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Water Resource Planning And Implementation For Chennai Metro Using GIS

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Abstract
Rapid urbanization throughout the world leads to pressure on infrastructure development for planners. The provision of clean water, treatment and disposal of wastewater has become a challenge to water resources and environmental engineers. It is perceived that new approaches will reduce the water stress and can contribute markedly to improve the availability of water. Chennai city, one of the major metropolises of India, is situated at the northern coastal edge of the State of Tamil Nadu. The city is more well-known by its older name of Madras. Currently, Chennai is inhabited by more than 7 million people in an area of 176 sq km. Water supply for this population is maintained by tapping a combination of surface storage reservoirs and aquifers. An decentralised approach is called for where powers are devolved to local institutions and where co-ordination among the state, private sector and civil society are ensured for evolving water supply options in urban India. For this, the State should decentralise the water sector to facilitate participation and inter-sectoral co-ordination, develop and operate water supply that is more responsive to the needs of the users and to engender a sense of ownership. Essentially our study indicates the opportunity for creating additional storages, making use of the available tank storages, additional water treatment plants with its location, to utilize the Telugu Ganga Water, Veeranam water and Palar waters within Chennai Metropolitan Area suitably. Various technical investigations essential for planning water resources development activities for Chennai Metropolitan Area are indicated. This will serve as the starting point for the long term development of water management policies for this area.

Keywords: Water Resource Planning, Implementation, Chennai Metro, GIS

1.INTRODUCTION
One of the major problems faced in CMA is the inability of the administration to keep pace with the increasing need for utility services particularly water supply and sewerage. This problem is not unique to Chennai alone and almost all the rapidly growing cities in India share the same. In Chennai City, Chennai Municipal Corporation was responsible for construction, operation and maintenance of water supply system till August 1978. It was transferred to the (then newly formed) CMWSSB with all assets and liabilities. The major supply sources viz. Poondi reservoir, Cholavaram lake and Redhills lake are under the control of the State PWD (Irrigation); further the PWD (Ground Water Cell) is responsible for the investigation of ground water resources within CMA to augment supplies. Chennai city is the capital of Tamil Nadu state, is located on the coast of the Bay of Bengal at latitude 13°4” North and longitude 18°15” East. Two rivers rush through Chennai, the Cooum river in the central region and the Adayar river in the southern region. Domestic and Commercial sources were polluted these two rivers with effluent and trash. The state government took responsibility on de-silted the Adayar river, which is much less polluted than the Cooum river. Source of water distribution is mainly based on:

- Surface water
- Ground water

1.1 Water Supply City System :Surface Water
In the northwest along GNT road, for about six km from the Red hills lake is situated were water is drawn for the Chennai city supply. The upper supply channel which diverts the flow at Tamaraipakkam to Cholavaram lake from there it flows to Red hills lake.This lake mainly receives its supply across the Poondi reservoir. Small number of lakes are also connected in the northwest of Chennai city, were a statistical analysis report shows that for period of 39 years 95% of probability is the safe potential up to 142 mid. This is because lakes are shallow and has 43% evaporation losses.The geology of Chennai comprises mostly clay, shale and sandstone. The city is classified into three regions based on geology, sandy areas, clayey areas and hard-rock areas. Sandy areas are found along the river banks and the coasts. Clayey regions cover most of the city. Hard rock areas are Guindy, Velachery, Adambakkam and a part of Saidapet. In sandy areas rainwater run-off percolates very quickly. In clayey and hard rock areas, rainwater percolates slowly, but it is held by the soil for a longer time.

1.2 Ground Water
In early water supply source to Chennai, people we depend on shallow wells situated in their own houses and some part if people mainly depend on public wells and tanks. At that time was no source water supply during the year 1914 protected alter supply system using filtration and pumping was achieved. An underground masonry conduit of size 1.52 m x 1.12 m and 11km long was constructed to convey raw water from Redhills to Kilpauk, with conveying capacity of raw water at the rate of 104 MLD. Slow sand filters to purify the water (60 to 70 MLD), four underground pure water storage tanks (29.50 ML capacity), steam engine driven pumps, an elevated steel

overhead tank (6.75 ML capacity) and 48" diameter steel pumping main from Kilpauk pumping station to shaft were installed. Subsequently the distribution system was remodelled and extended to all areas of the city.Poondi Reservoir (later named as Sathyamoorthy Sagar) was constructed in 1944 across the Kosathalaiyar River with a capacity of 72.86 Mm^3 (2573 Mcft) and placed in service for intercepting and storing Kosathalaiyar River water. Surplus water flows down the river, which is again intercepted by Tamaraipakkam anicut and diverted to Cholavaram Lake. The system was then designed for a supply of 115 LPCD for an estimated population of 0.66 million expected in 1961**.** A lined canal known as Poondi canal was later constructed in 1972 to convey water from Poondi Reservoir to Cholavaram Lake. Figure.1 shows water bodies in Chennai

