Optimizing Rainwater Harvesting and Design Strategies for Diverse

Housing Structures: A case study for Yedenipani Village (A Review)

R. C. Chandanshive[1], G. N. Kanade[2], Aarya Patil[3], Pranjali Desai [4], Prajakta Shinde [5], Neha Chavan[6], Disha Kamalakar [7]

[1,2] Asst. Professors Department of civil Engineering Tatyasaheb Kore Institute of engineering and Technology, Warananagar

[3,4,5,6,7] UG Students Department of civil Engineering Tatyasaheb Kore Institute of engineering and Technology, Warananagar

***Abstract*— Summer water scarcity poses a serious difficulty in Yedenipani Village, especially in Ward No. 1, where borewell productivity is low (<10 LPM) and groundwater levels are falling due to over-extraction. The optimization of rooftop rainwater harvesting (RWH) systems as a sustainable way to replenish home borewells is investigated in this study. The study intends to build recharge structures without storage tanks for 50 homes, taking into account the unique hydrogeological features of the area, such as the laterite soil properties**

To determine the recharge potential, the methodology uses population data, soil data from GSDA, and data analysis from groundwater prospect maps. The study assesses the effectiveness and viability of putting RWH systems in place for sustainable groundwater management, taking into account an average of 615 mm of rainfall per year. This study emphasizes the potential of community-based solutions to enhance water security in rural regions and offers a framework for optimizing RWH systems to handle seasonal water shortages.

***Index Terms*—Borewell recharge, Hydrogeological assessment, Rainwater harvesting, Recharge pit, Rural water management.**

I. INTRODUCTION

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth .Water is one of nature's greatest gifts and has been providing substance to life on Earth for millions of years. We need water for all our activities in day-to-day life. Water is the basic human need which is felt more acutely in the drought condition being faced by the country. It is most important that the water which people drink and use for other purposes is clean water. This means that the water must be free of germs and chemicals and be clear.

India is one of the well endowed countries in terms of primary source of water. India is currently, under no such stress; however, it is expected to become a moderate water scarce country by 2050. India is a developing country which needs water for its increasing population and economy. It is being projected that water demand in India is going to be as high as 24% by 2025 and 74% by 2050.Water is being always in high demands by people. If this demand is not met, then it will lead to water scarcity. Water scarcity is a major problem faced by the world. In India there is increasing demand of water because of growing population and rapid industrialization is unavoidable. Water scarcity in India is due to both natural and human-made causes. Main factors that contribute to water issues include poor management of resources, lack of government attention, and man-made waste. Also, due to less or no rainfall people faces the problem of water scarcity and drought condition.

Water supply agencies are unable to meet demand from existing surface sources, particularly during the summer, due to large regions' greater water usage and overpopulation. As a result, homeowners are already drilling their own tube wells. In order to enhance the water supply, even water service agencies have turned to ground water sources by drilling tube wells. Paving across open spaces significantly reduces groundwater replenishment. Due to indiscriminate groundwater exploitation, the ground water table (GWT) is lowered, drying out many bore wells and prompting the drilling of deeper bore wells.[2]

A method of collecting and depositing rainwater for later use before it reaches the aquifer is known as rainwater harvesting.

Rainwater harvesting was employed for irrigation by farming people in Baluchistan and Kutch around the third century BC. Rainwater harvesting became mandatory in Tamilnadu. Rainwater harvesting is the process of gathering rainfall from a building's roof, surrounding open spaces, farmlands, etc., and either storing it for later use or directing it to an existing well for replenishment. Subterranean and aboveground water tanks are the two types that are typically used.

