Atal Mission for Rejuvenation and Urban Transformation

Ministry of Housing and Urban Affairs
Government of India

National Institute of Urban Affairs

# MANAGING SHALLOW AQUIFERS IN CITIES

## A 6-Step Approach

**TITLE**

**Managing Shallow Aquifers in Cities: A 6-Step Approach**

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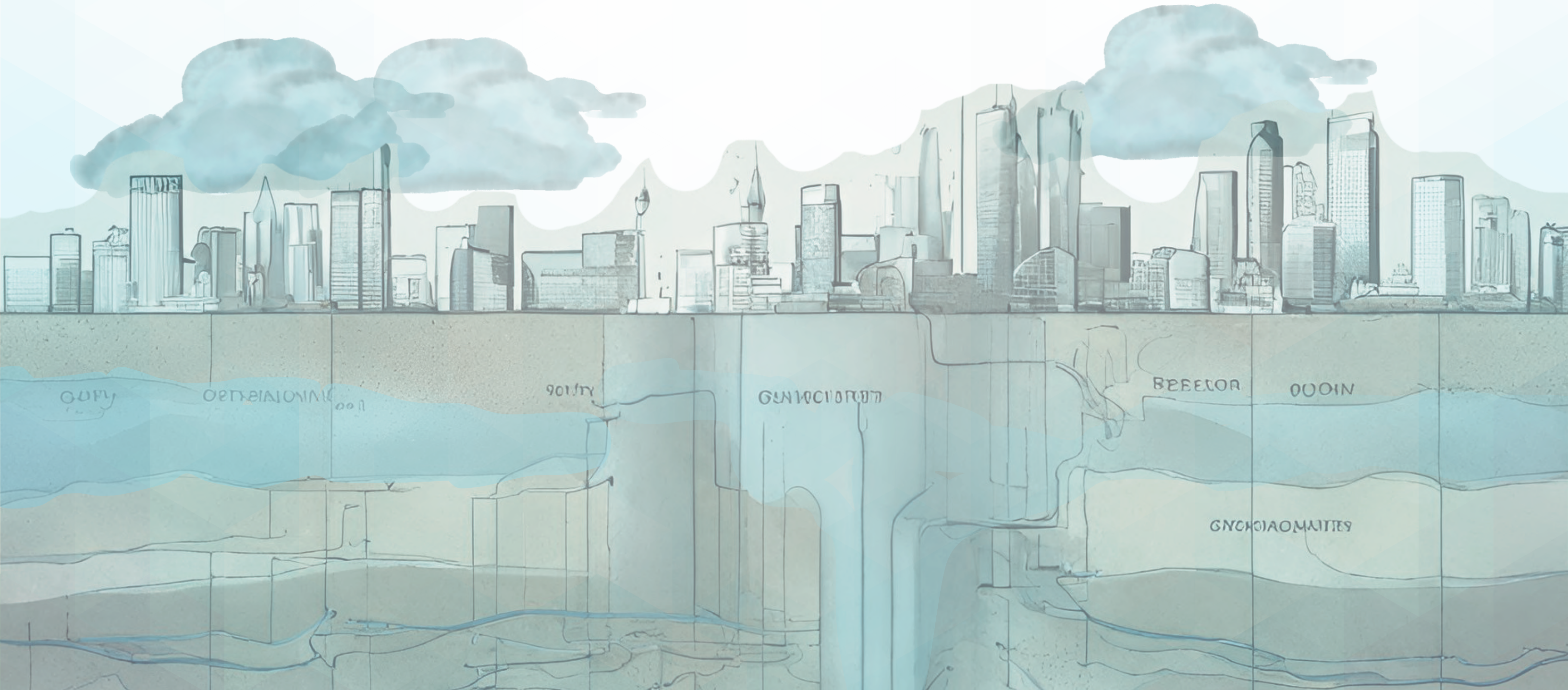
# Managing Shallow Aquifers in Cities

*A 6-Step Approach*



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## Message from the Mission Director, AMRUT 2.0, MoHUA

*“With an outlay of Rs 2,77,000 crore, AMRUT 2.0, one of the world’s largest sustainable urban water management programmes, aims to implement the vision of Hon’ble Prime Minister of India Shri Narendra Modi to ensure drinking water supply to every urban household in the country and hundred percent coverage of sewerage and septage in 500 AMRUT cities. This Mission aims to comprehensively transform the water sector scenario in Indian cities.”*

AMRUT 2.0 Mission represents a paradigm shift in our approach to create water secure cities. It recognises a multi-pronged approach, addressing all aspects of water resources, as the way forward to fulfil the drinking water and sanitation needs of the ever growing urban population in India. Bearing this need in mind, the Mission employs a wide array of tools and technologies to encourage the urban local bodies (ULBs) towards a holistic view of sustainable water management. Rejuvenation of water bodies and aquifer management to augment sustainable fresh water supply is an integral part of this objective. I am glad to inform you that, as a part of this mission, for the first time, emphasis is being given to the management of ground water resources, through a pilot project on ‘Shallow Aquifer Management (SAM)’, being conducted in ten Indian cities.

Ground water, an invisible resource, is often taken for granted. However, an increasing demand for fresh water makes it imperative to shift our focus on the judicious management of shallow aquifers. This perspective underpins the ongoing pilot project on Shallow Aquifer Management. In this context, I would like to appreciate the invaluable contribution of the officials of ULBs and civil society organisations in Jaipur, Dhanbad, Gwalior, Chennai, Hyderabad, Kolkata, Rajkot, Pune, Thane, and Bengaluru to realise this project.

I encourage city officials, urban planners, and water resource professionals to use this handbook to explore ways to conserve the existing shallow aquifers in cities. By incorporating the principles and practices outlined in this handbook, we can ensure more resilient and sustainable water management.

Ms. D Thara, IAS
Additional Secretary,
Mission Director, AMRUT 2.0
Ministry of Housing and Urban Affairs

## Message from the Director, National Insitute of Urban Affairs

*"Over the past five years, we have dedicated ourselves to the cause of nurturing and revitalising our urban rivers. This journey has not only broadened our horizons but has also unveiled a profound learning: the interconnectedness between  rivers and groundwater. The sustainable future of our cities hinges on our ability to manage all these water resources collectively."*

India has a rich legacy of shallow aquifers that has sustained our cities for centuries. Baoris, stepwells, wells, and such other ingenious recharge structures have been essential components of our urban landscapes. Today, as we embrace modernity, we must also cherish the wisdom of the past. It is in the fusion of new thinking and ancient knowledge that we find the path to sustainable urban water management.

This handbook serves as a bridge between these worlds. It combines contemporary insights and time-tested practices to inspire our cities to take charge of their shallow aquifers. By recognising the vital link between rivers and groundwater, we empower ourselves to forge a more resilient and water-secure urban future.

I am proud to be part of this endeavour to transform our understanding on urban groundwater. It reflects our commitment to equipping urban stakeholders with the tools and knowledge needed to address the complex challenges of the 21st century. I extend my heartfelt gratitude to all the individuals, experts, and institutions that have contributed to the creation of this handbook. Your collective wisdom and dedication are instrumental in shaping a brighter, more sustainable future for our cities and ensuring that our cities not only thrive but also safeguard the legacy of water wisdom that has sustained us for generations.

Mr. Hitesh Vaidya
Director
National Institute of Urban Affairs


Source: Canva

## Message from Dr. Himanshu Kulkarni, Scientist (Emeritus) ACWADAM, Pune

India's wide-ranging aquifer typology shows a common feature – the existence and use of shallow aquifer systems. The presence of large-diameter dug wells and the age-old systems of extraction through the human powered tenda or latha and the animal driven rahat, mahot and chadas indicate to us the legacy of this precious resource called the shallow unconfined aquifer. These aquifers are ubiquitous in their presence and usage, both in rural and urban India. India's growing demand for water, unprecedented growth of groundwater structures and the quest for deeper groundwater have together contributed to the neglect and disrepair of the shallow aquifer, particularly in rapidly growing cities and towns. This neglect has often led to the disconnect between the shallow aquifers and our river systems.

The SAM project, which is a unique process of collaboration and partnerships, is a hope in reviving and restoring the shallow urban aquifer in India. In some ways, the project builds upon a natural heritage approach in looking at aquifers not only as a groundwater resource but also as an integral part of various ecosystems, and perhaps also as an ecosystem onto itself. While the current set of pilots focus on systematic recharge and revival of wells, this project has paved a way to adopt the principles of managing and governing groundwater as a Common Pool Resource (CPR). It is necessary to further build on this initiative through the integration of the science of aquifers, the community that uses groundwater, and the systems of governance that will lead to improvements in the equitability and sustainability of groundwater resources in India.

## Message from Vishwanath S, Founder, BIOME Environmental Trust, Bengaluru

Shallow unconfined aquifers were the traditional sources of water for our towns and cities until they were gradually replaced by deeper confined aquifers and then piped water from distant surface sources. Recently, thanks to the variable and intense rainfall and urban flooding, there has been an increasing interest into looking at shallow aquifers for storage of excess rain. With lake, river, and wetlands rejuvenation receiving the much needed attention, as well as rainwater harvesting guidelines making it mandatory to store or recharge rainwater, aquifers have become a source of interest and study .

With groundwater as a critical supplement for our urban areas, it is necessary that we study the impact of urbanisation on the quantity and quality of urban aquifers. Simultaneously, a revival of such artefacts as dug wells and step-wells will help in generating peoples interest in the aquifer. Ultimately, an Integrated Urban Water Management approach will demand that aquifers be nurtured as a source of supplemental water supply and flood mitigation. This booklet is a timely intervention in what promises to be a long and rewarding journey to rejuvenate the aquifers of India and use them sustainably and wisely as a common pool resource.

## Introduction

India is the largest extractor of groundwater in the world. As per CGWB, approximately 50% of the water demand in our cities is met by groundwater. Indian cities use groundwater in both formal water supply and through informal water abstraction to meet the growing freshwater demand. In most cases, this is the water stored at shallow depths below the ground or in shallow aquifers. However, because of indiscriminate abstraction, several Indian cities have exhausted their shallow aquifers. While there is a tendency in cities to dig deeper for water, an easy solution would be to just manage their shallow aquifers more judiciously. This is because shallow aquifers are not only easily accessible water reserves but also relatively much quicker to recharge when compared to deep aquifers.

To promote sustainable shallow aquifer management (SAM), a pilot project was initiated in 2022 under AMRUT 2.0 in 10 cities. A variety of approaches/structures as means for shallow aquifer recharge were designed for the pilot cities, which also address the larger problems of groundwater depletion, urban flooding, and contamination of groundwater reserves. The SAM project cities are Bengaluru, Chennai, Dhanbad, Gwalior, Hyderabad, Jaipur, Kolkata, Pune, Rajkot, and Thane.

Currently, the implementation of the designed interventions is underway in the ten pilot cities. Several insights and learnings have emerged from the pilot projects about how to plan, design, and manage shallow aquifers. In addition to augmenting groundwater reserves, the learnings have also encompassed ensuing co-benefits in the form of addressing water logging, reviving historical water bodies and structures, and bringing back the cultural and community association of recharging wells and baoris.

This handbook captures the experiences from the 10 SAM cities to devise a simple 6-step approach for managing shallow aquifers. It advocates a step-by-step methodology that any city can follow to plan, design, and implement structures for managing its shallow aquifers and harnessing this water to supplement the city's water demands.

The handbook also presents practical examples from other Indian cities to acquaint the city decision-makers, technical officials, and implementing agencies with how shallow aquifer management can be institutionalised in the city's long-term water provision and management strategy.

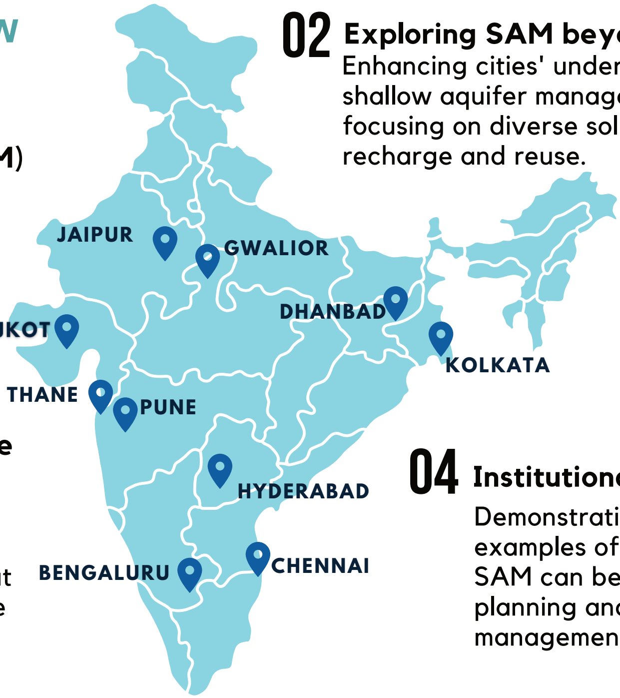
# SAM Project: Overview

## 01 Breaking down Shallow Aquifer Management (SAM) in urban settings

Detailing the process based on the experience of 10 SAM cities in 6 simple steps.

## 02 Exploring SAM beyond dug wells

Enhancing cities' understanding of shallow aquifer management by focusing on diverse solutions for recharge and reuse.




## 03 Understanding the probable slips and challenges

Enhancing the practical and action-oriented knowledge of city stakeholders by pointing out some critical errors that must be avoided.

## 04 Institutionalising SAM

Demonstrating through examples of Indian cities how SAM can be mainstreamed into planning and water management.

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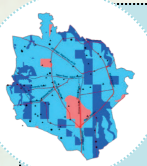
**KNOWLEDGE PARTNERS**

ACWADAM — NIUA National Institute of Urban Affairs — biome Environmental

**IMPLEMENTATION PARTNERS**

| Rajkot | Jaipur | Gwalior | Kolkata | Dhanbad | Thane | Hyderabad | Chennai | Bengaluru | Pune |
|---|---|---|---|---|---|---|---|---|---|
| Arid Communities & Technologies | Greater; Centre for Environment & Development (CEDS) | PSI | PRASARI | मेघ पईन अभियान Megh Pyne Abhiyan | Aga Khan Agency for Habitat India | GHMC; The Rainwater Project |  | Bruhat Bengaluru Mahanagara Palike; biome Environmental | Mission Groundwater भूजल अभियान |

# Shallow Aquifer Management project snapshot



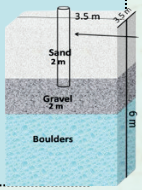
## Rajkot, Gujarat

An industrial city with shallow groundwater occurring mainly in loose alluvium and weathered zones of fractured basalts.

More than 3000 borewells and handpumps out of which about 646 have either dried up or face shortage of water during summer. City also faces recurrent water logging.

The city has developed a **city-level Aquifer Management Plan** backed by a robust database.

The city has devised a combination of percolation pits, stream channel widening and harnessing rainwater to recharge the drying wells and solve recurrent water logging.





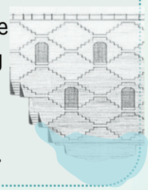
## Jaipur, Rajasthan

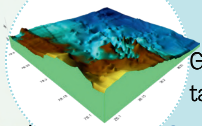
Jaipur, popularly known as Pink City, is in the semi-desert and arid region of Rajasthan.

