Introduction

Chennai and its suburbs – constituting the Chennai Metropolitan Area (CMA) are constantly plagued by water shortage. Rapid growth in population, coupled with irregular spells of monsoons has further intensified the problem in the past couple of years. The population of Chennai is expected to cross 4.5 million by the end of 2004. The city at the moment requires 848 million litres per day (MLD). Whereas the public system was able to supply only 433 MLD. The balance of nearly 50% of the daily consumption is met through private wells and borewells (groundwater). As a result of this unplanned large scale extraction of groundwater the water table in the city is depleting at an alarming rate causing serious quality problems. Hence it becomes essential to sustain the available limited groundwater sources through rainwater harvesting.

To design a proper rainwater harvesting system for groundwater recharge, parameters such as Geology, Hydrogeology and Hydrometeorology is required. As the Geology of Chennai city is highly complex and heterogeneous in nature, rainwater harvesting systems designed without considering the local hydro geological set up will not yield the desired results. The present study is to bring out an over view of the sub terrain configuration in Chennai city based on which terrain specific water harvesting systems can be designed.

CITY AT A GLANCE

Location

Chennai District is bounded by North Latitudes 12° 59’ 10” and 13° 08’ 50” and east Longitudes 80° 12‘ 10” and 80° 18’ 20” and forms part of survey of India Topographical Maps Nos. 66 C / 4 & and 66 D 1 and 5. The Geographical area of Chennai district is 170 .98 Sq. km and the extent of Chennai Metropolitan Area is 1170 Sq. km. (Refer Base map)
Land use and Administration.
The Forest Cover in Chennai district is only 300 ha (1.8 percent) and the rest 98.2 per cent of the areas is used for industrial purposes. The residential areas can be grouped as Prime residential, Commercial, mixed residential and slum areas.

Presently there are five taluks in the district, namely
(i) Purasavalkam Perambur
(ii) Fort – Tondiarpet
(iii) Mambalam- Guindy
(iv) Mylapore –Triplicane
(v) Egmore - Nungambakkam

Profile of Chennai Metropolitan area (Part) - General Features – Statistics.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Location</strong></td>
<td>Chennai city and part of Tambaram taluk.</td>
<td></td>
</tr>
<tr>
<td><strong>2. Total area</strong></td>
<td>174 sq km.</td>
<td></td>
</tr>
<tr>
<td><strong>3. Population</strong></td>
<td>42.16 lakh (city) 65.0 L (Metropolitan area)</td>
<td></td>
</tr>
<tr>
<td><strong>4. Major rivers traversing the area</strong></td>
<td>Adyar and Cooum, Otteri nullah.</td>
<td></td>
</tr>
<tr>
<td><strong>5. Canal</strong></td>
<td>Buckingham canal</td>
<td></td>
</tr>
<tr>
<td><strong>6. Mean Annual Rainfall (50 yr)</strong></td>
<td>1320 mm</td>
<td></td>
</tr>
<tr>
<td><strong>7. Cooum and Adyar basin Rainfall 50% dependability</strong></td>
<td>SW 445</td>
<td>NE 765</td>
</tr>
<tr>
<td></td>
<td>524</td>
<td>788</td>
</tr>
<tr>
<td><strong>8. Population density</strong></td>
<td>24,231 persons / sq km.</td>
<td></td>
</tr>
<tr>
<td><strong>9. Geology</strong></td>
<td>Crystalline basement rock, Upper Gondwanas, Tertiary and Recent to Sub Recent Alluvium.</td>
<td></td>
</tr>
<tr>
<td><strong>10. Terrain slope</strong></td>
<td>1:1500</td>
<td></td>
</tr>
<tr>
<td><strong>11. Forest cover</strong></td>
<td>274.57 hectare (1.5% of the total area under forest)</td>
<td></td>
</tr>
<tr>
<td><strong>12. Cultivable waste</strong></td>
<td>3,48,497 hectare (8,60,788 acres)</td>
<td></td>
</tr>
<tr>
<td><strong>13. Cultivable Fallow</strong></td>
<td>9,55,507 hectare (23,60,102 acres)</td>
<td></td>
</tr>
<tr>
<td><strong>14. Other fallow</strong></td>
<td>11,10,728 hectare (27,43,498 acres)</td>
<td></td>
</tr>
<tr>
<td><strong>15. Sewerage generation</strong></td>
<td>Total - 24,14,732 hectares (59,64,388 acres)</td>
<td></td>
</tr>
<tr>
<td><strong>16. Garbage generation</strong></td>
<td>540 mld (city only)</td>
<td></td>
</tr>
<tr>
<td><strong>17. Corporation roads</strong></td>
<td>3000 tones/ day. (2400 tones biodegradable in city only)</td>
<td></td>
</tr>
<tr>
<td><strong>18. Bus route&amp; interior roads</strong></td>
<td>302 km</td>
<td></td>
</tr>
<tr>
<td><strong>19. Total vehicle population</strong></td>
<td>1900 km</td>
<td></td>
</tr>
<tr>
<td><strong>20. Industries in Chennai</strong></td>
<td>13,00,000 (2001 approx)</td>
<td></td>
</tr>
<tr>
<td><strong>21. Coastline</strong></td>
<td>770 (as on 2000)</td>
<td></td>
</tr>
<tr>
<td><strong>22. Water supply during normal RF</strong></td>
<td>22 km (city only)</td>
<td></td>
</tr>
<tr>
<td><strong>23. During drought period 127 mld</strong></td>
<td>313 mld</td>
<td>78 lit per capita a day (LPCD)</td>
</tr>
<tr>
<td><strong>(Based on 1998 – 99 Tamil Nadu Land Use Board statistics).</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GEOMORPHOLOGY

