Volume 64, Issue 2, 2020
Journal of Scientific Research
Institute of Science,
Banaras Hindu University, Varanasi, India.

# Environmental Impacts of Rain Water Harvesting: A Case Study of Varanasi

U. K. Banerjee*[1], G. S.Singh[2], and Devendra Mohan[3]

[1]University Works Department, Banaras Hindu University, Varanasi – 221005, India.ukbanerjee2@gmail.com*
[2]Institute of Environmental Science and Sustainable Development, Banaras Hindu University, Varanasi – 221005, India.gssingh@bhu.ac.in
[3]Department of Civil Engineering, Indian Institute of Technology (BHU), Varanasi-221005, India. devendra.civ@iitbhu.ac.in

*Abstract:* **There have emerged severe limits on utilizable quantities of water owing to uneven distribution of water over time and space. In addition, there are challenges of frequent floods and droughts in one or other parts of India. With growing population and increasing needs of the fast development as well as clear indications of various impacts of climate change, availability of utilizable water will be a serious problem in future. Under these circumstances, large institutional campuses bear special responsibility to set examples of water conservation by collecting, storing, reusing and artificial recharging of the natural resource rainwater before it is wasted in drains, gets highly polluted and becomes the cause of many diseases. Banaras Hindu University is the largest residential Central University in Asia. The University has within its walled campus a newly established Indian Institute of Technology also. Together, these two institutions provide very huge suitable infrastructure, which can easily collect relatively clean rain water and the same could be economically used for various applications.**

**Banaras Hindu University is totally dependent on the Groundwater. It was observed that for last few years ground water level is steadily falling and the rate at which it is falling may not be sustainable in years to come. The present paper studies the ground water situation of the entire Varanasi district in general and BHU campus in particular. The paper also entails the rain water harvesting potential of the Campus and suggests a measure to supplement the water supply through rainwater harvesting. Extensive field data was collected and water sustainability option has been proposed.**

*Index Terms:* **BHU campus, Environmental impacts, Ground water recharging, Rainfall, Rooftop rain water harvesting.**

## I. INTRODUCTION

Water is the basic requirement for life, livelihood, food security and sustainable development. India has about 18% of the world's population, but has only 4% of world's renewable water resources and 2.4% of the land area (NWP, 2012). Domestic Rain Water harvesting (DRWH) or Roof Top Rainwater harvesting (RTRWH) is the technique through which rain water is captured from roof catchments and stored in tanks/reservoir/ groundwater aquifers. It consists of conservation of roof top rain water in urban areas and utilizing it to augment ground water storage by artificial recharge and/or for reuse of the rainwater by proper collection and relatively using minimum treatment. It requires connecting the outlet pipe from roof top to divert collected water to existing open well/ tube well/bore well or to a specially designed collection tank.

Ministry of water resources, Government of India formulated National Water Policy, 2012 with the following objectives: 'The objective of National Water Policy is to take cognizance of the existing situation, to propose a framework for creation of a system of laws and institutions and for a plan of action with a unified national perspective' in view of such perspective under Clause 6. 'DEMAND MANAGEMENT AND WATER USE EFFICIENCY', under Section 6, it is stated, 'a system to evolve benchmarks for water uses for different purposes, i.e., water foot prints and water auditing should be developed to promote and incentivize efficient use of water. The 'project' and the 'basin' water use efficiencies need to be improved through continuous water balance and water accounting studies. An institutional arrangement for promotion, regulation and evolving mechanisms for efficient use of water at basin/sub-basin levels will be established for this purpose at the national level' **(**NWP, 2012**).**

The university is a residential campus and provides hostel facility to most of its students, residential facilities to Teaching and Non-Teaching employees and has many more infrastructural facilities with permanent structures with mostly R.C.C roofs or metal sheets (in very few buildings). Roofs of these buildings like hostel buildings, departmental building, hospital building,

*Corresponding Author

sports complexes etc., forms very good catchment because being institutional buildings roofs are normally maintained in clean conditions.

Annexure A1 presents the groundwater, block-wise (eight blocks) in the district of Varanasi.

## II. LITERATURE REVIEW

Rain Water Harvesting & Conservation, is the activity of Direct Collection of Rain Water. The conservation of Rain Water so collected can be stored for direct use or can be recharged in the ground water. The main goal is to minimize flow of Rain Water through Drains/ Nallahs to Rivers without making any use of the same. Countries like Slovakiya, Israel, use water about 4-5 times before disposing off, however in India it is used only once before disposed (RWH & CM, 2019).

Based on the complaints of Lok Samiti regarding drying up of dug-wells, village ponds, hand pumps, and hardships to farmers for irrigation water around Coca–Cola plant a study was taken up by the Central Ground Water Board. The study found that excess ground water withdrawal is taking place inside the plant.

