Implementation of a village-wide Rainwater collection system

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Abstract. The design of facilities for rainwater harvesting systems is essential to harness a sustainable and valuable water resource. This abstract provides an overview of the key components and considerations involved in designing such facilities. It highlights the critical stages of catchment surface selection, gutter and downspout installation, storage tank design, filtration systems, distribution networks, and maintenance access. Additionally, it emphasizes the significance of legal compliance, sustainability, and community education in creating effective rainwater harvesting systems. The design process offers an opportunity to optimize rainwater utilization, conserve potable water sources, and promote environmental sustainability. This abstract serves as a starting point for engineers, architects, and communities seeking to implement efficient rainwater harvesting systems tailored to their specific needs and contexts.

Keywords. Rainwater harvesting, Facilities Design, Catchment Surface, Gutter and Downspout, Storage Tank, Percolation Pit

1. Introduction

Water scarcity is a progressively urgent global concern, intensified by climate change, population expansion, and fast urbanization. As these demands escalate, the necessity for sustainable and creative water management systems becomes critical. Rainwater collection, a time-honored technique, is emerging as a highly effective strategy in contemporary resource management. By capturing, storing, and utilizing rainwater, communities can reduce reliance on conventional water sources and establish more resilient systems to fulfill their water requirements. Rainwater harvesting entails the gathering of rainwater from surfaces like rooftops, roads, and open areas, followed by its storage for many applications, including home usage, irrigation, landscaping, and industrial purposes. Although the practice is not novel, its significance has increased in recent years as a sustainable method for mitigating water scarcity. Establishing a comprehensive rainwater harvesting system for the village signifies a proactive approach to climate adaptation, community resilience, and sustainable resource management. Designing and implementing such a system necessitates a thorough comprehension of local environmental conditions, technical proficiency, and community involvement.

The design process commences with the identification of catchment sites, usually rooftops or other impermeable surfaces, for the efficient collection of rainfall. The selection of these sites is essential for optimizing water capture, particularly in regions with fluctuating rainfall patterns. Essential elements like surface area, substance, and slope must be tuned to guarantee effective water collecting. Upon collecting, rainwater is channelled through gutters, downspouts, and conduits into storage systems. The meticulous design of these systems is crucial to avert water loss, contamination, or structural damage, hence guaranteeing the system's long-term efficiency. A vital element of the rainwater harvesting process is the first flush diversion system, which eliminates the early runoff that may transport pollutants from the catchment surface. This procedure markedly enhances the quality of the collected water, rendering it appropriate for diverse applications, especially in contexts demanding elevated water quality criteria. Based on its intended application, the water may after that undergo additional filtration and treatment operations to satisfy safety and quality standards.

The storage element of the system is of equal significance. Rainwater is generally collected in tanks, cisterns, or reservoirs, which must be adequately dimensioned to manage variations in rainfall and water consumption. In regions with seasonal precipitation, the storage system must be sufficient to retain adequate water for dry intervals. Furthermore, these storage facilities must be engineered to avert pollution, evaporation, and structural deterioration and ensure the water remains pure and accessible. After storage, the collected water must be conveyed to its final use locations through a distribution system. This system, whether gravity-fed or pump-assisted, guarantees the timely and effective delivery of water to houses, agricultural areas, or industrial sites. In certain instances, pressure regulators or more intricate systems may be required to address the particular demands of bigger or geographically varied regions.

A village-wide rainwater collecting system's effectiveness depends on its initial design, continuous maintenance, and community engagement. Regular inspections of catchment surfaces, gutters, and storage tanks ensure water quality and efficiency. Automated monitoring systems can improve efficiency by providing real-time data on water levels and usage trends. Community engagement during design, implementation, and maintenance fosters ownership and accountability, ensuring system sustainability. Educational initiatives emphasize water conservation and proper system utilization, enabling community members to oversee and sustain the system. A village-wide rainwater harvesting system reduces reliance on external water sources, mitigates drought effects, and strengthens climate change resilience. Meticulous system design, active community engagement, and education promote a sustainable, locally governed resource, fulfilling urgent water needs and fostering environmental preservation, financial efficiency, and improved quality of life.

