SUSTAINABLE GROUND WATER MANAGEMENT USING TEMPLE TANKS FOR URBAN MICRO-WATERSHEDS

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ABSTRACT

Artificial recharge mechanisms are resorted to when natural recharge is not sufficient for sustainable ground water levels. In urban areas, where open space is highly limited, temple tanks offer excellent scope for rainwater collection and recharging. Their capacity in storing and subsequent recharging will be highly effective to keep water tables relatively high. An attempt is made to determine the efficacy of Karaneeswarar temple tanks constructed during olden days for religious purpose in Adyar basin of Saidapet in Chennai. Detailed studies were conducted around Karaneeswarar Temple tank area to assess the ground water flow direction, recharge area of temple tank; road network catchment area delineation, delineation of aquifer boundary. Moreover, sediment load is assessed for the karaneeswarar temple tank, in which part of storm drain network is connected but not interconnected (independent) with other networks and part of near by roads connected by peep holes. The direction and area of influence of ground water has been assessed by observing the water table level and performing a Tracer study. Based on tracer study results, the velocity of ground water in the Adyar alluvial aquifer is determined as 0.002m/sec.

INTRODUCTION

Water has always been a scarce commodity in densely populated mega cities. Chennai, the fourth largest metro in India, is no exception to this fact that the present situation is so appalling and the water supply has been restricted to 40 lpcd. Things have started deteriorating over the last three consecutive dry years. Though Chennai receives a copious rainfall of 1200 mm annually, the problem, it seems is lack of facilities to store this water. However, it can be managed using under ground reservoir storages with proper management and maintenance. With the population of 3.84 Million as per 2001 census, together with a considerable floating population, the water supply demands have steadily and tremendously increased and the various efforts by government till date have not been commensurate with the water requirement. The gap could be filled up by the development of ground water locally by means of number of private abstraction structures. The surface water sources and ground water sources tapped for Chennai city are located outside the city limits. However, the abstraction from ground water sources locally for domestic requirement has become a reason for the present day water scarcity and reduced ground water levels and sea water intrusion problems in various parts of the City.

Tanks come to the rescue of this degrading situation by storing the rain water for subsequent recharge and replenishing the ground water. Tamil Nadu has as many as 39,202 tanks, out of which about 124 tanks are in the Chennai Metropolitan Area (CMA). The tanks have a waterspread area of approximately 5.5 percent of the CMA area, but many of these are extinct or encroached heavily. In addition, there are 34 temple tanks in the city with a total capacity of 5,14,409m^3. The list of Temple tanks in Chennai city are presented in Table 1. Urbanization has taken its effects, the storm watercourses feeding these tanks have disappeared and water flows into the sea without filling these tanks. Rejuvenation of these tanks with public participation for rehabilitation and continuous maintenance is an immediate necessity for sustainable water resources in urban conglomerates. This study aims at analyzing the hydrology of a temple tank in Chennai City and its effectiveness for recharging the wells in the surrounding areas through tracer techniques.

STUDY AREA

Karaneeswarar Temple tank located in Saidapet in Chennai was taken as the study area. The Temple tank has a storage capacity of 24,860 m^3. Maximum depth of water at full tank level is 6.5 m. It has inlets in south and east sides to be fed by storm drains. It also has an inlet on eastern side to collect water from temple area. The temple is believed to be 1000 years old. During the late seventies, the Senguntha mudaliars added new sections to the temple and also renovated the tank. The kumbabhishekham was performed on Thai Poosam day in 1982.

MYTHOLOGY

Sage Vasishta cursed Kamadhenu to be reborn in the world. In order to free Kamadhenu from this curse and get her back, Lord Indra approached Sage Vasista to seek guidance. He was advised to install a lingam in the midst of a grove at Karaneeswarar and worshiped it until he received the blessings of Lord Shiva. Lord Indra dug a tank to procure water for the daily pujas. Hence this tank came to be known as Indra thirtham.