Chennai district forms parts of Tamilnadu costal plains. Major part of the district is having flat topography with very gentle slope towards east. The altitude of land surface varies from 10 m above MSL in the west to sea level in the east. Fluvial, Marine transgression and regression and neo tectonic activity resulted in various present land forms.

Meandering streams with small sand bars are present along the course of Adayar River. The river shows some sharp angular trends in its course which may be the indication of the hidden structural features below. The pediment and buried pediment in Guindy area in and around the reserved forest, are the only areas where the geological system is less disturbed while the other areas are completely disturbed by built up areas with large scale human interference and pollution.

The number of water bodies existed in the district in the early period of this century were filled up with garbage, ( eg Valluvar kottam areas) transported sand and clay ( number of small ponds). The sand dunes and beach ridges were also converted into residential areas and as a result the natural landform got altered. Marina beach is the most natural beach in the world with a width varying from 150m to 600 m and a length of 5.6Km, also encroached by human activity. The marshy land and lagoon existing north of Adayar river are also transformed into build up areas. Theosophical Society, located on the banks of Adayar river mouth is the only area with well-preserved natural coastal morphology, sand dunes, beach ridges, flora etc.

DRAINAGE

Adayar river originates at the confluence (Thiruneermalai) of two streams that drain the upstream area of Chembarambakkam tank. It is a small river of 42km length and a catchment of 800 sq.km. The river carries flow all through 365 days of a year with an Average discharge of 89.43 MCM/ year at Kathipara cause way. It drains the southern part of the district and remains flooded during monsoon. During the high tides, the back waters from the Bay of Bengal enter inland upto 3-4 km.

Cooum is the other main river flowing through the middle part of district and carries only drainage water which is highly polluted. It originates from the surplus flow of the cooum tank in Tiruvallore taluk and also from the tanks enroute which discharge their surplus water into the river during flood season. The flow of Cooum river at Korattur is 40.2 MCM/year for an average duration of 31 days in a year. The number of days of maximum flow are 78 in 1964-75 & 1977-78 and the maximum discharge was 25.4 MCM in a day (on 25-11-1976).

Otteri Nulla is another small stream flowing in the northern part of the city. Buckingham canal is the main man-made channel used for navigational purposes in the area north of Ennore, but acts as sewerage carrier in the city.(Refer drainage map of Chennai)
There were about 162 small ponds and tanks in North Chennai north of Cooum river, 20 ponds and tanks in central Chennai between Cooum and Adyar and 17 to the south of Adyar river. Of these 35 were temple tanks. These tanks acted as major recharge structures for the city area. But constant depletion of water table, encroachment of catchment and diversion of inlets has made most of these water bodies dry.

