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Analysis of ground water quantity improvement using rain Water harvesting system: the case study of jamia millia Islamia south Delhi India

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ABSTRACT: *This paper is an attempt to focus on the methodology of Ground Water recharge by the rainwater harvesting which is very challenging issue for the environment otherwise water leads to flooding / public havoc. The feasibility & need for implementation of Ground water Recharge Scheme in the area was established through the detailed study & analysis of the factors governing the Ground Water Discharge & Recharge in the area: such a Ground water Level behavior, Ground water Quantity, Rainwater quantity, Rainfall Intensity & its distribution. The Ground Water & Rainwater Potential, Aquifer Geometry & Characteristics and Ground Water requirement of the area also feasible for the implementation of ground water recharge. The Depth to Water level measured at different locations in the area was utilized to study the annual & Pre-Post Monsoon water level fluctuations. There after the impact of Rainwater Harvesting on the Ground Water Quantitative Potential was established based on the mathematical calculations. The present study established that the ground water restoration through artificial recharge technique (rainwater harvesting system) would to some extent help in mitigating water crises in Jamia Millia Islamia University. The Jamia Millia Islamia is spread over vast area of 205 acres of land at Jamia Nagar, New Delhi. It has 15% covered area and the remaining area is open space. Depending upon the area of sub-campuses, the campus of the Jamia Millia Islamia is divided into Ten Zones for the installation of rainwater harvesting structures. Putting all data into a coherent and logical structure supported by a computing environment helps ensure validity and availability and provides apowerful tool for hydrogeological studies. A hydrogeological geographic information system (GIS) database that offers facilities for groundwater-vulnerability analysis and hydrogeological modelling can be designed. So we can say that the rainwater recharges and improves the quantity of ground water which is also depends upon the amount of rain water and the environment of rainwater collection.*

Keywords: *Rain water harvesting, Artificial recharge , Rainfall Intensity, salinity, open space potential , water level, Run off coefficient*

I. INTRODUCTION

Water is an essential and vital component for our life support system. In tropical regions ground water plays an important role with context to fluctuating and increasing contamination of surface water resources. Ground water has unique features which render it particularly suitable for public water supply. Ground water is widely distributed and can be frequently developed incrementally at points near the water demand, thus avoiding the need for large water storage, treatment and distribution system. In most of the instances, the extraction of excessive quantities of ground water has resulted in drying up of wells, damaged ecosystems, land subsidence, salt water intrusion and depletion of the resources. The rate of depletion of ground water levels and deterioration of ground water quality is of concern in major cities and towns of the country. Being a National Capital Territory, Delhi is facing multifaceted problems regarding water availability, quantity and quality. The population growth and rapid urbanization in and around Delhi has led to immense pressure on basic emanate such as water supply. This work is an attempt to analyzing the impact of rainwater harvesting on ground water quantity. The area of study is the Jamia Millia Islmia campus where the rainwater harvesting structures were installed at Engineering Faculty, Gaddha Colony. Department of Fine Arts, University Polytechnic and Administrative Block, though it is proposed at some other locations at the campus also, as given in the location map of injection wells. The Jamia Millia Islamia is spread over vast area of 205 acres of land at Jamia Nagar, New Delhi. It has 15% covered area and the remaining area is open space. Depending upon the area of sub-campuses, the campus of the Jamia Millia Islamia is divided into Ten Zones for the installation of rainwater harvesting structures.

1.1 Meteorology of the Study Area

The rainfall in Delhi area is confined to the month July, August and September (i.e. 90%) and rest of the 10% in the other nine months namely- February, March, April, May. October and November goes dry. According to Meteorological Department the average rainfall is about 611.0 mm per year with the humidity varying from 17% - 89% and temperature variation from 3º C to 48º C. The evaporation recorded as 1.7 m. The Specific Yield varies in the study area from 16% to 20%.