TOPOGRAPHY AND HYDROGEOLOGY

The study area is a prime residential and slum one, with an altitude of 10 m above MSL. Guindy reserved forest, with buried pediments, is an area with less disturbed ecological system while other areas are built up areas with large scale human interference and pollution. Reduced levels of the salient points surrounding the temple tank were taken using a Digital theodolite and EDM. The topographic contours were drawn using Vertical Mapper – MAPINFO GIS software. The contours indicated an inward slope in western and outward slope in northeastern directions with other areas in a plain region. The average rainfall of the district is 1285 mm, with predominance of northeast monsoon during September to November, contributing 60-65 % of rainfall. Resistivity survey was conducted using a Terrameter, which showed a barrier boundary in the west by Charnokite, semi barrier boundary of Clay soil and Coastal alluvium in the North and East directions. River Adyar acts as a recharge boundary in the south. Lithology contains alluvial soil. Ground water occurs in semi confined to confined conditions in porous alluvial formations. Gravel, Coarse to fine sand, clay and silt clays constitute the alluvial material and of these, the gravel and sand form the potential aquifers. The alluvium deposited by Adyar River is limited to 10.0 to 15.0 m. The depth of bore wells is 40 m on south and 25 m on north directions of Temple tank. Rain water harvesting is done by means of connecting the roof water to Bore or Dug wells, which also shows the land scarcity and intention of the people to use it efficiently. In the northern zone, people are exploiting the deeper aquifer and in southern zone, people are exploiting the shallow aquifer.

The study area is surrounded by recharge boundary in the south by means of Adyar River and barrier boundary in the west, which is confirmed by resistivity survey conducted in the corporation school campus situated in western side. Storm water drains are not planned to contribute to the temple tank completely. Even the connected drains are at a higher bed level that only apportion will drain into the temple tank..

METHODOLOGY

General Description of Fluorescence

Fluorometric analysis, or fluorometry, uses the physical phenomenon called fluorescence. Because fluorescence is the outstanding property of all tracer dyes, a general understanding of the phenomenon is necessary to assure its proper use in any application of dye tracing. Basically, fluorescence is a form of luminescence, a broad term for any emission of light not directly ascribable to heat. Fluorescence substances emit radiation (light) immediately upon irradiation from an external source; emission ceases when the source is removed. The almost instantaneous sequence of events in fluorescence is as follows: (i) absorption of energy from outside source such as the sun or an ultraviolet lamp, (ii) excitation of some of the electrons of the fluorescent substances, resulting in enlarged electron orbits – the "excited state," and (iii) emission of energy in the form of photons (light) as the excited electrons return to normal position – the "ground state." The emitted (fluoresced) energy nearly always has longer wavelengths and lower frequencies than the absorbed energy because some energy is lost in the process (Stokes law). It is this property of dual spectra a different specific combination of excitation and emission spectra for each fluorescent substance – that is used to make fluorometry an accurate and sensitive tool.

In fluorometry, wavelengths are given in either nanometers or angstrom units. Most substances are least mildly fluorescent, and most fluorescent occur in the 200 – 800 nanometer range of wavelengths- ultra violet and visible light. Strongly fluorescent substances convert a high percentage of absorbed energy into emitted energy. Most strongly fluorescent substance fluoresce in the ultra violet to green part of the spectrum. A few substances, including some of the preferred tracer dyes, fluoresce in the yellow range. Dyes that are useful for tracer application are strongly fluorescent and can be detected easily in small concentration. Fluorescence intensity is affected in varying degrees by certain physical and chemical factors such as solvent, concentration, temperature, pH , photochemical decay and fluorescence quenching.

Types Recommended for Tracing

Hundreds of commercial dyes are available in a variety of colours. A great number are strongly fluorescent, but only a few exhibit the combination of properties essential for water tracing. Two dyes, variation of the same basic organic structure (Xanthane), are preferred for use as water tracer: rhodamine WT and Pontacyl brilliant pink B. These dyes are generally good tracers because they are i) water soluble ii) highly detectable – strongly fluorescent (iii) fluorescent in part of spectrum not common to materials generally found in water, thereby reducing the problem of back ground fluorescence (iv) harmless in low concentration (v) reasonably stable in normal water environment.