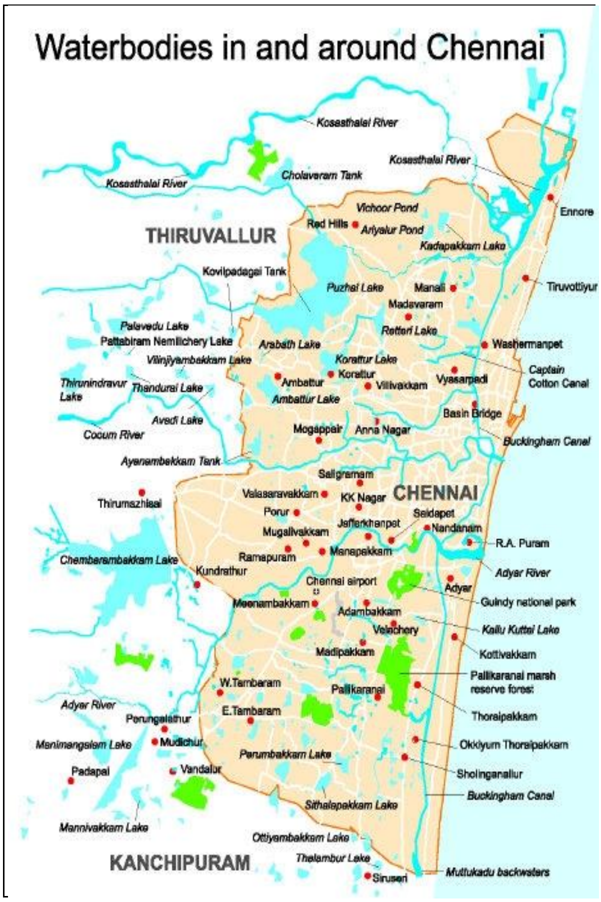

Figure. 1 Chennai City Map

1.3 Considerations For A Sustainable System

Technical Considerations – From the outset, the design and construction of the system should be done right, using the appropriate technology, equipment and materials. It is clear that if a newly built system experiences high NRW or unaccounted-for water at the start of its operational life, the correction of the likely systemic deficiencies would be very expensive, disruptive of operations and revenue streams, and almost futile.

Financial Considerations – Financial considerations have to do with building and operating the system at the least possible cost but in a way that meets all standards and the customers' requirements. These considerations must strike a balance between the acceptance and affordability levels of customers, on the one hand, and the appropriate cost recovery tariff structure, on the other, as the latter constitutes the primary source of funds needed to support the operational, maintenance and repair, and future requirements of the utility.

Social Considerations – This means engaging the population and gaining the broad community support that is needed to initiate and carry out the public utility project. The interests and concerns of the various stakeholders, including the local officials, businesses, community leaders, and the homeowners as groups and individuals have to be considered and their views given the proper respect. A small town water business needs to operate with a strong social base to support its role as a public utility.

Environmental Considerations – This means that the system should be built and operated in relation to its environment. It must be sure that its sources of water have not been, and will not be compromised by surrounding developments. At the same time it has to preserve the viability of its water sources, and to ensure that extractions are well within the limits of safe yields.

1.4 States Of Ground Water In Chennai Basin

The source of ground water are from the old well fields such as poondi, flood plains and kannigaipair and new well fields like panjetty, tamaraipakkam and minjur. Ground water are getting polluted because of effluent and plastic trash were the intrusion of sea water that contain salty waste product spoils the groundwater where does not meet the permissible limit for drinking purpose.

2.STUDY AREA

Chennai's water situation is severe. The capital city of the southern state Tamil Nadu represents the fourth largest metropolitan area in India accounting for a population of 8.7 million in 2011. Due to rapid population growth, difficulties regarding the provision of water demands have been arising. Extreme weather conditions during past years such as dry periods and heavy rainfalls increased the impact on the water supply infrastructure systems.

2.1 Climate

Chennai metropolitan area has a hot climate, were most of hottest part is late May and early June, with maximum temperatures 38-42°c (100-107°F).And the coolest part of the year is January, with minimum temperature around 19-20°c (66-68°F). Due to cyclones and low pressure development in Bay of Bengal Chennai city receives heavy rainfall and the area is regulated with sea breeze with high humidity. Table 1 shows the important season in Chennai metropolitan area and Table:2 shows Sources of Supply of Water to Chennai

Table 1:The important season in Chennai metropolitan area

SEASON	DURATION
Winter	January and February
Summer	March to May
South west monsoon	June to September
North west monsoon	October to December

Table:2 Sources of Supply of Water to Chennai

Source (in ML) for the whole year 2004	
Veeranam Lake	14,842
Redhills Lake	4,155
Rain water	1,691
TWAD Source	275
Distance Source	21,357

2.2 Rainfall

At the middle of October till December the rainfall currents sets from the north and about the earlier day of August till the middle of October, South flow parallel to coolest sets the rainfall received during south west monsoon is recorded as 760mm and during south east monsoon is 400mm. The average annual rainfall for the Chennai city is about 1,300mm.

2.3 Population

The major factor that demands the water is population. From the directorate of census operations, Chennai data have collected in which 34.2% of population living in urban centers ranks third most urbanized state in India. Chennai district verified increases to 13.07% to its population compared to 1991. The initial draft data released by census India 2011, shows that mass of Chennai district for 2011 is 26,553 people per.sq.km.

