GROUND WATER RECHARGE IN WESTERN UTTAR PRADESH

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ABSTRACT

The downward movement of water in the soil due to 1971 monsoon precipitation and supplemental surface irrigation has been traced at about forty-five sites in Western Uttar Pradesh, using a thin layer of moisture tagged with tritiated water. The tritiated layer was found to move down to different depths at different sites. The movement, averaged over the forty sites is found to be 96 cm, indicating that the average recharge for the year 1971 (a year of normal monsoon) was 21·5 cm of water.

INTRODUCTION

THE water resources of Indogangetic plain are known to be immense. There is vast reservoir of good quality water in the underground alluvium. In addition to generally adequate amount of local rainfall in the plain, a large amount of Himalayan run-off is carried by the rivers traversing the plain. The land is generally fertile.

The availability of good quality water and recent chemical, mechanical and biological aids in agriculture have aroused the hopes of supporting intensive and extensive cultivation over the entire plain. In fact the rapidly increasing population and other social pressures are beginning to make ever-increasing demands both on land and the water system. The cultivation of high yielding varieties, introduced recently in the plain, is resulting in rapidly increasing exploitation of groundwater. One question of paramount importance now is to determine how much draft of groundwater can be permitted on perennial basis, without causing any deleterious effect on the underground reservoir. The most important parameter that enters in evaluating the above problem is a prior knowledge of the rate of recharge of water in the given region.

The present investigation is aimed at determining the rate of recharge in a small part of the plain, *i.e.*, Western Uttar Pradesh. The bigger problem of management of all water resources of the entire plain is outside the scope of the limited and exploratory investigation described herein.

Several methods for determining recharge are available. Most of them require hydrological data which are either not available or are of uncertain nature. The recharge depends on a number of factors like amount of rainfall, the intensity and frequency distribution of rain, amount and type of irrigation applied, evapotranspiration, etc.

A direct method for measuring the recharge experimentally has been developed recently by Munnich and his associates (1968) at the University of Heidelberg. It is based on tracing the movement of a layer of moisture, tagged with tritiated water, downwards in the soil, on its way towards the water-table. The downward movement of the tagged layer is caused by the recharge of water from above. This method enables a determination of the recharge quite accurately in the alluvium provided certain conditions are met. We have found that the method developed by Munnich *et al.* works fairly well in Western Uttar Pradesh. Experiments are in progress in Punjab, and are planned for Haryana. In this paper, we report the results of our first experiment on the evaluation of recharge in Western Uttar Pradesh.

EXPERIMENTAL

Principle of the Method.—If tritiated water is injected as a "line", well below the root zone and away from any trees, it will move as a sheet of labelled moisture in due course of time towards the water-table due to the influence of percolation of rain and/or irrigation water at the top soil. This is shown diagrammatically in Fig. 1. Tritium injected at 70 cm depth will be found as a broad peak at perhaps 80 or 90 cm after a month or so due to some downward movement and may show some vertical spread due to molecular diffusion and velocity spread. After still longer period, the peak of the activity will move further down and the distribution would be still broader. The position of the tritium peak can be located by counting tritium in the moisture obtained from different depths in soil. Soil samples from different depths can be obtained using a hand auger. The moisture content of layer '*d*', displaced during the period intervening between the time of injection and time of soil sampling, represents the recharge during that period.

Procedure.—It was decided to carry out the experiment at about 4 or 5 sites in each district. The selection of any particular field for the experiment was completely random. The total of fifty sites selected for the purpose are shown in Fig. 2. The injection-layout is shown in Fig. 3.