Table 1 List of Temple Tanks in Chennai City

Sl. No.	Location	Volume of tank (m^3)
1	Adipuriswarar Adikesava Perumal Temple Agraharam, Chindadripet	2,230.00
2	Gangadeeswarar Temple, Purasawalkam	7,602.53
3	Kandaswami & Aadhi Mottaiamman Temple, Near Vasanthi Theatre, Kosapet	5,207.12
4	Angala Parameshwari Temple, Near Corporation Park, Choolai	3,233.25
5	Sri Agatheeswarar Temple, Near Bus Stand, Villivakkam	30,480.00
6	Parasuramalingeswar Temple, Near ICF Colony, Ayanavaram	10,668.00
7	Kasiviswanatha Parthasarathy Temple, Near Padamanaba Theatre, Peddunaikenpet	14,833.45
8	Raveeswarar Temple Near Vysarpadi Market, Vysarpadi	6,096.00
9	Karapadra Sivaswamigal Madam Temple, Vysarpadi	1,041.87
10	Chengaleeswarar Temple, Near Muthialpet Police Station, Mannadi	1,294.70
11	Krishnan Temple, Near Muthialpet Police Station, Mannadi	381.29
12	Kalyana Perumal Temple, Market Street, Near Odianmani Theatre, Kaladipet	2,430.38
13	Arunachalaswerar Temple, Tondiarpet	6,796.04
14	Angalaparameswari Temple, Opp. Royapuram Police Station, Royapuram	801.56
15	Karungaleeswarar Temple, Near 100ft Road, Koyambedu.	8,630.64
16	Masilamaneeswarar Mannadeeswarar Temple, Thirumullaivoyal	22,860.00
17	Ekambareswarar Temple, Mint Street	9,583.98
18	Kasiviswanathaswamy Temple, Ayanavaram.	13,244.67
19	Malligeswarar Temple, George Town	4,335.21
20*	Karaneeswarar Temple, Saidapet	24,860.16
21	Thyagarajar Temple, Thiruvottiyur - Theppakulam Chitthirakulam	31,141.59 1,507.33
22	Kachaleeswarar Temple, Armenian Street, George Town	5,870.65
23*	Agatheeswarar and Prasanna Venkata Perumal Temple, Nungambakkam	14,801.00
24*	Parasanna Venkata Narasimheswarar Temple, Saidapet	4,410.11
25	Vadapalani Andavar Temple, Vadapalani	18,393.73
26	Velveeswarar Temple, Valasaravakkam	5,651.00
27*	Kothandaramaswami Temple, West Mambalam	3,181.91
28	Marundeeswarar Temple, Thiruvanmiyur -Theppakulam Chithirakulam	27,928.06 1,884.10
29	Kapaleeswarar Temple, Mylapore	1,19,496.70
30	Virubaksheeswarar Temple, Mylapore	2,557.56
31	Adikesava Perumal Temple, Triplicane	40,928.00
32	Parthasarathy Perumal Tempal, Triplicane	40,928.00
33	Dandeeswarar Temple, Velachery	8,672.20
34	Thiruveteeswarar Temple, Triplicane	5,707.50
Total		**5,07,371.64**

Characteristics of the preferred tracer dyes are presented below in Table 2. Rhodamine WT is preferred for most water tracing uses. It is easy to use and has many other characteristics that are desirable for water tracing. The other dyes may be used to advantage under special conditions. All the dyes listed below are believed to have some use for ground water tracing, although acid yellow 7 has not been used for that purpose. There may be problems with the use of any of these dyes in tracing ground water though clay and silt soils because of sorption on the large surface areas associated with these soils. Since Rhodamine-B has fairly high delectability, it has been selected for tracer test.