2.4 Intrusion Of Sea Water

If the ground water level decline, sea water moves inland in which it threats the ground water. Most coastal area are dependent on local fresh water where intrusion of saline water into fresh ground water occurs commonly in coastal aquifers .The southern region of Chennai is also facing threat of contamination due to constant pumping and improper management. Digging of bore wells in south Chennai area like Besant Nagar, Triplicane has already started resilient brackish water with high TDS (total dissolved solids). Figure 2 shows Chennai Water Bodies Map

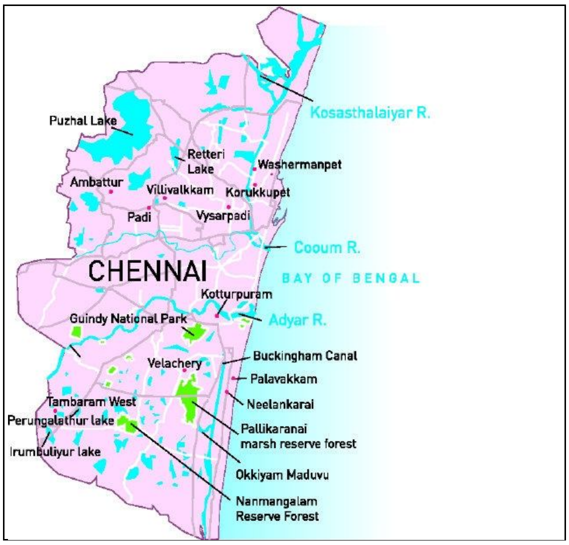

Figure 2: Chennai Water Bodies Map

The public pipe water network was shut down for a whole year resulting in the dependence on water tankers which went from household to household. Heavy rain falls in 2005 led to an end in the water supply crisis. However, these uncertain events clarify the drastic impact on currently established water supply infrastructures leading to shortages in the water provision. Thus, a proper managed and maintained pipe water network for reliable water supply is required to counteract such cases. The coastal city of Chennai has a metropolitan population of 8.24 million as per 2011 census. As the city lacks a perennial water source, catering the water requirements of the population has remained an arduous task.Although three rivers flow through the metropolitan region and drain into the Bay of Bengal, Chennai has historically relied on annual monsoon rains to replenish its water reservoirs since the rivers are polluted with sewage. With the population increasing over the decades, the city has faced water supply shortages, and its ground water levels have been depleted. Figure 3 shows Chennai Reservoir Map and Table 3 shows Characteristics of Existing Surface Reservoirs

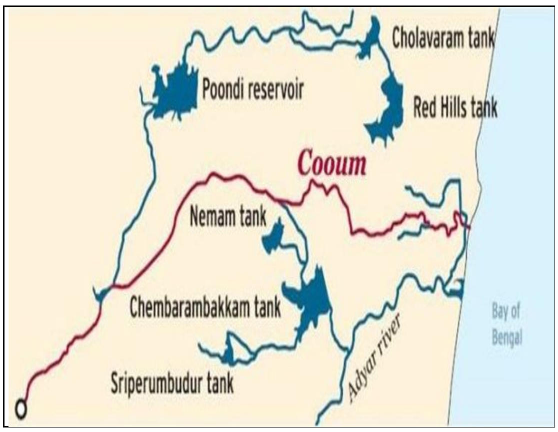

Figure 3: Chennai Reservoir Map

Table 3 Characteristics of Existing Surface Reservoirs

Reservoir	Maximum Water Elevation (Metre)	Drawl of elevation (Metre)	Maximum usable volume (million)	Full Area surface (million sq.ft.)	Mean Depth (Metre)	Catchment Area (Sq.km.)
Poondi	42.67	34.14	91.44	376.74	8.53	1983
Cholavaram	19.66	14.22	24.93	55.76	5.44	28.49
Redhills	15.30	8.59	87.02	195.15	6.71	30.00
Chembarambakkam	26.03	18.72	103.15	711.18	7.31	357.00
Veeranam	14.48	12.34	37.61		2.14	422.40
Total			306.54			2850.89

2.5 Management Of The Resources

2.5.1 Water Level And Quality

The water level varies between different regions of the city, such as sandy, clay, and rock areas. Sandy areas include New Washermenpet, George Town, Manali, Porur and Besant Nagar, where the water level stood between 5 m and 6 m in 2012. Clay areas include Kolathur, Pulianthope, Ambattur, Sholinganallur, K.K.Nagar and Virugambakkam, where the level was at 5.5 m to 6 m in 2012. Hard rock areas include Guindy, Perungudi, Taramani and Velachery, where the level stood at 6.5 metre in the same period. Unlike sandy area, recharge and dip in water level in hard rock areas is faster. The water quality too varies across the city. In 2012, the level of total dissolved solids ranged between 600 parts per million (ppm) and 1,500 ppm across the city against the permissible limit of 500 ppm. The water level and quality is monitored by the Metrowater from 145 observation wells spread across the expanded city. As of 2012, the average water level in the city ranges between 5 and 6 metre. The water level dips to its maximum during June when there is not much recharge. The level raises to a shallow depth of 1.5 m to 2m in January, immediately after the northeast monsoon. Although Chennai scores high in the working ratio in water utility, a measure of their operational efficiency, financial health and stability, compared to most of the other Indian cities, it still shows a poor working ratio, according to a study by Ernst & Young. In 2012, the Chennai Corporation began work on construction of 5,000 rainwater harvesting structures in storm water drains.

2.5.2 Treatment Plants

Chennai has reverse osmosis plants, namely, at Velachery, Nochikuppam, Kasimedu, and Ayodhyakuppam. The plants take in raw brackish water from bore wells, store in tanks, and then purify before supply.Water treatment plants are located
at Kilpauk (270 mld), Puzhal (300 mld), Vadakuthu (Veeranam Lake source) (180 mld),
and Chembarambakkam (530 mld).