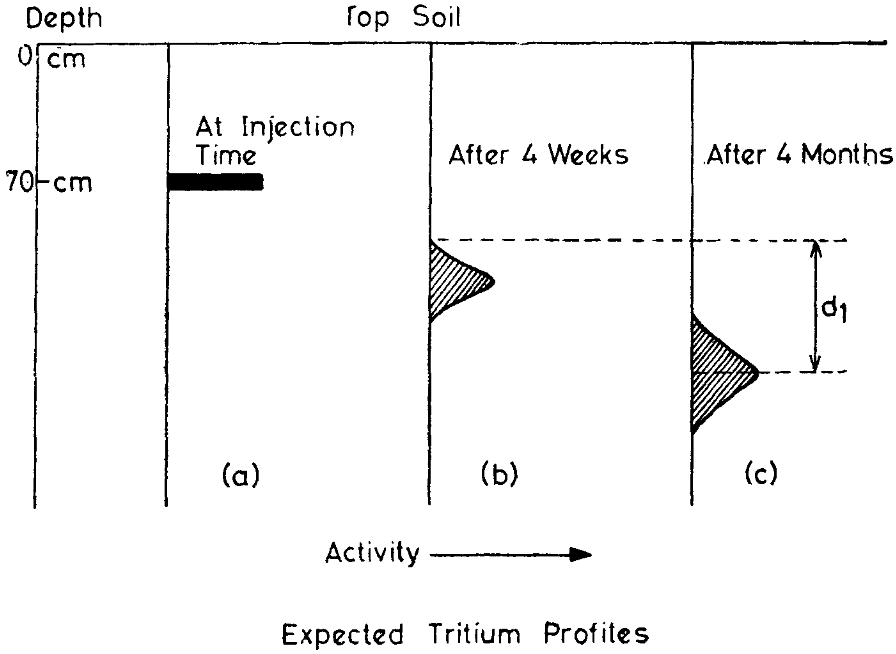
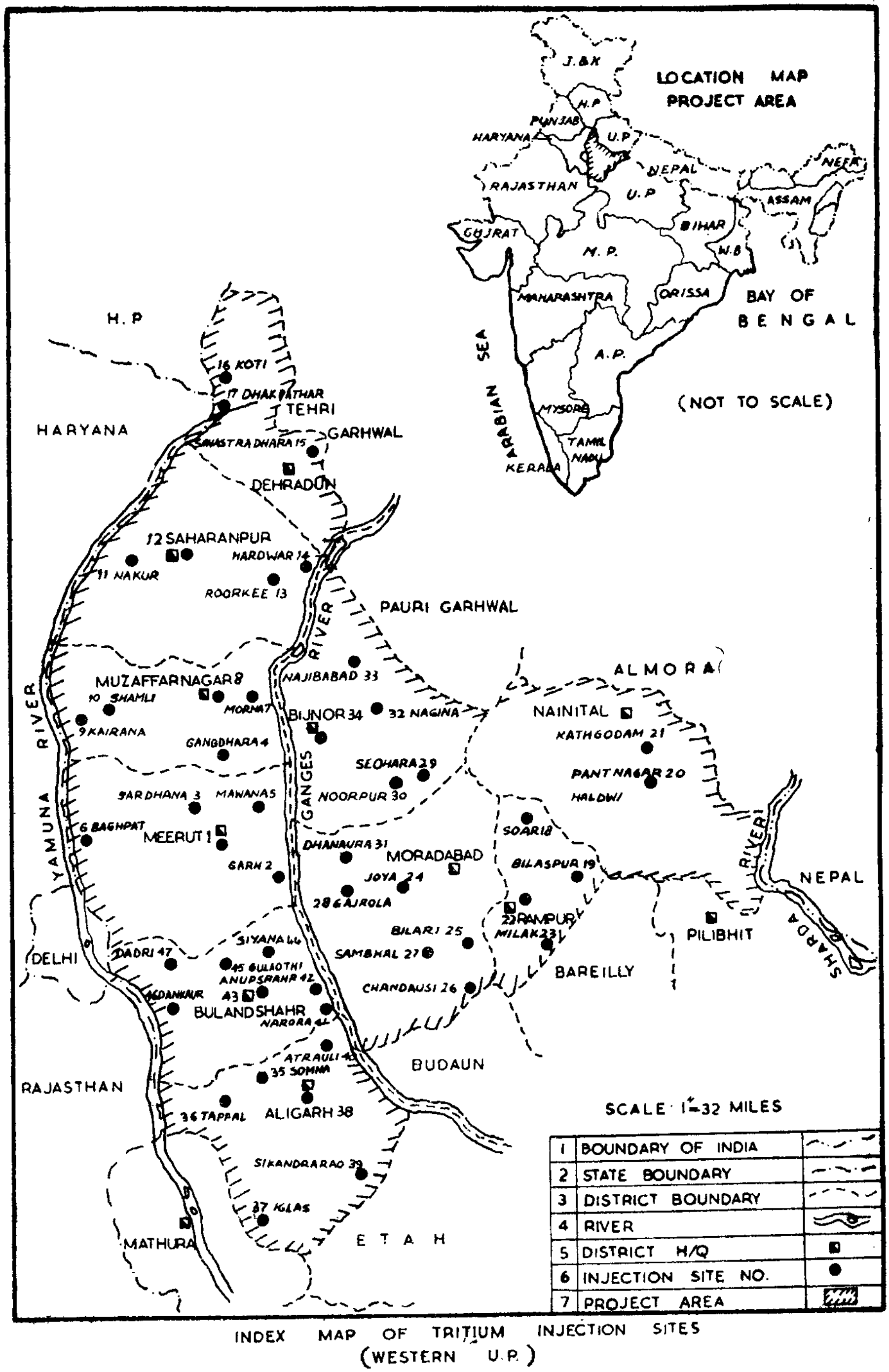