Around 1600 tubewells are used to supply 167 MLD of water to the city with groundwater dependency at 26 % . (2020)

The city has experienced reduction in the potential recharge area by 46.30 sq. km in the last 17 years. Lack of maintenance of a number of the existing recharge structures have made them redundant.

The city has taken up varied recharge approaches for the 5 pilots including **revival of a stepwell, recharge in a water-logged area, RWH in a school and a neighbourhood park.**





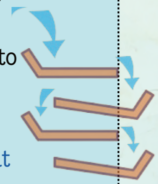
## Gwalior, MP

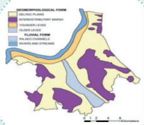
Gwalior city has a legacy of tapping into its shallow aquifers.

Groundwater in Gwalior is tapped through 2300 tubewells and borewells drilled by PHED, 504 tube wells installed with power pumps, 54 dug wells and 574 hand pumps, amounting to 18% of formal water supply being drawn from the groundwater reserves.

The city has created **an inventory of more than 1600 wells** and used the static water level data in these wells to plot its groundwater contours.

The city is looking to revive some of the heritage recharge structures that are still used by communities.

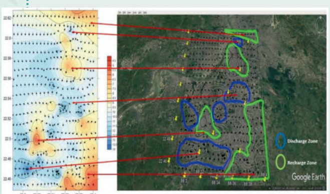




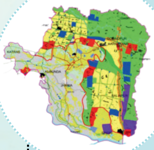
## Kolkata, West Bengal

Groundwater contributes to 25% of the city's water supply and is drawn by private motorized wells operated by the industry and housing estates. Approximately 10,000 public hand-pumped shallow wells are also estimated to exist in the KMC.

Declining trend of ground water level at an alarming rate. Brackish ground water with subsurface flow changing due to overexploitation. Presence of Arsenic in some areas.




Recharge sites in Kolkata have been zeroed down based on a rigrous analysis of static peizometric heads of 42 wells to **determine recharge and discharge zones.**



## Dhanbad, Jharkhand

The city is the coal capital of India with a large number of peri urban communities dependent on shallow aquifer wells.

With 52% of HHs covered by formal water supply, the other 48% mostly rely on groundwater.

The city conducted **a study in 35 out of 55 municipal wards** spread over 108 locations in both coalfield and non-coalfield areas of the municipal corporation to understand **the shallow aquifer dependence** .

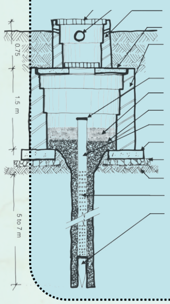
Well built by the local women community living in a water-scarce area in the coalfield to tap the shallow aquifer

Recharge sites in Dhanbad have been designed to harness rainwater to revive the drying community wells

## Thane, Maharashtra

Thane - the lake city, forms a part of the western slope of the Sahyadri hill range and is divided into two broad regions: an undulating hilly tract and a coastal plain in the western part.

The area is drained by innumerable streams and tributaries of the Ulhas and Vaitarna rivers.



The rapid growth of population, the emergence of new residential complexes, and the presence of small to medium-sized industries are exacerbating water shortages.

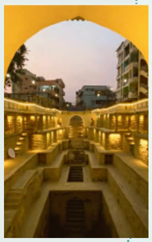
The wells have been chosen in the foothills for recharging the shallow aquifers, which will **benefit water sources at the lower levels in that watershed.**

## Hyderabad, Telanagana

Hyderabad is mostly covered with granitic terrain and has hard rock aquifers, so natural recharge can be only 7–8% of precipitation.

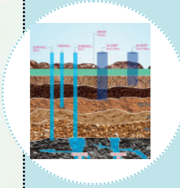
The dynamic ground Water Resources, CGWB estimates the ground water resources of the city as a single unit categorized as Over-Exploited.

During the monsoon rainfall, runoff quickly flows out of the area without giving sufficient time for natural recharge of ground water.



The recharge sites in Hyderabad have been identified based on water resource and **micro watershed analysis - looking at the interlinkages between slope, surface permeability and run-off.**

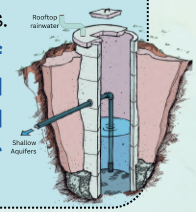
## Chennai, Tamil Nadu



Chennai is divided into three geological regions: sandy parts, clayey areas, and hard rock sections. In most places of Chennai, the ground water table is 4-5 m below ground.

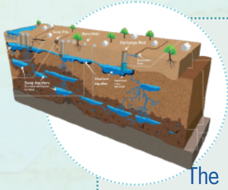
Chennai faces the dual problem of recurrent urban floods due to high water table and freshwater scarcity during lean season.

To counter this, a typical recharge well, 1.6 m in diameter and 6 m in depth, is proposed to augment the ground recharge by diverting the runoff from rooftops and streets.




In Chennai's case, **the reuse of water from the recharged aquifers is extremely critical** to address both freshwater scarcity and flooding.

## Bengaluru, Karnataka



Bengaluru, known as Garden City, is the third most populous city in India, wherein 40% of the total water demand is met by groundwater.

The other source being river Cauvery, which is approximately 100 km away and 300 m below, making this water economically and ecologically costly.

A study by ISEC2 in 2005 estimates that the number of borewells in Bengaluru is approximately 400,000, increasing at a rate of 6500 borewells per year and extracting 750 MLD.

The **Participatory Aquifer Mapping** project involving multiple user groups including well diggers have been engaged to build a complete understanding of the Shallow Aquifer, enabling city to develop better solutions for its management.

## Pune, Maharashtra

Pune is a rapidly growing IT city attracting a lot of in-migration. Historically, the city is known to face several spells of droughts. 20% share of water supply in the city is supplied through groundwater.

The shallow aquifers are predominant in several areas of the city and their annual replenishment is under threat due to change in land use and construction.

During the construction of tall buildings, it has been observed that in Pune City, the shallow unconfined aquifers have been removed, which has drastically affected the groundwater availability within the aquifers.

The pilot sites were derived on basis of their unique socio cultural and heritage aspects including a mix of desilting and catchment treatment of water bodies and recharge shafts.

## This handbook will help answering the following questions:


1. What are Shallow Aquifers? Pg. 07

2. Why are shallow aquifers important? Pg.08

3. How to manage shallow aquifers? Pg. 10

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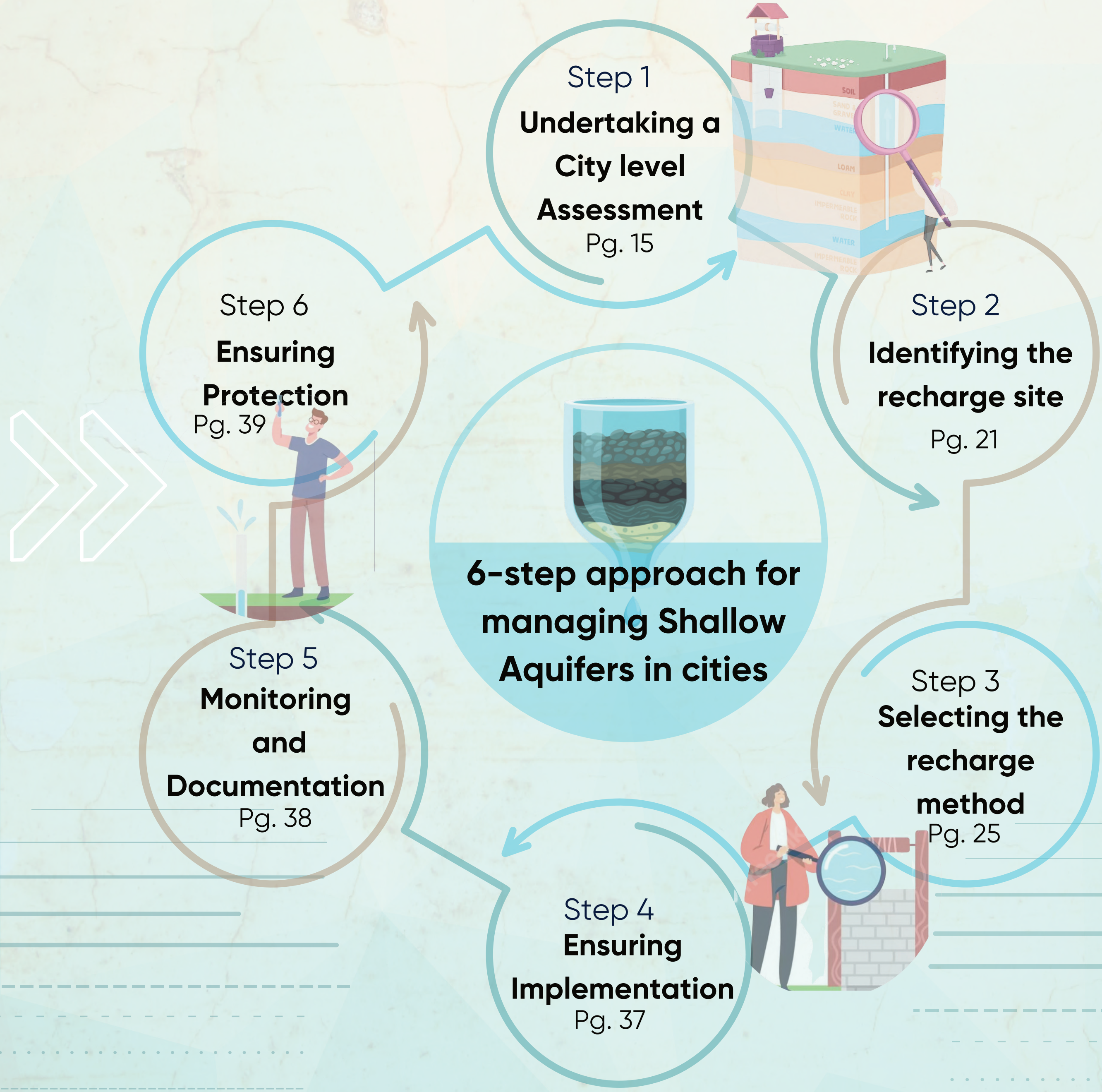
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# 1. What are Shallow Aquifers?

Aquifers are subterranean water-bearing formations that serve as vital underground reservoirs of water and play a crucial role in supplying freshwater to cities, communities and even to sustain surface water ecosystems.

They essentially function as subsurface water containers, invariably storing rainwater and surface runoff that infiltrates into the soil. The water accumulates in the interconnected pores, fissures, and cracks within the aquifer, creating nature's hidden water storage.

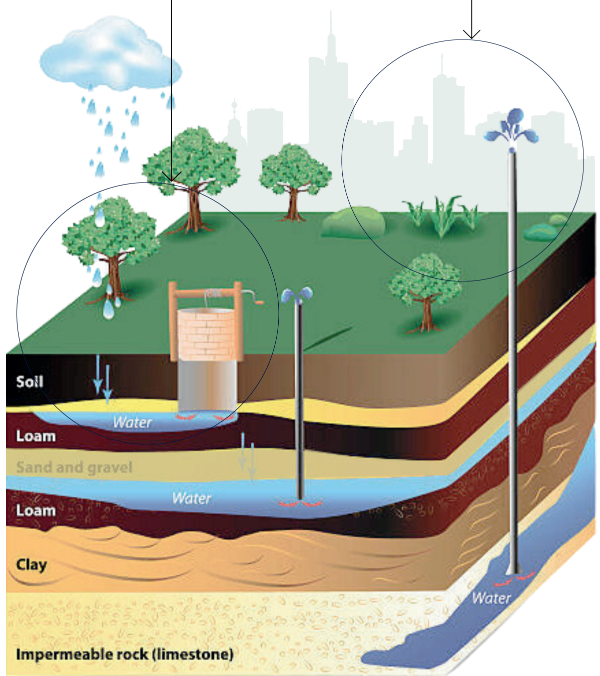
There are two primary types of aquifers based on their depth:

Confined Aquifers, often found deep within the Earth's crust, are a repository of water accumulated over extended periods of time. The surrounding impermeable materials effectively encase the water within, subjecting it to considerable pressure. This pressure often allows water from confined aquifers to gush forcefully to the surface when tapped. (Confined aquifers are commonly tapped in cities by pumping water through deep borewells.)

On the other hand, unconfined aquifers tend to be closer to the surface and lie beneath a permeable layer of soil or rock. Unlike their confined counterparts, unconfined aquifers are not subjected to the same intense pressure, which allows them to be accessed relatively easily. (Water in unconfined, shallow aquifers is accessed through dug wells, stepwells and springs.)

Water in Confined, Deep Aquifers gushes forcefully to the surface, making them valuable sources of high-quality groundwater.

Water in Unconfined, Shallow Aquifers with less pressure is accessed relatively easily.




Confined and Unconfined Aquifers, Source: National Geographic

## 2.Why are Shallow Aquifers important?

Shallow aquifers are often more accessible and an important source of water when it comes to cities, because of the following reasons:

- Ease of Access: Shallow aquifers are typically located closer to the Earth's surface, making them easier and less expensive to tap into for water supply purposes. This proximity reduces the energy cost and complexity of drilling deep wells or constructing water extraction infrastructure.

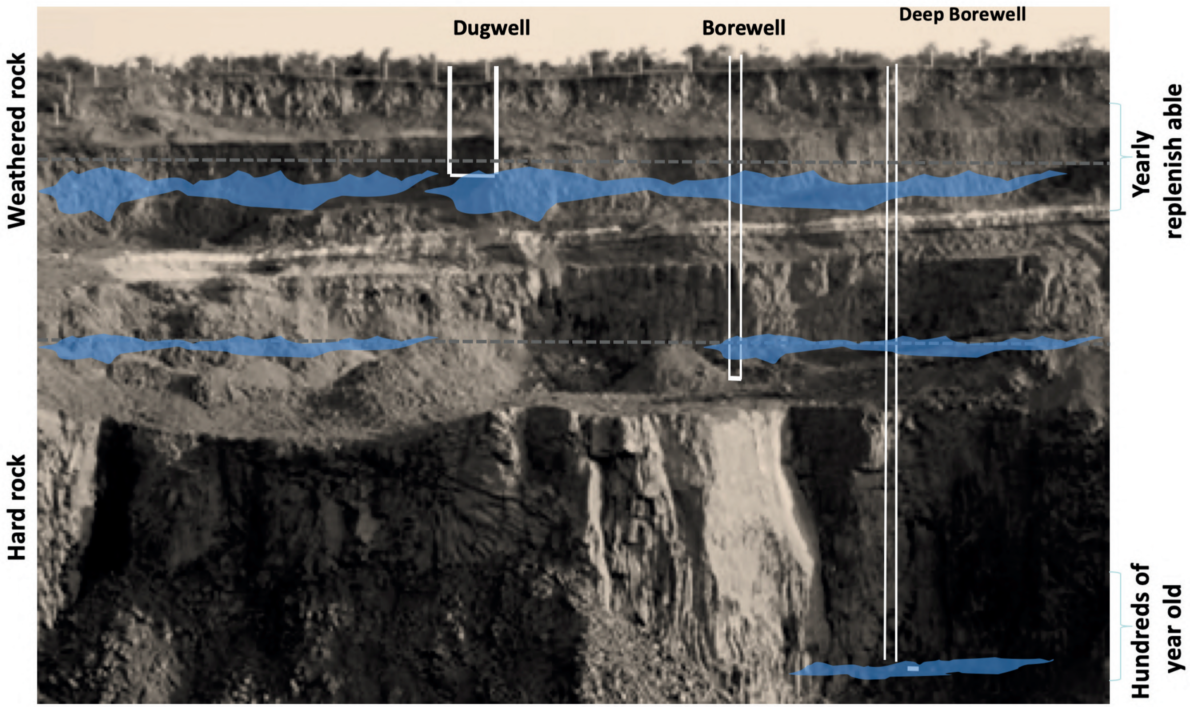
- Quickly Rechargable: Shallow aquifers are more readily replenished by precipitation and surface water sources. Rainwater and runoff from catchment areas and nearby rivers and streams can infiltrate the ground and recharge shallow aquifers relatively quickly. This natural recharge process helps maintain a sustainable and consistent supply of groundwater.