One of the various strategies to satisfy the increasing demand for water is the installation of Individual rainwater harvesting devices. Rainwater collecting is a sustainable way to deal with problems caused by big projects that use methods for centralised water management. Global population expansion is leading to similar issues and worries about how to provide everyone with clean water. The inexpensive substitute, commonly known as "Rain Water Harvesting" (RWH), is currently growing in popularity.The process of directly collecting rainfall and storing it for later use or recharging it into the groundwater is known as water harvesting. The process of collecting runoff for beneficial purposes has been identified as water harvesting.[1]

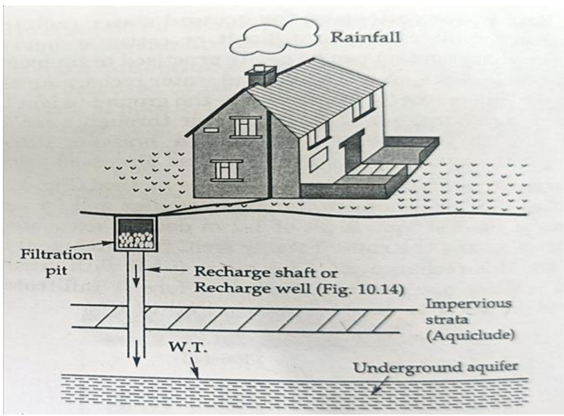


Fig.1.RECHARGING BOREWELL THROUGH ROOFTOP RAINWATER HARVESTING

(Source- Water Supply Engineering by S. K. Garg)

1.1 Need for Rooftop Rain Water Harvesting:

1. To meet the ever increasing demand for water.

2. To reduce the runoff which chokes the storm drains.

3. To avoid flooding of roads.

4. To augment the ground water storage and control decline of water levels.

5. To reduce ground water pollution.

6. To improve the quality of ground water.

7. To supplement domestic water requirement during summer, drought etc.

1.2 Advantages of Rooftop Rainwater harvesting:

a) One of the appropriate options for augmenting ground water recharge/storage in urban areas, where natural recharge has been considerably reduced due to increased urban activities and not much land is available for implementing any other artificial recharge measure. In rural areas also, rooftop rainwater harvesting can supplement the domestic requirements.

b) Rainwater runoff, which otherwise flows through sewers and storm drains and is wasted, can be harvested and utilized.

c) Helps in reducing the frequent drainage congestion in urban areas where fast rate of urbanization has reduced availability of open surfaces.

d) Recharging of aquifers with harvested water improves the quality of groundwater through dilution.

e) The harnessed rainwater can be utilized when needed at the time and place of scarcity.

f) The structures required for harvesting are simple, economical and Eco-friendly.

g) In coastal areas over extraction of groundwater leads to saline water ingress. Therefore, recharging of ground water aquifer in such areas helps to control saline water ingress.

h) Storing of harvested water underground through aquifer recharge. Wherever feasible, is advantageous as such storage is not exposed to evaporation and pollution. Aquifers serve as a distribution system as well supplying water when required.

II. LITERATURE REVIEW

A review of the literature on rainwater harvesting was conducted. Information on the use, function, and maintenance of water collecting systems was gathered using subjective research techniques. In order to examine experiences from water harvesting projects that have recently been realized by various organizations worldwide, an initial research of auxiliary information was conducted, including various publications, papers, regulations, and strategies.

The articles below were extracted from websites like the African Journals of Management, the Tata Institute of Social Sciences, the Journal of Cleaner Production, Research Gate, the Central Ground Water Board, the Universal Journal of Environmental Research and Technology, the Journal of Environmental Management, the Center for Science and Environment, the International Soil and Water Conservation Research, the International Journal of Scientific & Engineering Research, and the Journal for Contemporary Research In Management.

According to Patel et.al.(2015) "Rainwater Harvesting- A Case Study of Amba Township, Gandhinagar" It was observed that an annual yield of 1,46,27,284 liters of water could potentially be obtained. Acknowledging the significance of rainwater harvesting was recommended as one of the most logical steps toward this objective. This approach should encompass not only rooftop rainwater harvesting but also stormwater harvesting systems. Thus, an equal and positive thrust was deemed necessary for the development and encouragement of water harvesting systems. The need to capture water wherever and whenever it falls was emphasized. The findings suggested that rainwater, if conserved and utilized through rainwater harvesting technology, could serve as an effective tool for replenishing groundwater resources. The total amount of rainwater that could be harvested annually was estimated to be 1,46,27,284 liters, which would constitute 29.68% of the total water demand. Therefore, it was proposed that rainwater harvesting methods could enable the storage of rainwater into ground aquifers or percolation wells.