Fig. 1

Three sets of injections are made, each having six holes. This ensures that one can collect three samples at different times without affecting the natural soil and flow conditions in the unsampled set. Each set comprises of six injections. The injection syringe is shown in Fig 4. The drive rods are first pushed (or hammered) into the soil, so as to make holes, 70 cm deep and 7 mm diameter. The rods are pulled out and brass injection "needles" are inserted. 2·5 ml of tritiated water (1 μ Ci/ml) is injected into each hole. Iron bolts are hammered at 1 ft. depth at M_1 and M_2 which act as markers for subsequent location of the sets. After the three sets of injections, the holes are filled with soil. The field is left otherwise completely undisturbed



INDEX MAP OF TRITIUM INJECTION SITES
(WESTERN U.P.)

FIG. 2

and the farmer can continue his usual operations. The injection work was conducted just before the onset of monsoon of 1971.

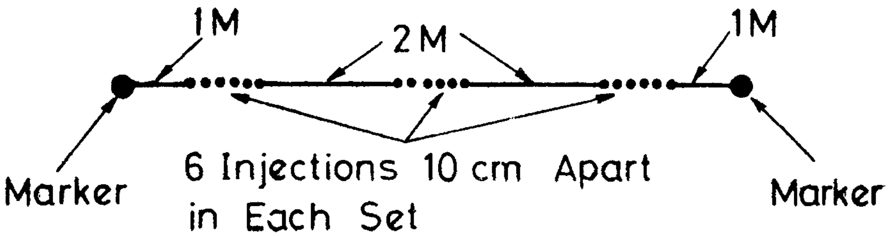


FIG. 3. Layout of injections in a field

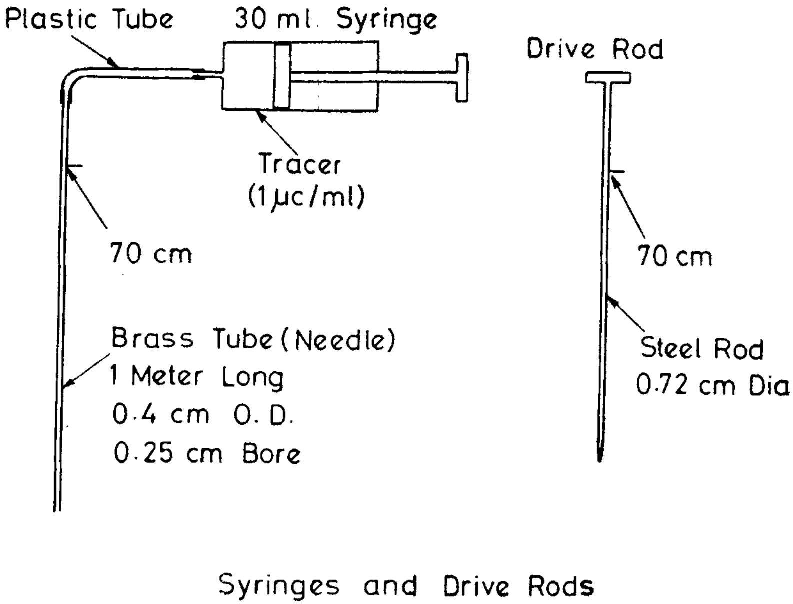


FIG. 4

Sampling work was begun in October 1971. All sites were sampled before June 1972. Soil is removed with a $1\frac{1}{2}''$ hand auger in successive depths of 10 cm, starting from 50 cm down to 300 cm. Samples of soil are stored in screw cap plastic containers and brought to laboratory for analysis.

