

INDEX CATCHMENT—A TOOL FOR WATER BALANCE STUDY IN THE ARID ZONE OF INDIA

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ABSTRACT

A considerable area of western Rajasthan is composed of impeded drainage basins bounded by the dune ridges and eroded rocky outcrops. Method for computing groundwater balance of impeded basins as independent hydrological unit have been termed as Index Catchments. The results obtained from three different methods of water balance computation of two index catchments in the Nagaur district and that of the district area, were statistically analysed and were found to be of same order. It has been suggested to adopt the 'Index Catchment's a method of water balance studies for minimal time and manpower requirements.

INTRODUCTION

During the past two decades, it has been realised that for management of groundwater resources, quantitative assessment is an essential requirement in any large scale utilisation. Water table in a region attains a state of dynamic equilibrium for a given annual recharge—discharge pattern and boundary conditions. It fluctuates during the year due to natural phenomenon or human activities. Moreover, this region does not have homogeneous and continuous aquifer. The aquifer occur as isolated basins having their own hydrological parameters. Thus, the recharge is restricted to a few zones only. Hence without knowing its potentials and limitations, the utilization of groundwater out of sheer necessity is causing (i) lowering of static water level (ii) reduction of yield from wells and (iii) increase in salinity of groundwater.

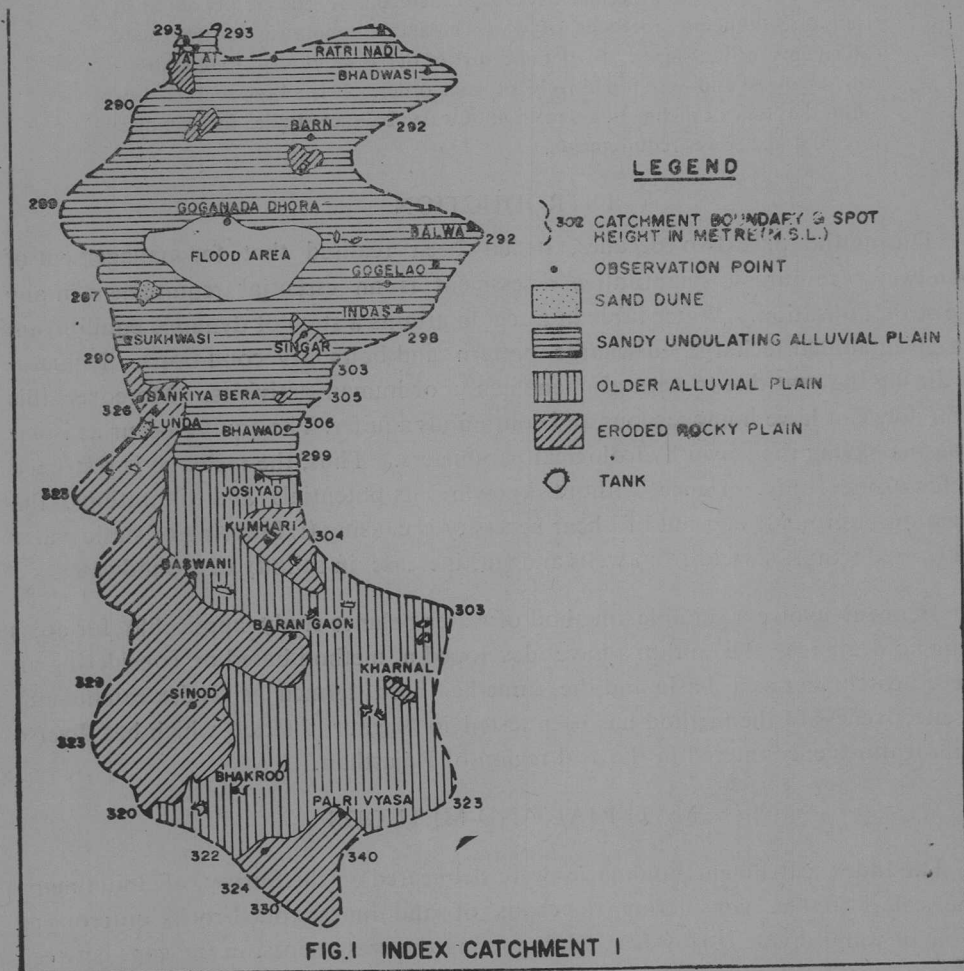
Hence to evolve a suitable method of water balance study applicable for areas having no drainage, the authors have developed a method based on considering an impeded catchment as a basin and the same has been termed as 'Index catchment'. The effectiveness of the method has been tested in Nagaur district which has diverse terrain features encountered in the arid region of Rajasthan.