The rate of decline of water level in plant premises is 1.19m per year however, in the area surrounding the plant, the rate of water table decline ranges between 0.5 to 0.75 m per year. Stage of ground water development was 72.84% in 2004 with safe category; while in 2009, the stage of ground water development increased to 96.39% and the block has been categorized as critical. The depth of water level in Piezometer in the plant premises has declined by more than 7 m in period of 5 years from year 2006 to 2011 (CGWB, 2012)**.** It will be relevant to note that the results of various studies on ground water falling in all the blocks of the Varanasi district as well as in Kashi Vidyapeeth block, where Banaras Hindu University is situated in last five years ( 2014-2018) ground water fall in all the blocks has been as shown in Table-1.

Pre-Monsoon = 3.46m, Post-Monsoon = 2.85m

This figure is almost matching with the observed ground water falling rate of the University campus after studying the long term bore well data i.e. 0.51m per year (Table-2). From all the above studies it is clear that ground water is falling consistently. Drawing water from such deep aquifers may become highly uneconomical in the coming years apart from generating more carbon foot prints progressively for which, entire humanity will suffer; particularly our country may be penalized by international agencies in some way. Falling of ground water table also has reduced the base flow of water to the river Ganges as observed by Mukherjee et al (2018).

In light of the above facts an estimate has been worked out for masonry water tank of above mentioned sizes (20mX10mX4m) with provision of filtration unit and pumping system which works out to about 16 to 20 lacs depending on the configuration shape etc. of tank. Initially 5 tanks in span of 8 to 10 years may be constructed. After realizing the benefits and cost of construction further decision can be taken. Since the academic institutional campuses provide enough space and opportunities to students and researchers for practical prototype model studies, these investments are justified from various counts, like it demonstrate a practical model to the students and the community as whole for water reuse, practical model for mitigation of excessive drawl of ground water, and effort to reduce green house generation, saving of financial resources etc. Ministry of Human Resources also insists that all the educational campuses shall implement ground water recharging and ground water reuse plans. These efforts will also satisfy ministry's direction towards rain water harvesting. National Building code 2016 (Vol.2 Cl. 4.2.2) also recommends use of waste water for non-domestic use after due treatment (NBC, 2016)**.**

## III. PROCEDURE

To calculate volume of rain water available for harvesting with respect to roof top area for the given annual rainfall of an area can be found from the available standards (RWH&CM, 2002).

Roof Top Rain Water harvesting and Conserving System, both for small and large areas, comprise of six basic components as described below:

1) Catchment area/roof: surface upon which rain falls.
2) Gutters and Downspouts: transport channels from catchment surface to storage.
3) Leaf Screens and Roof Washers: systems that remove contaminations and floating debris.
4) Storage Tanks: where collected rain water is stored for desired period.
5) Water Treatment: filters and equipment and additives to settle flocks, filter and disinfect.
6) Conveying/transporting system for treated rain water, either by gravity or pump.

According to the needs of the desired water quality, treatment process can be filtration by mechanical staining, sedimentation, biological metabolism and electrolytic charges etc. Use of needled non-woven fabric in combination of geo-grid filters the rain water accelerate the recharge rate.

The information available on the web sites of Uttar Pradesh Government's Ground Water Board indicates quite serious situation. Water situation for last ten years (2009-2018) presented in the Annexure –I, appended to this paper. Growing population and fast developmental works in both the city of Varanasi and the Banaras Hindu University needs more and more water whereas its aquifers are unable to sustain the current rate of water extraction which is clear from the falling ground water level of Banaras Hindu University as given in Table.1

In this paper, situation of groundwater around Varanasi city has been studied. Annexure -1 gives detail s of the falling status of the ground water (BJV, 2020).Further the ground water depletion status of the Banaras Hindu University campus has also been studied for finding out the appropriate solution for mitigating risk of BHU becoming a critical or dark zone in future.

Ground water data of the Banaras Hindu University has been compiled in four tables. Table 1 gives the data for fall of water level after the redevelopment of the bore well, table 2 gives details about the status of the bore well and the ratings of the pump installed, table 3 works out the energy consumed by the pumps and the energy cost, and table 4 gives details about average running hours of the pump throughout the year.

Details of the tube-wells installed in the Banaras Hindu University with developmental details and pump ratings are given in the Table 2. This will help us further assessing energy consumption out of functioning of these pumps.

It is interesting to know the cost of electrical energy out of the operation of these pumps which is tabulated in the Table 5. From this table, information about cost of electricity of each unit of water could be worked out.

Average cost of electrical energy charges for running submersible pumps in the campus per annum = 365 X 59839 = Rs. 2,18,41,235.

Long time average monthly running ours of all the pumps are given in the table 6. From this Table it is clear that pump running hours in the summer months are highest even though many hostels are closed due to summer holidays after examinations are over many hostels are vacated. In winter months the water consumption is lowest when all the hostels are fully occupied. In view of the above-mentioned adverse situations, i.e., falling ground water level and rising electricity expenses due to pumping from deeper levels has been compiled in Table 3. Table 4 presents average monthly running time of pumps in the campus. Roof top rain water potential of various buildings within the BHU campus has been assessed and shown in Table 5. Total quantum of ground water extracted from all the tube wells have been tabulated in Table 6.

