Groundwater Resource Estimation of Nakrekal Basin, Nalgonda District, Telangana State, India, using GIS and Remote Sensing Techniques

K.M.Ganesh, P.A.R.K. Raju

Abstract ***National water Policy (1987, 2002) of India which determines that groundwater assets could be utilized only up to its recharge limit, which are mentored of evaluation of groundwater assets. In India methodology for groundwater assets can be widely depends on Groundwater Resources Estimation Methodology, 1997 and had evaluation of annual renewed groundwater resources (recharge) were involved, the percentage of utilization and annual groundwater draft with respect to recharge (state of development). The procedure has been for the delineation of suitable zones for the artificial recharge structures. In addition, the inputs for estimating the groundwater recharge has been derived from the satellite data and computed the balance groundwater reserves available for future use and calculated the stage of groundwater development. The sub-basin wise groundwater resource estimation has also been carried out to prioritise the sub-basins for taking up the artificial recharge structures. Further, based on the suitable zones for artificial groundwater recharge and the prioritisation of the sub-basins, few sites have been tentatively located for taking up artificial recharge structures. The procedure for the delineation of suitable zones for the artificial recharge structures. Several thematic layers have been generated according to GEC-1997 method and estimated the groundwater resource and ground water balance. Based on the results obtained by the analysis in this study, the tentative sites for construction of recharge structures such as percolation tanks, check dams, farm ponds and the de-siltation of tanks have also been suggested. The field investigation is inevitable before implementing any water-harvesting program. Further, the groundwater resource estimation has to be taken up at the regular intervals to know the net balance available for future use.***

Index Terms: Groundwater, Remote sensing, G.I.S., Groundwater Estimation Committee-1997 GEC-97

I. INTRODUCTION

The groundwater resource estimation and budgeting deals with the quantity of water recharged every year from the rainfall and other sources to a particular basin or area, its utilization and groundwater balance available.

This is very important information required for planning and development of groundwater resource on sustainable basis.

The groundwater resources in the country are being estimated every year based on the recommendations made by the high power committee called The Government of India constituted "Groundwater Estimation Committee-1997" [1].

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The committee has recommended the basin (watershed)/administrative unit (block/mandal) as the groundwater assessment unit for the estimation groundwater resources. Further, the committee has reiterated that the area adopted for the assessment may have few sub-units within it. In position of groundwater development (utilization) and the lengthy term water level tendency were classified as the estimation units (block/watershed) [2].

Accordingly, with in the present study area (Nakrekal basin), groundwater resource estimation is made through the conventional method as well as from the inputs derived from the satellite imagery and the results have been compared.

In addition, the basin has been divided into 10 sub-basins and the groundwater resource estimation is made to study the effect of averaging of the rainfall and water table fluctuations in calculating the stage of groundwater development.

The methodology followed for estimating the recharge, draft, and the balance resource available for future use is briefly explained in the following sections.

A. Location

The Nalgonda district is one of the drought prone districts of Telangana and frequently being afflicted by famines. The study area, Nakrekal basin is a part of this district and falls in the Survey of India toposheet no's 56 0/8 and 56 0/12. It lies between the north latitudes of of $17^0$00'00" to 17^0 15' 07" and Eastern longitudes of 79^0 16'28" to 79^0 34'15", and covers an area of about 409 sq.km. Fig.1 depicts the location map of the area. The present study is intended to use the remote sensing data, G.I.S. technology and spatial modelling techniques, in the Nakrekal basin [3].

II. GEOLOGY OF THE AREA

In the area, biotite rich grey granites, pink granites, porphyritic granites and migmatitic granite gneisses are the common rock types and are referred in literature as the Peninsular gneisses. The migmatitic gneisses composed of feldspar, quartz, biotite and minor amounts of magnetite usually enclose biotite rich xenolith which shows considerable effects of interaction in the marginal zones. Veins of quartz, pegmatite, aplite and epidote are prevalent, and cut across all the granite rocks. Dolerite dykes, extending in length as much as 30 to 40 km. Cut across the rocks. Topographically the study area is undulating with scattered hills. Fig. 2. shows the geology map of the area.