**HYDROMETEOROLOGY**

**Climate**

Chennai district enjoys a tropical climate with mean annual temperature of 24.3°C (min) to 32.9°C (max). The hottest and driest part of the year is April – May. Temperature rise to 41.2°C, the extremes recorded are 13.9°C and 45°C. The lowest temperatures recorded in the range of 18.1°C to 25.9°C are in January. The humidity is usually in the range of 58 to 84% and sea-breeze in the evening hours is a blessing to combat the high temperature and humidity during summer months. The weather stations are located at Meenambakkam and Nungambakkam.

**Rainfall**

The North East monsoon during the months of October, November and December chiefly contributes the rainfall for the district. Most of the precipitation occurs in the form of one or two cyclones caused due to depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. The average annual rainfall of the district is in the range of 1285.6 to 1232.7mm.

The analysis of rainfall pattern at Nungambakkam and Mennambakkam indicate a wide variation within short distances and also from year to year. The frequency of mild drought is noticed at 21 years in the last 90 years duration, which means mild drought is expected once in 4 years. With precipitation of 0 to -25% The moderate drought (-25 to -50%) is experienced only in 8 years (9%) in the 90 years period and severe drought is very rare. The average annual rainfall in the district is higher than the state average and rainy days are also distributed throughout the year and 4 to 10 days rain in June to December is common.

**GEOLOGY AND STRUCTURE**

Chennai district is underlain by various geological formations from the ancient Archaeans to the Recent Alluvium. (Refer Geology Map). The geological formations of the district can be grouped into three units, namely

(i) Archaean crystalline rocks
(ii) Consolidated Gondwana and Tertiary sediments and
(iii) Recent alluvium.

Most of the geological formations are concealed since overlain by the alluvial materials excepting for a few exposures of crystalline rocks like charnockites along the railway track in Guindy area.
**Archaean Crystallines**

The Archaean crystalline rocks of the district comprise chiefly of charnockites, gneisses, and associated basic and ultra basic intrusives. The charnockites represent the major rock type in the area extending from Saidapet to Ramapuram. The charnockites also constitute the residual hills around Pallavaram, St.Thomas Mount, Vandalur. The crystalline rocks are weathered and jointed/fractured. The degree and depth of weathering varies from place to place and thickness of weathered mantle varies from less than a metre to about 12m in the district. There are more than two sets of joints in the crystalline rocks. The successful borewells drilled tapping the deeper fractured aquifers in Saidapet, Adyar, Kasturba Nagar, Gandhi Nagar and Ashok Nagar revealed the existence of fracturing down to depths of 60m below ground level. Near the War Memorial 2km south of Adayar river borewells encountered fractures down to 60m. A basic dyke of 30m width has recently been noticed on the southern side of Velachery lake and extends over 200m.

**Gondwana and Tertiary Sediments**

The Gondwana rocks are seen along the Adyar river bed outside Chennai, but no exposures are observed in the city. The Gondwana sediments are represented by sandstones, shales and clays. The shales and clays are highly consolidated. The Goundwana shales are exposed in Adayar river near Ramavaram and the Gondwana-crystalline contact (refer cross section-1) is a probable fault contact concealed by alluvium. The Gondwana shales are jointed/fractured and their thickness varies from 24m in Kilpauk, 20m in Ashok nagar and 130m in Koyambedu.

The Tertiary sandstones are reddish brown to grayish white and white in colours friable and mottled. The occurrence of Tertiaries in Chennai is not well demarcated. However, the Tertiary sediments seem to have been of limited thickness and often difficult to distinguish between compact alluvial sands during drilling.

**Recent Alluvium**

The alluvium covers the major part of the district, but for the localized crystalline pockets in south Chennai in Gandhi Mandapam – Saidapet Railway Station area. The alluvium consists of sand, silt and clay. The thickness of alluvium varies from place to place and a maximum of 28m is encountered in North Chennai near Perambur. Kilpauk water works area has 24m thick alluvium.

**Sub-Surface Geology**

The sub-surface basement configuration in Chennai district could not be precisely evolved due to paucity of data. Based on the lithological data collected from
various Government and Private agencies engaged in the construction of bore wells in Chennai district, the geological succession in the Madras district was prepared.