According to Pawar et.al. (2014) "A case study of rooftop rainwater harvesting of Renavi village in Sangli District of Western Maharashtra: New approach of watershed development in India"In this article, the success story of rooftop rainwater collection in Renavi a village, located in the Sangli region of western Maharashtra, is presented. The village's potential assessment showed that, in about 20 days, lakhs of liters of water collected from rooftops would be sufficient to meet the needs of a population of 1,300 people for at least 78 days. According to United Nations guidelines, this estimate was made. Government organizations and villages contributed a total of Rs. 6,04,000 to fund the rainwater gathering scheme, which is based on rainfall data. The area's runoff coefficient is calculated. After estimating the number of homes with and without roof-top rainwater collecting systems, the ground water quality was evaluated from the bore and open wells. This study came to the conclusion that rainwater gathering techniques help to meet household water needs while also raising groundwater levels by a few meters. However, the amount of fluoride in ground water was higher than allowed in several Indian states, including Andhra

In the Jagatsinghpur district of Odisha, in the Mirjita village of the Tirtol block, R. R. Mohanty et al. (2018) conducted a study in a household. Their analysis took into account the rooftop rainwater gathering technique. The region receives 1436 mm of rain on average each year, however the groundwater is of low quality because of seawater intrusion and high iron levels in the water. Therefore, the roof-top rainwater harvesting method was taken into consideration in order to reduce reliance on ground water and to make use of the rainwater. Meteorological stations provided the rainfall data, and a metric tape was used to measure the building's roof. 280 m2 is the estimated total rooftop area of the household. There were six people living in that household overall. The Gould formula was used to determine the rainwater gathering potential. Rainwater harvesting potential is calculated by multiplying the average annual rainfall by the runoff coefficient and catchment area. By using the average annual rainfall of 662.32 mm and the coefficient of runoff of 0.80, it was determined that the amount of water collected from the rooftop was 148.32 m3. The rooftop water can be collected and stored in a sump, which can then be used for plant watering and household use. In order to allow them to be used for consumption in that household, the study attempts to determine the amount of rainwater collected.

Rainwater harvesting plan and design for the Mangalayatan University campus was carried out by Harit Priyadarshi et al. (2018). Rooftop rainwater harvesting, which is regarded as a catchment region of the Mangalayatan University Campus in Aligarh, is the technical focus of this paper. The facility, which has more than 250 employees and roughly 2700 students, is located 39 kilometers from Aligarh city on a vast 72-acre plot of land. The necessary information is gathered and computed, including catchment regions, rainfall data, runoff, groundwater conditions, etc. After that, a recharge pit with the right size and shape is built. Using the hydrological analysis of the available data, the recharge pit's ideal position was determined. The project's cost is also computed. This study was shown to be both cost-effective and highly beneficial for replenishing groundwater in order to preserve it.

At SPSU Udaipur, Avinash Ojha and Lokesh Gupta (2016) conducted research on the design of a rainwater collecting system. The design of the rainwater harvesting system at Sir Padamapat Singhania University (SPSU), Udaipur, is the primary focus of this research project. This also covers the layout of abandoned bore wells or wells that have been dug for recharging. In order to replenish a dug well or an abandoned bore well, this system will gather water from the roof and transport it all the way up. The facility's operating expenses are essentially insignificant. Utilizing and designing roof-top RWH and conservation techniques is the study's goal in order to lessen the overuse of natural fresh subterranean water Resources.Rainwater harvesting systems can be installed in the area between Udaipur and Vallabhnagar tehsil because of the abundant rainfall that occurs there each year.

The findings of the research on rainwater harvesting (RWH) in central northern Namibia, which is a component of the transdisciplinary research project CuveWaters, were presented by Sturm.M et al. in their paper Rainwater Harvesting as an Alternative Water Resource in Rural Sites in Central Northern Namibia. Appropriate solutions for RWH are produced, discussed, and assessed based on hydrological, technological, social, and cultural factors. Analyzing their technical and financial viability as well as their affordability for potential users is the primary goal. Two small-scale RWH systems—ground catchments with treated ground surfaces and roof catchments with corrugated iron roofs as rain collection areas—are thoroughly investigated.