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The younger intrusive rocks (dykes) consist of fine-grained dolerite and shows the ophitic and at few places porphyritic texture. These dykes appear as boulder strewn linear ridges due to their characteristic resistance to weathering and act as groundwater barriers. These dykes are mainly trending north-south and north-west –south-east. One major dyke trending north-south traverses through the northwestern part of the study area. Another major dyke trending northeast-southwest traverses through the southeastern boundary of the basin. Some of the dykes in the study area are concealed in nature [4].

The secondary porosity and permeability resulting from structural discontinuities like faults, joints and fractures are the main sources of the movement and the occurrence of the groundwater in hard rock areas. In groundwater movement and introduce an element of directional variation in hydraulic conductance act as conduits of the structurally weak planes.

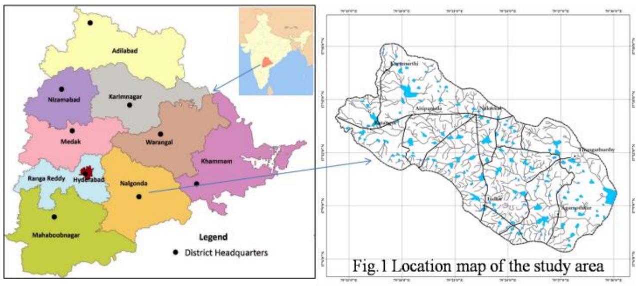

Fig.1 Location map of the study area

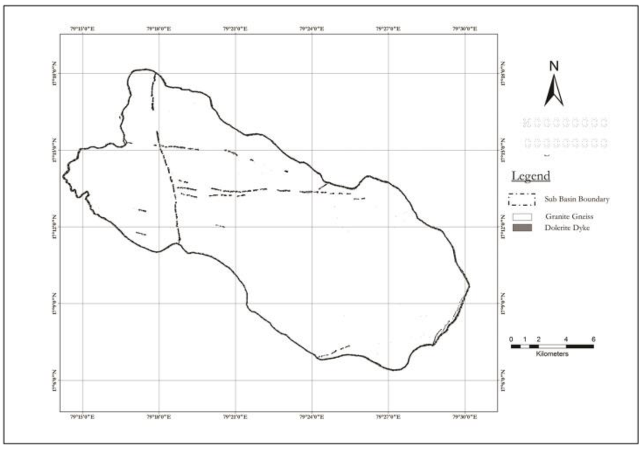

Fig.2 Geology of the study area

III. MATERIALS AND METHODS

A. Recharge estimation

The The groundwater recharge is the quantity of water recharged every year through rainfall and other sources (surface water bodies, irrigation water applied etc.). Natural phenomenon of the rainfall is performing significant discrepancies from year to year. The average rainfall over sufficiently long number of groundwater years were acquired as the 'Normal rainfall' which will be therefore the most appropriate basis for computing the rainfall recharge.

The recharge of the assessment unit can be computed by using - a) Water table fluctuation method and b) Rainfall infiltration method

During the present study, the recharge is computed by the inputs derived from the satellite data. In this method, the area suitable for recharge is precisely calculated by excluding the landforms un-favourable (inselbergs, pediments, linear ridges) for recharge.

In addition, the information about the landforms, soil type, land use, lineaments etc., delineated from the satellite data helped in determining the rainfall infiltration factors more accurately, within the range of values recommended by GEC-97 and for the better estimation of the recharge to the groundwater. Not only that, the water spread area of the water bodies is also precisely determined through the satellite data while calculating the recharge from the existing water bodies [5].

B. Rainfall Infiltration method

In this method, the groundwater recharge is computed by taking certain percentage of the rainfall as infiltration to ground, depending upon the type of rock formation.

The GEC-97 has recommended different rainfall infiltration factors and different specific yields for different rock types.

The gross groundwater recharge is computed by multiplying the average annual rainfall (R) with rainfall infiltration factor (RIF) and the rechargeable area (A).

But, the rainfall infiltration factors are not constant for a given rock type and they vary based on geomorphology, weathering, fracturing type of soil, land use/land cover, etc. within the same rock type. The Rainfall infiltration Factors adopted for calculating the recharge through the remote sensing approach are given in Table 1.