1.2 Groundwater Status - Quantity

In recent years due to over exploitation of groundwater resources the water level have been taken a declining trend it is because of the many factors i.e. growing number of tube wells, lower spacing between them and high tube well density and also because of the less infiltration due to increase in covered areas by buildings, road networks etc. Instead of recharging ground water aquifers, rain water goes to storm water drains which meet to the major drains and the major drains ultimately join the Yamuna River by virtue of which the Yamuna gets over flooded and the recharge potential of groundwater decreases. Hence, the aquifers do not saturate sufficiently, which affects the groundwater quality as well as quantity.

II. OBJECTIVE AND SCOPE OF THE STUDY SCOPE OF THE STUDY

Since the rainwater harvesting structures were installed at Engineering faculty, Gaddha Colony, department of Fine Arts, University Polytechnic and Administrative Block and the scope of the project is impact of rainwater harvesting on groundwater quantity, the fallowing steps are to be followed:

1. The groundwater quantity analysis data at pre-installation period of the rainwater harvesting structures at the JMI.
2. To collect the groundwater samples in the Post-Monsoon period covering the entire JMI campus area in order to analyses the impact of rainwater harvesting on groundwater quantity.
3. Collection of groundwater samples after few months to know the changes in the groundwater quantity since the post-monsoon times.
4. Comparative Study of quantity of all the three-groundwater quality test results in order to ascertain the overall impact of Rainwater Harvesting on groundwater quantity of the campus area.

III. METHODOLOGY

To achieve the objectives of the study following methodology have been adopted

1. Groundwater Quantity Test Results of February 2012 are arranged and analyzed.
2. Groundwater Samples were collected in the month of November, 2012 (Post-Monsoon period) and analyzed.
3. It was collected in the month of April 2013, in order to know the changes in the groundwater quantity since the rainwater recharge.
4. All the three groundwater quantity test results of the JMI was compiled and comparative study was done to reveal the overall impact of rainwater harvesting on groundwater quantity of the JMI campus.
5. Analysis of rainwater sample and groundwater sample of the JMI Campus in order to check the impact of rainwater harvesting.
6. Study of the impact of rainwater harvesting on groundwater quantity potential of the JMI

IV. GEOLOGY OF THE AREA

The study area of Jamia Millia Islamia, New Delhi, occupies thick alluvium. The Delhi System of rocks are mainly formed due to the foothill extension of the Aravali Mountain Chains.

4.1 Geological/Lithological Interpretations

Terrameteric investigations on macro grid and micro grid were undertaken and hence the sub surface geological interpretations for delineation of aquifers were completed.The Strata Charts as shown in the figure 1, depicts the subsurface dimensions of the aquifer and other formations on the basis of Terrameteric interpretation. In general the area is found dominantly clayey and horizontally mixing with kankar. The Unconfined Aquifers occupied the upper most sandy strata since there is no impervious strata and exist only Top Soil Formations. The Semi Confined Aquifers Occupied the second strata because there exist the Clay mixed Kankar layer in the upper part, which acts as semi pervious layers.The Strata Chart prepared after the Terrameteric investigations at the Bhopal ground shows the Top Soil layer from ground level to 3.0 meter depth, Fine sand is upto 3-9 metres, 9-24 m Kankar and Clay, 24-30 metres Fine sand, 30-34 metres Yellow Sand, 34-42 metres Kankar Clay, 42-48 metres Hard Clay with Kankar, 48-60 metres kankar Clay, 60-66 m Fine sand and Kankar and 66-70 metres Fine Yellow sand. The Strata Chart prepared for the Pink House shows the thickness of the top soiI layer 3 metres from the ground level, 3-12 metres Fine Sand, 12-25 metres kankar clay, 25-30 metres clay kankar, 30-34 metres Yellow sand, 34-54 metres Kankar Clay and 54-70, metres Fine sand and Kankar The inventions at the department of Fine Arts reveals the presence of the top soil layer upto the depth of 3 metres from the ground level, 3-12 metres Fine sand, 12-42, 42-54, metres Hard Clay with kankar and 54-65 Sand with Kankar it is therefore a 20 m deep injection wells were proposed for artificial recharging of ground water.