Total quantum of ground water extracted from all the tube wells have been tabulated in Table 6.

Table 1. Ground water fall within Banaras Hindu University campus (bore well details).

| S N | Location &Yr of Construction | Static Water Lvl.-Initial | Redevelopment Year & Static Water level | Fall of Lvl.(m) | Average fall in water table/ year,m |
|---|---|---|---|---|---|
| 1. | Ag.Farm: Feb.1993 | **67'(20.42m) | May2012: 74'(22.55m) | 2.134 | 0.112 |
| 2. | Ruiya Ground: Jul,1993 | 60'(18.29m) | 2001: NA | | |
| 3. | Kabir Col.: Mar,2014 | 59'(17.98m) | - | | |
| 4. | SSH Big Tank: Dec,1999 | 53' 3" (16.23m) | - | | Out of service |
| 5. | Bhatta Land: Sep, 2001 | 45'(13.72m) | Apr2012: 75'(22.86m) | 9.14 | 0.83 |
| 6. | Nariya: Jan, 2002 | 55' 5" (16.91m) | Mar2012: 74'(22.55m) | 5.79 | 0.58 |
| 7. | Principal Col.: Feb,2004 | 60'(18.29m) | Jun2010: 82'(25.00m) | 6.70 | 1.117 |
| 8. | Amphi-theatre: Mar,2004 | 60'(18.29m) | May2012: 70'(21.35m) | 3.05 | 0.381 |
| 9. | Broacha (H)#: Sep,2006 | 58'(17.68m) | Dec2018: 74'(22.55m) | 4.88 | 0.407 |
| 10. | BHU Press: Sep,2006 | 60'(18.29m) | Jan2019: 75'(22.86m) | 4.57 | 0.351 |
| 11. | Dhanraj-Giri (H)#: Sept.2006 | 60'(18.29m) | Dec.2018: 72'(21.95m) | 3.66 | 0.305 |
| 12. | A.N.D. (H)#: Oct,2006: | 60'(18.29m) | Jan.2019: 71'(21.64m) | 3.353 | 0.258 |
| 13. | Gargi (H)#: Dec.2006 | 62'(18.90m) | Jan,2019: 71'(21.64m) | 2.74 | 0.21 |
| 14. | Vivekananda(H)#: Feb.2011 | 80'(24.38m) | - | - | - |
| 15. | Chemistry Tank: Feb.2011 | 75'(22.86m) | - | - | - |
| 16. | Dhanwantri (H)#: Mar.2011 | 75'(22.86m) | - | - | - |
| 17. | MMV: May,2011 | 65' (19.81m) | - | - | - |
| 18. | Viswanath Temple: Jul. 2011 | 70'(21.34m) | - | - | - |
| 19. | MCH SSH: Dec. 2018 | 65'(19.8m) | - | - | - |
| 20. | | | | Avg. | 0.455 |
| | **Trauma Centre(TC)** | | | | |
| 1. | TC#1: Oct. 2011 | 72'(21.95m) | - | - | - |
| 2. | TC#2: Oct. 2011 | 72'(21.95m) | - | - | - |
| 3. | TC#3: May, 018 | 85'(25.91m) | - | - | - |
| | | | | 3.96 | 0.566 |
| | | | Grand. | | 0.51 |

Note: Figures in parenthesis are in metresTC# = Trauma Centre, (H)#= Hostel.

Table 2. Details of tube wells within BHU campus

| S N | Location | Construction Year | Re-development Year | Status | Rating of Pump (H.P.) |
|---|---|---|---|---|---|
| 1. | Children Ward Old | Sept. 1981 | --- | Defunct since 2017 | 33 |
| 2. | L-Quarter | Sept. 1987 | --- | Low yield, Since 2017 | 41 |
| 3. | Agriculture Farms | Feb. 1993 | 2012 | *Rng | 33 |