The presence of Gondwana shale is established in T. Nagar, kodambakkam and Nungambakkam areas. Basement high is noticed near Ashok Pillar and Jafferkhanpet areas. Basement high is also noticed in Villiwakkam area. The crystalline rocks are directly encountered below alluvium in Teynampet, Saidapet, Adyar and Velachery areas. The presence of thick black clay followed by fossil bed (old lagoon probably) and then crystalline rocks below 6m depth is a common feature in the vast stretch between Lattice Bridge road to Velacherry.

(Refer Cross Sections 1 and 2)

Tectonics

The presence of fault in crystalline basements is clear at Sterling road and at Nandyambakkam. The crystalline rock ridge running parallel to mount road has separated the district into two basins, southern basin shallow without Gondwana sediments. The northern side has extensive Gondwana sediments beneath the alluvium. The presence of bedding joints, shears and micro-folding are indicative of the extensive tectonic disturbance in the past Gondwana period. The recurrence of marine transgressions and regressions were inferred from the thick black marine clay beds (thickness 14m in Ashok Nagar) encountered in Gondwana shales. The presence of highly erratic thickness of sand and silt layers could be fluvial in origin. The coastal areas have sand dunes and beach ridges, resulting from the recent marine and fluvial interaction. The presence of the Thick shell bed below 2m clay in low grounds of Taramani, Velacherry is indicative of Old lagoon and marine regression activity.
CROSS SECTIONAL SCHEMATIC REPRESENTATION OF CHENNAI CITY

HYDROGEOLOGY
Ground Water in Chennai district occurs in all the geological formations viz. the Archaean crystallines, Gondwanas, Tertiary and alluvium and is developed by means of ring wells, dug wells, filter point wells, bore wells and tube wells. Ground water availability of the various geological formations were described briefly below:

**Ground Water in Archaean Crystallines**

The Southern part of the district is underlain by the crystalline rocks and the occurrence of ground water is essentially limited to the weathered mantle and fracturing rocks. These hard rocks aquifers are heterogeneous in nature and the water bearing characteristics like weathering and fracturing vary very widely both laterally and vertically. *(Refer Depth to hard Rock)* Ground water occur under the water table conductions. The thickness of weathering is only 4 to 6 m in Raj Bhavan area and in other areas the soil cover is extensive. In Velacherry areas there is a sheet of black clay over crystalline rocks. The bore wells located in Velacheerry area are giving moderate yield and the yield of well varies from 0.5 to 1 m³ / day depending on the topography and thickness of weathering. Many wells are dry in summer months due to limited thickness of productive zones or over development.

There are number of borewells in the city piercing the top 10 to 15 m thick alluvial cover and penetrate the crystalline rocks. Prominent fractures zone are reported in Sri Ram Colony Ashok Nagar area. However failure of many bore wells in Velacherry, Adambakkam, Nanganallur and Chrompet areas may be due to the absence of potential fractures.

The Depth to basement map shows the occurrence of hard rock in Chennai city. The basement is shallow in south Chennai (adambakkam and south) and is at deeper depths 100m in north Chennai. The occurrence of hard rock in coastal areas is at an average depth of 25m lying beneath the coastal alluvium. In north Chennai the alluvium is followed by shale.

**Groundwater in Gondwana**

Groundwater occurs under water table conditions in the Gondwana sandstones. The Shales and clays are consolidated and fractured and act like weathered crystallines. Moderate yields of 0.5 to 1 lps are obtained in borewells drilled in Ashok Nagar – Kodambakkam area. The top unproductive alluvium is cased and DTH drilling is undertaken in Gondwana sediments. The fractures and bedding joints within sandstones and shale contribute moderate quality of water. The presence of iron bearing clay lenses contributes iron content to the groundwater.

**Groundwater in Tertiaries**

The presence of Tertiary sandstone and shale are not clearly demarcated in Chennai city area. Ground water occur under unconfined conduction. The granular zones below the Kankar layer in the depth range of 20 to 28 m in Poes Garden probably represent the tertiary sandstone.

**Groundwater in Alluvium**
Ground water occurs under water table conduction in the porous alluvial formation. Gravel coarse to fine sands, clays and silty clays constitute the alluvial material and of these, the gravels and sand forms potential aquifers. The alluvium deposited by Adayar, Cooum and Koratalaiyar are limited in thickness from 10 to 28 m. (Refer Depth to Sedimentary Map). The thickness of alluvium is highly erratic and the eroded surface of Gondwana basin is filled with clays of lagoon deposits or estuarine deposits and the fluvial action by rivers have deposited very irregular lenses of sand and silt layers. The beach sands in Tiruvanmiyur belt had yielded high in the past. The yield has considerably reduced due to constant water table depletion.

