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Groundwater Recharge by Percolation Pit in Semi-Arid Region

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***Abstract*— The research work explores the practicality and efficiency of percolation pits in addressing the critical issue of declining groundwater level water scarcity and declining groundwater levels are pressing challenges in many regions. This research work focuses on the development and implementation of percolation pits as a sustainable method for groundwater recharge. We examine the hydrogeological aspects, construction techniques, and community engagement strategies to promote the adoption of percolation pits. Our research underscores the potential of percolation pits to replenish aquifers, enhance water security, and contribute to a greener and more sustainable future. Saurashtra Region, also known as the Kathiawar Peninsula, is selected as the study area, constitutes the western part of the state of Gujarat, India. It is characterized by a semi-arid climate that extends towards the Arabian Sea, making it susceptible to water scarcity issues. The research begins with a comprehensive assessment of specific gravity, a fundamental property of soil. By evaluating the specific gravity, we gain insight into the soil's density and composition, crucial factors in determining its suitability for percolation pit construction.**

Further, compute runoff quantity for the study area, velocity of suspended soil particles, standardize a filter material, and finally present a sustainable design of a percolation pit for aquifer recharge.

***Keywords*— Groundwater Recharge, Percolation Pit, Bore well Recharge technique, Saurashtra, Semi-arid region**

I. Introduction

India, in particular, finds itself at the corner of a significant water crisis. The excessive extraction of groundwater, coupled with intensive irrigation practices in major canal systems, presents a substantial threat to groundwater reserves. Reports indicate a startling decline in water tables, receding at a rate of 1-2 meters annually in various regions of the country CGWB 2011[5]. This, in turn, has led to a significant reduction in rainwater absorption into the subsoil, causing a gradual decline in groundwater recharge over time.

Nevertheless, various attempts are in progress to harness and revive underground water resources in response to the growing demands for water supply, especially over the past decades. Among the various approaches employed, percolation pits have consistently emerged as one of the most efficient techniques [4].

The management of groundwater resources in many parts of the country is witnessing the rapid depletion of groundwater resources, a situation driven by cooperation of factors including population growth, urbanization, industrial expansion, and the specter of climate change. At present, nearly one-fifth of the world's water supply is drawn from underground sources, with agriculture leading as the most efficient water consumer, utilizing 75% of the total[7].

Artificial Groundwater is the most effective way to battle the existing scarcity in the Saurashtra region. Groundwater water being recharged by natural and artificial processes. Any man-made facilities that add water to an aquifer may be considered as artificial ground water recharge (CGWB 1994, CGWB 2007) [2],[3]. Artificial groundwater recharge techniques include surface spreading techniques (Ditch and furrow, percolation pond, nala plugging and check dam, etc.) and subsurface techniques (injection well, gravity head recharge well, Percolation pits and shaft (CGWB 2020) [6]. A check dam is one of the most effective techniques to recharge the groundwater for an unconfined aquifer [9].

One promising solution to this problem is water recharge by a percolation pit [1]. This approach involves collecting rainwater from catchment areas or rooftops and directing it into percolation pits or recharge wells. These structures are designed to facilitate the natural filtration and seepage of rainwater, effectively replenishing groundwater aquifers [8]. This problem statement highlights the urgency and complexity of the issue, setting the stage for further research and the development of effective solutions for sustainable groundwater management in semi-arid regions.