4.2 Depth to water level

The water table at the Campus is from, 8.0 to 12.0 metres below the existing ground level it is less in the northern part of the campus and increases in depth towards south

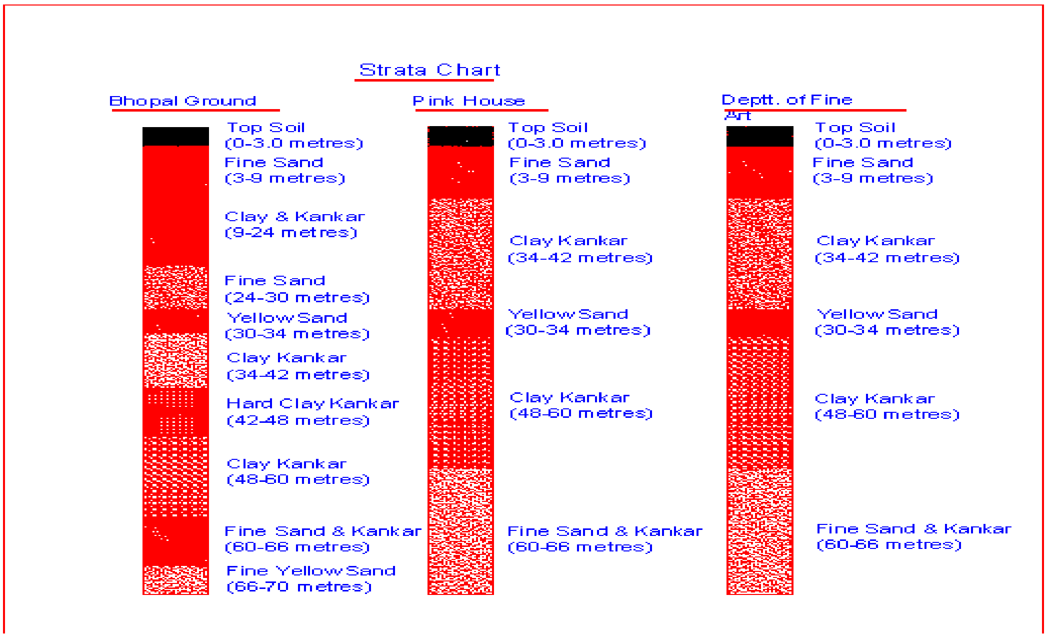

Fig. 1

V. PRINCIPLES OF ARTIFICIAL RECHARGE OF GROUNDWATER

5.1 Artificial Recharge

Artificial recharge is the process by which the ground water reservoir is augmented at a rate exceeding that under natural conditions of replenishment. Any man made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system. The most artificial recharge projects for specific purpose of saving or storing fresh water for subsequent use. Among these projects some may serve the dual purpose of eliminating objectionable amounts of water at the land surfaces and, at the same time putting this water into reserve for eventual extraction.

5.2 Hydraulic effects due to Artificial Recharge

The various hydraulic effects are generated by artificial recharge as a result of the head, which is applied in the recharge area and the mass of the water, which is introduced into the aquifer through the recharge area, the piezometric effect and the volumetric effect results in a rise in the piezometric surface in the unconfined aquifers and a rise of the artesian pressure in the confined aquifers. It is to factors which create a damping effect related to shape of the piezometric surface to the geological and hydraulic boundaries of the aquifer and to the type of location of the recharging device secondly, it is related to quotient T/C (T=transmissivity coefficient; C=replenishment coefficient which is equivalent of storage coefficient).Finally, it is related to the artificial recharge yield and the duration of operation. Other factors such as capillary forces water temperature and presence of air bubbles in the aquifers also have in impact on the piezomtric effect. The volumetric effect is related to specific yield, replenishment coefficient, the transmissivity coefficient and the boundary coefficient model studies that were checked through filled experiments have demonstrated that the bulk of the recharge water move according to the spreading out effect, with a speed related to the recharge flow, the other sliding effect, with a speed related to ground water flow.