Table 2. Characteristics of preferred tracer dyes

Dye colour, formula, and common name	Other names	Remarks
Rhodamine WT	Intracid rhodamine WT	High detectability, Low sorptive tendency, good diffusity, low acidity. Fluorecscence variable with temperature
Acid red 52 (often referred as Pontycyl pink)	Intracid Rhodamine B Pontacyl brilliant pink B	Fairly high detectability, low sorptive tendency, good diffusity, low decay rate, Fairly stable at Ph extremes. Fluorescence variable with temperature
Acid yellow	Lissamine FF Lissamine yellow FP Brilliant acid yellow 8G Overacid brilliant sulpho flavine FF	Fairly high detectability, low sorptive tendency, good diffusity, Fairly stable at Ph extremes. Little affected by temperature. Subject to background interference.

Method of Injection of Tracer

Pechimuthu(1990) used the method of injecting the dye by placing a both end open drum at 45 cm below the ground level and pouring the concentrated solution inside the drum that may create an additional head to push the solution into the ground. Kanagasabai (1991) has adopted the method of mixing Rhodamine –B dye with two buckets of water and adding this concentrated solution into the pond at a depth of 50 cm below the surface of water with thorough mixing. The above two methods pollute the pond water and the dye may get dissipated. Rhodamine – B is mixed with sand and placed in concealed packet with holes at top and bottom and it is placed at

the bottom bed of the tanks by means of labourers. The dilution of the dye could take place by the water entering through the open top holes and the dispersion would take place downward only. So, the appearance of dye on the tank surface is avoided. Sediment load is collected by means of wide open mouthed one litre plastic bottle at the outlet of the drains connected to temple tank. The sediment is collected during single rainfall event and its amount varied as the driving head varies during rainfall and after rainfall stops. The amount of the sediment colleted depends on the velocity of the approaching water in to the tank.

DATA COLLECTION AND ANALYSIS

Data collection is the primary role in any study. Primary data are collected about topography, Tank water level fluctuation and water level fluctuation. Topography of the Temple tank micro basin plays a major role in collection of storm water as sheet flow over roads, Gutter flow along the sides of the road, Channel flow. The catchment area of temple tank covers the built up area of Temple, adjacent roads on all sides and the area covered by Storm drains connected to it. Data collection is the primary role in any study. Primary data were collected about the topographic and well water levels. Topography of the temple tank micro basin plays a major role with the ground water recharge and flow. The topographic survey was done using dumpy levels. By considering the top of temple tank road as a temporary bench mark, the levels of the measuring points of selected wells and road intersection are deduced. Contour map of the study area was prepared using Vertical Mapper software package. From the contour map of Karaneeswarar temple tank area, one can define clearly that the general slope is towards east. Locally, steep slope is towards Northeast side of temple tank.

GROUND WATER LEVEL CONTOUR

Ground water levels are changing in response to recharge and drawl. Ground water levels contour helps to identify the ground water flow direction. The water levels are measured with reference to the deduced benchmark and water level observations have been taken four times for Karaneeswarar Temple tank area and the same are furnished in Table 2. The water level contour maps are prepared for the period between January to April 2002. With overlay of water level contour of different periods with topography map, it is inferred that flow direction of ground water is towards South, West and Southwest direction, which is against the natural topography of the area. This may be due to over exploitation of the ground water in the southern side of the temple tank. During the preliminary survey, it was observed that the population density is higher in the southern and western side of the temple tank compared to northern and eastern side of the temple tank. It is observed that the number of bore wells is more towards southern and western side of the temple. The presence of large number of Road side sintex tanks (meant for metro water collection) present in the Southern zone compared to northern zone confirms the population explosion status. which indirectly shows the over exploitation of the ground water.