1.1. Objective

The objective is to engineer pipelines for the effective conveyance of projected rainwater runoff and to construct percolation pits for natural aquifer replenishment. The pipeline system will facilitate efficient water transport, while the percolation pits will improve groundwater recharge, thereby supporting sustainable local water supplies.

1.2. Collection Procedure of Rain Water

Rainwater collected from rooftops can be managed in the following ways: a) Stored for direct use, b) Allowed to infiltrate for groundwater recharge, and c) A combination of storage and recharge. For this project, rainwater from public buildings such as parks and schools will be stored for direct use, primarily for domestic purposes. In contrast, rainwater from other houses and surface runoff from roads will be directed into percolation pits to facilitate groundwater recharge. To collect rainwater from sloping rooftops, lateral gutters (semi-circular pipes) will be installed to capture the rainwater and channel it to a common storage or recharge site. This water will then be transported through an underground pipeline network, ensuring efficient transfer to designated storage tanks or percolation pits, contributing to sustainable water management for the community.

Fig. 1. Figure showing sequence collection and conveyance of Rain Water

1.3 Design of Percolation Pit

1.3.1 Percolation Pit

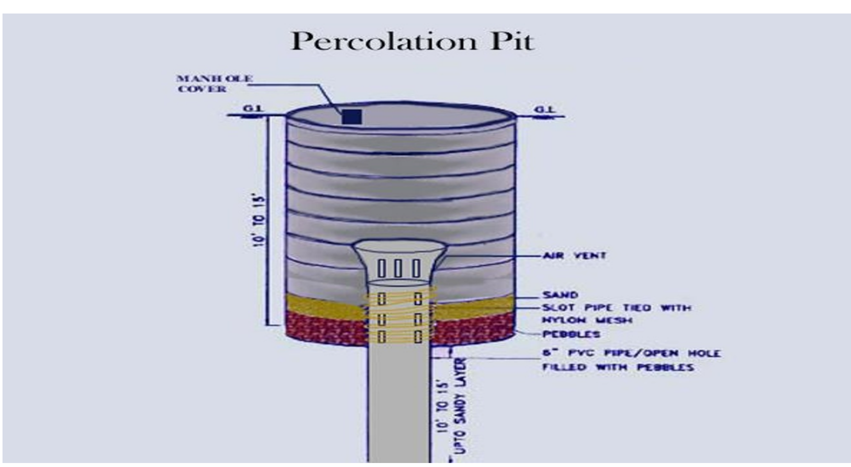

Fig. 2. The sectional view of percolation pit

A percolation tank is an engineered surface water reservoir intended to improve groundwater recharge by facilitating the infiltration of surface runoff through extremely permeable soil regions. For optimal functionality, the percolation tank must be positioned in an area with sufficient catchment and advantageous hydrogeological conditions. The permeability of the underlying rocks in the submerged region is essential, as they must facilitate efficient water percolation. Moreover, the weathering of the rocks must be uniform throughout the entire area, rather than localized, to guarantee continuous infiltration. The principal function of a percolation tank is to retain surface runoff and direct a maximum quantity of this water into groundwater storage. Consequently, the tank must be engineered to facilitate rapid infiltration of water collected post-monsoon, thereby reducing evaporation losses and enhancing groundwater recharge.

The dimensions of a percolation tank should be determined by the percolation capacity of the substrate in the tank bed, rather than the yield of the catchment area. If the percolation rate is insufficient, the stored water becomes stagnant and is lost primarily through evaporation, so depriving the downstream region of this precious resource. These are the predominant structures in India employed to replenish the groundwater reservoir in both alluvial and hard rock formations. The efficacy and practicality of these structures are greater in hard rock formations characterized by significant fracturing and weathering. In the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka, and Gujarat, several percolation tanks have been erected in basaltic lava flows and crystalline rocks. Percolation tanks are also viable in mountainous areas characterized by talus scree deposits. Percolation tanks may also be established in the Bhabar zone. Percolation tanks with wells and shafts may be created in regions where shallow or superficial strata exhibit high impermeability or clay content.

