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Groundwater Recharge in Panjab State (India) Using Tritium Tracer

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Vertical recharge to groundwater due to the 1972 monsoon plus supplemental irrigation has been measured at 21 sites in the state of Panjab (India) using tritium tracer. Average recharge is found to be equivalent to 8.5 cm of water. This is about 18% of the average rainfall and 12% of the total watering.

Introduction

The Panjab region, which is one of the major wheat producing states in India, is served by three rivers - Sutlej, Beas and Ravi which are tributaries of river Indus. The surface water has been extensively utilised (Chaturvedi 1971). For providing reliable and adequate amount of water needed for the expanding demands, groundwater resources are being increasingly exploited. A proper management of these resources depends greatly upon quantitative determination of recharge and various factors that influence it so that a stable groundwater level can be maintained. In earlier studies we have estimated the amount of vertical recharge in Western U.P. (Datta et al. 1973) and Haryana (Goel et al. 1977) using tritium tracer. In the present paper we report the results of our studies undertaken in the state of Panjab at about twenty sites to measure vertical recharge to the groundwater due to the 1972 monsoon rains and supplemental irrigation.

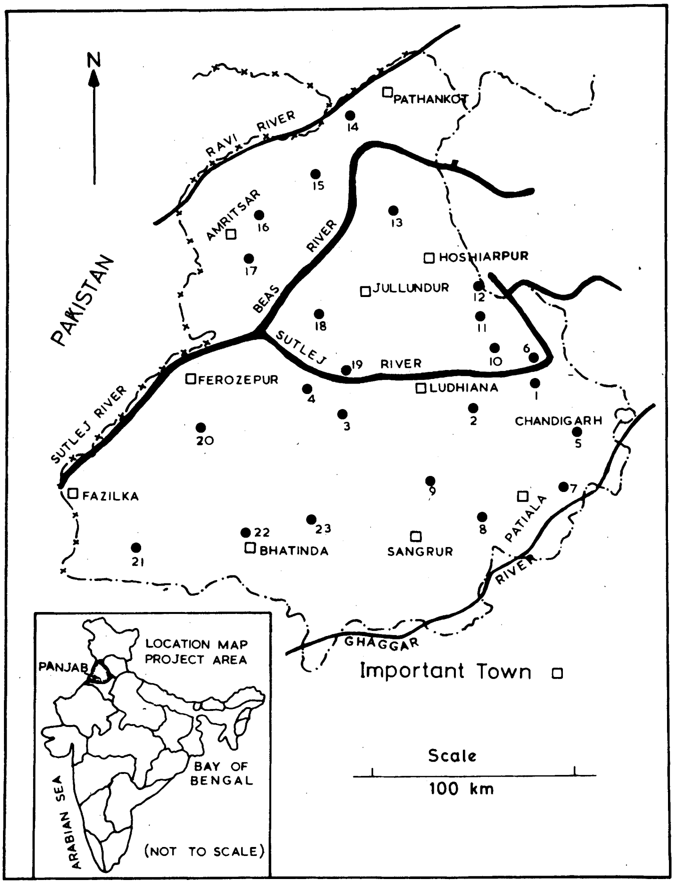


Fig. 1. Index map of Panjab state.

Physiography of the Region

The Panjab state (Fig. 1) has two major topographical regions: (1) the sub-mountainous tract, which runs parallel to the Siwalik ranges and is formed by the detrital deposits. The groundwater occurs under both confined and unconfined conditions. The depth of the water level in this region varies between 2 to 40 m below ground level. Average surface slope is about 2 m to 3 m per km, and (2) the alluvial plains, which constitute the central and most of the southern Panjab. The tract is covered by deposits comprising of sand of varying grades, gravel, pebbles, and clay with *kankar* (calcareous concretions). Groundwater occurs mostly in unconfined conditions. The average surface slope is about 0.4 m per km. Arid and semi-arid climatic conditions exist in most of the area.

