

# Inducing Recharge of Groundwater by Treated Waste Water - A Pilot Study in Southern Chennai Metropolitan Area

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## Abstract

Artificial recharge of groundwater using treated wastewater continues to rise, especially in arid and semi-arid countries. Artificial recharge as a means to enhance the natural supply of groundwater aquifers is becoming increasingly important in groundwater management. The present pilot study aims to planning and designing of artificial recharge structures for an ideal housing complex using treated waste water generated within the complex. Basic operational water requirement is estimated to quantify the water to be recharged for a balanced and sustainable water recharge cycle. The study estimated the volume of generated waste water as well as rainfall runoff water from the ideal housing complex. The rate of natural ground water recharge, rainfall runoff and total treated effluent available for recharge is estimated as additional or alternative source of recharge. Detailed Hydro geological study has been carried out to explore subsurface profile by drilling the bore holes in different locations inside the study area. A confined aquifer was found at a level of 4m to 8m in decreasing levels. The soil stratum below the aquifer was found impervious. Hence boring of recharge shafts up to a depth of 4m to reach a confined aquifer layer will be the best suitable method for recharging the aquifer. The depth of aquifer is varying from 3m to 6m. Water fluctuation during monsoon and non-monsoon period was found to be around 5m. The estimated water demand is 1.6 MLD. Based on the Rational Formula, the runoff quantity is estimated as minimum of 13.48 MLD and maximum of 55.47 MLD. Thus the study identifies the significant quantity of runoff from the study area during the monsoon periods. The total estimated effluent available for recharge is estimated as 1.28 MLD. By considering the sources available, hydro geological conditions, the recharge pond and recharge shaft is designed. It encourages not only the maximum utilization of available natural resources but it helps in reducing the demand for freshwater and sustaining the vulnerable resources for future.

**Keywords:** Artificial Recharge, Chennai Metropolitan Area, Groundwater, Treated Waste Water, Hydrogeology, Recharge Shaft

## 1. Introduction

Artificial Recharge Technique is a process of replenishing ground water by Surface and Sub-Surface methods. It is vitally important that groundwater should be recharged naturally or artificially in proportion to the quantum of depletion. As artificial recharge has improved in reputation, managers have begun to search for additional

sources of recharged water. In this context, recharge of groundwater using treated domestic effluent is a viable option that reduces the demand for freshwater and enhancing the waste water reuse. Various methods have been employed all over the world can be briefly classified under two categories as surface method and sub-surface methods<sup>1-3</sup>. In surface methods, available water is stored in an open area to let them percolate to the subsurface res-

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ervoir. In Sub-Surface Method the surface run-off water is sent to sub-surface directly through shafts or wells by natural flow or pumping it using mechanical pumps<sup>4</sup>. The present study is focused on the subsurface method of recharge shaft technique as it occupies comparatively less space and practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone. The rate of recharge is also significant as it directly reaches the permeable layers. The recharge shafts can be constructed in two different ways viz. vertical and lateral. The vertical recharge shaft can be provided with or without injection well at the bottom of the shaft.

Chennai city, one of the major metropolitan cities in India, is situated at the northern coastal edge of the State of Tamil Nadu, India. Chennai is inhabited by more than 7 million people in an area of 176 Sq.km. Water supply for this population is maintained by augmenting a combination of surface storage reservoirs and aquifers<sup>5,7</sup>. The Chennai Metro Water Supply and Sewerage Board (CMWSSB), a statutory body established in 1978, is responsible for water supply and sewerage services in the Chennai Metropolitan Area. The main sources of public water supply in the city are the three reservoirs namely Poondi, Redhills, Cholavaram. The other major resource is groundwater from the well-fields of Araniar-Kortaliyar basin and the southern coastal aquifer, and also a large number of agricultural wells located in the peripheral villages of Chennai city. Over-extraction of groundwater resulted in a rapid ingress of seawater, which results in potential threat to groundwater aquifer. Rainwater harvesting was made mandatory by state government of Tamil Nadu to replenish the sub-surface aquifer, which has given a reasonable result on ground water recharge<sup>6</sup>. Therefore, there is a growing need to make scientific investigations on the role of rainwater harvesting and recharge of groundwater in improving the groundwater availability. This system is also monsoon dependent which is ambiguous in nature and also available for a short period. Sustainable water supply demands the recharge of groundwater aquifer in all conditions irrespective of seasons<sup>8,12</sup>. The preset study is initiated by considering reuse of waste water to recharge the aquifer for augmentation of groundwater which is a viable option rather than demanding the additional sources.

