal irrigation = 1730.53 ha m.

Seepage from canals = 55.81 ha m.

Total annual recharge = 17673.21 ha m.

Net annual recharge (95% of TAR) = 16789.55 ha m.

Gross kharif draft = 1077.51 ha m.

Draft for irrigation = 4410.77ha m.

Draft for domestic and industrial use = 886.42 ha m.

Total annual draft = 5297.19 ha m.

Net annual draft = 5297.19 ha m.

Total groundwater balance = 11492.36 ha m.

Present stage of groundwater development = 31.55 %.

Future stage of groundwater development 5 years hence = 41.55%.

Groundwater for the entire Bhadra basin was assessed taking seventeen Theissen polygons as units for calculation and then apportioned sub-basinwise into 30 sub-basins of the Bhadra river basin (Table 1). Based on the results obtained, the present stage of groundwater development for the entire Bhadra river basin is found to be 32% and stage of development after five years is 42%. Since the stage of groundwater development is less than 70% as per the norms recommended by the Central Groundwater Estimation Committee (CGWEC, 1997), the entire Bhadra river basin falls under the ‘safe’ category.

As per recommendations of the CGWEC and based on the norms adopted by the Department of Mines and Geology, GoK, it has been suggested that for a draft of 1.1 ha m one bore well is recommended. Hence assuming a draft of 1.1 ha m for one bore well, for a balance groundwater of 11,492.36 ha m, for the Bhadra river basin, (11,492.36/1.1) there is scope for drilling 10,448 more wells in the basin for future groundwater development. Hence, it is evident that more attention has to be paid for harnessing groundwater reserves of the basin.

In spite of the fact that the Bhadra river basin is assessed as having a groundwater balance of 11,492.36 ha m, and comes under the safe category as per the CGWEC Report, an attempt was also made to classify the sub-basins on the basis of its groundwater balance.

The sub-basins were classified into four classes i.e., (i) Excellent - with groundwater balance greater than 400 ha-m, (ii) Good – with groundwater balance between 300 to 400 ha-m, (iii) Moderate – with groundwater balance between 200 to 300 ha-m, and (iv) Poor with groundwater balance less than 200 ha-m. Fig. 2 shows the groundwater assessment map based on this classification.

5. REFERENCES

RAJAGOPALAN, S.P., SHARMA, S.K., AND N.R.THANKIVALE (1997): Detailed Guidelines for Implementing the Groundwater Estimation Methodology, Central Groundwater Board, Ministry of Water Resources, Govt. of India, New Delhi, pp.118-145.

RAJU, K.C.B., (1987): Groundwater – Assessment and monitoring – A review - First National Water Convention, Conf., CBIP, Oct. pp. 1153 - 1170, New Delhi.

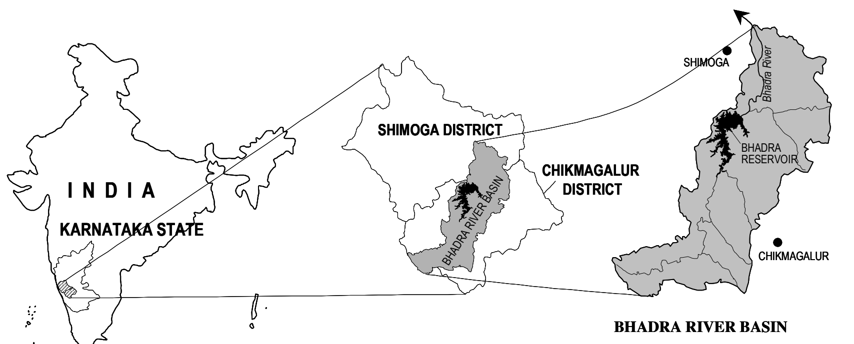

Fig. 1: Location Map of Bhadra River basin

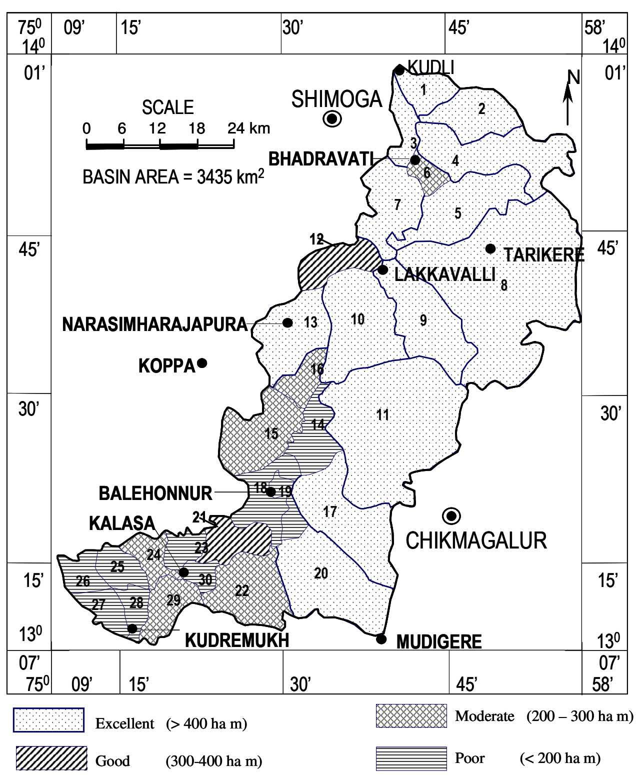

Fig. 2: Groundwater Assessment Based on Water Table Fluctuation Method for Bhadra River Basin (Sub-basin Wise)