- Support for Local Ecosystems: Shallow aquifers play a crucial role in sustaining local ecosystems by providing water for wetlands, streams, and vegetation. These ecosystems, in turn, help maintain biodiversity and contribute to the overall health and liveability of a city.

- Supplement the Water Demand: Groundwater, especially from the shallow aquifers, can typically cater to changes in water demand. Increasing water demand in cities exerts pressure on the existing water infrastructure. In such cases, cities tend to extract water from shallow aquifers to augment the water supply. Many urban poor and marginalised settlements in cities, disproportionately affected by water stresses, rely on water from shallow aquifers.

In a country like India, shallow aquifers have been in use for centuries. They have been tried and tested in planning of our city water systems since historical times and have acted as a reliable source of water, if managed effectively.

Easily replenishable, they can be instrumental in reducing pressure on the surface water sources. This makes them a vital resource for assuring long term water-supply security and critical in future climate-change adaptation.




Aquifer Disposition, Source: Groundwater Surveys and Development Agency, Govt. of Maharashtra

While deep aquifers can hold vast reserves of water accumulated over long periods, they are usually reserved for times of drought or when additional water resources are required.

In contrast, shallow aquifers are the first line of defense for meeting daily water demands in many regions and are therefore of greater immediate importance for cities and communities.

> A common misconception about aquifers is that they resemble underground rivers or lakes. It is essential to clarify that groundwater, while it can seep into or out of aquifers, cannot flow at the rapid pace associated with surface water bodies like rivers. Instead, groundwater moves much more slowly through the porous spaces within aquifers.

## 3. How to manage shallow aquifers?

> Natural recharge of groundwater, wherein rainwater and surface water infiltrate into aquifers through permeable surfaces like soil and rock, is a fundamental process that sustains groundwater levels.

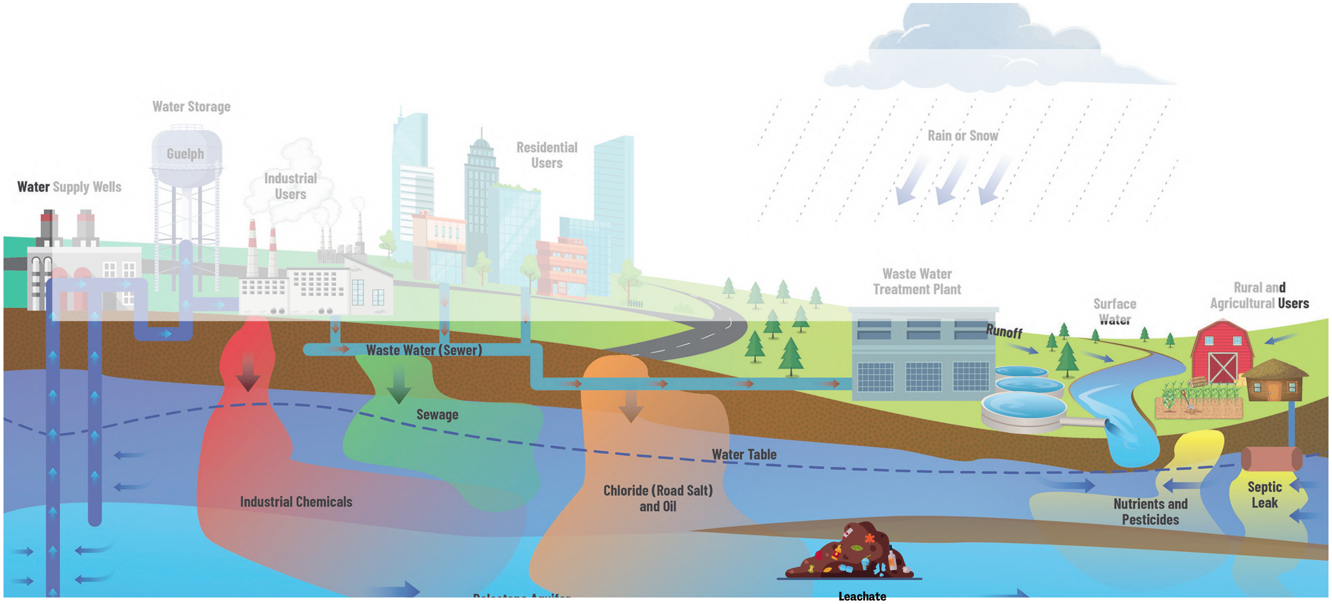
India's groundwater woes, Recreated by NIUA

Groundwater in Indian cities is mostly heeded from the supply lens, with interventions limited to developing infrastructure like well fields and pumping systems to extract groundwater. In most of the cities, this **abstraction is unaccounted and unregulated**.
Moreover, **extensive infrastructure development and concretisation** has replaced natural permeable surfaces with hard, impermeable ones. This has **hindered the ability of rainwater to infiltrate and recharge aquifers naturally.**

**In many cities of India,
Groundwater Extraction is far more than
Natural Recharge Rates**

Another looming threat to shallow aquifers is the **soil and groundwater pollution**. In urban areas, pollutants from human activities (such as leaks from in-situ sanitation, leaking sewer lines, inadequate storage and handling of industrial chemicals, and unscientific disposal of liquid effluents and solid wastes) have infiltrated the ground, particularly contaminating water at shallow depths. This affects the water quality of the entire aquifer, thereby posing a great risk to those dependent on them.

As Indian cities continue to expand and grow, the reliance on groundwater as a water source is intensifying. **With drastic local aquifer depletion, there are also more alarming threats of land subsidence** (recently witnessed in Joshimath, Uttarakhand), **salt water intrusion in coastal cities** (Kolkata and Chennai), **irreversible chemical contamination leading to serious health implications and permanent drying up of springs and groundwater-fed water bodies.**




Anthropogenic contamination of ground water is due to industrial discharges, landfills, diffused sources of pollution like fertilizers and pesticides from agricultural fields etc, Source: IWMA

All these risks to shallow aquifers prompted by rapid urbanisation can be effectively countered through SHALLOW AQUIFER MANAGEMENT.

**Shallow Aquifer Management or Managed Aquifer Recharge (MAR) refers to the conscious recharge of water in shallow aquifers for subsequent community use or environmental benefits.**

It looks at careful and strategic planning for **recharge, reuse, monitoring, and regulating use of groundwater in shallow aquifers,** thus, ensuring their sustainable and responsible utilisation.

It is a cost-effective way to increase the availability of water, act as a barrier to saltwater intrusion, or serve as a method to stabilise the water table in stressed systems.

Shallow Aquifer Management can help cities in:

- replenishing shallow aquifers to serve as a reliable and sustainable source of freshwater, especially during periods of drought or increased water demand.
- reducing surface runoff, mitigating flooding, and improve water quality by filtering pollutants.
- building overall community resilience by providing a buffer against climate change impacts, including more erratic rainfall patterns and increased water scarcity.
- reviving and maintaining surface water sources and ecosystems.

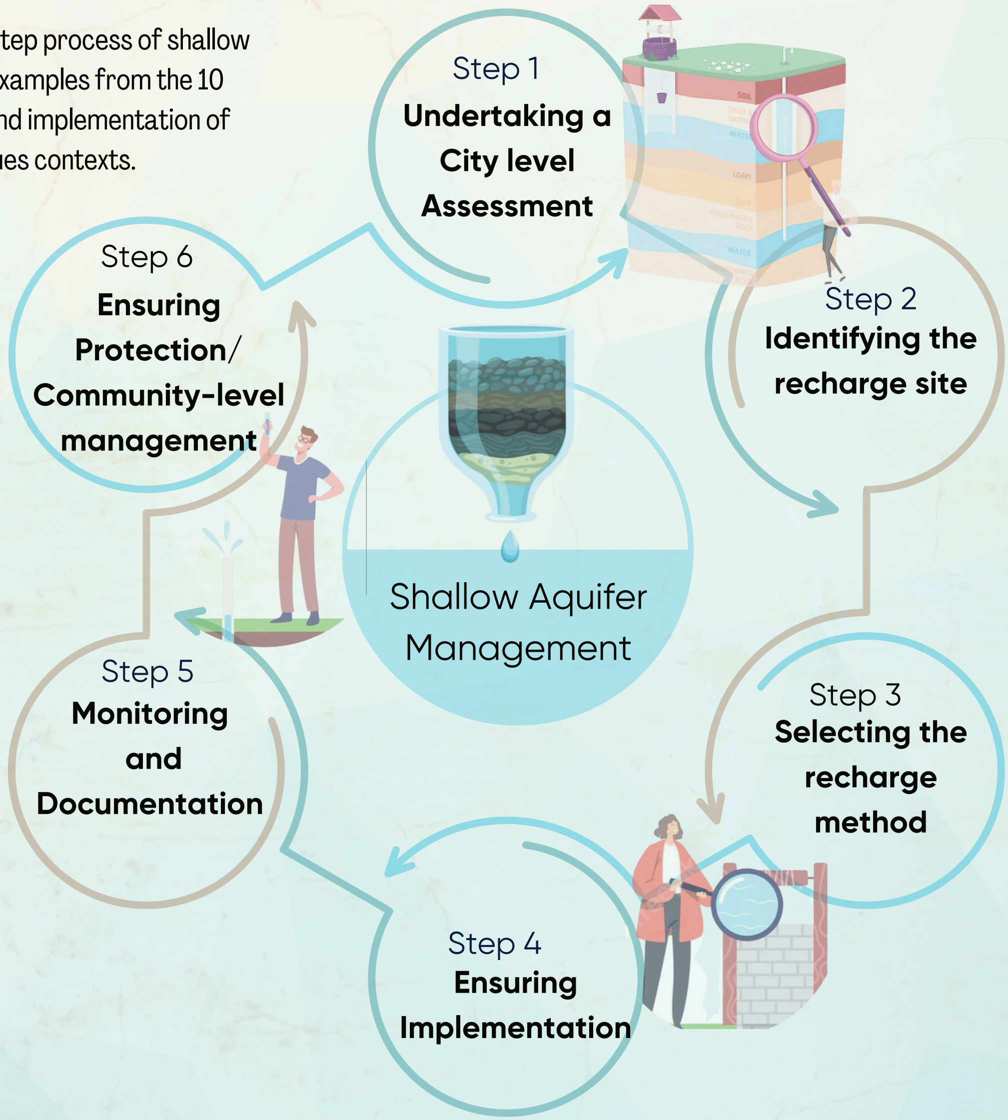

Source: Pixabay

## 3. How to manage shallow aquifers?

This section details out the step-by-step process of shallow aquifer management supported by examples from the 10 SAM cities to demonstrate end-to-end implementation of the recharge structures in their uniques contexts.

Considering the fact that shallow aquifer management has not been undertaken at a city scale in a comprehensive and scientific manner so far, experiences from the SAM cities help bring out the various roadblocks as well as opportunities within the urban and peri-urban contexts that can help guide other cities in designing their Plan of Action.

This section is designed to assist local decision makers, government officials, technical consultants, and other stakeholders to understand the basic steps of MAR for shallow aquifers.



Pune's Groundwater Viewed Through Its Wells, Source:Unravelling Pune's Aquifers - Framework for Groundwater Management and Governance

## Step 1: Undertaking City level Assessment

The first step for Shallow Aquifer Management is understanding a source that's beneath the ground. Although we cannot see aquifers, it is possible to map them to understand and manage them better. However, this is rarely taken up at an urban scale in India.

Aquifers vary depending on local geology – that is, the nature of soil and rock structure underground. Each aquifer has a limited capacity for holding water and a specific speed at which water flows through it. Knowing which aquifer(s) a city gets its water from is essential for making smart decisions about how to use and replenish them sustainably.

Following key data points help build a basic understanding of the local aquifer systems:

- **Hydrogeologic setting:** how water gets into the ground, how it flows in the subsurface (through aquifers), how groundwater interacts with the surrounding soil and rock (the geology).
- **Recharge/Storage potential of the aquifer**
- **Groundwater depth (pre and post monsoon)**
- **Groundwater quality**

Among the 10 SAM cities, Rajkot has undertaken a detailed data-backed study to understand the groundwater occurrence and distribution within the city. It has resulted in an aquifer plan for the city that can help inform the identification of potential sites for MAR.

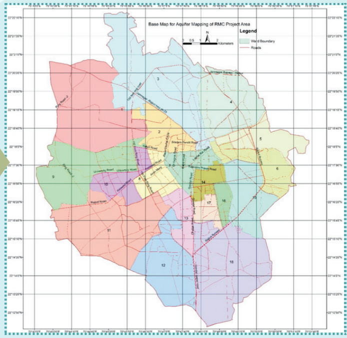
> "One simple way to start understanding these underground water sources is by keeping an eye on wells and borewells. These are like windows into the underground world and can give us basic information about the shallow aquifers."

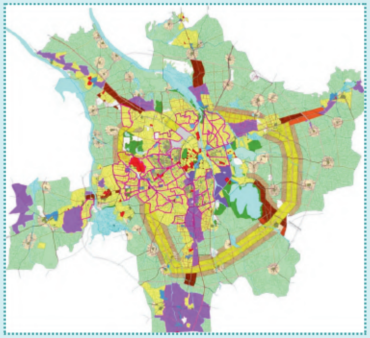
Based on Rajkot's example, there are three main steps to initiate a city-level assessment:

1. collect credible and the most recent data and maps from secondary sources (e.g., groundwater data and aquifer mapping by Central Ground Water Board (CGWB) and State Ground Water Board (SGWB))
2. conduct primary studies, surveys, field work, and community engagement exercises to create a robust database, comprising:
   - inventory of groundwater structures such as wells, borewells, and stepwells
   - lithologs: geologic description of the type, color, and character of the soil and rock materials penetrated by the drilling procedure or activity
   - water-logged areas
3. collate primary and secondary data on a map to build an understanding of the aquifer system.

