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STUDY OF RECHARGE TO GROUNDWATER DUE TO MONSOON RAINS USING TRITIUM TAGGING TECHNIQUE IN PARTS OF DISTRICT NARSINGHPUR (M.P.) PART-I

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667

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PREFACE

Recharge estimation to groundwater is crucial to better water resources management particularly in arid and semi-arid regions. Conventionally the recharge to groundwater is estimated from the specific yield and the water table fluctuation. But this data is not generally available for the entire basin. Further as the water table elevation is effected by more than one process, conventional method may not be universally applicable . Therefore, nuclear methods specially tritium tagging technique is more useful and increasingly find wider application in the developing world.

The National Institute of Hydrology has taken up the comprehensive hydrological studies in the Narmada catchment. As a part of these studies the Nuclear Hydrology Division has applied the tritium tagging technique to estimate the recharge to groundwater in parts of the Narsinghpur district, M.P. under Narmada catchment. This report presents the details of the methodology adopted and discusses the results. This report will be highly useful to the engineers of water resources organizations of M.P. and other states.

The present study has been carried out by Dr. Bhishm Kumar, Scientist E and Head Nuclear hydrology division, Sh. S.K. Verma, Scientist B and supported by Sh. Rajeev Gupta. RA, Sh. Suresh Kumar, Tech. Grade II and Sh. Jag Mohan, JRA.

(Dr. S.M. Seth)

Director

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ABSTRACT

Estimation of recharge to groundwater is crucial to better water resources management, particularly in arid and semi-arid regions. In general, it is difficult to estimate recharge to groundwater due to rainfall or irrigation using conventional methods due to nonavailability of adequate data. Nuclear methods, specially tritium tagging technique has been used successfully in different countries including many parts in India.

The National Institute of Hydrology has taken up the comprehensive hydrological studies in the Narmada catchment. As a part of these studies the Nuclear Hydrology Division has taken up estimation of recharge to groundwater due to rainfall and irrigation for which the tritium tagging technique has been used to carry out recharge studies in parts of the Narsinghpur district, M.P. under Narmada catchment. In the study area, experiments have been carried out in cultivated as well as in uncultivated fields. In the study area, mainly four types of soils were found, namely clay, clay loam, loam and sandy clay loam in which clay predominant. The average annual rainfall of the area is 1246 mm. The percentage of recharge to groundwater varies from 7.67 to 22.44 % in the study area with respect to the type of soil and other geohydrological conditions. This report presents the details of the methodology followed and details about the area including the results obtained with regard to the values of recharge to groundwater obtained mainly due to rains during the monsoon season of the year 1995.

1. INTRODUCTION

The recharge to groundwater from surface to the subsequent layers of soil is governed by the process of infiltration which is one of the most important parameters to study the movement of water through unsaturated soil. The infiltration may be defined as the process of the water penetrating from ground surface into soil mass.

Estimation of recharge to groundwater is essential for evaluation of groundwater resources. In most of the cases, major source of recharge to groundwater is due to precipitation. However, in the irrigated areas the return seepage also contributes to groundwater recharge significantly.

In addition to the precipitation and irrigation inputs, which contribute to the direct or vertical recharge to groundwater (unconfined aquifers), there is a lateral component of recharge through the sub-surface horizontal flow due to natural hydraulic gradient. The isotope techniques can be employed to estimate the vertical component of recharge.

The vertical component of recharge to groundwater can be estimated using naturally injected environmental isotopes like oxygen-18, deuterium and tritium including artificial tritium which is required to be injected at the selected sites. In the present study, the artificial tritium has been used to estimate the vertical component of recharge to groundwater.

Tritium is a beta ray emitter having half life of 12.43 years. It emits beta radiations of 18.6 keV energy. In India, tritium can be obtained from Board of Radiation and Isotope Technology (BRIT), Bhabha Atomic Research Centre (BARC), Trombay, Mumbai

In the present report, the recharge to groundwater due to rain and irrigation for the period from June 1995 to October 1995 in parts of district Narsinghpur (M.P.) are estimated using tritium tagging technique.

2.0 DESCRIPTION OF STUDY AREA

The Bargi multi-purpose project, renamed as Rani Avanti Bai Sagar Project, is one of the major river valley project on river Narmada by the Govt. of Madhya Pradesh as a part of the Narmada Valley Development Plan. On completion of the project, irrigation facilities will be available for 157,000 hectare in Jabalpur and Narsinghpur districts through Left Bank Canal System and 46,000 hectare in Jabalpur district through Right Bank Canal System.

The study area is a part of the Left Bank Canal Command of Bargi Multi-purpose Project. The canal is 132.2 km long and has a discharge capacity of 124.65 cumecs. This canal has culturable command area of 95,000 hectare.

2.1 Location

The study area is a part of Bargi dam left bank canal command area, which is situated in Narmada river basin. This area is a doab, encompassed by Sher river in east, Barurewa river in west and Bargi left bank canal in south, having an area of approximately 250 sq.km located in Narsinghpur district of Madhya Pradesh between latitude 22^0 50'N to 23^0 1'N and longitude 79^0 8'E to 79^0 23'E (Fig.1).

The first experimental site was selected as Kheri in Narsinghpur tehsil of Narsinghpur district on the left side of Narsinghpur-Jhansi road at a distance of about 5 km from Narsinghpur. The second site i.e. Ram Pipariya situated in Kareli tehsil of Narsinghpur district on the right side of Narsinghpur- Deva Kachhar road at a distance of about 12 km from Narsinghpur. The third site i.e. Jallapur was selected in Kareli tehsil of Narsinghpur district on the left side of Singhpur-Newari road at a distance of about 4 km from Singhpur. The fourth site i.e. Bhoot Pipariya was situated in Narsinghpur tehsil on the left side of Narsinghpur-Chhindwara road at about 14 km from Narsinghpur. The fifth site i.e. Bahoripar in tehsil Narsinghpur was situated on the left side of Narsinghpur-Jabalpur road at about 12 km from Narsinghpur. The sixth site i.e. Chilachon Khurd in tehsil and district Narsinghpur was selected on the right side of Narsinghpur-Shivani road at about 17 km from Narsinghpur. The seventh site i.e. Khamtara in tehsil and district Narsinghpur was situated on the left side of the Narsinghpur-Jabalpur road at about 5 km from Narsinghpur. The

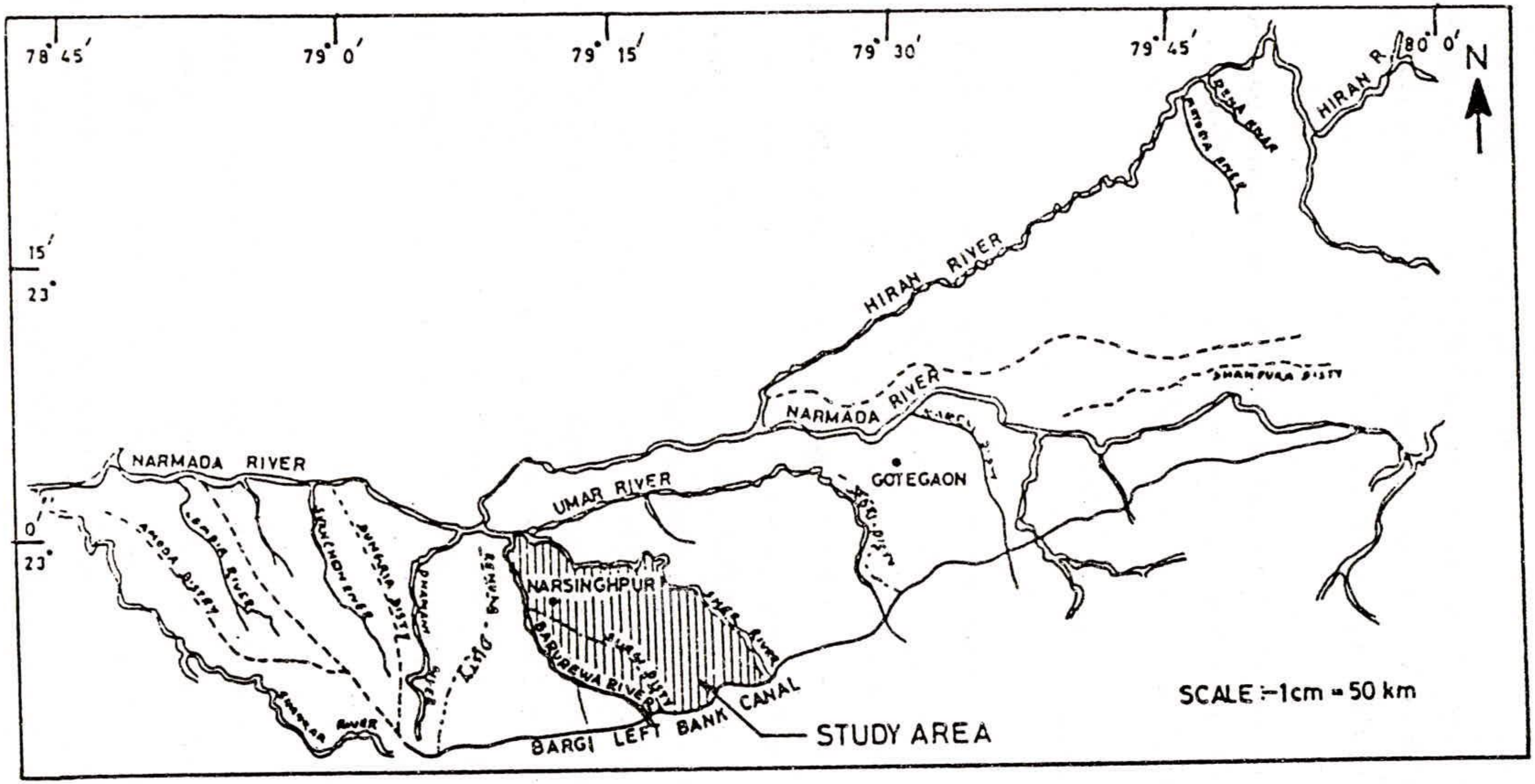


FIG.1 - BARGI LEFT BANK CANAL PROJECT

eighth site i.e. Karhaiya Kheda was selected in tehsil and district Narsinghpur on the left side of the Narsinghpur-Sakal road at about 4 km from Narsinghpur. These sites were selected on the basis of the type of soil indicated in the map which was obtained from the District Agriculture Office, Jabalpur. Location of the test sites is shown in Fig. 2 and these sites are listed in table 1 with other details.