MATERIAL AND METHODS

The Index catchment boundaries were delineated on the Survey of India maps of the scale 1:50,000, considering the crests of sand dunes/eroded rocky outcrops as the line of water divide. However, while joining the crest spots, in the gaps between the dunes, due weightage was given to the relative heights and the boundary line was passed through the highest elevated spots. Before finalising the catchment boundary,

the field checks were also carried out to ensure that these catchments are impeded drainage basins. Assuming that these basins are independent hydrological basins whose runoff and infiltration is governed by their crest lines.

Index catchment 1 (Fig. 1) occupies 347 km² area and is bounded by sand dunes. This area is covered with sand dunes, sandy undulating plains, older alluvial plains and rocky eroded plains. Below the sand cover, the principal aquifer of this area is composed of fine grained sandstone intercalated with shale. This type of aquifer covers 17.5 per cent of the district. Of this, 4.0 per cent area is unproductive as hills and rocky outcrops and the rest i.e. 96.0 per cent forms the aquifer. A net work of 16 raingauges and 26 observation wells were established.



Index catchment 2 (Fig. 2) occupies 258 km² area and is bounded by eroded and compact limestone and fine grained sandstone with low lying ridges. The area is covered by sand dunes, rocky pediments and buried pediments. The principal aquifer of this area is limestone. This aquifer covers 10.29 per cent of district area, of which 11.0 per cent is unproductive as hills and rocky outcrops and 89.0 per cent forms the aquifer. A network of 10 raingauges and 13 observation wells were established.