# Comprehensive Aquifer Mapping - Rajkot

**1. Basemap**

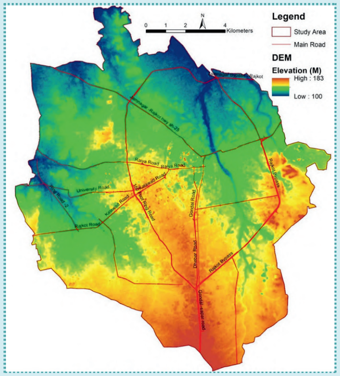




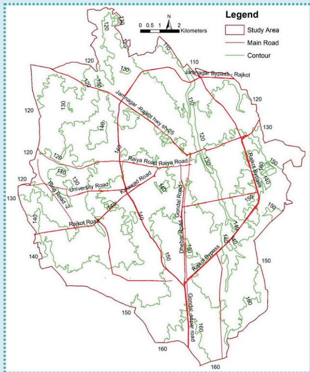
Base map creation with layers like:

- ward wise density/ HHs
- ward wise GW sources
- landuse map (built up open areas & water bodies)
- drainage/ topography
- rivers/ streams/ topography

**2. Layers used for mapping the recharge potential**




a. Topography (DEM)




b. Slope and Elevation

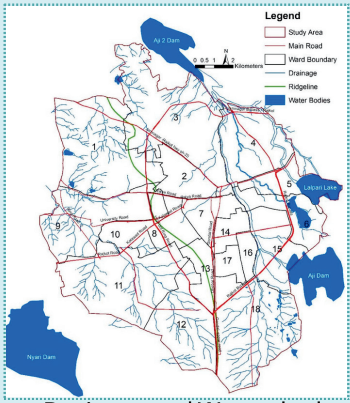
Mapping **terrain** characteristics:

a. Topography (to identify low lying areas)

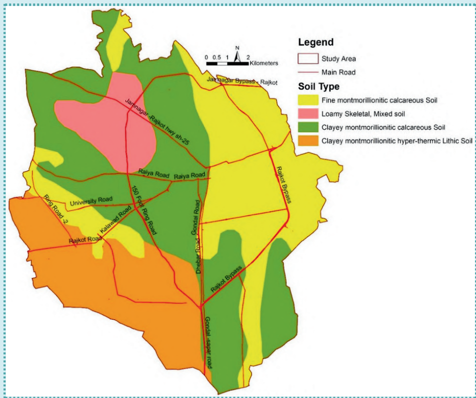
b.Slope and Elevation Contours (to delineate micro-watersheds along with drainage and water flow patterns)

c. Drainage and Watersheds (to map water flow/ direction)

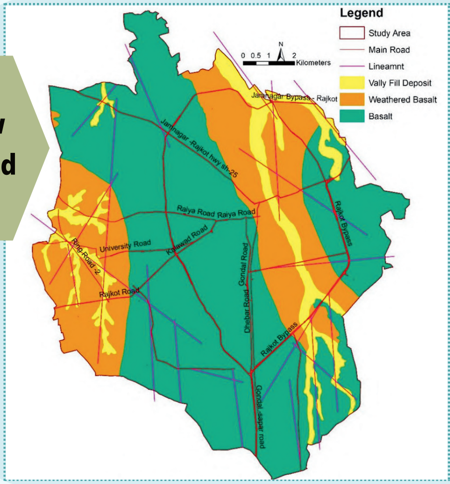
d. Soil (to understand the surface permeability)




c. Drainage and Watersheds




d. Soil



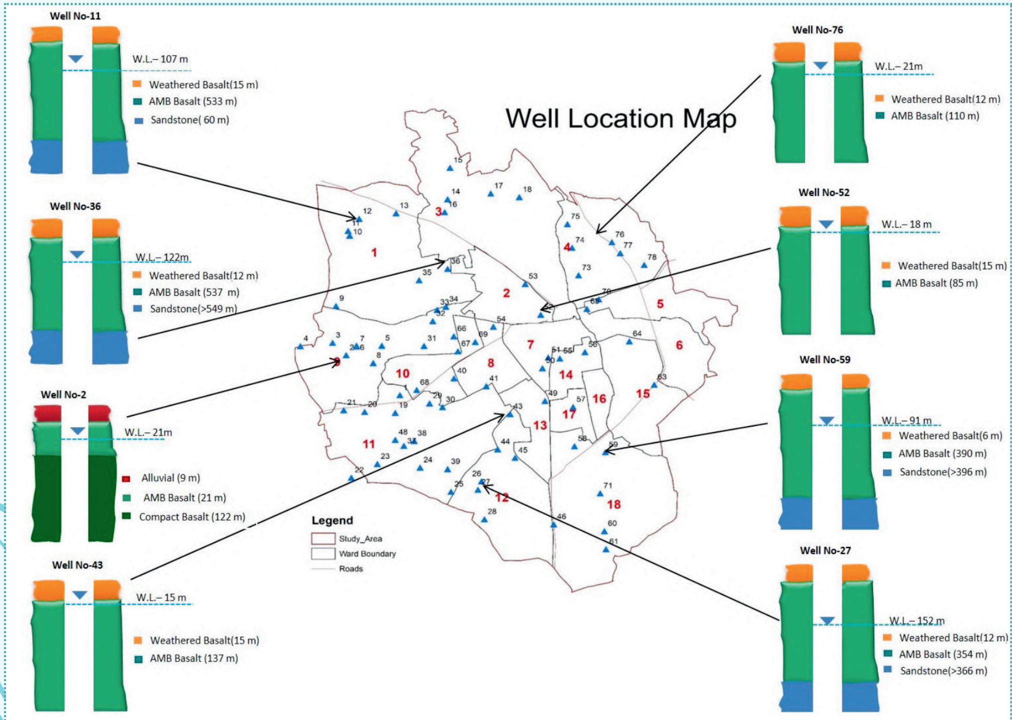

3. Primary data collection for shallow aquifer occurrence and recharge potential

Mapping **Geology**

a. Surface geology

- how water gets into the ground
- how it flows in the subsurface (through aquifers)
- how groundwater interacts with the surrounding soil and rock

**78 wells mapped in Rajkot city**




Mapping **Geohydrology**

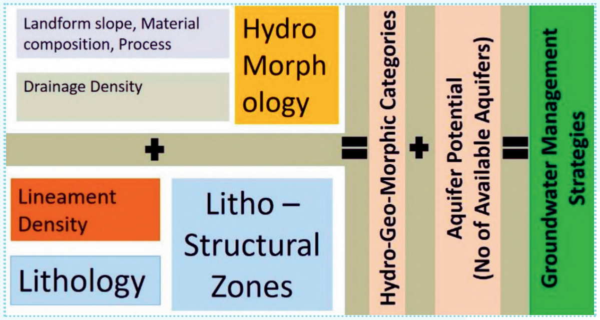
a. Grid wise well inventory to map:

- depth to water level,
- information about well position i.e. landform, aquifer composition, geological structure like dyke & hydro-fractures, characteristics of surrounding terrain.
- interaction with driller, bore well owner or local resource person to gather information regarding history of well, behaviour of water table and changes in quality with respect to season

b. Lithologs of the selected wells

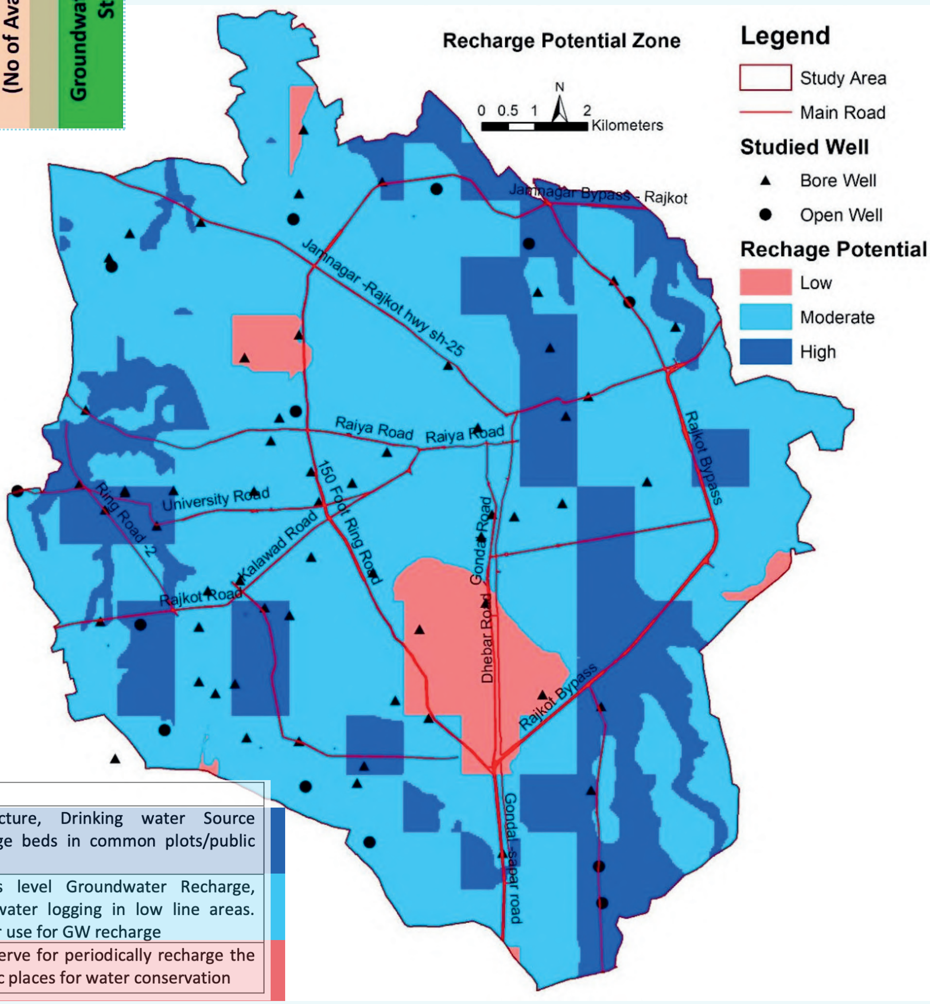
- for mapping the lineaments and fissures within the soil layers to project movement of water

## Comprehensive Aquifer Mapping - Rajkot




Geology, lineament fabrics, and landform characteristics are important physical parameters that have main control over groundwater occurrence as they are the governing factors for runoff generation and infiltration processes.

- Well inventory data of Rajkot city clearly reveals both confined and unconfined (shallow) aquifer systems.
- Geological cross sections clearly show that shallow groundwater occurs mainly in loose alluvium and weathered zones of fractured basalts. In majority areas of Rajkot, city static water level depth is found at 40 m.
- Such detailed comprehensive mapping has also helped informing decisions on the location and recharge strategies.




| GW Category | Strategies |
|---|---|
| Good Potential | Development of Surface Recharge structure, Drinking water Source Development. Percolation wells and recharge beds in common plots/public places |
| Moderate Potential | Existing Well/Bore well recharge, Campus level Groundwater Recharge, Treatment in catchment area contributes water logging in low line areas. Injection method for GW recharge. Roof water use for GW recharge |
| Low Potential | Surface Water harvesting, develop buffer reserve for periodically recharge the groundwater in down-stream areas. Use public places for water conservation |

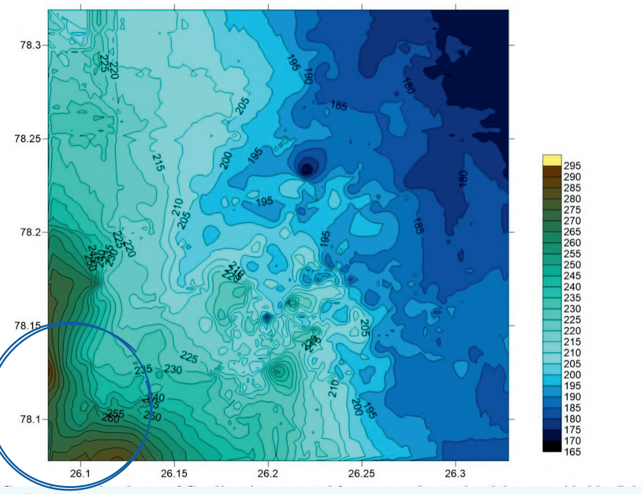
## Mapping groundwater depths at city level - Gwalior

Gwalior city has a legacy of tapping into its shallow aquifers. Groundwater in Gwalior is tapped through 2300 tubewells and borewells drilled by PHED, 504 tube wells installed with power pumps, 54 dug wells and 574 hand pumps, amounting to 18% of formal water supply being drawn from the groundwater reserves.

### Groundwater Contour Map: How did Gwalior do it?

Gwalior Municipal Corporation has initiated the development of an inventory of wells and *Baoris* with their locations and depths. **So far, 1600 wells have been surveyed, and data about their ownership, use, and groundwater depth** (**water depth from the ground level**) **has been collected**. These data points (latitude and longitude) thus collated, have been used to develop a **groundwater contour map. This can help predict the water flow directions and the depth of the shallow aquifer source at the city scale.**

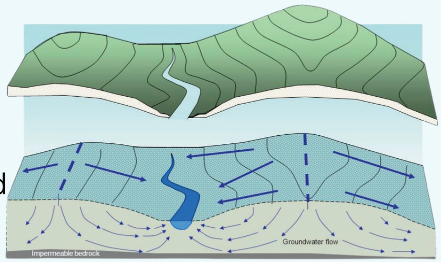
*A water-level contour map is a common tool used by a hydrogeologist to indicate groundwater flow directions*

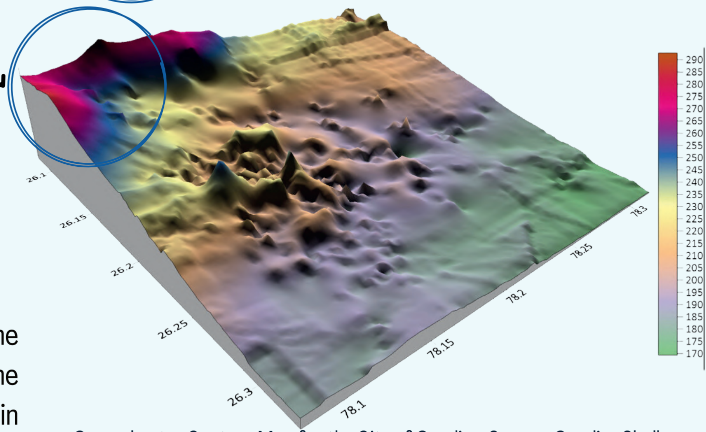


Shallow Aquifer well water head relatively deeper, showing water scarcity

Sub-surface

Underground



Groundwater Contour Map for the City of Gwalior, Source: Gwalior Shallow Aquifer Management DPR, PSI Dehradun

It helps in knowing the availability of water level in the region and to adopt suitable methods to overcome the water scarcity. The contour map can also help in mapping associated contaminant flow paths.

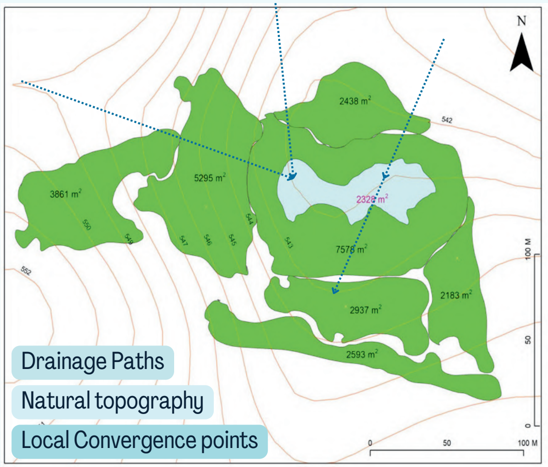
# Delineating Urban Watersheds - Hyderabad

**Watersheds are areas that channel rainwater and runoff and accumulate it in a larger waterbody (interchangeably used as catchment).** Depending on the size of the area and the topography, a watershed can contain numerous tributaries, such as streams and drains, and water bodies such as detention structures, natural ponds, and wetlands.