1.3.2. Site Characteristics and Design Guidelines

An exhaustive examination of precipitation patterns, encompassing the frequency of rainy days, arid intervals, and evaporation rates, in conjunction with thorough hydrogeological assessments, is crucial for determining appropriate locations for percolation tanks. In Peninsular India, characterized by a semi-arid environment, the design of percolation tanks must facilitate the infiltration of stored water into the groundwater reservoir by January or February. The submergence area for these tanks should preferably be situated on non-arable terrain to reduce agricultural damage.Percolation tanks must be carefully positioned atop extensively cracked and worn rock formations to enhance groundwater recharging. Boulder formations in areas with alluvial deposits are particularly advantageous for identifying these tanks. The aquifer undergoing recharge must possess a enough thickness of permeable vadose zone to facilitate successful recharge. Furthermore, the region receiving the recharge must possess a sufficient quantity of wells and arable land to effectively utilize the refilled water.

Hydrological analyses must be performed to evaluate runoff, and the tank's storage capacity should generally not surpass 50% of the total precipitation in the catchment area. A waste weir or spillway must be engineered to accommodate the maximum rainfall in a single day, facilitating the discharge of surplus water after the tank attains full capacity. Additionally, a cutoff trench must be constructed to reduce seepage losses both beneath and above the nala bed. To safeguard the embankment from erosion due to ripple action, stone pitching must be implemented on the upstream side, reaching the highest flood level (HFL). This guarantees structural integrity and reduces water loss, enhancing the tank's efficacy in groundwater recharging.

1.3.3 Essential Factors for the Implementation of Percolation Pit Structures

1. The percolation pit technique is suitable for all structures situated in regions with alluvial and hard rock formations, provided the groundwater level exceeds 15 meters below the surface.
2. Only uncontaminated rainwater from rooftop surfaces should be channelled into the recharge structure via an attached downpipe.
3. Prior to the commencement of the monsoon season, all rooftop catchment areas intended for recharging must be meticulously cleaned. To avert pollution, recharge structures must operate only during the monsoon season.
4. A mesh or screen must be affixed at the entrance of rooftop rainwater pipes to obstruct material, including leaves and solid waste, from infiltrating the pit. A bypass system must be implemented to channel the initial rain runoff into municipal drains, facilitating the elimination of preliminary impurities.
5. An overflow pipe must be built in the recharge chamber(s) to divert surplus water into the municipal stormwater drainage system.
6. The dimensions (length and width) of the recharge chamber may be modified according to site conditions as long as the volumetric capacity is maintained.
7. The dimensions of the reinforced concrete (RCC) slab and its reinforcement will be contingent upon the structural loads. A manhole equipped with a frame and cover must be installed for access, and the thickness of the recharge chamber walls should be determined based on depth and structural specifications.
8. The filter medium must be 1 meter in thickness and composed of three layers: 0.4 meters of boulders (5-20 cm) at the base, 0.3 meters of gravel (5-10 mm) in the center, and 0.3 meters of coarse sand (1.5-2.0 mm) at the top. This facilitates the deposition of silt at the surface, which may be readily extracted.
9. A 10 cm thick protective coating of pea gravel should be applied over the filter medium's coarse sand layer.
10. The recharge chambers must be sanitized before each monsoon season begins. This entails removing, cleaning, and replacing the filter media and replenishing the pea gravel layer.
11. Recharge chambers should be inspected and cleaned at seven-day intervals during the rainy season, or more regularly if required.
12. The depth of recharge wells must be sustained at 2-3 meters above the post-monsoon groundwater level, with the slotted pipe positioned next to the granular (sandy or cracked) zone.
13. If the recharge well is unable to accept water, it can be cleaned with an air compressor to restore its functionality.
14. Following the monsoon, the recharge chambers must be thoroughly cleaned and maintained to guarantee continued efficiency.