2.6 Rainwater Harvesting

The importance of conservation of water and rainwater harvesting cannot be understated. While issuing Planning Permission for construction of major developments such as flats, residential developments, office, shopping and other commercial complexes, the condition to provide rain water-harvesting structures within the premises was put and ensured to be provided before issue of Completion Certificates. Provision of rainwater structures in all types of developments, irrespective of size or use was made mandatory by amending DCR and Building Bye laws in the year 2001, not only for the buildings proposed to be constructed but also for all the existing buildings. After implementation of this scheme widely in CMA, a significant increase in the ground water levels and also quality of ground water was noted.

3.WATER SUPPLY

Water supply system**,** infrastructure for the collection, transmission, treatment, storage, and distribution of water for homes, commercial establishments, industry, and irrigation, as well as for such public needs as firefighting and street flushing. Of all municipal services, provision of potable water is perhaps the most vital. People depend on water for drinking, cooking, washing, carrying away wastes, and other domestic needs. Water supply systems must also meet requirements for public, commercial, and industrial activities. In all cases, the water must fulfill both quality and quantity requirements.

3.1 The Physical And Chemical Nature Of Water

Water is one of the most abundant substances on Earth without which life, it is said, cannot exist. It covers more than 70 per cent (70%) of the earth's surface and exists as vapor in the earth's atmosphere. It is considered as the universal solvent because of its ability to dissolve almost all organic and inorganic solids and gases it comes in contact with. For this reason, pure water is never found in nature. Even rainwater, the purest natural water, contains chemicals dissolved from the air. Pure water is obtained only by special methods of distillation and by chemical action in laboratories. Pure water is a tasteless, odorless and colorless liquid. Water in liquid form is most dense at 4° C, (39.2° F). The density of water at this temperature is used as a standard of comparison for expressing the density of other liquids and solids. At 4° C, one liter of water weighs 1 kilogram (a density of 1 gram/cc). In its gas form as a vapor, water is lighter than air, thus, it rises in the atmosphere.
Other important properties of water are the following:

- At 4°C pure water has a specific gravity of 1.
- The density of pure water is a constant at a particular temperature, and does not depend on the size of the sample (intensive property). Its density however, varies with temperature and impurities.

- Water is the only substance on Earth that exists in nature in all three physical states of matter: solid, liquid and gas.
- When water freezes it expands rapidly adding about 9 % by volume. Fresh water has a maximum density at around 4° C. Water is the only substance whose maximum density does not occur when solidified. As ice is lighter than liquid water, it floats.
- The specific heat of water in the metric system is 1 calorie – the amount of heat required to raise the temperature of one gram one degree Celsius. Water has a higher specific heat than almost any other substance. The high specific heat of water protects living things from rapid temperature change.

3.2 The Hydrologic Cycle

The hydrologic or water cycle is a conceptual model published on the internet that describes the storage and movement of water on, above and below the surface of the Earth. Since the water cycle is truly a "cycle," there is no beginning or end. Water occurs in one of its three forms (solid, liquid and vapor) as it moves through this cycle. The water cycle consists primarily of precipitation, vapor transport, evaporation, evapo-transpiration, infiltration, groundwater flow, and runoff.

3.3 The Phenomena In The Water Cycle

The various phenomena that characterize the water cycle are as follows:

Evaporation – Evaporation is the process by which liquid water is converted into a gaseous state. It takes place when the humidity of the atmosphere is less than the evaporating surface (at 100% relative humidity there is no more evaporation).

Condensation – Condensation is the change in state of water from vapor to liquid when it cools. This process releases latent heat energy to the environment.

Precipitation – Precipitation is any aqueous deposit (in liquid or solid form) that develops in a saturated atmosphere (relative humidity equals 100%) and falls to the ground. Most precipitation occurs as rain, but it also includes snow, hail, fog drip, and sleet.

Infiltration – Infiltration is the absorption and downward movement of water into the soil layer. Once infiltrated, the water becomes soil moisture or groundwater.

Runoff – This is the topographic flow of water from the area on which it precipitates towards stream channels located at lower elevations. Runoff occurs when the capacity of an area's soil to absorb infiltration has been exceeded. It also refers to the water leaving a drainage area.

Evapo-transpiration – This covers the release of water vapor from plants into
the air.

Melting – Melting is the physical process of a solid becoming a liquid. For water, this process requires approximately 80 calories of heat energy for each gram converted.

Groundwater Flow – This refers to the underground topographic flow of groundwater because of gravity.
Advection – This is the movement of water in any form through the atmosphere. Without advection, water evaporated over the oceans could not precipitate over land.

3.4 Water Supply System

A **water supply system** or **water supply network** is a system of engineered hydrologic and hydraulic components which provide water supply. A water supply system typically includes:

- A drainage basin (see water purification - sources of drinking water).
- A raw water collection point (above or below ground) where the water accumulates, such as a lake, a river, or groundwater from an underground aquifer. Raw water may be transferred using uncovered ground-level aqueducts, covered tunnels or underground water pipes to water purification facilities.
- Water purification facilities. Treated water is transferred using water pipes (usually underground).
- Water storage facilities such as reservoirs, water tanks, or water towers. Smaller water systems may store the water in cisterns or pressure vessels. Tall buildings may also need to store water locally in pressure vessels in order for the water to reach the upper floors.
- Additional water pressurizing components such as stations may need to be situated at the outlet of underground or above ground reservoirs or cisterns (if gravity flow is impractical).
- A pipe network for distribution of water to the consumers (which may be private houses or industrial, commercial or institution establishments) and other usage points (such as fire hydrants).
- Connections to the sewers (underground pipes, or aboveground ditches in some developing countries) are generally found downstream of the water consumers, but the sewer system is considered to be a separate system, rather than part of the water supply system.