Measurements on bulk density were carried out in the field. The entire soil samples from various depths were weighed at the site. The volume of the hole from which a soil sample was taken was measured by filling it with sand, filled in a graduated cylinder so that its volume could be measured. The data on density as calculated from these measurements for several sites are given in Table I. For others we will assume a value of 1·57 as found for most sites.

TABLE I

Average bulk density (g cm⁻³) of soil

Sl. No.	Site No.	Place	70 cm to 150 cm	150 cm to 250 cm	250 cm to 350 cm	70 cm to the C.G. of the tritium profile
1	1	Meerut ..	1·59	..	..	1·59
2	8	Muzaffarnagar ..	1·42	1·50	1·61	1·52
3	36	Tappal ..	1·54	..	..	1·54
4	40	Atrauli ..	1·49	1·55	1·60	1·52
5	42	Anupshahr ..	1·45	1·56	..	1·49
6	43	Bulandshahr ..	1·59	1·50	..	1·59
7	46	Dankaur ..	1·57	1·91	..	1·57

Water is distilled from each sample which has been weighed accurately. This gives the moisture content (by wt. per cent) and knowing the bulk density of soil one can obtain the moisture content by volume per cent. The water distilled from the soil is condensed and collected for measuring its tritium content. The tritium measurements of water samples were made by using liquid scintillation coincidence counting technique.

In the first series of samplings we took duplicate sets of samples for checking the magnitude of uncertainties in the methodology. The results both on moisture content and displacement of tritiated layer came out very close. Thereafter duplicate sampling was considered unnecessary and was discontinued.

RESULTS

Considerable experimentation was necessary before conducting the state-wide experiment. The data from some of these exploratory tests, carried out at Kanpur and Meerut, are shown graphically in Fig. 5. The tritium peak shows only a slight downward movement during the four months elapsed between the time of injection and time of sampling. Further, the peak stayed very sharp in the vertical. There was essentially no rain (only slight) during the period. The behaviour of the peak was, therefore, quite similar to that expected from observations of Munnich *et al.* and indicated the potential applicability of the method in the Indogangetic plain.