The detailed knowledge of geological and hydrological features of the area is necessary for adequately selecting the sites and the type of recharge. In particular, hydraulic boundaries inflow and outflow of waters; storage capacity; porosity; hydraulic conductivity; transmissivity; natural discharge of springs; water resources available for recharge natural recharge; water balance; lithology; depth of aquifer; and tectonic boundaries.

VI. RAINWATER HARVESTING AT JMI

6.1 Roof Top Harvesting Potential

In order to study rooftop harvesting potential, the total roof-top area was calculated using following data. In this method, the roof-top areas of various buildings in Jamia Millia Islamia was calculated and taking rainfall intensity of 5.5 cm/hr with the return period of 5 years and design for 15 minutes time duration for the design purpose and at average annual rainfall for the overall potential of the JMI campus area. So,

Return period = 5 years.
Intensity = 5.5 cm/hr.
Intensity for (15 min.) = 2.5 cm/15 min.
Runoff Coefficient = 0.85

Calculation of Roof-Top Potential for 25 mm Rainfall/15 Minutes. to design the Injection Wells:
(As Per the Norms Recommended by CG WB & IMD)
Rooftop Potential = Runoff Coefficient (0.85) x Intensity for 25 mm/ (15 min) x Area of Building

S.No.	Name of the Site	Area (m^2)	Roof Top Potential (61 cm)/Annum	Roof Top Potential (m^3/ 15 Min.)
1	Zone-1	6179.65	3772.59	131.32
2	Zone-2	6987.17	4261.79	148.48
3	Zone-3	7985.16	4306.47	169.68
4	Zone-4	11407.72	6958.43	242.41
5	Zone-5	4629.01	2805.26	98.37
6	Zone-6	11764.25	4980.15	250.00
7	Zone-7	8145.84	4968.81	173.10
8	Zone-8	2040.80	1238.01	43.38
9	Zone-9	7273.19	4336.63	154.56
10	Zone-10	5304.04	3232.36	112.71
GROSS AREA		71716.83	40860.50	1524.01

6.2. Open Space Harvesting

Total Land Area : 205 Acre (829942.5 sq. m.)
Total Building Area : 1, 24,330 sq. m.
Total Rooftop Area : 71,716.83 sq. m.
Open Space : 7,55,213.12 sq.m.
Green Space : 5,28,649.18 sq.m
Pakka Area & Road : 2,26,563.94 sq.m
Open Space Potential : 179665.262 cu. m./year
Green Space : 96742.86 cu.m./year
Pakka Area & Road : 82922.40 cu.m/year

Calculation of Green Space Potential for 25mm rainfall/15minutes. to design the Injection Wells:

S.No.	Name of the Site	Area of open Space (m^2)	Green Area (m^2)	Green Space Potential (61 cm)/Annum	Green Space Potential (m^3/ 15 Min.)
1	Zone-1	60968.90	46580.80	28433.39	349.36
2	Zone-2	60011.50	42700.00	26064.51	320.25
3	Zone-3	112403.00	68107.00	41573.19	510.80
4	Zone-4	86703.50	73287.74	44735.57	549.66
5	Zone-5	19508.50	12704.80	7755.14	95.29
6	Zone-6	110308.20	70082.31	42778.94	525.62
7	Zone-7	81003.20	52981.86	32340.66	397.36
8	Zone-8	59304.00	41175.44	25133.90	308.82

Calculation of Pakka Area and Road Potential for 25mm rainfall 15minute to design the Injection Wells Zone wise Total Open

S.No.	Name of the Site	Area of open Space (m²)	Pakka & Road Area (m²)	Pakka & Road Area Potential (61 cm)/Annum	Pakka & Road Area Potential (m³/ 15 Min.)
1	Zone-1	60968.90	14388.10	8782.64	233.81
2	Zone-2	60011.50	17311.50	10567.11	281.31
3	Zone-3	112403.00	44296.00	27038.72	719.81
4	Zone-4	86703.50	13415.76	8189.11	218.00
5	Zone-5	19508.50	6803.70	4153.05	110.56
6	Zone-6	110308.20	40225.89	24554.29	653.67
7	Zone-7	81003.20	28021.34	17104.51	455.35
8	Zone-8	59304.00	18128.56	11065.85	294.59
9	Zone-9	108002.30	30341.06	18520.49	493.04
10	Zone-10	57000.00	13632.00	8321.11	221.52
Total		**755213.10**	**226563.91**	**138296.88**	**3681.66**