II. METHODOLOGY

A. Determination of Ground Recharge Zone.

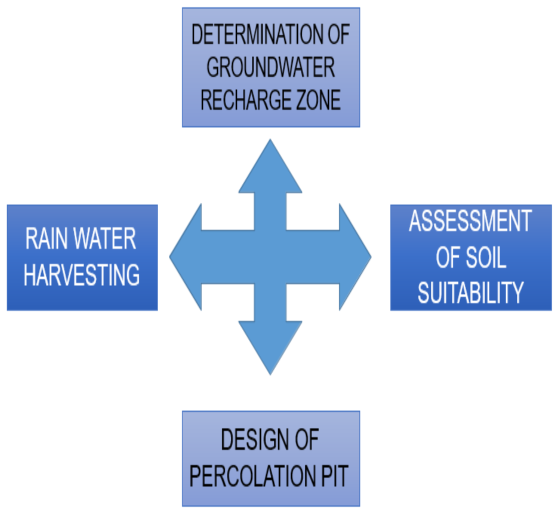

Fig. 2 Methodology of research work

Saurashtra Region, also known as the Kathiawar Peninsula, constitutes the western part of the state of Gujarat, India. It is characterized by a semi-arid climate that extends towards the Arabian Sea, making it susceptible to water scarcity issues. This climatic condition is characterized by infrequent and insufficient rainfall, indicating the necessity for effective groundwater recharge solutions. Agriculture serves as a primary economic activity in Saurashtra, heavily dependent on groundwater for irrigation. The critical nature of groundwater recharge in sustaining agriculture and averting the over-exploitation of aquifers cannot be overstated. The Excessive Use of groundwater for agricultural and other purposes has resulted in the decrease of water tables and the intrusion of saltwater into coastal aquifers within specific areas of Saurashtra. The government of Gujarat, including the Saurashtra region, has launched various water management attempts aimed at facilitating groundwater recharge. These attempts include incentives for the installation of rainwater harvesting systems, the construction of check dams, and the adoption of diverse strategies to rejuvenate groundwater resources [6].

Some of the Challenges in the region include uneven rainfall distribution, inadequacies in water storage infrastructure, and a rapidly growing population, all of which place a strain on the availability of water resources.

Groundwater recharge projects are specifically adapted to address these challenges and establish a foundation for water security. Importantly, numerous groundwater recharge projects in Saurashtra actively involve local communities and farmers, recognizing that community participation is often pivotal to the success of such initiatives.

In Gujarat State, water availability has significantly improved, benefiting 165 towns and 8911 villages with access to piped water as of March 2019. Nevertheless, achieving universal access to clean and reliable water sources remains an ongoing challenge. Rajkot is located in Gujarat and is characterized by the traits of a semi-arid climate. Unpredictable monsoons deliver an average annual rainfall of roughly 590 mm, creating the need for innovative water management to address water scarcity, particularly during the arid months. A promising solution to ease the reliance on groundwater in areas heavily dependent on it is rainwater collection. This practice, which harvests rainwater, serves as a sustainable method to fortify water supplies, thus reducing the strain on groundwater reserves. Rajkot's summers are characterized by scorching temperatures, ranging from 24 °C to 42 °C. This underscores the indispensable role of secure and clean water access for both daily life and agricultural endeavors. Initiatives such as the "Master Plan for Artificial Recharge to Groundwater in India 2020" are instrumental in tackling the water challenges confronting Gujarat State.

B. Assessment of Soil Stability

The most suitable areas to construct a percolation pit at Marwadi University Campus are;

- Near an existing Borewell, due to the constant use of groundwater at that particular location, it may be depleted, and so it needs to be replenished.
- At an Agricultural Field- To irrigate crops throughout the year, a constant supply of water is required, and so a percolation pit and borewell, in proximity, are needed to function hand in hand. None of the areas mentioned above benefits from any groundwater recharge technique, and this is a concern as we may inevitably face a groundwater depletion crisis in the near future. For that reason, soil samples were collected from the stated locations and tested for suitability for the construction of a percolation pit.

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Sample 1 to be tested in the Laboratory

Sample 2 to be tested in the Laboratory

III. Collection Of Soil Samples From The Study Area

A. Testing of Soil Samples In the Laboratory

The following tests were carried out to determine the percolation rate and filtration efficiency. In a case where a percolation pit is to be constructed at either of the study areas under consideration. Also, Specific gravity test and Sieve analysis test were conducted for the determination of velocity for suspended soil particles using Stokes' law.

Specific Gravity Test: It is a fundamental assessment used to evaluate the soil for its suitability in the construction of a percolation pit. The specific gravity of soil helps us in: Selection of material for the construction of the percolation pit, Determining Soil Density, Estimating the percolation rate through the calculation of porosity, Avoiding Clogging *of the percolation pit, etc. The Pycnometer Apparatus was used to determine the specific gravity of soil. The specific gravity of Sample 1 and Sample 2 is 2.33 and 2.6, respectively.*

Particle Size Distribution Test: This is done by sieve analysis, which allows us to comprehensively examine the particle size distribution within a given sample. The particle size distribution of soil helps us to: Assess the infiltration capacity of the soil; Determine the Size and depth of the percolation pit.

The Set of Indian Standard sieves (4.75mm,2.36mm,600µ,300µ,150µ, and pan) apparatus is used. Calculate the percentage passing for each sieve by dividing the mass passing the sieve by the total mass of the sample (100 - % retained). Create a particle size distribution curve by plotting the percentage passing against the sieve sizes on a semi-logarithmic graph. From the obtained results, the particle distribution curve of the two samples where plotted on Microsoft Excel. From fig.3, the values D10, D30, and D60 are determined that be 0.225, 0.6, and 1.8, respectively. From Fig. 4, the values of D10, D30, and D60 are determined that be 0.735385, 1.412308, and 2.530714.