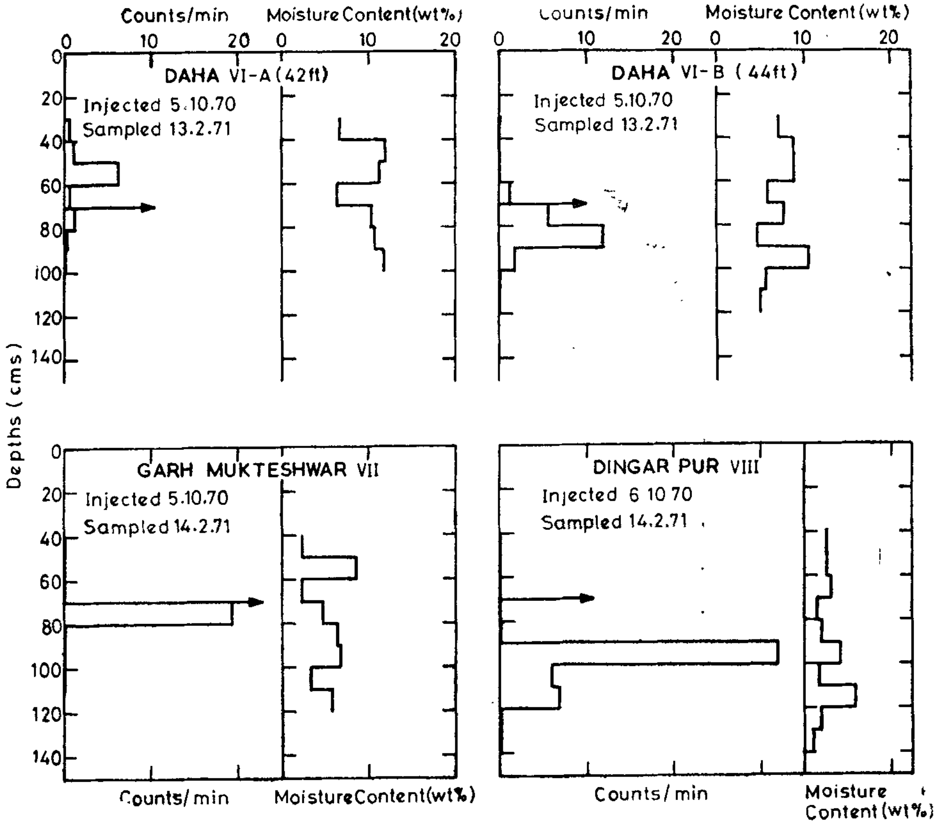


FIG. 5. Downward displacement of tritiated water.

The result on displacement of tritium peak observed at various sites due to 1971 monsoon are given in Tables II, III and IV. Some Typical data are also shown graphically in Figs. 6 and 7. The water recharge as estimated from the water content in the 1 cm^2 column of soil lying between 70 cm depth and the center of gravity of the displaced tritium activity are also shown in the tables. In most cases, the center of gravity of the displaced tritium activity coincided with the point of occurrence of the peak activity.

DISCUSSION

From the data in Tables I, II and III it can be seen that the recharge at different sites varies between zero to about 60 cm of water. Extremely low values of recharge are observed at some sites in Tarai, despite the highest rainfall. This obviously is due to the fact that the top soil at these sites is predominantly clayey. Most of the recharge seems to take place within the four monsoon months.

TABLE II

Experimental data for sites sampled after about one year

Site No.	Place	Date		Displacement of tracer		Average water content (Vol. %)	Recharge (cm)
		Injection	Sampling	Peak	Center of gravity (cm)		
1	Meerut ..	22-5-1971	19-5-1972	80	100	15·65	15·65
2	Garh ..	22-5-1971	19-5-1972	N.T. (>310)	..	7·81	24·21
3	Sardhana ..	23-5-1971	20-5-1972	90	86	24·54	21·10
4	Gangdhara ..	23-5-1971	20-5-1972	110	112	19·98	22·38
5	Mawana ..	23-5-1971	21-5-1972	80	80	17·74	14·19
6	Baghpat ..	23-5-1971	18-5-1972	130	131	20·00	26·20
7	Morna ..	24-5-1971	24-5-1972	220	200	18·70	37·40
8	Musaffarnagar ..	24-5-1971	24-5-1972	150	120	18·35	22·02
9	Kairana ..	24-5-1971	25-5-1972	70	110	10·98	12·08
10	Shamli ..	24-5-1271	25-5-1972	110	127	20·24	25·70
11	Nakur ..	25-5-1971	27-5-1972	50	80	18·68	14·94
12	Saharanpur ..	25-5-1971	27-5-1972	0	19	23·99	4·56
13	Roorkee ..	25-5-1971	28-5-1972	120	108	21·64	23·37
14	Narora ..	12-6-1971	22-5-1972	40	75	21·20	15·90
15	Sahastradara ..	28-5-1971	1-8-1972	90	76	20·74	15·76
P_2	Ghaziabad ..	15-2-1971	18-3-1972	N.T. (> 300)	..	17·38	52·14
P_3	Singhauli ..	15-2-1971	18-5-1972	220	200	15·38	30·76

N.T. Not Traceable.

The values of recharge as given in the tables are strictly applicable only to the respective sites. It may well be that the value in an adjoining farm is

TABLE III

Experimental data for sites sampled after about nine months

Site No.	Place	Date		Displacement of tracer		Average water content (Vol. %)	Recharge (cm)
		Injection	Sampling	Peak (cm)	Center of gravity (cm)		
35	Somna ..	11-6-1971	13-3-1972	190	166	16·66	27·65
36	Tappal ..	11-6-1971	12-3-1972	70	86	20·33	17·48
37	Iglas ..	11-6-1971	13-3-1972	110	112	22·86	25·60
38	Aligarh ..	11-6-1971	13-3-1972	210	210	15·09	31·69
39	Sikandrarao ..	12-6-1971	12-3-1972	80	88	12·99	11·43
40	Atrauli ..	12-6-1971	14-3-1972	130	142	20·25	28·75
42	Anupshahr ..	13-6-1971	15-3-1972	60	61	18·84	11·49
43	Bulandshahr ..	13-6-1971	16-3-1972	80	85	20·60	17·51
44	Siyana ..	13-6-1971	16-3-1972	200	190	15·69	29·81
45	Gulaothi ..	13-6-1971	17-3-1972	70	68	20·62	14·02
46	Dankaur ..	14-6-1971	16-3-1972	80	83	19·49	16·18
47	Dadri ..	14-6-1971	18-3-1972	90	93	21·29	19·80