These procedures are essential for guaranteeing the efficacy, longevity, and sanitation of percolation pits, thereby facilitating sustainable groundwater recharge operations.

Table 1. Determination of size of recharge structure.

Pits No	Discharge (m3/sec)	Discharge (lit/hr)	Rate of Filtration (lit/hr/m2)	Size of Recharge Structure L×B×H (m)
1	0.00129	4644	3000	2×1×3
2	0.002637029	9493.3	3000	2.6×1.3×3
3	0.000523221	1883.6	3000	1.4×0.7×3
4	0.000224354	807.67	3000	1×0.5×3
5	0.003039	10940.4	3000	2.8×1.4×3
6	0.002381794	8574.46	3000	2.4×1.2×3
7	0.000122289	440.24	3000	0.8×0.4×3

1.3.4 Design Dimensions of Percolation Pit

Calculation of size of recharge structure for Pit-1 (Sample)

Total rainwater stored per day =111.456m^3/day
Water stored per hour = 4.644 m^3/hour = 4644 lit/ hour
Assume the rate of filtration = 3000lit/hour/m2
Area of recharge structure required
A = water stored / rate of filtration
= 4644/3000
=1.548 m2
We know that L = 2B
A =L x B
=2B x B
=2B^2
B = (1.548/2)$^{1/2}$
= 0.879m, say 1m
L = 1×2 = 2m
We know that H = Q/A
H =4.644/1.548= 3.0m

1.3.5 Procedure for Constructing Percolation Pit Location Selection:

1. The site for the pit must be established by evaluating factors including the contributing micro-watershed, existing depressions, water sources, the pit's intended function (drainage or recharge), non-interference with agricultural activities, soil profile, proximity to adjacent wells, financial investment capacity, excavation methodology, and societal acceptance of the technology.
2. At the lowest point of the depression, a borehole with a diameter of 150 mm must be drilled to a depth of 12 meters.
3. Insertion of Strainer Pipe: A 100 mm strainer pipe must be introduced into the borehole, with gravel positioned between the pipe and the bore to facilitate filtering and provide stability.
4. The strainer pipe must extend 0.6 meters above the ground to prevent water or debris from directly entering the borehole.
5. Strainer Capping: A cap must be affixed to the upper section of the strainer pipe to avert mishaps and prevent foreign objects from increasing into the system.

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6. Excavate a pit measuring 2 meters by 1 meter and 3 meters deep surrounding the borehole.
7. The pit must be filled with a 1.5-meter-thick filter medium, applied in three distinct layers.
8. Base layer: 0.5 meters of boulders (5-20 cm in diameter) Intermediate layer: 0.5 meters of gravel (5-10 mm in diameter) Uppermost layer: 0.5 meters of coarse sand (1.5-2.0 mm in diameter). This configuration guarantees that silt from runoff accumulates at the surface, facilitating effortless extraction. A freeboard of 1.5 meters must be preserved to permit water retention in the pit.
9. Construct a brick wall encircling the pit, incorporating mechanisms to facilitate water ingress from the watershed area. A galvanized wire mesh or a removable RCC cover with perforations should be installed at the pit's entry site.

This building method guarantees the efficient and secure design of percolation pits for groundwater recharge, yielding enduring advantages in water resource management.