C. Water table Fluctuation method

The water balance approach depends on the water table fluctuation method in which the change in groundwater storage, in which all of the components in the water balance equation is known during the monsoon [6]. The assessment for this component involves the water table fluctuation in the course of the monsoon. The computational procedure for the recharge through the water fluctuation method involves the following steps.

- The sub unit has allocate the specific yield worth applicable
- Computing the change in groundwater storage by multiplying the specific yield, normal monsoon rainfall and the area suitable for recharge.
- Normalising the normal monsoon rainfall
- The percentage of the latter determined with computing the contrast between the rainfall recharge by the water table fluctuation method and that by the rainfall infiltration factor
- The rainfall recharge was taken as that attained by the water table fluctuation method, as if the contrast is greater than or equal to -20% and less than or equal to +20%.
- The value attained by the rainfall infiltration factor method if the differentiation is -20%, the rainfall recharge is taken as equal to 0.8 times

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- The value acquired by the rainfall infiltration factor method as if the dissimilarity is greater than +20%, the rainfall recharge is taken as equal to 1.2 times the value

The specific yields adopted in computing the recharge through the remote sensing approach are given in Table 1.

Table: 1 Rainfall infiltration Factors and Specific Yields of Geomorphic units

Geomorphic unit	Area suitable for recharge (ha)	Specific yield	RIF
VFS	2161	0.04	0.15
PPM	14274	0.03	0.13
PPS	22934	0.03	0.13
BPS	1916	0.02	0.10

During the computation of rainfall recharge, the difference between the RIF method and WTF method in the conventional approach is 30%, where as in remote sensing approach the difference is -16%.

Hence while computing the recharge, the corresponding value has been taken as the rainfall recharge as recommended by GEC-97.

The results obtained through the RIF method and WTF method are shown in Table 2.

D. Recharge from other sources

The origin of groundwater restore other than rainfall considered in estimating the recharge are – a) Irrigation water applied, b) Tanks and ponds and c) Water conservation structures. The recharge from these sources is computed by the guidelines of GEC-97 and is presented in Table 3.

IV. RESULTS AND DISCUSSION

A. Groundwater draft estimation

The gross groundwater draft is the groundwater drafted from the ground in an annum. The GEC-97 has suggested adopting any one of the methods presented in its guidelines. For the study area, the gross groundwater draft is estimated by using the Unit well draft method. The GEC-97 has specified unit groundwater draft per well during monsoon and non-monsoon season for each type of well for different States/Union Territories. The draft has been computed by multiplying the unit draft of the well, no. of days the well is in use and the number of wells in the area.

The draft is computed for different types of wells as well as for the monsoon and non-monsoon separately, and the total groundwater draft is presented in Table 3.

B. Net annual groundwater availability

The net annual groundwater availability is obtained by subtracting the unaccounted annual natural discharge from the sum of the rainfall restore and the restore from other resources.

The unaccounted annual natural recharge includes the base flow and the evaporation from the groundwater reservoir etc.

This unaccounted natural discharge is alloted as 5% of the total groundwater recharge wherever the water table fluctuation method is employed for computing the rainfall recharge. In the other case where the rainfall infiltration method is employed, the unaccounted natural discharge is alloted as 10%.

Based on the criteria given by the GEC-97, the unaccounted natural discharge is calculated and the same is subtracted from the sum of the rainfall recharge and the recharge from the other sources to get the net annual groundwater availability, which is presented in Table 3.

C. Stage of Groundwater development

The stage of groundwater development in a given assessment unit is defined as the current annual gross groundwater draft for all uses in that unit expressed as percentage of the net annual groundwater availability in that unit. Based on this the stage of groundwater development is calculated and is presented in Table 3.