Space Potential for 25mm rainfall/15minute to design the Injection Wells

S.No.	Name of the Site	Green Space Potential (m^3/15 Min)	Pakka & Road Area Potential (m^3/ 15 Min.)	Total Open Space Potential (m^3/ 15 Min.)
1	**Zone-1**	**349.36**	**233.81**	**583.17**
2	**Zone-2**	**320.25**	**281.31**	**601.56**
3	**Zone-3**	**510.80**	**719.81**	**1230.61**
4	**Zone-4**	**549.66**	**218.00**	**767.66**
5	**Zone-5**	**95.29**	**110.56**	**205.85**
6	**Zone-6**	**525.62**	**653.67**	**1179.29**
7	**Zone-7**	**397.36**	**455.35**	**852.71**
8	**Zone-8**	**308.82**	**294.59**	**603.41**
9	**Zone-9**	**582.46**	**493.04**	**1075.50**
10	**Zone-10**	**325.26**	**221.52**	**546.78**
Total		**3964.88**	**3681.66**	**7646.54**

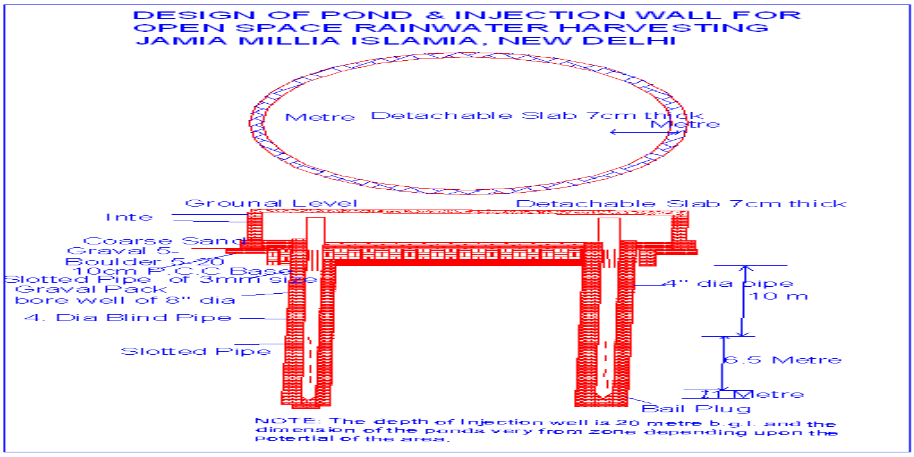

Fig 2

VII. Design of the Rain Water Harvesting Structures

The rainwater harvesting system suggested for Jamia Millia Islamia is designed for rooftop and open space harvesting by adopting injection well method.

The design of shaft, ponds and foundation are given in Figure 3. The Location of proposed Injection Wells for Rooftop Harvesting and Open Space Harvesting is given in the figure: 2.

The double - bore well harvesting structures is used for open space harvesting with the pipe diameter of 4 inches.