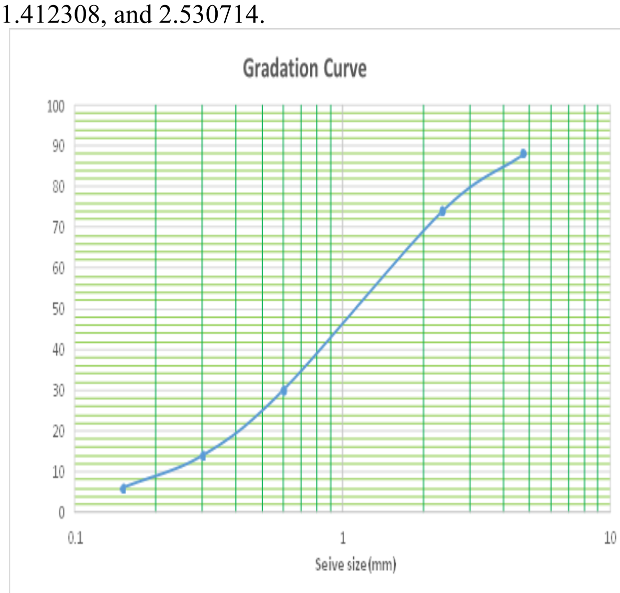

Fig. 3 Gradation curve

TABLE 1:
CALCULATION FOR PERCENTAGE FINER

Sample 1(Hostel B Borewell) Total mass of sample =500gm		**Sample 2(Agricultural field) Total mass of sample =500gm**	
Sieve Size (mm)	Cumulative passing (%)	Sieve Size (mm)	Cumulative passing (%)
4.75	88	4.75	86
2.36	74	2.36	58
0.6	30	0.6	6
0.3	14	0.3	3
0.15	6	0.15	1
pan	0	pan	0

TABLE 2:
CALCULATION FOR CU AND CC

Sample 1		Sample 2	
CU	8	CU	3.441348
CC	0.888889	CC	1.071769

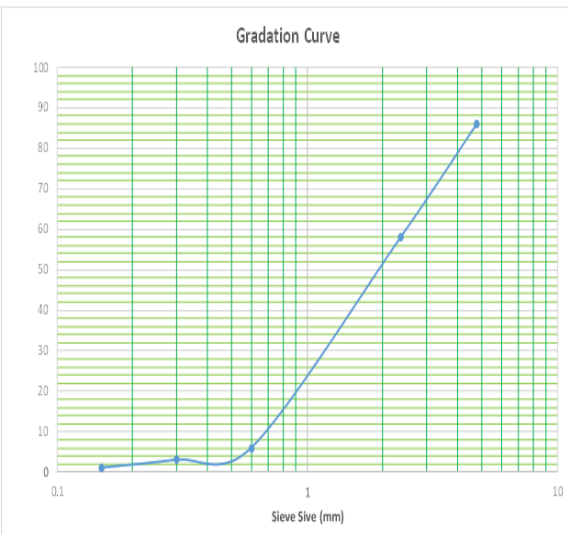

Fig. 4 Gradation curve for sample 2

For Sample 1, the particle size ranges from 0.225mm to 1.8mm. The Cc and Cu are 0.89 and 8, respectively. And for Sample 2, the particle size ranges from 0.735mm to 2.531mm. The Cc and Cu are 1.07 and 3.44, respectively. From the results analysis, it can be concluded that the area from which Sample 1 was collected is a more suitable field to construct a percolation pit. Because it is well-graded and has good drainage properties.

Percolation Test: It is used to assess the soil's ability to absorb water to determine the depth of the percolation pit. It is performed as per IS 2470-2 (1985). The apparatus, such as an auger, Bucket, measuring ruler, and stopwatch, was used to conduct this test. Dig a test hole of about 300mmx400mm, which is presented in Figure 5. The percolation rate of the soil helps us to: Determine the size of the percolation pit based on the soil's ability to absorb water; Align the design with the natural percolation capacity of the soil to prevent waterlogging or runoff.; Prevent unnecessary costs associated with the under-sizing or over-sizing of the percolation pit.

Fig. 5: Percolation Test Hole

Fig. 6: Saturation of soil

The next day, refill the hole to 300mm and observe how quickly the water seeps away. When the water level drops to 225mm full (75% full), start timing, in seconds, how long it takes the water to move 25mm below the 75% mark. That amount of time is taken as the percolation rate, and the test procedure is repeated to get accurate results. It took 317 seconds in the first trial and 333 seconds in the second trial. So an average value of 325 seconds is obtained as the percolation rate per 25mm.