The study area lies in the East of Narsinghpur town and is traversed by State Highway no.22 from Jabalpur to Hoshangabad. The main broad-gauge railway line from Howarh to Bombay also passes through the study area.

2.2 Topography

The elevation of the study area (which falls mainly in Bargi dam left bank canal command area in Narmada basin) above mean sea level varies from 313 m to 380 m. The general topography of the area appears to be flat except in the vicinity of the rivers, where deep gullies and ravines have formed giving rise to undulating to rolling topography. As such, the entire area is a broad plain of low relief. Local difference in elevation is small due to adaptations of "Haveli System" of cultivation, which has checked the erosion. The "Old Haveli System" of cultivation is practised in rabi. The preference to rabi cultivation is due to the high clay content of the soil which is difficult to work in rainy season. Broadly speaking, under Haveli system a large area is bunded and utilized for collecting rainwater during the monsoon and is left fallow during kharif season. The rain water stored as soil moisture helps to grow rabi crops. In the plain area, the slope ranges from 0 to 3%, but in area having undulating topography, the steeper slopes even upto 15% are noticed.

2.3 Soil

Broadly speaking, the soils of the area are in various shades of darkness and are derived from the Deccan trap rocks. Generally, the depth of soil goes more than 9 m. Below the dark brown soil, a yellowish layer is found. Towards the banks of river, the texture of the soil moves towards a lighter grade i.e. from clay to clay loam, loam, sandy loam and finally sandy. The colour of the soil also changes from dark greyish brown to brown, yellowish brown and finally yellow grey.

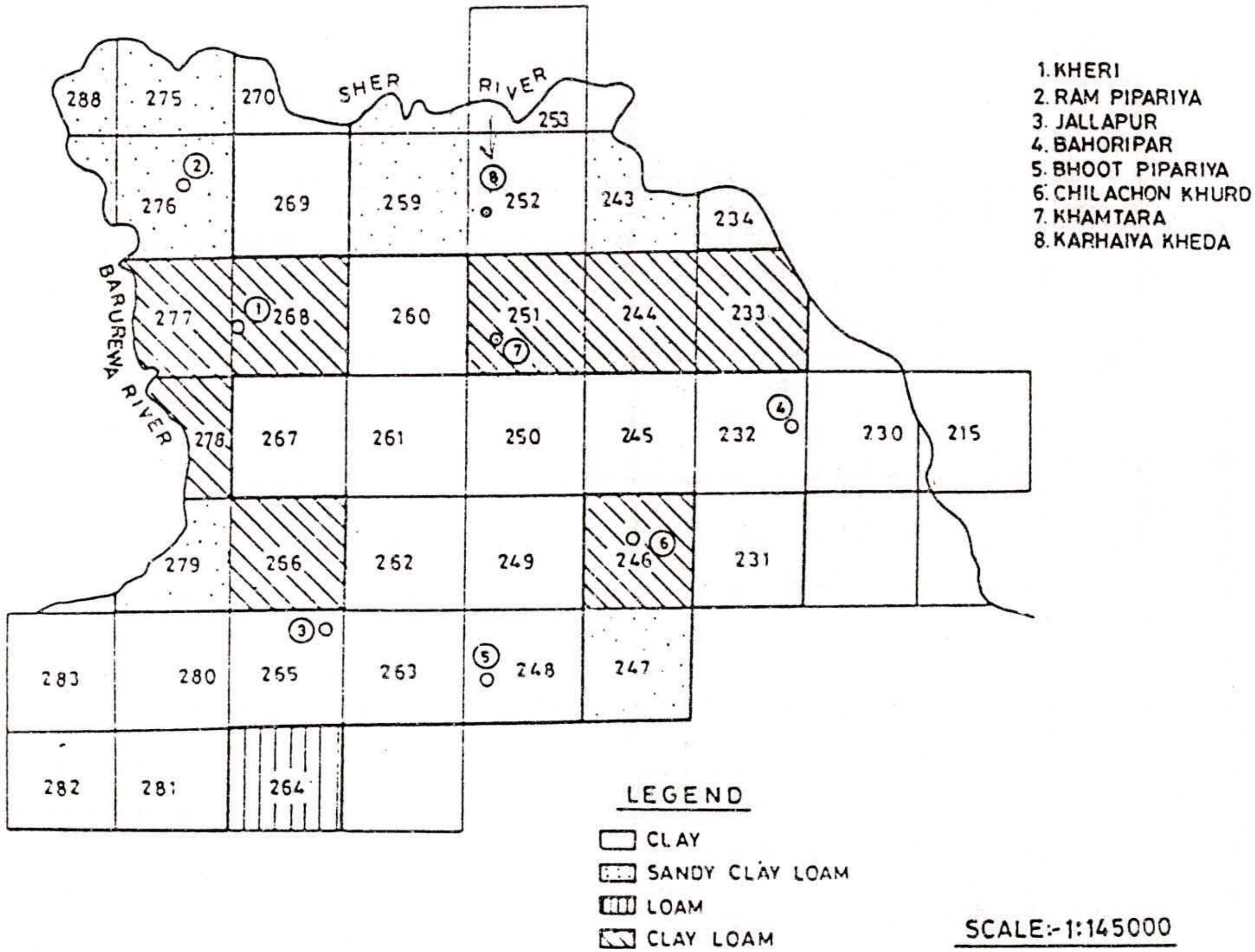


FIG.2-LOCATION OF TEST SITES WITH GRID NO AND SOIL TYPE IN STUDY AREA

Table 1: List of Experimental sites with other details

S.No.	Name of Site	Whether Cultivated/ Uncultivated	General soil type
1.	Kheri	Cultivated	Clay
2.	Ram Pipariya	-do-	Clay loam
3.	Jallapur	-do-	Clay
4.	Bhoot Pipariya	Uncultivated	Clay
5.	Baharipas	Cultivated	Clay loam
6.	Chilachon Khurd	-do-	Clay loam
7.	Khamtara	-do-	Clay
8.	Karhaiya Kheda	Uncultivated	Clay

In some places, the soils have been formed from sand stone parent material in which a lot of textural variation is found. It varies from sandy loam to clay. The soil crust is deep and has a fair amount of gravel or kankar along the depth of profile.

In the study area, there are only four types of soil. They are clay, clay loam, sandy clay loam and loam in which clay and clay loam are predominant.

The soil survey of the area had been carried out by soil survey unit, Jabalpur(1974-75) under Department of Agriculture, Govt. of Madhya Pradesh. Grid wise types of soil had been identified. The types of soil of area are listed in table 2 .

2.4 Climate and Rainfall

The tract enjoys a sub-tropical climate. The rainy season in area extends from June to October under the influence of South-West monsoon. The area also receives some rainfall during January and February from North-East monsoon. July and August are the heaviest rainy-months. Normally, the rainfall ceases by the end of September. However, in quite a large number of years, October receives good rainfall. There is considerable variation in rainfall from year to year as well as month to month in a year. The average annual rainfall of the area is 1246 mm. The rainfall data required for the study have been collected for the period from June 1995 to October 1995 from the office of the Superintendent, Land Records Department, Narsinghpur which are incorporated in table 13.

The temperature begins to rise rapidly from about March till May which is generally hottest month of the year. With the on-set of the monsoon in the second week of June, there is an appreciable drop in day temperature. From mid November onwards, both day and night temperature decreases rapidly. December and January are the coldest months of the year. In winter, cold waves affect the area in the wake of Western disturbances passing across North India. Normally, the temperature varies from a minimum of 2^0 C to a maximum of 45^0 C. On the whole, the days are warm and nights are cooler.

2.5 Water-table Condition

Table 2 : Types of soil in the study area

Sr.No.	Textural class	Grid no.	Total number of grids
1.	clay	229,230,231,232,234,242,245,248,249, 250,252,253,260,261,262,263,265,267, 269,270,280,281,282,283,284	25
2.	clay loam	233,244,246,251,266,268,277,278	08
3.	loam	264	01
4.	Sandy clay loam	243,247,258,259,275,276,279,287,288	09

Water table is a guiding factor which controls the movement of water through soil, though, by physical character, a soil may have different drainability. The level (depth) of water table was recorded at each site from its nearby open well with the help of water level indicator. It is a dry battery operated indicator. As soon as the needle point of indicator touches water, a sound is recorded. This needle is tagged with a plastic measuring tape, which directly indicates the depth of water table from ground. The water table of those open wells were taken in which pumps were not operative for a few days to get the actual level. But for a few wells water may be taken for domestic purpose.

The depth of water table was measured at each site during 26 June to 3 July 1995 and 6-12th Oct. 1995. The water levels measured at eight sites at different times are incorporated in table 3.

2.6 Irrigation Practices

As the general topography of the area under study is somewhat irregular, soil is highly impermeable due to its high clay content and more over surface/sub-surface method of irrigation are not efficient for the study area, Sprinkler method of irrigation is in general practice to irrigate the fields located in the study area. This method of irrigation consists of applying the water to the field in the form of a spray, somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually generated by pumping. However, the initial investment of the sprinkling and pumping system is high, but it reduces the wastage of water and crop yields have been found better than those obtained by normal irrigation practices.

For most of the sites which are cultivated, the soyabean was sown just before the onset of South-West monsoon i.e. during the months of June-July 1995 and which was harvested just after the monsoon i.e. during the months of October-November 1995. As the water requirement of the soyabean crop is very small during the monsoon period, no watering was done during the period from June 1995 to October 1995.

Table 3 : Water level in the wells at various experimental sites

Sr.No.	Name of site	Water level from ground surface in June-July'95 (m)	Water level from ground surface in October'95 (m)
1.	Kheri	8.09	7.10
2.	Ram Pipariya	20.09	18.90
3.	Jallapur	-	-
4.	Bahoripar	dry well	8.70
5.	Bhoot Pipariya	dry well	5.06
6.	Chilachon Khurd	dry well	8.00
7.	Khamtara	10.00	7.30
8.	Karhaiya Kheda	10.04	7.60

3.0 REVIEW OF STUDIES CARRIED OUT IN INDIA

This method was first applied by Zimmerman et al.(1967 a,b) in West Germany. Munnich(1968 a,b) also studied the moisture movement in the unsaturated zone by Tritium tagging method. The concept of water movement through soils, termed the piston flow model was developed.