Table 1: Sub-basinwise Assessment of Groundwater for the Bhadra River Basin

Sl. No. of sub-basins	Area (ha)	MRR (ha m)	NMRR (ha m)	RHA (ha m)	RT (ha m)	SC (ha m)	RGWI (ha m)	RCI (ha m)	TAR (ha m)	NAR (ha m)	NAD (ha m)	TGWB (ha m)	PSD (%)	DAF (%)	No. of wells
1.	5200.00	71.24	6.57	1.52	42.59	0.75	71.01	200.95	495.85	471.06	35.84	435.22	7.61	17.61	396
2.	8100.00	77.50	14.92	35.22	33.66	1.19	53.85	163.28	467.64	444.26	43.60	400.66	9.81	19.81	364
3.	5900.00	80.59	8.27	2.22	46.60	1.18	76.47	223.95	553.52	525.84	40.33	485.51	7.67	17.67	441
4.	15000.00	126.87	38.48	84.41	29.93	5.86	31.40	195.65	639.63	607.65	72.00	535.65	11.85	21.85	487
5.	10400.00	218.69	39.91	20.85	20.44	8.91	3.79	241.14	738.11	701.21	129.91	571.30	18.53	28.53	519
6.	7900.00	65.34	23.01	46.76	9.51	4.17	2.09	86.84	301.17	286.11	36.59	249.52	12.79	22.79	227
7.	11600.00	122.56	43.74	17.12	47.89	7.53	9.56	391.37	916.20	870.39	95.46	774.93	10.97	20.97	705
8.	55700.00	1189.34	168.08	302.38	126.81	15.95	48.26	102.74	2149.40	2041.93	752.59	1289.34	36.86	46.86	1172
9.	16100.00	202.77	65.91	77.81	251.35	3.90	7.03	47.40	690.83	656.29	102.75	553.54	15.66	25.66	503
10.	17100.00	370.89	58.20	68.85	516.58	4.04	13.72	49.00	1162.68	1104.55	284.17	820.38	25.73	35.73	746
11.	36400.00	243.36	36.08	1016.35	132.74	0.44	47.03	5.33	1622.28	1541.17	680.89	860.28	44.18	54.18	782
12.	7000.00	148.18	26.36	25.37	213.71	1.89	4.94	22.90	475.55	451.77	107.20	344.56	23.73	33.73	313
13.	13700.00	403.18	13.45	109.08	444.23	0.00	23.60	0.00	1087.22	1032.86	410.27	622.59	39.72	49.72	566
14.	3300.00	51.42	7.99	58.20	32.72	0.00	6.35	0.00	169.97	161.47	70.22	91.25	43.49	53.49	83
15.	10200.00	100.80	38.24	260.68	15.19	0.00	11.94	0.00	459.44	436.47	159.87	276.60	36.63	46.63	251
16.	9500.00	119.60	8.43	215.22	105.78	0.00	13.82	0.00	507.47	482.10	209.73	272.37	43.50	53.50	248
17.	23100.00	154.15	40.83	622.63	12.56	0.00	35.41	0.00	944.38	897.16	416.62	480.54	46.44	56.44	437
18.	8300.00	81.31	25.32	160.60	5.88	0.00	15.75	0.00	310.59	295.06	135.83	159.23	46.04	56.04	145
19.	3900.00	38.24	11.74	74.58	2.79	0.00	7.52	0.00	145.00	137.75	63.98	73.77	46.45	56.45	67
20.	20900.00	208.72	50.37	662.76	19.69	0.00	31.91	0.00	1075.17	1021.41	478.07	543.35	46.80	56.80	494
21.	10800.00	97.34	23.58	389.51	11.70	0.00	15.82	0.00	592.17	562.56	250.50	312.06	44.53	54.53	284
22.	9100.00	38.50	11.92	348.75	7.96	0.00	7.62	0.00	448.62	426.19	151.03	275.16	35.44	45.44	250
23.	4100.00	15.73	4.88	162.69	3.63	0.00	3.12	0.00	205.64	195.35	68.10	127.25	34.86	44.86	116
24.	7300.00	28.01	8.68	289.67	6.47	0.00	5.55	0.00	366.13	347.82	121.26	226.57	34.86	44.86	206
25.	2600.00	9.98	3.09	103.17	2.30	0.00	1.98	0.00	130.40	123.88	43.19	80.70	34.86	44.86	73
26.	3600.00	13.81	4.28	142.85	3.19	0.00	2.74	0.00	180.56	171.53	59.80	111.73	34.86	44.86	102
27.	4100.00	15.73	4.88	162.69	3.63	0.00	3.12	0.00	205.64	195.35	68.10	127.25	34.86	44.86	116
28.	1700.00	6.52	2.02	67.46	1.51	0.00	1.29	0.00	85.26	81.00	28.24	52.76	34.86	44.86	48
29.	8300.00	31.85	9.87	329.35	7.36	0.00	6.31	0.00	416.29	395.47	137.87	257.61	34.86	44.86	234
30.	2600.00	9.98	3.09	103.17	2.30	0.00	1.98	0.00	130.40	123.88	43.19	80.70	34.86	44.86	73
	343500.00	4342.20	802.21	5961.89	2160.72	55.81	564.95	1730.53	17673.21	16789.55	5297.19	11492.36	31.55	41.55	10448

MRR – Monsoon Rainfall Recharge,
NMRR – Non-Monsoon Rainfall Recharge
RHA – Recharge from Hilly areas
RCI – Recharge from Canals
RT – Recharge from Tanks
SC – Seepage from Canals
RGWI – Recharge from groundwater irrigation
TAR – Total Annual Recharge
NAR – Net Annual Recharge
NAD – Net Annual Draft
TGWB – Total Groundwater Balance
PSD – Present Stage of Development
DAF – Draft After Five Years