| | | | | | |
|---|---|---|---|---|---|
| 4. | Chemistry old | Nov. 1993 | 2002 | Low yield since 2016 | 33 |
| 5. | Ruiya ground. | July 1993 | 2001 | Rng | 41 |
| 6. | Kabir Col. | Mar 2014 | | Rng | 41 |
| 7. | SSH Tank | Dec 1999 | Required | Rng | 41 |
| 8. | Bhatta Land | Sept. 2001 | 2012 | Rng | 41 |
| 9. | Triveni Hostel | Oct. 2001 | 2010 | Standby | 41 |
| 10. | Hanuman Templ SSH | Nov. 2001 | 2010 | Defunct since 2018 | 41 |
| 11. | Nariya | Jan. 2002 | 2012 | Rng | 41 |
| 12. | Principal Col. | Feb. 2004 | 2010 | Rng | 41 |
| 13. | Amphitheatre | Mar. 2004 | 2012 | Rng | 41 |
| 14. | Poultry Farm | Aug. 2006 | | Rng | 7.5 |
| 15. | Broacha Hostel | Sept. 2006 | Required | Rng | 41 |
| 16. | BHU Press, (Replacement) | Sept. 2006 | Required | Rng | 41 |
| 17. | Dhanrajgiri Hostel | Sept. 2006 | Required | Rng | 41 |
| 18. | A.N.D. Hostel | Oct . 2006 | Required | Rng | 41 |
| 19. | I. M. S. | Nov. 2006 | 2011 | Rng | 41 |
| 20. | Gargi Hostel | Jan. 2007 | Required | Rng | 41 |
| 21. | Dairy | Sept. 2010 | | Rng | 5 |
| 22. | Vivekananda Hostel | Feb. 2011 | | Rng | 41 |
| 23. | Chemistry | Feb. 2011 | | Rng | 41 |
| 24. | Dhanwantri Hostel | March 2011 | | Rng | 41 |
| 25. | MMV | May 2011 | | Rng | 41 |
| 26. | Vishwanath Temple | July 2 011 | | Rng | 41 |
| 27. | Hyderabad Col. | June 2019 | | defunct | 41 |
| 28. | T C #1 | Oct. 2011 | -- | Rng | 10 |
| 29. | TC#2 | Oct. 2011 | -- | Rng | 10 |
| 30 | TC#3 | May 2018 | -- | Yet to made operational | 33 |

Note:

1) Maximum discharge of each tube well is 2000 lpm approx. for 41 hp and 1600 lpm for 33 hp pumps.
2) Cost of bore well development with pump house: Rs. 34.00 lakh.
3) Pumps are erected about 35m bgl.
4) Average rate of ground water fall = 0.455m per annum.

Table 3. Daily energy consumption for pumping during summer

| S.N. | Location& Status | Rating of pump (H.P.) | Avg. rng.hrs. | Energy consumption | Energy cost (Rs.) |
|---|---|---|---|---|---|
| 1. | Farm (irrigation), Rng | 33 | 14 | (33/0.9)*A*14*10 | 3830 |
| 2. | Ruiya ground, Rng | 41 | 10 | (41/0.9)*A*10*10 | 3400 |
| 3. | Kabir Col.,Rng | 41 | 10 | (41/0.9)*A*10*10 | 3400 |
| 4. | SSH Big Tank,Rng | 41 | 15 | (41/0.9)*A*15*10 | 5100 |
| 5. | Bhatta Land, Rng | 41 | 14 | (41/0.9)*A*14*10 | 4760 |
| 6. | Triveni,(Standby) | 41 | 0.00 | -- | 0.00 |
| 7. | Nariya °Rng | 41 | 0.00 | -- | 0.00 |
| 8. | Principal Col. ,Rng | 41 | 19 | (41/0.9)*A*19*10 | 6460 |
| 9. | Amphitheatre, °Rng | 41 | 0.00 | -- | 0.00 |
| 10. | Poultry Farm ,Rng | 7.5 | 20 | (7.5/0.9)*A*20*10 | 1245 |
| 11. | Broacha, °Rng | 41 | 0.00 | -- | 0.00 |
| 12. | BHU Press (New), °Rng | 41 | 0.00 | -- | 0.00 |
| 13. | Dhanrajgiri ,(Repl.), °Rng | 41 | 0.00 | -- | 0.00 |
| 14. | A.N.D. Hostel (Repl.), Rng | 41 | 8.00 | (41/0.9)*A*8*10 | 2720 |
| 15. | I.M.S.( Repl.), Rng | 41 | 6.4 | (41/0.9)*A*6.4*10 | 2175 |
| 16. | Gargi Hostel (Repl.), Rng | 41 | 13.00 | (41/0.9)*A*13*10 | 4420 |
| 17. | Dairy, Rng | 5 | 10 | (5/0.9)*A*10*10 | 415 |
| 18. | Vivekananda Hostel, Rng | 41 | 17 | (41/0.9)*A*17*10 | 5780 |
| 19. | Chemistry New (Replacement ) | 41 | 9.2 | (41/0.9)*A*9.2*10 | 3130 |
| 20. | Dhanwantri (Repl.), Rng | 41 | 17.00 | (41/0.9)*A*17*10 | 5780 |
| 21.. | MMV, Rng | 41 | 15.4 | (41/0.9)*A*15.4*10 | 5234 |
| 22. | Vishwanath Temple, °Rng | 41 | 0.00 | -- | 0.00 |
| 23. | TC #1 Rng | 10 | 12 | (10/0.9)*A*12*10 | 995 |
| 24. | TC #2 Rng | 10 | 12 | (10/0.9)*A*12*10 | 995 |
| 25. | TC #3 (recent) | 33 | -- | | |
| 26. | | | 222 | Total Daily Expend. | 59839 |