ZONE OF INFLUENCE

Ground water can be assessed by tracer technique. In this method every well sample was tested to detect the presence of dye so that the influence zone can be marked accurately. The dye Rhodamine – B was injected on 04.02.2003 in the tank bed. Water samples were collected two times from the surrounding wells to find the presence of Rhodamine –B. In the first set, samples from 11 wells were taken on 2nd day to find out the zone of influence. The second set of samples was collected on 5th day from 18 wells. The collected water samples were tested using Flouresence Spectro photometer model F-2000. The two sets of samples results are tabulated in Table 3. From this, it is inferred that at the end of first sampling, the area of influence is extended to a distance of 200m and 150m in Southwest and West direction respectively from the temple tank. At the end of sampling the zone of influence is extended to a distance of 500m and 150m in Southwest and west direction respectively from the temple tank. The total area of recharge is 100,000 m^2. The first set of zone of influence (i.e. two days after injection) extended to a distance of 200m and 150m in Southwest and southern direction respectively. The second zone of influence (i.e. 5 days after injection) extended to a distance of 500m and 225m in southwest and Southern direction respectively, which shows that the higher rate of velocity of ground water flow is 0.12 m/sec along southern direction.

Table 3. Observed ground water levels

Well No	Reduced level of measuring point	Reduced Levels (m)			
		28.12.2002	**18.01.03**	**16.02.03**	**16.03.03**
1	102.150	94.785 (7.365)	94.080(8.07)	93.210(8.94)	92.650(9.5)
2	102.050	94.655 (7.395)	94.115(7.935)	93.330(8.72)	91.950(10.1)
3	101.475	95.050 (6.425)	94.590(6.885)	93.770(7.705)	92.180(9.29 5)
4	100.680	95.180 (5.50)	94.670(6.01)	93.855(6.825)	92.430(8.25)
5	101.520	94.075 (7.445)	93.485(8.035)	92.710(8.81)	91.670(9.85)
6	101.790	95.695 (6.095)	95.070(6.72)	94.490(7.30)	93.275(8.51 5)
7	101.350	95.860 (5.49)	95.315(6.035)	94.535(6.815)	93.610(7.74)
8	98.785	96.325 (2.46)	95.595(3.19)	94.370(4.415)	93.870(4.91 5)
9	100.730	95.880 (4.85)	95.275(5.455)	94.775(5.955)	94.095(6.63 5)
10	100.590	95.980 (4.61)	95.420(5.17)	94.825(5.765)	94.130(6.46)
11	100.880	95.530 (5.35)	94.980(5.90)	94.125(6.755)	93.490(7.39)
12	101.970	96.720 (5.25)	95.715(6.255)	94.980(6.99)	93.655(8.31 5)
13	101.770	96.475 (5.295)	95.420(6.35)	94.475(7.295)	93.180(8.59)
14	99.375	94.970 (4.405)	94.010(5.365)	93.580(6.395)	92.575(6.8)
15	100.990	95.040 (5.95)	94.570(6.42)	93.975(7.015)	93.415(7.57 5)
16	101.715	95.865 (5.85)	95.050(6.655)	94.370(7.345)	93.765(7.95)
17	101.530	96.030 (5.5)	95.565(5.965)	94.875(6.655)	93.770(7.76)
18	99.220	94.935 (4.285)	94.210(5.01)	93.770(5.45)	92.835(6.38 5)

ESTIMATION OF INFLUENCE OF TEMPLE TANK WATER FOR GROUND WATER RECHARGE

From the tracer study, it is found that the zone of influence of Temple tank extends to an area of about 100,000 m^2. In assuming that the wells scattered over the entire area of influence, the average draw down in the recharge area during the study period is 2.435 m. Moreover there is no rainfall during the study period. Water levels were observed for the Karaneeswarar temple tanks during the study period and it is observed that 1.5m drawdown during the study period of 85 days. Considering the average evaporation of 5mm/day, recharges from the temple tank are:
Total depth of water level reduced in Temple tank from 21.12.2003 to 16.03.2003 = 1.5m
Total volume of water recharged = 45x 45 x 1.5 = 3037.5m^3.
Assuming Evaporation rate @ 5mm/day for Chennai city
Total evaporation from tank in 85 days (i.e from 21.12.2003 to 16.03.2003)=5x85= 0.425m

Total evaporation from tank in 85 days = 45 x 45 x 0.425 = 860.625m^3
Net recharge from tank during study period = 3037.5 – 860.625 = 2176.875m^3 = 21, 76,875 litres
Recharge rate from tanks = 2176.875 / (85 x 45 x 45) = 1.262cm/day = 1.46 x 10^{-5} cm/sec