Experimental

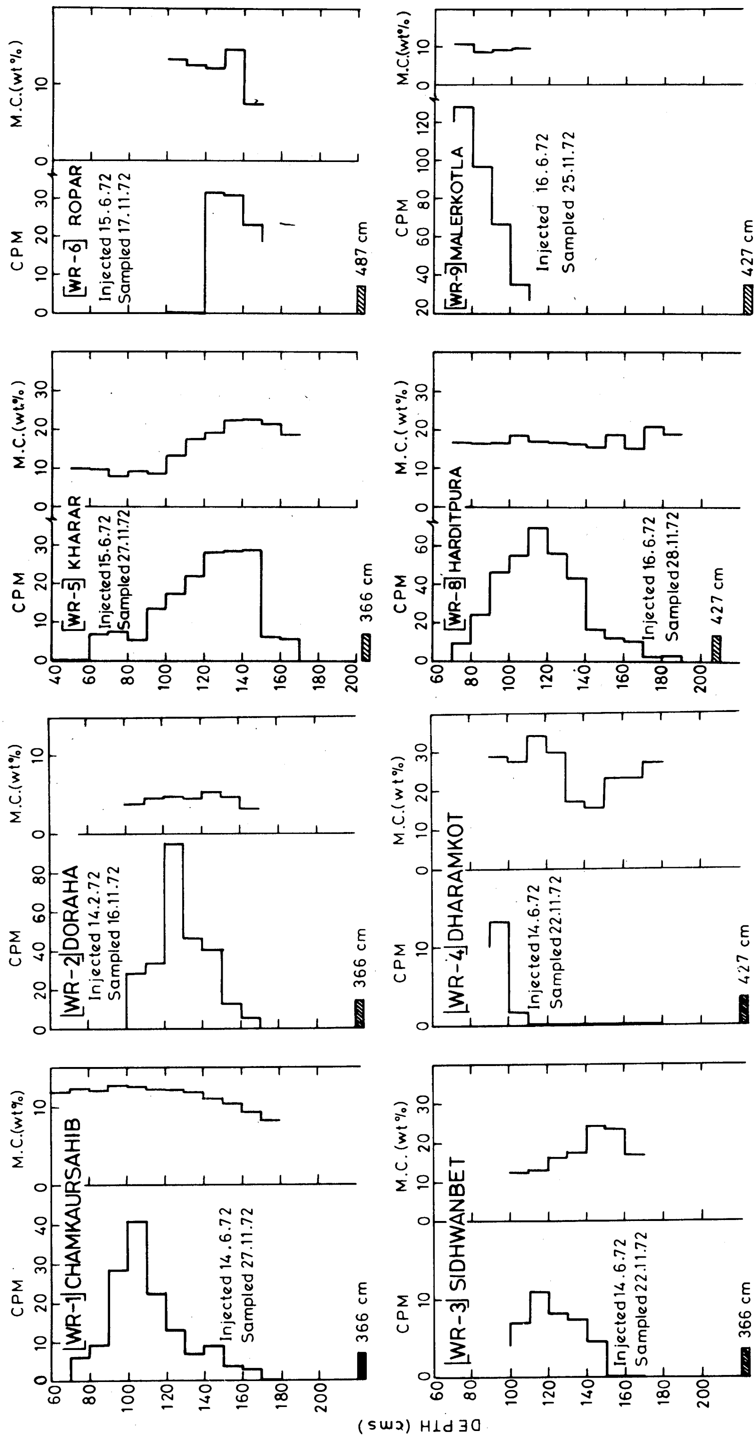
The technique has been discussed elsewhere (Datta et al. 1973, Goel et al. 1977). Tracer injections were carried out in June 1972 and first sampling was made in November 1972. Results of the experiments conducted earlier in U.P. showed that the tracer activity gets diluted significantly during the course of its movement in the soil. Therefore in the present injections a higher activity of tritiated water (4 μCi/ml) was used. The pore water from the soil samples was extracted by distillation under reduced pressure. The concentration of tritium in water samples was measured using liquid scintillation counting system (Tri-Carb).