Table 2 Difference in Recharge through RIF and WTF

Recharge (ha.m)	Conventional method	Remote sensing approach											
		Basin as a unit	Sub-basin wise resource estimation										
			1	2	3	4	5	6	7	8	9	10	Total
Recharge through RIF	2772	3656	301	226	233	316	264	401	387	403	336	488	3355
Recharge through WTF	2863	2754	164	159	167	302	266	375	250	330	336	342	2691
Normalised recharge through WTF (NWTF)	3931	3782	235	278	293	434	333	470	313	440	459	466	3917
Difference between RIF & NWTF as a percentage of RIF	42	3	-22	23	25	37	26	17	-19	9	36	-4	17
Whether WTF method adopted or not	No	Yes	No	No	No	No	No	Yes	Yes	Yes	No	Yes	
Recharge adopted	3327	3782	241	272	280	380	316	470	313	440	403	466	3581

D. Categorisation

The GEC-97 has stated in its guidelines to categorise each assessment unit as one of the following groups for the purpose of inaugurating the scope for future groundwater development in them.

a) Safe
b) Semi-critical
c) Critical
d) Over exploited

Further, it was mentioned that considering both the stage of groundwater development and the trend of water table during pre-monsoon and post-monsoon, the categorisation of the assessment unit should be made. Based on the stage of development of groundwater and the water level trend in the basin during the pre-monsoon and post-monsoon, the area is classified as semi-critical

E. Net annual groundwater availability for future use

The net annual groundwater availability for future use is calculated as follows:

The Net annual groundwater availability for future use = (Net groundwater availability)-((Current annual gross groundwater draft)+(Annual allocation for Domestic and industrial water supply)).

Based on the above the net annual groundwater availability is calculated and is presented in Table 3.

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Table: 3 Results of the Groundwater Resource Estimation

S.No.	Description of item	Conventional methodology	Remote sensing Approach	
			Basin	Sub-Basin wise total
1	Geographical area (Ha)	40924	40924	40924
	a) Area not suitable	0	638	638
	b) Area suitable for recharge	40924	40286	40286
2	Normal Rainfall (mm)	816	816	816
	a) Monsoon	616	616	616
	b) Non-monsoon	200	200	200
3	Recharge to groundwater through			
	a) Monsoon rainfall	3326	3782	3580
	b) Non-monsoon rainfall	899	573	1045
	c) Applied irrigation	1231	1231	1315
	d) Surface water bodies (MI tanks/PT/CD etc.	137	229	229
	e) Artificial recharge structures	40	40	40
4	Total Recharge	5634	5855	6330
5	Net Annual groundwater availability(Annual utilisable resource) ha.M	5070	5562	5739
6	Groundwater draft under different sectors			
	a) Domestic wells	272	272	272
	b) Industrial wells	0	0	0
	c) Irrigation wells	3783	3783	3783
7	Current annual gross groundwater Draft for all uses	4055	4055	4055
8	Annual allocation of GW for domestic and industrial water supply for projected demand at year 2025	438	438	438
9	Net annual Groundwater availability for future irrigation use	849	1341	1518
10	Stage of development of groundwater	80	73	71
11	Category	Semi-critical	Semi-critical	Semi-critical
12	Existing equivalent bore wells	3724	3724	3724
13	Optimum number of equivalent bore wells	2953	3331	3486

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Table: 4 Sub-basin wise groundwater resource estimation