Understanding urban watersheds allows cities to manage their water resources more sustainably. By **strategically placing recharge structures within watersheds, cities can recharge aquifers, which can serve as a vital source of groundwater recharge.**

For creating a base map, the following layers are required :

- Size of the watershed area
- Shape of the watershed
- Physiography of the watershed
- Rainfall in the watershed area
- Drainage patterns of the watershed
- Land use patterns of study area
- Vegetation covers of watershed area
- Geology and Soils of watershed area
- Hydrology of the watershed area
- Hydrogeology of the watershed area
- Socioeconomic information of the watershed area.




Local watershed mapping in KLN Park, Hyderabad to understand the recharge zones, Source: Hyderabad Shallow Aquifer Management DPR, Rainwater Project

Urban Watersheds - How Hyderabad did it?

1.Hyderabad took up the watershed analysis for its sites by simply using toposheets of the base layers for identification of the drainage lines, estimating run off/ storm waters, and general flows of the rainwater.

2. This exercise indicated that urban watersheds do not follow a natural terrain and all streams/ ponds are modified extensively. The lake within the park that was able to harvest rainwater/ run off water earlier and allowed excess water downstream, is now not behaving in the same manner. It also indicated that the storm water drains are collecting used water/ grey water from the neighborhood and disposing it into the lake, thus contaminating the lake as well as the GW below.

## Step 2: Identifying the Recharge Site

The process of zeroing down on sites for the recharge of shallow aquifers in any city involves two main approaches: identifying existing dysfunctional sites and finding new locations.

**Identifying existing structures/sites for recharge:**

1. Dysfunctional Handpumps/ Wells/Baoris/Step Wells: Start by identifying and assessing existing wells, baoris, or step wells within the city that are no longer in use or are functioning poorly. These structures might have been historically connected to aquifers and could serve as potential recharge points.
2. Urban Flooding Zones: Examine areas prone to urban flooding during heavy rainfall. These zones can indicate areas where excess rainwater can be channeled into aquifers for recharge. Proper design and management can prevent flooding and promote aquifer replenishment.
3. Water Bodies and Low-Lying Areas: Map and identify existing water bodies (such as ponds, lakes, or reservoirs) and low-lying areas prone to water accumulation and urban flooding.

Evaluate the potential for enhancing these water bodies through desilting, expanding, or creating additional storage areas. Develop a design that allows excess rainwater and surface runoff from urban flooding to flow into these water bodies for natural recharge.

It is also important to understand the extent to which the community depends on groundwater for drinking, domestic use, or other purposes. Thus, involving local communities and relevant stakeholders in the selection process can help gather input and ensure community buy-in.

Existing Stepwell (Baori), Gwalior, Source: NIUA

**Identifying New Recharge Sites:**

1. Slope Analysis: Analyze the topography and slope of the city. Identify areas with gentle slopes or depressions where rainwater can naturally collect and infiltrate into the ground. These areas are potential sites for groundwater recharge.

2. Soil Conditions: Evaluate the soil types and conditions in different parts of the city. Sandy or gravelly soils are more permeable and suitable for recharge. Identify areas with such soil conditions for potential recharge sites.

3.Land Use/Land Cover: Consider the land use and land cover of different areas. Open green spaces, parks, or unused land are good candidates for recharge. Prioritize public or municipal-owned lands for recharge projects to ensure ease of implementation

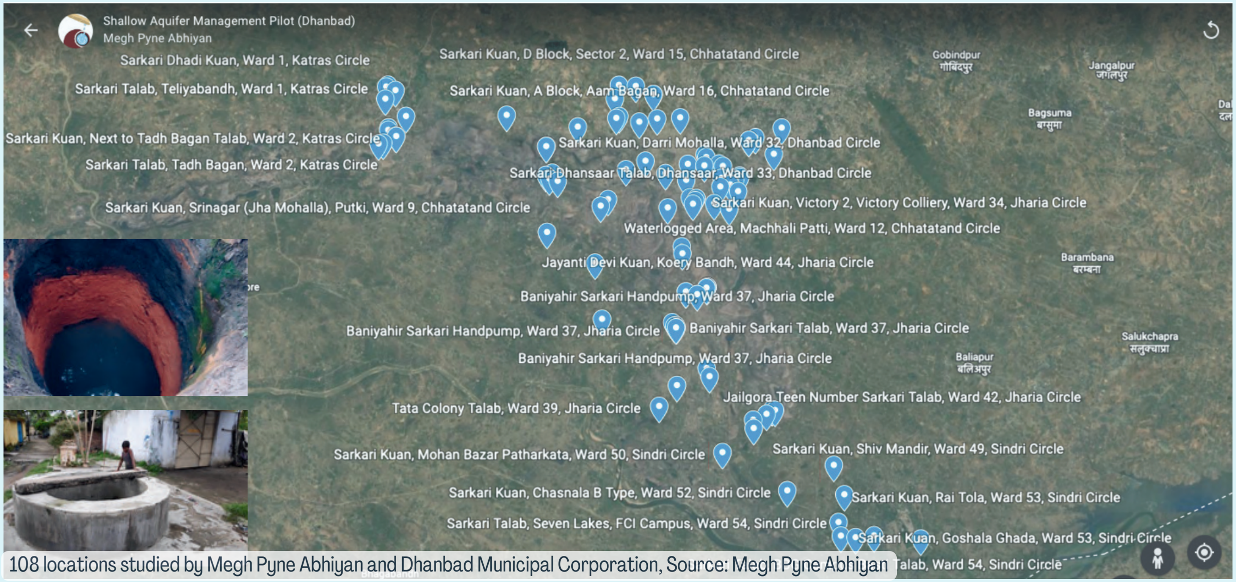
4.Existing Water Table: Use data on the current water table levels to identify areas where the water table is relatively closer to the surface. These areas are less suitable for groundwater recharge and can sometimes result in oversaturated aquifers and thus, flooding.

5. Potential Impacts/Dependence:
Consider the potential impacts of recharge on surrounding infrastructure and ecosystems. Ensure that recharge efforts do not negatively affect existing structures or habitats.
Assess the dependence of communities on groundwater in the vicinity. Ensure that recharge activities supplement local water supply.

6. Potential to tap into surrounding built to collect and divert rooftop rainwater
Asses the surrounding built areas to harness the rainwater from rooftops that can be diverted to the recharge structures.

By combining these approaches, cities can effectively identify both existing dysfunctional sites and new locations suitable for the recharge of shallow aquifers. Prioritizing existing sites can yield quick results, while selecting new sites based on various factors ensures a comprehensive and sustainable groundwater recharge strategy.

## Identifying the potential recharge sites - Dhanbad




108 locations studied by Megh Pyne Abhiyan and Dhanbad Municipal Corporation, Source: Megh Pyne Abhiyan

A study was undertaken in Dhanbad in 35 out of 55 municipal wards spread over 108 locations in both the coalfield and non-coalfield areas of the municipal corporation. The objective of the study undertaken by MPA with DMC was to **understand the relationship and extent of dependence of habitations in 35 wards on shallow aquifers.**

For collating information on the government's groundwater sources in Dhanbad Municipal Corporation Area (DMCA), a **detailed questionnaire for identification of groundwater (dug wells, and handpumps) and surface water (ponds) sources critical for Shallow Aquifer Management** was prepared.

In addition, a section on heritage dug wells and waterlogged areas was also included in the questionnaire. The survey was undertaken by the city managers of the five circles, and executed by sanitation inspectors, ward supervisions, and few safai karamcharies.

While conducting the survey-based study, **various user groups were consulted on:**

- **past and present water use,**
- **groundwater fluctuations in shallow aquifers, and**
- **key water issues at each location.**

These inputs helped in prioritizing and thus preparing a list of potential locations.

## Step 3: Design of the recharge structure/ approach based on local conditions

The earlier section explained on how to identify a site, whether restoring an existing recharge structure or implementing a new one. This section provides a catalogue of recharge approaches and recharge structures for shallow aquifer management that must be tailored to the unique local conditions and address the city's specific needs and challenges. The low hanging intervention in this is reviving existing wells or traditional recharge structures.

### Retrofitting and desilting existing degraded wells/ stepwells

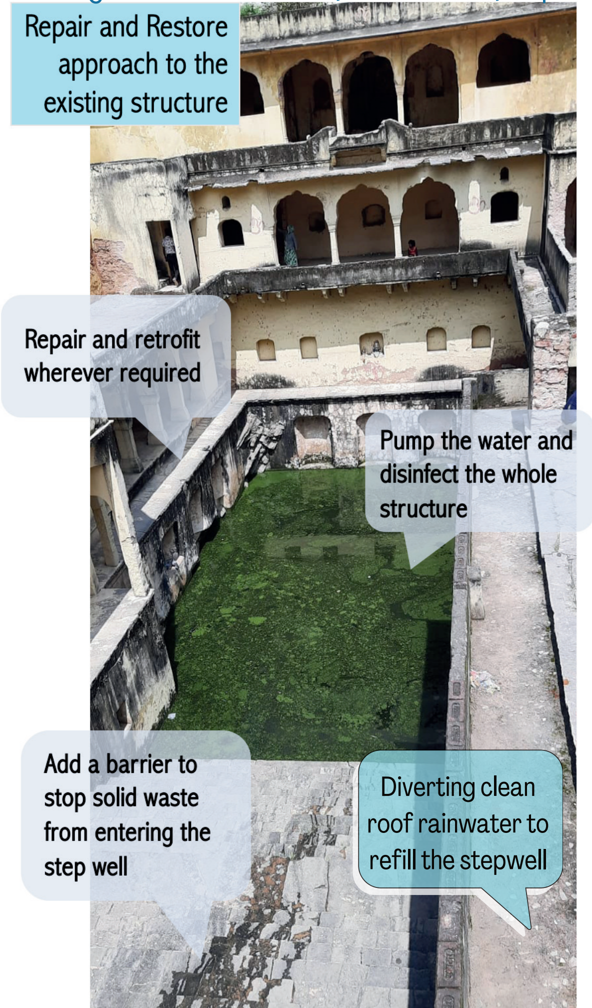
This approach involves repairing and cleaning traditional wells or step-wells that have fallen into disrepair, allowing them to collect and store rainwater.

Design Considerations:

- It is extremely crucial to restore the structure's integrity and functionality.
- Removing accumulated silt, solid waste, and debris from the well will increase its storage capacity and water quality.
- A solid waste trap must be put in place to prevent any waste or potential contaminant from entering.

Maintenance: The wells/ stepwells need to be regularly desilted and maintained to prevent it from becoming clogged or degraded again.

The city of baoris and wells, Jhut ki Baori, Jaipur




Jhut ki Baori demonstration site under SAM, Source: Jaipur Shallow Aquifer Management DPR, CDSE

## A case of bringing back the wells and the well diggers - Bangalore

Community well at Ajanapura, Avalahalli lake as demonstration site under SAM, Source: Bangalore Shallow Aquifer Management DPR, BIOME Enivronment Solutions

One of the many wells in Bangalore is the well (9ft diameter) at Anjanapura/Avalahalli lake, situated right next to a dwelling of a low-income community. The structure of the well has been destroyed and it is filled with garbage. This can contaminate the groundwater. Restoration of the well is required for it to be usable and also to avoid groundwater contamination, via the following simple steps:

- Cleaning the well by removing solid waste and desilting.
- Reconstruction of the walls of the well.
- Covering the well with a grill to prevent further dumping of garbage

This will provide a cheap, convenient and sustainable source of water for the low-income community and ensure prevention of groundwater contamination.

The well-diggers community of Bangalore have cleaned, deepened, dug new wells, and revived at least 10,000 such open wells in the city.

## Constructing New Recharge Wells

Recharge wells are specially designed holes dug into the ground to allow rainwater to percolate into the aquifer below.

Design Considerations:

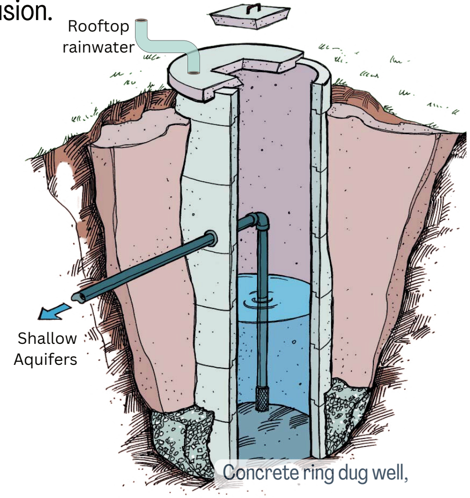
- **Location**: Choose areas with good soil permeability and proximity to existing aquifers.
- **Well Diameter and Depth**: Design the well size and depth based on the local geology and expected recharge rates.
- **Filter Media**: Use gravel or sand as filter media to prevent sediment from clogging the well.
- **Combination with Rainwater Harvesting (RWH)**: Rainwater from rooftops or other sources is collected through pipes, which then flows into the well and percolates into the ground.

Maintenance: Needs regular inspection and cleaning of the well as well as RWH system to remove any sediment or debris that may accumulate over time.

## Chennai to create fresh water reserves at shallow depths

In Chennai, communities have been drawing water from shallow aquifers since historical times. People dug wells by hand and went no deeper than the shallowest source of dependable water. In many areas, especially near coastlines, that would be a shallow aquifer separated from deeper groundwater by clay layers.

A typical recharge well, 1.6 m in diameter and 6 m in depth, is proposed to augment the ground recharge by diverting the runoff from rooftops and surface areas. A modular concrete ring construction has been adapted by the city to create fresh water reserves at shallow depths, that are rapidly turning brackish due to salt water intrusion.

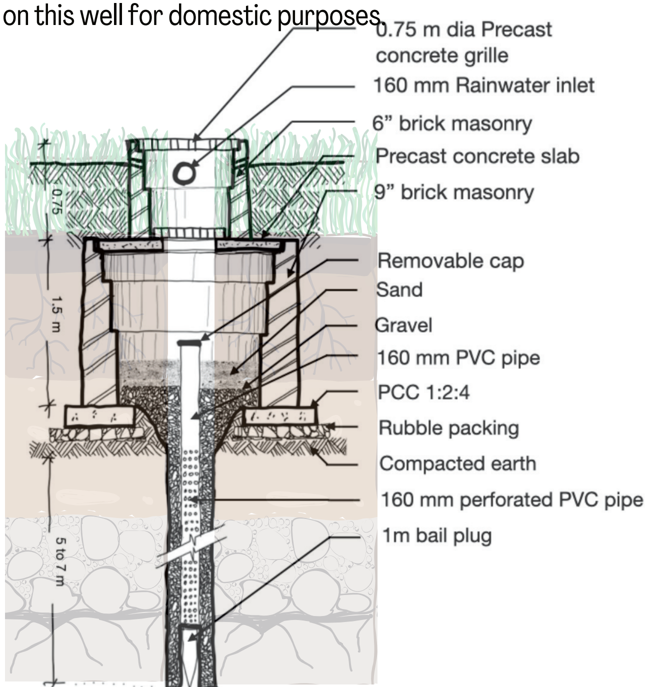


Concrete ring dug well,

## Thane looking to recharge the shallow aquifer wells in the peri-urban and tribal areas in the foothills.

A typical recharge shaft has been proposed in Thane to tap rainwater, using the sloping nature of the site. The rain water coming from the terrace will be channelised through a constructed storm water drain channel, and passed through a filtration chamber and recharge shaft to the shallow aquifer.