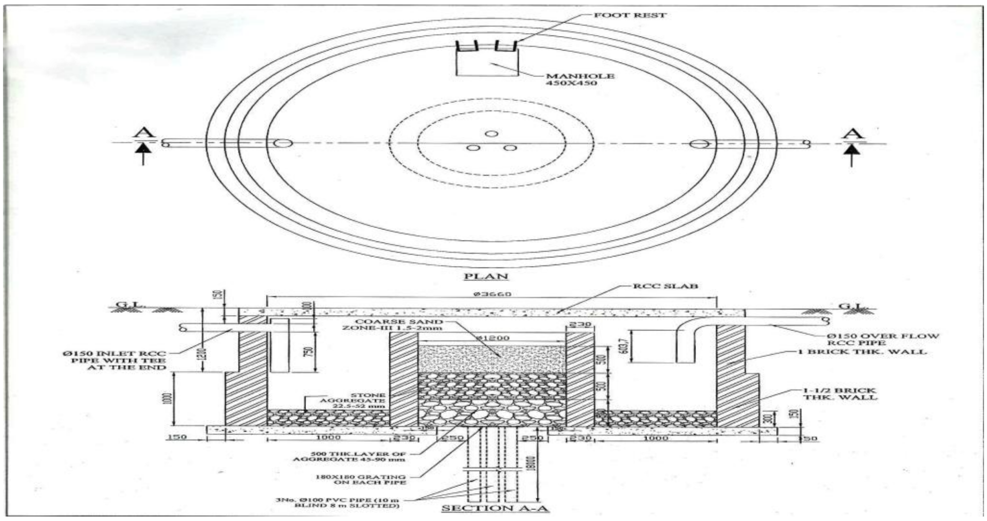

Fig 3

VIII. IMPACT ASSESSMENT OF RAINWATER HARVESTING AT JMI

A. Rainwater Harvesting and Groundwater Quantity

The rainwater harvesting is done primarily for the quantitative improvement, irrespective of its methods, whether collecting rainwater in ponds or reservoirs for future use or by recharging the rainwater to the groundwater aquifers through bore hole drilled for the purpose. The available quantity of ground water is the resultant of all the Processes and reactions, which taken place since the condensation of water in the atmosphere to the time it is retrieved in form of ground water from its source. The water has excellent property to accumulate substances in soluble form as it moves over and into the land resource, from the biological processes and from human activities. The quantity analysis conducted on the groundwater samples collected during the month of February 2010, in the post-monsoon period in the month of November 2010 and in April 2011 reveals this truth of qualitative improvement of groundwater through rainwater recharge to the aquifers,Initially, before the Rainwater Harvesting, the water table at the JMI campus was in the range of < 8 metres - 12 metres. The Depth to Water Table raised by 0.75 meter in areas of Engineering Faculty (from 10.4 metres to 9.65 metres) and Mass Communication Centre (1 1.2 metres to 10.45 metres) after the rainwater harvesting.