Results and Discussion

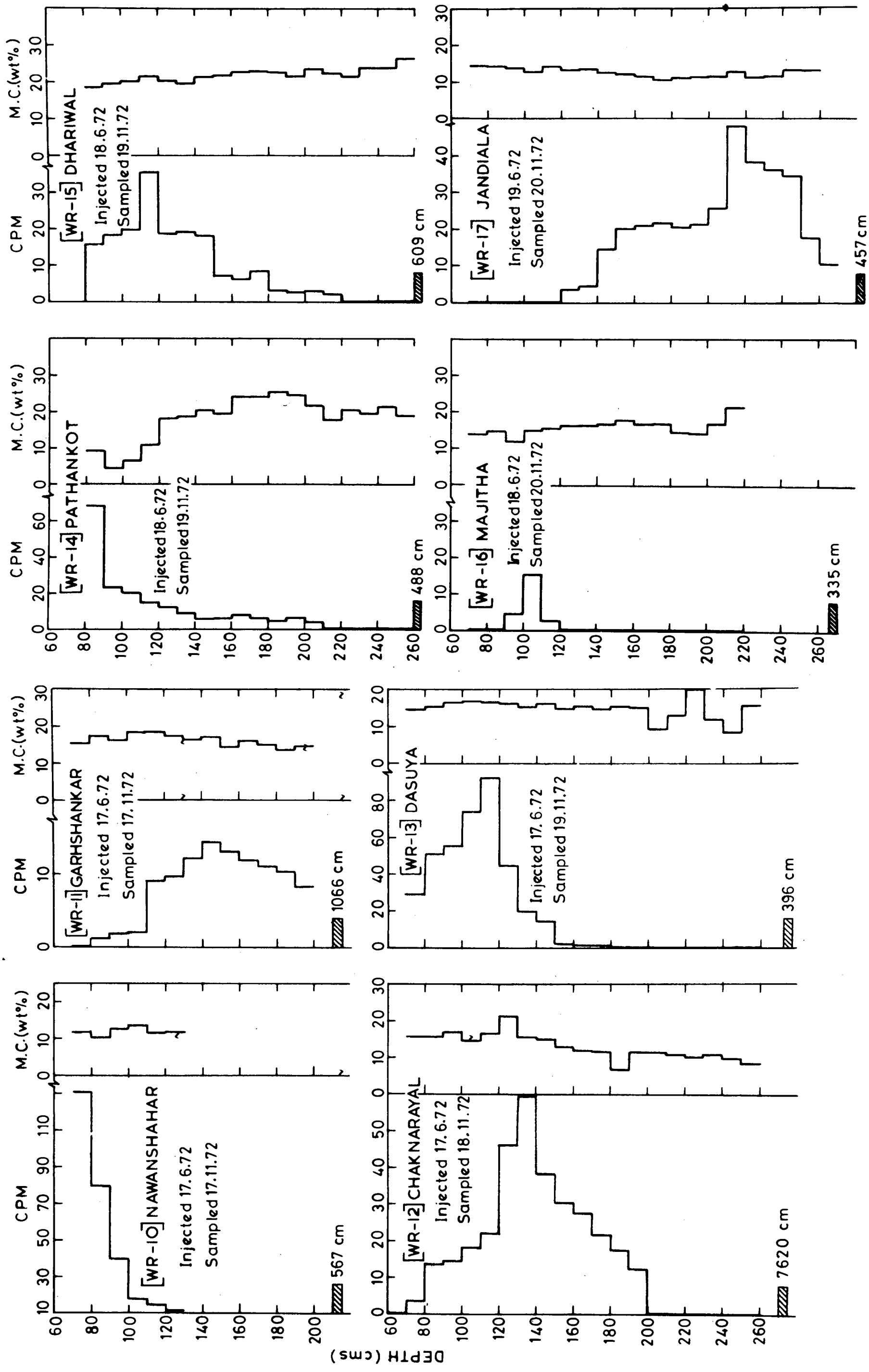
The tracer profiles as well as the moisture profiles for a number of sites are shown in Figs. 2 to 7. These shapes are similar to those seen earlier for various sites in the states of Uttar Pradesh (Datta et al. 1973) and Haryana (Goel et al. 1977). The movement of the tracer towards the water table is apparently by the layered displacement mechanism with molecular diffusion (Goel et al. 1977). The experimental data for all these sites sampled after the 1972 monsoon rains, are presented in Table 1. There is a wide variation in absolute as well as fractional recharge. Such factors as, amount of irrigation and rainfall, amount of clay in the soil, depth to the water table, etc., might be responsible for this variation. Low values of fractional recharge are found for areas of hard clay and shallow water table. Soil analysis could not, however, be performed.