Table 4. Tracer test results

Well No	Background samples collected on 27.01.03		Samples collected on 06.02.03 after two days of injection		Samples collected on 10.02.03 after five days of injection	
	Nm	I	Nm	I	Nm	I
1	618	0.125	610	0.166	612	0.115
2	618	0.115	613	0.190	612	0.193
3	618	0.115	613	0.101	629	2.120
4	690	0.039	613	0.090	613	0.107
5	670	0.030	614	0.093	611	0.100
6	612	0.106	611	0.132	610	0.138
7	613	0.100			613	0.102
8	690	0.028			613	0.098
9	No peak		No peak		No peak	
10	No peak		No peak		No peak	
11	No peak		No peak		No peak	
12	No peak		No peak		No peak	
13	No peak		No peak		No peak	
14	615	0.213			612	0.220
15		No peak			613	0.091
16	612	0.116			612	0.098
17		No peak			611	0.144
18	611	0.118			608	0.124

RESULTS AND DISCUSSION

Recharge area and ground water flow direction falls along the southern zone of Temple tank, where the soil type is sandy loam and it falls under Adyar alluvial aquifer. The ground water flow direction is towards the Adyar river, since the study is carried during post monsoon period (i.e during summer) and Adyar river is flowing at low level compared to ground water table condition of the study area. Hence, the base flow from river to basin is not present. Moreover base flow to the basin is from Northeast and East direction. Base flow to the basin is not from west direction since the soil type is Clay loam and more over the base is Charnokite rock which is confirmed by the resistivity test conducted on the western side. Recharge volume of water from temple tank is about 2176.875m^3 (i.e.21, 76,875 litres), which is used to serve 725 Person with 100litres/day for 30days. Since acute shortage is during May month of 30days. Since temple tank serves 725 Person during half capacity filling.

CONCLUSIONS

Detailed studies were conducted around Karaneeswarar Temple tank area to assess the ground water flow direction, recharge area of temple tank, road network, catchment area delineation and delineation of aquifer boundary. The direction and area of influence of ground water have been assessed by observing the water table level and performing Tracer study. The result indicates that the ground water flow against the natural surface slope and against the direction of base inflow of Adyar River. Based on tracer study results, the velocity of ground water in the aquifer is determined as 0.002 m/sec which is due to over pumping (due to population explosion) and hence a steep hydraulic gradient develops.

REFERENCES

Department of Agricultural Engineering, Government of Tamil Nadu, Sept.87. 'Technical Handbook on Percolation Ponds' – Design series Handbook 1/87,

Medina J., (1976), "Harvesting Surface Runoff and Ephemeral Stream Flow in Arid Zones", National Centre for Arid Zone Studies, Mexico.

Mohamed Ghouse, S., (2001), "Rain Water Harvesting in River Basins around Chennai", National Workshop on Water Resources and Water Quality Management for Sustainable Drinking Water Supply, pp. I 21 – 30.

Mohanakrishnana A., (1993), "Water Harvesting in Plains", Proceedings of the National Seminar on Water Harvesting, Regional Engineering College, Tiruchirapalli.

Muralidharan, D., (1997), "Role of Water Quality in Artificial Recharge through Borehole Injection Technique", International Conference on Management of Drinking Water Resources, pp. 139 – 150.

Ramalingam, M., (2001), "Delineation of groundwater recharge zones using remote sensing and GIS", National Workshop on Water Resources and Water Quality Management for Sustainable Drinking Water Supply, pp. IV 1-8.

Sivanappan R.K., (1993), "Roof Water Collection Utilization – Case Study of Tamil Nadu Agricultural University, Coimbatore", Proceedings of the National Seminar on Water Harvesting, Regional Engineering College, Tiruchirapalli.

Pechimuthu.N. (1990), 'Study on Recharge Mechanism of a Percolation Pond', M.E.Thesis, Anna University.