3.5 Types Of Water Supply

There are various ways in which it may be necessary to obtain the water supply for a building. The usual course in cities and towns is to employ the Municipal Water Works service. This, of course, settles the supply feature, and the plumber simply provides the house and yard pipe, 5/8-inch or larger main, according to the character of the work. If of lead, the pipe must be of strength according with the pressure. Any of the light-weight grades of lead supply will stand 1,000 pounds per square inch for a short time; and the usual strength used on 50- to 80-pound pressure will not burst under 1,400 to 1,600 pounds when new and unstrained. Under constant pressure, the enormous strain possible from water-hammer, and general deterioration from use, make it advisable to employ pipe which, when new, is 20 times as strong as that necessary to contain the pressure. No attention is necessary as to the strength of zinc-c Oated or tin-coated iron pipe; it will stand any pressure ordinarily encountered.

3.5.1 Public Water Supply
The drinking waters produced and distributed by Local Authorities or its agents are termed Public Water Supplies. These supplies are identified as Supply Zones , allowing for different sources and mixes of sources.The European Communities (Drinking Water) (No 2) Regulations 2007 (S.I. No. 278 0f 2007) established the Environmental Protection Agency as the Supervisory Authority over Water Service Authorities (Local Authorities). This assigns a range of executive powers to the Agency.

3.5.2 Group Water Supplies
Community groups also may produce drinking water. These schemes are called Group Water Supply Schemes. These schemes are operated and managed by the Group. A Group can consist of as few as 2 residences. Such groups in this county, receive subsidies from the Department of Environment, Heritage and Local Government. Tipperary County Council provides technical and administrative advice to these groups and administers the grants and subsidy schemes on behalf of the Department of Environment, Heritage and Local Government. Group Water Supply Schemes can be subdivided into two types:

- Where the water is produced by local authority and sold in bulk to the Group Scheme who manage the network. These are called Public Group Water Supply Schemes. There is one such schemes in this county.
- Where the water is fully produced and distributed by the Group. These schemes are called Private Group Water Supply Schemes.

3.5.3 Private Water Supplies
Individual premises or residences sometimes have their own drinking water source. It is the responsibility of the water supplier to ensure that the water quality meets the required standards.

3.6 Public Water System
Public water system means a system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. A public water system includes the following:

- Any collection, treatment, storage, and distribution facilities under control of the operator of the system that are used primarily in connection with the system.
- Any collection or pre treatment storage facilities not under the control of the operator that are used primarily in connection with the system.
- Any water system that treats water on behalf of one or more public water systems for the purpose of rendering it safe for human consumption.
- “Human consumption” means the use of water for drinking, bathing or showering, hand washing, oral hygiene, or cooking, including, but not limited to, preparing food and washing dishes.
- “Service connection” means the point of connection between the customer’s piping or constructed conveyance, and the water system’s meter, service pipe, or constructed conveyance. A connection to a system that delivers water by a constructed conveyance other than a pipe shall not be considered a connection in determining if the system is a public water system if any of the following apply:
- The water is used exclusively for purposes other than residential uses, consisting of drinking, bathing, and cooking or other similar uses.
- The department determines that alternative water to achieve the equivalent level of public health protection provided by the applicable primary drinking water regulation is provided for residential or similar uses for drinking and cooking.
- The department determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a passthrough entity, or the user to achieve the equivalent level of protection provided by the applicable primary drinking water regulations.
- Community water system means a public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the area served by the system.
- Non community water system means a public water system that is not a community water system.
- “Non transient non community water system” means a public water system that is not a community water system and that regularly serves at least 25 of the same persons over six months per year.
- “Resident” means a person who physically occupies, whether by ownership, rental, lease, or other means, the same dwelling for at least 60 days of the year.

3.7 The Distribution System

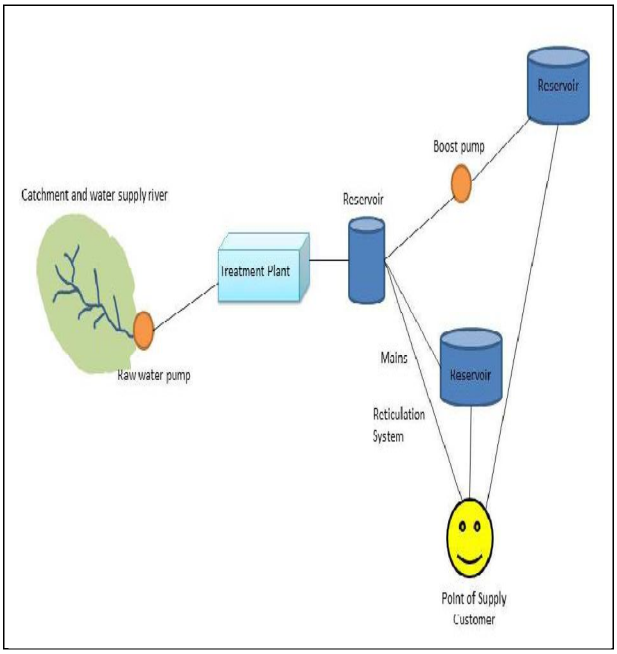

Figure 4: Distribution System

- At the top of the system is the catchment - this is the land where the rain falls and springs discharge groundwater and collectively form a stream.
- Water is pumped from the streams at the water supply intakes and piped to the water treatment plants.
- The treatment plant removes all the dirt and bugs, Chlorine is added to keep the water safe.
- Trunk mains (pipes) are used to move the water to reservoirs, where the treated water is stored.
- From the reservoirs the water is piped through the reticulation system to homes, businesses and other water users around the town.
- The Council's system ends at the outlet side of the water meter, known as the point of supply. Up to that point, it is the Council's responsibility to make sure everything works.
- After that the home owner, business or other user is responsible.