For the 20 sites an average recharge, *Re,* for the 1972 monsoon plus supplemental irrigation is found to be 8.5 cm of water. This is about 18% of the average rainfall, *R* (47 cm) and about 12% of the total watering. Since at most of the sites the supplemental irrigation, *I,* is comparable to the rainfall, the latter must contribute significantly to the recharge. In Fig. 8, we have plotted *Re* versus $(R + I)$ for all the sites. The empirical curve $Re = 2\,(P - 15)^{2/5}$ which gives the value of recharge (both *Re,* and *P,* in inches) for a given value of $P\,(P = I + R)$ has been suggested by Chaturvedi (1946), from some laboratory experiments, for climatic conditions of Uttar Pradesh. This empirical relation cannot be expected to give good agreement because it does not take into consideration such variables as soil properties, etc. (Datta 1975). However, it may be pointed out that the experimental recharge values are more often lower than higher from the curve. Since the climate of Panjab is drier compared to that of U.P. this trend is quite natural.

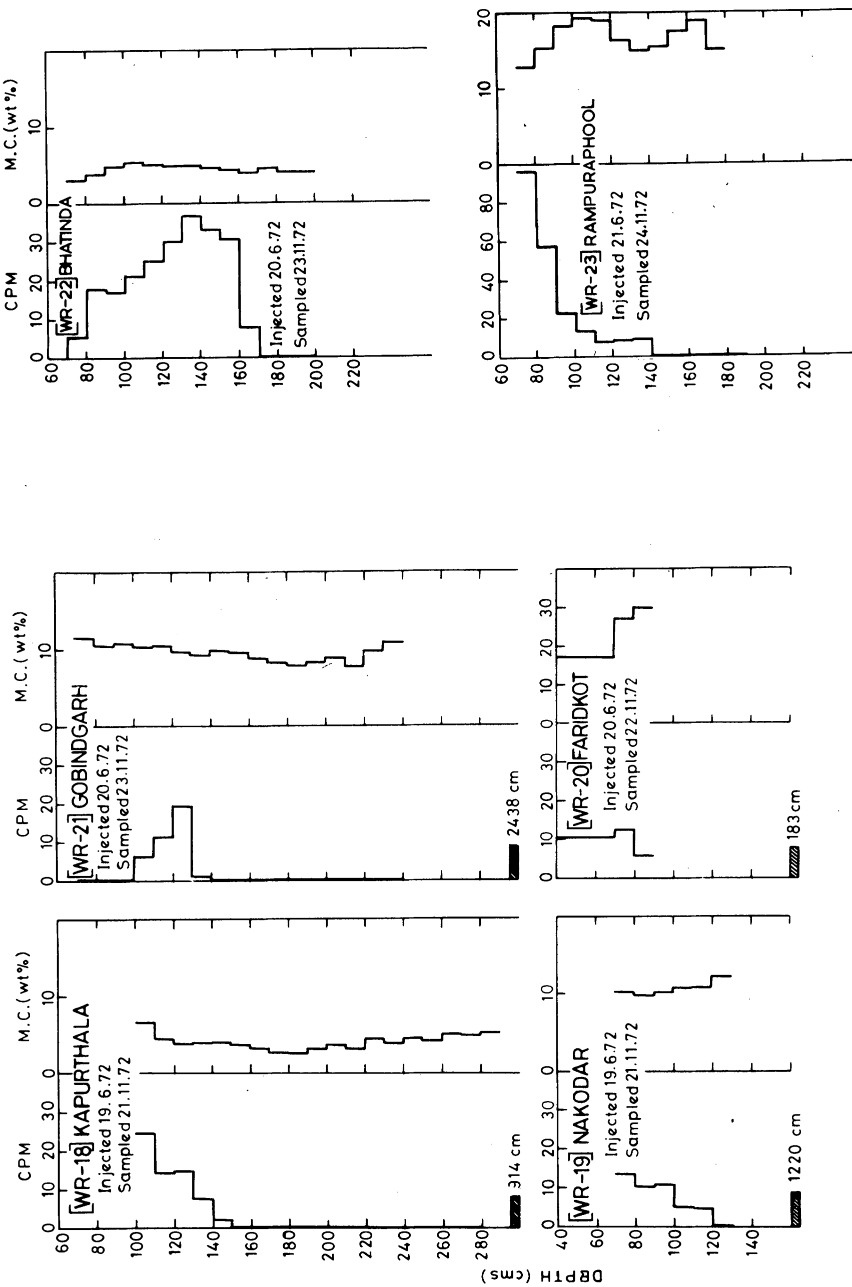
Working out the average discharge for a six year period, from 1966 to 1972, it has been assessed (Hoon 1974) that in Panjab a potential of 5550 m.cu.m. of water can be made available annually by exploiting sub-soil aquifers through tubewells. For the



Figs. 2-3. Tritium activity and moisture profiles at various sites.