The recharged reserves will potentially serve two chawls with 15 families in close proximity to the well and the well water will be used for domestic purposes. An apartment building with 45 families is also dependant on this well for domestic purposes.




Recharge pit with perforated pipe,
Source: Thane Shallow Aquifer Management DPR, Aga Khan Agency for Habitat

### Recharge Pits/ Recharge shaft/ Recharge trench

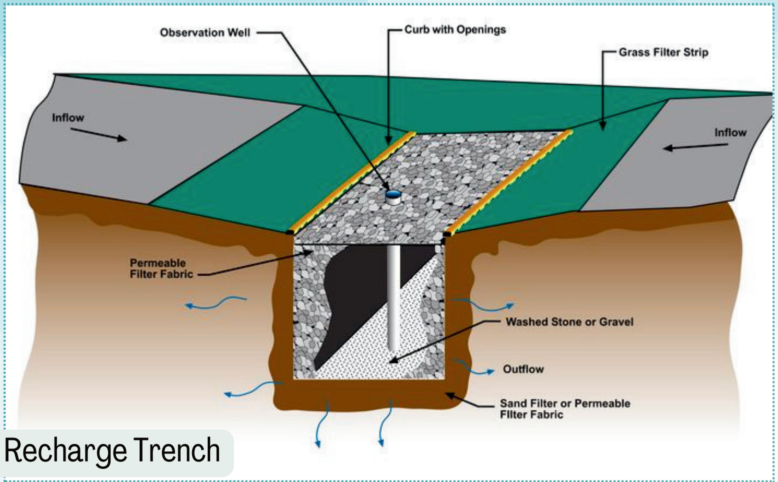
Recharge pits are shallow, excavated pits filled with permeable materials like gravel or stones to allow rainwater to seep into the ground.

Design Considerations:

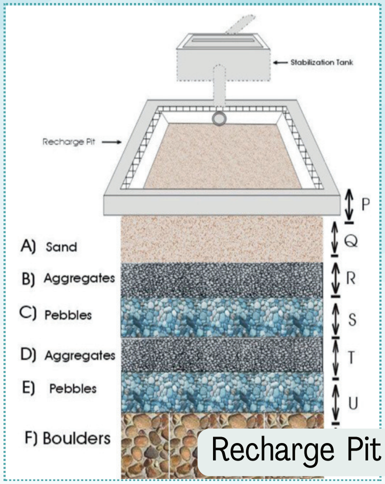
- Design dimensions of the pit are based on local soil conditions, quantum of rainfall, and the required recharge rate.
- Infiltration Media: Use of porous materials like gravel is efficient for water infiltration. Rainwater is directed into the recharge pit, where it gradually infiltrates the soil and replenishes the groundwater.
- A mesh should be put at the drainage point on the roof to prevent leaves or other solid materials from falling into the pit.
- A desilting/oil and grease collection chamber can also be constructed on the surface to stop silt, oil, or grease in case of runoff from roads.
- “Over Flow” system should be integrated for each recharge pit to counter heavy rains.

Maintenance: It needs periodical checks for clogs or sediment buildup, and to remove any obstructions to maintain efficient infiltration.

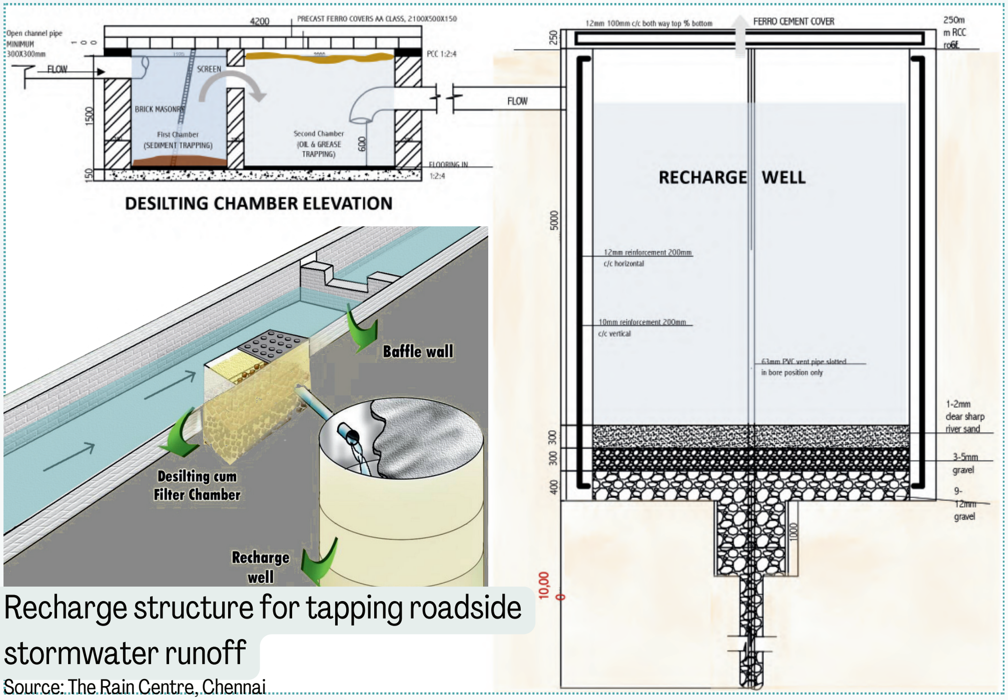
## Some other kinds of recharge structure designs



Recharge Trench



Recharge Pit



Recharge structure for tapping roadside stormwater runoff

Source: The Rain Centre, Chennai


CGWB stormwater structure, Jaipur,Source: NIUA

## Recharge through catchment treatment

Water bodies and streams naturally collect precipitation and runoff from their respective catchment areas.

Recharging a shallow aquifer through catchment treatment of streams and water bodies involves managing the natural flow of surface water to allow it to percolate into the underlying aquifer. In some cases, specialized systems can be designed to encourage controlled infiltration of surface water into aquifers.

There are multiple ways of catchment treatment, based on local conditions and development in and around the catchment. These can be broken down into the following steps:

1. Desilting and clearing the lake and catchment of any solid waste to increase the storage capacity and clear any obstructions.
2. Bank stabilization through stone pitching and plantation of native species.
3. Creating natural trenches and erosion prevention structures.
4. Creating recharge ponds to optimize recharge.

## Pune - watershed development for shallow aquifer recharge

The waterbodies of Pune City are an integral part due its peculiar undulating topography of hills and depressions. Lakes play a vital role in times of dire need, if situated in the recharge areas, by contributing to the natural groundwater recharge.

Harantale is a lake located near Lohgaon, which is a neighborhood in north-east Pune City, Maharashtra. **According to the aquifer map of Pune City by the ACWADAM (2022), the location of the Harantale Lake falls in the natural recharge area.** Harantale project is a potential recharge site to facilitate and enhance MAR through various artificial recharge interventions for the underlying unconfined shallow aquifer.

On the western part of the Lake, development is happening very fast. Hence, it is necessary to delineate and protect the catchment that can be instrumental in shallow aquifer recharge.

1. De-silting of the lake: Currently the lake has a storage capacity of around 50,000 m3. However, based on the study of all the cross-sections and the longitudinal section, it is observed that the lake is silted 2 to 4 m from the bottom. Presence of silt at the bottom of the lake prohibits infiltration and percolation of water.

2.Continuous contour trenches in the catchment of Harantale Lake would approximately arrest and hold up to 2,800 m3 of surface runoff. This will also help in arresting the contaminants in the upstream areas.

> Continuous Contour Trenches are basically soil conservation structures, which are constructed on hill slopes as well as on degraded and barren waste lands in both high and low rainfall areas along the contours. The trenches break the slope at intervals and reduce the velocity of surface runoff.

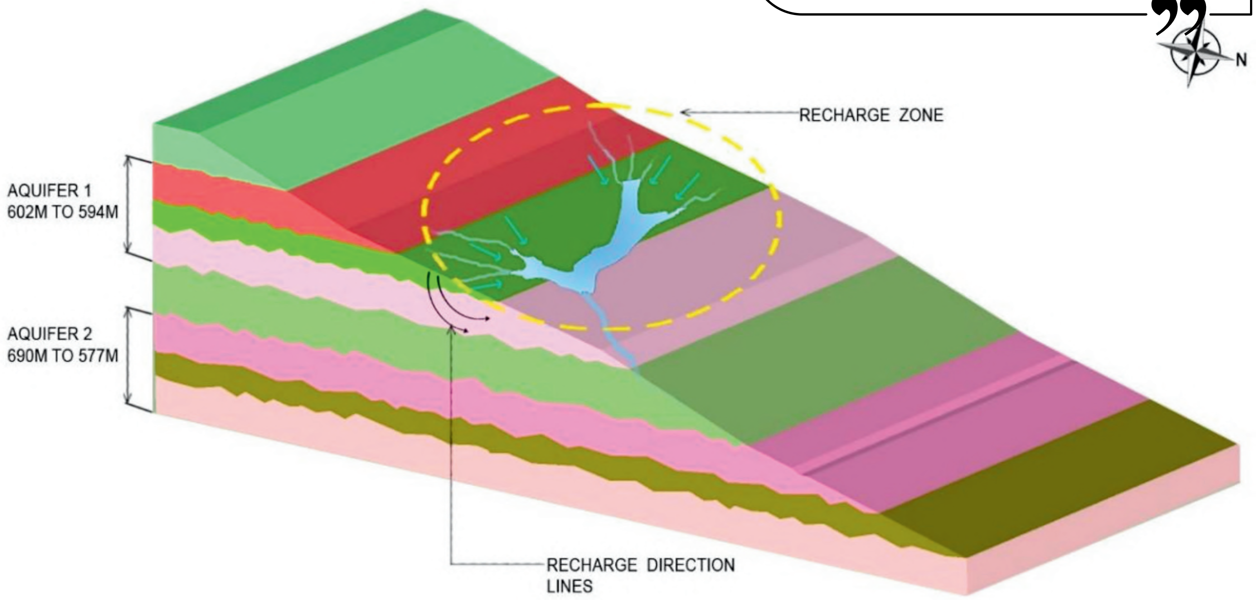



*Figure 8: Combination of LS along section BB' & Geological Section showing aquifer & recharge relationships in the area*

Harantal Lake catchment treatment as Shallow Aquifer Management demonstartion site,
Source: Pune Shallow Aquifer Management DPR, Bhujal Abhiyan and ACWADAM

### Staggered Contour Trenches (SCT)

The staggered trenches may be continuous or interrupted along the contours. The number of trenches is provided on the basis of slope and to ensure maximum storage volume. This is because as the slope increases, the soil stability decreases. SCT are suitable on gentle slopes with less than 15% incline. This helps in arresting the soil erosion and improve infiltration.

3. The SCT, as a whole, would approximately arrest and hold up to 2,600 m3 of surface runoff. Trees species and grasses can also be planted along with SCT to make the structure more sustainable.

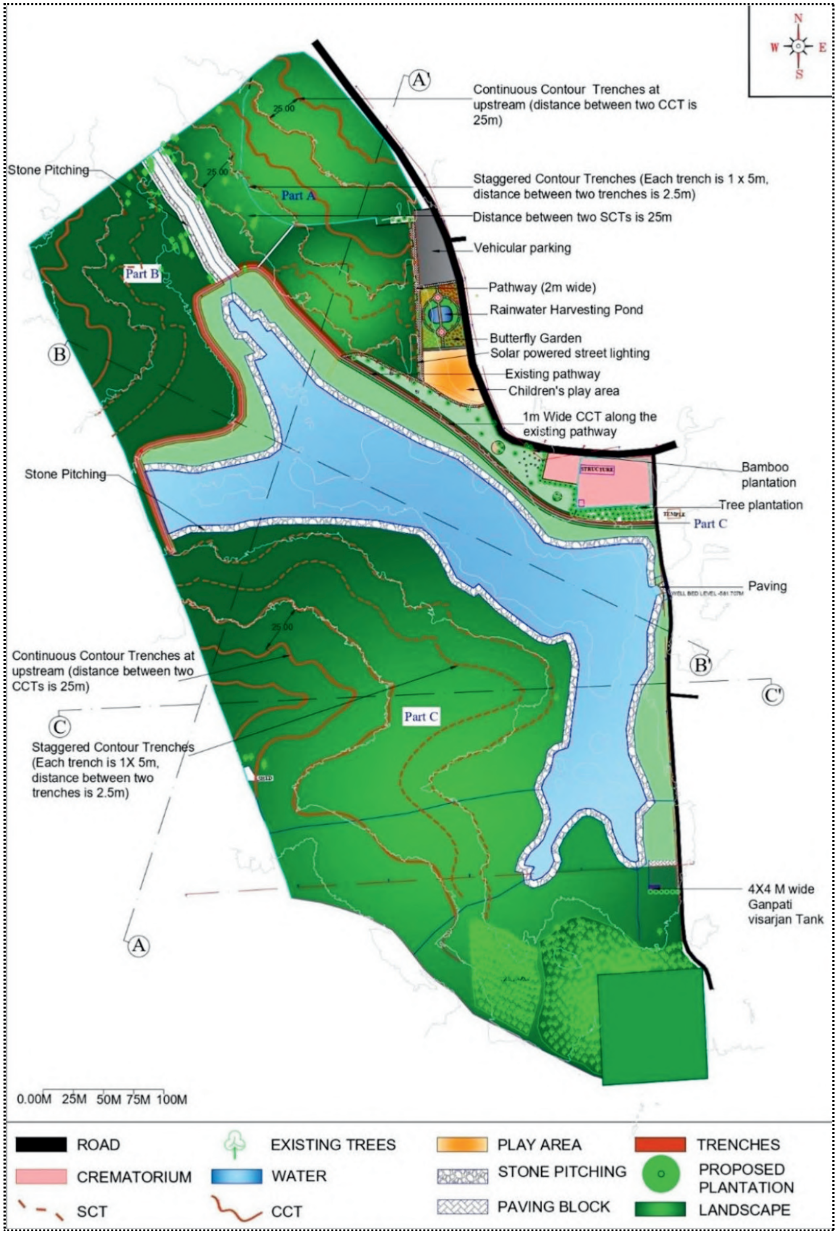
4. Rainwater Harversting Pond:

A rainwater harvesting pond has also been proposed to enhance the MAR, as sufficient rainfall is available for storage. The objective is capturing rainwater and enhancing MAR by around 2,000 m3 from this structure. This will help in creation of the micro climate locally, which will help in reducing the evaporation losses.