1.4 Estimation of the Project

Table 2. Estimating and Costing

Sl No.	Particulars	No	Length (M)	Width (M)	Height (M)	Quantity	Rate Per Unit	Amount (Rs)
	Percolation pits							
1	Pit 1							
a.	Excavation of earthwork							
	for tank	1	2.6	1.6	3	12.48 m3	209/m3	2608.32
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	2.6	0.23	3	3.59m3	5000/m3	17950
	short wall	2	1	0.23	3	1.38m3	5000/m3	6900
c.	Inside plastering	1	6		3	18 m2	175/m2	3150
d.	Filter media							
	Boulder	1	2	1	0.5	1 m3	135/m3	135
	gravel	1	2	1	0.5	1 m3	80/m3	80
	coarse sand	1	2	1	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	2.6	1.6		4.16m2	914.96/m2	3806.23

f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
2	Pit 2							
a.	Excavation of earthwork							
	for tank	1	3.2	1.9	3	18.24m3	209/m3	3812.16
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	3.2	0.23	3	4.42m3	5000/m3	22100
	short wall	2	1.3	0.23	3	1.79m3	5000/m3	8950
c.	Inside plastering	1	7.8		3	23.4m2	175/m2	4095
d.	Filter media							
	Boulder	1	2.6	1.3	0.5	1 m3	135/m3	135
	gravel	1	2.6	1.3	0.5	1 m3	80/m3	80
	coarse sand	1	2.6	1.3	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	3.2	1.9		6.08m2	914.96/m2	5562.96
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
3	Pit 3							
a.	Excavation of earthwork							
	for tank	1	2	1.3	3	7.8m3	209/m3	1630.2
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	2	0.23	3	2.76m3	5000/m3	13800
	short wall	2	0.7	0.23	3	0.97m3	5000/m3	4850
c.	Inside plastering	1	4.2		3	12.6m2	175/m2	2205
d.	Filtrer media							

	Boulder	1	1.4	0.7	0.5	1 m3	135/m3	135
	gravel	1	1.4	0.7	0.5	1 m3	80/m3	80
	coarse sand	1	1.4	0.7	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	2	1.3		2.6m2	914.96/m2	2378.9
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
4	Pit 4							
a.	Excavation of earthwork							
	for tank	1	1.6	1.1	3	5.28m3	209/m3	1103.52
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	1.6	0.23	3	2.2m3	5000/m3	11150
	short wall	2	0.5	0.23	3	0.69m3	5000/m3	3450
c.	Inside plastering	1	3		3	9m2	175/m2	1575
d.	Filtrer media							
	Boulder	1	1	0.5	0.5	1 m3	135/m3	135
	gravel	1	1	0.5	0.5	1 m3	80/m3	80
	coarse sand	1	1	0.5	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	1.6	1.1		1.76m2	914.96/m2	914.96
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
5	Pit 5							
a.	Excavation of earthwork							
	for tank	1	3.4	2	3	20.4m3	209/m3	4263.6
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	3.4	0.23	3	4.69m3	5000/m3	23450

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	short wall	2	1.4	0.23	3	1.93m3	5000/m3	9650
c.	Inside plastering	1	8.4		3	25.2m2	175/m2	4410
d.	Filtrer media							
	Boulder	1	2.8	1.4	0.5	1 m3	135/m3	135
	gravel	1	2.8	1.4	0.5	1 m3	80/m3	80
	coarse sand	1	2.8	1.4	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	3.4	2		6.8m2	914.96/m2	6261.73
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
6	Pit 6							
a.	Excavation of earthwork							
	for tank	1	3	1.8	3	16.2m3	209/m3	3385.8
	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	3	0.23	3	4.14m3	5000/m3	22050
	short wall	2	1.2	0.23	3	1.66m3	5000/m3	8300
c.	Inside plastering	1	7.2		3	21.6m2	175/m2	3780
d.	Filter media							
	Boulder	1	2.4	1.2	0.5	1 m3	135/m3	135
	gravel	1	2.4	1.2	0.5	1 m3	80/m3	80
	coarse sand	1	2.4	1.2	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	3	1.8		5.4m2	914.96/m2	4940.78
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484
7	Pit 7							
a.	Excavation of earthwork							
	for tank	1	1.4	1	3	4.2m3	209/m3	877.8