Figs. 4-5. Tritium activity and moisture profiles at various sites.



Figs. 6-7. Tritium activity and moisture profiles at various sites.

Table 1 - Experimental data from Panjab for recharge from June 1972 to November 1972

Site	Code*	*Depth of watering* Rainfall R(cm)	Irrigation I(cm)	Displace-ment *of Tracer (cm)* Peak	C.G.	Average water content (Vol.%)	Recharge *Re* (cm)	$\frac{Re}{R+I}$
WR- 1 Chamkaur Sahib	MT	47.0	20.4	40	45	17.2	7.7	0.11
WR- 2 Doraha	ST	31.4	Nil	60	63	6.6	4.1	0.13
WR- 3 Sidhwan Bet	LC	45.0	59.7	50	58	19.0	11.0	0.10
WR- 4 Dharamkot	LC	24.5	28.2	20	21	34.7	10.7	0.20
WR- 5 Kharar	HV	56.5	Nil	80	60	17.4	10.4	0.18
WR- 6 Balachaur	ST	46.4	8.6	60	69	18.0	12.4	0.23
WR- 9 Malerkotla	HT	62.2	21.7	0	20	13.4	2.7	0.032
WR-10 Nawanshahar	HT	66.5	32.5	0	21	15.3	3.2	0.032
WR-11 Garhshankar	MT	71.8	13.6	80	86	22.1	19.0	0.22
WR-12 Chaknarayal	LU	62.2	Nil	70	74	21.8	16.1	0.26
WR-13 Dasuya	MT	46.7	31.3	60	52	21.6	11.2	0.14
WR-14 Pathankot	MT	76.8	Nil	10	50	11.0	5.5	0.072
WR-15 Dhariwal	HT	77.1	5.5	50	61	25.9	15.8	0.19
WR-16 Majitha	HC	26.4	130.6	40	39	18.7	6.9	0.049
WR-17 Jandiala	MT	26.4	28.9	50	54	18.7	10.2	0.18
WR-18 Kapurthala	LT	21.5	16.2	40	52	7.4	3.8	0.10
WR-19 Nakodar	MT	31.9	10.8	0	25	14.2	3.5	0.082
WR-20 Bastinanak	MC	Data not available		0	6	28.2	1.7	-
WR-21 Gobindgarh	LC	43.4	7.2	60	54	14.8	8.0	0.16
WR-22 Bhatinda	LC	29.3	24.4	70	60	6.6	4.0	0.075
WR-23 Rampuraphool	LT	36.8	Nil	0	22	20.7	4.5	0.12

* Code: First letters stand for: H (heavy) L (light), M (medium) and S (sandy) soil types; the second letters stand for irrigation source, viz;T(Tubewell),C(Canal) and U(Unirrigated).

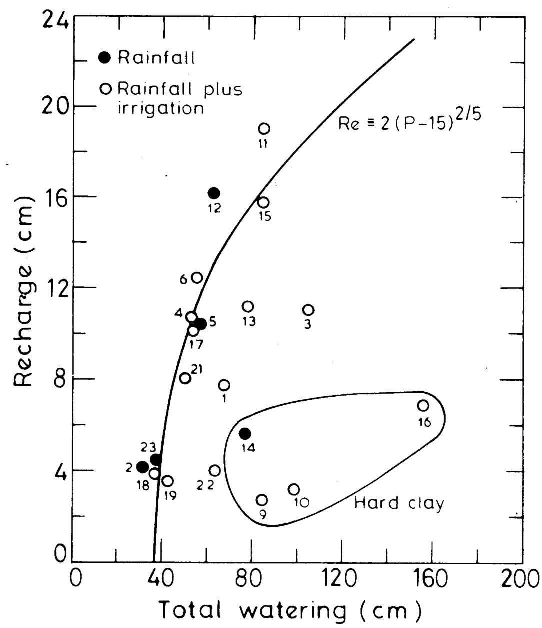


Fig. 8. Variation of recharge with total watering (rainfall and irrigation).

total area of Panjab (5 million hectares), this amounts to about 11 cm of water and is higher than the average recharge value obtained by us. Some contribution to groundwater must also come from seepage from canals. The current draft is likely to be higher than 8.5 cm even though during the past few years the exploitation of groundwater through tubewells has been curtailed due to a shortage of power. The steady depletion of groundwater regime of the tract as observed since 1965 (Uppal 1972) suggests that the total recharge to the aquifers (vertical recharge plus seepage from canals etc.) is insufficient to balance the draft.