Recently significant transformations have been observed in the nature and pattern of urban growth in India. Our cities are in the midst of restructuring space,

in terms of both use and form which results in growing demands for high rised buildings and increased population density in a restricted space. Thus demand for water is increased necessitates the imported water from the peripherals<sup>9</sup>. It creates water related inequity issues and conflicts between urban and peri-urban areas. It is evident that efficient management needs self-sustained measures to augment the resources<sup>10,11</sup>. The presented paper described the design of artificial recharge structure using waste water generated within their living space. Thus it aims to utilize the treated domestic effluent as a main source for artificial recharge technique. This may increase the water use efficiency by the approach of conjunctive use of surface water and groundwater thereby reduces the demand for freshwater sources.

## 2. Study Area

Sirucher, located at the south of Chennai city, Tamil Nadu, India is selected for conducting the study and it lies on the eastern coastal region. The designed structure for artificial recharge is planned at construction site which covers a wide spread area of 56000 Sqm. It entails 652 apartment units and all sorts of residential and commercial structures with all necessary basic facilities within it. It consists of eight blocks with 14 levels and two basements. Only 40% of the total area is used as built-up area and the remaining area is utilized for landscaping. Thus an integrated regulatory water management with sustainable ground water usage and integrated flood control would deliver higher returns on static water levels. It also improves the yield of borewells in and around the study area.

## 3. Materials and Methods

Population of the selected site is estimated from the total number of apartments and their types. In addition with 10% increase is added for service providers and maintenance. Based on the NBSS Report on land use (Soil Resources of Tamil Nadu, for Land -Use Planning Executive Summary Report, NBSS Publication No. 46, 1997)<sup>8</sup> of Tamil Nadu state, the various types of soil of the watershed were identified. Detailed Hydrogeological study has been carried out to explore subsurface profile by drilling the bore holes BH1, BH2, BH3, BH4 and BH5 in different locations inside the study area. Basic operational

water requirement is estimated to quantify the water to be recharged for a balanced and sustainable water recharge cycle. The rate of natural ground water recharge and rainfall runoff is also assessed which is pre-requisite for efficient ground water resource management. Total treated effluent available for recharge is also estimated as additional or alternative source of recharge<sup>13</sup>. Based on the available sources, the recharge shaft and pond is designed by considering the site hydrogeological characterization.

## 4. Results and Discussions

From the study conducted by the Central groundwater Board along the sea coast, there exist three aquifer system, viz., zone 1 and 2 of red brown sand, grey sand with shells – unconfined and zone 3 of grey sand – clay intercalation with limited extent – semi confined<sup>14</sup>. The basic soil types found in this study area are Inceptisol, Alfisol, Entisol. These soil types are corresponding to the following varieties found in the study area namely Red Sandy Soil, Gravelly clayey soil, Clay loamy soil, clayey soil and alluvial soil. Due to different stages of weathering of parent material, the above soil types are met with in combination. The Soil characteristics of study area is clayey from ground level to a depth varying from 4m to 8m and the infiltration capacity of clayey soil in study area is very low. Hence boring of recharge shafts up to a depth of 4m to reach a confined aquifer layer with sandy soil will be the best suitable method for recharging the aquifer.

The water demand owing the operational requirements of the project has been arrived based upon the following key factors. The domestic demand has been arrived as per IS 1172–1993 clause 4.1 in relationship to the population details. The Fire demand is worked out based on “Kuichling’s formula” ( $3182 \sqrt{P}$  in thousands). The Maintenance requirement is assumed as 100lpcd, and recreational requirement as 50lpcd.