Pioneering work in India using tritium tagging method was carried out by Datta(1975). Datta et al.(1973,1977) have first taken up this study in Western UP, Haryana and Punjab. The average recharge values reported by them in Western U.P., Punjab and Haryana are 25%, 18% and 15% of the average rainfall, 98.9 cm, 46 cm and 47 cm respectively. Datta et al.(1977) also measured the rate of downward movement of soil water alongwith groundwater recharge in Sabarmati basin in Gujarat covering an area of 22000 sq km . The downward movement rate varied from 5 cm/yr to 280 cm/yr, while recharge value was found to be 10% of the average rainfall, 80cm. Datta et al. have also developed a conceptual model for the study of transport of soil water or recharge through unsaturated soil zone.

Athavale(1977) has estimated recharge to the phreatic aquifer of lower Maner basin, covering 1600 sq km area and having seven different geological formations using tritium tagging technique and found the recharge values ranging from 4.7 cm to 24 cm with an average for the entire basin, 9.5 cm for annual average rainfall 125cm. Athavale et al.(1978,1980) have also carried out the recharge measurements in few basins namely, Godavari-Purna basin, the Kukadi basin in Deccan traps and Banganga basin between Jaipur and Agra.

Datta et al.(1980) and Gupta and Sharma(1984) have also carried out study of recharge to groundwater in Sabarmati basin and Mahi right bank canal command area respectively. About forty representative stations were established in different parts of the Sabarmati basin and soil moisture movement was monitored for a period of three years (1976-79). The results obtained for the percentage of recharge indicated a moderate to low values i.e. 18%, 14% and 6%. About 14% of the total average rainfall was estimated to be stored in the Sabarmati basin. In Mahi right bank canal command area, the percentage of recharge to groundwater was estimated little higher (23%) indicating a high return flow from irrigation. A comparison drawn from the results of recharge obtained in Sabarmati basin with those for the Ganga, the Ramganga and the Yamuna basins in Northern India indicated a relatively higher ground water recharge (18%).

Empirical formulae based on the experimental results have also been established by Datta et al.(1979). Studies of soil moisture movement and groundwater recharge carried out by PRL scientists in Thar desert using tritium tagging method indicated the factors which control groundwater recharge. The groundwater recharge was found to vary between 5-14% of the annual rainfall

Sharma and Gupta(1985) and Bhandari et al.(1986) have completed two major projects i.e. Sabarmati hydrology project and isotopic study of soil moisture movement in Thar desert. The scientists of PRL used various radioisotopes like tritium, radiocarbon, Si-32 and Uranium isotopes along with dissolved chemical constituents to find out the values of ground water recharge from infiltration of rain water in Sabarmati basin, Mahi Right Bank Canal command area and coastal Saurashtra.

Mukherjee(1986) and Muhkerjee et al.(1987) have also carried out study of recharge to groundwater in rain fed alluvial area and in IARI farm using tritium tagging technique. This group has also carried out a few experiments to study the recharge at different places having similar soil conditions but different crops and irrigation practices. These studies showed that more recharge takes place in fields with irrigation watering and less fractional recharge through fields with vegetation.

Rao and Jain(1985) have used potassium-cobalt-cyanide as a tracer instead of tritium for recharge measurements and reported its advantage over the tritium for recharge measurements. Its movement can be monitored in-situ by radiations logging of the ^{60}Co through an adjacent bore hole. This group has also carried out study of recharge to groundwater using tritium tracer in Tapi alluvial region in Maharashtra and in some parts of Rajasthan. Some studies are also carried out in Karnataka.

Singh and Satish Chandra(1978) have studied the recharge to groundwater due to rains using tritium tagging technique in Sharda Command area of Uttar Pradesh.

Raja et al.(1983) also carried out extensive studies of recharge to groundwater due to rain using tritium tagging technique in various areas of Uttar Pradesh like Gandak Command area, Ganga-Sarda area, Agra-Mathura area, Roorkee area, Deoband Branch Command area, Eastern Yamuna Canal Command area, Sarda Sahayak Command area, Saryu Canal command area and percentage recharge due to rain for these areas were found to be 21.38, 24.1, 22.54, 18.5, 18.2, 21.0, 20.85, and 21.25 respectively.

The U.P. Ground Water Department, Lucknow has also covered the Bundelkhand districts of U.P. by doing yearly study of recharge to groundwater due to rain and irrigation using tritium tagging technique in Bundelkhand and Vindhyan regions. The results of the recharge to groundwater due to rains in rainy season varied from 9% to 29% in Bundelkhand region. These studies are continued by U.P. Ground Water Department, Lucknow in Uttar Pradesh to cover other districts .

4.0 METHODOLOGY

4.1 Tritium Tagging Technique

As it is clear from its name, tritium, a radioactive isotope is used as a tracer to trace the movement of water as it fulfils the requirement of an ideal tracer. An ideal tracer should have the following characteristics:

a) The tracer should behave same as normal water and should not be lost or reiterated due to adsorption or ion exchange. Generally anions and neutral molecules are better in this regard to cations.

b) The tracer should have a high detection sensitivity.

c) The health and handling hazards should be minimum.

d) The duration of the study is generally about 1 to 2 years and hence the radio-tracer should have considerable half life (about 1 year) from the study point of view but less half life from health hazard point of view. Therefore, radio-isotopes are selected keeping in view the both aspects.

Tritium as Tracer

a) It behaves similar to normal water as it is a molecule of water.

b) It is a pure beta emitter of low energy (18.6 KeV) and belongs to the lowest radio-toxicity class.

c) It can be measured with a high detection sensitivity.

d) It has comparatively long half life (12.23 years) and hence useful for soil moisture movement studies. The long half life makes it possible to store the tracer in the laboratory and no particular shielding is required.

Principle of the Technique

The principle of the tritium tagging technique is mainly based on the following assumptions [Zimmermann et al. (1967) and Munnich, K.D. (1968)].

The vertically downward movement of soil moisture is very slow due to which the lateral mixing between soil moisture portions of different flow velocities even with the stationary also takes place and the moisture flows in a discrete layers in such a way that if any fresh water will be added to the top surface of the soil, the infiltrated layer of the water pushes the older layer downward in the soil system and so on till the last layer of moisture reaches the saturated zone. This concept of water flow in unsaturated zone has been treated as the concept of piston type flow.

On the basis of these assumptions, if a radio-isotope (tritium) is tagged below the active root zone and also not affected by sun heating (say below 75cm to 1m), the tagged radio-isotope will be mixed with the soil moisture available at the depth and act as an impermeable sheet. Therefore, if any water will be added to the top of the soil surface, it will be infiltrated into the ground by pushing down the older water, thus the shift in the tritium peak can be observed after some time (say after laps of one season). But, the tritium peak will be broadened due to molecular diffusion, stream line dispersion, asymmetrical flow and other hetrogeneties of the soil media.

The soil samples from the injection point are collected at the interval of 10 or 15 cm depth after pinpointing it very accurately. The soil core so removed are collected and kept in a air tight plastic container or polythene packs. The soil moisture is obtained from soil samples by vacuum distillation and also the dry density and moisture content determined by gravimetric method using either oven or infra-red moisture balance, the later is preferred due to superiority over the normal gravimetric method. The tritium contents are determined in the soil moisture, obtained by the distillation of the soil samples, with the help of Liquid Scintillation Spectrometer using suitable liquid scintillator. The counting rates so obtained, say counts per minute or per 100 seconds or per 2 minutes depending upon the number of counts obtained per second in order to increase the total number of counts to reduce the statistical error, are plotted with respect to depth and the center of gravity of the tritium peak so obtained is calculated. By subtracting the depth of injection from the C.G. of the tritium peak, the shift of the tritium peak can be obtained. Now as per the principle laid down by the founder investigators (1967), the multiplication of the tritium peak shift and average field capacity in the tritium peak shift region will provide the information of recharge to ground water during the time interval of tritium injection and sampling. But, it has been observed that in order to calculate the recharge to ground water, the users of this technique multiply tritium peak shift by the average volumetric moisture content in the peak shift region, which is obtained at the time of sampling (not at the time of injection which may be considered as field capacity of the soil strata provided there should be no rainfall or irrigation applied to the field for the sufficient time in past). This later procedure seems to be more accurate. Mathematically the equation for the estimation of percentage of recharge to ground water can be written as:

$$R = \theta_v \, d \, (100/p)$$

where,

R	is the percentage of recharge to ground water
θ_v	is the average volumetric moisture content in the tritium peak shift region obtained at the time of soil sampling
d	is the shift of tritium peak in cm
p	is precipitation and/or irrigation in cm

Source of Errors and Precautions

The use of tritium tagging technique may lead to the various source of errors due to different practical problems involved. The main source of errors can broadly be categorized in three steps, used to perform this study.

1) Conducting field experiment.
2) Estimation of tritium and volumetric moisture contents.
3) Estimation of recharge to ground water using experimental data.

Conducting Field Experiment

In order to conduct the field experiment, the following steps are involved which should be dealt very carefully to minimize the possible errors.

1) Selection of representative field (site).
2) Marking of site for relocation.
3) Quantity of activity and injection of tritium at certain depth.
4) Relocation of site, collection and storing of soil samples.

The procedure to be followed in the steps mentioned above, although purely depends on the practice and common sense of the user of this technique but the following criteria can be adopted in order to minimize the possible errors and variations that may occur in case of different users.

1) Selected site should represent the area i.e., it should have the topographical and geomorphological features similar to the nearby area.

2) Site should be plain for all practical purposes as this technique is not practically valid for hilly and very high sloppy areas.

3) The site should be at a place where the marking points like tree, electric poles or other similar types of natural or man made identification marks exist in maximum possible directions at same distance (not very close to site), otherwise, the identification marks will have to be fixed by the user.

4) Besides the identification marks already exist at some distance from the tritium injection points, few additional marks, iron nails should be fixed at very close distance, say 1 or 2 m around the injected point in order to reduce the inaccuracy that may occur in the measurement of long distances of natural or man made identification marks.

5) The availability of rainfall and/or irrigation data should be ensured before the selection of a particular site.