In the preceding paper (Goel et al. 1977) we have seen the recharge data from the state of Haryana where the climatic condition are similar (arid and semi-arid) to those in Panjab. It is interesting to compare the data from these two states. This is done in Table 2. There is a remarkable closeness in the data from the two states. This demonstrates that the method, inspite of limited number of sites, gives reasonable results for the averages.

The shapes of the tracer profiles are found to be Gaussian in many cases enabling us to calculate values of the diffusion coefficient of water in soils. These values range from 1.4×10^{-5} cm^2 sec^{-1} to 2.4×10^{-5} cm^2 sec^{-1} and are similar to those found for the states of Haryana (Goel et al. 1977) and U.P. (Datta 1975).

Table 2 - Comparison of Panjab and Haryana results

State	Panjab	Haryana
No. of sites	20	15
Period	June, 1972 November, 1972	June, 1973 November, 1973
Re	8.5 cm	8.0 cm
R	47 cm	49 cm
(*R*+*I*)	68 cm	55 cm
Ranges for *Re*	2 cm to 20 cm	3 cm to 18 cm
Re/*R*	0.18	0.16
Re/(*R*+*L*)	0.12	0.14

Second Sampling

At four sites samples were collected after a lapse of about 21 months so that two monsoons had infiltered into the soil. These data are presented in Table 3 and are shown in Figs. 9 and 10. The shape of tritium profile at Malerkotla (WR-9) is quite puzzling since it shows two peaks intervened with a few sections that show no activity at all. There is, at present, no satisfactory explanation for this. The center of gravity of the two peaks has been taken as the positions of the tagged layer for calculating the value of recharge. There is reasonable similarity in the results for the two successive years though the data for the second year are very few.

Table 3 - Sites sampled after two years (in February, 1974)

Site	FIRST SAMPLING				SECOND SAMPLING			
	R(cm)	*I*(cm)	*Re*(cm)	*Re*/ (*R*+*I*)	*R*(cm)	*I*(cm)	(cm)	*Re*/ (*R*+*I*)
WR- 9 Malerkotla*	62,2	85	2.7	0.032	101	125	11.4	0.050
WR-10 Nawanshahar	66.5	32.5	3.2	0.032	166	64	9.0	0.036
WR-13 Dasuya	47.7	31.3	11.2	0.14	132	60	19.4	0.10
WR-17 Rampuraphool	36.7	Nil	4.5	0.12	67	17	16.5	0.20

* The activity profile at Malerkotla found at the second sampling is not understood.

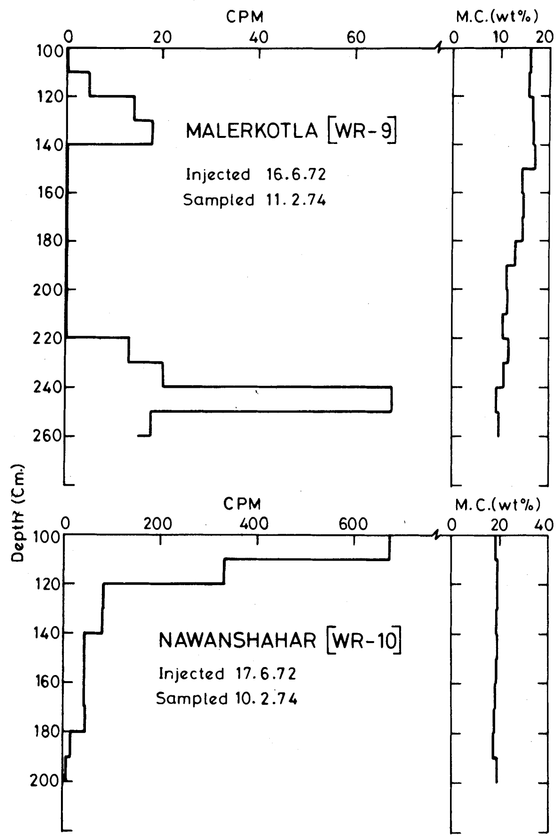


Fig. 9. Tritium activity and moisture profiles at the sites sampled after two monsoons.