Figure 4 shows Distribution System

4.DISTRIBUTION SYSTEMS

Distribution system is a network of pipelines that distribute water to the consumers. They are designed to adequately satisfy the water requirement for a combination of In general, most of existing rural water distribution systems were originally designed and constructed as Level II public faucet systems. The lower capital cost and lower tariff requirements were primary considerations, particularly at the inception of projects. Eventually, however, most of the consumers realized the value of household connections, and preferences shifted to Level III service levels. As a result, many Level II facilities upgraded their services, although in many cases, they maintained their public faucets even as they provided Level III connections. The combined Level II/Level III options allowed customers who could not afford a home connection to continue to rely on the public faucet.

- Domestic
- Commercial
- Industrial
- Fire fighting purposes

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4.1 Requirements Of An Adequate Distribution System

- Water quality should not deteriorate while in the distribution pipes.
- The system should be capable of supplying water to all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during fire fighting.
- The layout should be such that no consumer is without water supply, during the repair of any section of the system.
- All the distribution pipes should preferably be laid one metre from or above *sewer* lines.
- It should be fairly watertight to keep losses (e.g. due to leakage) to a minimum.

4.2 Methods Of Water Transmission And Distribution

Water can be transported from the source to the treatment plant, if any, and the distribution system, and eventually reach consumers through one of the following methods:

Through gravity flow: This is the ideal set-up when the location of the water source is at a considerably higher elevation than the area to be served. The operation cost of a gravity system is very low, as it does not require energy cost.

Through pumping with storage: Water is either (a) pumped to a distribution pipe network, then to consumers, with excess water going to a storage tank, or (b) pumped to a storage tank first, then water is distributed by gravity from the tank to the consumers. The maintenance and operation cost of this system is higher than a gravity system.

Through direct pumping to the distribution system: In this system, water is pumped directly from the source to the distribution system to the consumers. Where capital cost for a reservoir is not affordable at the initial stage of the water system, direct pumping to the distribution is usually resorted to. Variable speed or variable frequency drive pumps are most ideal for direct pumping operations, but the capital costs for such equipment are higher than for conventional water pumps. For purposes of designing the pipelines, the distribution systems are considered also in terms of the topology or layout that is used.

4.3 Branching Pattern With Dead End

Similar to the branching of a tree. It consists of

- Main (trunk) line o Sub-mains
- Branches
  Main line is the main source of water supply. There is no water distribution to• consumers from trunk line. Sub-mains are connected to the main line and they are along the main roads.
- Branches are connected to the sub-mains and they are along the streets.
- Lastly service connections are given to the consumers from branches.

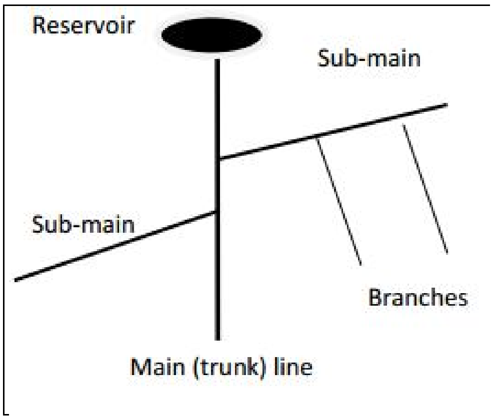

Figure 5: Branching Pattern with Dead End
Figure 5 shows Branching Pattern with Dead End

4.3.1Grid Pattern

In this system the main supply line runs through the centre of the area and sub mains branch off in perpendicular directions. The branch lines interconnect the sub-mains. This system is ideal for cities laid out on a rectangular plan resembling a gridiron. The distinguishing feature of this system is that all of the pipes are interconnected and there are no dead ends. Water can reach a given point of withdrawal from several directions, which permits more flexible operation, particularly when repairs are required. Figure 6 shows Grid iron system

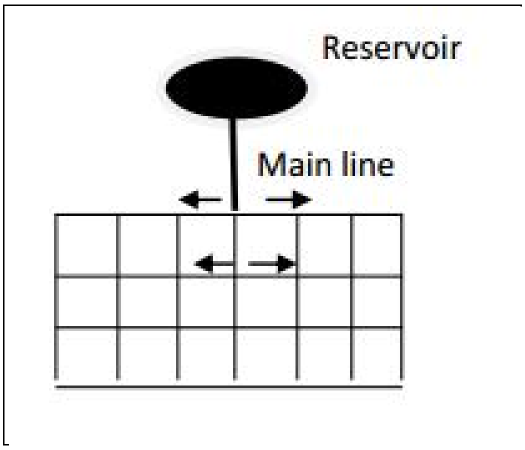

Figure 6 Grid iron system

4.3.2 Circular Or Ring Distribution System

In a circular or ring system, the supply main forms a ring around the distribution area. The branches are connected cross-wise to the mains and also to each other. This system is most reliable for a town with well-planned streets and roads. The advantages and disadvantages of this system are the same as those of the gridiron system. However, in case of fire, a larger quantity of water is available, and the length of the distribution main is much higher. Figure 7 shows Circular or ring distribution system