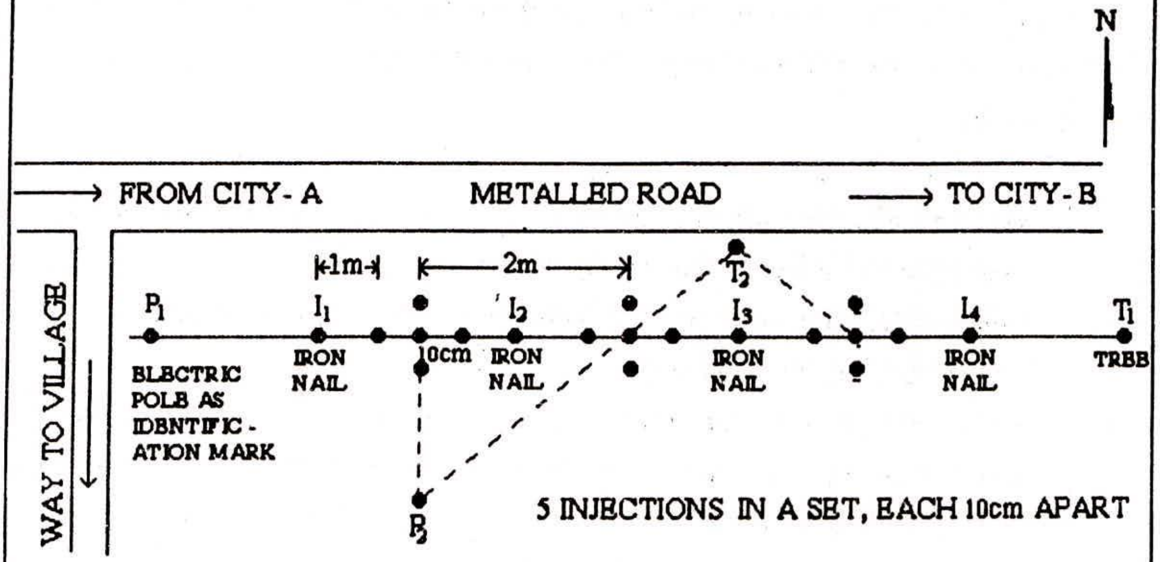
6) For correct estimation of the recharge to the ground water, the site should be selected in both type of fields i.e., cultivated and uncultivated fields.

7) Tritium should be injected directly at the specified depth using a syringe, plastic pipe and metallic pipe.

8) 2ml of tritium having specific activity atleast 25 to 40 μCi/cc should be injected at a depth well below the root zone and zone of sun heating, say 70 cm for temperate region to 100 cm for arid region, in all the five holes, each 10 cm apart after making a set of injection points, as shown in Fig. 3. The holes should be completely filled with soil after injecting tritium in order to reduce the direct loss of injected tracer due to evaporation and also to avoid the direct entry of water.

9) Layout of the experimental site should be prepared very carefully for the relocation of the site.

10) The site should be relocated very precisely and soil sample should be collected at the



LAYOUT OF EXPERIMENTAL SITE AND INJECTIONS IN A FIELD

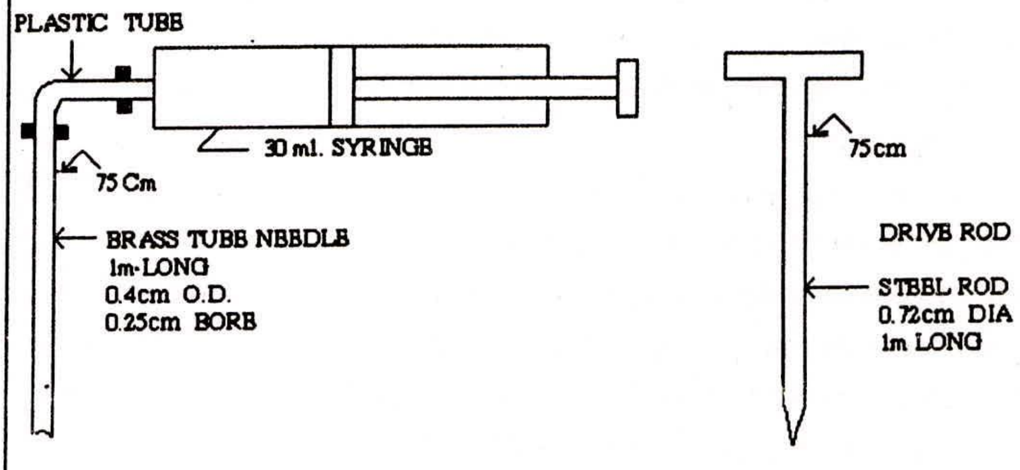


FIG 3- SYSTEMATIC DIAGRAM OF INJECTION LAYOUT AND IMPLEMENTS FOR ARTIFICIAL TRITIUM INJECTION AT FIELD SITE interval of 10cm or 15cm either using a hand auger or any other coring device having sampling tubes.

11) All precautions should be taken to collect the soil sample in vertically downward direction.

12) In order to minimize the contamination of soil samples at lower depths, all precautions should be taken at the time of lowering the sample collection device so that it could not touch to the side walls of the bore hole.

13) In order to minimize the loss of tritiated water content due to evaporation, the soil samples should be kept in an air tight plastic box or plastic bags to bring them to laboratory for various analyses.

Estimation of Tritium and Volumetric Moisture Contents

In order to estimate the tritium and volumetric moisture content, the following steps are involved which should be taken very carefully:

1) Measurement of volume and weight of the soil samples.
2) Gravimetric analysis of the soil samples.
3) Vacuum distillation of the soil samples.
4) Selection of the proper liquid scintillator and counting system.
5) Volumetric measurement of scintillator and tritiated water sample.
6) Measurement of tritium activity and counting time.

The points mentioned above are quite familiar and precautions which should be taken during the steps mentioned at sl.no.1 to 3 are very common. But, the selection of proper liquid scintillator and counting system needs some special attention in order to minimize the statistical error. Although, more tritium counts can be obtained either by increasing the counting time or by injecting more tritium into the ground to minimise the statistical error but, the first option is better as the injection of high activity should be avoided for all practical purposes. In addition, the selection of suitable liquid scintillator and counting system is also an important aspect to get the higher accur cy in the measurement of tracer activity.

The repeatability in the measurement of volumes of the liquid scintillator and tritiated water in case of each sample is very important in order to locate the tritium peak at its real position. The counting time should be increased to get the more tritium counts if all other precautions have already been taken into account and still tritium counts are appearing less per sec or per minute.

Estimation of Recharge to Ground Water

In order to estimate the correct recharge to ground water the following points should be considered carefully:

1) Centre of gravity of tritium peak.
2) Average volumetric moisture content in the peak shift region at the time of sampling.
3) Rainfall and/or irrigation data.
4) Type of soil and topography of the field.
5) Position of the ground water level.
6) Time period of the study.
7) Percentage of the cultivated and uncultivated fields in the study area.

Although the points mentioned above are self explanatory, but even if the required data like rainfall and/or irrigation, type of soil, water level fluctuations, ground water withdrawl, tritium peak shift, and moisture content etc. are available for the test sites, the common sense is required to arrive at any conclusion on the basis of the experimental data e.g., the recharge to ground water can not be more than the precipitation and/or irrigation while in certain conditions, the field may be completely submerged of water due to short duration flood or the site may be located at a place where the water from the nearby fields stores during the rainfall, the obtained value will show more ground water recharge at that site than the amount of water supplied, but in such a case the recharge value can not represent the nearby area. Similarly, if any area is having more %age of uncultivated land, the values obtained only for the cultivated fields can not be applied to calculate the total recharge to ground water due to precipitation and or irrigation to the aquifer existing in that area.

4.2 Field Experiments

Field experiments consisted of tritium injections at various sites located in the study area before on-set of monsoon season and carrying out sampling immediately after monsoon.

4.2.1 Tritium Injection

The selection of any particular site for the study was done considering only the type of surface soil and accessibility of the area. Tritium injections were carried out at 8 sites which are shown in Fig. 2.

Two sets of tritium (tritiated water) injection were made at 8 sites during June 1995. The sets were located on a line fixed by choosing appropriate bench marks (usually electric or telephone poles). Each set of injection consisted of one central injection on the line and four injections in a circle of radius 10 cm around it. This is done in order to make sure that the tracer is not lost due to a possible slight misalignment in pin-pointing the injection point while sampling the site. The drive rods (12 mm dia) were first hammered into the soil, for making 70 cm deep holes. The drive rods were then pulled out and stainless steel pipe (injection pipe) was inserted into each hole. The tritium of specific activity of 200 mCi/cc obtained from BRIT, BARC, Mumbai was diluted to the specific activity of 40 μCi/cc. About 2 ml of tritium of specific activity of 40 μCi/cc was injected in each hole with the help of plastic syringe through the injection pipe, care being taken that there was minimum disturbance to the natural condition of the soil due to the injection. Each hole was completely filled up with the soil after carrying out tritium injection in the same. At each site few iron nails were hammered on the line of sets of injection and left in the ground, which acted as markers for subsequent location of the sites. The field was left for its normal use by the farmers (for the application of irrigation and/or precipitation) .

4.2.2 Sampling

The sampling was carried out immediately after the monsoon i.e. during the month of October, 1995. Soil samples were collected layer by layer (10cm sections) with the help of a hand auger of 2" dia starting from ground surface to 150/200 cm. The soil samples were carefully collected and packed in properly sealed polyethylene bags so that there was no exchange of the moisture with the atmosphere and brought to the laboratory for the analysis.

4.3 Laboratory Experiments

The laboratory experiments consisted of particle size analysis, estimation of soil moisture content and measurement of tritium counts per minute in the soil samples.

4.3.1 Particle size Analysis

The samples collected from the field were tested in the soil water laboratory, National Institute of Hydrology, Roorkee, for the particle size distribution. Particle size distribution of the soil samples was carried out by sieve and sedimentation analysis. Soil samples were washed with distilled water to remove the soluble salts. The washed samlpes were separated into two fractions i.e. +75 micron and -75 micron through wet seiving. Sieve analysis was performed for the fraction of soil retained on 75 micron sieve (+75 micron). The portion passing through the 75 micron sieve (-75 micron) was analysed by sedimentation analysis using hydrometers. The test results of the analysis are given in table 4.