different. The present investigation was aimed only at determining the average value of recharge and not at delineating the influence of various factors affecting the recharge. Since the selection of sites was done at random it is believed that the mean result obtained from forty-five sites represent the actual recharge value for the entire Western U.P. under the conditions as they are. The mean value of 21·5 cm recharge is to be compared with the present exploitation of ground water in the region. The total draft at the end of Fourth Five-Year Plan (1974) is expected to be about 19 cm. The current draft is likely to be considerably smaller, perhaps around 15 cm. This raises the question whether a further draft of about 5 cm or even more is permissible. It is obvious that the excess of 5 cm (Recharge — Exploitation) must now be emerging in the streams as the regeneration water;

TABLE IV

Experimental data for sites sampled after about four months

Site No.	Place	Date		Displacement of tracer		Average water content (Vol. %)	Recharge (cm)
		Injection	Sampling	Peak (cm)	Center of gravity (cm)		
18	Sear ..	3-6-1971	26—9-1971	40	39	36·20	14·12
19	Bilaspur ..	3-6-1971	26—9-1971	0	9	30·49	2·74
22	Rampur ..	6-6-1971	26—9-1971	90	90	34·39	30·94
23	Milak ..	6-6-1971	26—9-1971	40	25	32·15	8·04
24	Joya ..	6-6-1971	29—9-1971	70	78	23·06	17·98
25	Bilari ..	7-6-1971	30—9-1971	30	40	26·37	10·55
26	Chandausi ..	7-6-1971	30—9-1971	30	39	23·23	9·06
27	Sambhal ..	7-6-1971	30—9-1971	70	75	22·79	17·09
28	Gajrola ..	7-6-1971	30—9-1971	N.T. (>220)	..	26·16	57·55
29	Seohara ..	7-6-1971	1-10-1971	110	108	23·82	25·72
30	Noorpur ..	8-6-1971	1-10-1971	70	71	31·56	22·40
31	Dhanura ..	8-6-1971	1-10-1971	N.T. (>300)	..	12·75	38·25
32	Nagina ..	9-6-1971	2-10-1971	60	59	25·18	14·85
33	Najibabad ..	9-6-1971	2-10-1971	90	85	23·37	19·86
34	Bijanor ..	9-6-1971	2-10-1971	210	177	16·13	28·55

N.T. Not Traceable.

perhaps a good part of this in small streams during the monsoon months itself. If the latter statement is true, then the exploitation of additional 5 cm will keep the water table lowered marginally during monsoon and thus withhold the excessive sub-surface run-off; thereby mitigating the floods also to some extent. On the other hand, if the excess goes to regenerate the streams mainly during non-monsoon months when the entire regeneration water is already committed, any further exploitation will be at the expense of regeneration. Investigations to decide this issue are now planned.

Further plans for micro-studies, *i.e.*, investigating return flow of irrigation water under various crop conditions are also in progress.