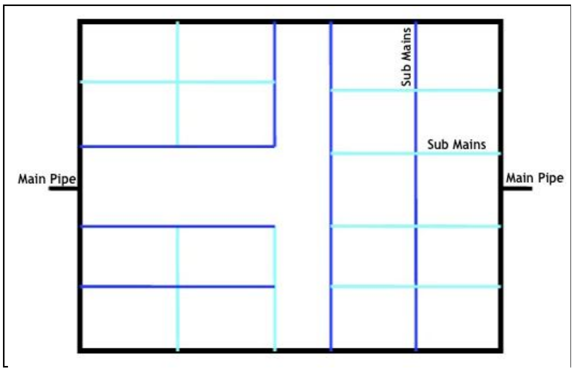

Figure 7 Circular or ring distribution system

4.3.3 Radial Distribution System

In this system, the whole area is divided into a number of distribution districts. Each district has a centrally located distribution *reservoir* (elevated) from where distribution pipes run radially towards the periphery of the distribution district. This system provides swift service, without much loss of head. The design calculations are much simpler. Figure 8 shows Radial distribution system

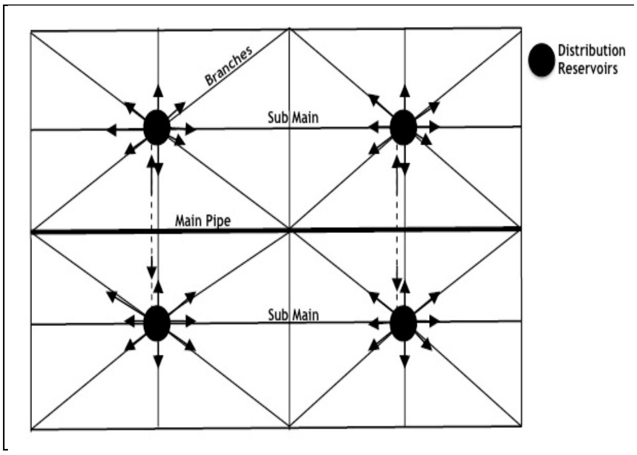

Figure 8 Radial distribution system

4.3 Hydraulic Analysis Of Distribution Systems

Most commonly methods used are:
a) Dead-end method
b) Hardy-Cross method
c) Equivalent pipe method

4.4 Development Of Water Supply System To Chennai City

4.4.1 Early Water Supply Source To Chennai (Madras)

Till about 1870, the people of Chennai (Madras) were dependent on shallow wells situated in their own houses or on public wells and tanks in the neighbourhood for their water supply needs. There was no protected water supply at that time and these sources were not satisfactory. Figure 9 shows Water supply scheme in Chennai

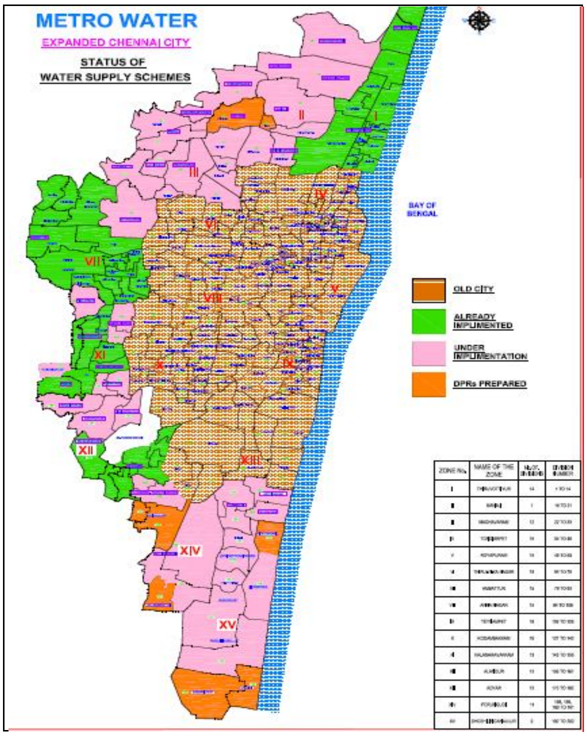

Figure 9 Water supply scheme in Chennai

4.4.2 Development Of Organised Water Supply System

The organised water supply to Chennai was commenced in 1872 which is the nucleus of the protected surface water supply system now in existence in Chennai City. A masonry Anicut (weir) of 1.8 m height was constructed, across the Kosathalaiyar River at Tamaraipakkam about 28 km. north-west of Chennai. The unfiltered water from this Anicut was brought to Kilpauk through Redhills Lake by an open channel by gravity and distributed through Cast Iron (CI) pipes to the nearby areas. This initial gravity system consisted of Tamaraipakkam Anicut, Upper Supply Channel of 13 km. length to convey the diverted water from the Anicut to Cholavaram Tank, Lower Supply Channel of 4 km. length to convey water from Cholavaram to Redhills Lake, an open channel of 11 km. length to convey water from Redhills Lake to masonry Shaft at Kilpauk and cast iron mains to distribute the unfiltered water to the city.