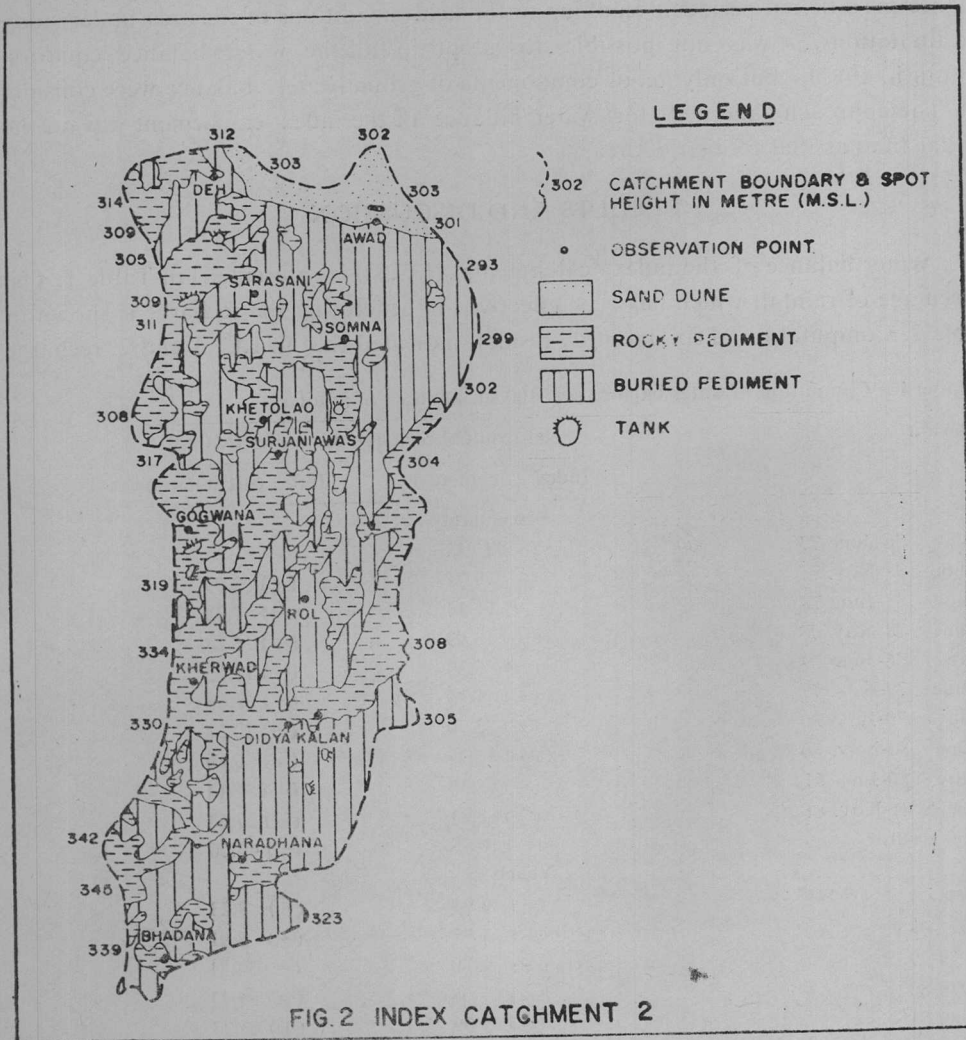


FIG. 2 INDEX CATCHMENT 2

Static water levels were recorded during the months of June and November every year for a period of five years (1976 to 1981). Various methods of water balance computation adopted in the study were : (1) area of the aquifer in the district (2)

water balance equation (3) aquifer area of the index catchment. Six monthly, yearly and five yearly variation of static water levels were considered in all the three methods for computation. The approach of computation of water balance was based on change in ground water storage = groundwater inflow (recharge) - groundwater outflow (discharge). In the first method i.e. area of the aquifer in the district; the extent of different aquifers in the district area, rainfall, variation in static water level, porosities of various aquifer types (Todd, 1959) were considered for computation of water balance in different periods. Looking to the field conditions of the area under study and limitations, it was not possible to adopt in full the water balance equation (Karanth, 1987), but only major components of groundwater balance were considered. The approach adopted for water balance of the index catchment was on the similar lines as that of district area.

RESULTS AND DISCUSSION

Water balance of the index catchments (I.C. s.) is presented in Table 1. The percentage of rainfall which has been effective in generating the recharge is shown in Table 2. Computation of six monthly results indicated that in I.C. 1 and 2, recharge

Table 1. Computation of water balance per 100 sq. km area of aquifer

Period	Net residual recharge to aquifer (MCM)	
	Index catchment 1	Index catchment 2
	Six monthly	
Nov. 76-June 77	(-) 19.17	—
June 77-Nov. 77	(+) 9.21	(+) 2.09
Nov. 77-June 78	(-) 11.34	(-) 7.24
June 78-Nov. 78	(+) 16.99	(+) 6.88
Nov. 78-June 79	(-) 8.30	(-) 13.35
June 79-Nov. 79	(+) 1.40	(+) 9.69
Nov. 79-June 80	(-) 2.70	(-) 20.28
June 80-Nov. 80	(+) 11.43	(+) 6.66
Nov. 80-June 81	(-) 5.59	(-) 52.14
June 81-Nov. 81	(-) 2.71	(+) 27.63
Net result	(-) 10.78	(-) 40.06
	Yearly	
1976-77	(-) 9.94	(-) 8.23
1977-78	(+) 7.55	(+) 8.91
1978-79	(-) 9.34	(-) 54.31
1979-80	(-) 17.08	(+) 54.33
1980-81	(-) 5.09	(+) 23.73
Net result	(-) 33.90	(+) 24.43
	Five yearly	
1976-81	(-) 26.59	(+) 9.31
(+) Recharge		
(-) Over exploitation		

was generated during each monsoon season of the study period, irrespective of total amount of rainfall. However, during the year 1981 for I.C. 1 exploitation far exceeded the quantum of recharge generated by rainfall. The net results of six monthly water balance (1976-81) for I.C. 1 and 2 indicated the over exploitation of 10.78 mcm and 40.06 mcm (Table 1) per 100 km² area of the aquifer, respectively. The annual computation of I.C. 1 indicated the deficit water balance varying from 5.09 to 33.90 mcm except for the year 1977-78. In I.C. 2 recharge variation from 8.91 to 54.33 was observed except the year 1976-77 and 1978-79. The net results of yearly water balance for I.C. 1 and I.C. 2 indicated the over exploitation of 33.90 mcm and recharge of 24.43 mcm, respectively. Similarly five yearly water balance assessment indicated deficit of 26.59 mcm in I.C. 1 and recharge of 9.31 mcm in the I.C. 2. From the above data it is apparent that computation of water balance on six monthly basis gives more reliable results.