4.3.2 Soil Moisture Content

The moisture content of the soil samples on wet weight basis was estimated by gravimetric method using infra-red moisture balance.

Wet weight of each sample was determined by weighing the sampling using electronic balance. After that small amount of soil sample (approximately 10 gm) was kept on the infra-red moisture balance in order to dry the sample due to the radiations from the equipment which gave direct value of soil moisture content (percentage on wet weight of the sample basis). Bulk density for each sample was determined by dividing the wet weight of the sample by the volume of the each sample which was equivalent to the volume of hand auger of known diameter for a particular depth of soil column. Volumetric moisture content for each soil sample was determined by multiplying the moisture content obtained by infra-

Table 4 : Particle size distribution for the study area

S.N.	Name of site	%gravel >2.0mm	%sand 2mm-0.075 mm	% silt 0.075mm-0.002 mm	% clay <0.002mm
1.	Kheri	2.60	5.65	42.25	49.50
2.	Ram Pipariya	8.60	17.90	30.00	43.50
3.	Jallapur	2.70	7.05	36.25	54.00
4.	Bahoripar	0.10	6.65	39.50	53.75
5.	Bhoot Pipariya	2.20	17.55	29.75	50.00
6.	Chilachon Khurd	0.50	27.00	15.50	57.00
7.	Khamtara	4.20	8.00	13.30	74.50
8.	Karhaiya Kheda	5.30	6.50	12.20	76.00

red moisture balance on wet weight basis and bulk density of the soil sample. The values of volumetric moisture contents are tabulated in table 5 to 12.

4.3.3 Water Extraction from Soil Samples

After determination of soil moisture content for the soil samples collected from each 10 cm depth using infra-red moisture balance, each sample was subjected to distillation under low pressure to avoid volatile impurities being collected alongwith the water. Water from each soil sample was extracted and stored in the vials.

4.3.4 Activity Measurement with LSC

The liquid scintillation system which is at present being used at Nuclear Hydrology Laboratory of National Institute of Hydrology, Roorkee is Model 'System 1409' (Wallac Oy, Finland) whose efficiency is around 60%. The system provides an elegant way of counting the activity of tritium using 'Easy Count' approach.

In order to carry out activity measurement with the liquid scintillation counter 'System 1409', 10 ml of scintiliation cocktail 'W' (SRL, Mumbai) was transformed into a teflon vial, which was free from any contamination. Cocktail 'W' is commercially available and composed of the following:

1,4 - Dioxane	1 litre
2,5 - Diphenyl oxazole (PPO)	10 gm
[1,4-Di-2,(5-Phenyloxazolyl)-Benzene] (POPOP)	0.25 gm
Naphthalene	100 gm

This vial was placed in the counting chamber of the liquid scintillation counter for 300 seconds and back ground counts (in counts per minute) for cocktail 'W' was obtained by the system. One ml of tritiated water extracted from each soil sample was mixed with 10 ml of cocktail 'W' (whose background counts was already measured with the LSC) in the teflon vials.

Table 5 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Kheri (cultivated)

Tehsil : Kareli

District: Narsinghpur (M.P.)

Date of injection: 28.06.95

Date of sampling : 10.10.95

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml
0-20	0.104	250.0
20-30	0.178	290.4
30-40	0.211	319.1
40-50	0.271	262.4
50-60	0.247	260.5
60-70	0.241	218.4
70-80	0.235	126.3
80-90	0.312	182.3
90-100	0.248	235.5
100-110	0.345	227.7
110-120	0.213	211.9
120-130	0.253	219.0
130-140	0.273	1164.1
140-150	0.240	791.7
150-160	-	-
160-170	-	-
170-180	-	-
180-190	-	-
190-200	-	-

Determination of recharge to groundwater for the period from 28.06.95 to 10.10.95

Depth of tritium injection = 70 cm

Tritium peak shift (d) = 22.99 cm

Average volumetric moisture content in peak shift region (θ_v) = 0.274

Recharge to groundwater (R) = θ_v X d = 6.30 cm

Table 6 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Ram Pipariya (cultivated)   Date of injection: 29.06.95

Tehsil : Kareli   Date of sampling : 09.10.95

District: Narsinghpur (M.P.)

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 29.06.95 to 09.10.95
0-10	0.110	2340.1	Depth of tritium injection = 70 cm
10-20	0.159	2776.7	Tritium peak shift (d) = 50.66 cm
20-30	0.212	305.7	Average volumetric moisture
30-40	0.182	2659.5	content in peak shift region
40-50	0.228	2737.6	$(\theta_v) = 0.297$
50-60	0.290	3978.0	Recharge to groundwater
60-70	0.292	245.2	$(R) = \theta_v \times d$
70-80	0.279	2353.1	= 15.03 cm
80-90	0.244	2540.4	
90-100	0.302	254.4	
100-110	0.176	4147.8	
110-120	0.266	2122.6	
120-130	0.217	1262.3	
130-140	0.244	4390.3	
140-150	0.355	2898.0	
150-160	0.321	2985.4	
160-170	0.310	423.8	
170-180	0.378	471.3	
180-190	0.352	2.3	
190-200	-		

Table 7 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Jallapur (cultivated)

Tehsil : Narsinghpur

District: Narsinghpur (M.P.)

Date of injection: 29.06.95

Date of sampling : 11.10.95

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 29.6.95 to 11.10.95
0-20	0.075	807.4	Depth of tritium injection= 70 cm
20-30	0.181	1324.7	Tritium peak shift (d) = 20.59 cm
30-40	0.202	1436.2	Average volumetric moisture
40-50	0.216	2069.5	content in peak shift region
50-60	0.254	33.5	(θ_v)= 0.259
60-70	0.264	3163.9	Recharge to groundwater
70-80	0.254	393.3	(R)= θ_v X d
80-90	0.264	195.7	= 5.33 cm
90-100	0.241	450.7	
100-110	0.261	544.8	
110-120	0.262	803.6	
120-130	0.330	631.3	
130-140	0.331	361.9	
140-150	0.381	1160.3	
150-160	0.379	334.4	
160-170	0.344	2534.7	
170-180	0.296	1340.6	
180-190	-	-	
190-200	-	-	

Table 8 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Bahoripar (cultivated)

Tehsil : Narsinghpur

District: Narsinghpur (M.P.)

Date of injection : 30.06.95

Date of sampling : 12.10.95

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 30.06.95 to 12.10.95
0-20	0.020	365.9	Depth of tritium injection = 70 cm
20-30	0.140	253.9	Tritium peak shift (d) = 33.75 cm
30-40	0.161	1477.8	Average volumetric moisture
40-50	0.218	867.3	content in peak shift region
50-60	0.266	245.5	$(\theta_v) = 0.241$
60-70	0.200	1286.5	Recharge to groundwater
70-80	0.246	1542.2	$(R) = \theta_v \times d$
80-90	0.322	477.1	= 8.13 cm
90-100	0.250	330.5	
100-110	0.317	772.7	
110-120	0.405	838.5	
120-130	0.418	552.5	
130-140	0.376	492.6	
140-150	0.408	496.9	
150-160	-	-	
160-170	-	-	
170-180	-	-	
180-190	-	-	
190-200	-	-	

Table 9 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Bhoot Pipariya (uncultivated) — Date of injection: 30.06.95

Tehsil : Narsinghpur — Date of sampling : 11.10.95

District: Narsinghpur (M.P.)

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 30.06.95 to 11.10.95
0-10	0.064	106.9	Depth of tritium injection = 70 cm
10-20	0.055	85.3	Tritium peak shift (d) = 34.24 cm
20-30	0.083	107.0	Average volumetric moisture
30-40	0.168	370.6	content in peak shift region
40-50	0.160	586.0	$(\theta_v) = 0.243$
50-60	0.108	172.5	Recharge to groundwater
60-70	0.179	341.5	$(R) = \theta_v \times d$
70-80	0.286	406.2	= 8.33 cm
80-90	0.220	235.8	
90-100	0.209	231.5	
100-110	0.258	223.3	
110-120	0.186	255.6	
120-130	0.249	121.4	
130-140	0.277	22.8	
140-150	0.260	49.1	
150-160	-	-	
160-170	-	-	
170-180	-	-	
180-190	-	-	
190-200	-	-	

Table 10 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Chilachon Khurd (cultivated) Date of injection : 30.06.95

Tehsil : Narsinghpur Date of sampling : 12.10.95

District: Narsinghpur (M.P.)

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 30.06.95 to 12.10.95
0-10	0.023	551.3	Depth of tritium injection = 70 cm
10-20	0.097	490.0	Tritium peak shift (d) = 61.00 cm
20-30	0.143	255.3	Average volumetric moisture
30-40	0.099	497.7	content in peak shift region
40-50	0.147	756.6	$(\theta_v) = 0.214$
50-60	0.167	4397.9	Recharge to groundwater
60-70	0.151	3368.2	$(R) = \theta_v \times d$
70-80	0.190	5347.8	= 13.05 cm
80-90	0.212	1039.2	
90-100	0.227	1303.3	
100-110	0.200	772.8	
110-120	0.214	2548.3	
120-130	0.246	11195.2	
130-140	0.299	12064.3	
140-150	0.277	3296.4	
150-160	0.279	1612.9	
160-170	0.294	932.5	
170-180	0.274	942.6	
180-190	0.284	1369.7	
190-200	0.297	2674.9	

Table 11 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Khamtara (cultivated) Date of injection : 02.07.95

Tehsil : Narsinghpur Date of sampling : 08.10.95

District: Narsinghpur (M.P.)

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 02.07.95 to 08.10.95
0-10	0.100	130.1	Depth of tritium injection = 70 cm
10-20	0.217	224.6	Tritium peak shift (d) = 43.88 cm
20-30	0.178	89.6	Average volumetric moisture
30-40	0.206	207.0	content in peak shift region
40-50	0.164	139.2	(θ_v) = 0.237
50-60	0.220	137.5	Recharge to groundwater
60-70	0.218	682.1	(R) = θ_v X d
70-80	0.200	1929.0	= 10.40 cm
80-90	0.186	369.1	
90-100	0.287	2608.9	
100-110	0.275	2153.3	
110-120	0.288	2560.3	
120-130	0.337	2663.4	
130-140	0.297	2289.1	
140-150	0.176	3742.3	
150-160	-	-	
160-170	-	-	
170-180	-	-	
180-190	-	-	
190-200			

Table 12 : Volumetric moisture content, Tritium count rate and recharge to groundwater at experimental site

Site : Karhaiya Kheda (uncultivated) Date of injection : 03.07.95

Tehsil : Narsinghpur Date of sampling : 08.10.95

District: Narsinghpur (M.P.)