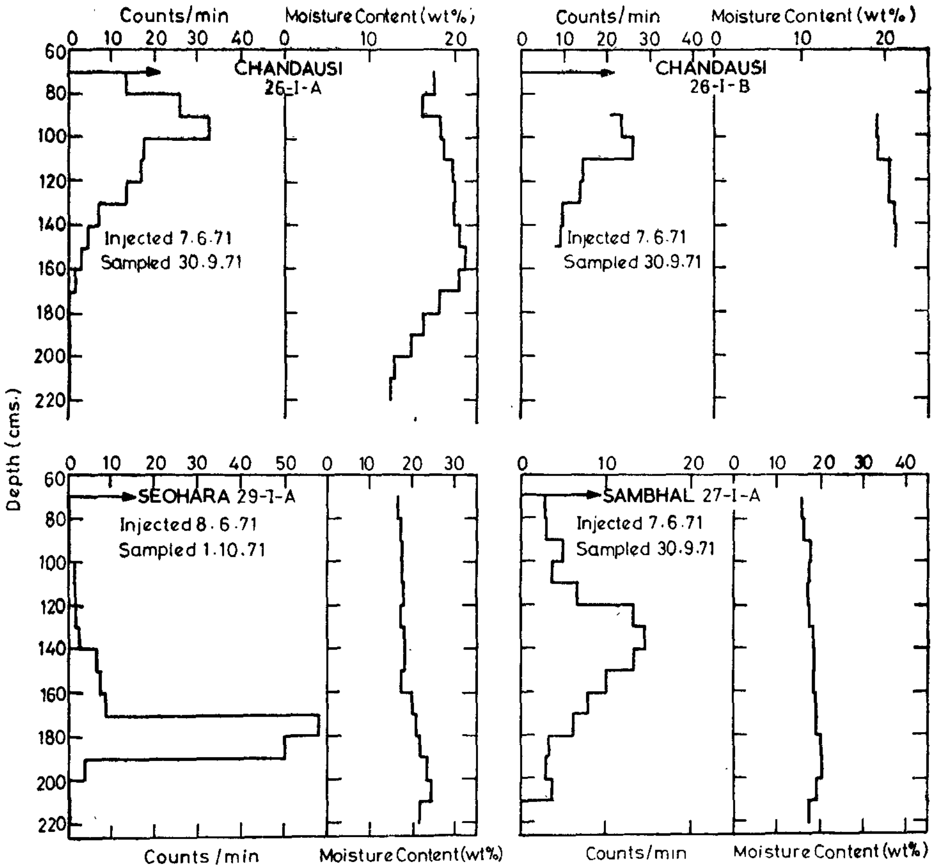


FIG. 6. Downward displacement of tritiated water.

CONCLUSIONS

The average groundwater recharge in Western Uttar Pradesh is found to be 21·5 cm. This is about 5 cm in excess of the present exploitation. Additional investigations to arrive at the most appropriate mode of utilizing this excess are needed.

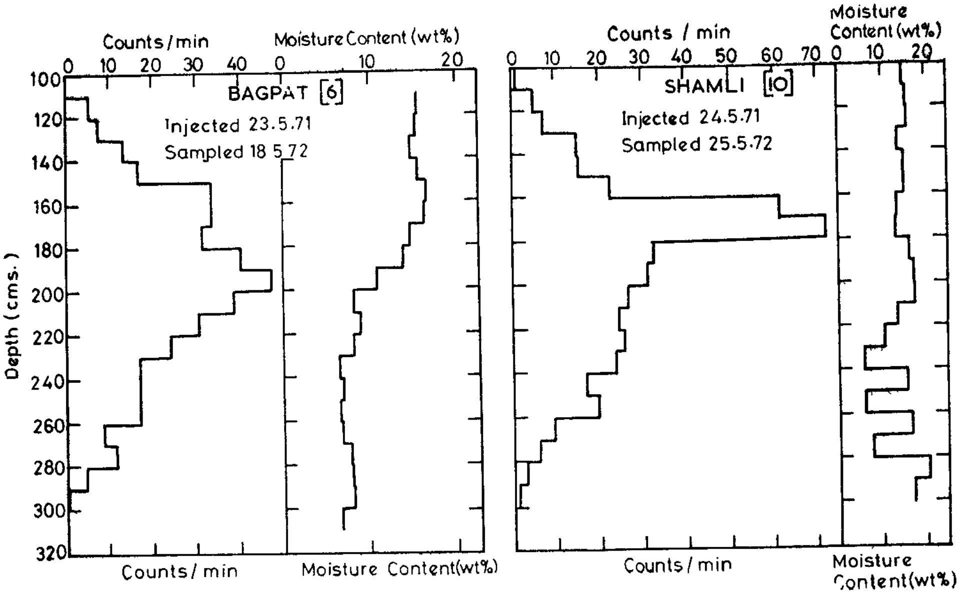


FIG. 7. Downward displacement of tritiated water

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