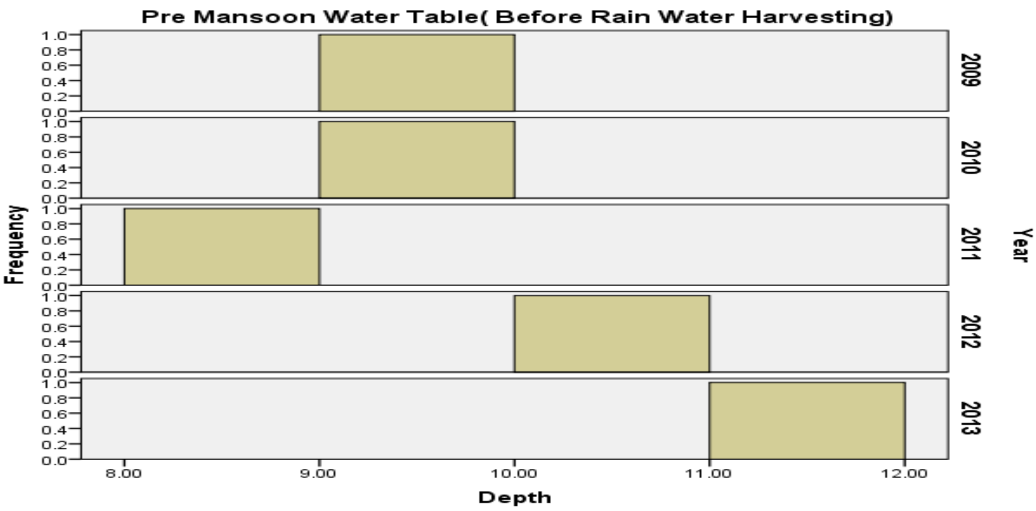

Fig. 4

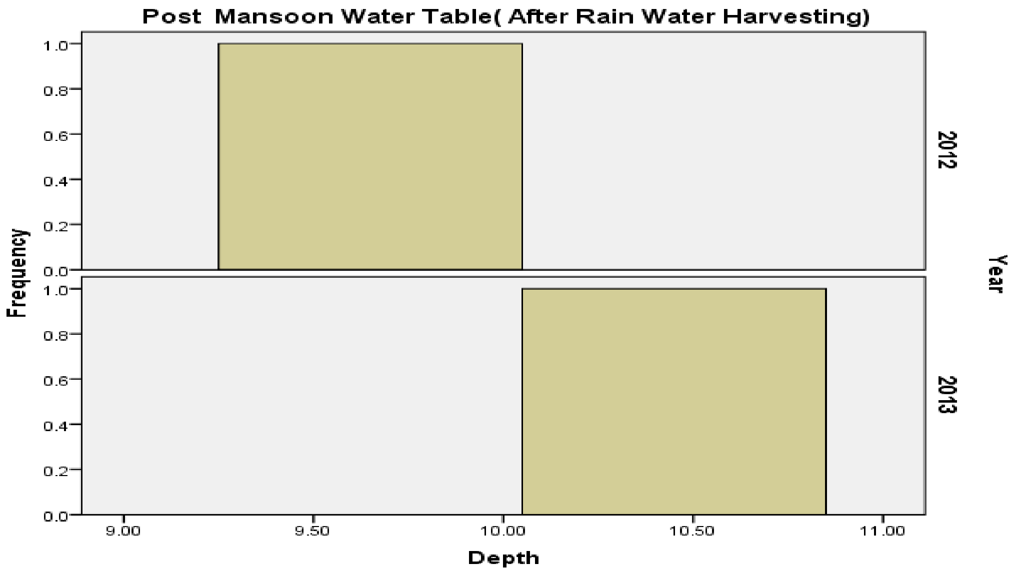

Fig. 5

B. Impact of rainwater harvesting on groundwater Quantity

The total Space Potential at the annual rainfall of 611 mm was calculated as 1, 79,665.26 cu.m. Whereas, the rainfall of 748 mm during the year 2010 added the potential of 88158.45 cu.m. And the total potential become 2, 67,823.71 cu.m. This is evident from the record of rise of 0.75 meter in water table of the campus in the month of November 2010, which was the range of <8-12 meters in pre-installation period of the rainwater harvesting structures. It again becomes deeper by 0.25 meters and ranged in April 2011, 7.25-11.5 meters.

C) GIS Data Processing for Groundwater Numerical Modelling

For groundwater studies**,** four main distinct applications of Geographical Information System (GIS) are recognized:

(1) The management of hydrogeological data and general hydrogeological analysis, (2) Hydrogeological map elaboration, (3) Vulnerability assessment (based on overlay and index methods), and (4) Hydrogeological database support for process-based Numerical modelling. The first three represent the extension in hydrogeology of classical GIS technology. The last one consists mainly of developing interactions between GIS and dynamic models used in groundwater studies. A good example of developing a hydrogeological database is given by the study of the impact of climate changes on the hydrological cycle at the basin scale. The modelled system involves the simulation of quantitative interactions between river, soil, and groundwater.

IX. CONCLUSION

The rainwater harvesting structures were installed at various at the JMI at the 20 meters depth. The other dimensions of ponds and injection wells are varying as per the designs and cross-sections enclosed. The Total space potential at the average annual rainfall of 611 mm was calculated as 1, 79,665.26 cu.m. Whereas, the rainfall of 748 mm during the year 2010 added the potential of 88158.45 cu.m, and the total potential becomes 2, 67, 823, 71 cu, m., which is 49% more than the normal potential. This is evident from the record of rise of 0.75 metre in water table of the campus in the month of November 2010, Which was in the range of <8-12 metres in pre-installation period of the rainwater harvesting structures. It again becomes deeper by 0.25 metres and ranged in April 2011, 7.25-11.25 metres. Therefore, in light of the present study, analysis and interpretations it can be concluded that the rainwater recharge improves the quantity of groundwater and depends upon the amount of rainwater recharged and the environment of rainwater collection and recharging.

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