The depth to sedimentary map prepared shows the occurrence and depth of sedimentary formations which is inclusive of Tertiary, Gondwana and alluvium. Individual sections prepared area wise gives the various formation encountered in the borewells drilled in these areas.
WATER LEVEL FLUCTUATION

Over exploitation coupled with limited recharge to groundwater has caused constant depletion of water table in Chennai city and its environs. Open dugwells which were
the major groundwater extraction structures almost vanished from madras landscape, drilling of deeper borewells and frequent borewell failures were the indicators of constant water table depletion. The depletion of water table in coastal areas has resulted in seawater intrusion causing irreparable damage to the coastal aquifers. Borewells drilled in Triplicane, Royapettah, Besant nagar areas has already started yielding brackish water with very high TDS(3000 – 4000 ppm).

In order to get an idea of the change water table in Chennai city, water table maps were prepared using the observation well data for 1991 and 2002 (Refer water level maps of 1991 and 2002). The map prepared for the year 2002 shows the extension of red polygon (ie., depth to water table between 7m and 10m ) extending in all directions with more predominance in north Chennai and coastal areas.

**GROUNDWATER QUALITY**

Because of the heterogeneous nature of the formations, quality of groundwater changes both seasonally and depth-wise. This may be due to the depositional environment, pollution and over development of groundwater. Analysis of shallow aquifers in around Chennai indicates that the groundwater is alkaline in general with PH values ranging from 7.8 to 9.0. Many pockets have high chloride and sulphate making the water unsuitable for drinking purposes. Groundwater quality is good in select pockets like Besant Nagar, Kotturpuram, Annanagar, Kilpauk and parts of Nungambakkam. Excess iron is noticed in a number of pockets like Adyar, Shastri Nagar, K.K. Nagar, Ashok Nagar, Raja Annamalaipuram and Mylapore.

The Buckingham canal constructed at sea level for navigation has resulted in seawater intrusion in the freshwater sediments. The intrusion of seawater due to over development of alluvial aquifer system is noticed in north Chennai. Floating lenses of freshwater and brackish water zones were observed in the Thiruvanmiyur – Covalam belt, which are the potential freshwater aquifers in dunes. The same is harnessed extensively resulting in local groundwater mining in Besant Nagar, Thiruvanmuyur, Kottivakkam, Neelangarai area and there is a danger of seawater intrusion locally.

The presences of number of industrial units in Guindy and Ambattur area and in north Chennai area add to the pollution of groundwater. Generally dilution of groundwater by artificial recharge will help in improving the water quality by reducing the concentration of salts.
RECOMMENDED RWH STRUCTURES FOR GROUNDWATER RECHARGE

In the coastal areas and in parts of north Chennai where the top soil is alluvium, shallow recharge wells of 3-4ft in diameter and depth up to 10ft is sufficient to harvest the roof top water.

In the hard rock terrain in South Chennai where the top soil is followed by weathered and fractured rock shallow wells of 3-4ft in diameter and depth up to the weathered rock (loose rock) is suitable to harvest the rainwater. An in well bore of 4.5” in diameter drilled in the bottom of the well up to fractured rock (up to 60ft) will increase the water intake capacity of structure.

In the Gondwana terrain where the top soil is clayey shallow recharge wells of 3-4ft in diameter and depth up to sandy strata would be ideal. The depth to sandy formation varies from place to place. In Annanagar the depth to alluvium is at around 20ft below ground level. An in well bore well inside the recharge well drilled to the full depth of the sandy bed and provided with slotted casing will facilitate downward percolation of harvested rainwater.

In locations where sufficient space is not available then percolation bore pits can be made. The dimension of the percolation pits should be 2ft x 2ft x 2ft provided with 9” brick work and bottom of the pit left unplastered. A bore of 8” can be drilled inside the pit up to porous formation and provided with slotted PVC casing. The intake capacity of percolation bore pit is much less when compared to recharge wells.

In order to get an idea of the depth of porous formation at different location within the city the sub surface lithology for selected locations in given in the lithology map.

(Refer Lithology Map and Zonewise Lithology)