A=0.746(factor ). , TC#= Trauma Centre, °Rng= Standby, Repl.= Replacement

Table 4. Month-wise average running time of pumps for 2017

| Months | Hours |
|---|---|
| Jan | 5421 |
| Feb | 5005 |
| Mar | 5825 |
| Apr | 6362 |
| May | 6471 |
| Jun | 5857 |
| Jul | 5510 |
| Aug | 5788 |
| Sept | 5654 |
| Oct | 5623 |
| Nov | 5519 |
| Dec | 5295 |

Table 5. Roof top rain water harvesting potential in BHU (including IIT(BHU) per annum
(Basis: annual rainfall = 1.0254 m, source: climatological tables of observation in India (1951-1980)

| S N | Description of Bldg. | Terrace area A ($m^2$) | **A | ***B | C* in ($m^3$) |
|---|---|---|---|---|---|
| 1. | Hostels | 142517 | 0.85 | 0.8 | 99,334 |
| 2. | Academic buildings | 174509 | 0.85 | 0.8 | 121680 |
| 3. | Mahila Maha -Vidyalaya | 9222 | 0.85 | 0.8 | 6429 |
| 4. | Hospitals /IMS | 50966 | 0.85 | 0.8 | 35537 |
| 5. | Ayurveda and other health centers | 10179 | 0.85 | 0.8 | 7097 |
| 6. | Trauma Centre | 12484 | 0.85 | 0.8 | 8703 |
| 7. | Schools | 4028 | 0.85 | 0.8 | 2808 |
| 8. | Miscellaneous buildings | 62339 | 0.85 | 0.8 | 43467 |
| 9. | Administrative buildings | 9068 | 0.85 | 0.8 | 6323 |
| 10. | Guest houses | 5384 | 0.85 | 0.8 | 3753 |
| 11. | Residential quarters | 114368 | 0.85 | 0.8 | 79745 |
| 12. | Total | 5,95,064 | | | 4,14,876 |

**A=Run-off Co-efficient, ***B= Co-efficient for evaporation, spillage, first flush etc., C*= Annual RWH Potential

*Annual water harvesting potential from the area as per the Table mentioned above

= AX1.0254mX**A X ***B = C* (Area of roof top) X (Annual rainfall in metre) X **A (Runoff co-efficient) X *** B (Constant co-efficient) = Annual RWH potential.

Table 6. Discharge / Withdrawal of Water from Tube Wells of BHU Campus

| S N | Tube well site & satus | Rating of pump (H.P.) | Avg. running hrs | Rated discharge (lpm) | Total discharge ($m^3$) |
|---|---|---|---|---|---|
| 1. | Ag.Farm, Rng* | 33 | 14 | 1600 | 1344 |
| 2. | Ruiya ground, Rng* | 41 | 10 | 2000 | 1200 |
| 3. | Kabir Colony, Rng* | 41 | 10 | 2000 | 1200 |
| 4. | SSH (Big Tank ), Rng* | 41 | 15 | 2000 | 1800 |
| 5. | Bhatta Land, Rng* | 41 | 14 | 2000 | 1680 |
| 6. | Triveni(low yield), Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 7. | Nariya, Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 8. | Principal Colony, Rng | 41 | 19 | 2000 | 2280 |
| 9. | Amphitheatre, Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 10. | Poultry Farm, Rng | 7.5 | 20 | 400 | 480 |
| 11. | Broacha, (new T/W), Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 12. | BHU Press(New), Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 13. | Dhanrajgiri, Rng□ | 41 | 0.00 | 2000 | 0.00 |
| 14. | A.N.D. Hostel ,Rng | 41 | 8.00 | 2000 | 960 |
| 15. | I.M.S. (Replacement), Rng | 41 | 6.4 | 2000 | 768 |
| 16. | Gargi (H)° (Repl. ), Rng | 41 | 13.00 | 2000 | 1560 |
| 17. | Dairy, Rng | 5 | 10 | 250 | 150 |
| 18. | Vivekananda (H)°, Rng | 41 | 17 | 2000 | 2040 |
| 19. | Chemistry New,( Repl,), Rng | 41 | 9.2 | 2000 | 1104 |
| 20. | Dhanwantri (Repl.), Rng | 41 | 17.00 | 2000 | 2040 |
| 21. | MMV, Rng | 41 | 15.4 | 2000 | 1848 |
| 22. | Vishwanath Temple, Rng□ | 41 | 0.00 | 2000 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| 23. | TC #1 Rng | 10 | 12 | 500 | 360 |
| 24. | TC #2 Rng | 10 | 12 | 500 | 360 |
| 25. | TC #3 NF°° | 33 | -- | 1600 | 0.00 |
| | | | 222 | Total Extraction | 21174 |

Rng□ = Running as per need, NF°° = Not Functional as yet

Rng*=Running, (H) ° = Hostel,

Water extracted from Bore wells per annum = 365 x 21174 = 77,28,510 $m^3$ (A)

**Note**: The essence of this study is to find ways of reducing withdrawal of this enormous quantity of ground water through deep tube wells because of which the ground water level has been going down at a fast rate. This situation is likely to deteriorate rapidly in future. According to the ground water Brochure, CGWB, ground water resource potential (as on 31.03.2011) is given in the Table 7. The block wise ground water situation is quite serious, one of the blocks namely Kashi Vidyapeeth block, in which Banaras Hindu University campus is situated, also shows high level of ground water falling,i.e,. upto 3.45 m in last 5 years (2014 to 2018) as shown in Table2 (Annexure A1).