Conclusions

Average vertical recharge in the state of Panjab is about 18% of the average rainfall and only 12% of the total watering. It appears that the irrigation water makes a substantial contribution to the groundwater recharge. It is essential that the lowering of the water table which has been observed in recent years should be judiciously controlled. There is thus a pressing need for full exploitation of surface water resources and to develop ways to increase recharge to the groundwater.

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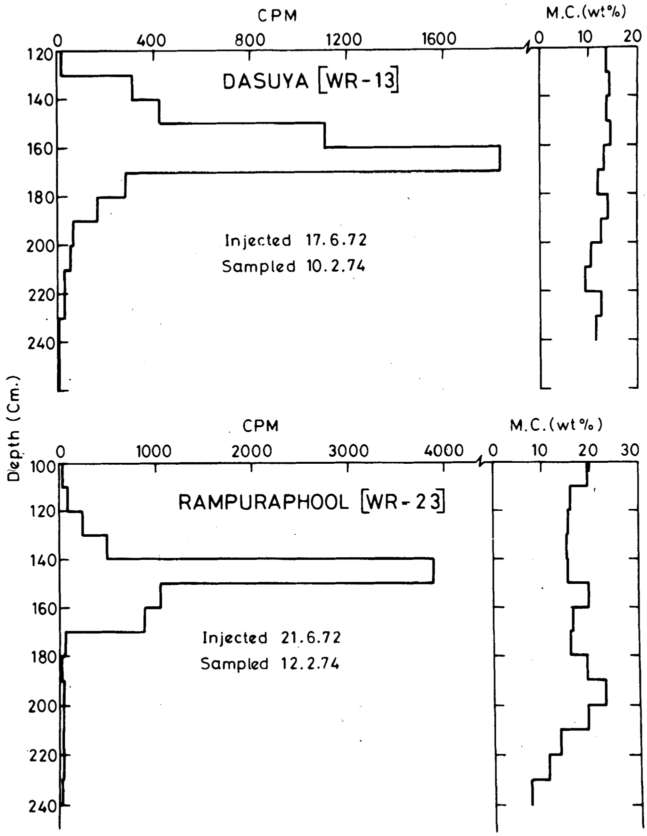

Fig. 10. Tritium activity and moisture profiles at the sites sampled after two monsoons.

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References

Chartuvedi, R.S. (1946) Annual Report on Research Progress during the year 1946. Technical Memo No. 17, Irrigation Research Institute, U.P. (Roorkee, India).

Chaturvedi, M.C. (1971) Conjunctive development of surface and groundwater resources. Symposium on »Integrated Development of Surface and Subsurface Water Resources«, New Delhi, Central Board of Irrigation and Power, Publication No. 113, Volume 1, pp. 75-84.

Datta, P.S., Goel, P.S., Rama and Sangal, S.P. (1973) Groundwater recharge in western Uttar Pradesh. *Proc. Ind. Acad. Sci., 78,* Sec. A: 1-12.

Datta, P.S., (1975) Groundwater Recharge Studies in the Indo-Gangetic Alluvium Plains Using Tritium Tracer. Ph.D. Thesis, Indian Institute of Technology, Kanpur.

Goel, P.S., Datta, P.S. and Tanwar, B.S. (1977) Measurement of vertical recharge to groundwater in Haryana state (India) using tritium tracer. *Nordic Hydrology 8,* 4.

Hoon, R.N. (1974) Development of irrigation and water requirements for areas served by Bhakhra. Ind. J. Power and River Valley Development, 24; 233-239.

Uppal, H.L. (1972) Serious waterlogging in Panjab and Haryana - how cured and measures to prevent its occurrence. Symposium on »Waterlogging - Causes and Measures for its Prevention«. Central Board of Irrigation and Power, 45th Annual Board Session, Pub. No. 118, Vol. II, pp. 1 - 31.

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