In 2018, Prof. S.J. Yadav and Dr. P.D. Sabale conducted a case study on Junnar Tahsil. In Nimgaon village, they designed the rooftop rainwater harvesting system. Rainwater harvesting from rooftops, which are regarded as catchment areas, is the technological component of this project.The project's goal is to gather, store, and use the water by offering appropriate filtration methods. They estimate the dimensions of the roof catchment area and carry out appropriate field planning work in Nimgaon to accurately picture the village's predicament.following the collection of the necessary data, such as temperature and hydrological rainfall data. They use physical, biological, and chemical taste tests to sample the gathered water. They give the residents of Nimgaon village a shared water tank.Prior to design, the village's water harvesting potential was estimated. The filter unit, which will be designed to be inexpensive, efficient, and possible to implement in the village or globally, is the project's key component

III. METHODOLOGY

3.1 Problem statement

The image is a *Ground Water Prospect Map* for YedeNipani village, located in the Sangli district, Walwa taluka. The map categorizes the area's groundwater potential using various colors, each representing different groundwater yield capacities. This information is helpful for understanding groundwater availability and planning water resources in the area.

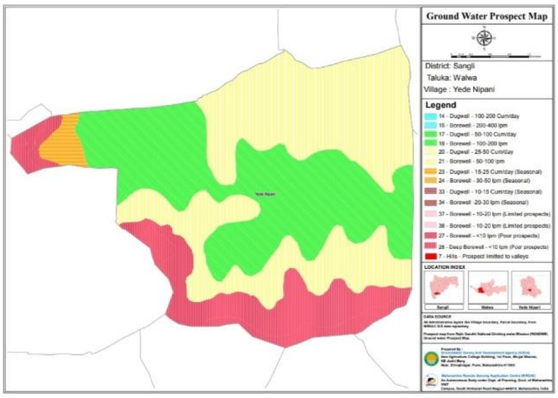


Fig.2 GROUND WATER PROSPECT MAP (Source – GSDA)

The red portion in this map signifies areas with *Deep Borewell <10 lpm (Poor Prospects)*. This means:

- Low Groundwater Yield**:** Borewells in this area are likely to produce less than 10 lpm, making it challenging to rely on them for water needs.
- Poor Water Prospects**:** The red zones are marked as areas with poor groundwater recharge potential. This aligns with low water tables and possibly low infiltration rates.

- High Dependency on Alternatives**:** Due to the low yield in these areas, alternative methods, such as rainwater harvesting or water conservation techniques, are essential to ensure water availability, especially in dry seasons.

3.2 Objectives

Present work is having following objectives

1) To investigate Yedenipani village's potential for rainwater harvesting.

2) To comprehend how people can participate in rooftop rainwater gathering through collective action.

4) To determine an appropriate harvesting system design.

5) To implement Yedenipani village's most effective and efficient rooftop rainwater collection system.

6) To recharge the rooftop water that has been collected in order to elevate the subsurface water table.

7) To research the filter unit and water tank designs.

8) To stop the fall of ground water and raise the ground water table.

9) To improve aquifer water quality.

3.3 Study area

This project aims to optimize rainwater harvesting designs for Ward No. 1 of Yedenipani Village, which faces groundwater depletion and limited borewell productivity (<10 LPM). Focusing on recharge structures without storage tanks, the project seeks to use rooftop rainwater to replenish household borewells, specifically in areas with low groundwater prospect.