Depth (cm)	Volumetric moisture content	Net Tritium count/min/ml	Determination of recharge to groundwater for the period from 02.07.95 to 08.10.95
0-10	0.168	264.8	Depth of tritium injection = 70 cm
10-20	0.144	315.8	Tritium peak shift(d) = 26.08 cm
20-30	0.214	1942.9	Average volumetric moisture
30-40	0.248	508.6	content in peak shift region
40-50	0.347	971.9	$(\theta_v) = 0.300$
50-60	0.336	311.6	Recharge to groundwater
60-70	0.267	943.7	$(R) = \theta_v \times d$
70-80	0.348	7273.7	= 7.81 cm
80-90	0.232	6335.7	
90-100	0.319	5241.6	
100-110	0.339	2504.8	
110-120	0.374	6301.8	
120-130	0.341	645.7	
130-140	0.367	2130.0	
140-150	0.315	327.1	
150-160	0.325	136.6	
160-170	0.372	107.4	
170-180	0.318	94.5	
180-190	0.325	109.1	
190-200	0.362	79.1	

These vials containing 1 ml of tritiated water and 10 ml of cocktail 'W' were placed in the counting chamber of the liquid scintillator counter 'System 1409' in order and each sample was counted for 300 seconds and count rate (in counts per minute) for each sample was obtained by the system. These count rates were corrected for background counts in order to get net tritium counts per minute. These net tritium count rates for various sites are tabulated from table 5 to 12.

4.4 Determination of Recharge to Groundwater

The net tritium count rate (counts per minute or CPM) for various sites were plotted as a histogram against the individual depth intervals which shows position of the original and shifted peaks of injected tritium. The movement of injected tritium and soil moisture at various experimental sites are shown in Fig. 4 to 11. After getting the shifted tritium peak, the centre of gravity of the peak was determined and the shift of the peak from original depth of injection of 70 cm was calculated.

The recharge to groundwater for various sites were estimated by multiplying the peak shift of tritium (as determined above) and average volumetric moisture content (at the time of sampling) in the peak shift region and are given in table 5 to 12.

The percentage recharge to groundwater at various test sites due to monsoon rains of 1995 are given in table 13.