Table 7: Ground water resource potential as on 31.03.2011

| S N | Ground water resource potential | |
|---|---|---|
| 1. | Net Ground Water Availability(Ham) | 47972.08 |
| 2. | Gross Ground Water Draft (Ham) | 38569.60 |
| 3. | Balance Ground Water Availability (Ham ) | 9402.48 |
| 4. | Stage of Ground Water Development | 80% |
| 5. | Number of Over Exploited Block | 01 |
| 6. | No. of Critical Blocks | 02 |
| 7. | Number of semi critical Blocks | 03 |
| 8. | Number of Safe Blocks | 02 |
| 9. | Number of Ground Water Monitoring Wells ( as on 1.3.2015 ) | |
| 10. | Number of Dug Wells | 16 |
| 11. | Number of Piezometers | - |

The above-mentioned brochure, mentions under the Cl. 7.1, ‘In Varanasi district, there is depletion of water level over last ten years. In all 8 (eight) blocks there is decline in water level over the years.

The Varanasi district is characterized with plains made by alluvium. The district contains two tehsils and eight blocks. The data of exploratory drilling conducted by C.G.W.B in the district that ground water occurs in sandy alluvium and older coarse grained sand, yield of well varies from 30 to 3100 lpm with 30m drawdown in the district. Water level data of all NHS falling in the district were analyzed from 2003 to 2012 which clearly shows that water level fluctuations ranges from 0.65 to 4.11m corroborating insignificant base flow of ground water in the area. Long term water level trends showed the decline in the ground water level from 0.11 to 1.03 m/year in entire district. The block wise ground water resource (2009) shows that out of eight blocks, two blocks namely Araziline and Harahaua are critical, one block (Sewapuri) is safe and the rest five blocks are under semi -critical category. The ground water development of the district is 80%.The above mentioned situations demand immediate action towards rain water harvesting.

## IV. RESULTS AND DISCUSSION

1) Relevant details shown above are as per the latest data available up to October, 2019 including those for Trauma Centre and Agriculture farms of Banaras Hindu University.
2) About 12 MLD (12000 cum per day) is discharged into the sewerage System.
3) Assuming 80% of the domestic sewage generation rate of the water supplied, total domestic water consumed in household works, will be (100/80) X 12 = 15 MLD i.e. equal to 15,000.00 $m^3$ and from this figure the calculated usage of domestic water supply is 365 x 15,000= 54,75,000 $m^3$ per annum.
4) About 6.174 MLD or 6,174 $m^3$ (21174 – 15,000 = 6,174 $m^3$) of water is being used per day for other usages like washing cars, lawn and garden, irrigation, pipe leakages and wastages etc.
5) If agricultural use of water is totally deducted from the total consumption of water then the quantity for other use related works comes out to be 6,174 – 3,024 = 3,150 $m^3$ per day.
6) From the Table 5, the total potential for the rain water harvesting is 4,14,876 $m^3$ per annum.
7) As per RWH&CM, 2019, the average drinking water required per person per day is equal to 10 litres (Cl.2.7.1, P10). If the above rooftop water is collected effectively it can provide drinking water requirement for population = {(414876 x 1000)/365}/10 = 1,13,665 persons per annum. This quantity is more than double of the requirement of the Banaras Hindu University for drinking and cooking purposes.
   Even though National Building Code of India Part-II, Part-9, Section-I Water Supply Under Table 1 water Requirements for Buildings other than Residences consumption per day is 135 litres per head per day and for communities with population 20000 to 100000 together with full flushing system 1000 to 135 lphd is considered.(NBC, 2016).
8) Equivalent cost for electric power consumption for drawing bore well water = 59839 / 21174 = Rs. 2.83 per m3
9) If the rooftop rain water is fully utilised for domestic water consumption so that withdrawing of bore well water is reduced to this extent, savings on account of electricity expenses alone will be equal to an amount of Rs. 414876 X 2.83 = Rs 11,74,099 as an additional benefit in terms of the money saved. If the BHU decides to develop facility in a

phased manner, the payback period will not be more than 10 years.

10) Design of storage Tanks: Storage facility could be designed using following basic data:
    a) Average annual rainfall
    b) Size of the catchment
    c) Drinking water requirements
    d) Alternate use requirement of water

Number of rainy days in Varanasi is 48 days. If we consider storage of at least 6 months of drinking water of total population of the campus including all types of consumers like resident employees, hostellers, hospital patients, attendants of the hospital patients, visitors of BHU, floating population , nonresident employees, canteens etc. about 74,000 population have to be catered excluding requirement of dairy.