Fig. 3 YEDENIPANI VILLAGE (SOURCE – Google Earth)

Above map shows Yedenipani Village Located in Walwa Tehsil Dist. Sangli

With 17.5539 Latitude and 74.1434 Longitude

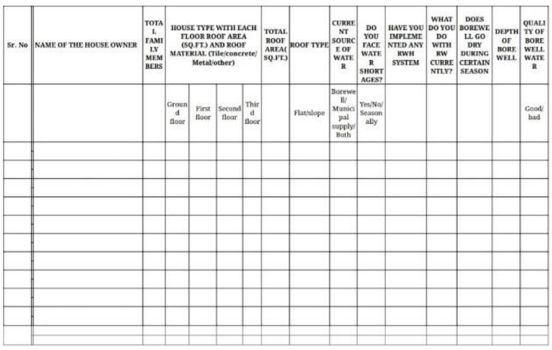
3.4 Data collected

Collected population and household data for Ward No. 1, including roof area measurements for rainwater collection.

Acquired and analyzed rainfall data for the region, noting trends that will inform design for both average and low-rainfall years.

Studied the groundwater prospect and soil data maps from GSDA to identify viable locations for recharge pits.

Conducted calculations on potential recharge volume per household based on roof area, rainfall, and soil characteristics. For example, estimated recharge volumes were derived by calculating potential water collection for each household roof area during the rainy season.



Sr. No	NAME OF THE HOUSE OWNER	TOTAL FAMILY MEMBERS	HOUSE TYPE WITH EACH FLOOR ROOF AREA (SQ.FT.) AND ROOF MATERIAL (Tile/concrete/ Metal/other)				TOTAL ROOF AREA(SQ.FT.)	ROOF TYPE	CURRENT SOURCE OF WATER	DO YOU FACE WATER SHORTAGES?	HAVE YOU IMPLEMENTED ANY RWH SYSTEM	WHAT DO YOU DO WITH RW CURRENTLY?	DOES BOREWELL GO DRY DURING CERTAIN SEASON	DEPTH OF BORE WELL	QUALITY OF BORE WELL WATER
			Ground floor	First floor	Second floor	Third floor		Flat/slope	Borewell/ Municipal supply/ Both	Yes/No/ Seasonally					Good/ bad

Fig.4 QUESTIONNAIRE FOR VILLAGERS

TABLE 1 RAINFALL DATA FOR WALWA TEHSIL

Sr.No.	Year	Average Rainfall (mm)
1	2014	665
2	2015	196
3	2016	733
4	2017	190
5	2018	665
6	2019	1918
7	2020	731
8	2021	603
9	2022	553
10	2023	605

The chart represents the average annual rainfall data for Yedenipani village from 2014 to 2023, showcasing significant fluctuations in rainfall over the years. Key observations include:

Highest Rainfall: The year 2019 recorded the highest rainfall at 1918 mm, a substantial increase compared to other years.

Lowest Rainfall: The lowest recorded rainfall occurred in 2015, with only 196 mm, indicating a very dry year.

General Trend: The data reflects irregular rainfall patterns, with alternating periods of low and high rainfall. For instance, 2015 and 2017 show very low rainfall (below 200 mm), while 2016 and 2020 show comparatively higher values (above 700 mm).

The average annual rainfall over this period is 635.9 mm. This average suggests that the village generally experiences moderate rainfall, though year-to-year variability is notable, impacting water resources and emphasizing the need for efficient water management strategies, such as rainwater harvesting, to cope with these fluctuations.

3.5 Total precipitation calculation

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area. And the amount that can be effectively harvested is called the water harvesting potential. The formula for calculation for harvesting potential or volume of water received or runoff produced or harvesting capacity is given as:-

Harvesting potential or Volume of water Received (m^3)
= Area of Catchment (m^2) X Amount of rainfall (mm) X Runoff coefficient

Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. Runoff coefficient accounts for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all contribute to reducing the amount of runoff. Runoff coefficient varies from 0.5 to 1.0. Eco-Climatic condition (i.e. Rainfall quantity & Rainfall pattern) and the catchment characteristics are considered to be most important factors affecting rainwater Potential. As in present study the roof area is of concrete so, we have taken runoff coefficient as 0.85

3.6 Recharge volume estimation

Recharge volume estimation is going to be done by considering the soil properties and total amount of water which is going to be collected

The soil which is in Yedenipani due to village being in hilly area is Laterite type, so void ratio considered for ground water recharge estimation is 0.5

Size and shape of recharge structure is also to be determined according to above properties

3.7 Water filtration

As water is going to be discharged directly to already existing borewells dug by villagers the water should be clean so that it should not contaminate already existing underground water resource.