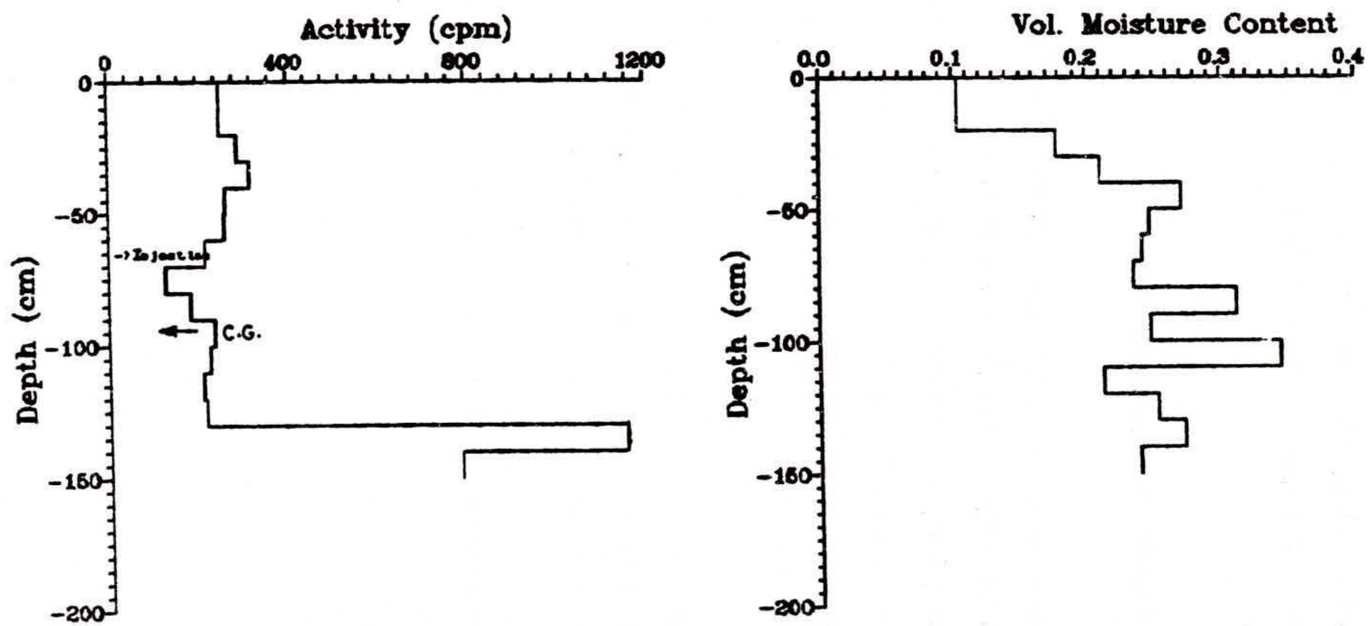


Fig.4 : Movement of Injected Tritium and Soil Moisture at Kheri

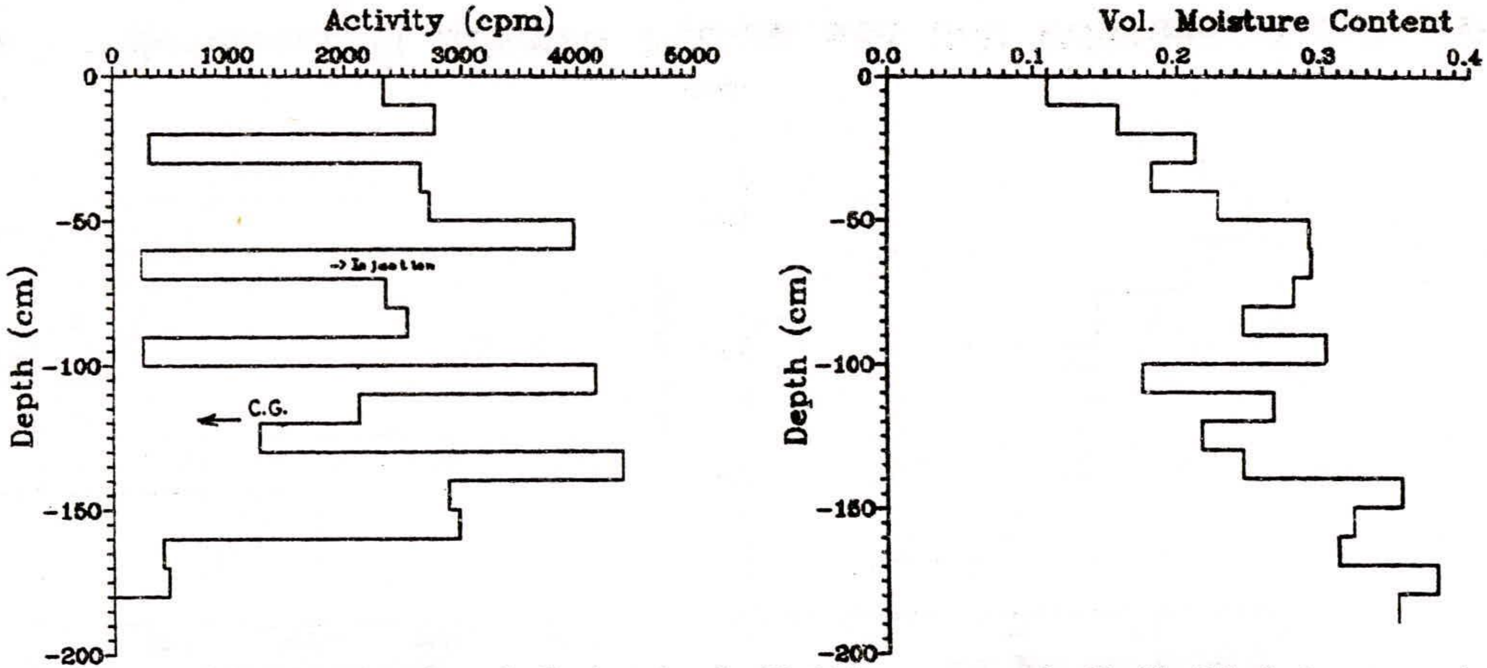


Fig.5 : Movement of Injected Tritium and Soil Moisture at Ram Pipariya

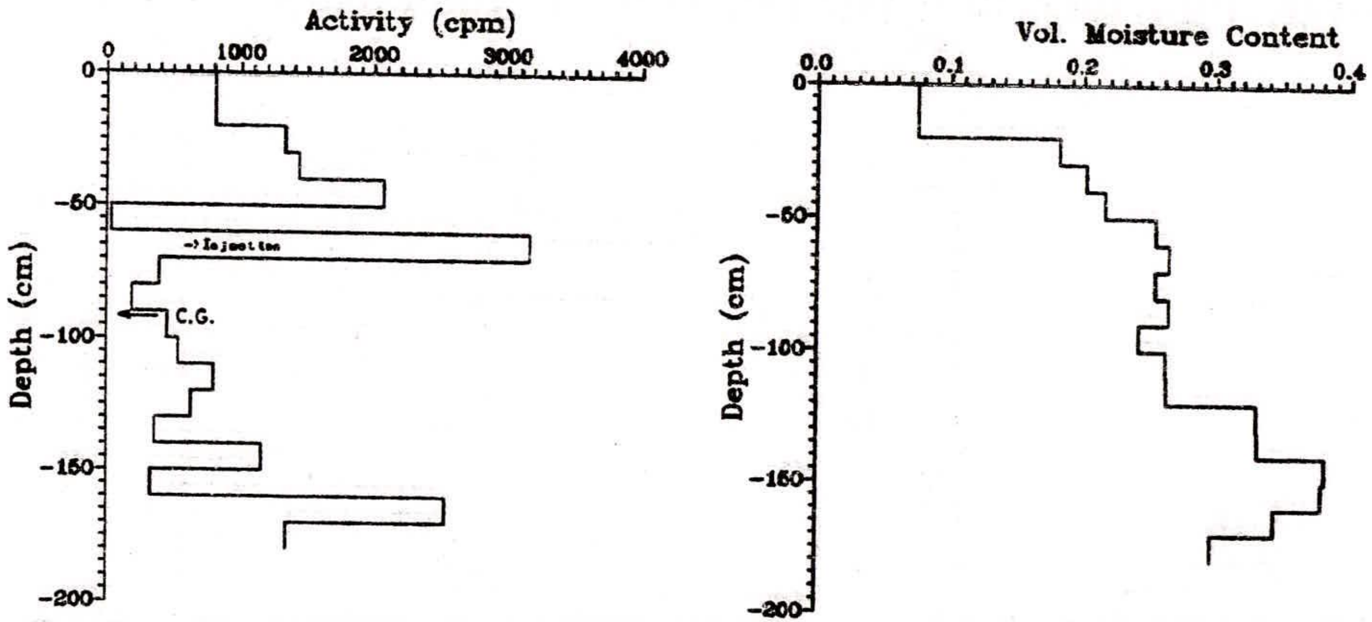


Fig.6 : Movement of Injected Tritium and Soil Moisture at Jallapur

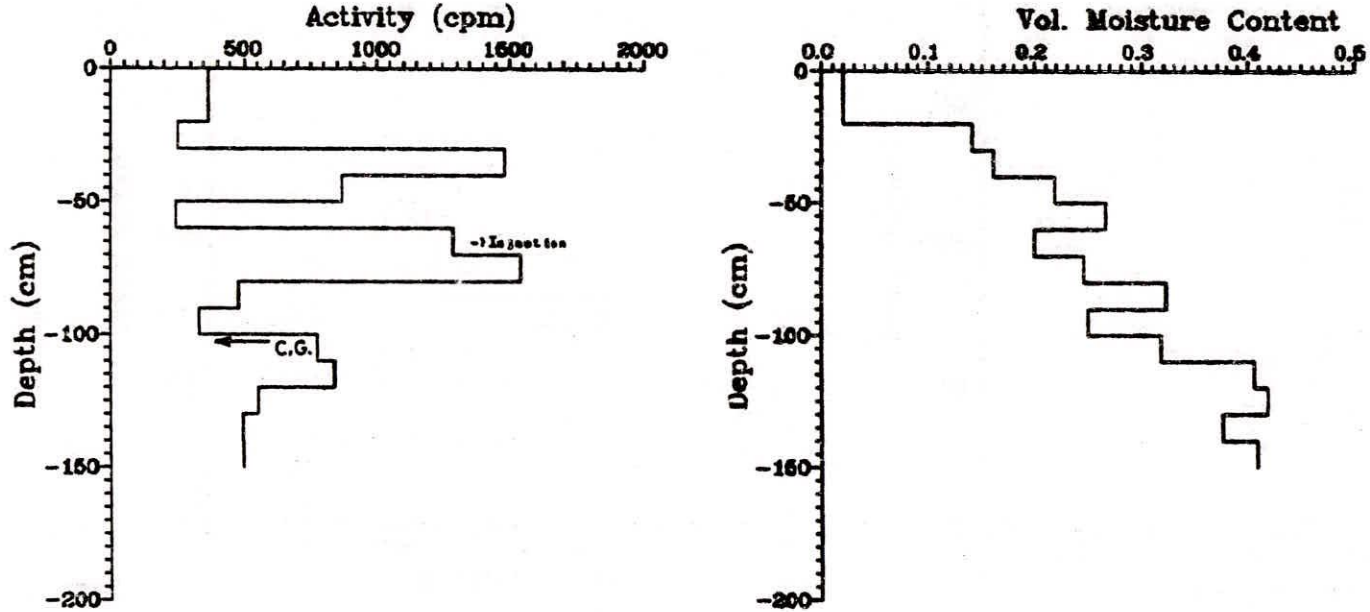


Fig.7 : Movement of Injected Tritium and Soil Moisture at Bahoripar

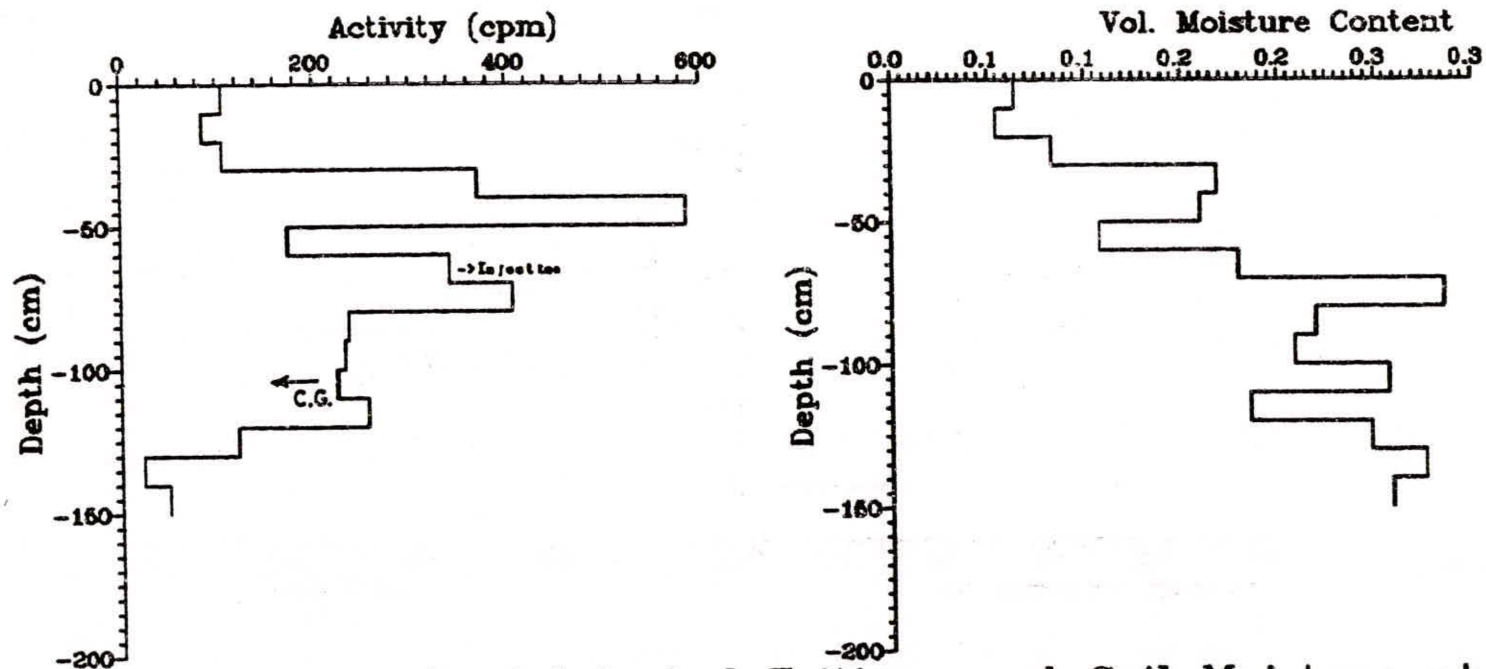


Fig. 8 : Movement of Injected Tritium and Soil Moisture at Bhoot Pipariya

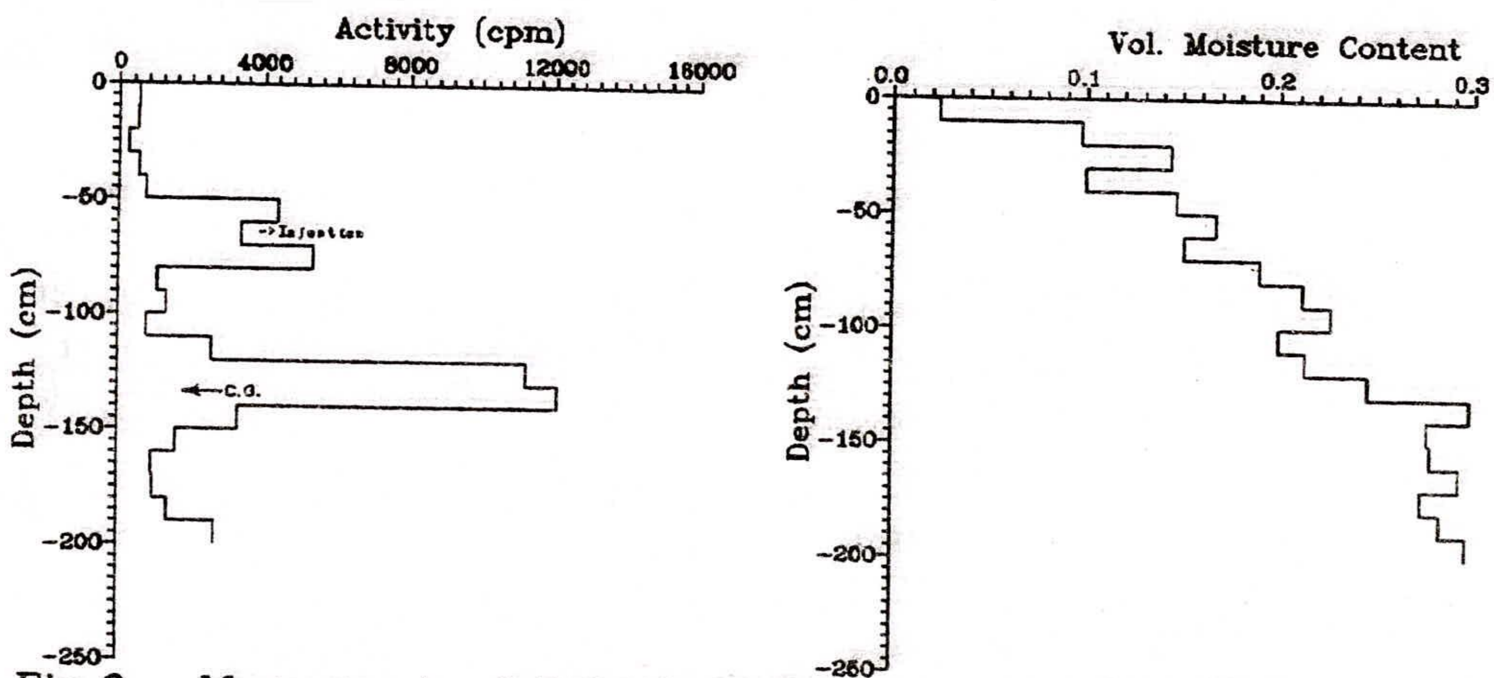


Fig.9 : Movement of Injected Tritium and Soil Moisture at Chilachon Khurd

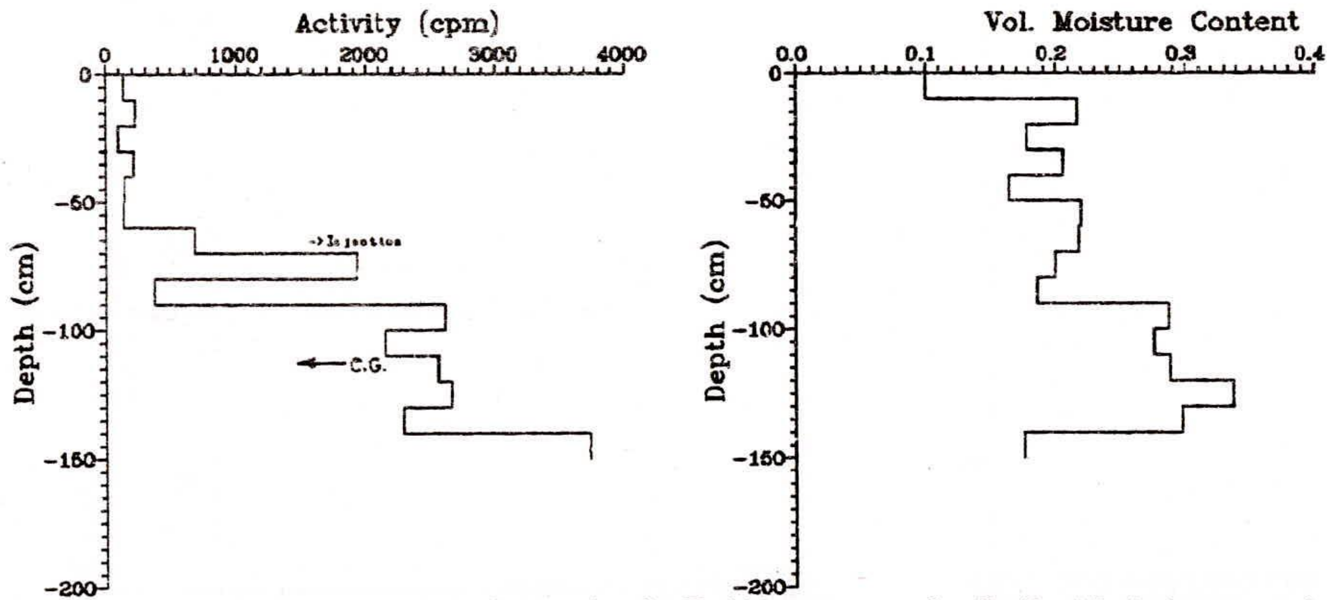


Fig.10 : Movement of Injected Tritium and Soil Moisture at Khamtara

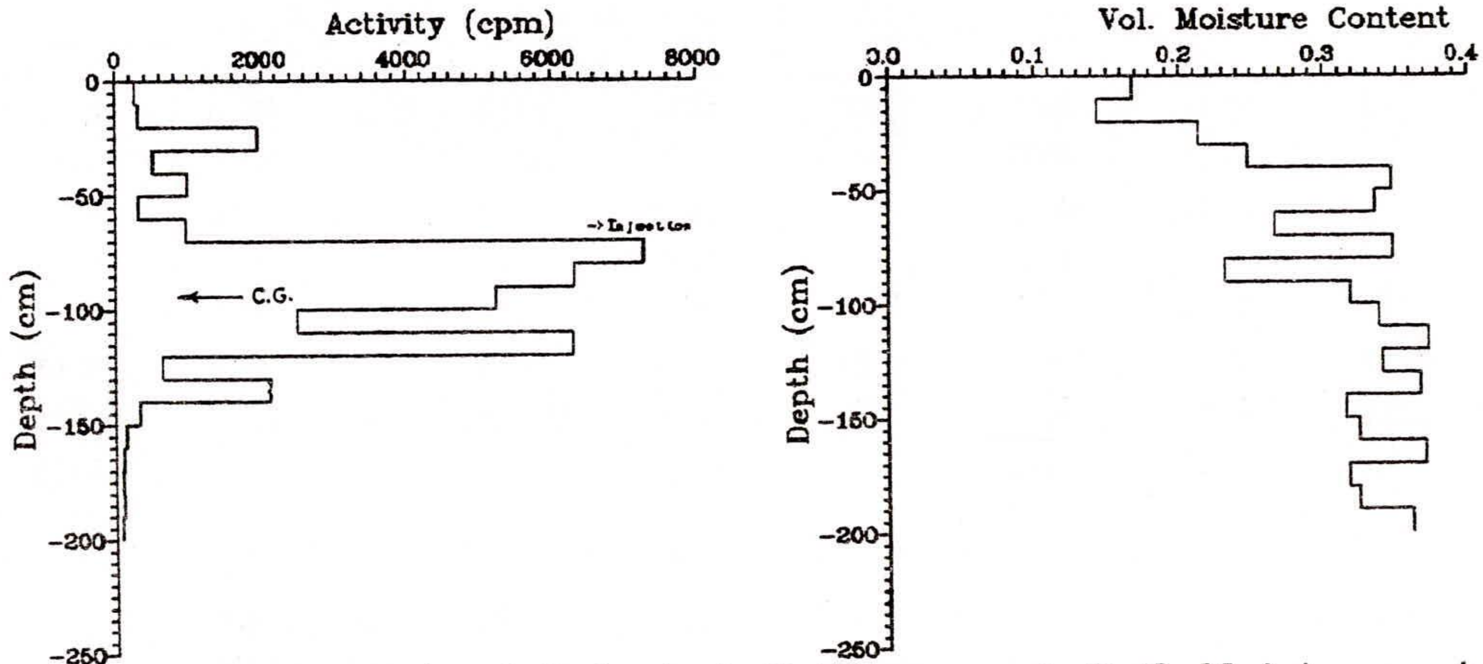


Fig.11 : Movement of Injected Tritium and Soil Moisture at Karhaiya Kheda

Table 13 : Peak shift, Av. volumetric moisture content, Recharge, Rainfall, Irrigation, % Recharge for various experimental sites

Name of site	Peak shift (cm)	Av. Volumetric moist. content	Recharge (cm)	Rainfall (cm)	Irrigation (cm)	% Recharge	Silt+clay (%)	Gravel (%)
Kheri	22.99	0.274	6.30	82.09	0.0	7.67	91.75	2.6
Ram Pipariya	50.66	0.297	15.03	67.00	0.0	22.44	73.50	8.6
Jallapur	20.59	0.259	5.33	67.00	0.0	7.96	90.25	2.7
Bahoripar	33.75	0.241	8.13	75.33	0.0	10.80	93.25	0.1
Bhoot Pipariya	34.24	0.243	8.33	75.33	0.0	11.05	79.75	2.2
Chilachon Khurd	61.00	0.214	13.05	75.33	0.0	17.30	72.50	0.5
Khamtara	43.88	0.237	10.40	75.33	0.0	13.80	87.80	4.2
Karhaiya Kheda	26.08	0.300	7.81	75.33	0.0	10.37	88.20	5.3

5. RESULTS AND DISCUSSION

The percentage of recharge to groundwater at various test sites, namely, Kheri, Ram Pipariya, Jallapur, Bahoripar, Bhoot Pipariya, Chilachon Khurd, Khamtara, and Karhaiya Kheda due to monsoon rains of 1995 are given in table 13 alongwith other details.

The percentage of recharge to groundwater at sites Kheri, Ram Pipariya, Jallapur, Bahoripar, Bhoot Pipariya, Chilachon Khurd, Khamtara and Karahaiya Kheda are 7.67, 22.44, 7.96, 10.8, 11.05, 17.3, 13.8 and 10.37% respectively. The percentage of recharge to groundwater at sites Kheri, Jallapur, Bahoripar, Bhoot Pipariya and Karahaiya Kheda are comparatively less i.e. 7.67, 7.96, 10.8, 