	drilling bore hole	1			9	9 m	65/feet	1919.29
b.	Brick wall on all sides							
	long wall	2	1.4	0.23	3	1.93m3	5000/m3	9650
	short wall	2	0.4	0.23	3	0.55m3	5000/m3	2750
c.	Inside plastering	1	2.4		3	7.2m2	175/m2	1260
d.	Filtrer media							
	Boulder	1	0.8	0.4	0.5	1 m3	135/m3	135
	gravel	1	0.8	0.4	0.5	1 m3	80/m3	80
	coarse sand	1	0.8	0.4	0.5	1 m3	900/m3	900
e.	Detachable R.C.C. Slab with holes	1	1.4	1		1.4m2	914.96/m2	1280.94
f.	100 mm. Slotted pipe	1	11.5			11.5 m	216/m	2484

Total Cost	**266930.15**
Add 5% contingency charges	**13346.50**
Add 2% contractor charges	**5500**
Grand total	**307000**

2 Conclusion

Water scarcity constitutes a substantial and persistent issue in Chhadvel Korde village. The over dependence on groundwater extraction via deep tube wells to satisfy increasing water demand has resulted in a continuous fall of the water table. The depletion of groundwater is exacerbated by the challenges associated with the natural recharge of the aquifer. Consequently, identifying sustainable solutions is imperative, and rainwater harvesting presents an efficient approach to replenish the groundwater level and ensure adequate water storage for future utilization. This project sought to assess the sustainability and efficacy of rainwater collecting in the hamlet, with specific emphasis on the system's quality in fulfilling both storage and recharge requirements. Following thorough investigation, it was determined that the village possesses considerable potential for rainwater harvesting due to its catchment areas. The entire catchment region was classified into two categories: (1) Rooftop area: 190,694 square meters (19.069 hectares) and (2) Non-rooftop area: 37,277.5 m^2 (3.727 hectares). The village's rainfall outflow was estimated, resulting in a total runoff of 882.64 m^3/day. The significant runoff volume illustrates the viability of establishing a rainwater collection system to satisfy water demand and facilitate groundwater recharge. In summary, rainwater collection provides a sustainable and enduring solution for the Chhadvel Korde community. By successfully utilizing the available catchment areas, the village may substantially alleviate its water scarcity problems and secure a dependable water source while also aiding in the replenishment of its groundwater supplies.

• The diameter and length of PVC pipes used for transporting the rain water are:

Table 3. diameter and length of PVC pipes

Diameter	Length
15mm ø	177.13m
20mm ø	1011.95m
40mm ø	1819.2m
80mm ø	296.24m
50mm ø	170.22m
100mm ø	450.52m

• In order to recharge a ground water by percolation pit the discharge and dimensions obtained are:

Table 4. discharge and dimensions of Percolation Pit.

PITS	DISCHARGE (lit/hr)	SIZE OF RECHARGE STRUCTURE L×B×H (m)
PIT-1	4644	2×1×3
PIT-2	9493.3	2.6×1.3×3
PIT-3	1883.6	1.4×0.7×3
PIT-4	807.67	1×0.5×3
PIT-5	10940.4	2.8×1.4×3
PIT-6	8574.46	2.4×1.2×3
PIT-7	440.24	0.8×0.4×3

The whole projected expenditure for the execution of this rainwater harvesting initiative, encompassing all related costs, totals Rs 307,000. Implementing a rainwater collection system and creating natural percolation pits will result in a significant increase in the groundwater table, along with enhancements in soil moisture levels and fertility. These modifications will promote augmented vegetation and greenery in the vicinity, so enhancing the village's environmental health and beauty. This straightforward yet efficacious practice provides numerous advantages, such as water conservation, groundwater replenishment, and enhanced soil quality, all of which foster a more sustainable and aesthetically pleasing environment. The rainwater harvesting system offers numerous benefits and poses no detrimental effects, rendering it a crucial instrument for fostering long-term environmental and water resource sustainability in the village.

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