### 4.1 Bore Hole Analysis

The borehole analysis conducted at the site to reveal the hydrogeological condition and the occurrence of groundwater<sup>16</sup>. It indicated that soil strata for the first 4m to 8m from the ground level were found as a dense clayey soil. A confined aquifer was found at a level of 4m to 8m in decreasing levels. The soil stratum below the aquifer was found impervious and the water table contour was found

sloping down towards north side from the South end. The depth of aquifer is varying from 3m to 6m. Water fluctuation during monsoon and non-monsoon period was found to be around 5m. Figure 1 shows the schematic diagram of residential setup with recharge structure.

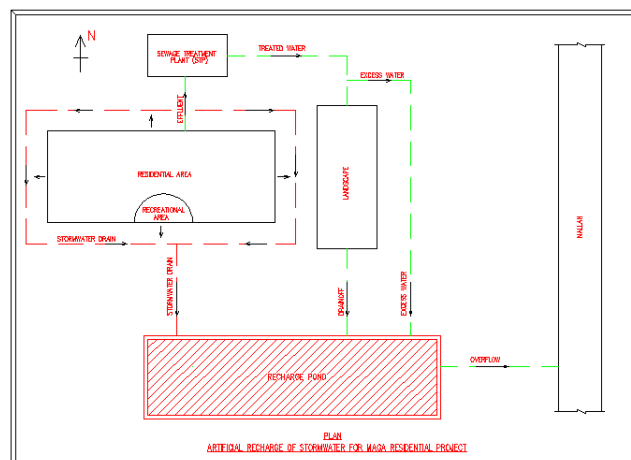


Figure 1. The schematic plan of recharge structure.

### 4.2 Assessment of Demand for Water

The study area is located in the southern suburban of Chennai city and it experiencing the escalating residential, industrial and institutional developments. It increases the demand for freshwater in the study area. Table 1 indicates the assessment of demand for water in the study area. The conducted study effectively reuses the consumed water for recharging the aquifer.

### 4.3 Runoff Calculation

Assessment of the rate of natural ground water recharge and rainfall runoff is a pre-requisite for efficient ground water resource management. It is particularly important in regions with large demands for ground water supplies, where such resources are the key to economic development<sup>8,10,11,15</sup>.

Based on the land use data, runoff co efficient and the rainfall data, the total runoff generated from the study area during monsoon is calculated using the formula (Table 2).

$$Q = CiA / (3600 \times 1000)$$

Where, Q - runoff quantity in cum/sec.

C -run-off coefficient.

I -intensity of rainfall.

**Table 1.** Assessment of demand for water in the study area

	Purpose	Population	Per Capita Demand Per Day	Total Demand	Remarks
	Domestic Purpose	5300	135lpcd	715,550	As per IS 1172-193(4.1)
	Maintenance	5300	100lpcd	530,000	Assumption
	Recreation	5300	50lpcd	265,000	As per kuchlings Formula
	Fire Fighting	5300	$3182X\sqrt{P}$ l/min	7328	
Assuming 12hrs Req. as Storage for Fire Fighting				87934	$3182x\sqrt{P}$ Where P in Thousands
Total Water Demand Per Day in litres				1,598,434	
Say				1.6 MLD	

**Table 2.** Assessment of runoff in the study area

SL No.	Area	Area in Sq.m (A)	Rainfall Intensity in mm/hr (I)		Co-Efficient of Runoff	Total Minimum Flow (m <sup>3</sup> /sec)	Total Max flow (m <sup>3</sup> /sec)
			Minimum	Maximum			
1	Buildings and Podium	2283	40	165	0.5	0.013	0.052
2	Landscape	22403	40	165	0.3	0.075	0.308
3	Services	2810	40	165	0.5	0.015	0.064
4	Road	9521	40	165	0.5	0.053	0.218
		37017				0.156	0.642
Max. Avg. No. of Rainfall days					58	Days	
Total Minimum Run Off Quantity. Available for Recharge Per Day					13478.4 m <sup>3</sup> /Day	13.48	MLD
Total Maximum Run Off Quantity. Available for Recharge Per Day					55468.8 m <sup>3</sup> /Day	55.47	MLD