11.05 and 10.37% respectively. However, keeping in view the percentage of silt+clay alongwith gravel, the recharge values seem to be justified. In addition, sites Bhoot Pipariya and Karahaiya Kheda belong to uncultivated fields and there should be comparatively less recharge to groundwater. But due to less percentage of silt+clay and higher of gravel in comparison to sites Kheri, Jallapur and Bahoripar, the percentage of recharge to groundwater are almost at par with these sites. The recharge to groundwater at site Khamtara is little higher than the recharge at sites Kheri, Jallapur, Bahoripar, Bhoot Pipariya and Karahaiya Kheda while little lesser than the recharge at Ram Pipariya and Chilachon Khurd sites, but if we consider the percentages of silt+clay and gravel, it also appears to be justified.

The groundwater table fluctuation data, as presented in table 3 indicate less groundwater recharge at site Kheri in comparison to site Ram Pipariya while it is more at Khamtara and Karahaiya Kheda sites. Although, the groundwater table fluctuation is occurred due to many processes like vertically downward recharge due to precipitation, irrigation return flow and groundwater draft taken by various means, the baseflow from the rivers in influent or effluent conditions also effect greatly the groundwater table condition in the area located in the vicinity of rivers. A close look on the map of the study area reveals that there is a sharp bend in river Sher where the site Karahaiya Kheda is located. Therefore, it is quite expected that the decrease in river water velocity will increase base flow considerably to the ground water aquifers during the monsoon season. The site Khamtara is also not very far from site Karahaiya Kheda and it seems that the river baseflow also influence the groundwater table fluctuation during the monsoon season. That is why, the ground water fluctuations at these two sites are more in comparison to other sites while the groundwater recharge due to precipitation is less. However, these facts require further investigations.

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ANNEXURE

Director:	**Dr. S. M. Seth**
Divisional Head:	**Dr. Bhishm Kumar**
Scientist:	**S. K. Verma**
Supporting Staff:	**Rajeev Gupta**
	Suresh Kumar
	Jag Mohan