5. Stabilisation of stream banks is important for reinforcement of the course of the stream. Erosion along a stream bank can cause loss of land and property damage during events of floods. Stabilisation in stone is the long-term solution proposed against the bank to protect it from erosion while absorbing wave and flow energy.

6. Shrub beds and tree plantation: Shrub beds have been proposed along the pathways around the lake and around the rainwater harvesting pond. Planting of local species of grasses and shrubs on the mounds downstream side of the trenches will help prevent soil erosion.

7. Permeable paving blocks: The most commonly used permeable pavement surfaces are interlocking pavement blocks, amended soils, or landscape rocks. The main objective of this detail is to ensure maximum infiltration of rainwater.




Harantal Lake catchment treatment as Shallow Aquifer Management demonstartion site, Source: Pune Shallow Aquifer Management DPR, Bhujal Abhiyan and ACWADAM

Janak taal (lake) is a beautiful historical monument of heritage importance, people used Janak Taal's water for domestic and drinking purposes. However, presently Janak Taal has less water due to decrease in flows to the Janak Taal by feeder streams and lowering of groundwater table in the surrounding area and also because of dumping of garbage.

Janak Taal, Gwalior, Source: NIUA

## Step 4: Ensuring implementation

Implementing structures for shallow aquifer recharge involves a systematic approach, from planning to execution.

### Pre-feasibility checks before implementation

Lithologs and Aquifer Mapping: Document geological information through lithological logs, and update aquifer maps as construction progresses.

Determine the need for aquifer recharge structures based on groundwater availability, community dependence

Collecting Baseline information on levels and quality.

### Detailed Project Report Development

Design and Engineering: Develop detailed design plans for the selected structures, including dimensions, materials, and construction techniques.

Cost Estimation: Prepare a comprehensive cost estimate for the project, covering construction, operation, and maintenance expenses.

Stakeholder Engagement: Consult with local communities and stakeholders to gather input.

### Contracting

Tendering: Prepare tender documents and invite bids from qualified contractors for the construction of aquifer recharge structures.

Contract Award: Select the contractor through a competitive bidding process with Quality Assurance.

### Construction

Drilling / Digging: Begin construction according to the project plan, which may include drilling wells or involving local well diggers.

Monitoring Wells: Install monitoring wells to track changes in groundwater levels and quality over time.

### Quality Checks and Testing

Water Quality Testing: Regularly test the quality of water entering the aquifer recharge structures to ensure that it meets required standards.

## Step 5: Monitoring and Documentation

Regular monitoring and documentation can alert authorities to over-extraction or contamination issues, allowing for prompt corrective measures to prevent depletion or pollution.

### Visual Monitoring:

- Surface Water Observation: Regularly inspect the area surrounding recharge structures, such as lakes feeder streams or water bodies, to check for visible signs of seasonal variation in groundwater levels, water infiltration, or surface runoff.
- Vegetation Growth: Monitor vegetation growth in and around recharge areas, as healthier vegetation can indicate successful aquifer recharge and improved groundwater levels.
- Structural Integrity: Visually inspect the condition of recharge structures, ensuring that they remain intact and free from blockages or damage.
- Sediment Accumulation: Observe if sediment or debris is accumulating within recharge structures. This may require periodic removal to maintain functionality.
- Catchment Protection: Monitor the catchment areas of water bodies in recharge zones, low lying areas, and groundwater recharge potential zones for any encroachments or polluting activities.

### Piezometer Monitoring:

- Installation of Piezometers: Install piezometers at strategic locations within the aquifer recharge area. These piezometers should penetrate the aquifer to measure groundwater levels and quality.
- Regular Groundwater Level Measurements: Conduct regular measurements of groundwater levels in the piezometers. This data helps assess changes in groundwater levels over time.
- Water Quality Sampling: Periodically collect water samples from the piezometers to assess groundwater quality. Analyze the water samples for various parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, major ions, and any specific contaminants of concern (e.g., heavy metals, organic compounds).

## Step 6: Ensuring Protection

For long term sustainability of shallow aquifers, management considerations need to be integrated into urban planning guidelines and land use planning. This will entail:

### Zoning Regulations:

**Designating Recharge and Discharge Areas:** Identify and designate groundwater recharge and discharge areas within the city's zoning regulations. Ensure that these areas are protected from activities that could lead to contamination or over-extraction.

**Limiting Impervious Surfaces:** Reduce use of impervious materials and surfaces, such as concrete and asphalt, particularly in green and open areas, water streams and waterbodies to reduce surface runoff and promote infiltration of rainwater into the aquifer.

**Low-Impact Development (LID) Techniques:** Encourage the use of LID techniques, such as permeable pavements, vegetative swales, and rain gardens, to manage stormwater locally and promote aquifer recharge.

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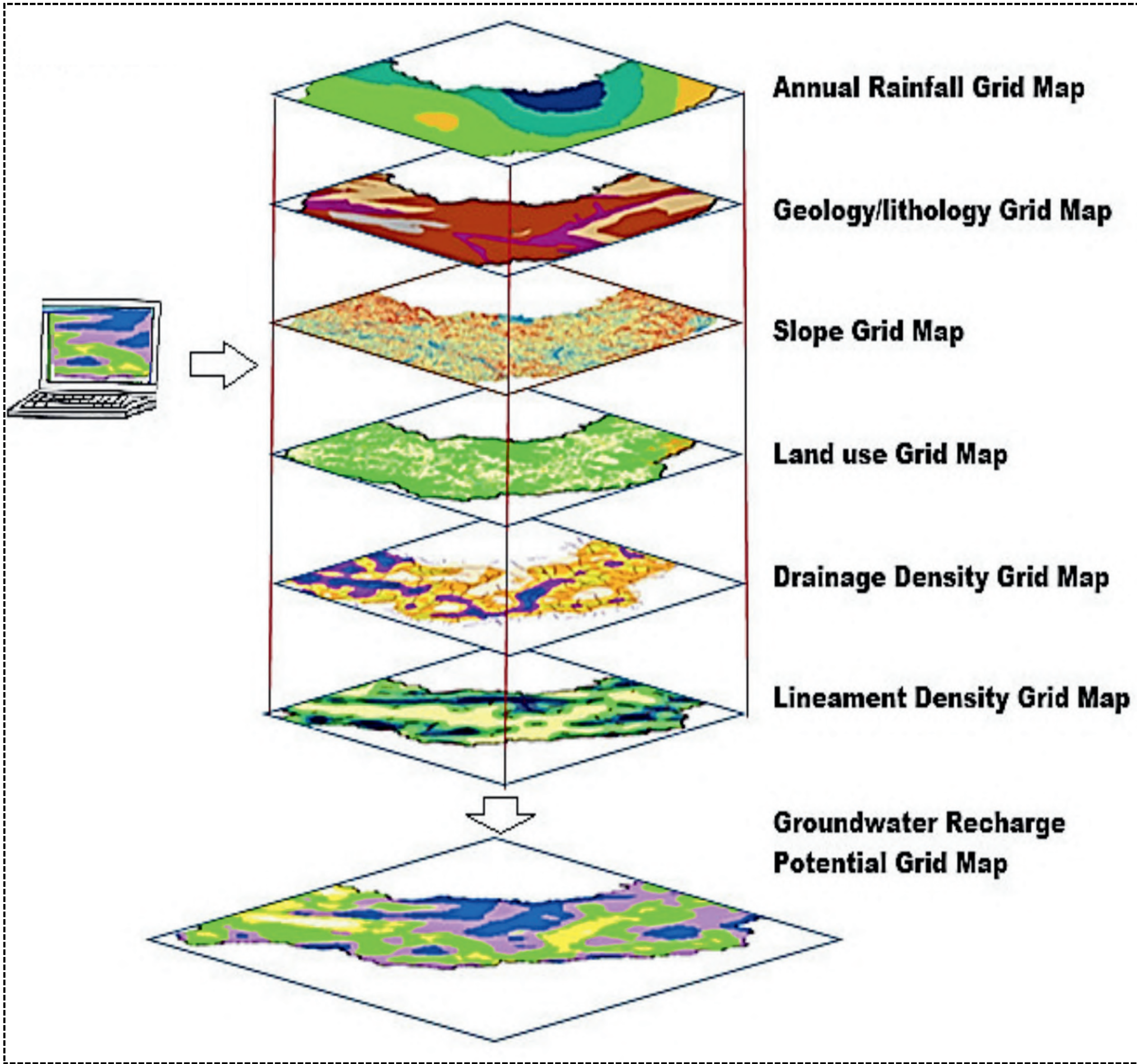
**Preserve and Create Green Spaces:** Preserve existing green spaces, wetlands, and riparian zones that naturally contribute to groundwater recharge. Create new green spaces within the city to enhance infiltration.

**Comprehensive Landuse Planning:** Integrate groundwater considerations into comprehensive landuse planning, ensuring that land use, transportation, and infrastructure planning account for aquifer protection and maintenance. Implement measures to control and monitor landuse that can be potential sources of groundwater contamination, such as industrial zones, hazardous material storage, and sanitation systems.




Different layers to inform landuse planning, Source: Nepal: Building Climate Resilience of Watersheds in Mountain Eco-Regions, Integrating GIS to Mapping Ground Water Recharge Potential, ADB

## 4. What are some typical errors while implementing recharge structures for shallow aquifer management ?

Implementing recharge structures for shallow aquifer management in urban areas requires careful consideration of potential pitfalls and "not-to-dos" to ensure the protection of groundwater resources. Following are some considerations that cities must take into account:

- Recharge Source Water Quality : Failing to assess the quality of the source water before implementing recharge structures can lead to contamination of the aquifer. It is important to identify potential sources of contamination, such as oil and grease from roads, contaminants in industrial areas, or wastewater discharge points, and consider additional treatment if necessary before recharging.

- High Water Table Areas with Saturated Soil: To avoid water logging, the cities must refrain from implementing recharge structures in high water table areas with highly saturated soils. It must be ensured that the recharged water can effectively infiltrate the aquifer without contributing to flooding of water bodies and low lying areas.

- Horizontal Rupturing of Aquifer Layers: While implementing the recharge structures, proper care must be taken to avoid horizontally rupturing the aquifer layers during the installation of recharge structures. Disrupting the natural stratigraphy of the aquifer can hinder the effectiveness of the recharge process.

- Proximity of Sanitary Facilities to Wellheads: Implementors must be be cautious about locating sewerage and on-site sanitation structures too close to wellheads or areas where groundwater is sourced for drinking, ensuring prevention of potential pollution from reaching the aquifer.

- Negligible Low Permeability Layer at Surface: While siting the location of recharge structures, implementors must be mindful of areas with negligible low permeability layers at the surface. With no permeable surfaces, recharge in these areas can pose a risk of urban flooding.

- Recharge Wells in Heavy Industry Areas: Any city must avoid siting wells in heavy industrial areas where the risk of groundwater contamination is higher due to industrial activities. In absence of a treatment facility, the effluent waste is directly disposed off in open areas. This kind of soil contamination runs a high risk of contaminating the whole aquifer.  Where existing wells are present,  monitoring and protective measures should be in place.

- Leakage from Sewers or Subsurface Ducts: The city bodies must implement measures to prevent leakage from sewers or other subsurface ducts, as this can introduce pollutants into the aquifer.

- Standard In-Situ Sanitation Units: In areas with standard decentralized in-situ sanitation units such as soak pits, there may be a higher risk of pathogens penetrating the aquifer. The city must ensure that sanitation systems are designed to minimize the risk of contamination.

In summary, careful planning and consideration of potential sources of contamination, aquifer characteristics, and protective measures are essential when implementing recharge structures for shallow aquifer management in urban areas. Avoiding these "not-to-dos" can help protect the quality and sustainability of groundwater resources.

The urban waterbody wetland in Kolkata, when revived can serve as a crucial natural reservoir, vital for recharging the shallow aquifer. Its ability to filter and store rainwater helps sustain groundwater levels, ensuring a reliable source of freshwater for the city's inhabitants


Urban Wetland, Kolkata; Source: Author

## 5. How to create an enabling environment for shallow aquifer management?

In the Indian urban context, so far, groundwater has only been seen from the lens of supplementing the municipal supply or as a means to continuous domestic and commercial supply by private stakeholders. Water being a state subject, effective rainwater harvesting/recharge of groundwater including taking up groundwater projects for its sustainable management usually comes under the State mandate.

Moreover, in most Indian cities, there is a **lack of professional hydrogeological expertise when it comes to city water management.** Municipal water supply utilities often prioritize day-to-day operational needs without considering groundwater as a significant urban resource to be protected and recharged. It is also true that urban groundwater management decisions have always involved institutions with specialised knowledge in water resources at the national and state level, but so far, not at a city scale.

Given this context, it is crucial to create an enabling environment for urban groundwater management to be a focus area for municipal decision-makers and experts. This can be done through the following approaches:

1. Policy Provisions: Water being a state subject, groundwater management and protection policies at the state level can influence effective decision making for the quantitative as well as qualitative improvement of groundwater at the city level. States like Uttar Pradesh, Karnataka, Tamil Nadu have formulated groundwater policy and acts and have seen some encouraging results.

The Uttar Pradesh State Groundwater Policy 2013 is a first among many cities and puts dedicated focus on 'urban' groundwater management, with actions like:

- Under **data strengthening** programme of the Ground Water Department, urban areas in the state have been included for the first time for monitoring of groundwater levels, and approximately 1200 piezometers have been installed, covering a grid of 2 x 2 km.
- **Roof top rain water harvesting is mandatory for plot size 300 sq m or more**. The provision has been included in the Building by- laws of Housing and Urban Planning Department
- **Conservation of existing water bodies** with catchment restoration in all urban areas is mandatory.
- In parks, only 5% area is allowed to be covered with concrete / pavements.
- **Maintenance and upkeep** of the recharge structures should be an integral part of all the recharge schemes.

2. Regulatory Frameworks: Given the city's heavy reliance on groundwater for various purposes, including drinking water supply and agricultural irrigation, the depletion and degradation of this resource pose significant threats to public health, environmental sustainability, and urban resilience. An example of Indian cities that have recognized this need and implemented successful groundwater protection measures is Bengaluru, which has adopted rainwater harvesting and strict zoning regulations to safeguard its depleting aquifers. The city has instituted regulations to control industrial pollution and encroachment on water bodies, aiming to safeguard groundwater quality and recharge mechanisms.

Delhi has implemented zoning laws and building codes that restrict construction in groundwater recharge zones and mandate rainwater harvesting systems in new developments to replenish aquifers.

Chennai has adopted land-use planning strategies that prioritise the preservation of green spaces and natural drainage systems to prevent urban flooding and enhance groundwater recharge.

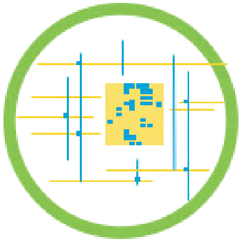
3. Incentivization Mechanisms: Incentivizing groundwater recharge and protection measures is crucial for sustainable water management in Indian cities. Some examples of these mechanisms are:

- Pune's initiative of offering property tax rebates to homeowners installing rainwater harvesting systems serves as a prime example of encouraging individual contributions to replenishing groundwater resources.
- Delhi's Master Plan incorporates the concept of the Green Blue Area Factor, providing developers with extra Floor Area Ratio (FAR) for integrating green and blue infrastructure, such as rainwater harvesting pits and permeable surfaces, which facilitate groundwater recharge.
- Additionally, industrial areas in Noida have introduced groundwater credits, rewarding businesses for injecting clean water into the ground, thereby replenishing aquifers and mitigating groundwater depletion.