Total drinking water requirement of all the above mentioned population for six months of a year = 74000 x 10 x 180 = 13,32,00,000 l or = 1,33,200 $m^3$. This requirement is 133200/414876 = 32.10 % of the total potential of rooftop rainwater harvesting of the buildings of BHU. Therefore, out of the total potential of roof top rainwater harvesting only less than one third if collected effectively then drinking water requirement for six months can be met from roof top rain water. If full quantity of water is utilized then we can meet drinking water requirement for the full year plus we shall have sufficient good quality surplus water. The following calculation justifies the above:

Total population to be served per day = 74000

Drinking water requirement per day = 10 litres

Total Drinking water required per day = 74000 X 10 = 740 $m^3$

Capacity of the tank suggested above: 20X10X4X0.9 = 720$m^3$

Therefore one such tank will be sufficient for one day's requirement, since consumption is a continuous process the tank will very well cater for one day's storage purpose.

However, if buffer stock of water needs to be maintained for more days, number of tanks be increased and constructed.

For providing this buffer stock including free board allowance storage tank capacity of 8000$m^3$ may be considered to cover both rainy period and dry period.

Size of each modular tank may be 20m x 10m x 4m; the tanks can be positioned 2 metres below ground level and two metres above ground level. Total 10 numbers (these can be reduced if buffer storage for less than 10 days are desired) of such tanks can be constructed in strategic locations in phased manner in few years span according to the availability of the financial resources.

## CONCLUSIONS

India is suffering from a very significant water crisis due to national economic growth, livelihoods, human well-being, as well as economic sustainability. The macro–water availability and numbers are unsettling. India is home to about 18% of world's population but has only 4% of world's freshwater resources. About two lakh people die every year due to inadequate water, sanitation and hygiene. The entire green revolution in the country was based on ground water resources. This is fundamentally a wrong strategy in view of over exploitation of ground water and growing number of water stressed areas. India is third largest exporter of ground water through virtual water trade CWMI (2019).

Varanasi district as a whole is witnessing serious types of falling trends of ground water. Kashi Vidyapeeth block in which the BHU campus is situated is in the semi critical category as per Brochure 2014-15 (Singh, 2015). The rainwater harvesting in all its suitable forms must be adopted, whether it is by impounding the water in existing or artificially dug out earthen tanks. Preferably, rainwater runoff should not be allowed to flow in to the municipal drains as these pick up lot of pollutants in the course of its flow which is very difficult and costly to treat and clean afterwards for making it fit for human consumption. These storm water also pollutes surface water like river, lakes etc. BHU has very long and well laid out storm water drains. Excess runoff water flowing through these drains be utilised for ground water recharging after making due provisions of cleaning, sedimentation, filtration disinfection etc.

## ACKNOWLEDGMENT

The help and cooperation extended in various forms by the office of Indian Meteorological Department, Banaras Hindu University; Department of Geophysics, BHU; Er. Ram Kumar Singh, Assistant Engineer, Electric and Water Supply Services, BHU and Mr. Indrajit Patel, AutoCad Draughtsman of University Works Department, BHU are thankfully acknowledged in relation to this work.

## REFERENCES

NWP: National Water Policy (2012). Ministry of Water Resources, Government of India

CWMI: Composite Water Management Index (2019). NITI Aayog , August 2019, pp 27 – 187.

RWH & CM: Rain Water Harvesting & Conservation Manual (2019) published by the Central Public Works Department, Government of India.

Singh, R. (2015). Ground Water Brochure of Varanasi District, U.P., published by Central Ground Water Board, Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India.

BJV (2020). BhoogarbhaJalVibhag, Government of Uttar Pradesh, Retrieved June 16, 2020 from http://upgwd.gov.in/StaticPages/GWDStatus-hi.aspx

Mukherjee, A., Bhanja, S., and Wada, Y., 'Ground water depletion causing reduction of base flow triggering Ganges river summer drying' Scientific Reports 8, Article number 12049 ( 2018 ).

CGWB (2012). A short report regarding need to stop, over-exploitation of ground water by M/s Hindustan Coca- Cola Beverages Ltd., Mehendiganj, Varanasi District, U. P. by the Central Ground Water Board, Allahabad, Feb.2012.

NBC: National Building Code of India (2016), Cl. 4.2.4, Vol. 2, Part 9, P 13.