As per the metrology data from Metrological station, Chennai for the year 2011 to 2012, the average maximum number of rainy days as 58 days. Based on the Rational Formula, the runoff quantity is estimated as minimum of 13.48MLD and maximum of 55.47 MLD. Thus the study identifies the significant quantity of runoff from the study area during the monsoon periods.

#### 4.4 Source for Additional Recharge

The site has been employed with a sewage treatment plant of capacity 750 kilo liter per day. The additional water necessary for recharge has been identified to be the sewage and kitchen effluent after treatment. Total water consumption of the project is estimated as 1.6MLD. By assuming 60% as kitchen and plain water (0.96 MLD) and 20 % as sewage water (0.32 MLD), the total effluent available for recharge is estimated as 1.28MLD. The STP effluent quality has been listed in Table 3.

**Table 3.** Characteristics of treated waste water

Parameter	Values
pH	6.0-8.5
BOD	Less than 10mg/l
Suspended solids	Less than 2mg/l
COD	Less than 60mg/l
Oil and Grease	Less than 5mg/l
E.Coli	nil

#### 4.5 Design of Recharge Shaft and Pond

The treated effluent, discharged from sewage treatment plant is taken into account while designing recharge shaft and pond, which is available throughout the year while comparing with rainfall runoff which is available for more or less 58 days per year. Figures 2 and 3 show the design aspects of artificial recharge structure.

$$A = Q_w \div (Rif \times Tf)$$

$$N = (Ap \times Rif) \div (As \times Ds)$$

Where,

$A$  - Area of recharge pond.

$Q_w$  - Water to be infiltrated.

$Rif$  - Rate of infiltration of bed.

$Tf$  - Period of infiltration.

$Ap$  - Area of recharge pond.

$As$  - Area of recharge shaft.

$Ds$  - Diameter of the shaft.

The treated effluent, discharged from Sewage Treatment Plant is taken into account while designing Recharge Shaft and Pond, which is available throughout the year while comparing with rainfall runoff available on an average 58 days per year.