S.No.	Description	Sub-Basin									
		1	2	3	4	5	6	7	8	9	10
1	Geographical area (Ha)	3558	3012	3083	3853	2811	4621	5151	5221	3916	5698
	a) Area not suitable	35	19	16	156	12	293	8	28	34	37
	b) Area suitable for recharge	3523	2993	3067	3697	2799	4328	5143	5193	3882	5661
2	Normal Rainfall (mm)	848	787	787	848	909	909	784	794	861	861
3	Recharge to groundwater through										
	a) Monsoon rainfall	241	272	280	380	316	470	313	440	403	466
	b) Non-monsoon rainfall	92	80	82	97	71	108	129	136	102	148
	c) Applied Irrigation	178	91	79	122	66	126	153	201	149	150
	d) Surface water bodies (Mi tanks/PT/CD etc)	28	15	16	11	15	24	47	20	22	31
	e) Artificial recharge structures	0	0	0	0	0	0	0	0	0	0
4	Total Recharge	660	458	457	610	468	728	641	806	677	825
5	Net Annual groundwater availability (Annual utilisable resource) ha. M	586	412	411	549	421	692	609	766	609	784
6	Groundwater draft under different sectors										
	a) Domestic wells	22	23	19	27	16	67	20	28	23	27
	b) Industrial wells	0	0	0	0	0	0	0	0	0	0
	c) Irrigation wells	428	208	185	364	202	424	447	601	455	471
7	Current Annual gross GW draft for all uses	450	231	204	391	217	491	467	629	478	498
8	Annual allocation of GW for domestic and industrial water supply for projected demand at year 2025	35	37	31	44	25	108	32	45	38	43
9	Net annual GW availability for ‘future irrigation’	23	168	196	141	194	160	130	120	117	269
10	Stage of GW development	93	56	50	71	52	71	77	82	78	64
11	Category										
12	Existing equivalent bore wells	419	204	184	352	196	408	448	600	448	465
13	Optimum number of equivalent bore wells	320	247	256	328	273	435	351	435	354	488

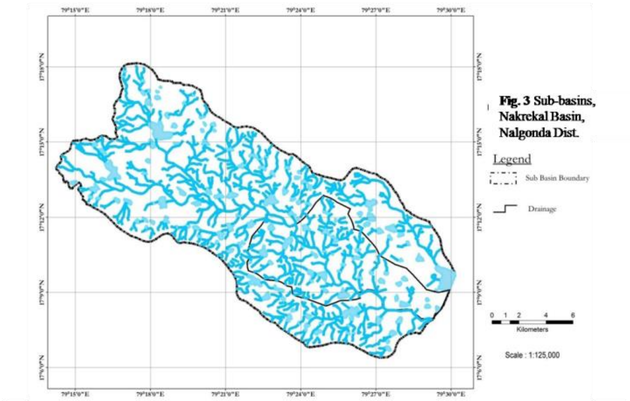

Fig. 3 Sub-basins, Nakrekal Basin, Nalgonda Dist.

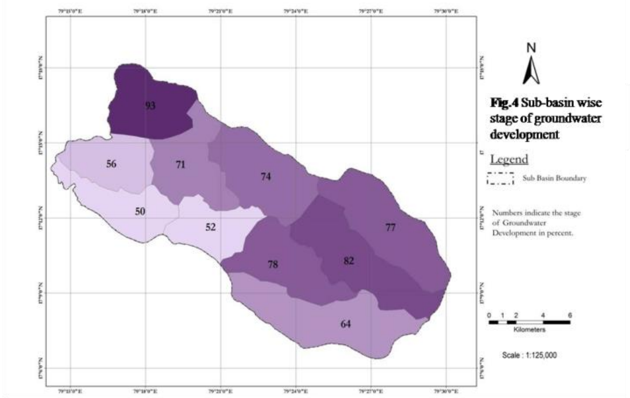

Fig.4 Sub-basin wise stage of groundwater development

V. CONCLUSIONS

The Nakrekal basin has been divided into ten sub-basins for this purpose as shown in Fig.3. The sub-basin wise groundwater resource estimation is made as per the methodology. Based on the results obtained through the sub-basin wise estimation, it is noticed that one sub-basin is falling under critical category, five sub-basins are under the 'semi-critical' stage and the remaining four sub-basins are falling under 'safe' category. The computations are made, by using the rainfall data of the nearest rain gauge station and the water table fluctuation of the nearest observation well. The results of the sub-basin wise groundwater resource estimation are shown in Table 4 and the stage of groundwater development is shown in the Fig. 4. Grey granites, pink granites, migmatites, aplites and younger basic intrusive like dolerites are the local variants of granite gneisses which marked as geology. The study area has been classified as Potable and Non-potable by integrating the three parameter maps.

Further the causative parameter(s) responsible for non-potability of the groundwater has also been determined. As far as the Groundwater Resource Estimation of calculation is concerned the entire basin has been categorised as semi-critical and one sub-basin as critical, five sub-basins as semi-critical and the remaining four sub-basins have been categorised as safe.

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