ANNEXURE – A 1

Groundwater Level (Block Wise Average)
Pre and Post Monsoon Period
(bgl in metre) for Varanasi District (BJV, 2020)

A = Pre Monsoon, B = Post Monsoon

Table A 1

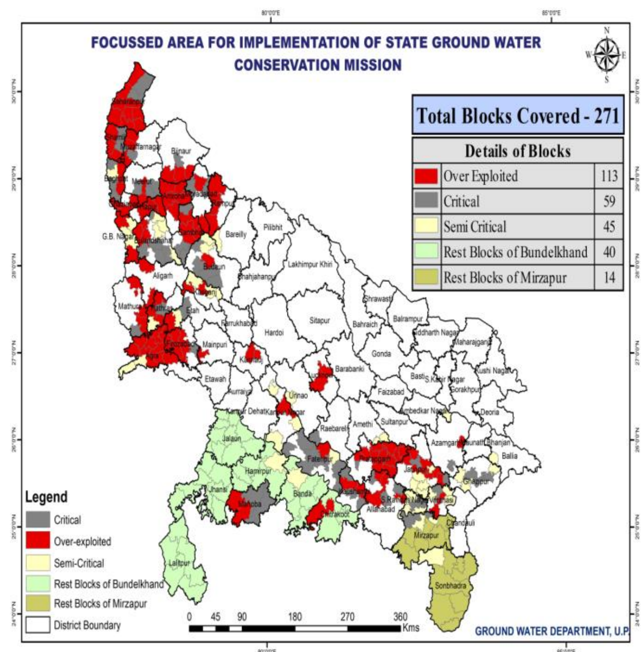
| SN | Yr | BLOCKS | | | | | |
|---|---|---|---|---|---|---|---|
| | ↓ | ARAZI-LINE | | BARA-GAON | | CHIRAI-GAON | |
| ↓ | | A | B | A | B | A | B |
| 1 | 2009 | 16.45 | 15.40 | 10.00 | 9.75 | 11.68 | 8.50 |
| 2 | 2010 | 18.56 | 16.45 | 12.31 | 9.67 | 11.64 | 9.70 |
| 3 | 2011 | 18.24 | 12.79 | 11.75 | 9.44 | 12.05 | 8.76 |
| 4 | 2012 | 16.48 | 16.48 | 11.85 | 10.70 | 13.32 | 11.95 |
| 5 | 2013 | 15.53 | 11.04 | 10.88 | 8.63 | 13.06 | 9.53 |
| 6 | 2014 | 15.28 | 12.65 | 9.58 | 7.68 | 10.60 | 7.91 |
| 7 | 2015 | 15.58 | 13.92 | 10.63 | 10.63 | 11.46 | 8.20 |
| 8 | 2016 | 15.13 | 10.40 | 12.84 | 7.78 | 12.73 | 9.08 |
| 9 | 2017 | 14.42 | 10.92 | 10.30 | 8.39 | 10.96 | 9.16 |
| 10 | 2018 | 17.54 | 10.71 | 11.44 | 9.22 | 12.04 | 8.85 |

Table A 2

| SN | Yr | BLOCKS | | | | | |
|---|---|---|---|---|---|---|---|
| | ↓ | CHOLA-PUR | | HARHUA | | VIDYA-PEETH | |
| ↓ | | A | B | A | B | A | B |
| 1 | 2009 | 6.89 | 3.80 | 11.41 | 9.01 | 11.42 | 11.11 |
| 2 | 2010 | 7.27 | 5.13 | 11.54 | 9.83 | 11.67 | 11.13 |
| 3 | 2011 | 8.36 | 4.30 | 11.56 | 10.77 | 10.77 | 10.17 |
| 4 | 2012 | 9.18 | 6.62 | 12.55 | 11.29 | 11.13 | 9.88 |
| 5 | 2013 | 8.89 | 5.14 | 13.01 | 10.60 | 10.71 | 8.97 |
| 6 | 2014 | 8.42 | 5.69 | 13.04 | 12.43 | 10.69 | 7.68 |
| 7 | 2015 | 7.55 | 4.81 | 13.40 | 11.97 | 11.05 | 9.68 |
| 8 | 2016 | 9.18 | 4.76 | 14.72 | 11.46 | 11.75 | 6.03 |
| 9 | 2017 | 7.79 | 5.95 | 13.82 | 13.13 | 11.18 | 8.95 |
| 10 | 2018 | 9.22 | 5.88 | 15.07 | 14.40 | 14.15 | 10.53 |

Table A 3

| SN | Yr | BLOCKS | | | |
|---|---|---|---|---|---|
| | . ↓ | PINDRA | | SEWA-PURI | |
| ↓ | | A | B | A | B |
| 1. | 2009 | 9.13 | 9.69 | 13.04 | 12.20 |
| 2. | 2010 | 10.77 | 9.45 | 15.16 | 12.60 |
| 3. | 2011 | 10.34 | 7.44 | 14.31 | 11.88 |
| 4. | 2012 | 9.86 | 7.66 | 13.21 | 12.27 |
| 5. | 2013 | 9.98 | 6.49 | 13.10 | 10.00 |
| 6. | 2014 | 8.81 | 7.03 | 12.25 | 10.17 |
| 7. | 2015 | 9.07 | 7.23 | 13.36 | 11.82 |
| 8. | 2016 | 13.35 | 3.62 | 14.46 | 7.56 |
| 9. | 2017 | 9.89 | 6.06 | 12.38 | 9.73 |
| 10. | 2018 | 14.36 | 7.49 | 13.55 | 10.64 |




***