Depth of Recharge Pond (With Filtration Bed) = 1.5m

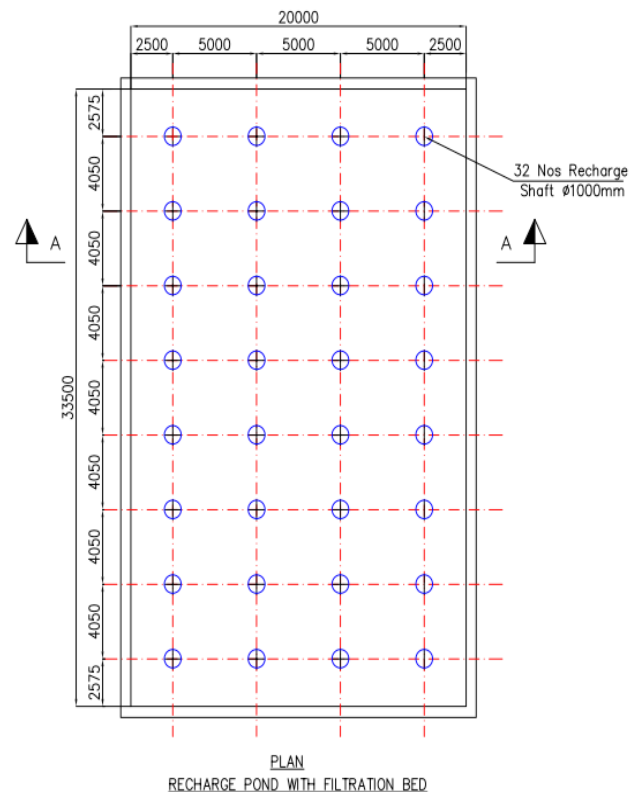
Depth of Recharge Shaft = 4m

Volume of water to be recharged from the Effluent = 1.20 ML

Rate of Infiltration of Filtration Bed = 150 lit/hr/sqm

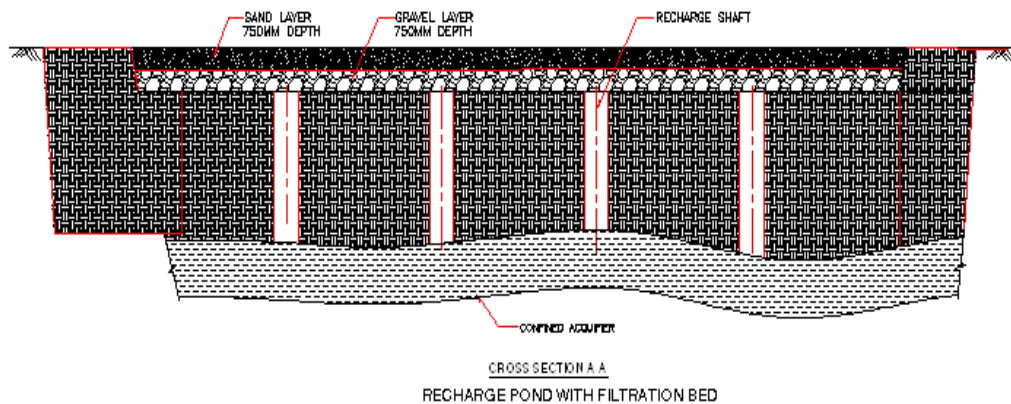
$$\begin{aligned} \text{Area of Recharge Pond} &= \frac{\text{Water to be Infiltrated}}{\text{Rate of Infiltration of Bed} \times \text{Period of Infiltration}} \\ &= 1200000 / (150 \times 12) \\ &= 666.67 \text{ Sqm} \end{aligned}$$

Area of Recharge Pond = **670 Sqm**



**Figure 2.** Schematic diagram of recharge pond with filtration bed.

$$\begin{aligned}
 \text{Size of Recharge Pond} &= 33.5 \text{ m X } 20 \text{ m} \\
 \text{Diameter of Recharge Shaft} &= 1.0 \text{ m} \\
 \text{Number of Recharge Shafts} &= \frac{\text{Volume of Water to be recharged}}{\text{Volume of Recharge Shaft}} \\
 &= \frac{\text{Area of Pond} \times \text{Rate of Infiltration}}{\text{Volume of Recharge Shaft}} \\
 &= \frac{(670 \times 0.150)}{((\pi \times 1.0 \times 1.0)/4) \times 4} \\
 &= 31.99 \text{ Say } \# \text{ 32 nos.}
 \end{aligned}$$



**Figure 3.** Cross section of recharge pond with shaft.

## 5. Summary and Conclusion

The study area is located in the southern suburban of Chennai city and it is experiencing the escalating residential, industrial and institutional developments. It increases the demand for freshwater in the study area. The conducted study effectively reuses the consumed water for recharging the aquifer. The recharge technique with a combination of recharge pond with filtration bed and recharge shaft up to confined aquifer was found to be effective for the study area. This system is concluded best as it takes into account the local area soil and hydro-graphic characteristics. In such mega township projects, density in population /unit land area is high and the projected demand for freshwater is also high. However it was clear that the presented observation and analysis, the methodology of employing artificial recharge only from rainfall is found to be highly ineffective. Hence it is mandatory to employ the reuse techniques of treated effluent

water to recharge the aquifer and thereby it may reduce the demand of freshwater especially in the water scarce regions particularly for developing countries. Further, the presented study may continue to consider the runoff water in addition with the effluent as the conjunctive management for the further scope of study. Policies and guidance for executing new groundwater recharge projects using inventive options are needed, and would help as the basis on which future and present groundwater projects would be planned and designed.

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