4. Disincentization/ Punitive Mechanisms: Punitive measures serve as deterrents, signaling the seriousness of groundwater protection and dissuading violators from engaging in activities that degrade or deplete this vital resource. For instance, the Central Pollution Control Board (CPCB) in India has established stringent regulations under the Water (Prevention and Control of Pollution) Act, 1974, which empower authorities to levy substantial fines on industries violating discharge standards and polluting groundwater. Additionally, local municipal corporations may impose water cess or surcharges on entities extracting groundwater beyond permissible limits, disincentivizing overabstraction and encouraging responsible water use.

## A case of Delhi Master Plan 2041

### Green Blue Factor (GBF)



Mandated for all new projects & developments.

Computed by combining the prescribed weightage of specific green and blue features provided in the site and building design.

| S. No. | Type of Blue/green element (X) | Factor |
|---|---|---|
| 1 | Impervious surface (including paved areas, black top driveways and internal streets, roof surface without green roof) | 0 |
| 2 | Chlorinated water feature (e.g. swimming pool) | 0.2 |
| 3 | Green Wall (supported vertical systems for plants on external wall surfaces) | 0.2 |
| 4 | Pervious surface with water absorbent tiles | 0.3 |
| 5 | Pervious surface with manicured lawn and/or Greenhouse | 0.5 |
| 6 | Green Roof (minimum 70% area covered with plantation and shrubs) | 0.6 |
| 7 | Pervious surface with natural grass/ground and vegetation (including urban agriculture) | 0.8 |
| 8 | Area under tree cover (canopy density 10-40%) | 0.9 |
| 9 | Area under dense tree cover (canopy density 40% or more) | 1 |
| 10 | Open water body with non-lined bottom (non-chlorinated) | 1 |

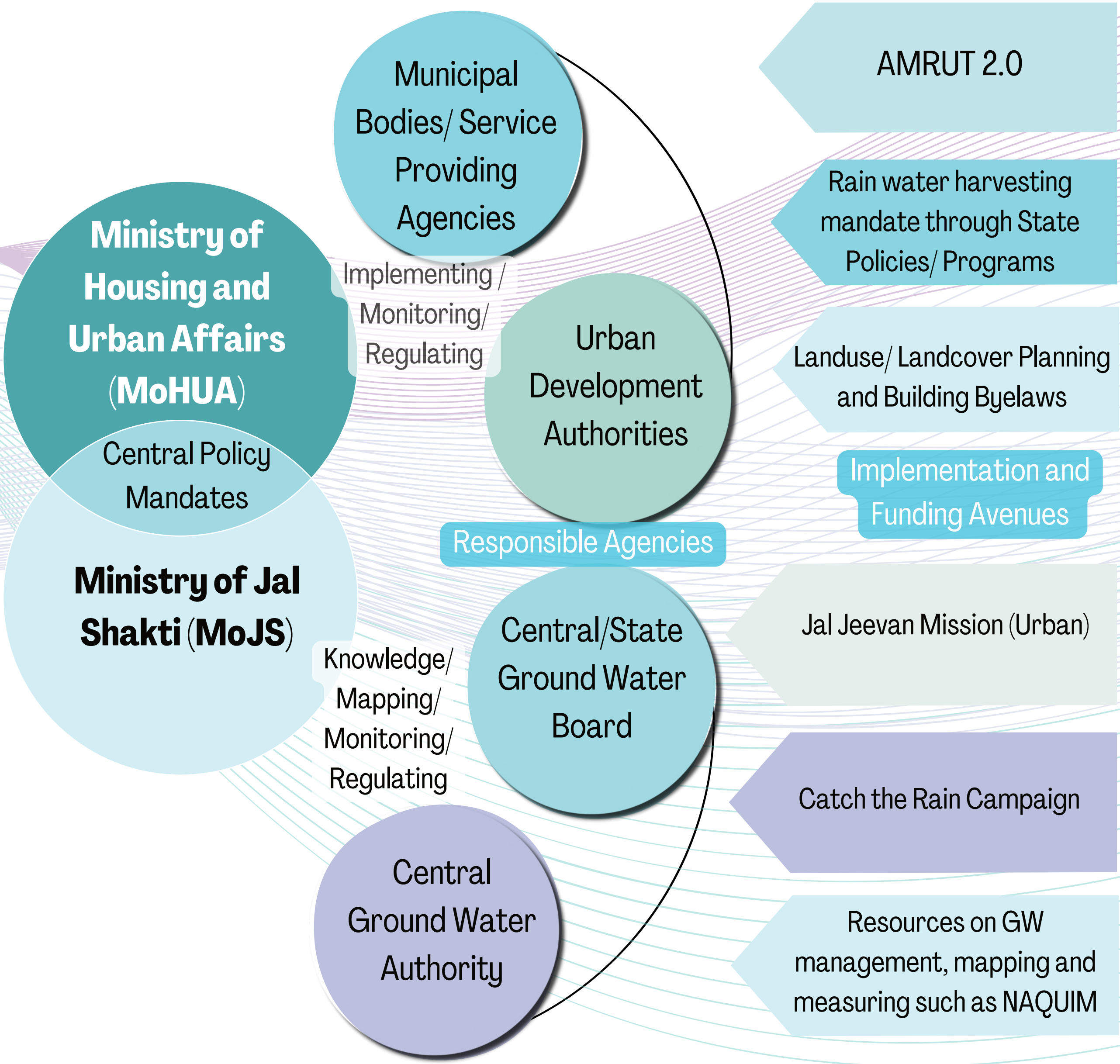
GBF for a plot shall be calculated using the following formula:

**GBF = {(Area under element X corresponding factor) +... (Area under element nX corresponding factor)}/ Total plot area**

5. Dedicated cell/ body: Cities seeking effective groundwater management can draw inspiration from successful models like Pune's Groundwater (GW) Cell. Establishing dedicated city-level units, akin to the GW Cell, can provide a focal point for comprehensive groundwater actions. These units should encompass experts, officials, and stakeholders committed to monitoring, conservation, and regulation. By centralising efforts, cities can lead targeted interventions, enforce sustainable practices, and enhance public awareness.

These institutional units become vital knowledge hubs, facilitating data-driven decision-making and fostering collaboration for a resilient and sustainable urban water future.

## Existing institutional setup and policies on GW management at the national level



## 6. How can **ULBs implement Shallow Aquifer Management** ?

Urban local bodies, including city municipalities and governing authorities, can play a crucial role in the implementation considerations of shallow aquifer management within urban areas. Here are several key roles and responsibilities that ULBs can undertake to effectively manage shallow aquifers:

Managed Aquifer Recharge: Develop and implement aquifer recharge strategies within the urban area, such as recharge structures, rainwater harvesting, stormwater management, and the protection of natural recharge zones. This will also include promoting and enforcing sustainable use and extraction practices.

Groundwater Monitoring: Implement and maintain groundwater monitoring networks to track water levels and quality in shallow aquifers. This data is essential for informed decision-making.

Regulation and Permitting: Establish and enforce regulations related to groundwater extraction, well construction, and water use permits within their jurisdiction.

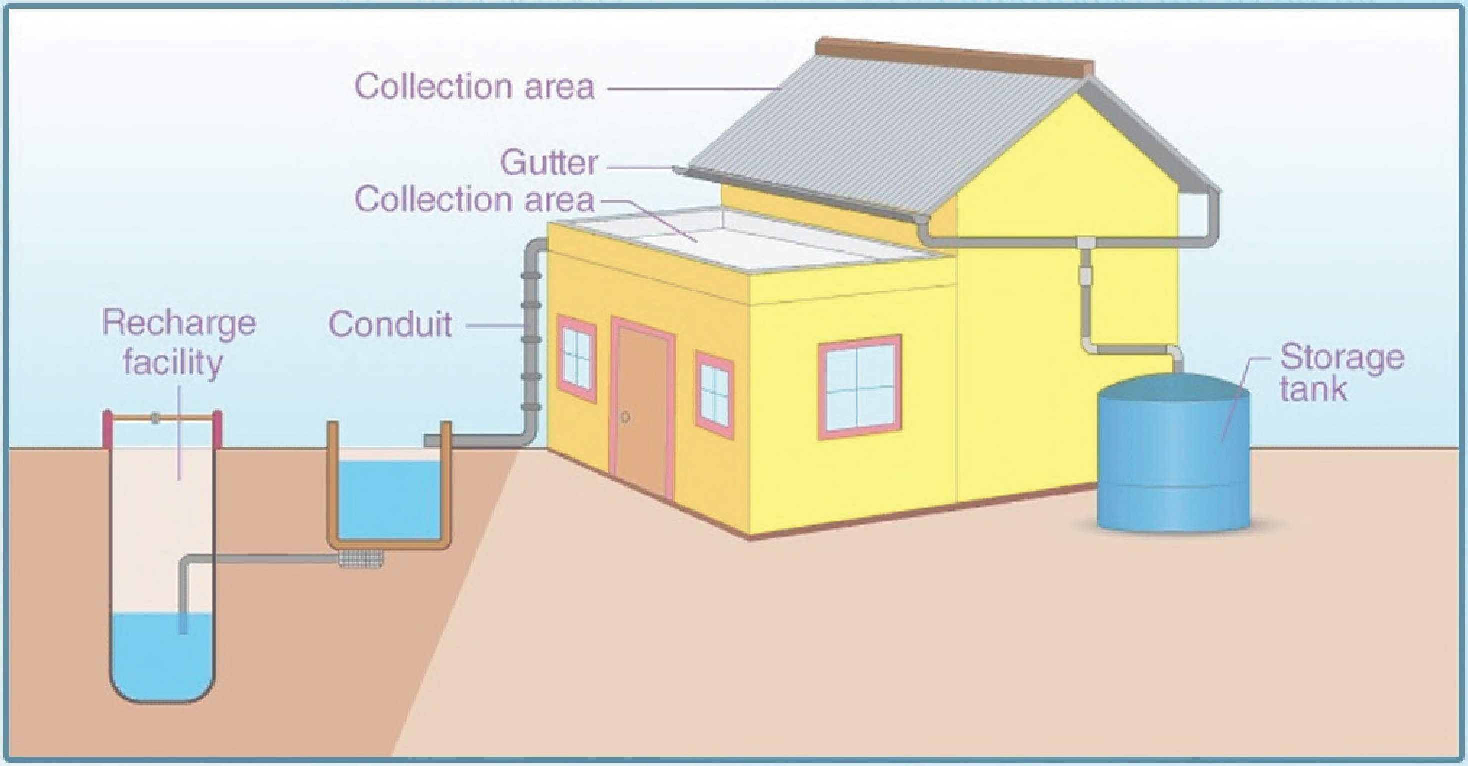
Water Quality Management: Implement measures to prevent contamination of shallow aquifers from various sources, including industrial discharges, wastewater, and landfills. This may involve regulating industrial activities and ensuring proper sanitation and waste management.

Land Use Planning: Integrate groundwater considerations into urban land use planning and zoning regulations. This can include restrictions on certain types of development or land uses in areas vulnerable to groundwater contamination or over-extraction.

Community Engagement: Engage with local communities, stakeholders, and water users to ensure that management decisions align with their needs and concerns. Foster awareness of the importance of groundwater conservation.

Funding and Resource Allocation: Allocate budgetary resources for groundwater management initiatives, infrastructure development, and maintenance. Explore partnerships and funding opportunities with state and central government agencies for groundwater projects.

**Pune Municipal Corporation** has established a dedicated **Groundwater Cell,** aiming to identify and safeguard groundwater reserves, gather data on bore well water extraction rates, and prevent groundwater pollution.



## GLOSSARY: Demystifying Groundwater

Aquifer: A subsurface rock or sediment layer that can store and transmit water, providing a source of groundwater.

Cone of Depression: A temporary lowering of the water table around a heavily pumped well, which can lead to reduced groundwater levels in the vicinity.

Drawdown: The decrease in the water level of a well or the water table as a result of groundwater pumping or other water extraction activities.

Groundwater Dependence: The extent to which a community or region relies on groundwater as a primary source of freshwater for drinking, irrigation, and other essential needs.

Groundwater Management: The sustainable and responsible use, monitoring, and regulation of groundwater resources to ensure their long-term availability.

Groundwater Monitoring: The systematic collection of data and measurements to assess the quantity, quality, and trends of groundwater resources over time.

Groundwater Recharge: The process by which surface water infiltrates into the ground and replenishes underground aquifers, either naturally through rainfall or artificially through techniques like percolation ponds.

Groundwater Remediation: The process of cleaning up contaminated groundwater through various techniques and technologies to restore its quality for safe use.

## GLOSSARY: Demystifying Groundwater

Groundwater Sustainability: The condition in which the extraction of groundwater does not exceed its natural recharge rate, ensuring the resource's continued availability for future generations.

Managed Aquifer Recharge (MAR): A systematic approach to enhancing groundwater recharge through human interventions, which may include construction of structures, diversion of surface water, and treatment of water before recharge to improve water quality.

Over-Extraction: The situation in which the rate of groundwater withdrawal exceeds the rate of natural recharge, leading to a decline in groundwater levels and potential long-term resource depletion.

Percolation: The movement of water through the soil and into the underlying aquifer, often facilitated by gravity or capillary action.

Permeable Surface: Surfaces that allow water to pass through, such as natural soils and gravel, enabling infiltration and groundwater recharge.

Shallow Aquifer: An aquifer located at relatively shallow depths below the ground surface, often used for local water supply.

Water Table: The level at which the ground is saturated with water, representing the upper boundary of the saturated zone within an aquifer.

Handpumps accessing shallow aquifers, Kolkata; Source: NIUA

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सत्यमेव जयते

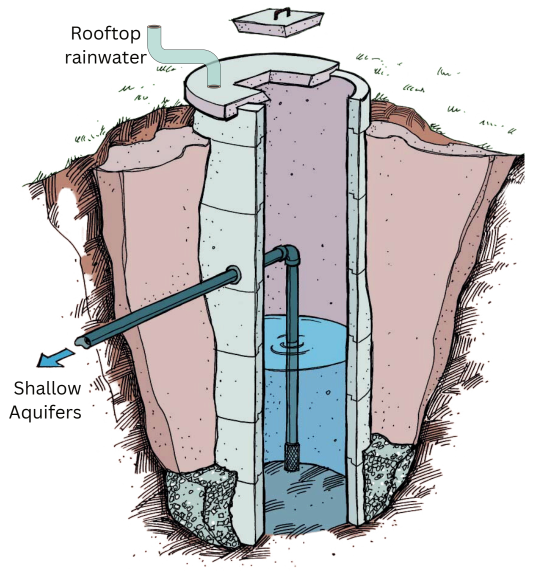
Ministry of Housing
and Urban Affairs
Government of India

अमृत

Atal Mission for Rejuvenation
and Urban Transformation

NIUA

National Institute of Urban Affairs



Rooftop
rainwater
Shallow
Aquifers