Some studies have stated that adding rainwater to the borewell decreases salinity of borewell water (8)

We are going to test the water from rooftop, borewells as well as current source of groundwater for villagers i.e. well and suggest and design required filtration systems

IV. RESULT AND DISCUSSION

Various rainwater gathering techniques from recent studies conducted worldwide were used in the current scenario. Sangli district in Maharashtra state is the area we have chosen. These study articles contained all the information that was required for our endeavor.

Rainfall is currently the primary and best source of fresh water. Rainwater collection would be successful if there was greater understanding about this. Rainwater harvesting systems provide water for a variety of uses, such as cooking, drinking, cleaning, flushing toilets, cleaning floors, fish tanks, and gardening. To achieve these uses, the rainwater must be treated to remove contaminants and heavy metals, and it requires filtration and disinfection.

By researching every method, design, we will create an effective rooftop rainwater system with upkeep and discipline. The contents of this rooftop rainwater harvesting system include ground water recharging. The filter media design would be effective rainwater harvesting that can be easily implemented anywhere in the world to help with the summer water crisis

V. ACKNOWLEDGEMENT

We are grateful to our guides, Prof. R.R. Chandanshive Sir and Prof. G.N. KANADE Sir, for their support and advice. We are incredibly appreciative of their unwavering support and direction. We are also grateful to our department and our HOD, Dr. D.M. Patil Sir, for their support and direction, without which we could not have finished the project report. We are also appreciative that the Yedenipani Grampanchayat gave us permission to carry out this project in their community.

VI. REFERENCES

[1] ”Rainwater Harvesting-A Case Study of Amba Township, Gandhinagar” National conference on “Transportation and Water resources Engineering"

[2] A case study of rooftop rainwater harvesting of Renavi village in Sangli District of Western Maharashtra: New approach of watershed development in India (IJERT)ISSN: 2278-0181 IJERTV7IS040402 Vol. 7 Issue 04, April-2018

[3] NEW APPROACH IN RAIN WATER HARVESTING THROUGH ROOFTOP WATER MANAGEMENT TECHNIQUE-CASE STUDY

[4] Rain Water Harvesting Plan and Design for Mangalayatan University Campus, Aligarh” Uttar Pradesh, India” Harit Priyadarshi Int. Journal Research and Application ISSN:2248-9622, Vol.8, Issue5(Part-III) April 2018, ppl18-28

[5] DESIGN OF RAIN WATER HARVESTING SYSTEM AT SPSU UDAIPUR Avinash Ojha*, Lokesh Gupta (IJESRT) ISSN: 2277-9655

[6] Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia

[7] Review on Design of Rooftop Rainwater Harvesting in Nimgaon Village- A Case Study of Junnar Tahsil (IJERT) ISSN:2278-0181 Vol.7 Issue 04, April-2018

[8] Rainwater Harvesting through Point Recharge Method for Efficient Recharge of Tube Wells for Sustainable Management of Groundwater Resources in Karnataka

[9] Shiras Preeti P., Maske Nikhil A., “Design And Analysis Of Rooftop Rainwater Harvesting System For Y.C.C.E. Campus”, IJARSE, Vol.3 Issue 1, Sept.-2014, 44-54.

[10] Solanki Nikunj,HulsureVishal, “Rain Water Harvesting in KJCOEMR at KJEI Campus, Pune”, International Journal Of Modern Trends In Engineering And Research Volume 2, Issue 7, 2-4 July-2015,794-801.

[11] Government of India, Ministry Of Water Resource, “Master Plan For Artificial Recharge To Ground Water In India”, Central Ground Water Board, 2013.

[12] Kumar Rohitashw, Thaman S., Agarwal G., Sharma Poonam, “Rainwater Harvesting and Ground Water Recharging in North Western Himalayan Region for Sustainable Agricultural Productivity” Universal Journal of Environmental Research and Technology, Vol. 1, Issue 4, 2011, 539-544.

[13] Artificial recharge guide by CGWB