4.4.3 Beginning Of Protected Water Supply System

The first major milestone towards protected water supply using of filtration and pumping was achieved during the year 1914. An improved intake tower, named as Jones Tower, was constructed in 1881 at the deepest point in the Redhills Lake. An underground masonry conduit of size 1.52m x 1.12m and 11 km. long was constructed to convey raw water from Redhills to Kilpauk, in the place of the open earthen channel, with conveying capacity of raw water at the rate of 104 MLD (23 MGD). Slow sand filters to purify the water (60 to 70 MLD), four underground pure water storage tanks (29.50 ML capacity), steam engine driven pumps, an elevated steel overhead tank (6.75 ML capacity) and 48" dia steel pumping main from Kilpauk Pumping Station to Shaft were installed. Subsequently the distribution system was remodelled and extended to all areas of the city.

4.4.4 Development Of New Sources

Poondi Reservoir (later named as Sathyamoorthy Sagar) was constructed in 1944 across the Kosathalaiyar River with a capacity of 2573 Mcft and placed in service for intercepting and storing Kosathalaiyar River water. Surplus water flows down the river which is again intercepted by Tamaraipakkam Anicut and diverted to Cholavaram Lake. (A lined canal known as Poondi Canal was later constructed in 1972 to convey water from Poondi Reservoir to Cholavaram Lake). The combined storage of three lakes viz. Poondi, Cholavaram and Redhills was 5596 Mcft (Poondi: 2573 + Cholavaram: 583 Redhills: 2440). The system was then designed for a supply of 115 lpcd for an estimated population of 0.66 million expected in 1961.

4.4.5 Improvement Works Carried Out During 1946 To 1966

To meet the immediate needs, various works for conveyance, treatment and distribution were carried out between 1946 and 1966. Rapid gravity sand filter treatment facilities with 45 MLD capacity were completed in 1959. Construction of a second underground masonry conduit (size 1.98m x 1.22m) to convey additional quantity of 146 MLD of raw water (32 Million Gallon per day) from Redhills to Kilpauk, installations of Electrical pumping units at Kilpauk replacing the 3 steam engine driven pumpsets, second 48" pumping main from Kilpauk Pumping Station to Shaft, 42" Trunk Main to serve South Chennai, 2 additional underground filtered water tanks of 9 ML capacity (2 Million Gallons) each at Kilpauk and expansion and improvement to distribution system are important works carried out.

4.4.6 Source Augmentation Works

Simultaneously, action was taken to augment the sources and improve the treatment and storage facilities. The construction of a lined channel from Poondi to Tamaraipakkam for a length of 15 km. to convey water from Poondi to Tamaraipakkam was completed in 1972 to reduce the transmission loss. The combined capacities of Cholavaram and Redhills lakes were increased by 700 Mcft by raising the lake bunds. Thus, the combined storage capacity of Poondi, Cholavaram and Redhills was increased to 6296 Mcft (Poondi: 2573 + Cholavaram: 881 + Redhills: 2842). The irrigation rights of Cholavaram lake and Redhills lake were acquired in 1962 and the entire storage was made available for the City supply.

4.4.7 Veeranam Water Supply Project

The Veeranam Water Supply Project was implemented as additional source of water to Chennai City. The Project was commissioned in the year 2004 to supply 180 MLD of water to Chennai City by drawing water from Veeranam Lake. This lake receives water from Cauvery River system through Kollidam, Lower Anicut and Vadavar Canal besides rainwater from its own catchment area. The capacity of the lake is 1465 Mcft. The lake water is treated at Vadakuthu Water Treatment Plant by pumping raw water at a distance of 20 km. from Sethiathope to Vadakuthu through 1775 mm dia mild steel pipe. The treated water is then pumped at a distance of 8 km. to Break Pressure Tank at Kadampuliyur through 1750 mm dia mild steel pipe and from there the water is conveyed to a distance of about 200 km. through the mild steel pipe of 1875 mm and 1500 mm dia by gravity to Porur Water Distribution Station near Chennai. From this Distribution Station, water is pumped to a distance of 1.2 km. and distributed to Chennai City through Trunk mains and Water Distribution Stations.

5.CONCLUSION

Reservoir operation forms a very important part of the planning and management of water resources. The release from a reservoir, at any time, depends on the prevailing demands, the available water in the reservoir, information about the likely inflow in the reservoir and likely demands of the remaining part of the water year. An operating policy is developed to guide the operators at the reservoir site in deciding about the release at any time.

- To examine the patterns of water sources, supply, access to consumer, connections in Chennai city and infrastructures;
- To estimate the quantity of water supplied, access to water and quantity of water for multiple uses in the study area;
- To analyze the Willingness to Pay (WTP) and Affordability to Pay (ATP) for water supply among the people of Chennai; and
- To examine and analyze sanitation, hygiene, illnesses, indoor and outdoor risk factors for health in the study area so as to make recommendations and suggestions for overcoming them.

Huge amount of efforts have already been made towards the development of water resources management models for managing the Chennai city's water supply system. However, due to the complexity and difficulty in using those models in the real time situations, a simple model has been developed through this work. This model highlights on ease of use, efficiency, and reliability. So, this simple model can directly be applied in the field for reliable and equitable distribution of surface water. From the rainfall source drinking water supply from various reservoirs like poondi,chembarampakkam, cholavaram, red hills supplies surface water for drinking and other purposes. In our project work helps to create awareness among people on storing ground water for future demand purpose during draught season as a source of supply of water.

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