IV. DESIGN OF PERCOLATION PIT

A. Determination of the Velocity of Suspended Soil Particles

Since particle sizes range from 0.225mm to 1.8mm in the soil sample. For particle size greater than 1mm $Vs = \sqrt{3.339g(G-1)d}$, where d=1.8mm, V_{max}=8.84 mm/s.

For particles 0.1- 1mm, where d=0.225mm

$$Vs = \frac{\sqrt{4g}}{3Cd}(G-1)d$$

$$Cd = \frac{24}{R} + \frac{3}{\sqrt{R}} + 0.34$$

Calculated velocities such as Vmin and Vavg are 2.25mm/s and 5.55×10^{-1} m/s, respectively.

B. Filter Materials Standardization

The head through which water passes was determined as H =V x t = 180cm. The depth of filter material was worked out as 150cm with 30cm as a head of standing water, which is essentially required for easy flow of water through the filtration unit.

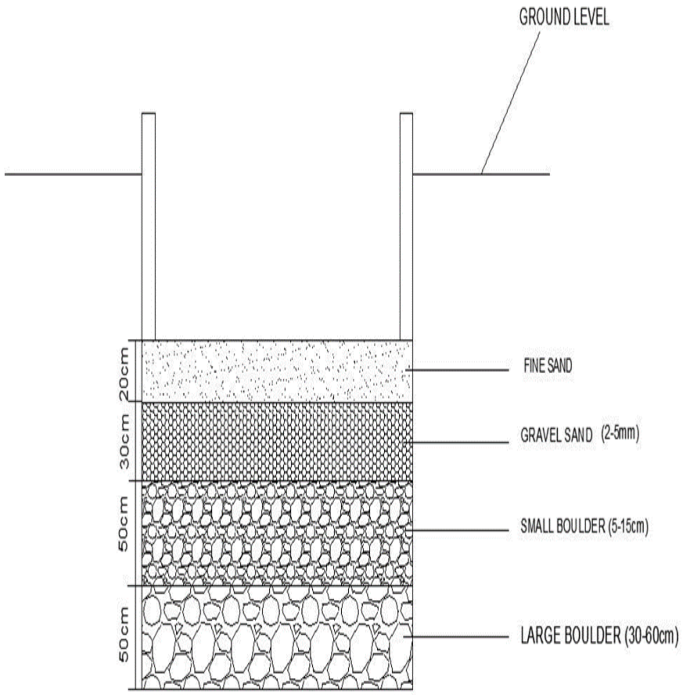

Fig. 7 Schematic view of Percolation Pit

The percolation rate obtained indicates that the site is suitable for the design of a percolation pit, as water can drain from the soil at a rapid rate. The soil exhibits a high capacity for water absorption, further supporting its suitability for percolation pit construction. These findings underscore the effectiveness of the chosen location in facilitating efficient groundwater recharge and minimizing water wastage.

V. Runoff Calculation

The runoff is calculated by use of the Runoff Coefficient Method equation.

Q = KP, where Q = Runoff in mm
P = Precipitation in mm
K = A constant having a value less than or at most equal to 1, depending on the imperviousness of the drainage area.

The most recent daily rainfall occurrences were documented at Marwadi University in 2023. On June 27th and July 10th, the heaviest rainfall amounts were observed, with 67.40 mm and 61.20 mm of precipitation recorded, respectively. In our research area, we will take our K value as 0.4, as it is classified as an urban area where 30% of it is impervious.

TABLE 3:
CALCULATION OF RUNOFF

Date	**Rainfall (mm)**	**Runoff (mm)**
27th June 2023	67.40 mm	26.96 mm
10th July 2023	61.20 mm	24.48 mm
TOTAL	128.60 mm	51.44m

VI. Conclusion

This research presented the design of a percolation pit for the selected study area. Further it is presented comprehensive assessment of specific gravity, a fundamental property of soil. By evaluating the specific gravity, we gain insight into the soil's density and composition, crucial factors in determining its suitability for percolation pit construction. The selection process is further refined through the analysis of particle size distribution, which enables us to categorize soil types based on their grain sizes. By understanding these characteristics, we can identify the optimal location for a percolation pit, taking into consideration soil permeability, infiltration efficiency, and percolation rates. The research work has demonstrated the potential replenishment of groundwater levels by allowing rainwater and runoff to infiltrate into the ground. The percolation not only conserves water but also improves its quality. The simplicity and cost-effectiveness of this approach make it suitable for widespread adoption in various regions.

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