Table 2. Recharge rainfall relationship 1976-81

Year	Rainfall (mm)	Rainwater generated (MCM)	Recharge to aquifer during monsoon (MCM)	Per cent of rainfall recharged
Index catchment 1				
1976-77	413.00	143.31	57.56	40.16
1977-78	352.84	122.43	31.97	26.11
1978-79	369.37	128.17	59.90	46.73
1979-80	197.40	68.50	4.86	7.09
1980-81	378.48	131.33	40.64	30.94
June 81- Nov. 81	141.03	48.94	16.56	33.83
Average	308.68	107.11	35.25	30.81
Index catchment 2				
1976-77	413.00	106.55	7.67	7.19
1977-78	385.45	99.44	11.59	11.65
1978-79	499.66	128.91	18.60	14.42
1979-80	179.01	46.18	25.04	54.22
1980-81	378.48	97.65	17.17	17.58
June 81- Nov. 81	418.61	108.00	48.62	45.01
Average	379.03	97.78	21.44	25.01

The results of water balance (Table 3) with three methods per 100 km² area of the aquifer were statistically analysed. Considering the range of variation in net water balance values as a measure, method 3 has given better results for I.C. 1. For I.C. 2, method 2 has given better results as indicated by least variation in recharge and over exploitation values. Taking net result as measure of assessment again method 3 is suitable for both the index catchment. The actual value of coefficient of variation are negative (-ve) and hence the least value has been taken as highest. This is mainly because the negative values indicate overdraft rather than recharge.

Table 3. Recharge (MCM) computed per 100 km²

Period	Methods		
	As per total area of the particular aquifer in the district	As per the water balance equation	As per aquifer area of the index catchment
Index catchment 1			
Nov. 76-June 77	(+) 0.17	(-) 2.25	(-) 19.17
June 77-Nov. 77	(+) 6.24	(+) 9.21	() 9.21
Nov. 77-June 78	(-) 4.20	(+) 16.43	(-) 11.34
June 78-Nov. 78	(+) 13.44	(+) 11.72	(+) 16.99
Nov. 78-June 79	(-) 26.10	(-) 35.70	(-) 8.30
June 79-Nov. 79	(-) 9.99	(+) 10.01	(+) 1.40
Nov. 79-June 80	(-) 3.58	(-) 37.11	(-) 2.70
June 80-Nov. 80	(+) 14.11	(+) 26.30	(+) 11.43
Nov. 80-June 81	(-) 0.89	(-) 31.42	(-) 5.59
June 81-Nov. 81	(-) 23.18	(+) 4.01	(-) 2.71
Net results	(-) 33.98	(-) 28.80	(-) 10.78
Coefficient of variation	3.98	8.07	10.28
Index catchment 2			
June 77-Nov. 77	(+) 3.43	(-) 4.08	(+) 2.09
Nov. 77-June 78	(+) 0.99	(+) 3.88	(-) 7.24
June 78-Nov. 78	(-) 4.09	(-) 21.09	(+) 6.88
Nov. 78-June 79	(-) 56.80	(-) 13.33	(-) 13.35
June 79-Nov. 79	(-) 6.10	(+) 9.71	(-) 9.69
Nov. 79-June 80	(-) 4.81	(-) 20.28	(-) 20.28
June 80-Nov. 80	(+) 18.27	(+) 6.66	(+) 6.66
Nov. 80-June 81	(-) 7.23	(-) 52.14	(-) 52.14
June 81-Nov. 81	(-) 2.36	(+) 3.18	(+) 27.63
Net results	(-) 58.70	(-) 87.49	(-) 40.06
Coefficient of variation	3.12	2.02	5.11
(+) Recharge (-). Over exploitation			

The above results were subjected to 't' test. Values of 't' comes out to be non-significant in all the combination of the three methods for both the catchments which indicates that the water balance for 100 km² is of the similar order. The results could be extrapolated for the entire area of the particular aquifer, situated under similar climatic and terrain characteristics in the region and not only within the district boundaries. More over the hydrological cycle for this region is of 15 years and such studies could be undertaken for longer duration rather than five years. This method will also minimise, to a considerable extent, the capital expenditure, time and manpower requirement and would give results of water balance which are meaningful and of practical utility. Hence it can safely be suggested to adopt Index catchment method of water balance studies for the area having no well defined hydrological basins.

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REFERENCES

- Karant, K.R. 1987. Groundwater assessment development and management. Tata Mc Graw Hill Publishing Company Ltd. New. Delhi. pp. 720.
- Todd, D.K. 1959. Groundwater Hydrology. John Wiley & Son Inc., New York. pp. 336.